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Technical feasibility of integration of renewable energies in the EU

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Abstract: According to the Article 4(3) of Directive 2009/28/EC on the promotion of the use of energy from renewable energy sources the EU Member States submitted their forecast documents. The analysis of the forecast documents resulted that the EU will exceed the 20 % renewable energy consumption target with 0,3 % in 2020. The paper gives an overview about the technical feasibility of the integration of the renewable energy sources in the energy systems in the EU and analyze the critical factors and possible solutions.

Keywords: *EU Renewable Energy, Integration, National Renewable Energy Action Plan*

1. Introduction

In accordance with Article 4(3) of Directive 2009/28/EC and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources each Member States shall adopt a National Renewable Energy Action Plan. The MS-s had to submit them to the Commission by 30 June 2010 using a template according to the Commission Decision of 30 June 2009.

In the national renewable energy action plans each member state has to set the national targets for the share of energy coming from renewable energy sources consumed in electricity, heating and cooling, and transport sector as well in every second year up to 2020; taking into account the effect of energy efficiency related measures on final consumption of energy compared to the indicative trajectory. The member states announce the excess or deficit production which can be used in the cooperation mechanism or in the statistical transfer.

However, each member state has its own different technical, environmental, economic and political situation to consider in meeting its commitments. Cost competitive production of renewable energy and the system by which it reaches are key issues in establishing a viable market. Besides competitiveness, another important issue is security of supply, and a mechanism should be created for resource adjustment at a European level. This could be achieved through international partnerships and contracts, and possibly by establishing adequate storage capacity.

On the subject of environmental protection, emissions trading might prove helpful. Whether competitiveness, environmental protection or security is perceived as having the greatest priority will depend on the circumstances of the specific state. Programs in most of the EU Member States promote a reduction in energy consumption and increase energy efficiency. With a move away from traditional energy sources, the demand for power can only be met by a corresponding increase in energy generation from renewable sources. The main questions are: how realistic are the goals and what potential domestic energy resources can be exploited? What are the main drivers and barriers – mainly from technical point of view - of the integration of renewable energy sources in the energy systems?

2. Methodology

The Directive 2009/28/EC on the promotion of the use of energy from renewable energy sources requires Member States to adopt a National Renewable Energy Action Plan (NREAP) and to submit to the European Commission by 30 June 2010 using a template in accordance with Article 4 of the Directive [1]. Previously all Member States have prepared their forecast documents [2] and submitted them in accordance with the Article 4(3) of the Directive.

The forecast documents indicated the estimated excess production from renewable energy sources compared to the indicative trajectory which could be transferred to the other Member States and the estimated demand for energies from renewables to be covered by means other than domestic production until 2020. It had to be stated also how big is the estimated potential for joint projects until 2020.

Comparative and summary analysis has been executed in order to see the size and the ability of the contribution of the Member States from the forecast documents and national and European project reports [3, 4].

3. Results

Most of the EU Member states are optimistic on the way to meet their target from only domestic action and resources. The forecast documents of the Member States resulted that the EU in 2020 will exceed the 20 % Renewable Energy consumption target with 0,3 %. From the forecast analysis it can be expected also that the EU will reach a net surplus also in the interim period until 2020 probably each year as it is presented in the Figure 1.

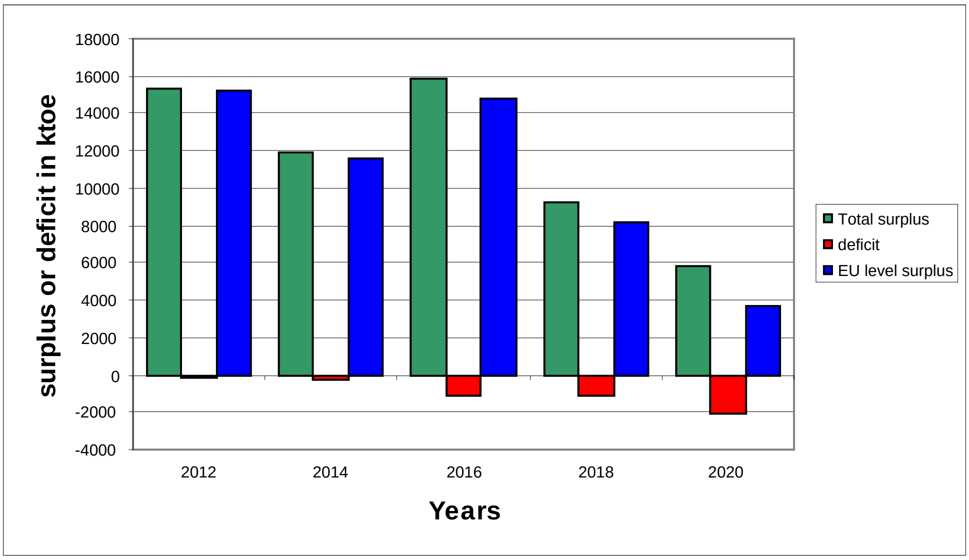


Fig. 1. The RES surplus or deficit between 2010 an 2020 in the EU27 .

3.1. Energy consumption Scenarios

The Member States prepared their forecast taking into account the Additional energy efficiency scenario and many Member States emphasized that the projected targets can be reached only applying the energy efficiency measures.

The main renewable energy resources are biomass, hydro and wind. The majority of the Member States announced biomass as the main renewable energy resource, some of them emphasized also hydro energy and wind energy.

9 Member states announced **surplus** by the year 2020 as it is presented in Figure 2. The highest surplus in absolute term has Germany and Spain with 1387 and 2700 ktoe respectively.

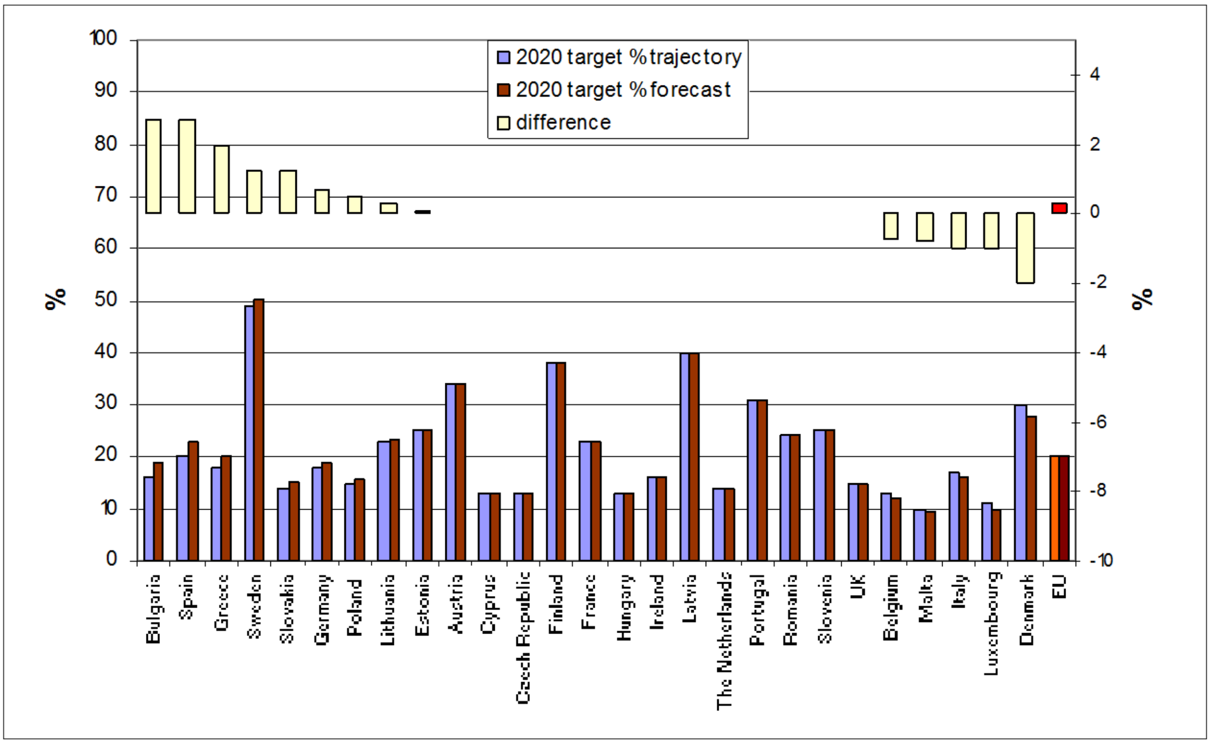


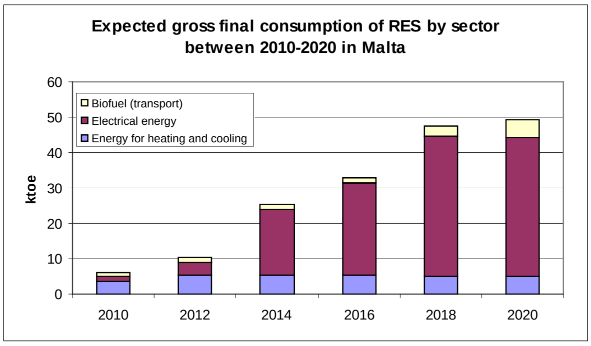
Fig. 2. The indicative and forecasted share of the Renewable Energies in the EU 27 by 2020

5 Member states forecasted **deficit** in 2020, Italy has the highest absolute deficit with a -1170 ktoe (-1 %).

The member states can use cooperation mechanisms to help with their surplus or meet their deficit. 13 member states are willing to use the **Joint projects**, and 8 to use the **statistical transfer**. Wind and biomass are the most involved resource in the joint projects in power generation using the existing electricity links in the Balkan area.

3.2. Sectorial use break down

Some Member States already provided forecast on the sectorial breakdown of the RES development until 2020. Among these countries the highest share had the renewable electricity and also heating and cooling represented a big proportion, as it is demonstrated in the Figure 3.



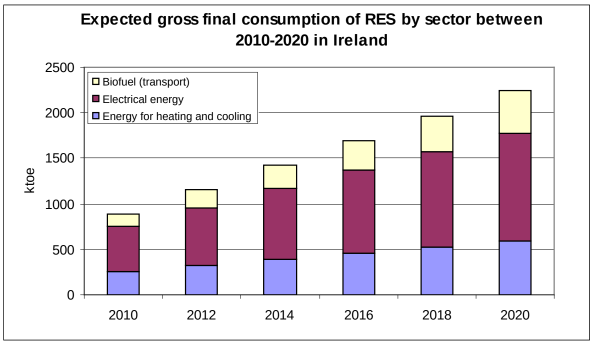


Fig. 3. Forecasted sectorial breakdown of RES final consumption in some member states

Many of the Member States raised critical factors which are barriers in reaching the targets or which need development in order to achieve a better performance of the targets. Among the obstacles countries mentioned their isolated geographical situation and restrictions in interconnection capacity; thus they expressed the need of development in interconnections.

Regional differences appear from the recourse aspects and also in the energy use. Countries like Italy and Greece have a high PV potential, high air conditioning penetration but have high summer peaks, and countries like France or Bulgaria have high level of electrical heating and lower PV potential but low summer peaks.

However it is a good potential of offshore wind resource, the implementation depends mainly on the development of infrastructure for integration wind energy to the grid.

Solar energy has the highest potential in terms of availability, with daily and seasonal variation in different geographical location. There is an expressed need for flexibility of grid management and of generation mix. The advantages of PV are that it can provide peak power and can be used in the decentralized electricity; this means reduction of network losses. Grid electricity losses are proportional to the distance between the points of generation and use, so as PV is a distributed and decentralized source it needs shorter transmission route.

The integration of wind and biomass could help increase the predictability, in the storage and in the simultaneity aspects, although wind and PV require the same measures in the grid development. PV is easier to forecast and less impacted by local topography, wind has higher energy density and its integration into the grid is more similar to that of conventional concentrated generation.

General need is the modernization of electrical grids, the reinforcement of grid infrastructure and electricity interconnection and also the offshore wind development. As the share of RES electricity from renewable is around 35 % in the EU there is a general need to improve the stability of the European electricity grid which requires new infrastructure. There is no harmonized method for transmission planning over the EU Countries and there is a lack of harmonization of the grid connection rules of wind plans

There are inconsistencies in regulations of the transmission planning, i.e. there are different policies in different countries; RES has not the same priority in all countries, the related grid expansion costs are shared differently and not always in transparent way. There is inconsistency in the technical requirements and the separation of generation, transmission and retail services complicates the process.

4. Conclusions

The system integration challenges are dependent of several factors like the energy resource (location, potential, technical development), technology and the technological development of the system components (from the production through the transformation, storage, distribution system, interconnection capacities, etc.).

The biggest challenges appear in the electricity as the main form of the energy integration. The penetration of PV, wind and bioelectricity is highly dependent on the system flexibility. In the different EU member states the different transmission and distribution grids means a kind of barrier, and as it was formulated already in the forecast documents the grid infrastructure needs to be reinforced and requires new infrastructure at generation, at transmission and also at distribution level. An integrated European grid needs harmonized codes, policies, regulations and technical standards; as well an improvement in the transmission planning method. With these measures the indicative targets can be achieved.

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[1]The views expressed in this paper are those of the authors and do not necessarily represent European Commission policy.

Development of the Sustainable Technology Balance Sheet (STBS) - A generic method to assess the sustainability of renewable energy technologies

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Abstract: The impacts of technologies on sustainability have to be assessed through structured approaches to provide decision-makers with strategic information. Traditional technology assessment methods can be complex and highly resource intensive with long lead times; consequently, the applications of these methods are limited, especially in Africa. Where these methods have been applied, the conclusions that are generated are also not always effectively communicated, which leads to limited buy-in from stakeholders. The paper therefore proposes a generic rapid technology assessment framework and implementation process that utilises a popular method that has been modified to include sustainability factors and a systems approach, while remaining simple and intuitive: the Sustainable Technology Balance Sheet (STBS). The method addresses technology assessment from a qualitative view by including sustainability criteria developed through stakeholder engagement and technical factors through expert opinion, while inducing a life cycle approach to ensure system awareness. A case study approach, using a bioenergy value chain, is used to demonstrate the developed STBS method.

Keywords: *Sustainability assessment, technology assessment, Africa.*

1. Introduction

Energy is closely linked to the sustainable development paradigm. The impact of energy technologies can include climate change, which is associated with excess use of energy, and poverty, due to a lack of access to energy. Solutions to these sustainability problems may be achieved by using new technologies, such as renewable energy technologies (RETs), that reduce pollution and, in some instances, provide development opportunities. Such solutions can, however, only be achieved if the correct technology strategies are followed by effectively assessing and communicating viable options to policy makers.

A key issue for sustainable development is the various implications of the extraction, generation and use of energy that must be evaluated in a comprehensive manner. As the worldwide demand for energy resources increases so too does the diverse range of impacts that occur over the respective energy value chains relating to the various acquisition and operational activities as well as from the utilised technologies.

In attempting to address the sustainable development challenges that technology presents, structured approaches and firm methodologies must be developed and implemented as a prerequisite to ensure the comprehension and coordination to reach intended outcomes. Technology assessment methods can provide the basis for this development [1].

2. Development of the Sustainable Technology Balance Sheet (STBS) method

The conventional Technology Balance Sheet (TBS) is one technology assessment method that has been utilised effectively [2]. It is a graphical representation of the interrelationships, inter-dependence and reliance between the factors of technologies, processes, products, and markets. The foundation for the TBS is the relative relationship between these four factors.

Originally the relationship was based on economics and how the factors met each other's demands [3].

The simplistic logic of the framework, which is indicative of the relationship between the factors considered, makes use of a simple matrix to relate two specific factors. This is then augmented by other matrices to enhance the relationship or connection between factors while still retaining the straightforward logic behind each matrix (see Fig. 1).

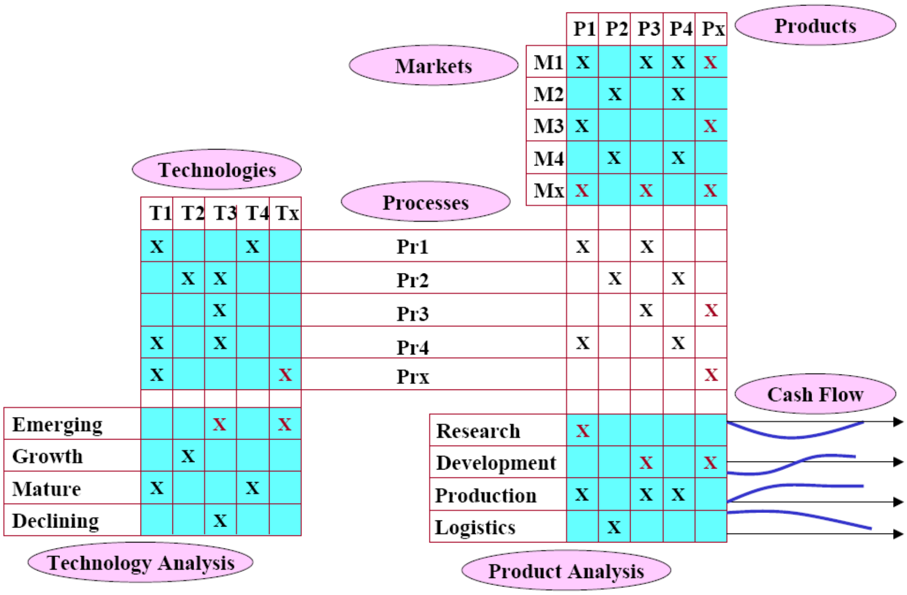

Fig. 1. The conventional Technology Balance Sheet method [3].

Within this framework, when a new technology is incorporated into an existing or new process to produce a product, which meets an established market demand, or creating a whole new market niche. The technology thus acts as a driver for new products and processes due to its enabling characteristics needed for existing products and process. This defines the connection between the four factors through the interconnected nature of the factors [4].

The TBS is a business-orientated tool designed to aid managers in the technology decision making process. The tool intends to facilitate and guide an enterprise through a technology assessment process towards a clearer understanding of the conclusions ultimately produced by the framework. The enlightenment generated by the process is often more valuable than the outcome obtained. This would include a better understanding of how organisational structures relate to each other and how operational flows affect the business, both by means of a greater internal and external awareness. Nevertheless, the TBS will still be a communication tool, to effectively communicate the outcomes to those not involved in the process, as well as non-technical stakeholders who will be able to draw logical conclusions and intrinsically generate the correct answer, which is so important for personal buy in and ultimate project success [4].

The TBS answers the questions of "where we are" as a business looking at technology and provides strategic direction by answering "where to go" as well as "where to get out" by making use of technology s-curves and analysing where a technology is located in the technology life cycle [3]. The TBS indicates the forces at work within the techno-economic system. These forces manifest themselves within the organisation as opposing directional force, simply as a push or a pull [3]; they are produced by different elements within the factors. A market force can be described as a pulling force pulling business output towards the market demand, be it though desired products, which occur only once the force has been transmitted to the processes to generate the capabilities within the business. However to produce the products and develop these processes only occurs once the pull force has been transferred to the technology factor to grow, develop and provide the methodologies required to generate the processes required to create the products to meet the market need. If one considers technology as a push force we can experience a force from a new technological invention or development pushing along new capabilities and new processes, which can lead to new or advanced products and through their existence create new markets or change the dynamics of existing ones. These two forces can have a feedback effect on the entire system as the process and capabilities continue to grow and so a type of causal loop system has been created.

The TBS provides organisational value by highlighting the drivers at work within the organisation and how these can be manipulated to be successful in meeting the business goals. As one becomes more aware of how each factor relates to the others, one is more able to grasp their impact. This would not only be unique to being economically successful, as is the traditional intent of the TBS, but by reviewing the intent, aligning the point of view and reassessing the goals we will be able to use the simple TBS framework to meet any desired outcomes; for the problem at hand, to address sustainability while critically assessing different energy technologies. Therefore, sustainability can be introduced in the TBS by making use of the principles or criteria used for the assessment of environmental, social and economic sustainability and would include those applied in the broad sustainability body of knowledge [5] and refined through a needs analysis that comprises stakeholder engagement.

2.1. STBS framework and Implementation Process

A sustainable technology assessment tool has subsequently been developed [6] and consists of two parts: first, the Sustainable Technology Balance Sheet (STBS) which is a rapid technology assessment and communication framework; and second, an integral part that is referred to as the Implementation Process, which is a structured method through which the relevant stakeholders can be engaged and qualitative data can be obtained. Each part consists of specific methodologies and underlying logic, which can be summarised as shown in Fig. 2.

The Implementation Process consists of four steps initiated by a facilitator during stakeholder engagement workshops to generate the information needed to populate the STBS, create system awareness and project enlightenment among these stakeholders [6]:

- Step 1a: Value Chain Generation: through a life cycle analysis and by the investigation of the product/process life cycle to generate, firstly a generic value chain and secondly, once the components of the value chain are validated, a case specific process value chain is generated.
- Step 1b: Sustainability Criteria Development: Sustainability aspects addressed by stakeholder engagement and literature review, which is done concurrently during the initial engagement stages. Once systems-thinking has been instilled, discussions surrounding the creation of specific Sustainability Criteria may be fulfilled. This would reaffirm the stakeholders' intentions toward sustainability.
- Step 2: Technology and Process Awareness: Achieved through the creation of input-process-output diagrams, which indicate process linkages known as Technology Super Structures. This is done for each one of the value chain components indicated by the dashed rings of Fig. 2. A short discussion surrounding the grouping or indexing of Sustainability Criteria into sectors may also be accomplished.

- Step 3: STBS Development: The utilisation of the generated information and understanding to populate the STBS so as to formalise the information and to communicate conclusions accurately.
- Step 4: Strategic Direction and Conclusion Analysis the presentation of STBS outcomes to relevant stakeholders is of vital importance. This new impetus, created by the indicated strategic direction, needs to be subscribed to and further investigations can be made in an enlightened and qualified direction. These investigations can include, amongst others, multi-criteria decision analysis (MCDA) trees and life cycle analysis (LCA) studies to add more rigour to the indicated outcomes and strategic conclusions.

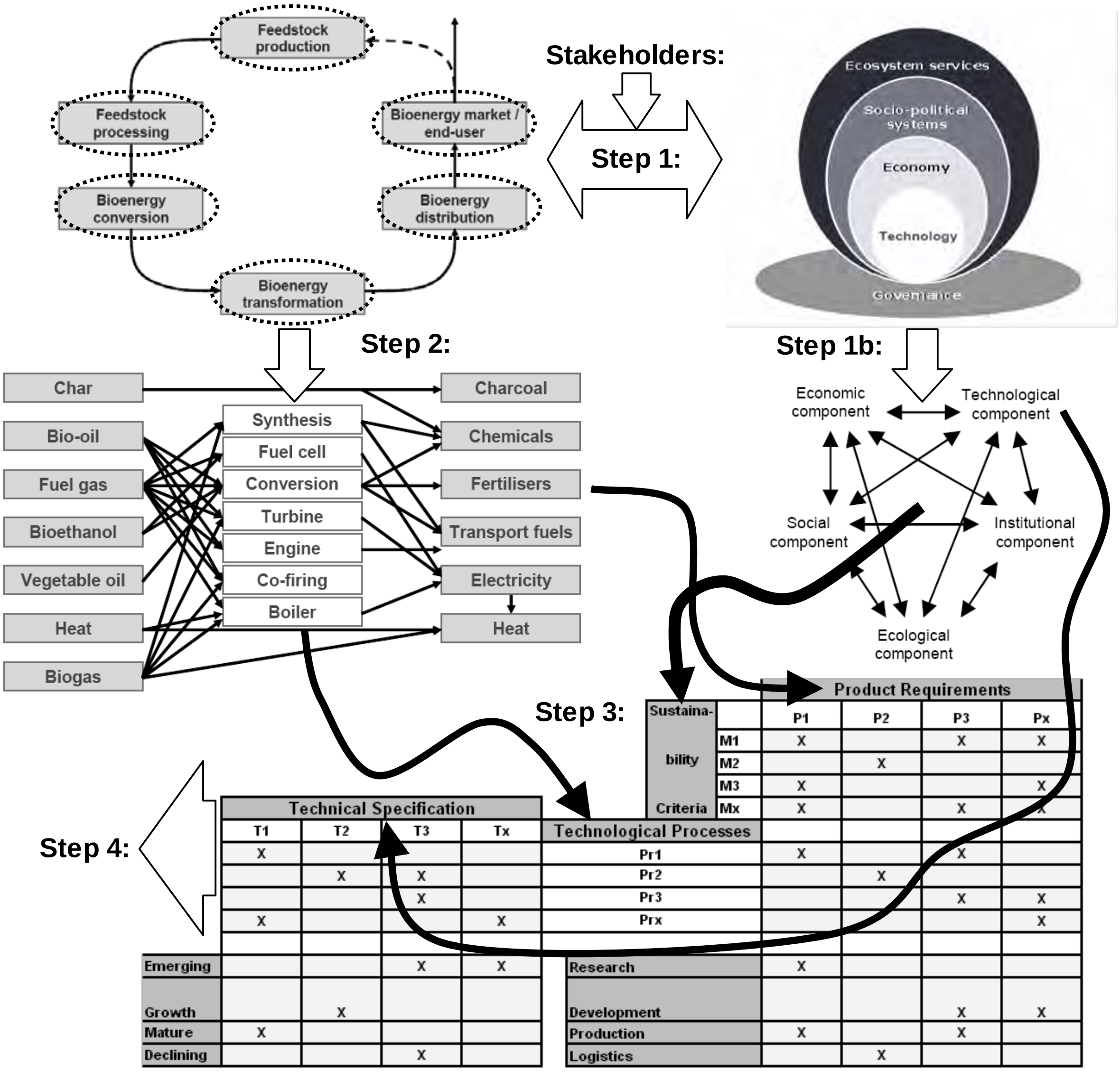

Fig. 2. The Implementation Process of the Sustainable Technology Balance Sheet (STBS).

3. A case study to investigate the STBS method

A case study approach was used to understand and test the developed STBS method. The case is of the Working for Energy (WfE) programme, which is an initiative of the South African Department of Water Affairs and Forestry (DWAF) to utilise waste invasive alien biomass as an energy source effectively adding value such as job creation and energy resources to the Working for Water projects through new Public Private Partnerships (PPPs). The need to assess suitable technologies for these PPPs was identified and the STBS tool was deemed as a suitable option.

The STBS was firstly discussed informally among a group of energy technology analysis experts to generate relevant information and determine the key stakeholders, which can be utilised during the development of the tool. These meetings then became provided feedback of developments and obstacles to the various experts and stakeholders.

Finally, a formal presentation of the proposed STBS tool was made during a workshop to experts, which included members of the national DWAF and other stakeholders at which time further inputs could be given. The consequence was a process of conceptualisation of a modified TBS, making use of a reiterative approach to generate constant learning.

4. Results

Step one of the STBS involves the creation of the value chain (see Fig. 2). These are useful to identify specific components for the value chains and by providing the relevant technologies to be assessed. Consequently, the first step in the STBS process is to investigate the project life cycle so that a generic project value chain can be formulated. In this case, the value chain would initially take the form of a generic bioenergy value chain, which can then be evaluated and expanded to add specific information pertaining directly to the specific case under evaluation. These value chains are an efficient way to generate system- and complexity-understanding and to communicate this knowledge easily to non-technical individuals.

Within a 'Call for Expression of Interest (EOI)' document, the WfE programme clearly indicated their understanding of the relevant components that form the project value chain. This provided the WfE group with insights relating to the relevant technologies and the four interrelated factors that influence each other:

- Technological Process indicates the conversion processes and the intrinsic technology used. These two factors, process and technology, are inseparable and are thus assessed as a functional unit. The linkage between the technological process and products created is also undeniable as the one determines the other, which must thus also remain within consideration. These factors are easily generated by expert opinion, as they are the available processes required to meet the desired outputs and the project goals. For the Primary Energy Conversion component, four main technological processes were identified due to the overwhelming relevance of these technologies within literature as well as within the market place especially within the EOI. The Technologies proposed were combustion, slow pyrolysis, fast pyrolysis and gasification.
- Technical Specifications are technical aspects that pertain to the technology for only this specific point in the product life cycle or specific value chain component. From an operational point of view, these factors are invaluable to more technical stakeholders as they pertain directly to constraints and challenges, which will be faced. These factors include: complexity of operations, feedstock requirement, residence time and capital cost. Technical Specification focuses on the operational aspects of the Technological Process and may be general or specific.
- Product Requirements creates a linkage between the technological process, its products and their specifications, as required by stakeholders or subsequent processes. This is done to improve the assessment of the technology, as one cannot generate conclusions from the technological process if one does not take aspects and requirements of its products into account. These include the meeting of the stakeholder requirements as well as indicating the various process/product strategies and their affects on sustainability thus the close link

between the technology, the process, and the product is required to assess performance in relation to the Sustainability Criteria. In this specific case the Product Requirements are difficult to quantify as most of these products are merely subsidiaries and do not directly meet the needs of stakeholders. It is, however, imperative that the stakeholders' needs are considered at this stage so that the correct process/product strategies may be implemented at this early stage to ensure customer satisfaction and ultimately ensure a true reflection of sustainability. The process/product strategy becomes especially important when multiple products and undesirable wastes are produced thus highlighting product benefit trade-offs, as the product number and specifications can be manipulated by changing the process and technical specification. In this case study example it was not deemed necessary to investigate all the various process/product strategies nor all of the products, which could be generated by each general Technological Process. The EOI documents were used as a guide and only products specified within these were assessed, so as to limit the assessment scope as indicated by the stakeholders.

- Sustainability Criteria are key areas that need to be considered for sustainability. Stakeholder engagement and expert opinion is utilised to develop areas for the assessment of the technology in terms of its sustainability. This is the key factor to the STBS and the technology assessment body of knowledge in addressing sustainability. By considering the Sustainability Criteria with the Product Requirements (representing the Product/Process/ Technology complex) matrix in Fig. 3, the clear influence of technology assessment, such as the Multi Criteria Decision Analysis (MCDA) methodologies can be seen. This has been implemented in a simplistic fashion along with the understanding that the Sustainability Criteria and the outcomes generated are likely to form part of an MCDA study to be done after the initial STBS study indicating a strategic direction. The synergies between the STBS and the MCDA are apparent as the STBS facilitates the initial stages of the MCDA cutting down on the time and engagement required by the MCDA but as a rapid assessment tool lacks its quantitative rigour. The STBS focuses qualitative data providing a strategic standpoint through the ranking of factors. Further investigations using strong quantitative data can vindicate the STBS strategic direction and provide further insights. STBS proves valuable in reducing time and costs of a blind MCDA by providing rapid direction and limiting the possibilities assessed by the MCDA, thus limiting the expense of such a time-consuming study. Life Cycle Analysis (LCA) was also investigated and regarded as an excellent tool to further guide decision makers once the STBS had indicated general strategic directions. The LCA decision trees are invaluable to assess process/product strategies that were initially identified by the STBS, quantified by the MCDA and then synthesised by the LCA.

These factors are compared in three assessment matrices to provide insights to the viability and sustainability of the technologies; Fig. 3 provides an example:

- The Technological Process vs. Technical Specification Matrix - evaluates the Technological Process using Technical Specifications to indicate the viability of the various projects and technologies.
- The Technical Process vs. Product Requirement Matrix - evaluates the product aspect pertaining to the ability of the process to provide products that can meet the demands of the market.
- The Technical Process and Product Requirement vs. Sustainability Criteria Matrix-evaluates the products that are integral to the Technological Process and the Sustainability Criteria pertaining to the sustainability of the Product/Process.

Product Specification and Requirements												
Sustainability criteria	Charcoal from Slow pyrolysis	Electricity from Combustion plant	Charcoal and briquettes from Slow pyrolysis	Electricity from Gasification	Weighting per sustainability group	Comments	Specific Energy Supply and Need: Heat	Specific Energy Supply and Need: Steam	Specific Energy Supply and Need: Bio-char	Specific Energy Supply and Need: Bio-Oil	Specific Energy Supply and Need: Gas	Specific Energy Supply and Need: Syngas
Efficiency (1)	2	2	3	5	3					x	x	x
Maturity (2)	3	5	3	5	3		x	x	x			
Modularity (3)	3	1	3	2	3				x			
Size capacity and distribution	2	1	2	3	3				x			
Local capacity (5)	2	1	2	1	3		x	x	x	x	x	x
Lifespan (6)	2	2	2	2	3		x		x			
Product(s) (7)	2	3	2	4	2					x	x	x
Unit cost EROI (8)	3	5	3	4	2						x	x
CAPEX (9)	3	5	3	2	2				x			
OPEX (10)	4	3	4	2	2				x			
Energy balance, EROEI (11)	3	3	3	4	4		x	x			x	x
GHG footprint (12)	4	4	4	4	4		x	x	x	x	x	x
Water footprint (13)	5	3	5	4	4		x	x	x	x	x	x
Biodiversity (14)	5	4	5	4	4		x	x	x	x	x	x
Waste (15)	3	3	3	5	4					x	x	x
Job creation (16)	2	2	2	3	5		x	x	x	x	x	x
Skills development (17)	2	1	2	2	5		x	x	x	x	x	x
Poverty reduction (18)	2	2	2	2	5		x	x	x	x	x	x
Welfare benefits (19)	2	4	2	4	5		x		x	x		
Change in land-usage and	4	4	4	4	5		x		x	x	x	x
Energy security (21)	4	5	4	5	5			x	x	x	x	x
Energy sovereignty (22)	1	1	1	1	5				x			
Community acceptance (23)	3	4	3	4	5		x		x			
Race (24)	5	3	5	3	5				x			
Gender (25)	5	3	5	3	5				x			
Income group (26)	4	3	4	3	5				x			
REFIT (27)	2	4	2	4	1		x	x	x	x	x	x
CDM/CER (28)	4	2	4	5	1		x	x	x	x	x	x
Other (29)					1							
Total	5.1875	4.59125	4.9375	5.34875								

Fig. 3. The Technical Process and Product Requirement vs. Sustainability Criteria Matrix [6].

5. Conclusions and recommendations

The recommendations of the WfE stakeholders and experts were diverse, including simple suggestions on framework structure to improve legibility and complex discussions surrounding the communication of STBS factors, driving forces, and the underlying logic of the method. The outcomes included:

- Unambiguous understanding of the conceptual framework and underlying logic, even if the process would still require a facilitation aspect in order to retain integrity.
- A clear buy-in of all the assessment factors in general was communicated and special attention was given to the Sustainability Criteria factor, the formulation of which was deemed to be of critical importance.
- The effectiveness at which the data surrounding the factors where communicated was commended especially the awareness of the Technical Specification factors.
- The strategic intent and direction was intrinsically communicated by the framework.
- The concern surrounding the trade-off between the rapid assessment and the rigour of the assessment was highlighted and it was concluded that the rigour was dependent on the quality of the data used and rate at which the assessment was required. Both factors can be adjusted within the STBS tool to meet the stakeholder requirements.

Thus, the framework itself provides an accurate communication tool aimed at non-technical stakeholders and political decision-makers at various stages in the project life cycle. It provides them with a simple-to-understand strategic direction, a better understanding of the complex system under review using the implementation process insights, which systems thinking provide. This ensures a much improved stakeholder buy-in as well as general "trust brokering". The framework acts as a high-level cognitive decision tool making use of stakeholders' priorities, and together with the implementation process it is designed to compliment and integrate with other tools such as the MCDA and LCA, from which it draws heavily and where the STBS act as a precursor.

The STBS also utilises information generated by other preceding stakeholder engagement tools, thus acting as a truly integrative tool creating a link between other tools and methodologies, which is invaluable to both stakeholders and practitioners alike. In general, expert opinions had been positive in regards to the STBS addressing sustainability, its rapid flexibility and its ease of communication.

As a way forward, the STBS needs further refinement and active development by further case study analyses. The case study requirement is based on specifically utilising the STBS from an early project stage and providing focus for the STBS as the main strategic assessment tool. This would, however, be done in relation to and in close conjunction with other integrative tools developed so as to add value to the STBS and other tools utilised.

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The SIMPLE methodology for supporting innovations in the field of renewable energy and energy efficiency

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Abstract: In this article, I present my experiences stimulating development of new products and services in small companies in the environmental arena. The focus on small companies is justified since many new innovations originate from such companies and they often have special needs compared to larger companies. In the region of Östergötland Sweden, we have developed a model called SIMPLE (Successful implementation of eco-design in small enterprises) to support small companies' environmental innovations. SIMPLE uses the Triple Helix approach. Triple Helix is often used to describe the interaction between university, government, and industry to promote innovation by building on active participation and interaction between regional actors. In short, the SIMPLE methodology uses coaching, network activities and education, and financial support to encourage development of new ideas. Three cases are presented to illustrate the diversity of innovations that can be supported using the SIMPLE methodology. Observations suggest that individual company's needs must be the main concern of any methodology and networks can significantly stimulate individuals and organizations to speed up the development process and time to market.

Keywords: *Innovation, Small Companies, Renewable energy, Energy efficiency.*

1. Introduction

A rapidly growing demand for renewable energy solutions and energy efficient products calls for innovations. New products and services are realized in a large diversity of organizations including companies of various size and character. This paper focuses on the small company. Product and service development is strategically important for the development of a company, yet Gibb and Scott [1] noted the absence of formal planning models in small companies. Even when the development is strategically important, much of the planning is iterative and not formalized. This is rather far from the linear and structured product and business development models often presented in student textbooks (see Ulrich and Eppinger [2]). Gibb and Scott [1] also noted the importance of strategic awareness and personal commitment. One of the recommendations the authors give to policy makers is to encourage "the development of the strategic awareness and personal commitment of the owner manager".

To stimulate environmentally driven development of small companies, several national and regional initiatives are currently on going in Sweden and Europe. Different approaches and methods can be used and the aim of this paper is to present a methodology, the SIMPLE methodology, developed in the region of Östergötland, SE Sweden. The paper starts with a general description of the methodology followed by three cases of small companies developing new products and services. Special focus is on innovations in the field of renewable energy and energy efficiency. The experiences using the methodology are discussed and conclusions are drawn on the general applicability of the presented methodology.

2. Methodology

The approach used in this study can be referred to as action research. The description of the SIMPLE methodology and all findings in this paper primarily are based on my observations, as a researcher, actively taking part in the general management of the project. The SIMPLE methodology has been developed and tested in three different business development projects involving approximately 50 SMEs in Östergötland, Sweden between 2002 and 2010. The findings presented in this article are from the latest project lasting from May 2008 to December 2010. Earlier descriptions of the methodology can be found in Hjelm [3] and Rennie et al. [4]. My tasks in the current project were to arrange network meetings and to coach actively the companies. However, I did not take part in the individual development projects at the companies. At the end of the project (September-October 2010), I performed semi-structured interviews with company representatives. During these interviews, the respondents were asked to describe their product development and their experiences with the project. I also had continual contact with the companies during the project and collected documentation such as consultancy reports and marketing material produced by the companies. All companies made project plans for the development projects and wrote a short report after finalizing their projects.

In total, 26 companies took part in the latest project including furniture producers, creativity consultants, and heat pump producers. For this paper, I have made a selection of three companies based on the character of their business activities and development. All three are active in the field of renewable energy and energy efficiency, but I tried to select companies having differing characteristics to demonstrate the diversity of companies/innovations that can be supported using the SIMPLE methodology. General facts about the case study companies are found in Table 1.

Table 1. General facts regarding case study companies.

Company	Size (employees)	Main competence area	Development project
Rydell & Lembke, Kyl och Värmeteknik AB	11	Construction and production of cooling and heating equipment	New generation of cooling and heat pump
Pencraft Services AB	3	Renewable energy solutions for generation of electricity and hot water	Energy efficient heater (biogas driven)
Biototal AB	8	Waste product management. Nutrient recycling	Harvesting of biomass for removal of nutrients and substrate for biogas production

3. Description of the SIMPLE methodology

The SIMPLE-model builds on formal and informal networks between companies, the project team, and external resources. This can be visualized as a triangle as described in Figure 1.

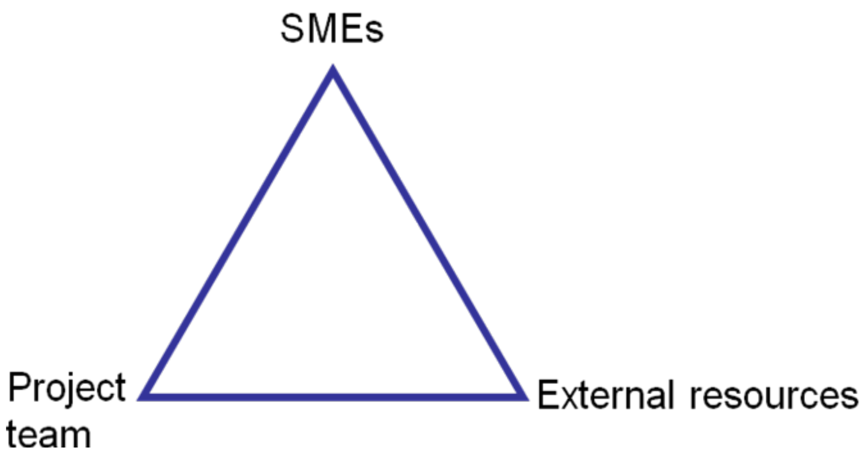

Fig 1. The SIMPLE Model. Each corner represents a different type of network that together constitute the project members. Interactions between the different networks are further described in the text. SMEs=Small and Medium Sized Enterprises.

To explain the different components and structure of the model, it is beneficial to know the underlying goals for the different development projects using the methodology. The main aim has been to create economic growth by stimulating product and business development in small companies and simultaneously solving environmental problems. A secondary aim has been capacity building among regional actors for regional sustainable development and building up a strong network of companies, authorities, and business support organizations in this field. The model is inspired by the Triple Helix approach. Triple Helix is a model used to describe the interaction between university, government, and industry to promote innovation in a region. The triple spiral symbolises the dynamic cooperation between the three actors and the model builds on active participation and interaction between regional actors. A common vision is developed and resources for development are coordinated to increase the capacity for innovations and produce a higher yield as related to the resources spent.

3.1. Small and medium sized enterprises (SMEs)

Two types of companies have participated in the projects. One group includes companies which have products that aim to reduce environmental problems (sometimes labelled as Cleantech companies), while the other group involves companies developing ordinary products that take into consideration environmental concerns (environmentally conscious design). The companies included had been established for at least a couple of years (no start ups were allowed) and had the financial and personal resources to start and finalize a development project. Company size varied between 2 and 75 employees.

Three types of development projects were conducted. The first type included projects that aimed to reduce use of material and energy, to increase conscious choices of material, to substitute toxic materials or chemicals, and to improve recyclability, etc. The second ype of development projects included products or services that solve an environmental problem. The third type included products or services that provide the same customer value but with significantly lower environmental impact compared to established products or services.

3.2. Project team

From the beginning, the project team was designed to comprise individuals and organizations with complementary skills. During all three projects, the organizations represented in the project team have been the County Administrative Board of Östergötland, Linköping University, and the business support organization ALMI företagspartner AB. All actors were members of a larger regional partnership for stimulating regional development and had agreed on a set of regional development strategies that included stimulation of environmentally driven business.

The County Administrative Board is the national government representative office in the county of Östergötland. The Administrative Board has many responsibilities and those of special relevance for this study are development of business and trade as well as protection of the environment. Although these activities are normally managed by different offices, both offices were included in the project reported in this article. The County Administrative Board had the role as project owner and provided administration duties and co-financing.

ALMI företagspartner AB is a state-owned company that provides financing and business development. Each region has a local ALMI-company working together with other actors to improve regional development. It has daily contacts with companies and helps support innovation, a focus of particular interest in this article. As a consequence, ALMI has a very broad network of consultants and other business developers. Before the start of environmental development projects, they had little experience with environmental considerations in business development. Therefore, one ambition has been to develop skills and experience among ALMI-officers in this type of business support.

The local university, Linköping University, added the knowledge of environmental technology and management skills to the project team. The university joined the project to become more involved in direct business development and interact more with the society, acting as a bridge between the academy and business. Zilahy et al. [5] discussed the role of academia in fostering sustainable regional development and give several examples of roles universities can take as first movers and as a resource that offers competent staff and knowledge of the complex issue of sustainable development, goals all in line with the role Linköping University has had in these projects. Furthermore, the university acted as a change agent [6] together with the other organizations in the project team trying to accelerate the region’s transition towards sustainability.

3.3. External resources

The external resources are a very loose and informal network of consultants, researchers, students, industrial designers, research institutes, etc. who were found to have the skills needed for in the development projects. This group was not determined beforehand; however, depending on the needs of each individual company in the project, these resource organizations were identified by the project team or the individual company. This is further described below.

3.4. Way of working

The different steps in the model are presented and explained below.

3.4.1. Start up

After deciding to start a new project (often after securing financing), one of the first tasks for the project team was to find companies willing to enter the project so as to develop the network. The process of finding companies was started by compiling a long list of potential companies. This list was shortened (about 20-30 companies) by scrutinizing each company's line of business, financial status, etc. Companies also were identified if they already had approached one of the project team organizations seeking cooperation. In selecting companies, no special line of business was favoured; instead we sought diversity. A first individual visit was done to present the project and learn more about the company's activities and its ambitions and ideas for development. If the company was judged as suitable, it was offered a place in the project. Finally, an agreement was signed between the company and the project. After a suitable number of companies (7-10) had joined the project, the network was closed and all companies met for a first network meeting.

3.4.2. Network meetings

Network meetings can have many purposes. In the SIMPLE model, we used four to six meetings for education, exchange of experiences, and stimulation of individual meetings between the companies. Experts from academia and business were invited to present lectures and workshops on subjects decided by the group members jointly. These forums included information about eco-design methodologies, intellectual property rights, marketing, and sales. Each network meeting also had a designated time for the companies to present their recent development activities and experiences gained during the process. These sharing of experiences induced further discussion and also inspired the other companies in their development projects.

3.4.3. Individual development project

As indicated above, all companies worked on an individual development project. Typically, this involved development of a new customer's offer. The aim and activities of the development project were described in a simple project plan, and based on this plan a decision was made for financial support. This support (a consultancy check) could be used to cover 50% of the costs incurred by the company for hiring of external resource organizations. The companies did not participate in the exact same activities, so each company decided what activities to support using this financial aid. Typical activities were pre-studies, design, prototype construction, testing, and verification.

3.4.4. Coaching activities

Members of the project team had regular contact with each company via telephone and face-to-face meetings. At these contacts, the development projects were discussed, and eventual changes or extra need of support (such as longer discussions with the project team or meetings with other experts) were discussed.

3.4.5. Completion

Each group worked for approximately 18 months. When completing a group, the results in new products and services and knowledge gained were collected via interviews and written reports. To strengthen the benefits of reporting, a publication for each project was produced and a public exhibition and seminar was arranged to market the participating companies and their projects. These seminars also intended to stimulate further development both in the participating companies and among other actors attending these events.

4. Cases

To illustrate the diversity of development projects that can be supported, the following section contains a description of three small companies that participated in the project. For each company, a short general presentation is given followed by their development project.

4.1. Rydell & Lembke Kyl och Värmeteknik AB

This company (11 employees) builds cooling and heating equipment. Within the project, they developed a new generation of a combined refrigeration machine and heat pump, a combination that has many applications. The method is based on refrigerants encapsulated in small, sealed systems and is built on a different technical platform compared to conventional cooling machines.

4.2. Pencraft Services AB

Pencraft Services (three employees) mainly works with new product development. Its main business area is renewable energy solutions for generation of electricity and hot water. In the current development project, they have been developing energy efficient heating solutions for tap hot water and heating in family houses or small apartment buildings. The system is built on an accumulator for heat storage combined with an air/water heat pump, solar panels, and an extra facility for peak heat demands. All parts of the system are built on existing technologies except the extra device for peak heat demands. The company wanted to solve the peak heat demand by using a burner driven by biofuels. In the project, several options were evaluated and finally biogas was chosen as the fuel for the burner. Consequently, the company developed such a burner to complete the energy system for hot tap water and heating.

4.3. Biototal AB

Biototal (eight employees) is active in nutrient recycling and their general business idea is to recycle nutrients from different wastes. Recycling is achieved by quality assurance of wastes, nutrient balance calculations, and mediation of different nutrient-rich waste products. For example, mediation of by-products from biogas production can produce fertilizer in agriculture. The development project run in this project was a feasibility study for harvesting of biomass from highly eutrophicated waters. This harvested biomass could then be used as a substrate for biogas production and the by-products formed could be used as fertilizer in agriculture. By creating this eco-cycle, several environmental benefits are achieved including substitution of fossil fuels via biogas production and replacement of energy demanding production of commercial fertilizers, removal of nutrients from the water environments, replacement of non-renewable fertilizer with bio-fertilizers in agriculture, and finally increased biodiversity in water environments as a result of the harvesting. The feasibility study highlighted several opportunities and Biototal is currently conducting the first large-scale field tests to verify the results of the feasibility study.

5. Discussion and conclusions

Two of the cases presented above resulted in new products introduced on the market (Rydell & Lembke and Pencraft Services). Biototal is still performing field experiments needed before going to market. This subsample illustrated fairly well the general results of the project. Out of 26 companies, only three did not develop any new products or services. The reasons for this were market problems or that pre-studies identified already existing technologies available. At the end of the project, company leaders from the participating companies were asked about their experiences of being part of the project. The experiences were generally positive. More specifically, they mentioned three major benefits of being part of the project: creation of networks, development of contacts with the university and other support organizations, and receiving extra funding for financing the development projects.

As mentioned in the introduction, Gibb and Scott [1] noted the absence of formal planning models in small companies; hence they recommended that policy makers encourage strategic awareness and personal commitment. In the SIMPLE model, we have addresses Gibb and Scott's concerns in several intertwined ways: networking, education, financial support, and direct coaching. The SIMPLE-methodology is based on the assumption that networks can significantly stimulate business development. It can be argued that small companies always work in networks since they cannot do everything themselves because of their small size [7]. There are many different forms of networks. In this model, we use strategic formalized networks as well as informal networks. Strategic networks can be defined as a cooperative relationship between two or more companies that i) have made an active choice to cooperate and ii) provide some sort of representative for the strategic network [8].

The experience with this project indicates that trust issues are important for well-functioning networks. Since all companies developed new products or services, intellectual property rights (IPR) and patents were important. In the SIMPLE-model, we tried to achieve a balance between openness to present and share new ideas and the protection of these ideas (secrecy). Such issues were thoroughly discussed at the first network meeting and a contract governing secrecy was presented. However, no group signed any contract but instead a verbal agreement was reached. In short, that agreement regulated openness between participants and active participation with the awareness to not mention issues that might hinder such things as patent applications. A general agreement also was concluded not to mention details to people outside the network. These "gentlemen's agreements" proved to be sufficient and we have not experienced any problems with IPR. The oral agreement was sufficient and an open atmosphere contributed to sharing of experiences and mutual learning in the networks.

One important learning outcome from conducting the project is that company perspectives must come first. This can be discouraging for the researcher or business developer who has developed a tool or an approach that the companies are supposed to follow. We tried to minimize the formal procedures and document writing by focusing on the development project as such. The coaching was mainly in the form of discussions with the business leaders so as to help them find the right competencies for their needs. Here the extra funding via the consultancy checks was very useful for companies seeking help from consultants, researchers, etc.

Most likely, the method described in this article can be applied in any type of project trying to stimulate small businesses development of products and services. Important building stones are strong networks, access to a broad group of resource organizations, and some extra money to stimulate the companies to seek help from outside their own organizations.

Acknowledgements

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Tools and mechanisms fostering EU GCC cooperation on Energy Efficiency

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Abstract: In order to respond to the need for European Union (EU) - Gulf Cooperation Council (GCC) clean energy cooperation and provide a practical instrument fostering such activities, the EC External Relations Directorate General has launched the project "Creation and Operation of an EU-GCC Clean Energy Network". To the best of our knowledge, there are no practical tools and instruments to guide structured discussion on EU-GCC clean energy cooperation avenues, acting as catalyst and element of coordination.
Aim of this paper is to present the first outcomes of the Discussion Group "Energy Demand Side Management (DSM) and Energy Efficiency (ENEF)" of the Network. Indeed, there exist a significant potential for promoting cooperation EU-GCC on ENEF & DSM and specific areas of cooperation of mutual benefit, which are identified and discussed in this paper. The key message is the importance of taking action over discussion for promoting cooperation on ENEF & DSM, in the sharing of related expertise and knowledge and in raising general public awareness and collaborating in the framework of common project activities.

Keywords: *Gulf Cooperation Council, European Union, Clean Energy, Network, Cooperation*

1. Introduction

The Gulf Cooperation Council (GCC) is a regional organization created in May 1981, to promote stability and economic cooperation among the Arab States of the Gulf, namely Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates (UAE). The GCC countries are among the world leading oil and gas producing and exporting countries, and constitute prominent members of the Organization of the Petroleum Exporting Countries (OPEC). Indeed, in the GCC countries all power generation is oil and gas based. Especially, the quantities of proved reserves of crude oil and natural gas were estimated to represent about 39.5 per cent and 22.9 per cent of the world's total reserves respectively in 2008 [1].

These countries are also among the highest energy consumers worldwide; especially domestic energy consumption continues to increase fast. Based on International Energy Agency (IEA) data, the GHG emissions have increased by more than approximately 50 per cent in the last decade [2]. Furthermore, electricity demand is increasing particularly fast, at average growth rates of 7 per cent, which implies a doubling of the needed power generation capacity every 10 years. The electricity load curve in the GCC countries shows very high summer loads - in general and in particular during peak hours. At the same time approximately 45 per cent of domestic electricity consumption is linked to these appliances [3]. This strong electricity demand growth is also driven by artificially low prices.

Despite the high exploitable potential, till now, only pilot, research and some small scale activities related to the renewable energy and energy efficiency were conducted in the Arab States of the Gulf and as a result, some small and medium capacity projects were installed and tested [4]. However, the current situation has been changing as the government, the financial organizations, the academics, the general public and the private sector start realizing the inevitability of putting climate change issues on the top of the priorities' list in the process of sustainable development [5]. Furthermore, the price fluctuations, the rapid population growth and the increasing energy demand contribute to the increased necessity of sustainable energy solutions, as the region cannot depend on conventional fuels forever. As also depicted in recent studies, the GCC countries have recently adopted a more pro-active approach toward ecological modernization. This reorientation has not yet resulted in the development of consistent strategies and policies. However, pioneering projects such as Masdar City, the Energy City Qatar and innovative regulation like the green building code in Dubai will spread within the GCC [6-8].

The European Union (EU) has a well founded interest to cooperate with the GCC countries and support them in addressing and successfully tackling clean energy issues. This is particularly true taking into consideration that on one hand EU is the leading world proponent of climate change prevention and on the other hand is one of the world's major importers of hydrocarbons. Indeed, the global warning poses certain constraints to energy usage with direct impacts to the international economic activity and the producer-consumer dialogue is currently focused on the identification of prospects and opportunities for the development of a sustainable energy economy in order to pass from the current carbon constrained economy to new and prosperous sustainable development paths.

To the best of our knowledge, there are no practical tools and instruments to guide structured discussion on EU-GCC clean energy cooperation avenues, acting as catalyst and element of coordination. Aim of this paper is to present the first outcomes of the Discussion Group "Energy Demand Side Management (DSM) and Energy Efficiency (ENEF)" of the Network. Indeed, there exist a significant potential for promoting cooperation EU-GCC on ENEF & DSM and specific areas of cooperation of mutual benefit, which are identified and discussed in this paper.

The paper, apart from this first introductory section, is structured along the following sections. Section 2 is focused on a short description of the EU-GCC Clean Energy Network initiative. Section 3 provides, in a concise way, the activities and methodological procedures followed within the D/G of the Network. Section 4, which is the main part of the study, focuses on the first outputs within the Energy Demand Side Management and Energy Efficiency D/G, providing areas for EU-GCC cooperation under this D/G. Section 5 presents the main conclusions drawn from work carried out so far under the Energy Demand Side Management and Energy Efficiency D/G.

2. The EU GCC Clean Energy Network

The EU-GCC partnership started officially in 1988, when the EU and the GCC signed a Cooperation Agreement, which put into place a regular high level framework of dialogue. The Cooperation Agreement established two important bodies:

- On the strategic level, an annual Joint Council and Ministerial Meeting between the EU and the GCC foreign ministers and between senior officials at a Joint Cooperation Committee.
- On the operational level, an Energy Experts Group that started its work at the beginning of 1990's.

The EU – GCC on the 17th GCC-EC Joint Co-operation Committee (March 2006) outlined the need for policy support towards the promotion of renewable and energy efficiency options in the Arab States of the Gulf. In the EU – GCC expert meeting on climate change on the 22nd of January 2007 in Brussels, all participants underlined the importance of Clean Development Mechanism (CDM) projects for GCC countries and especially in the areas of Carbon Capture and Storage (CCS) technology, energy production, energy efficiency and conservation, petroleum refining and petrochemical industries. Respectively, the EU – GCC meeting on climate change on the 11th of February 2008 in Brussels focused on the need for better technology cooperation frameworks and technology transfer progress. The Workshop "Enhancing the EU-GCC Relations within the New Climate Regime: Prospects and Opportunities for Cooperation", on the 26th of February 2009 underlined the importance of EU-GCC co-operation issues related to energy and the environment [9].

In this context, the European Commission (EC), External Relations Directorate General has commissioned the project "Creation and Operation of an EU-GCC Clean Energy Network". The specific objective of this project, aimed to create and facilitate the operation of an EU-GCC Clean Energy Network. This network aims to act as a catalyst and element of coordination for development of cooperation on clean energy, including the related policy and technology aspects, among various stakeholders in the EU and GCC countries. The 20th EU-GCC Joint Council and Ministerial Meeting, Luxembourg, 14 June 2010, welcomed the EC-GCC Clean Energy Network.

In light of the above facts, an integrated procedure for the identification of appropriate renewable and energy efficiency solutions could stimulate the interest of donors (GCC funds, EU funds, International donors' funds, National Funds) and foster joint activities and deployment of technologies in the area of clean energy. It is also noted that the Network will support the identified project ideas, by the:

- Identification and mobilisation of available sources of financing for joint EU-GCC projects and activities;
- Identification, preparation & submission of applications and implementation of research projects under FP7 funding and other R&D financing programmes;
- Assistance in development of project fiches and submission to international donors and other financing institutions.

This Network's scope and operation aims to identify the huge potential for EU-GCC cooperation, as well as to strengthen the cooperation ties between these two regions.

3. Discussion Groups' Structure and Methodological Procedures

To achieve these results, the network (EU-GCC Clean Energy Network) is designed in a way that allows robust operation, efficiency and flexibility, so as to provide the wide variety of services necessary to achieve the expected results. Essential features of the project are the Discussion Groups (D/G) that focus on areas of common interest.

The thematic Discussion Groups (D/Gs) contribute to the Network's strategic objectives for enhancing EU-GCC clean energy cooperation. The five key thematic areas on which the D/Gs' work is focused are:

- D/G 1: Renewable Energy Sources
- D/G 2: Energy Demand Side Management and Energy Efficiency
- D/G 3: Clean Natural Gas and Related Clean Technologies
- D/G 4: Electricity Interconnections and Market Integration
- D/G 5: Carbon Capture and Storage (CCS).

The Discussion Groups (D/G) are structured in a simple way, so as to allow ease of operation and flexibility. The proposed organisational structure of a D/G is presented in the following Figure 1.

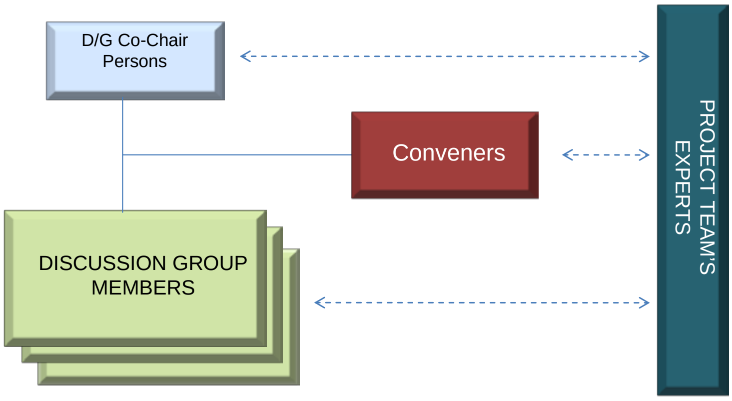

Fig. 1. Structure of a Discussion Group.

The D/Gs work in a continuous "collaboration mode", by communicating mainly through the Network's Communication- Collaboration- Dissemination Platform (NCCDP). There is a specific "area" within the NCCDP for each D/G, where D/G members have full access. The D/Gs works under an agreed yearly Work-Plan with clearly identified working directions regarding analysis and advice on:

- Best practice technologies.
- EU and GCC Policies.
- Cooperation opportunities- projects among EU and GCC entities.
- Exchange of ideas/know-how for the specific D/G clean energy topics.

Communication and collaboration within the D/G members is supported by the NCCDP "D/G area" that provides tools for: discussion on topics, exchange of documents and information, collaborative work on documents, web-meetings (convened by the D/GC or D/G Co-Chair Persons), Training Webinars, etc. The D/GC assisted by the D/G co-chair persons mobilize, coordinate and facilitate communication and collaboration. Discussion Group members are registered in the D/G Mailing List to receive important D/G notifications from the D/GC, the D/G Co-Chair Persons and the Network Administration.

4. First Outputs within the Energy Demand Side Management and Energy Efficiency D/G

In the following parts, the main points drawn up from the background report elaborated within the D/G are presented. It is noted that this background report is a collaborative work/contribution among D/G experts, which is aimed to be further enhanced so as to constitute a "Thematic EU-GCC Co-operation Roadmap" on DSM and ENEF.

4.1. EU & GCC State of Play

4.1.1. EU State of Play

The EU region is a frontrunner in tackling climate change and energy efficiency issues. The 20-20-20 target set for 2020 has placed very ambitious goals for the reduction by 20% of GHG emissions and primary energy consumption.

According to a WEC report [10], EU has one of the lowest primary energy intensities in purchasing power parities in the world, and significantly lower than the world average. Figure 2 below depicts this favorable EU standing in the world as far as the primary energy intensity levels in 2008 are concerned.

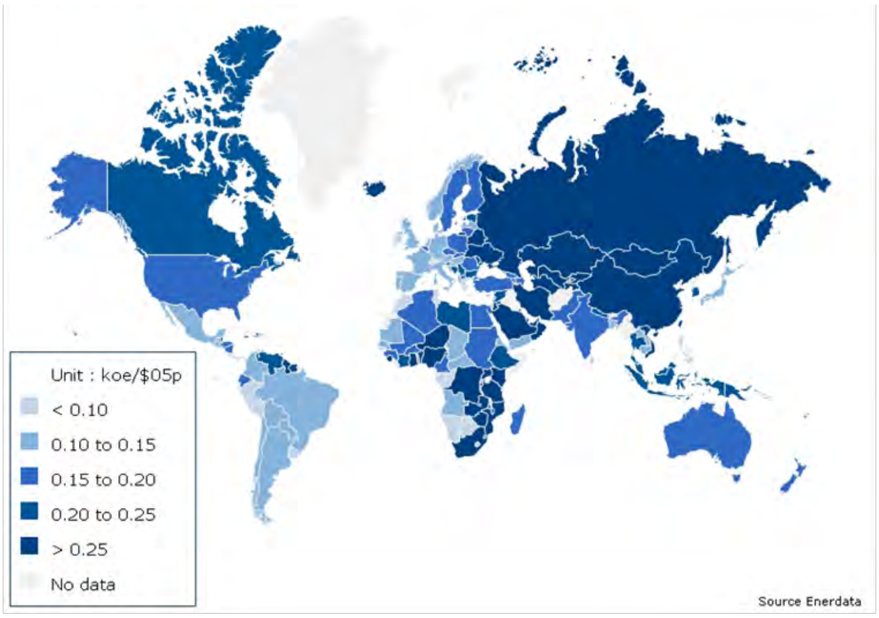

Fig. 2. Primary energy intensity levels by country (2008).

Source: WEC 2010

EU has taken significant legislative action so as to further enhance energy efficiency in the region. Although tackling energy consumption through demand side management activities in the national level remains a very challenging task, EU central policy developed is a key driver towards the achievement of the 20-20-20 target.

4.1.2. GCC State of Play

While no harmonized policy on DSM exists in the GCC states, recent developments show some changes in individual GCC countries. In the following paragraphs, an outline of the prevailing situation in these countries is presented.

- **UAE:**
  - Urban master Plan Abu Dhabi 2030 addresses sustainability as a core principle. Estidama, which is the Arabic word for sustainability, is an initiative developed and promoted by the Abu Dhabi Urban Planning Council (UPC), while the early aspirations of Estidama are incorporated into Plan 2030 and other UPC policies.
  - The Pearl Rating System for Estidama is one of the key tools for driving and determining the core principles of sustainable development. It is a framework for sustainable design, construction and operation of communities, buildings and villas, specifically tailored to the hot climate and arid environment of Abu Dhabi.
  - The Economic Affairs Unit of Abu Dhabi is currently working with other government and non-government entities to develop a comprehensive Demand Side Management strategy for electricity and water consumption within the Emirate.
  - As regards Dubai, the government adopted a sustainable development policy ("Dubai Strategic Plan 2015"), covering all aspects of society. In the energy branch, green building standards, and water and energy conservation and management are

relevant aspects. The Green Building Regulation came into effect in April 2010 and aimed at reducing energy demands of new buildings by up to 40%.
  - Moreover, the Emirates Authority for Standardisation and Metrology (ESMA) has launched a new energy efficiency label and standard scheme in a bid to reduce country's environmental impact. The new certification will be placed on electronic goods - in particular air-conditioning units - and will be based on an international standards template while being specifically designed for the UAE market.
- **Kuwait:** The Ministry of Electricity and Water has developed a code of practice for energy conservation in buildings, placing emphasis on HVAC, since 1983. A revised version of the code was issued in 2010.
- **Saudi Arabia:**
  - Ministry of Water and Electricity systematically promotes DSM, by founding the Energy Conservation and Awareness Department, imposing limits to the maximum power that can be delivered to electricity consumers, establishing DSM actions, and rationalizing the use of electricity.
  - Saudi Arabian Standards Organization adopted several standards aiming to limit the penetration of in-efficient electrical appliances, without however having the effective power to enforce these standards.
- **Qatar:**
  - Qatar Green Building Council (QGBC) with mission to educate and increase awareness and develop a set of green building best practice guidelines.
  - Qatar Sustainable Energy and Water Utilisation Initiative is a project to improve desalination technologies, and promote public awareness of sustainable use of energy.
  - National Vision 2030 on sustainable development is supported by Dohaland, introducing edge urban living concepts, aimed at delivering a sustainable development that is energy-efficient, high in performance and low in wastage.
- **Oman:** Electricity companies trying to implement certain DSM programmes are facing difficulties, such as large subsidies offered for tertiary sectors' tariffs.
- ***Bahrain:*** A number of activities promoting energy conservation and DSM measures have been realized. These programmes are targeted towards thermal insulation, energy audit, power factor, CFLs, labels and energy standards, load control and awareness raising.

4.2. EU & GCC main technology and policy fields of interest

Main technological focus till now from the GCC side has been placed upon Combined Heat and Power Generation, as well as the development of cross-cutting technologies in the industrial sector (compressed air pumps, electric motors, ventilation and air conditioning, steam generation, cooling etc.). Nevertheless, the significant progress being made on the implementation of RUE technologies in the tertiary sector cannot be neglected.

Some potential technology and policy fields of interest for EU/GCC cooperation include:

- Application of efficient labels and standards for energy household appliances;
- Redesign of subsidies offered for tertiary sector tariffs;
- Use of bioclimatic architecture;
- Promotion of energy efficiency awareness campaigns;
- Promotion of energy audits in all sectors (industries, tertiary sector buildings, households);
- Realization of RUE technologies in public buildings, as demonstration projects;
- Common efforts of government/electricity companies to promote DSM measures;

- Introduction of smart meters not only for the large consumers, but for the household sector as well.

4.3. Promoting co-operation on Energy Efficiency & Demand Side Management

Particular emphasis was laid on the discussion for the identification of a few concrete examples of areas on which the EU and the GCC could cooperate. These areas are the following:

- Air Conditioning (AC) maintenance and AC technicians' certification,
- Replacement of incandescent lamps, further introduction of solar water heaters, reverse osmosis.
- To support legislation and infrastructures e.g. through information platforms and the development of standards

In addition, fruitful discussions were elaborated on financing measures that could foster related cooperation activities, such as:

- Lower than market cost tariffs halter the significant promotion of energy efficiency. However, raising prices to more cost reflecting tariffs is already happening.
- District cooling is a promising option for GCC. However, currently the district cooling pricing is double than the cost of using AC units.

5. Conclusions

The main points drawn from the discussion group on "Energy Demand Side Management and Energy Efficiency", as also discussed within the 1st Meeting of the Network's Discussion Groups, 30th November - 1st December 2010, Dubai, UAE, include the following:

- The GCC region is facing increasing energy demand and high environmental concerns. Especially as concerns the electricity consumption, the increasing rates in the GCC region have more than doubled within a ten years period, while the load curve shows very high summer loads in general and in particular during peak hours.
- Implementation of Demand Side Management (DSM) schemes is gaining ground in the region. More specifically, Abu Dhabi has incorporated their utilization in the energy policy 2030, while efforts are being made for their implementation also in Bahrain, Oman and Saudi Arabia. In addition, KSA and UAE have already started pilot projects on smart energy meters, while activities such as the Abu Dhabi Masdar City, the Qatar Energy City, the Bahrain World Trade Center and the KAUST Sustainable Campus, show the GCC interest in these fields.
- The EU has placed significant emphasis on promoting energy efficiency through the adoption of the 20-20-20 target. In addition to the EU common policy measures, the EU member states possess significant experience in the promotion of energy efficiency measures and technologies.
- GCC countries can benefit, through the exchange of experiences and know how in the field of policies and measures, based on the EU related efforts and activities. The FP7 Programme could also provide opportunities for related collaborations of EU/GCC entities.

Indeed, the Discussion Group outcomes in terms of exploration of possibilities for joint projects (both technological research and pilot industrial scale projects) are of significant importance for enhancing EU-GCC Clean Energy Cooperation in fields of mutual interest.

The future direction is to make this Network a forum of action and not just discussion. The discussion and networking opportunities this platform provides the potential users/

beneficiaries with should be a means to deliver projects which could push forward the GCC region on the global scene in the field of clean energy. These potential users/ beneficiaries, including donors (GCC funds, EU funds, International donors' funds, National Funds), other financing institutions and energy actors, should work together for preparation & submission of applications as well as implementation of research projects under FP7 funding and other R&D financing programmes.

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The emerging bio-economy in Europe: Exploring the key governance challenges

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Abstract: The purpose of this paper is to identify, analyse and discuss the key governance challenges for the emerging Knowledge-Based Bio-Economy (KBBE) in Europe focusing on bioenergy, particularly biofuels for transport and the biorefinery concept. This paper is based on a literature review, discussions with European researchers and practitioners, and questionnaires of bioenergy industry associations. The growing bio-economy and bioenergy in Europe face a host of socio-technical issues that comprise a mix of technological, economic, social, political, environmental, regulatory and cultural aspects. More specifically, this research work highlights three key governance challenges of increasing relevance for the bio-economy, including: the important role of public-private networks; city-regions as drivers for the KBBE, especially through climate governance; and consumer-citizens and NGOs as key players in the development of the bio-economy.

Keywords: *Bio-economy, Bioenergy, Governance, Socio-technical, Sustainability*

1. Introduction

The emerging Knowledge-Based Bio-Economy (KBBE) in Europe represents a significant transformation from economic, social and environmental perspectives. In short, the concept of the KBBE can be understood as an economy where the basic building blocks for materials, chemicals and energy are derived from renewable biological resources, such as plant and animal sources [1]. Worth nearly €2 trillion, the existing bio-economy in Europe currently employs around 22 million people across sectors as diverse as agriculture, forestry, fisheries, food, and bioenergy [2]. The increased attention on the bio-economy is being driven by the recent surge in scientific knowledge and technical competences that can be used to harness biological processes for practical applications as well as efforts to reduce greenhouse emissions and dependency on oil and fossil fuels.

Within the KBBE, the focus of this paper is on bioenergy – particularly biofuels for transport and the biorefinery concept (see Box 1). The purpose of this paper is to identify, analyse and discuss the key governance challenges for the emerging bio-economy in Europe. There are two underlying objectives. The first is to investigate different perspectives and understanding of the bio-economy and its key components. The second is to consider the bio-economy in terms of positive and negative impacts as well as drivers and constraints. Overall, this paper begins to explore the complexity of the socio-technical issues (covering technological, economic, social, political, environmental, regulatory and cultural aspects) that surround the bio-economy. It is timely to investigate the role of governance for the bio-economy as a European KBBE strategy is expected to be launched in 2011 [3].

2. Approach

The emerging bio-economy in Europe is attracting the attention of a diversity of actors (with different interests and values) since it affects a range of sectors and activities. Furthermore, biofuels for transport (and the biorefinery concept) are under intense debate regarding sustainability issues. In this paper, governance is considered as encompassing complex processes, which involve multiple actors in decision-making and policy-making [4]. This paper further defines governance in two ways. First, it refers to the different tiers at which governance takes place and the interactions between the tiers, which for Europe is local municipalities, national governments and the EU. Second, it refers to the myriad of networks between public and private actors that shape governance activities.

Box 1: Bioenergy

Humans exploit biomass (plant and animal matter) for many purposes. When it is utilized to produce heat, electricity or fuels for transport it is commonly called ***bioenergy***. Biomass can be considered as 'stored' solar energy because the process of photosynthesis 'captures' energy from the sun in growing plants. Utilizing biomass for energy purposes is in fact tapping into the vast energy available from the sun. Bioenergy systems comprise both technical aspects, such as conversion technologies, and non-technical aspects, such as government policies.

Biofuels for transport are commonly categorised as follows: first generation biofuels made from food crops, such as wheat and sugar beet; second generation biofuels from non-food biomass, such as lignocellulosic materials; and third generation biofuels from algae. At present only first generation biofuels can be produced on a large-scale. However, the commercialisation of second generation biofuels is expected over the coming decades. The third generation biofuels are in a research and development phase.

The ***biorefinery concept*** offers exciting potential to better manage and capture value from biomass resources. Similar to petroleum refineries, which produce multiple fuels and products from petroleum, biorefineries imply the integrated production of energy, fuels and chemicals from biomass. Biorefineries have been identified as one of the most promising routes towards the KBBE. While partial biorefineries exist today, considerable research, development, demonstration and commercialisation is required to make advanced biorefineries a reality.

Source: [5]

This research work utilised different research methods to meet the requirements of 'method' triangulation, including a literature review, discussions with European researchers and practitioners, and questionnaires of bioenergy industry associations. The World Bioenergy Association (WBA), the European Biomass Association (AEBIOM), the Swedish Bioenergy Association (SVEBIO), the Spanish Bioenergy Association (AVEBIOM), and the Renewable Energy Association (REA) in the UK, which represents bioenergy interests, completed questionnaires. The discussions with informants from a range of sectors and different backgrounds also ensure 'informant' triangulation.

3. Analysis

3.1. What is the bio-economy? What are the key components of the bio-economy in Europe?

Bioenergy industry associations show some diversity in perspectives on the bio-economy. Heinz Kopetz (questionnaire, 18 June 2010) of AEBIOM states: "The bio-economy is a rather new word. It is that part of the economy that relies on energy and raw materials originating from green plants." Tricia Wiley (questionnaire, 3 September 2010) of the REA points out the UK Biomass Strategy provides a definition of the bio-economy as "economic activities which capture the latent value in biological processes and renewable bioresources to produce improved health and sustainable growth and development". The UK Biomass Strategy is based on the definition of the OECD [6]. Furthermore, the OECD [6] highlights the important role of biotechnology in the emerging bio-economy (see Box 2).

Box 2: Biotechnology

Biotechnology can be understood as the science of using living things to produce goods and services. It therefore involves manipulating and modifying organisms to create new and practical applications. ***Industrial biotechnology*** or ***white biotechnology*** uses enzymes and micro-organisms to make bio-based products in a diverse range of sectors, including chemicals, food and feed, bioenergy, paper and pulp, and textiles. ***Green biotechnology*** is biotechnology applied to agricultural processes. ***Blue biotechnology*** is a term that has been used to describe the marine and aquatic applications of biotechnology. And finally, ***modern biotechnology*** is used to distinguish newer applications of biotechnology, such as genetic engineering and cell fusion, from more conventional methods, such as breeding or fermentation.

Source: [6]

Kjell Andersson (questionnaire, 14 June 2010) of SVEBIO states: "I was not aware that there is a concept of an 'emerging bio-economy'. I think we have a very strong move towards a more sustainable energy system, with more energy efficiency and more renewable energy, which bioenergy is an important component." Francisco Gonzalez (questionnaire, 4 August 2010) of AVEBIOM states that bioenergy is at the core of the bio-economy. Overall, Kent Nyström (questionnaire, 20 August 2010) of the WBA highlights that the key components of the bio-economy are sustainability in a broader sense including fair competition between energy, food and feed as well as fair competition for water supply and land use. This highlights that sustainability is central to the KBBE but also the challenges of designing and managing the bio-economy.

The concept of the bio-economy has generated considerable 'excitement' in Europe and around the world. However, it is immediately apparent that the bio-economy means very different things to different people. A better understanding of the bio-economy and its key components remains a vital foundation for the growth of the KBBE in Europe. Interestingly, the bio-economy is one of the oldest sectors (including all industries and economic activities that produce, manage and exploit biological resources, such as agriculture, food, forestry, fisheries and bioenergy), but it is being transformed into one of the newest sectors. The key components of the bio-economy include biotechnology and the biorefinery concept. Biofuels for transport are a key product and agriculture is the primary source of raw materials.

3.2. Why promote the bio-economy in Europe? What are the main positive and negative impacts of the bio-economy?

Not surprisingly, bioenergy industry associations in Europe are largely optimistic about bioenergy. However, there is a strong awareness that supportive policy schemes need to stimulate well-designed bioenergy systems that incorporate strict sustainability standards. Heinz Kopetz (questionnaire, 18 June 2010) of AEBIOM believes that negative impacts will occur if a sustainable production of biomass is not achieved, which includes the fertility of soils and the availability of water, or if more biomass is used than annually produced, and a competition between food and non-food use of biomass takes place. Kent Nyström (questionnaire, 20 August 2010) of the WBA is confident the expanding bio-economy can avoid substantial negative impacts. However, there are challenges ahead for the expanding bio-economy to meet stricter sustainability requirements.

Kjell Andersson (questionnaire, 18 June 2010) of SVEBIO states that the main positive outcomes of the bio-economy are "a more sustainable energy and material system, based on solar energy and natural processes, instead of depleting finite resources.” Tricia Wiley (questionnaire, 3 September 2010) of the REA suggests there are a number of economic, security and environmental benefits associated with the bio-economy, including job creation as well as investments in industry and deprived areas and communities. Francisco Gonzalez (questionnaire, 4 August 2010) of AVEBIOM argues that the generation of employment opportunities in rural areas and new incomes streams for farmers will be some of the major positive results of the growing bio-economy.

When looking at the positive and negative impacts of the bio-economy a distinction needs to be made between the near-future as opposed to the long-term perspective based on visions. There are diverging visions of the bio-economy from wildly optimistic about an industrial revolution in the coming decades [7] to ‘real’ concern about significant negative impacts, especially related to increasing biofuels for transport [8]. Additionally, the current status of the bio-economy remains unclear, despite studies to define the scale and attributes of the existing bio-economy. Finally, there is growing knowledge related to the biorefinery concept and efforts to speed up the development and implementation of biorefineries in Europe, but there is still great uncertainty about the potentials and impacts associated with biorefineries.

3.3. How can the bio-economy expand in Europe in a sustainable and competitive way? What are the main drivers and constraints for the bio-economy?

The marginal understanding of the bio-economy and the ‘missing’ carbon taxes in many European countries are considered key constraints by some bioenergy industry associations. Heinz Kopetz (questionnaire, 18 June 2010) of AEBIOM states: “The basic principle of the bio-economy lies in the fact that the carbon comes via photosynthesis from the atmosphere and not from the earth’s crust. As long as the depletion of the earth’s crust brings more profit than the use of carbon via photosynthesis the development of the bio-economy will be held back.” There are in fact discussions about carbon taxes across the EU, especially based on the positive experiences from Sweden. In addition to expanding bioenergy, Sweden has also made significant progress on biofuels for transport, especially bioethanol (see Box 3).

Box 3: Bioenergy and Bioethanol in Sweden

In 2009, ***bioenergy*** overtook oil as the largest source of energy in Sweden. Oil accounted for 30.8% while bioenergy provided 31.7% of the total energy use. A major reason for the growth of bioenergy in Sweden has been the carbon tax established in 1991. It is based on the ‘polluter pays principle’ in that emitters of CO2 pay for the costs of CO2 emissions. The carbon tax makes it profitable to use fossil fuels efficiently and switch to renewable energy. The carbon tax has transformed the energy system in Sweden towards bioenergy.

Over 1,400 of Sweden’s 4,000 service stations offer fuels from renewable energy sources, predominantly ***bioethanol***. In addition to economic incentives, service stations (of certain sizes) are mandated by law to provide a renewable alternative. Presently, there are some 4.2 million cars on Sweden’s roads and almost 200,000 are flexi-fuel cars (that can operate on bioethanol, petrol or varying blends). There are economic incentives to purchase flexi-fuel cars, and subsidies and tax reforms make bioethanol competitive with regular petrol.

Source: [9,10]

Kjell Andersson (questionnaire, 18 June 2010) of SVEBIO states: “Strong traditional industries lobbying to preserve their dominance (oil, coal, gas, nuclear) and big ‘sunk costs’ in the existing energy systems make it hard for new alternatives to compete. The fossil energy systems also do not, in most countries, pay for their full external costs, like damage on the economy, climate costs, and safety and security costs (nuclear).” Francisco Gonzalez (questionnaire, 4 August 2010) of AVEBIOM concurs that the main obstacles for the KBBE arise from the capacity of the oil and gas sectors to lobby political and business leaders. For the UK, Tricia Wiley (questionnaire, 3 September 2010) of the REA suggests that complex and inconsistent regulations, and the perceived risks of policy changes, are constraints for the bio-economy.

The drivers and constraints for the bio-economy are mixed together with challenges (and opportunities). There is also a difference between global and European issues and trends, and more ‘concrete’ drivers or constraints at the national and local levels. Supportive policy schemes and social acceptance by a broad range of stakeholders appear to be key ingredients for the growing bio-economy. A more integrated and strategic policy approach is required to stimulate the KBBE in Europe, which is combined with a strong emphasis on engagement with the general public and key stakeholders. While there is an increased effort on research and development, it is imperative to also fund demonstrations and implementation. There are also many difficult policy decisions to make, especially regarding the sustainable supply of raw materials for the bio-economy [11].

4. Discussion

4.1. The importance of public-private networks

The bio-economy is critically dependent on policy ‘intervention’ that creates a favourable environment for investment. The type of governance that is shaping the bio-economy in the EU is not liberal or market-based or coordinated and state-led, but it is rather characterised by public-private networks. There is a pattern of combined public and private investments in various parts of the bio-economy, which involves a complex interplay between publicly funded science and business firms, regulated markets, emerging professional groups, attempts to integrate activities across government authorities, and efforts to create positive public attitudes to the KBBE [12]. The development of public-private networks appears to be an essential characteristic of the emerging bio-economy, particularly for the biorefinery concept, which requires significant support and investment.

EuropaBio [13] states that the main challenges in Europe are that a more integrated and strategic approach is needed for the EU to develop a globally competitive bio-economy within the next decade. This paper suggests that such an integrated approach should be focused on long-term opportunities and open to partnerships between public and private actors within the EU (and around the world). For EuropaBio [13] it should involve five key aims, including: improving and securing access to renewable raw materials; supporting targeted research, training and innovation; developing technologies and systems, and bridging the gap between research and markets; stimulating demands for bio-based products; and improving awareness of the bio-economy through communication and educational activities.

4.2. The role of city-regions

In a European context, many of the policies and strategies that are implemented by local municipalities were formulated by the EU and filtered through national governments. Silvestrini et al. [14] examine the implementation of the Biofuels Directive in Germany, the UK, Italy and Finland by looking at the role of city-regions, namely Berlin, London, Milan and Helsinki. Interestingly, and extremely relevant for the emerging bio-economy, is that networking between city-regions is allowing an exchange of knowledge and experiences, and contributing to practical and policy learning around the Biofuels Directive [14]. This paper argues that city-regions and local municipalities are well-positioned to play an important role in the KBBE, especially in relation to biofuels for transport.

The scope for action by local municipalities is defined by their jurisdiction and responsibilities, and their financial independence. However, Gupta et al. [15] suggest that local municipalities are often able to establish more ambitious goals and policies than national governments, which is particularly evident in regards to climate governance. Furthermore, the goals and policies of city-regions related to the bio-economy can be framed through climate governance, which can help to mobilise actors and coordinate diverse interests. For the bio-economy, climate governance by local municipalities and city-regions can be an important mechanism to translate abstract visions of the KBBE (often framed by national or international actors) into concrete agendas based on local and regional contexts.

4.3. The engagement of consumer-citizens

Creating awareness amongst the general public and key stakeholders about the KBBE appears to be a vital foundation for expanding the bio-economy in Europe. This paper argues that an EU strategy for communication and stakeholder involvement is necessary, which is combined with actions across countries and city-regions. However, it is clear that increased information and communication do not directly translate into public acceptance. On the contrary, the success of the bio-economy will likely depend on active public and stakeholder engagement both in policy formulation and specific projects. Demonstrating the benefits of expanding the bio-economy in parallel with trade-offs to consumer-citizens will be required to create the foundations for the KBBE in Europe [16].

The concept of consumer-citizens can be utilised to shape communication strategies. On the one hand, the bio-economy needs to be marketed to 'consumers', and on the other hand, proponents of the bio-economy need to also actively engage 'citizens' in planning and implementation processes. Additionally, there is a need to identify and positively engage with target audiences, particularly opinion-formers, such as NGOs, that can influence the general public. NGOs are currently establishing their positions on the KBBE. It can be expected that NGOs will become further engaged as the bio-economy grows. NGOs are likely to be important opinion-formers for the implementation of the biorefinery concept and they are already deeply engaged in debates on biofuels for transport.

5. Reflections

This paper concludes with two reflections. First, serious concerns have been raised about the sustainability of biofuels for transport, which are an integral part of the KBBE. The underlying message is that biofuels only make sense if the raw materials are based on truly renewable and sustainable sources. The European Commission has decided to establish binding sustainability criteria for biofuels, which will become stricter over time. The efforts by the European Commission all point towards increased emphasis on the sustainability for bioenergy generally and biofuels for transport specifically. Furthermore, the biorefinery concept offers the potential to move towards more sustainable production of biofuels combined with other bio-based products.

Second, while sustainability appears to be on the top of the political agenda, it is impossible to measure the sustainability of biofuels, the biorefinery concept or the bio-economy, without taking into consideration the scale and pace of growth. This challenges current thinking and ideas about the economy. Put simply, the bio-economy cannot replace the fossil-based economy as it is set-up today. On the contrary, the emerging bio-economy demands attention on consumption issues as much as the production side. For example, biofuels for transport must be integrated into broader mobility strategies that encompass more than the introduction of 'new' fuels. Ultimately, the move towards a sustainable KBBE is directly connected to achieving sustainable development on a 'grand' scale.

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Tools for Sustainable Energy Engineering

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Abstract: Exergy concepts and exergy based methods offer an insight to the understanding of sustainable energy engineering. The utilization of energy and other resources by applying physical concept as exergy and exergy based methods and the value of these tools in the design and optimization are presented, in particular Life Cycle Exergy Analysis (LCEA). Optimization methods incorporating both exergy and economic conditions are also presented. This brings a new approach and insight to the engineering conditions for a sustainable development that is further elaborated. The importance of introducing this new knowledge into present engineering education and practices is argued for.

Keywords: *Renewable energy, Energy Policy, Energy engineering, Sustainable development, Education.*

Nomenclature

E	exergy	J
$E_{indirect}$	exergy indirect input	J
E_{in}	exergy input	J
$\dot{E}_{in}$	exergy power input	W
E_{out}	exergy output	J
$E_{net,pr}$	exergy net of product	J
E_{pr}	exergy of product	J
$\dot{E}_{pr}$	exergy power of product	W
E^{tot}	total exergy	J
E_{tr}	transit exergy	J
E_{waste}	exergy of waste	J
H	enthalpy	J
i, j, k, l	unit, 1, 2,…	
P_0	pressure of the environment	Pa
Q	heat (thermal energy in transit)	J
S	entropy	J K^{-1}
S^{tot}	entropy of the total system, i.e. the system and the environment	J K^{-1}
t	time	s
t_0	time when a project starts, e.g. the first steps to build a power plant	s
t_{close}	time when an operation closes, e.g. a power plant close down	s
t_{life}	time when a project finally closes, i.e. after complete restoration to original state	s
$t_{payback}$	time when a payback situation is reached	s
t_{start}	time when an operation starts	s
T	temperature	K
T_0	temperature of the environment	K
U	internal energy	J
V	volume	m^3
μ_{i0}	chemical potential of substance i in its environmental state	J mol^{-1}

1. Introduction

Exergy is a well established scientific concept suitable in the work towards sustainable development. Exergy accounting of the use of energy and material resources provides unique knowledge on how effective a process is in utilizing physical resources. This knowledge can identify areas in which technical and other improvements should be undertaken, and indicate the priorities, which should be assigned to conservation measures, efficiency improvements and optimizations. Thus, exergy concept and tools are essential to the creation of a new engineering paradigm towards sustainable development.

2. Exergy

The exergy concept originates from works of Carnot [1], Gibbs [2], Rant [3] and Tribus [4] and the history is well documented [5]. Exergy of a system is [6], [7]

$$E = U + P_0V - T_0S - \sum_i \mu_{i0} n_i \tag{1}$$

where U, V, S, and n_i denote extensive parameters of the system (energy, volume, entropy, and the number of moles of different chemical materials i) and P_0, T_0, and μ_{i0} are intensive parameters of the environment (pressure, temperature, and chemical potential). Analogously, the exergy of a flow can be written as:

$$E = H - T_0S - \sum_i \mu_{i0} n_i \tag{2}$$

where H is the enthalpy.

All processes involve the conversion and spending of exergy, thus high efficiency is of utmost importance. This implies that the exergy use is well managed and that effective tools are applied. Presently, an excellent online web tool for calculating exergy of chemical substance is also available [8].

Energy is always in balance, however, for real processes exergy is never in balance due to irreversibilities, i.e. exergy destruction that is related to the entropy production by

$$E_{\text{in}}^{\text{tot}} - E_{\text{out}}^{\text{tot}} = T_0 \Delta S^{\text{tot}} = \sum_i \left(E_{\text{in}} - E_{\text{out}}\right)_i > 0 \tag{3}$$

where ΔS^{tot} is the total entropy increase, $E_{\text{in}}^{\text{tot}}$ is the total exergy input, $E_{\text{out}}^{\text{tot}}$ is the total exergy output, and $(E_{\text{in}} - E_{\text{out}})_i$ is the exergy destruction in sub process i.

The exergy loss, i.e. destruction and waste, indicates possible process improvements. In general "tackle the biggest loss first" approach is not always appropriate since every part of the system depends on each other, so that an improvement in one part may cause increased losses in other parts. As such, the total losses in the modified process may in fact be equal or even larger, than in the original process configuration. Also, the use of renewable and non-renewable resources must be considered. Therefore, the problem needs a more careful approach.

3. Exergy diagrams

In engineering, flow diagrams are often used to describe the energy or exergy flows through a process. Fig. 1 shows a typical thermal power station, its main components and roughly the main energy and exergy flows of the plant. This diagram shows where the main energy and exergy losses occur in the process, and also whether exergy is destroyed from irreversibilities or whether it is emitted as waste to the environment. In the energy flow diagram energy is always conserved, the waste heat carries the largest amount of energy into the environment, far more than is carried by the exhaust gases. However, in the exergy flow diagram the temperature of the waste heat is close to ambient so the exergy becomes much less. The exergy of the exhaust gas and the waste heat are comparable.

Fig. 2 illustrates the energy and exergy flows of an oil furnace, an electric heater, an electric heat pump and a combined power and heat plant, i.e. a cogeneration plant. The produced heat is used for space heating. In the oil furnace the energy efficiency is assumed to be typically about 85%, losses being due mainly to the hot exhaust gases. The exergy efficiency is very low, about 4%, because the temperature difference is not utilized when the temperature is decreased, to a low of about 20°C, as a comfortable indoor climate.

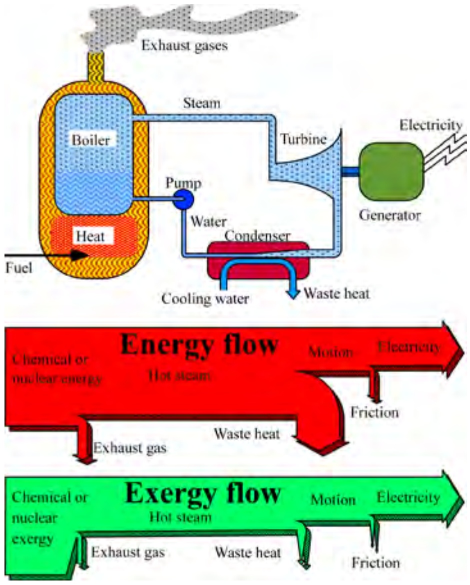

Fig. 1. Energy and exergy flow of a thermal power plant.

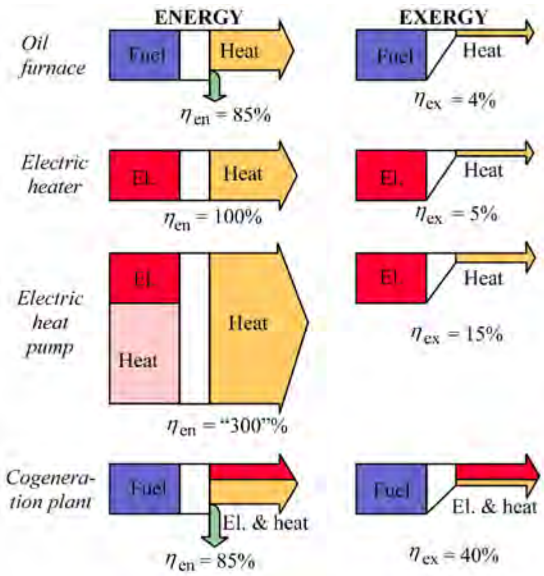

Fig. 2. Energy and exergy flows through typical some energy systems.

Electric heating by short-circuiting in electric resistors has an energy efficiency of 100%, by definition of energy conservation. The energy efficiency of an electric heat pump is not limited to 100%. If the heat originating from the environment is ignored in the calculation of the efficiency, the conversion of electrical energy into indoor heat can be well over 100%, e.g. 300% as in Fig. 2. The exergy flow diagram of the heat pump looks quite different. The exergy efficiency for an electric heater is about 5% and for the heat pump, 15%.

In Fig. 1 the energy and exergy efficiencies are the same since both energy and exergy is almost equal for the inflow of fuels and the outflow of electricity. For a combined power and heat plant, i.e. a cogeneration plant (Fig. 2) the exergy efficiency is about the same as for a thermal power plant (Fig. 1). The main exergy loss occurs in the conversion of fuel into heat in the boiler. Since this conversion is practically the same in both the condensing and the combined power plants, the total exergy efficiency will be the same, i.e. about 40%. However, it may be noted that the power that is instead converted into heat corresponds to a heat pump with a coefficient of performance (COP) of about 10. Thus, if there is a heating need a cogeneration plant is far superior to a condensing power plant. The maximum energy efficiency of an ideal conversion process may be over 100%, depending on the definition of efficiency. The exergy efficiency, however, can never exceed 100%.

4. Exergy analysis

To estimate the total exergy input that is used in a production process it is necessary to take all the different inflows of exergy to the process into account. This type of budgeting is often termed Exergy Analysis [6] & [7], Exergy Process Analysis, see Fig. 3, or Cumulative Exergy Consumption [9], and focuses on a particular process or sequence of processes for making a specific final commodity or service. It evaluates the total exergy use by summing the contributions from all the individual inputs, in a more or less detailed description of the production chain.

Environmentally oriented Life Cycle Analysis or Assessment (LCA) are common to analyze environmental problems associated with the production, use and disposal or recycling of products or product systems, see Fig. 4. Every product is assumed to be divided into these three "life processes", or as it is sometimes named "from cradle to grave".

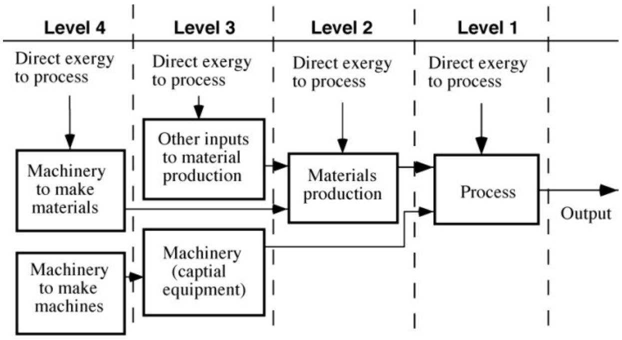

Fig. 3. Levels of an exergy process analysis.

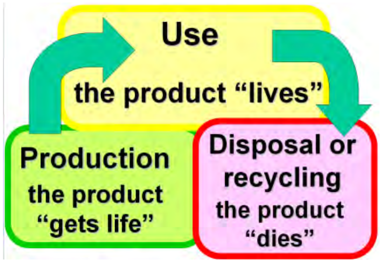

Fig. 4. The life cycle "from cradle to grave".

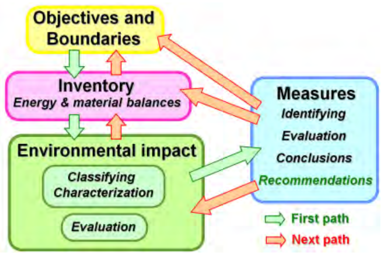

Fig. 5. Main steps of a LCA.

For every "life process" the total inflow and outflow of energy and material is computed, thus, LCA is similar to Exergy Analysis. In general Exergy Analysis and LCA have been developed separately even though they are strongly linked. This inventory of energy and material balances is then put into a framework as described in Fig. 5. Four stages in the LCA can be distinguished: (1) Objectives and boundaries, (2) Inventory, (3) Environmental impact, and (4) Measures. These four main parts of an LCA are indicated by boxes, and the procedure is shown by arrows. Green arrows show the basic steps and red arrows indicate suitable next steps, in order to further improve the analysis.

In LCA the environmental burdens are associated with a product, process, or activity by identifying and quantifying energy and materials used, and wastes released to the environment. Secondly one must assess the impact on the environment, of those energy and material uses and releases. Thus it is divided into several steps (Fig. 5).

The multidimensional approach of LCA causes large problems when it comes to comparing different substances, and general agreements are crucial. This problem is avoided if exergy is used as a common quantity, which is done in Life Cycle Exergy Analysis (LCEA) [10].

In this method we distinguish between renewable and non renewable resources. The total exergy use over time is also considered. These kinds of analyses are of importance in order to develop sustainable exergy supply systems in society. The exergy flow through a supply system, such as a power plant, usually consists of three separate stages over time (Fig. 6). At first, we have the construction stage where exergy is used to build a plant and put it into operation. During this time, $0 \leq t \leq t_{start}$, exergy is spent of which some is accumulated or stored in materials, e.g. in metals etc. Secondly we have the maintenance of the system during time of operation, and finally the clean up or destruction stage. These time periods are analogous to the three steps of the life cycle of a product in an LCA. The exergy input originating from non renewable resources used for construction, maintenance and clean up we call indirect exergy $E_{indirect}$. Indirect exergy input originating from renewable recourses are not accounted for. When a power plant is put into operation, it starts to deliver a product, e.g. electricity with exergy power $\dot{E}_{pr}$, by converting the direct exergy power input $\dot{E}_{in}$. In Fig. 6 the direct exergy is a non-renewable resource, e.g. fossil fuel and in Fig. 7 the direct exergy is a renewable resource, e.g. wind.

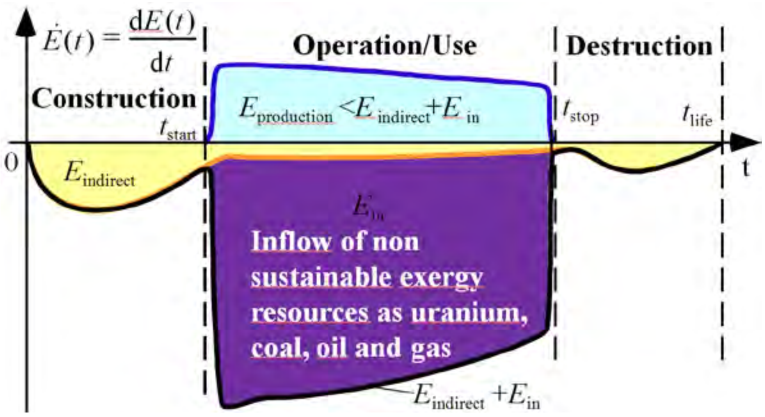

Fig. 6. LCEA of a fossil fueled power plant.

Fig. 7. LCEA of a wind power plant.

In the first case, the system is not sustainable, since we use exergy originating from a non-sustainable resource. We will never reach a situation where the total exergy input will be paid back, simply because the situation is powered by a depletion of resources, we have $E_{pr} < E_{in} + E_{indirect}$. In the second case, instead, at time $t = t_{payback}$ the produced exergy that originates from a natural flow has compensated for the indirect exergy input, see Fig. 7, i.e.

$$\int_{t_{start}}^{t_{pay\,back}} \dot{E}_{pr}(t)dt = \int_{0}^{t_{life}} \dot{E}_{indirect}(t)dt = E_{indirect} \qquad (4)$$

Since the exergy input originates from a renewable resource we may not account for it. By regarding renewable resources as free then after $t = t_{payback}$ there will be a net exergy output from the plant, which will continue until it is closed down, at $t = t_{close}$. Then, exergy has to be used to clean up and restore the environment, which accounts for the last part of the indirect exergy input, i.e., $E_{indirect}$, which is already accounted for (Eq. 4). By considering the total life cycle of the plant the net produced exergy becomes $E_{net,pr} = E_{pr} - E_{indirect}$. These areas representing exergies are indicated in Fig. 7. For modern wind power plants this time is less than one year [11]. Then the system has a net output of exergy until it is closed down, which for a wind power station may last for decades. Thus, these diagrams could be used to show if a power supply system is sustainable.

LCEA is very important in the design of sustainable systems, especially in the design of renewable energy systems. Assume a solar panel, made of mainly aluminum and glass that is used for the production of hot water for household use, i.e. about 60°C. Then, it is not obvious that the exergy being spent in the production of this unit ever will be paid back during its use, i.e., it might be a misuse of resources rather than a sustainable resource use. The production of aluminum and glass require a lot of exergy as electricity and high temperature heat or several hundred degrees Celsius, whereas the solar panel delivers small amounts of exergy as low temperature heat. LCEA must therefore be carried out as a natural part of the design of renewable energy systems in order to certify a sustainable resource use. Another case to investigate is the production of biofuels in order to replace fossil fuels in the transport sector. This may not necessarily be sustainable since the production process uses a large amount of fossil fuels, directly for machinery or indirectly as fertilizers, irrigation and pesticides. Thus, it may well turn out to be better to use the fossil fuels in the transport sector directly instead. This will be well described by a LCEA.

Sustainable engineering could be defined as the use of renewable resources in such a way that the input of non-renewable resources will be paid back during its life time, i.e. $E_{\mathrm{pr}}>E_{\mathrm{in}}+E_{\mathrm{indirect}}$. In order to be truly sustainable the used non-renewable resources must also be completely restored or, even better, not used at all. Thus, by using LCEA and distinguishing between renewable and non-renewable resources we have an operational method to define sustainable engineering.

LCEA diagrams are of particular importance in the planning of large scale renewable energy systems of multiple plants. Initially, this system will consume most of its supply within its own constructions phase. However, some time after completion it will deliver at full capacity. Thus, the energy supply over time is heavily affected by internal system dynamics.

5. Exergy and economics

Exergy measures the physical value of an energy resource. Thus, it relates to the economic value, which reflects its usefulness. This makes exergy a valuable energy policy tool.

In order to encourage the use of sustainable resources and to improve resource use, an exergy tax could be introduced. The use of non-renewable resources and its waste should be taxed by the amount of exergy it accounts for, since this is related to depletion of resources and an environmental impact. In addition to this, toxicity and other indirect environmental effects must also be considered. In the case of irreversible environmental damage, a tax is not suitable, instead restrictions must be considered. Eventually, this should also be the case for the depletion of assets from future generations. At least it indicates a moral dilemma.

A system could be regarded as a part of two different environments, the physical and the economic environment. The physical environment is described by pressure P_0, temperature T_0, and a set of chemical potentials μ_{i0} of the appropriate substances i, and the economic environment by a set of reference prices of goods and interest rates. These two environments are connected by cost relations, i.e. cost as a function of physical quantities (Fig. 8).

With the system embedded in the physical environment, for each component there are mass and energy balances needed to define the performance of the system. In addition, these balances describe the physical behavior of the system.

If the cost relations are known, then the physical and economic environments could be linked. The cost equations can sometimes be simplified to a scale effect, times a penalty of intensity. Then the system of lowest cost, which is physically feasible, can be found. Usually the maintenance and capital costs of the equipment are not linear functions, so in many cases these costs have more complex forms. If, by some reason, it is not possible to optimize the system, then at least cost could be linked to exergy by assuming a price of exergy. This method is called Exergy Economy Accounting (EEA).

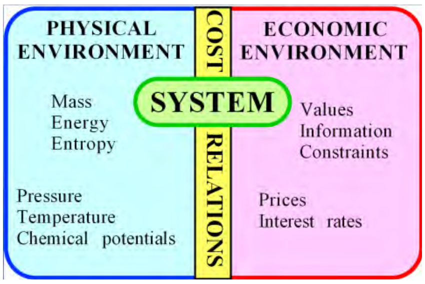

Fig. 8. The system surrounded by the physical and the economical environments, which are linked through cost relations.

Since exergy measures the physical value, and costs should only be assigned to commodities of value, exergy is thus a rational basis for assigning costs, both to the interactions that a physical system experiences with its surroundings and to the sources of inefficiency within it. The exergy input is shared between the product, and the losses, i.e. destruction and waste.

EEA simply means determining the exergy flows and assigning economic value to them. Thus, EEA does not include consideration of internal system effects. It does not describe how the capital investments in one part on the system affect exergy losses in other parts of the system. In the EEA method the exergy losses are numbers and not functions. However, this simple type of analysis sometimes gives ideas for, otherwise, not obvious improvements, and a good start of an optimization procedure, in which the exergy losses would be functions.

When constructing a system, the goal is often to attain the highest possible technical efficiency at the lowest cost, within the existing technical, economical and legal constrains. The analysis also includes different operating points (temperatures, pressures, etc.), configurations (components, flow charts, etc.), purpose (dual purpose, use of waste streams, etc.), and environments (global or local environment, new prices, etc.). Usually, the design and operation of systems have many solutions, sometimes an infinite number. By optimizing the total system, the best system under the given conditions is found. Some of the general engineering optimization methods could be applied, in order to optimize specific design and operation aspects of a system. However, selecting the best solution among the entire set requires engineering judgment, intuition and critical analysis. Exergy Economy Optimization (EEO) is a method that considers how the capital investments in one part of the system affect other parts of the system, thus optimizing the objective function. The marginal cost of exergy for all parts of the system may also be calculated to find where exergy improvements are best paid off.

6. Final words

These tools must be incorporated with energy engineering and policy to develop sustainable energy systems. My own experience from education is a strong positive feedback from the students and parts of the educational establishment, e.g., the UNESCO project *Encyclopedia* *of Life Support Systems* (EOLSS) [12]. However, sometimes there is also a strong skepticism among the academic establishment for this that also has to be dealt with. Thus, traditional boarders between different disciplines must be removed and more of interdisciplinary studies and activities must be applied at both high school and university levels. More problem oriented approaches and a focus on sustainable development issues are also to be encouraged.

7. Conclusions

Exergy based tools are excellent to describe the utilization of renewable energy resources and important within sustainable energy engineering. A system that consumes the exergy resources at a faster rate than they are renewed is not sustainable. The educational system has a crucial role to play to introduce these tools in order to promote education for sustainable development. This education must be based on a true understanding of our physical conditions. Exergy is a concept that offers a physical description of the life support systems as well as a better understanding of the use of energy and other resources in society. Thus, exergy and descriptions based on exergy are essential for our knowledge towards sustainable development.

8. Acknowledgements

The permission to use my work for the UNESCO's Encyclopedia of Life Support Systems [12] for this paper is hereby gratefully acknowledged.

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Policy intervention and technical change in mature industry: The Swedish pulp and paper industry and the biorefinery

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Abstract: Energy technologies based on biomass conversion are put forward as major means to curb climate change and enable a transition to a carbon neutral society. Many policies at international and national level are set up to support this transition. The pulp and paper industry is strongly linked to the conversion of biomass in Sweden and have a decisive role for the future of these technologies. This study aims to describe and explain the Swedish pulp and paper industry's reaction to policy with regard to the development of biorefineries. It turns out that firms are developing along two technological trajectories; 1) gasification for fuel production with a business model similar to the current one and 2) separation and refining for production of high value products, which requires a modified business model. Firms are also repositioning themselves within the regime and across regime borders. We conclude that the regime is in a phase of fragmentation. The policy implications from this analysis are that effective policy intervention needs to consider that multiple signals that are affecting the regime and policies should be designed depending on what degree of regime fragmentation that is desirable.

Keywords: *Energy policy, Biorefinery, Pulp and paper industry, Multilevel perspective, Incumbent firm strategy*

1. Introduction

A transition to a carbon neutral society will require extensive efforts to curb climate change. This involves large-scale changes in the energy system, switching from fossil to renewable energy sources. In Sweden increased use of biomass is considered as one step along this path, since the country has large biomass resources. Policies at international and national level, e.g. EU's directive on promotion of use of energy from renewable sources and the green certificates in Sweden, put forward energy technologies based on biomass conversion as major means to enable this transition. The pulp and paper industry in Sweden is strongly linked to the development of energy technologies based on biomass conversion, since the industry are in control of a large proportion of the biomass flow and have extensive knowledge of technologies based on biomass feedstock. Thus the industry can effectively hinder or induce the development of these technologies and consequently the transition that large-scale diffusion of these technologies could permit. Implementation of this type of technologies in the pulp and paper industry is often referred to as conversion of pulp and paper mills to biorefineries, i.e. a plant that efficiently use the incoming biomass to produce chemicals and energy simultaneously or instead of conventional fibers for paper products (definition inspired by [1]). Moreover, the pulp and paper industry is a large actor in the Swedish society, employing around 23,000 people in the country and contributing to 11% of Swedish exports [2]. Due to the strong link to biomass conversion and the size of the industry, it is an important actor for the development of biorefineries in Sweden. Policies' strong incentive for development of these technologies and the pulp and paper industries central role for biomass conversion make it important to understand the industry's reaction to policy. This study aims to describe and explain the Swedish pulp and paper industry's reaction to policy with regard to the development of biorefineries. In order to describe how the regime, that constitutes the Swedish pulp and paper industry, is reacting this article combines literature on transition and strategy.

2. Methodology

This section describes how data was collected and the theoretical framework used for the analysis.

2.1. Data collection

For this study data was collected 2009-2010, through semi-structured interviews with representatives (often technical directors) from the Swedish pulp and paper industry. Other stakeholders, e.g. Universities and research companies, were also interviewed. The companies interviewed for this study represents more than 75% of the pulp and paper production in Sweden. The study is mainly focusing on the companies' operations in Sweden, even though it can be difficult to isolate international companies' strategies and actions to one country.

2.2. Theoretical framework

What policy that is viewed as effective in the steering of technical change processes depends on what model that is used to understand the system. A simple model could be that policy is seen as a signal going into the system urging the system to react. In contrast to this model, empirical evidence suggests that the adoption and wide diffusion of novel technologies tends to take many decades [3] and that incumbent firms are unwilling to make radical changes but tend to focus on incremental change along a trajectory within the prevailing technological paradigm [4, 5]. Nevertheless, over longer time frames the economy is characterised by the emergence, development and decline of different industries [6, 7]. Rip and Kemp [8] suggested a three layer model of technical change, further developed by Shot and Geels [9, 10] to explain the dynamics of such technological transitions. The intermediate layer, called the 'regime level', is constituted by a well-established socio-technical system that provides a function or a set of products. This includes the incumbent firms in an industry, consumers and other involved actors as well as technical infrastructures and production systems and the regulatory, normative and cognitive rules deciding what is allowed, desirable and sensible. At a micro level new technological options grow in 'niches'. Over time these may challenge the existing regime and form new systems. It is argued that such change is made possible by changes at a higher society wide macro level, the 'socio-technical landscape', which put pressure on the regime and destabilizes it and thereby opens windows of opportunities for niche technologies [9].

In the multi-level perspective (MLP) tradition it is recognised that regime change can take many pathways [10]. Additionally, as has been recognised before in the literature on economics of innovation [e.g. 7], incumbent actors may have critical roles also in radical change processes [10]. New biomass conversion technologies need to be linked up to biomass flows already governed by mature industries. This may indicate that biorefineries are more likely associated with a 'transformation path' [10], rather than more disruptive transition patterns. If such a transformation path is to be guided by policy, we believe it is crucial to develop more refined descriptions of regime dynamics. In the MLP literature 'the regime' tends to be treated at a highly aggregated level. To trace the emergence of regime fragmentation and transformation processes we see a need to decompose this aggregate. More specifically, we believe that much could be gained if the implications of the diversity among incumbent firms were studied more closely. To this end the literature on firm strategy can contribute.

According to Porter [11], a firm should strive to create a unique and valuable position. There are two strategies to achieve this. Either the firm should try to perform different activities compared to its rivals or it should perform the same activities as its rivals, but perform them differently. In addition, the strategy should protect the industry structure, rather than threaten it since this could result in decreased industry profitability. Thus from Porter's perspective incumbent firm gain the most by diversifying its activities, but only so much that they still reinforce the prevailing industry regime. Porter also stresses the importance of clusters for driving direction and pace of innovation [12]. Another perspective is offered by the resource based view, in which e.g. Grant [13] claims that a competitive position is best explained by the firm's resources and capabilities. Firms should identify its internal resources and skills and match these against the opportunities and risks created by its external environment. However, incumbent firms often find it difficult to adapt to changes at the landscape level if it requires strategies that are not aligned with its core capabilities, which then can become core rigidities [14]. Additionally, firms are not acting in accordance with some universal rationality. Instead, they are guided by mental models, which are used as a filter to simplify reality and enable decision making [15]. These models are based on successes and failures of previous actions, but are seldom explicit. Yet, these models are only valid as long as the variables and circumstances they are based on are not changed [15]. Thus changes at the landscape level could imply that a new mental model must be developed in order to make better decisions.

In combination these views on firm strategy suggest that if we want to understand regime response to multiple landscape pressures and new technological opportunities we need to take into account the relative positioning of firms in industries, geographical clusters, the firms' capabilities and their individual historical experiences of success and failure.

3. A multilevel perspective on the Swedish pulp and paper industry

This chapter describes the Swedish pulp and paper industry from a multilevel perspective, including the industry structure at a regime level, changes at a landscape level and finally technological developments at a niche level.

3.1. Industry structure at regime level

The companies within the Swedish pulp and paper industry have different characteristics and prerequisites for development and implementation of biorefinery options. From a technical perspective, the type of mill is important. Most mills are integrated mills, which mean that they have both pulp and paper production at the same site [16]. Integration of biorefinery options is of interest in pulp mills, which can be divided into two categories mainly mechanical, i.e. the raw material is grinded mechanically, or mainly chemical, i.e. the raw material is treated with chemicals and heat to degrade and dissolve the lignin from the cellulose and hemicelluloses [16]. Due to the large flow of by-products in chemical processes there are many opportunities for integration of biorefinery solutions in chemical pulp mills.

Within the industry, there are large variations in firm size and extent of vertical integration, ranging from firms operating one single mill, e.g. Domsjö Fabriker, to large multinational companies, e.g. Stora Enso. The diversity in the industry is illustrated in Fig. 1, in which the extent of vertical integration and difference in size are shown for six Swedish pulp and paper firms.

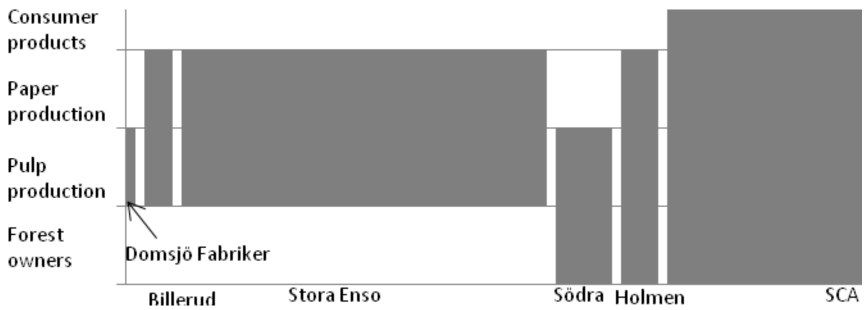

Fig. 1 The diversity in vertical integration and firm size for six Swedish pulp and paper firms. The value chain is characterised by four segment; forest ownership (ownership of 50% or more of raw material requirements), pulp production, paper production and production of consumer products. The size is indicated by relating the number of employees to the size of the bar that represent each firm.

Firms' actions are also governed by the mental models. One example of two different mental models of company leaders could be seen when Domsjö Fabriker was created in 2000, as a result of a small group of people buying the pulp mill from the corporation MoDo. In contrast to the former owner the new owners were convinced that the unprofitable pulp mill could be transformed into a modern biorefinery [17].

3.2. Landscape changes

We can identify three main trends at the landscape level that are influencing the industry: changing patterns of demand for paper, economic and industrial development in South America and Asia and increased political attention to energy and environmental issues. While none of these have unambiguous effects, all of them create tension at the regime level.

During the last decades the printed media has experienced competition from electronic media, the industry has experienced decreasing demand, particularly for news print [18]. On the other hand, demand for personal care products is increasing as living standards are raised in many countries. The same applies for packaging products, probably as a result of the debate on climate change that has emphasised the importance of renewable materials [19].

The European market is the main market for most Swedish pulp and paper companies and Sweden's part of the supply has increased at the same modest pace as the European consumption [18]. The rapid economic growth in other parts of the world opens potential new markets. However, increased production capacity in South America and Asia reduces the possibility for European companies to take advantage of these emerging markets. Instead, these companies face competition from firms outside Europe with lower production and feedstock costs.

The debate on climate change and security of energy supply has resulted in raised prices on electricity and fuels, which has increased the production cost for the European pulp and paper industry. European mills have become more energy efficient, less fuel oil and other fossil fuels are used and the fraction of biomass in total fuel consumption has increased [20]. These trends are also valid for the Swedish pulp and paper industry, which produces more electricity with back-pressure power and deliver more heat to nearby communities [18].

3.3. Technological developments at niche level

The technological development of biorefineries has been going on for decades and can be divided into two main technological fields; 1) gasification and 2) separation and refining. In Sweden, the development of the gasification started in the 1970s with an emphasis on production of methanol, mainly through gasification of coal and peat, but biomass was also considered as a possible fuel [21]. As the focus shifted to ethanol produced by enzymatic hydrolysis in the 1980s, gasification was no longer prioritized. Despite this the competence about the technology lived on in the electricity sector [21]. In the mid 1990s to early 2000s the gasification technology re-emerged in three parallel tracks; biomass gasification for production of dimethyl ether (DME) or Fisher Tropsch (FT) diesel and finally gasification of black liquor to produce methanol [21]. The future development of both gasification and enzymatic hydrolysis for ethanol production is now dependent of successful pilot and demonstration plants. Some technologies have, however, reached a commercialisation state for example LignoBoost, which is a process for lignin extraction and an example of a separation technology. Södra is today working on a plant in commercial scale and research for future applications of lignin is going on in parallel [22].

4. Regime response

The result of changes at landscape level and technological niche developments can be seen in the regime, as the first signs of a fragmentation becomes visible. We identify restructuring along two different technological trajectories. We also observe repositioning within existing value chains and more radical repositioning, i.e. repositioning that transcends traditional industry boundaries.

4.1. New technological trajectories

Biorefinery concepts offer new business opportunities for an industry regime under pressure from landscape changes. However, while fuel production from the large biomass resource of the Swedish forests has been a primary target for Swedish Energy Authorities since the end of the 1970s, the Swedish pulp and paper industry has demonstrated little interest [21]. With the increased pressure over the last couple of years this is now slowly changing. While few companies have gone so far that they have actually started to implement biorefinery technologies many are now becoming engaged in research and investigations of options that can convert their mills into biorefineries. In different ways, the companies try to match the new technological options with their existing processes and business models. At this point we can distinguish two main technological trajectories.

4.1.1. Gasification and fuel production

The first trajectory is centred on gasification technologies. Biomass or black liquor can be used as raw material for this process. The product is syngas, which can be used for the production of a spectrum of refined products for example methanol, methane, DME, FT diesel and hydrogen. Companies that are interested in gasification of biomass or black liquor tend to focus on production of bio fuels rather than chemicals, which equally well could be produced. In most cases the companies are interested in gasifying low grade biomass in parallel to continued production of pulp or paper. The business model behind this strategy seems to rely on the possibility to sell large volume of fuel, in a similar way as pulp or paper are sold today. However, additional biomass will be needed for implementation of these technologies.

Stora Enso motivates its preference for biomass gasification technology with the argument that it is flexible in the choice of end product and in the choice of raw material, thus different raw materials could be used at different geographical locations [19]. The preference for transportation fuels is driven by the competences their partner, Neste Oil, has in this field and the belief that the production of fuels can contribute more to prevent climate change than production of materials [19]. The arguments for this option reflect the present business model's focus on efficient production of bulk products. While implying major investments in new technology, the change in business model is minor and the core business of producing pulp and paper is not questioned.

4.1.2. Separation and refining to high value products

The processes employed in the second trajectory are typically enzymatic processes, hydrolysis and fermentation. Compared to gasification technology the choice of process is linked more directly to a specific product. Companies in this trajectory have a broader perspective on the kind of products they could produce in the future; chemicals, materials or possibly fuels. The business model linked to these products focuses on the possibility to sell small quantities of these products at a high price. One key argument for this strategy is to use the full potential of the fiber in biomass. The industry has traditionally done a lot of research on cellulose fiber. Consequently, utilising knowledge about cellulose fibers for production of materials and chemicals relates to one of the industry's core competences.

Södra with their implementation of the LignoBoost technology and Domsjö Fabriker's production of specialty cellulose for production of viscose clothes are both examples of development along this trajectory. These firms have in common that they operate (non-integrated) chemical pulp mills. Södra has investigated many different technological options, driven by the will to extend capacity at its mills and the need to find new energy carries to increase the export of energy from the mills [22]. The outspoken argument for production of specialty cellulose, for the clothes market, at Domsjö is that cotton is claimed to be less environmentally friendly due to the large quantities of chemicals and water that is used for its production. Hence, materials produced from forest products, like viscose, could offer a more environmentally friendly solution [23]. Since the amount of raw material needed for realization of options along this trajectory could be small, the original process could be affected to a minor extent and additional biomass is not necessarily needed. In this way companies can create more value from the same input. There are, however, technological options along this trajectory that would include the entire raw material flow, such as production of ethanol from cellulose, but none of the interviewed companies show any signs of interest in restructuring its processes entirely for this process.

4.2. Repositioning within a regime and across regime borders

Vertical integration is a strategy that could be used to achieve a competitive position within an industry. For SCA, which has a high degree of vertical integration (see Fig. 1), it seems to have been a successful choice to keep its forests and at the same time pursue a vertical integration towards personal care products [24]. Billerud is another example of a firm that shows a tendency to extend its vertical integration as they have initiated a co-operation with a well-pap packaging company, which contributes to increase Billerud's access to the market for transportation of fruit and vegetables [25].

One example of a more radical repositioning, i.e. repositioning beyond current value chains or across regime borders, is the joint venture between Stora Enso and Neste Oil for development of gasification technology and transport fuels [19]. Smaller firms seek collaboration in local clusters, e.g. in the area around Örnsköldsvik a cluster involving research company, universities, municipalities and the pulp producing company Domsjö Fabriker are working together to develop 'the biorefinery of the future'. In southern Sweden, Södra has been operating closely with the research organisation Innventia and Chalmers University of Technology. Within this cluster there is a shared belief in the development of high value products that can be produced in parallel to the existing pulp process. The repositioning between regimes indicates that a radical form of regime fragmentation involving several industry regimes may wait around the corner. The growing use of biomass for energy has made utility firms interested in biomass as a source of energy. The development of different types of biorefinery concepts for production of chemicals or fuels also attracts the chemical industry, the oil and gas industry and the car industry.

5. Conclusions

Political attention to energy and environmental issues has resulted in policies aiming at increased implementation of biorefinery concepts. However, this is not the only signal urging the industry to react. The Swedish pulp and paper industry regime is affected by several landscape changes and technological niche developments. Furthermore within the regime the firms have different prerequisites to react to policy and other external signals. The industry's reaction is characterised by technological development along two technological trajectories and a third trajectory of repositioning (partially overlapping the technological trajectories) within the regime and across regime borders, see Fig. 2. This can be regarded as a phase of fragmentation of the Swedish pulp and paper industry regime, but it is by no means clear where this regime fragmentation will end.

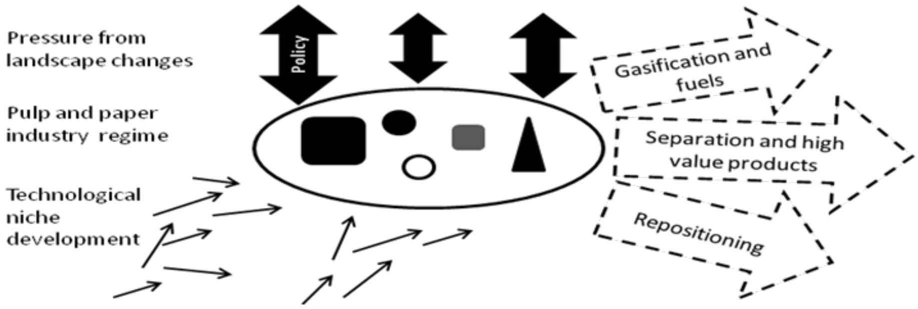

Fig. 2 The Swedish pulp and paper industry is affected by pressure from landscape changes, including policies, and technological niche developments. Furthermore within the regime the firms have different prerequisites for their reactions. The Swedish pulp and paper industry regime is restructuring itself along several trajectories initiating a phase of fragmentation.

In this context, policy makers need to consider how much fragmentation that is desirable. Strong policies will guide the industries towards a more uniform response, which could be attractive for achieving a rapid diffusion of novel technologies. A less forceful policy might encourage several trajectories to be followed in parallel, which could be desirable if policy makers have doubt about which technologies to diffuse and therefore would like several technologies to be developed and diffused.

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Incentive regulation of CHP performance

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Abstract: Main contentious issues of public regulation to support CHP as an efficient thermal power cycle are discussed. First the merit of CHP is defined as the transformation of residual heat in conventional power plants into useful heat; this merit suffices to rank CHP activity prior to standard thermal power generation wasting the heat. Second, the main metrics of CHP performance is the amount of co-generated electricity requiring uncontested identification when CHP activity is mixed with condensing power generation (mainly in extraction-condensing steam turbines). The proper method is based on design characteristics of CHP processes, not on arbitrary averages as CEN proposes. Therefore, the novel concept of "bliss point" of a CHP activity is developed. Third it is argued why co-generated power – clearly measured – is a sufficient performance indicator. Additional qualifications based on external benchmarks (as the EU-Directive allows) may imply perverse incentives in impeding CHP development qualitatively and quantitatively. The difference between perverse and benign regulations explains the wavering position of the EU-2004 Directive on the promotion of CHP.

Keywords: *CHP quality, Power-to-heat ratio, EU Directive, Incentive Regulation, Benchmarking*

Nomenclature

E	*Electricity or power*	*MWh or MW*	β	*power loss factor*	
F	*Fuel energy or fuel flow*	*MWh or MW*	σ	*power-to-heat ratio*	
Q	*Heat energy or heat flow*	*MWh or MW*	η	*efficiency*	

Acronyms for activities CHP = Cogeneration; Cond = Condensing; Plant = both activities

1. Introduction

Cogeneration or Combined Heat & Power (CHP) is as old as its natural cradle, the thermal power plant that after power extraction dumps all residual heat in the environment. Diverse CHP technologies are applied in plants ranging from a few kW to a few hundreds MW. CHP diffusion in countries with similar economies is uneven, due to diverging energy policies and according regulations. CHP is in principle more energy efficient than its counterpart that dumps the residual heat. Public policy in favor of efficient fuel use also supports CHP. This was intended by EU-Directive 2004/8/EC [1], but not confirmed by effective and efficient regulation. This section introduces the subject. Section 2 highlights different visions on the merit of CHP, determining the acceptability of proposed policies. Quality of CHP is shown to equal quality of standard thermal power generation, and "CHP-specific" qualification is not needed. Section 3 covers the issue of defining and measuring CHP activity in a transparent and accurate way. Section 4 shows how external benchmarking of CHP plants can be the source of very perverse incentives for the development of CHP. A brief conclusion follows.

1.1. CHP support

Why should the EU support CHP in itself? Many argue that support is only warranted when CHP delivers a reduction in CO_2 emissions and/or reduction in fuel combustion because high efficiency separate heat and power generation might be better in reducing CO_2 than a low efficiency CHP facility. The latter argument points to the core issues of what about CHP is why supported. During the 2004 EU Directive's preparation phase proposals abounded to evaluate along CHP other aspects like the type of fuel used or the amount of reduced CO_2 emissions. However well intended, this debate created confusion and obliterated the attention for the core duty: what attributes or results of CHP are eligible for support? Poorly answering this question backfires on the good regulatory intentions when biased methods of CHP qualification are applied (section 4).

The core task is accurately identifying what CHP activity means, in particular in plants that simultaneously mix CHP and condensing power generation. Once CHP activities are fully characterized it is possible to discuss what aspects of that activities may be promoted and supported, and how this can be done in the most transparent and effective way.

1.2. Incentive regulation

Incentive regulation sets the factors right that improve the economics of CHP activities. It obeys the overall standards of proper regulation such as: identify precisely what is the object of regulation; select the appropriate variables to monitor and measure the object; preclude arbitrary values or averages; specify specific but similar rules for similar cases to minimize discrimination; promote stated goals by appropriate rules and incentives. The promotion of CHP as a competitive power generation practice needs consideration of salient aspects like: optimize technical characteristics and select high power-to-heat ratios; stimulate economies of scale and high capacity factors by opening a large market for both outputs of CHP plants; guarantee fair terms for exchanges of power (as surplus, make-up, or back-up flows) with the grid. The latter terms significantly impact the development of any independent and decentralized power generator. But for CHP the complexity increases because the joint outputs power and heat are delivered to separate markets. When regulations truncate CHP's freedom of operation on the power market the economics of CHP deteriorate.

One peculiar aspect of the EU CHP Directive is the adoption of external benchmarking as the basic method for qualifying the outputs of CHP plants. Generally benchmarking is '*the continuous, systematic process of comparing the current level of own performance against a predefined point of reference, the benchmark, in order to evaluate and improve the own performance*' [2]. The choice of benchmark is crucial because the own performance is measured as a 'distance-to-targets' with the benchmark characteristics as targets, and because the own activity is changed to resemble the benchmark as much as possible. When benchmarking is applied in a private context, the actor controls the selection of targets and the degree and pace of approaching the targets. The actor can accommodate fuzzy aspects in definitions, data availability and methods applied. In a public regulatory context the definitions must be based on argued, transparent and robust methods requiring indicators that are measured in an uncontested way. The first issue is whether the benchmarking framework as such makes sense, i.e.: are the benchmarks valid references for improving the regulated subject's performance? (e.g. do they belong to comparable categories?). When diversity is too high, it is problematic to screen and evaluate diverse participants (competitors) on a particular performance, in particular when followed by remunerations or penalties.

1.3. CHP performance

What variables can express CHP performance? Using the recovered heat $\mathbf{Q_{CHP}}$ as indicator is not recommended because investors and operators are not stimulated towards high-quality cogeneration activity. Also as an additional indicator there are few arguments to include the heat output variable, neither when taking the quality of the useful heat into account [3]. While heat at higher temperature corresponds to a higher availability (quality) of the energy flows, rewarding this in CHP activities counteracts the incentives to reduce the applied temperatures of heat end-uses in buildings and processes. The lower the useful end-use temperatures of heating applications can be set, the more "nearby waste" heat flows can be recuperated, the more ambient heat sources can be included (solar heating, heat pumps) and the more efficient cogeneration systems can be inserted (in particular Rankine cycles). The necessary and sufficient CHP performance indicator is the amount of co-generated electricity $\mathbf{E_{CHP}}$ when measured accurately. Because $\mathbf{E_{CHP}} = \boldsymbol{\sigma}.\ \mathbf{Q_{CHP}}$ maximizing $\mathbf{E_{CHP}}$ includes incentives to maximize heat recovery ($\mathbf{Q_{CHP}}$) and quality (power to heat ratio $\boldsymbol{\sigma}$) of the CHP activities.

2. CHP Merit and Quality

Opposite visions on the merit of CHP in the energy economy create diverging propositions about CHP's role with impact on its valuation (2.1). There is much fuss about quality of CHP processes, but does quality differ for CHP and non-CHP thermal power processes? (2.2).

2.1. Opposite visions on the merit and role of CHP

Policy starts with a vision on the subject of regulation. Visions on the merit and the role of CHP range from Promoting to Blocking CHP development (Table 1). One favors the development of CHP when taking the position that the merit of CHP is in recovering all or part of the heat being otherwise discarded to the environment in a thermal power plant. Adding additional tests upon this basic merit leads to fencing in the application of the CHP principle. For example one can require that CHP plants perform a factor X better in generating power and heat jointly than the best available references of separate generation technologies (power condensing plants and heat only facilities). External benchmarks provide valuable information to a would-be investor in CHP capacity and to the operator of existing CHP facilities, but must be handled more carefully in a regulatory context (see section 1.2).

Table 1: Promoting and blocking views on the merit and role of CHP

	Promoting CHP	Blocking CHP
CHP Merit	Use of – all or part of – the discarded fatal heat at thermal power plants	CHP has but merit when it excels above the best separate power and heat benchmarks
CHP Role: who first?	CHP dominates the condensing only thermal power generation cycle, and therefore is, ceteris paribus, preferred. Valid is also part recovery of fatal heat.	Limit CHP to full heat loading operations. As a corollary: obstruct CHP plants operating in part/full condensing mode

When the basic merit of CHP is recognized it is logical to attribute priority to the CHP mode above the condensing only mode for investing in thermal power plants[1]. The blocking vision sees the role of CHP very restrictive to particular joint power-heat load conditions where a full heat load can be guaranteed 'all the time'. This attitude also fences the entry to the power market by setting particular tariffs for power exchanged between the CHP facility and the interconnected grid. Unfair conditions for exchanging power with the grid are main barriers to a balanced development of CHP in both the heat and the power markets [4].

2.2. The quality of thermal power and of CHP

CHP is always based on some thermal power generation cycle. The latter is its natural cradle and determinant of the performance, economics and quality of the CHP process. Every thermal power process rejects residual heat in the environment. The merit of CHP is to

[1] In Denmark the 1979 Heat Supply Act has made this principle reality.

recover part or all of this heat and transform it into 'useful' heat. Some CHP processes (steam turbines) occasion a loss of power output when condenser heat is upgraded to useful heat. The power loss **β** is almost proportional to the temperature of the extracted heat (steam) from the turbines, and therefore it is important to minimize the required temperature of the heat applications that are supplied by CHP processes. Gas turbines, internal combustion engines, some fuel cells, do not occasion significant power loss because generally the temperature of the rejected heat is sufficiently high for the heat end-use purposes.

The quality of CHP processes is recorded by the power-to-heat ratio **σ**. There is no generally approved definition of this ratio. The metamorphosis of a condensing power process into CHP is happening by transforming residual heat into useful heat. Therefore the high (low) quality CHP process is embedded in a thermal power plant of high (low) electricity conversion efficiency (the linkage is further discussed in section 3.3).

3. Identifying and measuring CHP activity

The valid indicator of CHP activity is the amount of co-generated electricity $\mathbf{E_{CHP}}$ (section 1.3). For a thermal power plant without residual heat rejection, no $\mathbf{E_{CHP}}$ identification problem exists because all activity of the plant is combined and all electricity is co-generated. Defining this variable and measuring it when co-generation takes place *joined to* condensing power generation, is the problem to solve. In addition, but fully overlooked in the EU regulation, is it necessary to identify and measure the share of fuel consumed for the combined activity $\mathbf{F_{CHP}}$. The bottleneck holding up effective regulation by the EU Directive is identification, and so reliable measurement, of what precisely is CHP *activity*.

3.1. The EU CHP Directive [1] on measuring CHP activity

Annex II "Calculation of electricity from cogeneration" of the Directive opens with "Values used for calculation of electricity from cogeneration shall be determined on the basis of the expected or actual operation of the unit under normal conditions of use." Then it splits the approach in two cases. First, when the overall thermal efficiency of the operations exceeds 75% for steam back-pressure turbines, gas turbines with heat recovery, internal combustion engines, micro turbines, Stirling engines and fuel cells, all power generated is accepted to be co-generated. Analogously, an 80% efficiency threshold applies for CCGT with heat recovery and for steam condensing extraction turbines. Second, when overall efficiency falls short of the stated thresholds of 75/80 %, co-generated electricity $\mathbf{E_{CHP}}$ should be calculated according to the formula $\mathbf{E_{CHP} = \sigma . Q_{CHP}}$ with **σ** the power-to-heat ratio. Article 3(k) states "'power to heat ratio' shall mean the ratio between electricity from cogeneration and useful heat when operating in *full cogeneration mode* using *operational* data of the specific unit". The latter expression is not specified, although most CHP units cannot operate in full cogeneration mode. Hence the Directive's method is incomplete in identifying and measuring $\mathbf{E_{CHP}}$. By lacking the correct method, Annex II offers average default values by technology group, but this is "*notably for statistical purposes*".

The wrong answer to the difficulties in quantifying $\mathbf{E_{CHP}}$ is to negate the question, and proceed without solution. The EU does this by Annex III forgetting Annex II and qualifying cogeneration performance on the basis of mixed values with perverse effects for the development of CHP (section 4). The EU skips identification of fuel consumption $\mathbf{F_{CHP}}$, necessary to assess the efficiency $\mathbf{\eta_{CHP}}$ of the cogeneration activity of a thermal power plant. Simplifying estimations of $\mathbf{E_{CHP}}$ by splitting CHP activities in two groups, as Annex II does, increases the workability, but average 75/80% default efficiencies are arbitrary, not promoting "high efficiency CHP". Field data [5] document CHP efficiency ranges between 60 and 94%.

The Directive (Art.12) does not impose its immature methods, allowing member states the use of "Alternative calculations". Unsolved identification of CHP activity is not increasing harmonization, stated as a "general objective of the Directive" (Whereas n° 15). For overcoming the identification problem the novel concept of "bliss point" of a CHP process is developed in section 3.3.

3.2 The CEN manual [6] for Measuring CHP activity

The objective of the CEN Manual is "to present a set of transparent and accurate formulae and definitions for determination of CHP (cogeneration) energy products and the referring energy inputs. The CEN/CENELEC Workshop Agreement shall simply formulate the procedure for quantifying CHP output and inputs." CEN adopts the Directive Annex II proxy of splitting CHP plant outputs in above and below 75/80% average efficiency operations, the "above ones" seen as full CHP. For the "below ones", CEN addresses the disentangling of CHP from the *mixed* activity and searches to quantify both $\mathbf{E_{CHP}}$ and $\mathbf{F_{CHP}}$ values. CEN hereby distinguishes cogeneration processes *with* power output loss when recovering residual heat at the thermal power process from the ones *without* power output loss when heat is recovered. CEN focuses on extraction-condensing steam turbines[2] where mixed activity and power loss are prominent, with the added complexity that useful heat extraction may occur at several pressures (temperatures). For this most important and most complex CHP case CEN elaborates a seven-step approach [6, p.38-40], but steps 3 and 4 contain a "circular reference": $\mathbf{E_{CHP}}$ is calculated in step 4, but step 3 includes $\boldsymbol{\eta_{CHP}}$ whose assessment requires $\mathbf{E_{CHP}}$ (next to $\mathbf{Q_{CHP}}$ and $\mathbf{F_{CHP}}$). CEN escapes from its circular reference by applying "the CHP overall efficiency according to Annex II of the CHP Directive" [6, p.38], or more clearly: CEN adopts a fixed value of 75/80% for $\boldsymbol{\eta_{CHP}}$. Adopting averages does not cover the reality of CHP technologies and applications and ripples the CEN stated objective of "transparent and accurate formulae".

3.3. Closing the CHP identification and measuring gap: find the "bliss point"

A consistent regulation has no need for arbitrarily fixed parameters [7]. The first law of thermodynamics applied on a thermal power plant states: Fuel input = Electricity output + (Recoverable) Heat output + (Non-recoverable) Losses. For a CHP plant showing the split between CHP and condensing activities the law applies as (table 2):

$$\mathbf{F_{CHP} + F_{Cond} = E_{CHP} + E_{Cond} + Q_{CHP} + Q_{Cond} + \text{Non-recoverable Losses}}$$

Table 2: Energy flows in a CHP plant obey the First Law of Thermodynamics

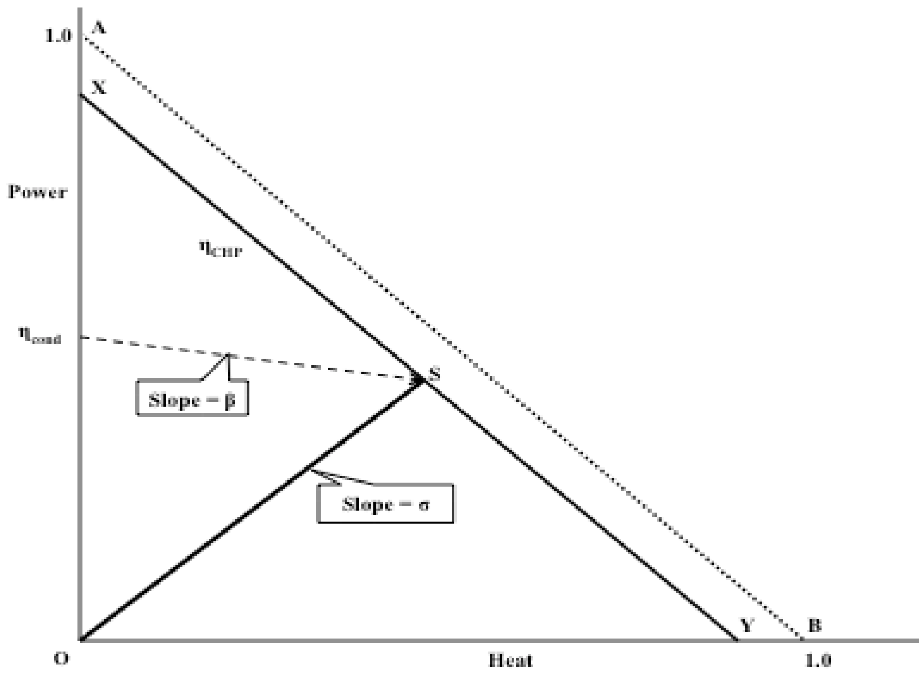
	CHP	+ Condensing	= Plant
Fuel F =	F_{CHP}	F_{Cond}	F_{plant}
Electricity E	E_{CHP}	E_{Cond}	E_{plant}
+ Heat Q	Q_{CHP}	Q_{Cond}	Q_{plant}
+ Losses non-recoverable	-	-	L_{plant}

[2] CEN/CENELEC [6, p.14] considers backpressure steam turbines as units *without* power loss, based on the argument of complementary power and heat outputs. However, power loss in steam turbines is due to heat extraction at above ambient condensing regimes.

When $\mathbf{Q_{Cond}} = 0$, it follows $\mathbf{E_{Cond}} = 0$; $\mathbf{F_{Cond}} = 0$, and $\mathbf{E_{CHP}} = \mathbf{E_{plant}}$; $\mathbf{F_{CHP}} = \mathbf{F_{plant}}$. Rather than by adopting arbitrary 75/80% efficiency thresholds, all electricity is $\mathbf{E_{CHP}}$ when the plant does not deliberately reject heat. There may be peculiar conditions why the overall efficiency of a CHP plant falls short of the 75/80% thresholds, e.g. when the plant is combusting waste fuels. The distinguishing property among "mixed" and "pure" CHP plants is whether they reject – yes or no – recoverable heat. If "no" ("pure" CHP activity) the $\mathbf{E_{CHP}}$ identification problem vanishes because all power relates to cogeneration and the 75%/80% thresholds are of no use.

When cogeneration and condensing activities take place jointly none of the variables in table 2 equals zero, but directly observed are only: $\mathbf{Q_{CHP}}$, and the total plant flows $\mathbf{F_{plant}}$, $\mathbf{E_{plant}}$, $\mathbf{Q_{plant}}$, $\mathbf{L_{plant}}$. In order to split the fuel and electricity quantities in their CHP and condensing shares, two additional process characteristics are needed: $\boldsymbol{\eta_{cond}}$ or the condensing power efficiency when no cogeneration occurs, and the power loss factor[3] $\boldsymbol{\beta}$ of the transformation of $\mathbf{Q_{Cond}}$ into $\mathbf{Q_{CHP}}$ ($\boldsymbol{\beta}$ may be zero when no power is lost during that transformation, e.g. at gas turbine plants). Then all information is available to find the *bliss point* ***S*** and the *design* power-to-heat ratio $\boldsymbol{\sigma}$ of the CHP plant. The bliss points can be multiple and virtual, so also the ratio's $\boldsymbol{\sigma}$ can be multiple, but the $\boldsymbol{\sigma}$ are always real [7]. Fig. 1 shows the method graphically with efficiency units on both axes. The line AB assumes 100% efficiency with all fuel converted in electricity or recoverable heat (representing the fictive case of non-recoverable losses being zero). The parallel line XY subtracts from AB the non-recoverable losses, i.e. compared to line AB, XY represents $\boldsymbol{\eta_{CHP}}$ (the CEN proposal fixes XY = 0.75AB or = 0.80AB).

Figure 1: Finding the bliss point ***S*** *and power-to-heat ratio* $\boldsymbol{\sigma}$ *of a CHP activity*



the ordinate and follows the slope of the power loss factor $\boldsymbol{\beta}$. The two data define the dashed

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[3] Power loss is discussed widely in the technical CHP literature but generic statistics are published rarely because the loss factors are application specific. See however figure 1 in [8].

downward sloping line η_{Cond} – **S**, and the crossing with XY fixes point **S**. The design power-to-heat ratio σ is the then found as the slope of **OS**. The production possibility set of the CHP activity is given by the triangular area **O** – η_{Cond} – **S**. While CEN is compatible with the method of fig. 1, avoiding the insertion of arbitrary efficiency numbers is more accurate and transparent (see [7] for further detail).

4. External Benchmarking and the EU Directive Qualification

The EU CHP Directive benchmarks the outputs of CHP plants on the efficiencies of separate generation processes of power and of heat. The imposed power reference is the high efficient CCGT process and at the heat side it is a high-efficiency boiler. Next to the difficulties in pointing down the "right" efficiency values, the assumption that CHP power and CCGT power are perfectly comparable and exchangeable all time of the year[4] weakens the case for applying external benchmarking [9]. Some countries have based their regulation on external benchmarking: acceptance or exclusion of CHP plants from support depends on their performance on the *quality norm*. This *norm* links the outputs of a CHP ***plant*** to the efficiencies of reference separate heat and power generation processes. It is shown [10] that the *quality norm* entails little incentive to improve the real quality of the CHP process. This is a crucial shortcoming because the future of CHP depends on its competitive position and this in turn is dependent on the quality of the processes. The more electricity a CHP plant can generate the better for the competitiveness of CHP. The *quality norm* is not effective in stimulating CHP quality and is perverse in truncating the production possibilities of CHP plants. Investment in well-scaled and flexible CHP capacity is choked by the qualification procedure. In existing plants CHP operators are driven to produce smaller quantities of power either by partly loading or by shutting down capacities. Most of the negative effects are due to the amalgamation[5] of the cogeneration and condensing activities in the CHP plants into plant quantities, and by omitting separate identification and measurement of the actual CHP activity within such plant (see table 2).

Conclusion

Public regulation obeys a number of quality standards to reach its stated objectives. Incentive regulation of CHP sets the factors right that improve the economics of investing and operating high quality processes. External benchmarking of CHP plants on separate high-efficient power and heat production processes implies perverse effects. A good CHP regulation starts at clearly stating the merit of CHP as the transformation of all or part of the residual heat of thermal power processes into useful heat. This merit assigns, ceteris paribus, to CHP activity

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[4] In actual power systems, CCGT is not a marginal power supplier (high efficiency CCGT requires constant full load conditions). A common CHP plant of 35~40 percent power efficiency is of higher merit than a peak-load unit of 25~30 percent efficiency, but CHP activity will be constrained by imposing the 50~55 percent benchmark efficiency. This shows how external benchmarking becomes perverse. It obliterates the regulatory roles. Comparing power generation performance of CHP with grid power is to be done by a clear regulation of grid access pricing. Promoting CHP (as the EU wants) is to be done on the basis of the own merit of CHP.

[5] A metaphor of wrong amalgamation: a city board wants to promote cycling in the city by rewarding bike use (assumed: in the city perimeter). Some lobby imposes that bikes only get support when faster than motorized traffic. Bikes are equipped with a meter registering distance and running time. Within the city perimeter most bikers are faster than motorized traffic. However the biker's performance is the sum of all km and time (within and beyond the city perimeter) compared with the external benchmark. This obviously will not stimulate a good deployment of bike use in and around the city.

a priority ranking above standard thermal power. The performance of CHP is fully gauged by the quantity of cogenerated electricity when identified and measured in the proper way. The latter task is tricky when the CHP activity is mingled with condensing power generation. The article offers a solid methodology based on the first law of thermodynamics; new is the definition of the "bliss point" of a CHP activity, being the crossing of the lines with as slopes respectively the power-loss and power-to-heat parameters. Bliss points are virtual in most condensing-extraction cycles and multiple when heat is recovered at various pressures. This finding is the basis for assigning the proper power-to-heat characteristic to various CHP activities, sidelining the inaccurate use of average efficiencies as proposed by CEN [6]. Using arbitrary averages for efficiencies does not provide the right incentives to maximize real efficiencies when investment in CHP plants takes place.

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An optimization model for the integration of renewable technologies in power generation systems

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Abstract: In view of the expanding Renewable Energy Sources (RES) generation worldwide and in particular in European Union, it is crucial for every country to consider the cost of integrating the necessary mixture of RES-E technologies in their existing and future generation systems. In this work, an optimization model for the integration of RES electricity (RES-E) technologies in power generation systems is developed. The purpose of the optimization procedure is to assess the unavoidable increase in the cost of electricity of a given power generation system at different RES-E penetration levels. The optimization model developed uses a genetic algorithm (GA) technique for the calculation of both the additional cost of electricity due to the large penetration of RES-E technologies as well as the required RES-E levy in the electricity bills in order to fund this RES-E penetration. The above GA procedure enables the estimation of the level of the adequate (or eligible) feed-in-tariff (FiT) to be offered to future RES-E systems. The overall cost increase in the electricity sector for the promotion of RES-E technologies, for a given period, is analyzed taking into account factors, such as, the fuel avoidance cost, the carbon dioxide emissions avoidance cost, the conventional power system increased operation cost, etc. The applicability of the developed optimization model is applied to the small isolated power generation system of the island of Cyprus. The results indicated that in the case of 15% RES-E penetration by providing FiTs with a 10% internal rate of return the required level of RES-E levy in the electricity bills will be 0.53€c/kWh.

Keywords: *Power generation, renewable energy sources, genetic algorithm, optimization*

1. Introduction

The European Union (EU) has already tuned its energy policy into achieving maximum carbon dioxide (CO_2) emissions reduction from power generation plants. In this context, it has already set out a strategic objective of achieving at least a 20% reduction of greenhouse gases by 2020 compared to 1990 levels [1]. This strategic objective represents the core of the new European energy policy. Recognizing the positive effects of renewable energy sources (RES) technologies towards achieving this goal, the EU has taken a range of specific actions in the direction of enhancing the integration of RES in the existing European power generation system as a major step towards the reduction of global warming and climate change phenomena. Specifically, an action plan in the form of an EU Directive on the promotion of the use of energy from renewable sources [4] has been introduced by the EU whereby a target of RES share of 20% out of the gross final energy consumption of the EU has been set to be reached by the year 2020. The RES Directive [4] establishes a common framework for the promotion of energy from RES. It sets mandatory national targets for each Member State for the overall share of energy from RES in gross final consumption of energy and for the share of energy from RES in transport. Also, it lays down rules relating to statistical transfers between Member States, joint projects between Member States and with third countries, guarantees of origin, administrative procedures, information and training, and access to the electricity grid for energy from RES.

In line with the EU RES policy, each Member State must adopt a national RES action plan. The national RES action plans are expected to set out Member States' national targets for the share of energy from RES consumed in transport, electricity and heating and cooling in 2020, taking into account the effects of other policy measures relating to energy efficiency on final consumption of energy, and adequate measures to be taken to achieve those national overall targets. In view of the expanding RES generation in EU, it is crucial for Member States to consider the cost of integrating the necessary mixture of RES-E technologies in their existing and future generation systems up to the year 2020. For such an investigation, it is fundamental to perform an analysis of the new technical, economic and environmental status that the integration of such technologies will affect in the current and long term strategic planning of the EU generation systems expansion. The available existing software can only provide an estimate of the cost increase based on predetermined capacity factors or energy production of RES-E technologies. However, in order to perform more detail analysis and more accurate cost estimates there is a need for the implementation of an optimization model implementing unit commitment algorithms

In this work, an optimization model for the integration of RES electricity (RES-E) technologies in power generation systems on a unit commitment basis is developed. The purpose of the optimization procedure is to assess the unavoidable increase in the cost of electricity of a given power generation system at different RES-E penetration levels. The optimization model developed uses a genetic algorithm (GA) technique for the calculation of both the additional cost of electricity due to the large penetration of RES-E technologies as well as the required RES-E levy in the electricity bills in order to fund this RES-E penetration. The algorithm combines the WASP IV software [11], for optimal expansion plan for a given power generating system and the IPP v2.1 software [7] for the optimum cost of electricity produced from both conventional and RES technologies. Also, this GA procedure enables the estimation of the level of the adequate (or eligible) feed-in-tariff to be offered to future RES-E systems. The applicability of the developed optimization model is applied to the small isolated power generation system of the island of Cyprus.

In section 2, the simulation methodology and the optimization GA developed are described. In section 3, the methodology is demonstrated for the integration of RES-E technologies in the Cyprus power generation system. The conclusions are summarized in section 4.

2. Optimization model

The optimization model developed uses a GA technique for the calculation of both the additional cost of electricity due to the large penetration of RES technologies as well as the required RES-E levy in the electricity bills in order to promote such penetration. A schematic diagram of the optimization flow chart is shown in *Figure 1*. The algorithm combines the WASP IV software [11], for optimal expansion plan for a given power generating system and the IPP v2.1 software [7] for the optimum cost of electricity produced from both conventional and RES technologies. Both have been used extensively during the past years for similar studies (e.g., [8], [10]). A brief description of simulation software follows.

2.1. WASP IV software

The future generation system is simulated using the Wien Automatic System Planning IV (WASP IV) software package [11], which is widely used for automatic generation planning. The WASP IV software package finds the optimal expansion plan for a given power generating system over a period of up to 30 years. The foreseen seasonal load duration curves, the efficiency, the maintenance period and the forced outage rate of each generating plant are taken into account. The objective function, which shows the overall cost of the generation system (existing and candidate generating plants), is composed of several components. The components, related to the candidate generating units, are the capital cost and the salvage capital cost. The components, which are related to both the existing and candidate generating units are the fuel cost, the fixed operation and maintenance costs, such as, staff cost, insurance charges, rates and fixed maintenance, the variable operation and maintenance costs, such as, spare parts, chemicals, oils, consumables, town water and sewage.

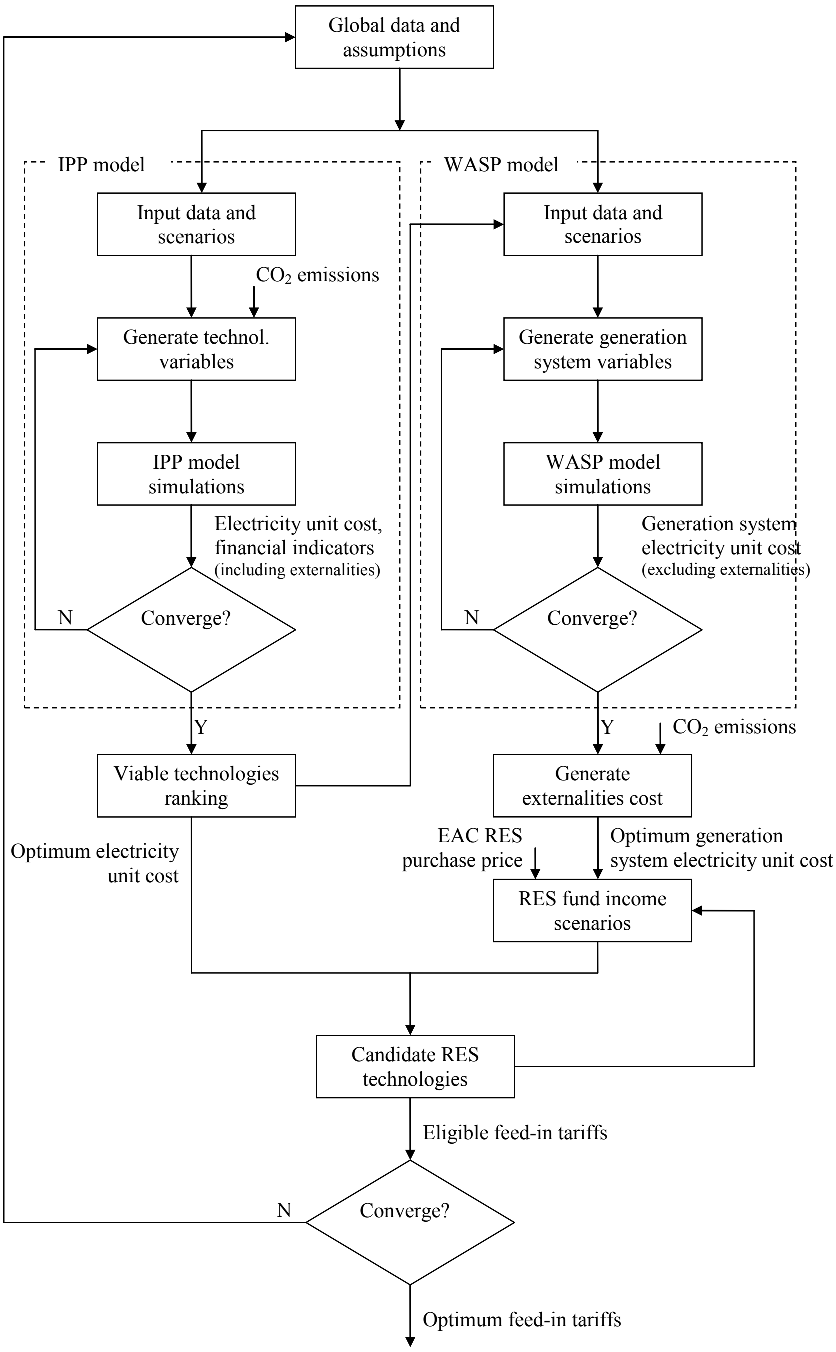

Figure 1: Flow chart of the optimization model

The cost to the national economy of the energy not served (ENS) because of shortage of capacity or interruptions is, also, taken into consideration. In the production simulation of WASP, a one-year period is divided into, at most, 12 s ub-periods for each of which probabilistic simulation is applied. Equivalent load duration curves in the probabilistic simulation are approximated using Fourier series. The Fourier expansion makes it computationally simple to convolve and deconvolve generating units in the probabilistic simulation. The decision of the optimum expansion plan is made by the use of forward dynamic programming. The number of units for each candidate plant type that may be selected each year, in addition to other practical factors that may constrain the solution is specified. If the solution is limited by any such constraints, the input parameters can be adjusted and the model re-run. The dynamic programming optimization is repeated until the optimum solution is found. Each possible sequence of power units added to the system (expansion plan) meeting the constraints is evaluated by means of a cost function (the objective function), which is composed of (a) capital investment costs, *I*, (b) salvage value of investment costs, *S*, (c) fuel costs, *F*, (d) non-fuel operation and maintenance costs, *M*, and (e) cost of energy not served, Φ. Thus,

$$B_j = \sum_{t=1}^{T} \left[I_{jt} - S_{jt} + F_{jt} + M_{jt} + \Phi_{jt} \right], \qquad (1)$$

where, B_j is the objective function attached to the expansion plan *j*, *t* is the time in years (1, 2, …., *T*) and *T* is the length of the study period (total number of years). All costs are discounted to a reference date at a given discount rate. The optimum expansion plan is the $minB_j$ among all *j*. Details of the optimization algorithm implementing the above mathematical formulation can be found in [11].

2.2. IPP v2.1 software

In order to calculate the cost of electricity from the various RES candidate technologies each plant operation is simulated using the IPP v2.1 software [7]. The software emerged from a continued research and development in the field of software development for the needs of power industry. This user-friendly software tool can be used for the selection of an appropriate least cost power generation technology in competitive electricity markets. The software takes into account the capital cost, the fuel consumption and cost, the operation cost, the maintenance cost, the plant load factor, etc. All costs are discounted to a reference date at a given discount rate. Each run can handle 50 different candidate schemes simultaneously. Based on the above input parameters for each candidate technology the algorithm calculates the least cost power generation configuration in real prices and the ranking order of the candidate schemes. A brief description of the optimization procedure is given below. The technical and economic parameters of each candidate power generation technology are taken into account based on the cost function:

$$\min\left(\frac{\partial c}{\partial k}\right) = \min\left\{ \frac{\sum_{j=0}^{N}\left[\frac{\frac{\partial C_{Cj}}{\partial k} + \frac{\partial C_{Fj}}{\partial k} + \frac{\partial C_{OMFj}}{\partial k} + \frac{\partial C_{OMVj}}{\partial k}}{(1+i)^j}\right]}{\sum_{j=0}^{N}\left[\frac{\frac{\partial P_j}{\partial k}}{(1+i)^j}\right]} \right\}, \qquad (2)$$

where c is the final cost of electricity in €/kWh, in real prices, for the candidate technology *k*, C_{Cj} is the capital cost function in €, C_{Fj} is the fuel cost function in €, C_{OMFj} is the fixed O&M cost function in €, C_{OMVj} is the variable O&M cost function in €, P_j is the total electricity production in kWh, *j*=1,2,…*N* is the periods (e.g., years) of installation and operation of the power generation technology and i is the discount rate. The least cost solution is calculated by:

$$least\ cost\ solution = \min\left[\frac{\partial c}{\partial k}\right] . \tag{3}$$

During the simulations procedure the following financial feasibility indicators are calculated (a) electricity unit cost or benefit before tax (in €/kWh), (b) after tax cash flow (in €), (c) after tax NPV (net present value: the value of all future cash flows, discounted at the discount rate, in today's currency), (d) after tax IRR (internal rate of return: the discount rate that causes the NPV of the project to be zero and is calculated using the after tax cash flows. Note that the IRR is undefined in certain cases, notably if the project yields immediate positive cash flow in year zero) and (e) after tax PBP (payback period: the number of years it takes for the cash flow, excluding debt payments, to equal the total investment which is equal to the sum of the debt and equity). Details of the optimization algorithm implementing the above mathematical formulation can be found in [5], [7].

3. RES-E integration analysis

In this section, the above model is tested for the assessment of the cost increase of electricity by the integration of the necessary RES-E technologies mixture by 2020 in the case of the island of Cyprus. The optimization model used is based on a GA technique, for the calculation of both the additional cost of electricity due to the large penetration of RES technologies as well as the required RES-E levy in the electricity bills, in order to promote and fund such penetration.

3.1. RES-E penetration scenarios

Over the study horizon, the analysis examines 4 levels of RES-E penetration in the electricity sector of 10%, 15%, 20% and 25%. Based on the above levels of penetration a total of 5 scenarios, regarding the future power generation expansion of the Cyprus generation system are examined. The first scenario considers the expansion of the Cyprus generation system without any RES-E technologies but only with natural gas combined cycle technologies of 220MWe capacity, which is considered as the BAU expansion scenario. The remaining four scenarios consider expansion with RES-E technologies. This is done in order to assess the additional electricity unit cost (compared to the BAU scenario) of the future Cyprus generation system with the expected integration of the necessary RES-E technologies mixture by the year 2020.

In all four RES-E scenarios, the natural gas combined cycle plants of 220MWe capacity remain a candidate option for the system expansion, with the addition of four RES-E candidate technologies, namely wind, PV, biomass and CSP with 6 hour thermal storage [9], in different capacity mixtures per scenario based on (a) satisfaction of the minimum indicative trajectories for the penetration of RES-E technologies in the Cyprus power generation system as set out in [3] and [4], (b) available potential of each individual RES-E technology, (c) level of penetration of each individual RES-E technology into the grid without any technical problems, (d) RES-E capacity installation priority and (e) RES-E contribution to the power generation system capacity reserve margin. Real data have been used in the case of conventional power generation technologies and RES-E technologies technical, economic and environmental parameters. In the case of fuel prices as well as CO_2 EU ETS trading cost, projections have been used in line with recent EU estimates.

3.2. Simulations results and discussion

One of the measures for the promotion of the use of RES-E technologies is the feed-in tariff (FiT) measure. FiT sets a guaranteed premium price to the RES-E producer and puts an obligation on the grid operators to purchase the output. The FiT price is typically guaranteed for a long period in order to encourage investments in new RES-E plants. Therefore, in order for the FiTs, corresponding to various RES-E technologies, to become attractive, a satisfactory IRR to the RES-E producer is necessary. The optimum results concerning FiTs, with an acceptable level of IRR to the RES-E producers, of 10% are illustrated in Figure 2.

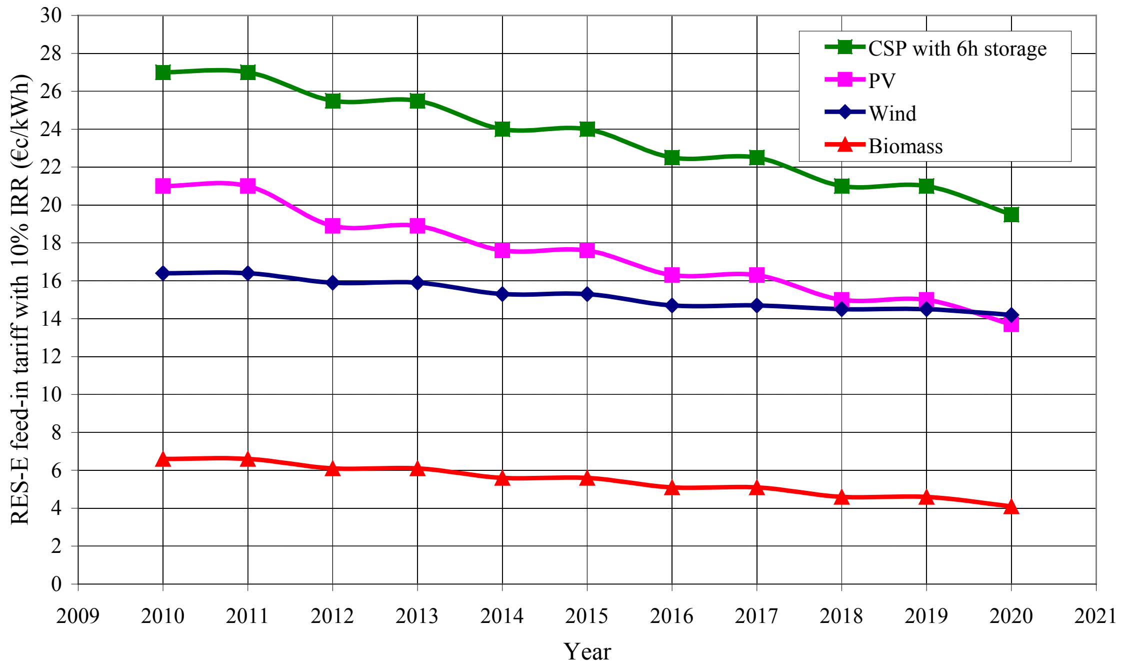

Figure 2: Optimum RES-E FiTs for 10% IRR

The results concerning the estimated overall cost increase in the electricity sector for the promotion of RES-E technologies, for the period 2010-2020 are illustrated in *Figure 3*. This is a differential cost increase compared of each RES-E scenario to the results obtained with the BAU scenario and takes into account the following factors: (a) fuel consumption since by increasing RES-E penetration fuel consumption is reduced, (b) CO_2 emissions since by increasing RES-E penetration CO_2 EU ETS trading cost is reduced and (c) conventional power system since by increasing RES-E penetration the conventional power system operating cost is increased due to the increased requirements of conventional reserve capacity and due to the operation of conventional plants at lower capacity factors.

The overall cost increase in the electricity sector is expected to be recoverable through the electricity bills partly as a direct cost (RES-E levy) and partly as an indirect cost (utility RES-E purchasing price and/or CO_2 trading auctioning). For comparison purposes the following two cases are examined: (a) RES-E investments with no profit (i.e., IRR at 0%) and (b) RES-E investments with profit (i.e., IRR at 10%). The overall results concerning the differential electricity unit cost from BAU scenario (no RES-E penetration) for the different RES-E penetration scenarios investigated are illustrated in Figure 3. For example, for 15% RES-E penetration, in the case of investments with no profit (i.e., IRR at 0%) the overall additional cost will be 0.79€c/kWh (in real prices), however, in the case of investments with FiTs with

IRR at 10% the overall additional cost will be 1.28€c/kWh (in real prices). For the latter the required level of RES-E levy in the electricity bills need to increase from the current level of 0.44€c/kWh to 0.53€c/kWh.

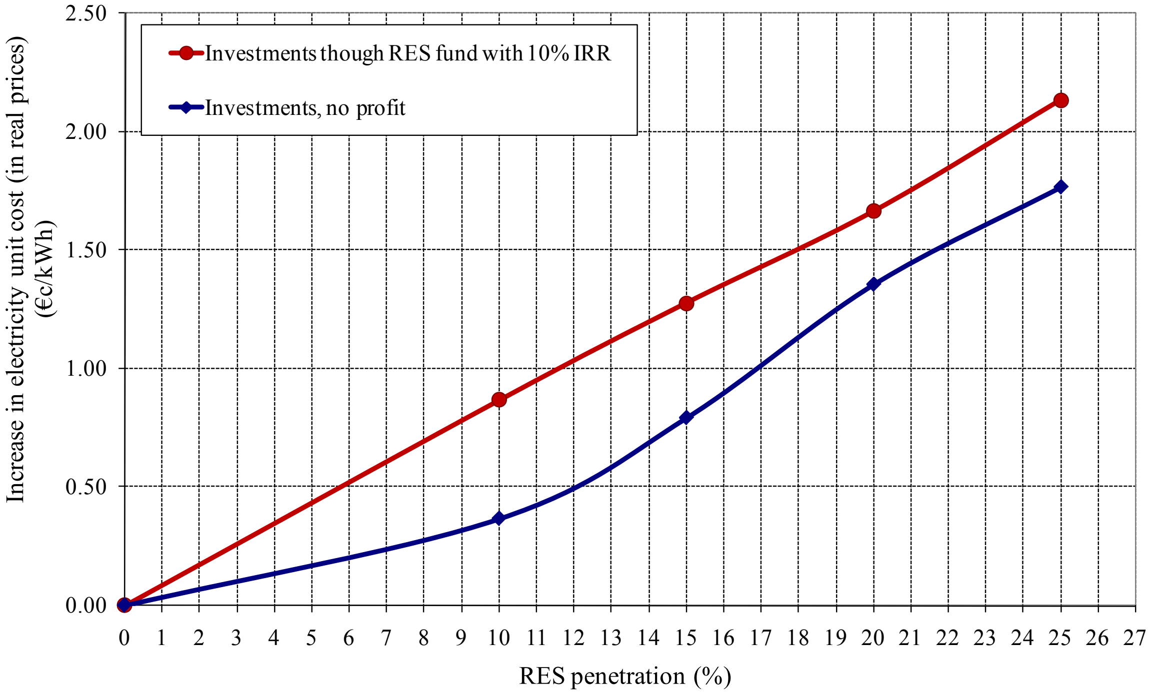

Figure 3: Overall results for the differential electricity unit cost from BAU for RES-E promotion (in real prices)

4. Conclusions

The main purpose of this work was to assess the unavoidable increase in the cost of electricity of a generation system by the integration of the necessary RES-E technologies for the EU Member States to achieve their national RES energy target. The optimization model developed uses a GA technique for the calculation of both the additional cost of electricity due to the penetration of RES-E technologies as well as the required RES-E levy in the electricity bills in order to fund this RES-E penetration. Also, the procedure enables the estimation of the level of the optimum FiT to be offered to future RES-E systems. Such decision support methodology for the optimum RES-E penetration cost level is of high importance not only from an economic point of view, but also from a political prespective since it can be used to help politicians to decide on the least cost RES-E penetration scenarios.

The applicability of the developed optimization model was applied to the small isolated power generation system of the island of Cyprus. The overall cost increase in the electricity sector for the promotion of RES-E technologies, for the period 2010-2020, was analyzed. This is a differential cost increase compared of each RES-E scenario to the results obtained with the BAU scenario and takes into account factors, such as, the fuel avoidance cost, the CO_2 emissions avoidance cost, the conventional power system increased operation cost, etc. The overall results indicated that in the case of RES-E investments with IRR of 10% the cost of integration is higher compared to RES-E investments with no profit (i.e., IRR at 0%) by 0.3€c/kWh – 0.5€c/kWh (in real prices), depending on the RES-E penetration level.

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U.S. Climate and Energy Policy: *What Went Wrong, and What it Means for Global Renewable Energy Technology Development*

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Abstract: This paper examines the breakdown in discussion and the legislative process in the U.S. Government that led to the surprising failure to enact meaningful energy or climate legislation during the first two years of the Obama Presidency, while his Democratic party held control over the Government, including factors like opposition, the legislative process, the Gulf oil spill, and lack of understanding. From this critical understanding the paper will examine where U.S. policy stands today, and what the likely path forward for U.S. energy and climate policy may be and how those policy decisions absent climate legislation will effect renewable energy technology development and deployment in the U.S. and global marketplace over the coming years.

Keywords: *Policy, Renewable energy, Climate, U.S., Greenhouse gases*

1. Introduction

While reports have the U.S. slipping behind China as the now second largest consumer of energy on the globe, [1] U.S. action on climate and energy remains one of the critical pieces of the global policy discussion about the future of renewable energy.

Proponents of climate change legislation in the U.S., were dealt a stunning defeat when the U.S. Senate failed to reach a consensus and pass a climate and energy law. In November of 2008 the Democrats won a 'supermajority' in Congress and took control of the White House—seemingly the only question was how quickly the U.S. would take a global leadership role on climate change. More than 2 years into the Obama Presidency, no significant law on climate change or energy policy has been enacted, and the path forward for a changed energy and emission policy in the U.S. remains strikingly opaque.

2. Methodology

Following several inquiries about the process and explanations for the failure of the U.S. congress to pass comprehensive climate legislation during 2010 the author began to compile information on the process through major media coverage, direct interviews with members of the U.S. congress and their respective staffs. In combination with available information on U.S. and global energy markets, this collected information was analyzed to determine why legislation was not passed, and what the near-term future of U.S. energy and climate policy will likely be.

3. What Went Wrong

That the U.S. Government did not pass a comprehensive carbon cap and trade law during 2009 or 2010 was surprising to many observers both inside and outside of the U.S. The consensus government, with Democrats controlling the White House, House of Representatives and with a super majority in the Senate, appeared perfectly positioned to act on the campaign promises of Barack Obama that the U.S. would act in a meaningful way on climate change by signing greenhouse gas limits into law, would take a leading role in managing greenhouse gases globally, and accelerate the development of a clean energy economy. For proponents of renewable energy this inaction by the U.S. government, while Democratic supporters were so well positioned to take decisive steps on both climate and energy, was seen as significant failure.

The first hint that the passage of sweeping legislation related to climate change might face substantial headwinds despite the Democratic control of the government came in the weeks leading up to the Conference of Parties in Copenhagen in December of 2009. Despite Obama's publically expressed desire to go to Copenhagen with a new U.S. law as a base for negotiations there was little compromise in the month leading up to the COP on what that platform would be and effectively no legislative action. [2] With results from the Copenhagen meeting providing less clarity on the future plan for global climate change action than supporters had hoped (and with many pointing to the U.S.'s unwillingness to commit as a key reason why there was not more progress during the Copenhagen talks), the President returned to the U.S. again pledging action on new laws in the U.S. [3]

Throughout the winter and spring following Copenhagen, the debate over U.S. climate and energy policy circled around two proposals which were both based on cap and trade programs similar to the EU's cap and trade scheme designed to reduce greenhouse gas emissions. The American Clean Energy and Security Act of 2009 (also known as the Waxman-Markey Bill) was passed by the House of Representatives in June of 2009.[4] Several members of the U.S. Senate worked to pass a companion bill which could be reconciled with Waxman-Markey and then sent to the President to be signed into law. Of the many ideas and positions that were raised, the leading option that eventually took center stage in the Senate was a proposed collaboration by Sen. John Kerry, a Democrat, Sen. Joe Lieberman, an Independent and Sen. Lindsay Graham, a Republican. This bill, nicknamed KGL, was eventually drafted and formally introduced in the Senate, but not before Sen. Graham had splintered from the group citing concerns over Democratic action over immigration policy, growing concerns about the potential negative economic impact of cap and trade and tremendous pressure from some of his Republican colleagues.

The resulting bill, the American Power Act [5] was introduced late in the Spring of 2010. Timing, increased partisanship over energy and climate, lingering economic concerns, and a strong lobbying presence by fossil fuel companies, all combined to limit substantive discourse on this bill. By the time the bill was actually introduced on May 12th the Senate was nearly through its Spring session leaving only a light Summer schedule, which ended at the start of August under the 111th Congress [6] to debate and vote on legislation that was both divisive and complex on an unprecedented scale. Republicans pulled together in an increasingly tight anti-climate block during this period, pointing to potential economic damage to a still weak U.S. economy. Similarly, fractures in the Democratic majority over those economic concerns and tremendous uncertainty about broader energy policy questions as the Deepwater Horizon spill in the Gulf of Mexico continued unabated though the summer eroded support and slowed the debate process. During this period the fossil fuel industry waged a coordinated lobbying effort to erode the support of both Democrats and Republicans for the bill by highlighting the potential increases in energy costs and job losses. The result was that Democratic leadership in the Senate never managed to even get the bill brought up for a full vote by the Senate.

During this period a number of alternative proposals designed to directly support the renewable energy industry had been developed and introduced in both Houses of Congress. Bills ranging from national renewable energy standards to expanded renewable energy research and development funding to energy efficiency and building use targets all gained substantial support. Leadership kept the Climate Bill as effectively the first order of business, with the only other focus of the session being related to rules governing offshore drilling—and there was even a movement to combine these two efforts into a sweeping climate and offshore drilling package. The result was that these two high-profile, but extremely divisive issues stayed in front of every other clean energy proposal and the Senate's summer session closed without even targeted energy legislation moving forward.

There is little doubt that the results of the recent congressional elections in the U.S. will mean less support for incentives or new regulation that benefit the manufacture or deployment of renewable energy facilities. Republicans now control the House of Representatives. The party has, broadly, been less supportive of renewable energy integration or of restrictions on CO_2 emissions. This lack of support has found very specific backing by several members who are attacking the science underlying the connections between fossil fuel use and climate change, as well as the widely held belief that the integration of energy resources, which are viewed as more expensive than traditional energy mix, will cause irreparable damage to an already struggling economy. This includes very open attacks by the members who vied for control of the House Energy and Commerce Committee, which was eventually won by Rep. Fred Upton. [7]

4. Where U.S. Policy Stands

The current make-up of the U.S. government makes it difficult for either party to pass a new law. Democrats control the Senate and the White House while Republicans hold a strong majority in the House of Representatives. In order for a new law to be enacted, it must pass both the House and the Senate (and because of procedural rules, the minority party can prevent a proposed law or bill from passing by using a minority block of 41 votes to prevent a bill from being debated or voted upon. [8] Only after passage in both chambers of Congress is the bill sent to the President, who would then sign the bill into law or exercise his power of veto to reject the bill.

Given the divide that has been growing between Democrats and Republicans over energy and climate, the current split in the control of Congress means that finding areas of compromise on energy or climate issues will be difficult, if not impossible over the next two years.

A national cap and trade bill is very clearly not a viable near-term option. The next presumed Speaker of the House, Rep. John Boehner, commented before the election that “This election is going to be a referendum on [Democrats’] job-killing policies, one of which is cap and trade,” Boehner said. “There will be no tax increases; there'll be no cap and trade bill,” he added. [9] The failure of Democratic leadership to consolidate support this past summer to pass comprehensive climate legislation, combined with an increase of climate-science denial rhetoric by the Tea Party and the far-right of the Republican party means that there is simply no path to legislate a national price on greenhouse gases over the next two years (unless there is some very significant exigent event that dramatically focuses public perception on climate change).

It seems very clear that natural gas, and possibly nuclear power, will play a meaningful role as lower-carbon options in the policy focus for both the power and transportation sectors over the next few years. Natural gas, as an expandable source of electric generation (and as a potential power source to meet increased demand from the electrification of the transportation sector, which has broad support of both Democrats and Republicans) and as a direct use fuel in the transportation fleet, appears to be the most likely near term area of policy compromise.

There is substantial and inexpensive domestic supply of natural gas supported by the rapid growth in recoverable unconventional or shale gas made available by advances in hydrological fracturing technology. As this is domestically sourced fuel, this new expansion of natural gas supply is seen to address energy security and trade imbalance concerns. Additionally, on a relative basis natural gas has a much lower carbon output than the current energy supply mix in the U.S., so a shift to natural gas is seen as a step towards cutting greenhouse gas emissions. When speaking at a press conference following the election, President Obama indicated his support of natural gas development, "We've got, I think, broad agreement that we've got terrific natural gas resources in this country," Obama said. "Are we doing everything we can to develop those?" [10]

A rapid expansion (relative to the typical pace of energy infrastructure development) of natural gas use and demand is likely if part of an energy bill includes incentives to switch from coal to natural gas fired electric generation. The scale and pace of the demand expansion is unclear, and it will be limited by the available economically-competitive excess natural gas supply (and the real cost of new nuclear development as that becomes better understood). It is not clear at this early stage whether the election results will dramatically change the landscape with respect to environmental regulations related to non-conventional gas extraction (specifically for shale gas and the issues associated with hydraulic fracturing), as there is effectively no Federal oversight of these activities currently in place, though there are rules enforced at by state governments. A meaningful set of environmental controls could eventually act to slow available low-cost gas supplies and limit the role of natural gas as the driver of U.S. energy policy. In any event, the use of natural gas will likely be the lead approach in all energy and climate policy platforms developed in the U.S. over at least the next two years.

Another dynamic at play in the national policy debate around greenhouse gas limitations is that there are a series of rules being drafted by the EPA under its authority to manage greenhouse gas emissions under the Clean Air Act.[11] The Clean Air Act, however, does not include any specific language with respect to greenhouse gases, and whether and how the Act should be applied to carbon emissions is a point of considerable acrimony. Republicans in the House have already pledged to attack the EPA directly as well as through funding cuts to slow this rulemaking process.

This attack the EPA regulation of greenhouse gases will be a priority for Republicans, and the initial reaction from the Obama Administration is that it will work to find a compromise on the scope and pace of EPA regulation of greenhouse gases in exchange for other policy platforms that will act as alternative carbon mitigation tools, such as expanded use of renewables power and natural gas as a coal replacement. President Obama reinforced the idea this week, stating that "the EPA is under a court order that says greenhouse gases are a pollutant that fall under their jurisdiction. . . Cap and trade was just one way of skinning the cat; it was not the only way. . . And I'm going to be looking for other means to address this problem. . . I think EPA wants help from the legislature on this. I don't think that the desire is to somehow be protective of their powers here. I think what they want to do is make sure that the issue is being dealt with."[12]

5. Where Does the U.S. Go From Here

As things currently stand it appears that any action on energy (or climate) by the U.S. Government will be cautious and targeted. Given the failures of several attempts at comprehensive policy changes, the safer and therefore more likely near-term approach will be small, targeted initiatives. These targeted policy platforms tend be directed at specific industries and have historically been incentive based. Some of these platforms can actually be contradictory, as constituencies push for support of their own areas of focus without regard for the broader energy or climate policy landscape. The result is that short term market distortions and the lack of long term certainty of price signals reduces investor appetite in all segments of industry development. Even when considered in concert with the broad concerns over the lack of a developed approach to national energy and climate challenges, these problems will almost certainly not be an adequate incentive to revisit a more sweeping approach to energy or climate policy for at least the next two years.

The most likely program platform will be direct incentive based programs have historically proven complex and challenging. Especially for non-U.S. based companies, requiring a U.S. tax base or deep understanding of the U.S. tax system. Some programs require compliance with rules such as U.S. sourced materials and labor. The most significant support mechanism for renewable energy has been tax credits for the development or operation of renewable energy facilities. Most of these credits are in place through the term of the new Congress, with two notable exceptions. The credit for wind power generation is set to expire at the end of 2011 and will require legislative action in order to be extended. Also, the popular 1603 Grant program, which provides a direct payment in lieu of the tax credits is currently set to expire at the end of 2010, though this may be extended by a year through last minute dealings in the final days of the current "lame duck" Congress. These two programs, along with other popular programs like funding for energy research and development are a very real risk, despite widespread conceptual support, as the focus of government programs is turned to balancing the budget and deficit reduction. Extending or re-funding these programs may require matching offsets to produce the savings or revenue increases necessary to make the net cost to the government zero, which is an extremely contentious process.

Another popular program, at least from the Government's perspective is the Federal Loan Guarantee Program, which is administered by the U.S. Department of Energy and supports, among other things, the deployment of renewable energy technologies and manufacturing capacity. As with many of the direct incentive programs these guarantees have been complex and challenging to secure, which has been a source of substantial criticism from the industry and investors. Further, the potential default of some early guarantees may also bring potential program costs into sharp focus as further program funding is contemplated, leaving the future of these programs in some doubt.

Enactment of a national clean energy standard is one broad platform possibility in the coming months (and a program may be enacted by the time of the World Renewable Energy Congress). Renewable Energy Standards have been a popular state government tool, but despite several attempts the program has never been enacted at the national level. These programs are generally structured so that the local distribution company is required to hold Renewable Energy Certificates (RECs) commensurate with a set percentage of power that is required to be produced from identified renewable resources. Production of renewable power creates a REC for every unit of power that is produced, which can be sold along with the power or separately. Due to its regulatory requirements to hold some number of RECs, the local distribution company sets overall demand (possibly in combination with some voluntary buyers) based its need to meet the target for renewable power purchases.

It appears likely that in the near term states and regional programs will take the lead on climate specific rule-making (and possibly more aggressive renewable power targets). As many states as many as 33 states have some form of renewable portfolio standard in operation. A handful of states have begun to experiment with feed-in-tariff programs similar to those used in Germany and Spain to drive rapid growth in solar and wind development. Several northeastern states are part of the Regional Green House Gas Initiative, which is a low-cost carbon cap and trade program for electric production facilities within member states, and in the Western US, the Western Climate Initiative as well as aggressive targets for California are both driving the development of regional markets. These state based programs have generally been embraced by the public and local politicians, at least sufficiently to see programs enacted and expanded. During the mid-term elections that saw historic Republican victories, California voters rejected a challenge to that state's cap and trade law, and New Mexico simultaneously enacted its own cap and trade program.

6. Impact of Inaction by the U.S. on Global Energy and Climate Developments

The slow pace with which the U.S. is embracing clean energy and climate policies will mean that deployment opportunities in the U.S. market will remain limited. The U.S. accounts for as much as 25% of global energy resource consumption, and the lack of U.S. commitment will create friction against the pace of a global energy transition. Given the scale of the U.S. energy economy, its pool of available energy investors, and the fact that the lack of clearly defined market for much of the new technology due to the lack of policy clarity will lead to less talent being engaged in the development of clean energy technology and business than would otherwise be engaged in the U.S., this resistance will be a drag on the pace of global growth for renewable power.

Despite the absence of the U.S. as a fully engaged stakeholder in this global energy and climate transformation, the absolute scale of the global opportunity will keep some U.S. companies and investors engaged in the new energy economy and continue to drive some U.S. investment into these industries. This limited role by the U.S. market will lead to better opportunities in both those developed nations where policy is better defined and in developing nations where sharp demand growth in fuelling investment. Development of renewable energy in Europe has matured more quickly than in in the U.S., as it has been supported by the EU ETS and targeted renewable energy programs like feed-in-tariffs combined with higher energy prices. In China aggressive government driven development programs have accelerated the maturity of the clean energy industry there, and by some accounts China has overtaken the U.S. in clean energy investments.[13]

7. Conclusion

Inaction by the U.S. Congress on climate and energy policy has created a great deal of uncertainty in the both the U.S. and global energy marketplace. Short-term relief for companies with exposure to greenhouse gas emission limitations will quickly give way to challenges planning for mid- and long-term investment choices. This uncertainty is intensified when combined with a likely increase in volatility in the global oil market. The one point of confidence that all stakeholders can work from is that the fall-out from this legislative push for climate legislation all but guarantees that for the next few years (notwithstanding a significant disruptive event), the path forward in the U.S. will be driven locally, or in very measured steps nationally. As arguably the most important energy market in the world, the lack of clear long-term market signals in the U.S. will continue to impair the real value of many new energy and emission mitigation technologies.

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Follow-up of local energy and climate strategies – A study of six small Swedish municipalities

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Abstract: Local authorities are important actors in the transition of energy systems towards renewable energy resources and efficient energy use. One mean to manage and develop local energy systems is using energy and climate strategies. Sweden has a long history of energy-planning, which effectiveness has been debated. However, in the light of climate change, many Swedish local authorities have adopted energy and/or climate strategies in recent years. These strategies are intended to clarify, prioritize and suggest measures for achieving energy and climate related goals. To be able to assess the strategies' effectiveness it is important to identify progress and goal achievement. There is little knowledge whether and how local authorities do this kind of follow-up.

The aim of this paper is to explore approaches to energy strategy follow-up in six small and medium-sized local authorities in Sweden. Based on interviews with representatives from six Swedish municipalities, this paper discusses prerequisites for energy and climate strategy follow-up. Challenges for the follow-up, such as methodological descriptions, organization and lack of high quality data are identified and discussed. A conceptual model for a systematic approach to follow-up is presented. Conclusions on how a systematic approach to follow-up could facilitate organizational learning and a more strategic approach to energy issues are drawn. It is also discussed how a developed practice could be beneficial in terms of common methodologies and possibilities to request better statistical data from the national level.

Keywords: *Energy and climate strategies, local authorities, evaluation, follow-up*

1. Introduction

The local level is important when it comes to developing sustainable energy systems. Arguments for this is for example the proximity to citizens, but also the diverse roles of local authorities such as responsibilities for planning, maintenance of infrastructure and as educators are important when it comes to forming and implementing energy strategies [1, 2]. Another important role of the local level is that there is greater emphasis on hands-on projects and what can actually be affected [3]. This means that local authorities have an important role in the transition of energy systems towards renewable energy resources and energy efficiency. To support local authorities in these issues there are a number of initiatives to provide networks, information sharing and knowledge transfer. For example, in the EU a large number of cities and communities participate in initiatives such as ManagEnergy Programme and the Covenant of Mayors. In Sweden there are several programs supporting local authorities in their work with energy and climate related issues, for example Sustainable Municipalities initialized by the Swedish Energy Agency and the Climate Municipalities funded by the Swedish Environmental Protection Agency. One important component in all of these programmes is the formulation of local energy and/or climate strategies or plans [4-7]. Such strategic documents are used to clarify, prioritise and suggest measures connected to the local authority's fields of responsibility and activity within the energy system. There is also a legal requirement in Sweden that all municipalities should adopt a municipal energy-plan.

The potential of local energy strategies have been highlighted in a number of studies [8-10]. Historically there have however been debates about the effectiveness of producing such documents, for example because many of the factors influencing the energy system lie beyond the reach of local authorities [11, 12]. To what extent energy strategies have been implemented is however not known, partly because follow-up has been paid little attention. Follow-up is central to long-term overall effectiveness of a plan or an effort as it facilitates continuity and taking experiences from the past into the present. There is no formal requirement for follow-up of energy-plans in Swedish legislation and follow-up is often neglected in planning practice [13].

However, energy-plans should be subject for environmental assessments and environmental assessment of programs and plans according to the EU directive 2001/42 should include follow-up [14]. Follow-up in environmental assessments is advocated in literature for example as a means for controlling plan implementation and, if necessary, formulating adaptive management actions. Follow-up may also and enhance organizational learning and process development [15]. This means that there is a powerful potential for improved energy-planning practice as follow-up processes generate information that can be used in different ways for improving the actual environmental situation and for improving working procedures and processes [16].

1.1. Aim of this paper

The aim of this paper is to explore approaches to energy strategy follow-up in six small and medium-sized local authorities in Sweden and discuss the possibilities for developed practice.

2. Methodology

Initially it was decided to choose municipalities for this study based on two criteria: they should be small in a Swedish context, which means less than 25,000 inhabitants and the energy-plan should be recently adopted. The first criterion was chosen because two thirds (192 of 290) of Swedish municipalities have 25,000 inhabitants or less [17]. The latter criterion, that the energy-plan should be recently adopted, was chosen as it was regarded more likely that the persons involved during the energy-planning process would still be working at the local authority and thus available to answer questions about how the issue of follow-up was treated in the planning process. These criteria however proved hard to fulfill as only six small in municipalities that possess such recent energy-plans were identified. Three of these declined to take part of the study for different reasons, for example since the person who had been responsible for the planning process changed jobs. In order to get a more information on how follow-up of energy plans is undertaken additionally three (in a Swedish context, 30,000-45,000 inhabitants) medium-sized municipalities were chosen. The final set of municipalities in the study is presented in, table 1.

Table 1. Empirical basis in the study: six small (<25,000 inhabitants) and medium sized (<45,000 inhabitants) Swedish municipalities.

Municipality	Size	Energy-plan adopted	Responsible for planning process	Follow-up	No of Respondents
A	Small	2008	Workgroup and external support	Yes	2 (Public official, energy advisor)
B	Small	2009	Workgroup and external support	No	2 (Public official, energy advisor)
C	Small	2003	Workgroup	Yes	1 (Energy advisor)
D	Medium	2008	Consultant	No	2 (Public official, consultant)
E	Medium	2010	Workgroup	Yes	2 (Public officials)
F	Medium	2003	Consultant	No	1 (Public official)

For all municipalities the energy-plan was analyzed regarding how follow-up were supposed to be handled. In those cases where a person was stated as responsible he or she was interviewed about how follow-up had been conducted in practice. The named authors of the energy plan were interviewed about whether follow-up was regarded during the planning process. All interviews were conducted by telephone in a semi-structured form.

3. Results

This section presents the intentions for follow-up in the energy-planning process, how this was manifested in the energy-plans, and how follow-up has been conducted in practice in the six studied municipalities.

3.1. Municipality A

According to the energy-plan the progress should be monitored yearly in an annual "energy account". Regional monitoring of environmental goals by the County Administrative Board will also be used as indicators of goal effectiveness. The municipal government is utmost responsible for this account, which is then presented to the municipal parliament. Two persons are involved in the practical work compiling the energy account. One was part of the planning process and one is new in the organisation. This new person has experienced difficulties in interpreting how the baseline values were calculated. This means that some parts of the energy-plan have not been followed up. This respondent also comments that the indicators chosen for goal achievement are not necessarily suitable for the purpose. For example, whether district heating leads to less emission depends on the fuel mix in the incinerator and what is substituted. An experienced obstacle for the follow-up is the quality of the available national statistics. The respondent means that local data is preferable to national statistics but in practice a mix is used. However the mix of different data sources is a problem since methodology descriptions from the baseline calculations during the planning process are missing.

3.2. Municipality B

Two persons are working with strategic energy issues in municipality B. One person has the main administrative responsibility and functions as contact person to the politicians. The other person's main responsibility is to make sure that actions proposed by the energy-plan are implemented. The intended methodology for follow-up is to produce an environmental account where progress in implementing actions from the energy-plan is described. Focus in the follow-up will thus be on actions and whether they are implemented or not. The next step is to analyse to what extent this action has contributed to fulfilling goals in terms of decreased energy use and lowered emissions. This analysis is regarded as important since it sends a distinct message to the politicians. Exactly how the follow-up will be performed is not yet decided. However, the respondents emphasise the importance of this follow-up to become part of ordinary working procedures to avoid that the work becomes yet another burden for the public officials. Also in this case the low quality of available statistics is regarded as an obstacle to follow-up; therefore indicators based on local data will be used instead.

3.3. Municipality C

The energy and climate plan does not include any description on follow-up. The respondent in Municipality C has a supportive and advisory role in the energy-planning process; however he/she has not been involved in the follow-up. The energy-plan was followed up annually between 2004 and 2006, but since then no follow-ups have been performed. The respondent experiences that there has been a lack of continuity in the follow-up process during the last few years and that the work with the energy and climate plan has been very dependent on one specific person. According to the respondent, there are no clear directives on how to proceed with the energy-plan. Follow-up was not an issue during the energy-planning process. Few of the goals stated in the energy-plan are quantifiable, which would complicate the follow-up process. Some follow-up has however been performed since the implementation of actions suggested in the energy-plan has been monitored.

3.4. Municipality D

According to the energy-plan, follow-up will be part of the local authority's annual economical account. The energy-plan presents a follow-up system based on forms to be filled out by each part of the municipal administration and that compilation of the results will be made by the environmental coordinator. In addition to this, the energy-plan states that a number of indicators to monitor progress towards local environmental goals shall be designed.

The environmental coordinator has the overall responsibility for the follow-up. This person was not employed at the local authority during the energy-planning process and the energy-plan for the municipality was produced by a consultant. This consultant means that they did not only produce an energy-plan for the municipality, they also designed a strategic and continuous energy-planning process for the local authority to "inherit". Even though the process was meant to be easily adopted into the local authority's organisation, the environmental coordinator has experienced difficulties in understanding methods used and origins of data. Since a method description is missing, also the consultant has difficulties in explaining how data was obtained and how calculations were made in retrospect. The environmental coordinator does not think that there will be any problems in following up whether actions are accomplished or not, since they are very "hands-on". But when it comes to evaluating whether actions lead to any actual decrease of carbon dioxide emissions this person thinks there will be difficulties. In the energy-planning process there was little attention paid to how to follow-up whether measures contribute to the overall goal for the plan. Instead efforts were laid on how to monitor whether actions are implemented. Also in this case the low quality of available statistics is mentioned as an obstacle to the follow-up.

3.5. Municipality E

Municipality E has a long tradition of producing and monitoring energy-plans and follow-up is a part of the administrative routines in the local authority. Results from the annual follow-up are presented in the municipality's annual environmental account. All goals stated in the energy-plan are connected to indicators for monitoring whether goals are fulfilled or not. Also actions will be followed up in the environmental account as they are implemented in the environmental action program. The environmental coordinator has main responsibility for this and leads a group of public officials that work with the follow-up.

As the last energy-plan was produced an extra human resource was employed. Both this official and the environmental coordinator tell that the goals and indicators for the energy-plan were carefully chosen to suit available data and the (poor) quality of the national statistics. Describing the baseline year and methods for calculations have also been important parts of the work. Feasibility for follow-up has therefore been a precondition in the energy-planning process. When it comes to actions in the energy-plan, focus is to follow-up their implementation. To what extent different actions contribute to overall goals are currently not followed up as it proved complicated to perform such calculations.

3.6. Municipality F

In municipality F the local climate strategy also functions as energy-plan. According to this climate strategy follow-up should be conducted annually by monitoring the development in the energy field. If there are any significant changes in practice compared to what is stated in the plan, the plan should be revised. However, there are no concrete instructions for follow-up in the climate strategy, nor are there any time plans or responsibilities designated for implementing proposed actions.

The respondent in Municipality F has no formal role in the follow-up of the climate strategy. However, this person was active in the design process since one of the local environmental goals is connected to energy issues. According to the strategy a steering group and a reference group should be formed to take responsibility for energy issues. Also a local energy group with stakeholders should be initialized. However, none of these supportive structures have been formed. The goals in the climate strategy have instead been integrated in the local environmental goals where they also are followed up. The respondent means that one reason for the lack of follow-up of the climate strategy is that there is no organization for this task and that this work would have been facilitated if follow-up had been regarded during the climate strategy design.

4. Analysis

The results from this study indicate that follow-up has not been particularly prioritized in the energy-planning process, at least when it comes to defining working procedures for this follow-up. In one of the six studied municipalities with recent energy-plans follow-up is not mentioned in the energy-plan at all. Some kind of Follow-up activities have been undertaken in three of the six. Only in one case are there both structured documentation and organization for energy-planning follow-up (municipality 4). This municipality has long traditions and continuity in their strategic energy work and also resources allocated for these tasks.

One reason for not doing follow-ups is, according to the respondents, lack of resources. Another reason is that there were no thought about follow-up in the active planning phase and that it has taken time to build up structures for the follow up. When follow-up is conducted these activities are limited to monitoring whether or not actions are implemented. To follow-up whether these actions lead towards desired goals is however regarded too complicated. One of the obstacles towards calculating contribution to overall goals is lack of high quality data. Several of the respondents are frustrated with the low usefulness of the statistics produced at the national level. Since this data is unreliable there is a need to complement with local data. This in turn leads to methodological challenges as data origin from different years and sources. If the methods for data collection and baseline calculations are not very carefully reported follow-up will be almost impossible. In one case where the energy-plan was produced by consultants (municipality 2) this situation is evident. There were no methodological descriptions for calculating baseline values in the energy-plan, which has lead to that the public official needs to recalculate everything and invent own indicators for follow-up.

5. Discussion - How may follow-up be facilitated?

Municipalities produce a wide range of plans, programs and policies and what is common for all, is that that in order to be effective, follow-up and evaluation is needed. Planning is often seen as a linear process where follow-up is little discussed [16]. Evaluating the plan's implementation by analyzing the development after the adoption is of course important not

only in order to decide whether revision is needed but also to explore the effectiveness of the plan and to learn from that; If the plan did not lead to the desired changes, how should the plan and planning process be designed to be more effective?
When adopting such continuous approach to energy-planning it is important to remember that municipal plans exist in a context. This context includes various institutional aspects and practices. Experience has shown that a success factor for energy-planning is taking the existing working procedures into account [18, 19]. Many local authorities have implemented environmental management systems [20] and in these, making use of the already implemented systematic approach and continual improvements may be a way forward to improving follow-up practice in energy-planning [16, 21]. Standardized Environmental management systems (EMS) approach is organizational oriented and aims at continual improvements. This means that follow-up has a key role [22]. Adopting the systematic approach and continuity of EMS to planning could help overcoming the shortcomings in energy-planning follow-up, for example by providing annual follow-ups of goals and actions. Opportunities of connecting environmental management systems (EMS) to the planning processes have been discussed by for example Hjelm et al [16], where it is argued that EMS could contribute with continuity, routines and improvements of plans and planning. Connecting EMS processes and knowledge to energy-planning could also lead to other benefits as professionals from traditionally different fields meet and exchange knowledge and ideas. Figure 1 presents a conceptual model for the connections between energy-planning and EMS in the local authority.

However, EMSs are more often used in larger local authorities so in the case of the municipalities in this study such an approach may be overkill. Several of the municipalities in this study have instead related their energy-plans to either their environmental account or budget system. This is to some extent analog to the EMS connection to the planning, since it implies continuity. The annual reports in accounts or budget systems could contribute to a systematic gathering of information for follow-up and revision of energy-plans.

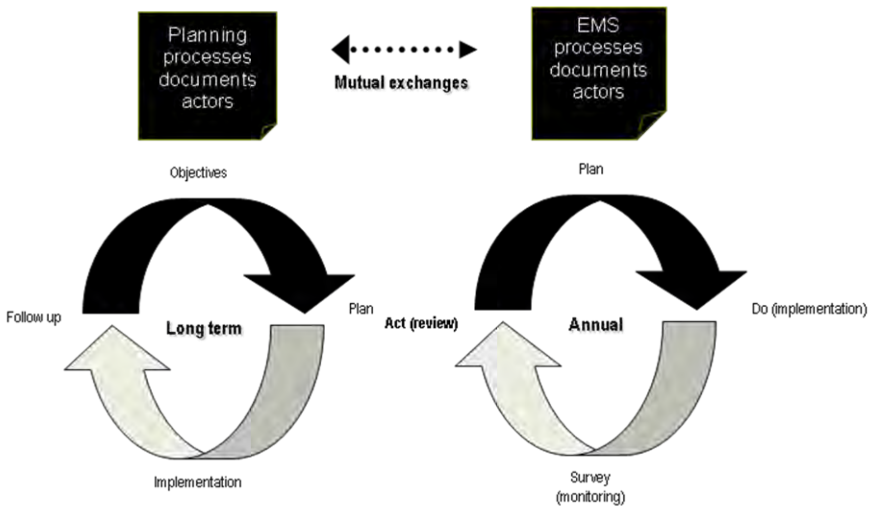

Figure 1**.** Conceptual framework for a continuous approach to planning and to link planning activities to organizational management such as EMS. The picture is inspired by Hjelm et al [16].

Based on the findings in this study, the municipalities seem to mainly follow-up whether or not actions have been taken rather than evaluating if the actions have led to e.g. reduced emissions of greenhouse gases. There is a challenge to find a methodology or approach, including this latter type of follow-up or evaluation. Also in this case a systematic approach with a clear organizational setting with settled responsibilities could facilitate to make the energy-plan integrated in the daily work. Only when energy issues are a natural part of the daily work will it be possible to take the step further to strategic goals rather than implementing separate actions. If an EMS-approach is adopted, several advantages would be achieved: there are existing guidelines and vast practical experience from the EMS-field. The guidance in ISO 14004 stresses the importance of planning for the follow-up in terms of methods, indicators for activities and processes that give the most useful information [23]. The guidance also points out the importance of documented routines for follow-up. It would also be natural to lead experiences from implementation and monitoring back into the policy and planning processes for organizational learning and to formulate new actions as implied by for example Partidàrio [15].

Another aspect on the adaption of an EMS-inspired approach to energy-planning follow-up related to the identified obstacles identified in this study is that it can facilitate the development of a common working practice and methodology. This would not only benefit the public officials who would recognize working procedures even if they change working places. Also, if many local authorities (and also consultants) adopt a similar working approach it would be easier to enquire better quality on specific statistical data from the Swedish Energy Agency.

6. Conclusions and recommendations

The aim of this paper was to explore approaches to energy strategy follow-up in six small and medium-sized local authorities in Sweden and discuss the possibilities for developed practice. It was found that in these cases follow-up is limited. Sometimes follow-up is neglected already in the planning phase and sometimes it is limited due to of lack of resources. Those who manage to conduct their follow-up have related their energy-plans to either their environmental account or budget system. This is one way to include the follow-up in a continuous process.

If energy-planning follow-up is included in processes of continual improvement there are several possible gains: the working procedures in EMS are well-known and can facilitate the development of working practice and also the standardization of data use and methodology. This systematic work could also lead to well-defined organizational settings for energy issues which can both contribute to putting strategic energy issues on the municipal agenda and to organizational learning and adaptive local energy policies.

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Green Jobs? Economic impacts of renewable energy in Germany

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Abstract: The labor market implications of large investment into renewable energy (RE) are analyzed in this text. Although a growing RE industry can be observed in Germany the overall effect of large increases of expensive electricity and heat generating technologies on the German economy require a careful model based analysis. The paper shows the overall effects under different assumptions for fossil fuel prices, domestic installations and international trade. Most of these scenarios exhibit positive effects.

Keywords: *Renewable Energy, Germany, Economic Effects*

1. Introduction

The positive impacts of an increasing share of renewable energy (RE) on the mitigation of climate change as well as on the decrease of the dependence of energy imports are indisputable. However, such are currently still the additional costs of heat and electricity generation from most renewable energy sources (RES). For a stable economic development, the overall balance of positive and negative effects under different possible future development pathways of fossil fuel prices, global climate policies and global trade is of interest. To account for all effects in a consistent framework, a macroeconometric model is employed. Economic development is measured via the comparison of economic indicators such as GDP and employment from different simulation runs. Overall net positive effects can be seen for instance as higher employment in one simulation run compared with the other.

Additionally, the sectoral disaggregation of our model leads to a wide array of interesting results in terms of winners and losers of policies to support renewable energy. This contribution is organized as follows: This introduction is followed by section 2 on the methodology applied. The modeling framework is explained and the scenarios are described. Section 3 presents modeling results followed by a discussion. Section 4 concludes.

2. Methodology

2.1. Net economic effects

The discussion about employment effects of the increase of renewable energy often centers on so-called net employment. The rising installation of renewable energy systems in some European countries such as Germany, Denmark and Spain has intensified the discussion of costs and benefits of renewable energy systems. One suggestion is that price increases from increasing shares of renewable energy lead to job losses somewhere else in the economy and the net effects will be negative.

Production, installation, operation and maintenance of windmills, solar modules, biomass power plants or heating systems as well as biogas and solar thermal applications have a positive investment effect on the respective industries (Figure 1). Employment in these sectors increased steadily in Germany over the last years (cf. [1]) and is often referred to as gross employment. International demand for RE technologies increases employment in these sectors. The wind industry, for instance, makes up to 70% of its 2009 turnover from exports. Hydro energy and solar modules also exhibit high export shares in their respective turnover.

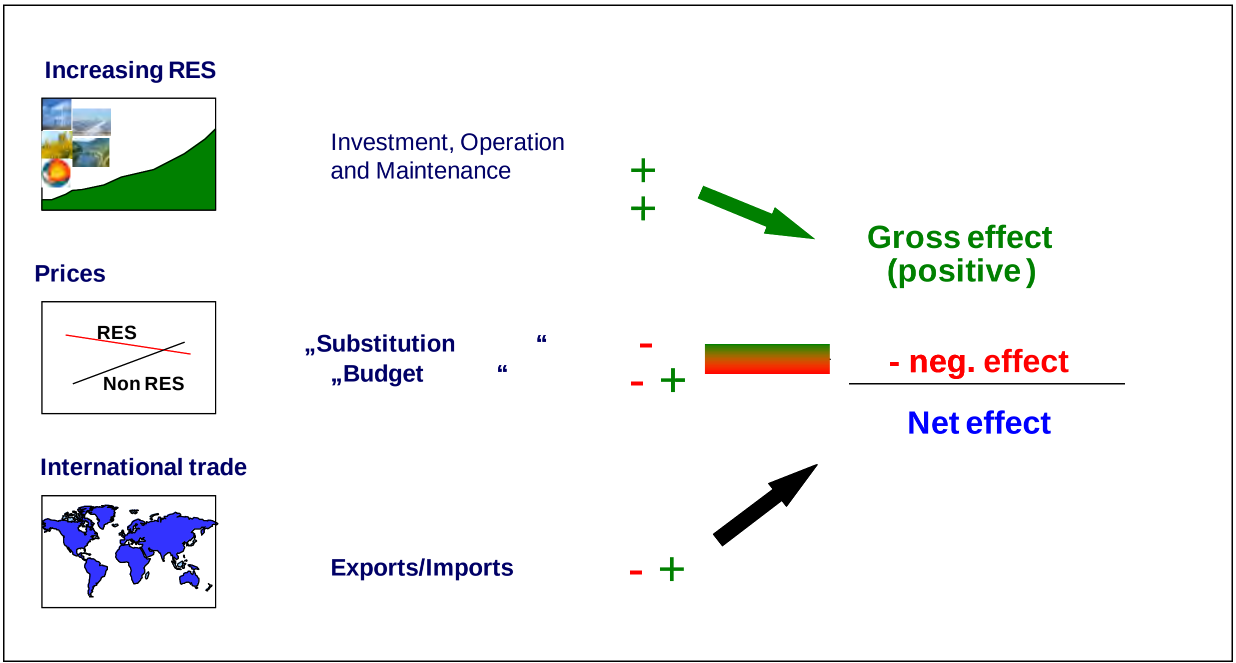

Figure 1: Economic effects of an RE increase on the labor market (cf. Staiß et al. 2006)

Negative impacts on the economy stem from 2 different sources: firstly, investment in renewable energy technologies crowds out investment in fossil fuel technologies such as coal fired power plants, oil fired heating systems and maybe at some future point gasoline driven cars. This substitution effect leads to profit losses in the respective economic sectors.

The second negative effect is larger than the substitution effect and comes from the additional costs of RE systems. Germany supports RE electricity with a feed-in tariff, which leads to electricity price increases for households and firms. This so-called budget effect (Figure 1) reduces the budget for other expenditures resulting in job losses in the respective sectors. Positive and negative impacts are multiplied and distributed through the economic system: additional employment results in additional expenditure on consumption and additional jobs in the respective sectors as well as additional taxes and therefore increases in the governmental budget. Negative impacts affect the economy through the same channels. For information on the net effects one has to employ a model of the total economy.

2.2. Model

The environmental macroeconometric model PANTA RHEI is at the core of our methodological approach. PANTA RHEI is an environmentally extended version (cf. [2], [3], [4], [5]) of the macro-econometric simulation and forecasting model INFORGE. It is based on official statistics and consistently describes inter-industry flows between 59 sectors. It includes consumption, government, investment, construction, inventory and exports as well as prices, wages, labor compensation, profits, taxes, etc. on the sectoral and macroeconomic level [6],[7].

The behavioral equations reflect bounded rationality rather than optimizing behavior of agents. All parameters are estimated econometrically from time series data (1991 – 2008). Producer prices are the result of mark-up calculations of firms. Output decisions follow observable historic developments, including observed inefficiencies rather than optimal choices.

The energy module captures the dependence between economic development, energy input and CO_2 emissions. It contains the full energy balance with primary energy input, transformation and final energy consumption for 20 energy consumption sectors, 27 fossil energy carriers and the satellite balance for renewable energy [8]. The energy module is fully integrated into the economic part of the model.

To examine the economic effects of increasing shares of renewable energy in Germany our analysis applies PANTA RHEI to a set of scenarios and compares the resulting economic quantities.

2.3. Scenarios

Scenarios, in contrast to forecasts, present consistently derived different possible future developments. They enable a "what-if" analysis. For Germany, we apply the official scenario for the development of new RE installations, the so-called "Lead Scenario [9]. This scenario includes bottom-up modeled cost-structures of RE technologies, based on the learning curves for 10 RE technologies. It is a target oriented scenario, in which 84.7 percent RE will be reached in electricity generation, 49.4 percent in heat generation and 49.5 percent in primary energy supply. A scenario with zero investment in RE since 2000 serves as the respective (hypothetical) reference development.

The scenario technique is often applied when future development hinges on the development of some crucial quantities, whose development is highly uncertain. Future employment effects from increasing renewable energy, for instance, critically depend on the relative costs of renewable energy compared to fossil fuels, on national policies for the support of renewable energy and on international climate regimes and RE strategies.

Thus we constructed the following scenarios for the development of each of these decisive factors (cf. Table 1):

1. two different price paths for international energy prices
2. three different scenarios for the domestic investment
3. four different export scenarios, which vary by the share of imports and domestic production in 10 world regions and 10 technologies and with respect to the trade shares of Germany.

2.3.1. International energy prices

International energy prices determine the reference price for the additional costs of renewable energy systems in Germany, because large shares of fossil fuels are imported. The future development path of import prices for fossil fuels is highly uncertain considering the large fluctuations in the past couple of years. Therefore we implement a lower price scenario and a higher price scenario with the respective consequences for renewable energy diffusion. The price scenarios follow essentially the projections of the IEA. The higher price level coincides with the projections in the World Energy Outlook (WEO) 2009 [10]. The lower price level is lower than the more recent projections in WEO 2010, [11], but the upper price level exceeds the assumptions there. Since our analysis tries to stay on the conservative side of things, in the following we report the findings for the lower price level.

2.3.2. Domestic investment

Germany has experienced a boom in the installation of photovoltaic panels in 2010. While the German government annually updates its "Lead Scenario" [12] for the future development of electricity and heat from renewable energy, the latest update in 2009 did not include this rapid increase. Therefore, we included two more scenarios in our analysis, taking the likely PV developments into account. It turned out that the higher path of this set will even be overachieved in 2010, so that only the results of the original scenario and the highest sensitivity will be reported here.

2.3.3. International development and exports

Export is a major driver of the economic performance in Germany. This holds for the economy as such as well as for the sector of the production of facilities for the use of renewable energy. Earlier studies have shown [2] that net employment strongly depends on export levels. Therefore, RE technology exports have been modeled in great detail. Our analysis follows an idea developed by [13] for "green" goods. They analyze the world market for green goods and derive German export quantities from shares of traded goods in this market and shares of German producers in world trade. We follow a similar logic and determine the trade volume of renewable energy technologies for as a calibration for the projections. For this year, the trade shares of German producers can be estimated from statistical data and additional structural knowledge. For the future we develop four scenarios, all of them based on the Energy [r]evolution scenario for global installations [14].

Table 1: An overview of the most important scenario assumptions (highlighted scenarios are reported further), real prices (2005)

	2009			2020			2030		
1. import prices	Oil $/bbl	Gas €/TJ	Coal €/t	Oil $/bbl	Gas €/TJ	Coal €/t	Oil $/bbl	Gas €/TJ	Coal €/t
a. high	58	5,794	79	96	10,700	155	118	13,800	202
b. Low	58	5,794	79	79	8,400	123	94	10,000	147
2. domestic investment					billion $€_5$				
a. lead scenario	20.4			15.4			15.1		
b. higher PV	20.4			16.0			14.1		
c. high PV	20.4			16.6			14.0		
3. export					billion €				
a. minimum	8.6			7,1			7,1		
b. slow	8.6			19.9			32.7		
c. optimistic	8.6			32.9			47.8		
d. maximum	8.6			41.3			59.1		
BMU (2010)									

The minimum case for exports is defined by holding the volume of exports constant until 2030. This translates into a high loss of German trade shares. The maximum case is determined by holding the trade shares constant on a rapidly expanding market, which can be seen as an almost tenfold increase of export volumes. Both scenarios serve as an upper and lower boundary to the more likely developments. The optimistic scenario assumes that Germany maintains significant shares in global trade. The slower scenario can either be seen as a slowdown in German competitiveness or as a tendency to wall off markets in the future. Table 1 gives an overview of the main scenario settings.

Instead of a business-as-usual reference run, which in many studies describes a development under which no further measures are taken [15], this study uses a zero scenario (for the same approach [16]). It describes a consistent hypothetical development in energy generation without renewable energy from 2000 onwards and includes the additional fossil power plants and heat generation plants that would then be necessary along with the associated investment. In this scenario, renewable energy makes only a very limited contribution to the heat and electricity supply, for the latter predominantly from large-scale hydropower, which was already competitive even before the Renewable Energy Sources Act came into force.

In the following analysis results will be reported for the low price path and the high domestic investment path. All export scenarios will be included in the reported results.

3. Results

The economic impact of an activity such as the expansion of renewable energy is assessed by comparing a simulation without the activity or economic policy measure with a simulation that includes the activity.
The zero scenario based on the low price path is now compared to a development with differing degrees of domestic investment in RE and differing export trends based on the same price path. The comparison of simulation results shows macroeconomic effects such as net employment effects which can be traced back to the different scenario assumptions.

3.1. Net employment

To gain an overview of selected results in all the simulation runs, the charts below show the results for net employment over time. Absolute deviations from the zero scenario with the low price path are shown. Positive values should be seen as positive net employment by comparison with a development without expansion of renewable energy. Negative values indicate that employment lags behind the value it would have had without the expansion of renewable energy.

The increase of renewable energy leads in most of the scenarios studied to positive net employment, rising steadily, particularly from 2020 onwards. The net effects are negative in the scenarios with minimal exports (i.e. remaining constant at today’s level), although this should be seen here more as a notional lower limit. In this case, for the two expansion paths (Lead Scenario 2009 and PV2) lower values for employment are observed by comparison with the zero scenario. However, at the end of the observation period there is a reversal in these cases: the net employment effects become slightly positive or are neutral. The influence of exports on the domestic employment level also becomes very evident in the scenarios studied: using the optimistic expectations, the positive net employment effect rises by 2030 to values in excess of 150,000. In combination with cautious export expectations, there are less positive deviations from the zero scenario up to 2015. After that the positive employment effects of exports become apparent.

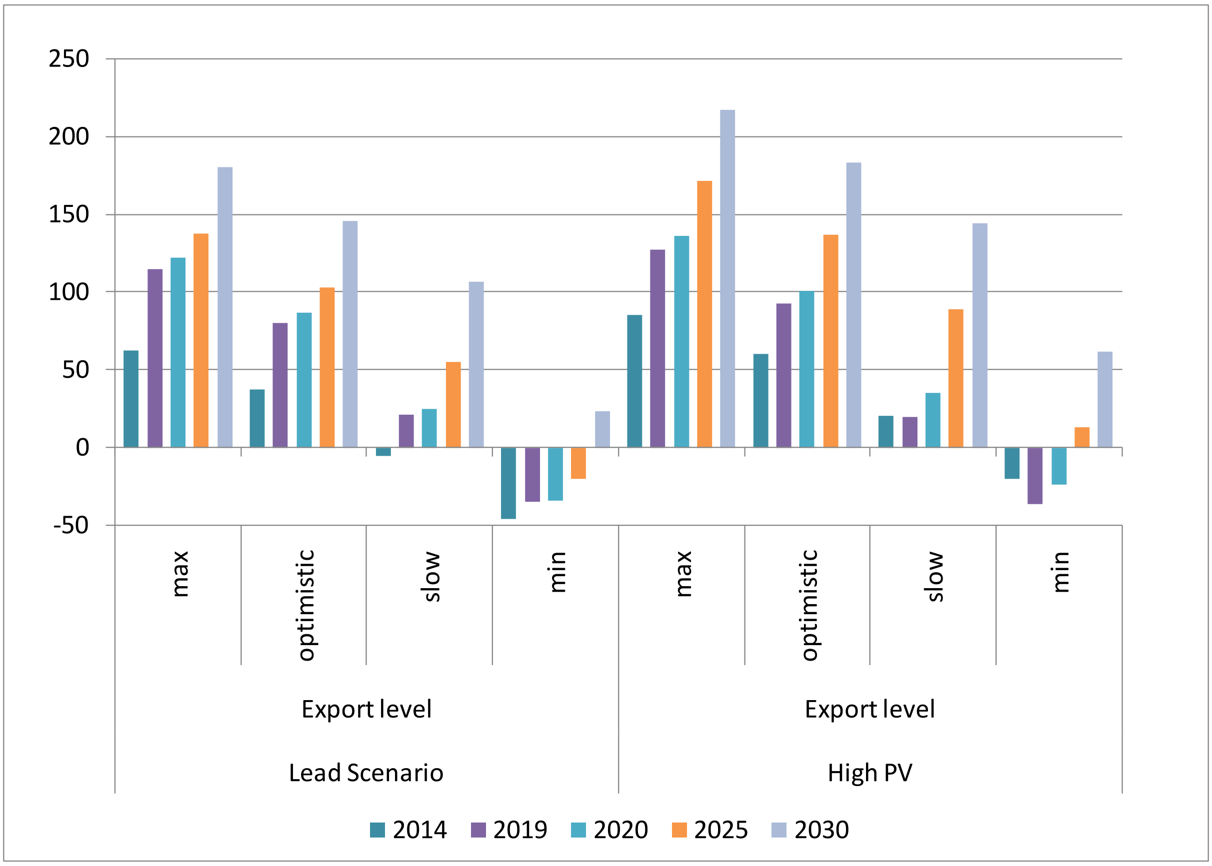

Figure 2: Employment in absolute differences to the zero scenario, in 1000 persons.

Since we are demonstrating only the low price path here, the higher additional costs, brought about by low prices for fossil energy sources, attenuate the positive net employment effects. Overall, the highest net employment stems from maximal export in combination with high PV expansion. Here net employment in 2030 is a little in excess of 200,000 people higher than it would have been without expansion of renewable energy in Germany.

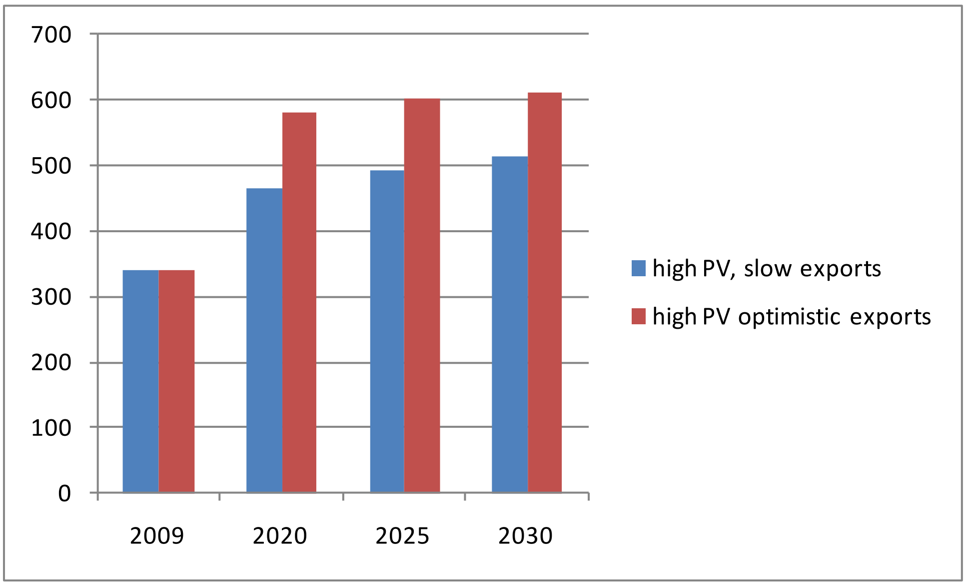

Figure 3: Gross employment in 1000 for two selected scenarios based on high domestic photovoltaic increase combined with slow (blue) or optimistic (red) exports.

The RE industries will employ 500-600.00 people. The figure rises with firms continue to be successful on international markets. The importance of global markets can be read from Figure 3. The different assumptions about exports lead to 100.000 jobs more in the RE industry in the optimistic export scenario.

The future increases in gross employment will not be as fast as they have been in the past. In Germany, the industry doubled its employment between 2004 and 2009 [17]. 2009 339,500 people worked in the production, operation and maintenance, fuel production and input production of RE systems. Our results show a little less than twice this number by 2025.

4. Discussion and Conclusions

Our analysis shows possible positive impacts of the expansion of renewable energy in Germany – and the conditions and policy implication for a positive development. The literature also provides analysis with the prediction of negative impacts – for Germany and other countries. Frondel [18] calculates the additional costs of a projected increase with a national focus and claims that especially the costs of photovoltaic systems cannot be balanced. For Spain, Alvarez [19] showed negative economic impacts, only focusing on the domestic market. However, the main wind energy systems producer, Gamesa, realizes more than 90% of its turnover abroad. A sensible consideration of exports and global markets helps to understand the dynamics of countries which developed a RE industry sector.

For the EU27, the EMPLOY-RES project [20] showed slightly positive effects. The two models used in this study are either more rigid in their price adaptation or they assume perfect substitution of all factors. The PANTA RHEI approach is less rigid but does include adaptation costs as opposed to perfect substitution.

The issue of economic impacts of the expansion of renewable energy will be part of the sustainability discussion for the time to come. On the one hand, increasing installation brings down the specific costs through learning curves and scale effects. On the other hand, parity of electricity generation costs from renewables will only be reached within the next 10-15 years. The German example shows how a large domestic market leads to the development of a successful industry. However, these successes are vulnerable to abrupt policy changes, as experiences with the US industry or the Spanish market show.

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Cost and benefit of renewable energy in europe

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Abstract: Costs and benefits of renewable energy use in electricity generation in the EU are assessed during low oil prices 1998-2002 and high oil prices 2003-2009. The EU statistical data is used. The renewable energy use in the EU was about 21% of the total energy inputs in 2008 and it was growing by 5% annual average during 2003-2008 compared to nearly nil growth of the fossil fuel input. During high and fast increasing oil prices, the correlations between the changes of consumers' electricity prices and the growth of renewable energy use indicates that the large and growing use did not increase the prices but decreased the consumers' electricity prices in several EU countries. An explanation is that the renewable energy enabled input diversification in electricity generation, which has reduced the costs. Consumers' electricity prices are simulated in case these had followed the fossil fuel input costs and compared with the observed prices. It is found that high oil prices invoked substantial efficiency-increase and that the renewable energy input has been net beneficial to the EU citizens even when the periods of low and high fossil fuel prices are taken together.

Keywords: *Renewable energy, Electricity prices, Cost-benefit, Feed-in tariffs*

1. Introduction

The European Union (EU) policy aims at a shift in electricity generation away from fossil fuels (coal, oil, gas and nuclear) towards renewable energy resources, which are biomass and waste, hydro-, geothermal-, solar-, and wind power; co-generation heat plants (CHP) is sometimes included (EU, 2005). This shift, however, is not evident because energy policies of the twenty seven EU member countries differ (Blok, 2006) and because renewable energy use for electricity generation is considered costly (Steger et al., 2005; EU, 2008). However, the cost-reducing technological progress (Gross et al, 2008) in combination with increasing oil prices after the year 2003 till 2008 created a competitive edge for renewable energy use in electricity generation called grid parity and global investments in renewable energy expanded from USD 29 billion in 2004 to USD 151 billion in 2008, out of it more than a third in the EU (UNEP, SEFI, New Energy Finance, 2010). Oil prices fluctuate cyclically, they fell down after 2008, and the renewable energy use became costly. A challenge in the EU policymaking is how to foster the shift regarding the oil price cycle.

The EU policy could act anti-cyclic. It could support renewable energy during low oil prices. This support would maintain high investments entailing the cost-reducing technological progress and thereby, anticipate high oil price when no or little support is needed. Such an anticipation policy, however, causes social costs because it drives up electricity prices above the prices that would be based on the lower input prices on international markets. A higher input price also provides social benefits because it invokes efficiency-increase and reduces pollution, especially greenhouse gas emission due to lower combustion of fossil fuels (Sensfuß et al, 2007). A few available cost-benefit studies are inconclusive. For example, a study commissioned by the German government suggests that the German support of renewable energy in 2006, if scaled up to the EU level, would provide net benefit of 9.4 billion euro in the EU, out of it 5 billion euro efficiency increase, 1 billion lower imports and 3.4 billion euro due to lower pollution (Böhme and Dürrschmidt, 2007:29), but another German study, one into a fossil fuel tax in electricity generation, indicates net costs of this policy, albeit the benefits of lower pollution and innovations in energy saving are unaccounted (Walz and Schleich, 2009). Studies in the US suggest that some technical and social benefits of the renewable energy use are often omitted, such as lower thermal, transport and conversion losses in electricity generation, transmission and use (NREL, 1997; Sawin and Moomaw, 2008), respectively self-reliance and local job creation (Bird et. al., 2008).

2. Methodology

The starting point in this paper is that supporting renewable energy during low oil prices to anticipate high oil prices is a costly policy. It is justifiable only if the renewable energy use would be net beneficial during the whole cycle of low and high oil prices, which means when the costs of renewable energy use during low oil prices would be outweighed by the benefits during high oil prices. This paper looks back at the last oil price cycle from the year 1998 when the annual average price was at the lowest point in the last half century to 2008 when the price was at the highest point (www.inflationdata.com). Question is if renewable energy in electricity generation in the EU was net beneficial during the price cycle. The price cycle is divided into a period of low oil prices 1998 – 2002 when prices have fluctuated around the price in 2002 and the period of high oil prices 2003 – 2008 when the prices have annually increased. In the calculations, all fossil fuels prices are annual averages in constant (year 2000) FOB prices using the US Energy Information Administration (EIA) data (www.eia.doe.gov). All EU data is based on the EUROSTAT (the EU statistical bureau), which is data on energy and electricity generation and consumption. The consumers' electricity prices are excluding taxes in constant (2005) Euro (www.statline.eu). The assessment covers only the statistically observable prices.

The uses and prices of energy inputs in electricity generation are presented in Section 2. The impact of the renewable energy use on consumers' electricity prices during high fuel prices is discussed in Section 3. The costs and benefits of the renewable energy use in electricity generation are covered Section 4. The conclusions are drafted in Section 5.

3. Results

3.1. Energy inputs

The question addressed in this section is if renewable energy has substituted fossil fuels. The following data is compiled for the periods 1998 – 2002 (low oil prices) and 2003 – 2008 (high oil prices): the shares of energy inputs in electricity generation in 2008, the average annual volume growth, the annual average international market prices of fossil fuels and the prices of fossil fuel mix in electricity generation (weighed for volume). The prices of nuclear power and renewable energy are not found. Table 1 shows the data.

The energy inputs in electricity generation have changed during the prices cycle 1998-2008 alongside with 2% annual electricity generation growth. During high oil prices, coal and oil inputs decreased, even though the coal price is below the oil price, nuclear somewhat decreased, and the gas use has increased albeit its price follows neatly the oil price. The renewable energy has grown by 5% during the high oil prices compared to 1% in the period of low oil prices. In result, the share of renewable energy in total energy inputs increased from 18% in 1998 (not shown in the table) to 21% in 2008. In addition, the CHP share in energy input increased from nearly nil in 1998 to 11% in 2008. Hydropower and biomass & waste are the largest renewable energy uses, whereas solar- and wind energy uses grow very fast though the volumes were nearly nil in 1998. Renewable energy use has substituted fossil fuels. The substitution cannot be attributed to the public support of renewable energy because the support of fossil fuels in the EU was much larger (EEA, 2004). The renewable energy use in electricity generation has, apparently, advantages during high oil prices.

Table 1 Energy inputs for electricity generation, excluding CHP and geothermal energy

*Volume data from Eurosta *), prices data from EIA(**)*	*Input in total*	*Average annual volume growth*			*Average annual prices €/t.o.e.*		
	2008	*1998-2008*	*1998-2002*	*2003-2008*	*1998-2008*	*1998-2002*	*2003-2008*
Coal	18%	-0.1%	1%	-1%	85	62	104
Oil	3%	-6%	-3%	-9%	230	161	288
Gas	26%	7%	8%	7%	194	159	223
Nuclear	31%	0.0%	1%	-0.9%	N.A.		
Fossil fuels mix (volume weigh)	79%	1%	2%	0.6%	149	115	177
Biomass & waste	5%	5%	2%	8%	N.A.		
Hydropower	12%	0.3%	-0.1%	0.6%			
Solar	0.2%	61%	47%	73%			
Wind	4%	29%	38%	22%			
Renewable energy	21%	3%	1%	5%			

*(*) No Eurostat data for the biomass & waste use; here assumed 80% of all production is for electricity generation with 15% conversion efficiency. (**).Price converted into €/t.o.e.: Euro/USD with the www.inflationdata.com*42.2 €/GJ * EIA inputs prices, which are for coal USD/metric ton*24GJ, for oil USD/b.o.e*6.1 GJ, for gas USD/1000m^{3}feet*35.5*39GJ*

3.2. Consumers' electricity prices

In this section we discuss whether renewable energy growth caused higher consumers' electricity prices in the EU. If renewable energy would be costly compared to fossil fuels, its growing use would drive up consumers' electricity prices, this predicts theory, and this impact on prices would be significant because the renewable energy use has a substantial share in the total energy inputs. To assess this impact, the countries' annual volume growth of renewable energy in electricity consumption is rank correlated with the annual changes of consumers' electricity price. A positive rank correlation of the volume growth with the price change indicates that the renewable energy use causes higher price, and vice versa a negative rank correlation indicates that the use causes lower prices. A rank correlation (R^2) 0.8 and higher, or – 0.8 and lower is assumed to indicate a significant impact. The assessment covers the period 2003 - 2008 and within this period the timeframe 2005 – 2008 when the oil prices almost doubled. Table 2 shows: countries' share of the renewable energy use in electricity consumption, energy growth, prices changes and the rank correlations during 2003 - 2008 and 2005 – 2008.

Table 2 Growth of the renewable energy use in gross electricity consumption and changes of the consumers' electricity prices (without taxes). Bold: significant negative correlation, italic: average consumers electricity prices above the EU average price (2005-2008), Minus: net importers of electricity

Eurostat data for the volume and prices	*2008(*) Renewable energy use electricity consump.*	*2003-2008 Volume growth*	*Prices*	*Correlat. Volume: prices*	*2005-2008 Volume growth*	*Price*	*Correlat. Volume: prices*
EU(**)	17%	3%	6%	(0.2)	6%	5%	0.0
Belgium -	5%	19%	1%	0.4	26%	7%	(0.4)
Bulgaria	7%	13%	3%	(0.5)	4%	5%	(0.3)
Czech R. -	5%	8%	2%	0.7	18%	13%	(0.6)
Denmark	29%	10%	-3%	(0.5)	7%	7%	(0.9)
Germany -	15%	16%	1%	(0.4)	17%	1%	(0.8)
Estonia -	2%	53%	5%	0.9	33%	4%	0.8
Ireland	12%	20%	7%	0.4	25%	10%	0.2
Greece	8%	13%	9%	(0.8)	-2%	13%	(0.9)
Spain	21%	8%	4%	0.1	3%	6%	0.7
France -	14%	-2%	-5%	0.1	2%	0%	0.4
***Italy* -**	17%	-1%	19%	(0.1)	2%	5%	(0.9)
Cyprus	N.A.						
Latvia -	41%	4%	11%	0.8	9%	16%	0.8
Lithuania -	5%	14%	5%	0.6	20%	8%	0.5
Luxemb.	4%	7%	-4%	0.5	17%	5%	0.1
Hungary	6%	48%	7%	(0.0)	68%	13%	(0.7)
Malta	N.A.						
Netherland	9%	13%	-3%	0.6	15%	6%	0.5
Austria	62%	0%	5%	0.2	5%	7%	(0.2)
Poland -	4%	14%	1%	0.9	26%	9%	0.8
Portugal	27%	13%	-2%	0.1	8%	-4%	0.2
Romania -	28%	2%	10%	0.8	6%	15%	1.00
Slovenia	29%	-1%	-4%	0.2	4%	2%	0.3
Slovakia	16%	1%	1%	0.6	10%	3%	0.6
Finland	31%	3%	2%	(0.4)	7%	3%	(0.8)
Sweden -	56%	0%	-2%	0.1	8%	5%	(0.9)
Un.King -	6%	14%	0%	0.4	17%	14%	(0.8)

(*) Renewable energy use is excluding CHP
(**) The EU average price is total EU value of sales divided by the volume of sales.

In the period 2003 - 2008 the significant positive rank correlations between the renewable energy growth and the changes of consumers' electricity prices are found for Estonia, Latvia, Poland and Romania but all these countries hardly use renewable energy, which is largely imported. The high negative correlation is found for Greece that is a large user of renewable energy. The findings in the period of the fast increasing oil prices 2005 – 2008 provide more insight. Next to the significant positive correlations for the countries that hardly use renewable energy, significant negative correlations are found for Denmark, Germany, Greece, Italy, Finland, Sweden and United Kingdom. All these countries except United Kingdom are large users. These significant negative correlations cannot be explained by cheap domestic and imported hydropower because it has decreased in all EU countries except Bulgaria and Romania. Cheap imports of other renewable energy inputs can be somewhat relevant for Germany, Italy, Sweden and United Kingdom but not for Greece, Denmark and Finland that are net exporters of renewable energy. It could be that the countries in which the significant negative impact is found already experience higher consumers' electricity prices than the EU average, which holds for Germany, Italy and United Kingdom but not for Greece, Denmark, Finland and Sweden.

The growing renewable energy use had low impact on the consumers' electricity prices during 2003-2008 and it has contributed to the lower electricity prices during 2005-2008 (when fossil fuel prices increased very fast) particularly in the countries that are large users of renewable energy. A plausible explanation is that the electricity generators that start with using renewable energy face higher input costs, which are reflected in the higher electricity prices. The generators that use much renewable energy learn to benefit from this input diversification with positive effects on the production costs, which are reflected in the lower consumers' electricity prices

3.3. Cost and benefits of renewable energy

Regarding the positive impact of renewable energy use on the consumers' electricity prices question is whether its use is costly throughout the oil price cycle. Therefore, the observed annual consumers' electricity prices are compared to a hypothetical situation in which electricity prices would have follow the fossil fuel mix prices (see Table 1). The social benefits are in case of lower consumers' electricity prices than if the prices had shadowed the fossil fuel mix prices, and vice versa the social costs are in case of higher consumers' electricity prices than had they shadowed the fossil fuel mix prices.

In the assessment, the year 2002 is taken as the reference because thereafter the oil prices have annually increased and the renewable energy use has grown. Since the electricity prices during 1998 - 2002 are not available for all EU countries it is assumed that they equal to the price of 2002, which is acceptable for this assessment because the annual fossil fuel mix prices fluctuated around the 2002 price. The total social costs and benefits are assessed and the costs and benefits that can be attributed to the renewable energy use, which is based on the additional renewable energy use compared to the reference year 2002. Table 3 shows the energy inputs and outputs in electricity generation, the renewable energy use and its additional use after the reference year, costs of energy outputs and electricity prices, social costs and benefits.

Table 3 Social costs and benefits of renewable energy use in electricity production.

	Reference 2000	*Average a year 1998-2002*	*2003-2008*	*Year 2008*
Energy inputs and electricity generation in GWh				
Total energy inputs	2,753,671	2,667,958	2,930,344	2,987,611
Renewable energy use	474,417	482,221	550,345	628,069
Additional use compared to 2002	-	7,804	75,928	153,652
Electricity consumption	2,599,739	2,510,120	2,779,549	2,855,561
Price of energy inputs and electricity in €/GWh				
Fossil fuels prices	9,826	9,849	15,207	18,784
Electricity price (‘98-‘01 equal 2002)	83,019	83,019	102,632	115,033
Index energy input cost	100.0	100.2	155	191
Index electricity price	100.0	100.0	124	139
Social costs and benefits of electricity consumption in € billion				
Had electricity followed fossil fuel price	216	210	358	453
Observed electricity prices	216	208	286	328
Total net social benefit	-	1.88	72	125
Benefit additional renewable energy use	-	0.65	8	18

During low oil prices (1998 – 2002), the consumers’ electricity prices closely shadowed the fossil fuel prices, but during high oil prices (2003 – 2008) the consumers’ electricity prices were well below the fossil fuel mix prices. The improvements created a net social benefit on average 72 billion euro a year, which is equivalent of 20% efficiency increase. Out of this benefit on average 8 billion euro a year should be attributed to the additional use of renewable energy. Note that in 2008 the total net social benefit has peaked to 152 billion euro, out of it 18 billion euro attributable to the renewable energy use. Throughout the whole oil price cycle 1998 - 2008 the total net benefit attributable to the renewable energy use approached 49 billion euro. When looking back, support of the renewable energy with the incentives of this order of magnitude would be justifiable because it would create cost-neutral renewable energy capacity that would enable to anticipate increase of fossil fuel prices.

4. Conclusions

With reference to the EU policy that aims to shift from fossil fuels to renewable energy in electricity generation, the question is discussed whether it is socially beneficial to support renewable energy during the low oil prices in order to anticipate high oil prices. An answer is given using statistical data for the periods of low oil prices (1998-2002) and high ones (2003-2008). The fossil fuel mix prices in electricity generation have shadowed oil prices though coal at lower prices. During high oil prices 3% of the fossil fuels use is substituted by renewable energy because the latter has grown much faster and within fossil fuels the coal and oil use is substituted by gas. The growing use of renewable energy in the EU did not increase the consumers’ electricity prices except in the countries that hardly use it but had a significant calming effect on the prices in the countries that are large user of renewable energy. A plausible explanation of this finding is that the renewable energy diversifies energy inputs and thereby creates opportunities for efficiency increase in inputs allocation. The cost - benefit assessment for the whole oil prices cycle 1998 – 2008 confirms it. The observed electricity prices are compared with the electricity prices had they shadowed the fossil fuel prices and it is assessed whether the additional renewable energy use has caused higher costs or benefits. It is found that 72 billion euro net social benefits are attained in the EU (about 20% efficiency increase). About 11% these net benefits are attributable to the additional energy use. For the whole oil price cycle 1998 - 2008 the total net benefit attributable to the renewable energy use is estimated at 49 billion euro. The renewable energy, though it is uncompetitive during low oil prices, becomes a viable option during high fossil fuel prices. The policy that anticipates the high prices through incentives for renewable energy has a calming effect on consumers' electricity prices and is socially beneficial.

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Utilities' Business Models for Renewable Energy: Evidence from Germany

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Abstract: This study on German utilities' business models for renewable energies provides new insights into the thinking of Germany's leading utilities about future business models. Two generic business models are derived from the literature and are subsequently analyzed based on a series of in-depth interviews. A core result is that utilities clearly favor large scale projects over small scale projects on the customer-side. This result can be explained with the return potential and renewable energy portfolio standards. Contradictory to the existing literature, German utilities do not see electricity generation on the customer-side as threat to their business model. Instead, they develop very different approaches for large scale projects. It can be concluded that utility engagement in customer-side business models will remain limited in Germany, whereas large scale projects are seen as a promising future business model. The analysis from a business model perspective also shows that both business models, for small scale as well as for large scale projects, still offer room for innovation. Hence, business model innovation can help utilities to create and capture more value in the energy transition.

Keywords: *Renewable Energy, Business Model, Utility, Energy Transition*

1. Introduction

About 82% of the world's electric energy supply is either based on fossil fuels like coal, gas, and oil, or nuclear energy [1]. A key measure to fight climate change and resource depletion is the transformation of the electric power sector towards a more sustainable form of energy production based on renewable energies [2]. It is expected that the transformation will change the structure of the industry and the electric utilities as its largest actors. Several studies on this issue indicate that there will be little room for the utilities' business model in its present form [3][4][5].

The present study contributes to the discussion about utilities' business models for renewable energies by providing insight into the thinking of Germany's leading utilities. The traditional utility business model is delivery of electricity generated from large centralized power plants to the end customer. Since renewable energies are more decentralized, some authors argue that the increasing share of renewable energy generation by customers is a threat to the traditional utility business model, because it leads to decreasing electricity demand and, consequently, erosion of revenues [3][4][6][7]. Following this argument, finding new approaches to serve customers with less and cleaner energy requires a fundamental rethinking of how utilities produce, transmit, and sell electricity. Therefore the research question of this work is: *How do German utilities shape their business models for renewable energies?*

Two generic business models are derived from the literature and are subsequently analyzed on the basis of in-depth interviews with managers of German utilities. The preliminary results show that utilities clearly favor large scale projects and do not expect small scale renewable energy projects on the customer-side to be of great importance. This preference can be explained with transaction costs, economies of scale, and ambitious renewable portfolio standards.

The study is organized as follows. Section 2 introduces the business model concept and provides a literature review on utilities' business models for renewable energies. Section 3 describes the methodology, section 4 displays the results. The essay finishes with a discussion in section 5 and a conclusion in section 6.

2. Literature Review

2.1. The Business Model as a Tool for Analysis and Management

The business model is a valuable new tool for analysis and management in research and practice [8]. In terms of analysis, the concept enables the examination and comparison of companies and markets in a structured way. Using the business model as a classifying device helps to expand the understanding of business phenomena by building generic categories and the development of ideal types [9]. As a management tool, the business model helps managers to design, implement, operate, change, and control their business [10]. In this context, business models can function as "recipes" or "blueprints" that are ready for copying or variation and innovation [9]. Furthermore, thinking in business model terms also enable managers to react to external factors and influences quicker and more appropriately.

Despite the increasing importance of the business model concept in the academic literature there is no generally accepted definition. A review of the literature shows that many business model definitions are comprised of *four basic elements* [11][12][13]. The *value proposition* describes the products and services that are offered to the customers [11][14]. The *customer interface* describes the overall interaction with the customer [15]. The *infrastructure* comprises the companies’ activities and assets required to create the value proposition, thus the internal organization of the value creation process [11]. The *revenue model* represents all revenues and costs associated with selling the value proposition [13][14][15].

Table 1. The Business Model Conceptualization [12][15]

Business Model Pillar	Description
Value Proposition	The value proposition describes the bundle of products and services that create value for the customer and allows the company to earn revenues.
Customer Interface	Customer interface comprises the whole contact with the customer.
Infrastructure	The infrastructure describes the architecture of the company's value creation.
Revenue Model	The revenue model describes the relationship between costs to produce the value proposition and the revenues that are generated by offering the value proposition the customers.

The conceptualization of the business model displayed above refers to the terminology of Alexander Osterwalder and Yves Pigneur [12][15]. The authors define: *"a business model describes the rationale of how an organization creates, delivers, and captures value"* [15]. This conceptualization offers some advantages: first, it is easy to apply and has been extensively tested in practice. Second, the terminology is widely used and accepted, and third, it has already been successfully applied to the field of renewable energies [16].

2.2. Utilities' Business Models for Renewable Energy

The renewable energy business model currently most widespread in Germany (as well as in the United States and Europe) functions as follows: the customer or a private investor owns and controls a renewable energy system, while the utility provides grid connection and is obliged to purchase the electricity. The costs for these services can be passed on to the consumer, but no return may be earned from this service [6]. The utility remains passive and just complies with the regulation. In this model, an increasing share of renewable energies is a threat to utilities, because utilities lose market share and revenues.

Many studies on utilities' business models have focused on this threat from customer-side renewable energy systems. Authors of these studies argue that an increasing share of renewable energy systems owned and operated by customers leads to decreasing electricity demand and consequently erosion of revenues [3][4][5][6][7]. Hence, the question for utilities is how to benefit from increasing customer-side generation. The literature provides different ideas on how an utility business model for customer-side renewable energy could look like [6][7]. For example, Frantzis et al. observed that the most promising approach for utilities is to own and operate the renewable energy system, because a return on the assets can be earned [3][6]. Referring to these studies a generic business model for customer-side renewable energy can be characterized as follows:

> *Customer-side renewable energy business model:* In this business model the renewable energy systems is located on the property of the customer. Possible technologies are photovoltaic, solar thermal hot water, CHP micro power, geothermal heat pumps, and micro wind turbines. The size of the systems usually ranges between a few kilowatts and about 1 MW. The value proposition offered by the utility can range from simple consulting services to a full-services package including financing, ownership and operation of the asset [3][4][5]. Utility financing and ownership of customer-side assets intensifies the customer relationship and can provide access to new customer segments, of customers who otherwise could not afford installation of renewable energy systems [4]. As far as the utilities' architecture of value creation is concerned, a management approach for small scale projects is needed [7]. The revenues for the utility come from return on the assets and charge for services, while costs arise from administration, installation and operation of the systems [6].

Another option for utilities is to invest in large scale renewable energy projects. This approach is represented by the second generic business model:

> *Utility-side renewable energy business model:* The projects are larger than customer-side projects and range from one to some hundred megawatts. Typical technologies are on- and offshore wind farms, large scale photovoltaic projects, biomass power plants, and solar thermal power plants [4][6][7]. The value proposition in this business model is bulk generation of electricity that is fed into the grid [6]. Therefore, the customer interface consists of power purchase agreements on a business to business level, rather than a relationship to the end-customer. As far as the infrastructure is concerned, these projects are much more similar to traditional centralized power plants than the customer-side business model. They are much closer to the utilities' core competency of asset management and operation [6][7]. Costs arise from construction and operation of the

energy project, while revenues come from regulated feed-in tariffs for electricity or tax- or investment credits.

The two generic business models are "ideal types" and represent the two sides of a spectrum [9]. Of course variations are possible. Both business models will be subsequently analyzed in the context of the German utility sector to identify challenges and potential and eventually derive evidence for future trends.

3. Methodology

The present study is based on an explorative qualitative research design, because there is no empirical evidence on this issue from the German market yet. The data is derived from a series of semi-structured interviews with managers of German utilities. The sample selection focuses on Germany, because the country is considered one of the world's leading markets for renewable energies. Of some 800 utilities of very different size and scope of activity four categories were identified by theoretical sampling [18]. Since the selected qualitative approach does not allow to derive statistically relevant information, the innovation leaders in every of the four category were selected - following the idea of extreme cases by Yin [19]. The selected companies were identified through internet research and consultation of industry experts from utilities, industry associations, and consulting.

Table 2. Categories of German Utilities

Category	Revenues in million €	Size of Category
1. Multinational utilities	>10.000	4
2. Regional utilities	10.000-1.000	10
3. Large Local Utilities	999-100	~ 80
4. Small Local Utilities	100-0	~700

To date, 15 interviews have been conducted, with managers from 11 utilities. In some cases two interviews per utility were helpful when the responsibility for customer-side and utility-side business models lay in different departments. It is planned to conduct 9 more interviews in the coming weeks. Therefore, the results of this essay are preliminary. So far, the following utilities are included in this study: E.on, Vattenfall, EnbW, RWE, Stadtwerke München, EWE, Mainova, HEAG Südhessische Energie, Stadtwerke Aachen, Stadtwerke Karlsruhe, and Hamburg Energie. The interviewees are directors or managers, mainly from business development departments. The interviews are partly conducted in person and partly via telephone. Length of the conversations varies between 45 and 90 minutes. The interviews are recorded on tape and subsequently transferred into a written protocol. The protocols were analyzed following the conceptual business model components presented above.

4. Preliminary Results

The results show that the interviewed utilities have very different opinions on the future role of customer-side renewable energies. Whereas the future development in this market is not at all clear today, the business model for utility-side projects is clear and plays a significant role in utilities current activities. The reasons for this result can be explained by analyzing the two generic business models following the four pillar structure (see section 2.1).

4.1. Customer-Side Renewable Energy Generation

The interviews show that contrary to the argumentation in the literature, 9 out of 11 interviewed utility managers do not see customer-side generation as a threat to the current utility business model. They mainly see customer-side renewable energy as a niche market without much revenue potential for utilities.

4.1.1. Value Proposition

Five of the 11 interviewed companies offer customer-side renewable energy products or services. For example they support their customers to install solar PV systems or micro CHP systems. But in practice, none of them is actively promoting these offers, because none of the offerings is actually profitable. In practice, it is far from clear what utilities intend to offer to their customer. Only 2 out of 15 interviewees expect customer generation to become a severe threat to the current value proposition. The rest does not see a profitable market and thus no urgent need to develop new value propositions in this field. The utilities that actively try to develop new value propositions admit that they severely struggle to find economically sustainable business models.

4.1.2. Customer Interface

Renewable energy is considered to have positive effects on the customer relationship by all interviewees. The existing products and services for end-customers are designed to increase the individual customer relationship and secure long term gas and electricity delivery. Projects like installation of solar systems on schools or public buildings are used to demonstrate community involvement.

4.1.3. Infrastructure

Infrastructure for customer-side business models exists on a very small scale, because the projects are not profitable yet. Activities are seen as "pilot project" and are organized in separate firms to have better control over costs and revenues. The main purpose is testing the market. New infrastructure is hardly built up before the value proposition and revenue model are clear. One approach to be active without the need to build up own infrastructure is to establish partnerships with local companies that provide installation and other services.

4.1.4. Revenue Model

All interviewed utilities' that have some sort of some customer-side renewable energy business model struggle to earn sufficient returns. There is no economic sustainable revenue model in the market yet. Customer-side projects are too small and too fragmented to be able to contribute significantly to the earnings of the company. An economically sustainable revenue model is the key to unlock the market of customer-side renewable energies for utilities.

4.2. Utility-side Renewable Energy Generation

The interviewed utilities are currently investing billions of Euros into utility-side renewable energy projects. Most attractive technologies are on- and offshore wind energy as well as biomass and biogas. Solar energy only plays a minor role in investment budgets, since this technology only contributes a small share to the electricity generation capacity.

4.2.1. Value Proposition

The interviewees do not see the traditional value proposition under pressure by increasing shares of large scale renewable energy projects. On the contrary, most managers see an additional value that can be offered to the customer in the form of green electricity tariffs.

4.2.2. Customer Interface

The interviewees perceive customers as increasingly critical towards utilities. In this context utilities try to strengthen their customer relationship by positioning themselves as environmentally friendly. In addition, the regional and local utilities use renewable energies to demonstrate community involvement. On the other hand, utilities face stakeholder opposition towards new large scale renewable energy projects. One approach to ease such a conflict is offering participation in the project. This way utilities and customer become joint investors. Overall, the utilities see the customer interface positively affected by renewable energies.

4.2.3. Infrastructure

Utilities are currently investing massively in projects to create their own renewable generation infrastructure. In this context they also develop the corporate infrastructure to operate and manage the renewable energy assets. The main question in this context is in which steps of the renewable energy project value chain the utility should become active. Larger utilities tend towards integration of project development and maintenance services into their business model. This way they enhance the value creation in the project and are able to earn a higher overall return with the energy project. Smaller utilities rely much more on external service providers for project development and maintenance service, because it is too costly to hire skilled personnel for a small generation infrastructure. While “blueprints” for utility-side revenue models are available in the market, it seems as if the project value chain offers room for business model innovation for all types of utilities.

4.2.4. Revenue Model

Investment decisions for utility-side renewable energy projects are usually based on well defined return expectations. Therefore, the revenue model is the key to the decision whether a renewable energy project is realized or not. Although renewable energy projects provide lower returns than conventional power projects, they include less risk which makes them attractive to utilities from a financial viewpoint as well. While the interviewed multinational utilities point out the role of business model innovation to increase revenues and decrease costs, the interviewed regional and local utilities emphasize the need to also include community aspects in their decisions. The optimization of the value chain according to the utilities competencies offers large potential to increase earnings.

5. Discussion

The present study shows that the interviewed utilities mainly do not perceive revenue erosion by customer-side electricity generation as a threat to their current business model. Only two interviewees speak of a severe threat. The utilities clearly favor large scale utility-side projects over customer-side projects, as the former offer more attractive returns and allow to reach renewable portfolio standards more quickly. The higher returns were identified to be mainly a consequence of transaction costs, which e.g. comprise project development cost, such as costs for planning, permission, and administration. These costs account for a significant portion of the overall costs and do not rise in proportion with the size of the project. Also larger projects allow favorable cost structures for asset management as well as operation and maintenance. Therefore, larger projects have comparatively lower project development costs [20]. Besides, for the same reason larger projects make reaching a certain renewable portfolio ratio in a given time easier and cheaper. Furthermore, the analysis from the business model perspective revealed that utility-side projects offer a series of advantages: they do not make new value propositions necessary, the customer interface is positively affected, and revenue potential is clearer than is seen with customer-side projects. Customer-side renewable energy was not considered an interesting future market by most interviewed utilities. Some of the utilities have undertaken first steps to build customer-side business models, but activities are at a very early stage and budgets are small. The analysis reveals that many questions about the value proposition, the infrastructure, and the revenue model are unanswered. The main challenge is to reach profitability of the revenue model.

Many authors on utilities' business models for renewable energy argue that customer-side electricity generation from renewable energies requires utilities to develop new value propositions to combat loss of market share and revenue erosion [3][4][7]. The analysis in this study shows that most utilities focus on large scale projects and do not see customer-side renewable energy as a threat to their business. From a business model perspective it makes sense to invest in large scale projects, because business model templates are available and returns are higher. Furthermore, large scale projects make it easier to reach the renewable portfolio standards. From these findings it can be concluded, that utility engagement in customer-side business model for renewable energy will remain limited in Germany, whereas large scale renewable energy projects are a promising future business model for utilities.

The findings are subject to some limitations. The method of conducting qualitative semi-structured interviews has proven well suited to gain a first insight into utility thinking, but it does not allow drawing any rigorous generalizations. Furthermore, the high level approach in the interviews creates the danger of over-simplification. The same is true for the approach to analyze two generic business models, which cannot cover all details of real world utility business models. Furthermore, business models are highly dependent on the regulatory framework, so the results might not easily be transferred to other markets [6]. Also, the data collection is not fully completed yet, therefore, the results of this article are preliminary.

The research raises a series of new questions on how utilities can improve their business models. Further research should focus on both utility-side business models as well as customer-side business models in more detail. The former still offer room for revenue improvement when further steps in the value chain are integrated or suitable collaborations are installed. The latter represents a market which is mainly untapped by utilities to date, due to comparably low return expectations. Research on new business model designs might help to overcome this hurdle and open a large new market for utilities.

6. Conclusion

The present study shows that utilities focus on large scale utility-side project rather than on customer-side projects. The analysis showed that both business models offer much room for innovation. Consequently, utilities should intensify their thinking about business models to increase their potential to create and capture value from the energy transformation. Furthermore, policy-makers should pay close attention to the developments in this field in order to shape the framework for a truly sustainable energy future.

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Energy Security Centres in support of the development of a comprehensive EU Energy Policy

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Abstract: There are paradoxes and contradictions in the interpretation of the concept of energy security among the micro sphere (the level of business organizations and individual users), the macro sphere and the global level. For example, in the global interpretation it is no longer sufficient to focus on meeting objective social needs for energy alone. We should also take into consideration the environmental impacts of meeting these needs (global warming, climate change etc.) as well as sustainability. We need to adopt a comprehensive approach at the level of our energy security policy as well. This may be effectively supported by Energy Security Centers (ESC), which are virtual energy security knowledge centers. The essay analyses the issues for consideration listed in the "Stock taking document - Towards a new Energy Strategy for Europe 2011-2020" from the aspect of the possible application of ESCs to the solution and support of these issues and proposes the EU level establishment of ESCs. Based on the analysis of the stock taking document, the aim of the study is to highlight the advantages resulting from the institution of an European network of knowledge centres (Energy Security Centres) for the implementation of the European Energy Policy.

Keywords: *Energy policy, Energy Security Centres, European Union*

1. Introduction

The authors' research in the field of energy security has revealed the necessity of the establishment of energy security centres to facilitate the knowledge management support of the solution of energy security problems. Regarding their basic nature, energy security centres function as virtual energy security centres. In a legal sense, they are autonomous public administration institutions. By autonomous public administration institutions we mean institutions like agencies of various profile in the United States, directly subordinated to Congress. This legal status along with normative financing ensures the independence of these institutions, which is a prerequisite for authentic operation. According to our concept [1], the main role of such an Energy Security Centre (ESC) is to provide authentic information to aid the solution of energy security problems and to create the conditions required for decision makers to use this authentic information effectively in practice. With the help of knowledge centres it also becomes possible to place the knowledge transfer supporting energy security on qualitatively new foundations. The authors hold that the establishment of knowledge centres and the development of a knowledge centre network open up new opportunities in the interactive development and implementation of the comprehensive energy policy of the European Union.

The study points out the issues for consideration listed in the Stock taking document towards EU Energy Strategy for the period 2011 – 2020 [2] where the application of knowledge centres is of outmost importance. Based on a background analysis, the study considers the most important advantages resulting from the functionality of ESCs, points out the most important aspects of developing an ESC network, and makes specific recommendations regarding its establishment.

2. The Role of Energy Security Centres: A Comprehensive Approach

2.1. The Functionality of Energy Security Centres

Former inquiries regarding the concept of energy security reveal that there are paradoxical contradictions among micro level, macro level and global interpretations. [3] As a result, certain statements which may be true using a given approach, for example at the level of the micro sphere, will not hold if we apply a macro level or global approach. It is becoming more and more typical that even the management of relatively simple, local problems requires a global approach.

With reference to the above study we should mention that the interpretation belonging to the micro sphere, in other words to the world of companies and organization, starts out from a threat to the satisfaction of our demands for energy and applies a supply security centred approach. The macro level interpretation of energy security focuses on issues related to the satisfaction of the objective energy needs of a given society. The global interpretation examines the question of need satisfaction in close connection with the results of the satisfaction of needs. It takes into consideration that the method of need satisfaction will have an impact on the possibility of the satisfaction of future needs.

Accordingly, the complete satisfaction of energy demands in a given country by no means guarantees that objective energy needs in that country are also completely satisfied, or saturated. The recognition of needs and their transformation into demand is influenced by a number of distorting factors. The most important of such factors are related to our shortcomings in recognizing these needs and the impact of various interests on demands. The recognition of needs is a task for science, while the transformation of these needs into goals is a political task, and the determination of specific demands belongs to the realm of the market and the economic interests in play. These three areas are characterized by close interaction and a contradictory relationship with each other. What they all have in common is that none of them can exist without authentic factual information. The importance of the need for factual information is well illustrated by an EU Commission Staff Working Document [4], which states the following:

"The problem that requires action is the lack of consistent data and information on investment projects (in their different phases) and the related shortcomings. .... EU institutions lack relevant/consistent data on the development of energy infrastructure in the EU to assess the strategic supply/demand balance. Industry is potentially affected by insufficient transparency on the likely evolution of the EU energy system." [4]

The solution of energy security problems through the application of a global approach may be effectively supported by energy security centres. [1] Regarding their basic nature, energy security centres are virtual energy security centres with the following functionality:

A) Fast and efficient output of new knowledge and information required for competent energy-related policy-making, energy-related developments, environment statutes, etc.

B) Acceleration of the acquisition of practical knowledge required for competent energy related policy-making, implementation of policy guidelines and for the identification of specific problems arising in connection with energy security.

C) Creation, maintenance and continuous improvement of a platform designed for the efficient transfer of knowledge; establishment of foundations with completely new characteristics, to be used in addressing energy security issues in order to provide best practice methodology.

The application of modern ICT solutions and knowledge management to support the implementation of energy policies and the solution of energy security problems is not a unique idea. For example, we should mention the book edited by M. Bazilian and F. Roques [5] and the work of K. Metaxiotis [6] The concept of ESCs is different from the approaches appearing in these works and various other publications in a sense that it treats the creation of the authentic spatial information required for problem solving, the development of the capacities required for the effective use of information, and knowledge transfer as part of the same system.

The realization of the basic functions of energy security centres in accordance with the above is relevant not only to the solution of specific energy security problems but the implementation of energy policies as well. A network of energy security centres covering EU member states would be able to provide effective support to the implementation of a comprehensive EU Energy Policy. In the following we will discuss the role of a network of energy security centers in the implementation of the Stock Taking Document [2].

2.2. The basic concept of the " Stock Taking Document"

An analysis of the Stock Taking Document reveals that the approach used at its drafting reflects what we have referred to as a global approach. The document addresses the following issue:

"Completing the internal energy market, achieving energy savings and promoting lowcarbon innovation are the main vectors to reach the objectives of competitiveness, sustainability and security of supply. A well functioning internal market, based on regional and pan-European interconnections, will serve all consumers, ensure energy security and allow the transition towards a low-carbon electricity system. There remains large scope for cost-efficient energy saving measures in order to reduce greenhouse gas emissions; energy savings also lower the energy bill and reduce dependence on energy imports. Finally innovation will be essential to make our energy system sustainable and to renew Europe's manufacturing base and create green jobs." [2]

In other words, the Stock Taking Document aims to resolve the contradictions between supply objectives based on demand and objective needs, and states that there is a need for the recognition and exploitation of the connections between existing needs and the consequences of the satisfaction of these needs.

The Stock Taking Document lists the key issues of Energy Strategy for Europe 2011-2020 as well as the priority areas for the future strategy. They are the following [2]:

- Modern integrated grids
- Making progress towards a low-carbon energy system
- Leadership in technological innovation
- A strong and coordinated external energy policy
- Protecting EU citizens against the lack of supply and/or unaffordable energy prices

The document summarizes the issues for consideration for the short-term as well as the issues for consideration for the longer-term with regard to each priority area, the following of which may be effectively supported through the realization of the basic functions of energy security centres:

a) Strengthening cooperation and coordination at EU-level of energy networks to build a pan-European integrated, interoperable, secure and modern grid.
b) Strengthening the role of ACER (Agency for Cooperation of Energy Regulators) & ENTSOs (European Network of Transmission System Operators) to develop a more integrated regional and European energy market.
c) Using consumer-centred tools (e.g. labels, information campaigns and long-term education initiatives) to promote energy savings, smart use of energy and fuel switching by energy users.
d) Using market-based instruments to give the right price signals and incentives for energy savings, smart use of energy and fuel switching by energy users, through the emissions trading scheme (ETS), energy taxation and phasing-out of fossil fuel subsidies.
e) Developing a more coordinated European approach towards the licensing and design certification framework for nuclear investments.
f) Implementing the European Strategic Energy Technology Plan (SET-Plan)
g) Launching a dedicated set of large industrial innovation programmes of strategic importance for European energy future.
h) Intensifying efforts in the global energy organisations and initiatives (e.g. IEA, G20, WTO) to promote well-functioning, open, transparent and competitive energy markets, good governance and comprehensive energy policies.
i) Deepening cooperation with consumer countries, including emerging economies, to promote adoption of sustainable energy policies and a shared view on energy security.
j) Increasing transparency. Improving market transparency on network operation and supply which guarantees equal access to information, making pricing more transparent, increasing trust in the market and helping to avoid market manipulation.
k) Providing with guidance on the appropriate tools to facilitate consumer participation in the energy markets through transparency and clarity of information and comparability. [2]

Specific support may be characterized by the following:

- By ensuring the authenticity of the information used, ESCs make an effective contribution to the development of coordination and collaboration. This is particularly important in case of the tasks listed in points a), b), e), f), g), h), i) since authentic information is a basic requirement for good collaboration and successful coordination. Authentic information can be provided through the realization of the first basic function of ESCs. The second basic function, which is the acceleration of the acquisition of practical knowledge, also has a fundamental role in the support of coordination and collaboration. Coordination and collaboration are not only a question of intent: Their implementation requires a considerable amount of expertise. ESCs can support the fast and effective acquisition of this special knowledge with their simulation services.
- The implementation of objectives c), d), j) and k) also requires access to authentic information. This is important not only with regard to the direct use of information. The authentic information provided by ESCs also makes it possible to control the authenticity of the information published by market players, governments and various other institutions, and the existence of such a control will force data providers to adopt an ethical behaviour.
- While the main aim of the second function (the function based on simulation) is to support the preparation and work of decision makers and developers (for example in objectives f), g), h), i)), transparency, information provision and the strengthening of conscious consumer attitudes are ensured through the realization of the third (knowledge transfer)

function. Access to authentic information has a crucial importance regarding the above objectives, especially the ones listed in point j) such as "helping to avoid market manipulation", as well. The realization of effective knowledge transfer has primary importance in strengthening the role of ACER & ENTSOs in accordance with point b). It must be emphasized that our first priority is not the knowledge transfer development between ACER & ENTSOs and national (member state) institutions collaborating with them. Rather, we point out the importance of the knowledge transfer taking place between and among member state institutions and market players. This knowledge transfer will ensure the development of a unified view at the EU level and the recognition of the significance of collaboration with ACER & ENTSOs.

- ♦ The implementation of the SET-Plan and launching a dedicated set of large industrial innovation programmes require the coordinated realization of the three basic functions.
- ♦ Basically, all the issues for consideration listed in the Stock Taking Document [2] could be supported by knowledge centres one way or another. The objectives set in a)-k) and highlighted above specifically require and cannot lack such support. The matrix below illustrates the strongest connections between the different functions and the issues for consideration.

Table 1. Connections between ESC functions and issues for consideration

	Functions of ESC		
Issues for consideration	A)	B)	C)
a)	X	X	
b)	X	X	X
c)	X		
d)	X		
e)	X	X	
f)	X	X	X
g)	X	X	X
h)	X	X	
i)	X	X	
j)	X		X
k)	X		

Besides the support resulting from the realization of the basic functions, the implementation of issue j) also depends on the way ESCs are applied and the regulations in force. Member state and EU level regulations should ensure access to authentic factual information provided by knowledge centres free of charge. Access to simulation and knowledge transfer services should also be made available with one condition: namely, that in the case of certain services users may have to pay a charge.

Apparently, the income resulting from the provision of the above services is not sufficient to finance the operation of knowledge centres. Member state and EU level support are both needed, and the form of support should ensure the independence of knowledge centres. The essay previously referred to [1] discusses in detail the possible forms of financing; here we will only note that it would make sense to develop a normative financing method, where the sums of support are determined in proportion with the income and expenditure of individual member states and the European Union. The independence of knowledge centres, which is a guarantee for their authenticity, should be strengthened with legal regulations. At the nation state level, these institutions should be set up and operated as autonomous public administration institutions. In other words, they should be subordinated only to legislative bodies such as Parliament or Congress. In this regard, we should consider the practice applied in the United States concerning the establishment of agencies subordinated to Congress alone. We should note that, as a result of developments in political power relations, in certain member states not even such measures will be sufficient to guarantee independence. In that case we can still count on the authenticating function of the ESC network, through which the not authentically functioning ESC may be excluded from cooperation.

3. A Few Questions Regarding the Application of Energy Security Centers

The application of energy security centres to solve the issues raised in the Stock Taking Document has the following guidelines: The energy security centres should be set up in the member states (possibly one in every member state) so that they enjoy autonomy and operate independently from the central government. This is a basic requirement in order to ensure authentic and credible operation. [1] EU level recommendations should also be made to promote the standardization of the legal status of energy security centres.

The authorization of energy security centres for cooperation and information exchange should constitute an integral part of legal regulation. It should be a commonly applied principle that energy security centres may obtain information only from open sources such as the internet, journals, books, conferences, governmental and market data provision etc. The situation is similar regarding the classification of the confidentiality of output information as well: Information provided by energy security centres may not be classified. This rule will no doubt create considerable problems at the level of individual nation states, but desired levels of efficiency cannot be attained otherwise and the missing, or zero information created as a result of classification could create serious problems in simulation procedures supporting the realization of the second basic function.

The virtual solution, according to which the operation of the centres is based primarily on rented ICT capacities, makes possible the application of an exceptionally cost effective solution due to network level cooperation. For example, one or more European super computer centres would be able to serve the entire network of European energy security centres. It is already apparent that there is sufficient band-width available at the level of the entire European Union. What should be concentrated due to the costs involved in interfaces is the simulation capacity required. Therefore, an European energy security simulation centre should be established after the model of The National Exercise Simulation Center (NESC) of Federal Emergency Management Agency (FEMA) of US Department of Homeland Security [7]. As it has been discussed in detail in the essay published in Energy [1], the functionality of FEMA NESC is very close to the second function of energy security centres, which is placing the acquisition of empirical knowledge on qualitatively new foundations. This does not mean that simulation cannot be of divided parameter at the same time. In this regard applications such as IBM Serious Games could play an important role. All the above could be realized on the basis of cloud computing as well. In the case of individual ESCs the goal was the creation of the conditions required for virtual simulation. However, an ESC network would be able to create such an interface and other conditions which would make it possible to employ a mix of live, virtual and constructive simulations.

As the example of the 2009 gas crisis shows, the failure of gas supply can seriously affect electricity supply, domestic heating and industrial heating. The lack of gas supply could also lead to shutting down factories and plants, resulting in serious economic consequences. One of the tasks of the simulation centre may be the modelling and analysis of the impacts of the disruption of gas supply and the exploration of the possible consequences of unexpected events. The other task of simulation is the analysis of the effectiveness of measures aiming to reduce or avoid negative impacts. This analysis could provide a basis for the further development of common EU energy policy tools as well.

The interactive conference centre module can also be virtualized or set up as a divided parameter network of accredited conference criteria. In this regard, the application of standardized video conferencing systems is of primary importance. A new element compared to the former concept of energy security centres is the institutionalization of the application of IBM Jam. It means that the European Union could organize EU level IBM Jams on a regular basis to promote the solution of problems emerging during the implementation of the energy strategy and to support innovation. The usefulness of the application of the IBM Jam in this field is supported by a number of references. [1]

4. Conclusions

A network of ESCs, outlined only briefly due to the scope of the present paper but discussed in more depth in earlier publications, is capable of satisfying "ripe" objective needs. We should add that these needs do not appear only at the level of the European Union, but at a global level as well. The reason for that is that energy security is a global problem, which can only be solved through global cooperation. Knowledge centres of a different specialization created after the model of the ESC Network will create the background for the qualitative changes envisioned by Manuel Castells [8], according to which the present, oversized national state institutions trembling under the burden of hopeless problem solving will be transformed into development states focusing on planning a desirable future.

We have pointed out that the significance of the creation of an EU level ESC network goes beyond the question of the solution of direct energy security problems and it would create qualitatively new conditions for the implementation of the new energy policy of the European Union. The establishment and development of an ESC network is an EU institutional development task. Its realization requires the support and cooperation of the member states and the creation of an EU level legal regulatory framework.

It must be emphasized that the ESCs should by no means be regarded as research institutions or think-thanks. The task of the latter is to add value information to authentic factual information, while ESCs focus solely on supplying authentic factual information. While it is not possible to support the above argument in more detail in the present paper, the authors hold that there are no significant functional overlaps with regard to other EU or nation state institutions either.

The virtual solution proposed with regard to the establishment of ESCs would create a background for the cost effective development of an EU level ESC network. The European Energy Security Simulation Centre would be the only component of the network tied to specific geographic coordinates, the creation of which could be based on various other, similar EU institutions. The simulation centre should be set up at a location where the critical mass of intellectual and technological potential required for interactive development is already available.

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Based on the above, we recommend the following:

I. The initiation of the development of a European ESC network and its global extension by the EU Presidency.
II. The inclusion of the creation of an ESC network in EU strategies and plans, with special focus on EU Energy Policy and the SET-PLAN.
III. The development and financing of research and development programs and projects required for the creation of an ESC Network.
IV. The simulation of the development of the ICT infrastructure required for the operation and collaboration of ESCs.

As a form of support to the realization of the above, we offer the results of the eSCIT'09 (Global IT Infrastructure of Energy Security Centres) organized on 5-6 October 2009 in Veszprém, Hungary and the expected results of the eSCIT'11 conference, the organization of which is taking place currently.

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Diversity, security, and adaptability in energy systems: a comparative analysis of four countries in Asia

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Abstract: In ecology study, numerous ecologists have been concerned with the concept of diversity in studying the structure and functions of ecosystems for a very long time. Diversification can be seen as a long-term survival strategy of ecosystems by allowing high flexibility and adaptability. Similarly, diversity is also seen as an important characteristic of a stable socio-economic system. In energy policy, diversity plays important roles in energy supply security, efficiency of energy use, and adaptability of energy system. Many of the trends reflect the increasing significance of renewable energy relative to conventional energy sources, and it will increase diversity of energy supply. It is also beneficial for a system both through extending choice and increasing competition. However, changing the structure of energy sources and increase energy diversity for strategic system security can be difficult for the countries which highly depend on the imported energy. This paper considers that the diverse distributions of energy flows in a system can open up more possibilities and channels for cooperation and interdependency in energy utilization. Not only diversity of supply side, but also diversity of demand side is critical for an energy system because increasing variance and balance of the energy consumers enhances efficiency and adaptability. In this paper, we develop a quantitative analysis method to explore both of supply and demand sides of energy system structure for four Asian countries, Japan, Korea, Taiwan and Indonesia based on the OECD data set from 1987 to 2006. The tremendous growth Asian countries have seen in recent decades required a huge amount of energy. Energy systems of Japan, Korea, and Taiwan are short of indigenous energy sources and highly dependent on imported energy sources except Indonesia. Indonesia's indigenous energy source reserves support national economy as a source of energy, industrial raw material and export goods. And then Indonesia's renewable energy also can be as a source of energy to support energy use. Furthermore, we are not only to compare the diversity temporal patterns of national energy supply and use, but also to compare the industry sector diversity temporal patterns of energy use of these countries.

Keywords: *Energy system, Diversity, Security, Adaptability*

1. Introduction

In recent years, there have been many interests in energy security due to the high oil prices and the geopolitical supply tensions. Security of energy supply can be defined as a system's ability to provide a flow of energy to meet demand in an economy in a manner and price that does not disrupt the course of the economy [1]. Many of the trends reflect the increasing significance of energy sources, including renewable energy, relative to conventional energy sources (including coal, oil, natural gas, and nuclear). Measuring security of energy supply is therefore becoming an important topic on the studies of energy policy. Diversity in energy (fuel) type and geographic sources is thought to be an important means of hedge against supply risks [2,3] and is used frequently as a key indicator to assess energy security. For example, Stirling's application of the Shannon-Wiener diversity index to electricity resources provides some useful insights into how government and electric utilities can objectively measure diversity and thereby gauge the effectiveness of their own investments in alternative resources [4].

Stirling (1999)[5] argues that an index of energy diversity should consider three key elements: Variety (the number of categories into which the quantity in question is partitioned), Balance (the pattern in the apportionment (spread) of that quantity across the relevant categories), and Disparity (the nature and degree to which the categories themselves are different from each other). Both through extending choice and increasing competition, energy diversity is thought as an important characteristic in energy supply security, financial risk, efficiency of energy use, and the environment [4,6]. Increasing diversity of energy supply is beneficial for a system both through extending choice and increasing competition. It is traditionally argued that diversity is best achieved by a mix of fuel sources and by a preference for domestic over imported energy supplies [7].Grubb et al. (2006) [1] calculated diversity of fuel source mix to represent one dimension of security-robustness against interruptions of any one source and applied diversity indices to electricity system scenarios. Furthermore, diversity is considered as an important property of energy system which provides resilience against physical supply disruptions. Global energy disruptions are more and more translated into price shocks, which can spill over from one market to another [3].

In ecological researches, however, measuring diversity is not a new method for studying ecosystem properties. Numerous ecologists have been concerned ecological diversity in studying the structure and functions of ecosystems [8,9,10,11,12]. From a systematic perspective, diversity of interacting components builds feedback loops and these loops regulate materials absorption, storage and release and landscape structure construction[13,14]. Webs of connections and feed-back information are the basis of system's self-regulation. Following a succession adjustment period, feedbacks regulate absorption, storage and release of materials, and construction of landscape structures [13]. A diversified ecosystem system is therefore considered as a more resilient and stable system. By allowing high flexibility and adaptability, the existence of diversity can be seen as a l ong-term survival strategy for systems as a consequence of permanently changing environmental condition [15]. Ecosystems either adapt to their internal scarcity by optimizing the use of the scarce resources or are flexible and able to changing environmental conditions [15,16].

Additionally, one can transfer the knowledge and the understanding from biological sciences to social sciences based on t he analogies between biological and socioeconomic evolution [17]. Matutinović (2001) [17]argued that the functional properties of diversity in socioeconomic system are analogous to that of biological evolution: (1) adaptation to different environment, (2) avoidance of head-to-head competition, (3) efficient use of energy and resources and (4) providing a range of responses to new selective pressures. Socioeconomic system diversity is therefore expected to generally increase during development and to improve efficiency, productivity and output of the system [18,19]. In order to studying the relationships between diversity and socioeconomic development, Templet (1999) [19] defined diversity of economic system as the number of sectors by using energy and the equitability of the energy flows among them. He adopted an energy flow network method and development capacity formula [18] to investigate the relationships among economic diversity, output and development policy. His conclusion is that economic system is generally capable for making more efficient use of energy and reducing energy intensity as the diversity rises.

Based on ecological theory of diversity and the analogies between ecological and energy systems, diversity of interacting components in energy systems is thought as an important property to build feedback loops regulating energy use, storage, and release. Diversity of energy system can enhance the energy efficiency and open up t he channels for the cooperation of energy use. A diversified energy system is therefore considered as a m ore resilient and adaptable system to cope with disturbances. However, most of recent studies on energy diversity are generally focused on t he issues of energy supply. The importance for diversifying systemic components and building feedback loops in energy systems were gotten fewer attentions in energy policy studies. Moreover, for the countries which highly depend on the imported energy, changing the structure of energy sources to increase energy diversity for strategic system security is relatively difficult. This paper therefore considered that not only the diversity of energy sources (supply side) but also the diversity of energy use (demand side) is critical for an energy system because increasing variance and balance of the energy consumers enhances efficiency and adaptability. In this paper, we develop a quantitative analysis of diversity to explore both of supply and demand sides of energy systems for four Asian countries, Japan, Korea, Indonesia and Taiwan based on the data sets from 1987 to 2006. Furthermore, we are not only to compare the diversity temporal patterns of national energy supply and use, but also to compare the industry sector diversity temporal patterns of energy use of these countries.

2. Methodology

2.1. Diversity indicators

The index mostly used to measure diversity is the Shannon–Wiener index:

$$H = -\sum_i p_i \ln p_i$$

with p_i representing the share of fuel *i* in the energy mix or the market share of supplier *i*. The higher the value of *H*, the more (dual concept) diverse the system is. This index rises monotonically with increasing variety and balance.Ecologists frequently apply diversity as an index of ecosystem stability [14]. Templet (1999) [19] use the Shannon and Weaver (1949) equation to capture how many deferent types of economic activities exit within the system and how equitably energy is distributed between them. The Shannon-Weiner index was considered to be the most satisfactory measure of energy diversity because it incorporates the concepts of variety and balance [4].

In this study, we also use the Shannon–Wiener index to calculate the diversity of energy consumption and industry sector. We consider that the diverse distributions of energy flows in a system can open up more possibilities and channels for cooperation and interdependency in energy utilization. Not only diversity of supply side but also diversity of demand side is critical for an energy system because increasing variance and balance of the energy consumers enhances efficiency and adaptability.

2.2. Data sets of four countries in Asia

Our quantitative analysis method primarily based on the OECD data sets: Energy balances of OECD and non-OECD countries, from 1987 to 2006 [20,21]. Year presented the energy balances in various sources of energy and different origins and uses. In energy supply side, six types of energy supply source data (see Fig.1.) are analyzed diversity index in these four countries by year (see Fig.2.). In energy consumption side, energy demand data of these four countries is collected into five categories labeled industrial, transport, residential, commerce and public services, and agriculture sector. Then, we calculate energy demand data by economic sectors (see Table.1.) and analyzed diversity index in these four countries by year (see Fig.3.). Energy demand data of industry sector are also collected into 13 categories labeled iron and steel, chemical and petrochemical, non-ferrous metals, non-metallic minerals, transport equipment, machinery, mining and quarrying, food and tobacco, paper, pulp and printing, wood and wood products, construction, textile and leather, and non-specified. To analysis diversity index trend in these three countries highly depend on imported energy, we calculate these data sets and draw the lines of result by year (see Fig.4.).

Japan is the world's second largest economy after the United States in 2009 [22]. Gross domestic product (GDP) per capita of Japan increases almost two fold between 1987 (i.e. $20,025) and 2009 (i.e. $39,372) [23]. Because of low self-sufficiency index (0.1788 in 2008), Japan is the first-largest net importer of coal (114.19 Mtoe) in 2008, and increases coal use for power generation; Japan is also the second-largest net importer of oil (224.82 Mtoe) in the world [20], and most all the oil is imported from the Middle East. Above all, the aim of Japan's energy policy will achieve the 3E's goal-energy security, economic growth and environmental protection-in an integrated manner [24].

Korea has experienced tremendous economic growth over the last three decades. GDP per capita of Korea increases over six fold between 1987 (i.e. $3,366) and 2009 (i.e. $22,055) [23]. As low self-sufficiency index (0.1971 in 2008) like Japan, Korea's energy policies currently promote a stable energy supply, market efficiency through competition, and implementation of an environmentally friendly energy system with the end-goal of sustainable development [20,25].

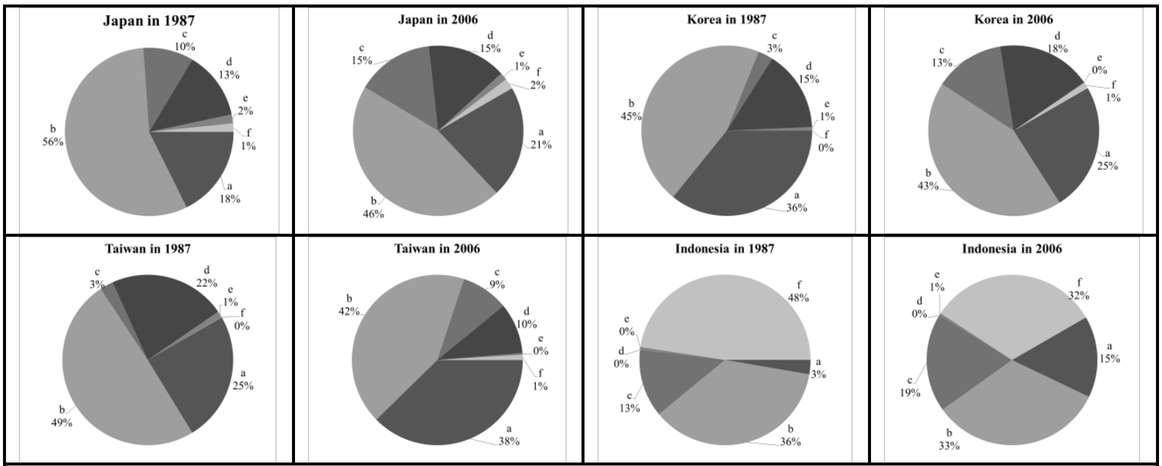
Taiwan is one of the most densely populated areas in the world, and GDP per capita of Taiwan increases over three fold between 1987 (i.e. $5,276) and 2009 (i.e. $18,867) [23]. There are no oil or coal reserves in Taiwan, but gas reserves are around 8.4 billion cubic meters [24]. Here, Taiwan has very limited domestic energy resources and relies on imports for most energy requirements. According to IEA's indicator, Taiwan's total energy self–sufficiency index is 0.12 in 2008 [21]. In 2009, Taiwan draw up the "Master Plan on Energy Conservation and GHG Emission Reduction" [26] and set up the national reduction targets as energy efficiency, emission reduction and low carbon energy. One of these targets is reducing energy intensity by 2% per annum and totally reducing 25% in 2015. Further reduce energy intensity by 50% in 2025 with technological breakthrough and administrative measures.

Indonesia's GDP per capita of Indonesia is $511 in 1987; it is $2,323 in 2009[23](IMF estimated). Indigenous oil, gas and coal reserves have played an important role in Indonesia's economy as a source of energy, industrial raw material and foreign exchange. In 2008, oil and gas exports contributed the largest share (21.1%) of Indonesia's total exports of USD 136.76 billion, followed by minerals (including coal) at 18.8% [24]. According to IEA's indicator, Indonesia's total energy self–sufficiency index is 1.75 in 2008 [21].

3. Results of energy analysis

3.1. Diversity index of energy supply side

Total primary energy supply (TPES) of four countries respectively increases rate of 41.24% (Japan), 224.29% (Korea), 176.79% (Taiwan), and 136.88% (Indonesia) between 1987 and 2006. Comparing to four countries' supply fuel shares in 1987 and 2006 (see Fig. 1.), TPES in Japan, Korea and Taiwan is dominated by oil and coal, through the portion of natural gas has increased rapidly in recent year. Japan and Korea both increase nuclear energy supply, however, Taiwan decreases the nuclear supply and Indonesia does not have the energy supply in TPES. Relative to conventional energy supply, the renewable energy supply share (including hydro, geothermal, solar, wind, etc.) of Indonesia's TPES is much higher than Japan, Korea and Taiwan. The renewable energy supply shares of Indonesia's TPES in 2006 are 33%, but other three countries' are below 3%.



a. Coal and coal products / b. Oil and products / c. Natural gas / d. Nuclear /
e. Hydro / f. Geothermal, solar, wind, etc.

Fig.1. Fuel shares in these four Asia countries (source: IEA, 2010).

A representative set of country's supply diversities are shown in Fig 2 over time. Comparing to diversity of four countries' energy supply, Japan's diversity index trend is the highest and it is going steadily. Indonesia's diversity trend is going up continuously, and in 2006 its diversity index is the highest of the four countries. Before 1994, Taiwan's diversity trend is going down and it reaches the lowest point in 2002. After 2002, it goes up quickly, but in 2006 its diversity index is the lowest of the four countries. Korea's diversity number is lowest in 1992, but it has a peak in 1994, then, after 1997 it is going up straightly.

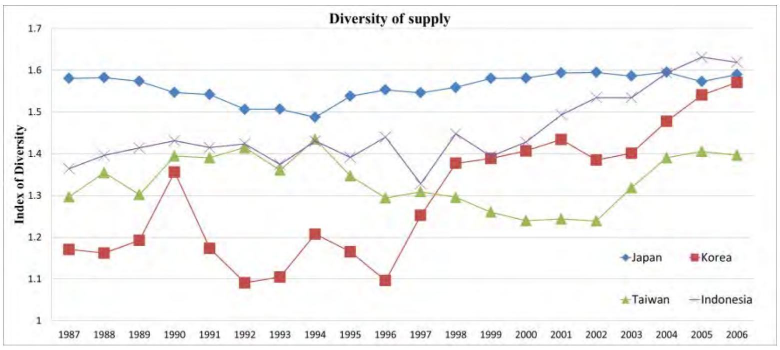


Fig.2. Country diversity of energy supply by year.

3.2. Diversity index of energy consumption side

Total final energy consumption (TFC) of four countries respectively increase rate of 39.40% (Japan), 170.99% (Korea), 128.72% (Taiwan), and 120.36% (Indonesia) between 1987 and 2006. By sector of energy use, industry sector are the large share of energy consumption, accounting for almost or over 30% of total demand, and the industry sector of Indonesia has the distinct growth rate of energy use(see Table 1). By energy source, oil products are the most important one of energy consumption, accounting for over 50% of total energy demand in Japan, Korea and Taiwan. Oil products and bio-energy are accounting separately for 34.2% and 35.44% of total energy demand in Indonesia.

A representative set of country's demand diversities are shown in Fig 3 over time. Comparing to diversity of four countries' energy consumption, the diversity index in Korea is the highest of the four countries. The diversity index trends of Korea and Japan are similar, and these lines go down gently. Taiwan's diversity index trend climbs up gently, and Indonesia's diversity index climbs up obviously.

Table 1. Sector of energy use. (Source: IEA, 2010)

Sector of Energy Use	Japan		Korea		Taiwan		Indonesia	
	1987	2006	1987	2006	1987	2006	1987	2006
Industry sector (%)	40%	33%	31%	36%	51%	44%	13%	28%
Transport sector (%)	28%	29%	23%	28%	25%	30%	15%	21%
Residential sector (%)	16%	15%	32%	17%	11%	11%	70%	46%
Commerce and public services sector (%)	12%	22%	10%	16%	6%	8%	1%	3%
Agriculture sector (%)	4%	1%	4%	3%	7%	7%	1%	2%
Total final consumption (only energy use) (Mtoe)	224.89	313.50	41.78	113.22	21.76	49.77	55.45	122.19

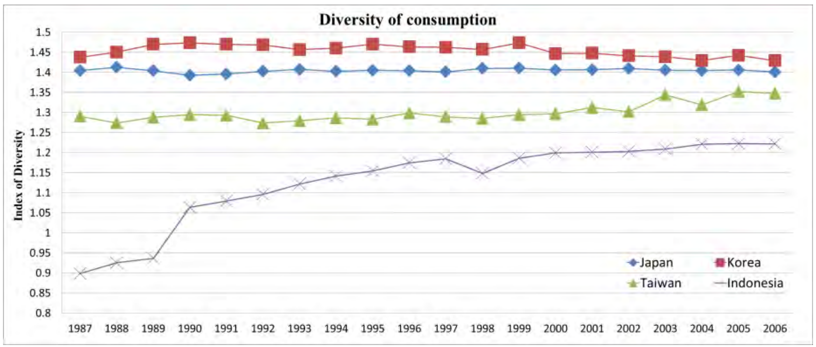


Fig.3 Diversity of national energy consumption

Due to Japan, Korea and Taiwan highly depend on the imported energy, except Indonesia. And all three countries face rapidly economic development and their energy supply and demand rate increase significantly. In the same way, industry sector of three countries is the primary energy consumer (see Table.1.) Therefore, we focus on industry sector diversity index trend in three countries, and analysis the meaning of them. As shown in Fig 4 over time, Korea's line climbs up continuously, but Japan and Taiwan go down steadily.

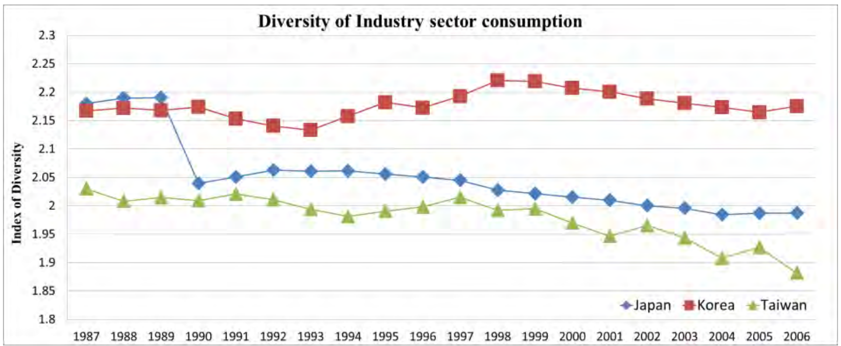


Fig.4. Country industry sector diversity of energy consumption by year.

4. Discussion and conclusion

4.1. Discussion and Conclusion

The fuel shares of these four Asia countries are shown in Figure 1 in this paper, and our quantitative analysis method primarily based on the OECD data sets from 1987 to 2006. Energy systems of Japan, Korea, and Taiwan are short of indigenous energy sources and highly dependent on imported energy sources except Indonesia. Indonesia's indigenous energy source reserves have played an important role in national economy as a source of energy, industrial raw material and export goods. And then Indonesia's renewable energy also can be as a source of energy to support energy use. These three countries are usually other-directed for the imported energy types, price, and geographic sources and are sensitive to the fluctuations of international fuel supply. Therefore, it is difficult for them to change the structures of energy sources to increase diversity for their strategic energy security. The restricted variation of fuel-type diversity of energy supply of Japan, Korea, and Taiwan are revealed in Figure 2. However, the diversity index pattern of an indigenous energy system as Indonesia reveals a more flexible characteristic.

Recent years, all the total energy consumptions of these four countries were dramatically increased. Industrial sectors are the main energy consumers in Japan, Korea, and Taiwan. The energy consumption of commerce and public services sectors in these countries increase a little bit (see table 1). In Indonesia the residential sector is the main energy consumer. This study calculated the diversity index for national energy consumption (demand side) and the results showed that the temporal patterns of energy diversity in demand side of Japan, Korea, and Taiwan remained steady over two decades. However, energy diversity of Indonesia rose due to the significant decrease of residential sector and the raise of the energy consumption in industrial and transportation sectors (see Fig. 3).

Furthermore, this study also investigates diversity of energy use in the industrial sectors because the industrial sector of Japan, Korea, and Taiwan is the main energy consumer. The results show that energy diversity of Taiwanese industrial sector was going down due to the concentration of energy use in the iron and steel sector as well as the chemical and petrochemical sector (see Fig. 4). The energy diversity of Japanese industrial sector was also going down because several industrial production sectors were shrinking in past two decades. Relatively, diversity of Korean industrial sector was remained steady. The decreasing diversity of Industrial sector indicates a centralization of energy flow in the dominated industrial production.

Based on the analyses of energy diversity of fuel types, the results show that changing the structure of energy sources and increase energy diversity for energy security is difficult for the countries which are highly dependent on imported energy source. However, from the analogies of the concept of diversity between ecological and socioeconomic systems we argue that the diversified distributions of energy flows in an energy system can open up more possibilities and channels for cooperation and interdependency in energy utilization. The diversity of energy distribution in demand side is critical for an energy system. Diversity can increase variance and balance of the energy consumers and enhances energy efficiency. Moreover, diversity also improves the internal adaptability for coping with energy scarcity and external disturbances.

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Applications of energy security assessment in Strategic Environmental Assessment

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Abstract: Energy security is crucial for an energy policy but so far is not included in the current Strategic Environmental Assessment (SEA) program in Taiwan. The SEA report of energy policy prepared by the Bureau of Energy, Ministry of Economic Affairs, also demonstrated the same need. However, a feasible and quantifiable indicator has been missing. For the reason, this study is aimed to establish a practical assessment tool to assess energy security. Two indexes are suggested, which are the energy mix diversification (EMD) and energy import diversification (EID). The former one considers the national energy structures and expressed as Shannon index. The later is to assess the dependency on imported sources. The both indexes result in low energy security in Taiwan because of too high percentage of imported coal and oil in energy structure. The example of SEA policy is according to the Taiwan's Sustainable Energy Policy Framework, in which the energy efficiency is set to increase 2% annually in the future eight years. The increasing energy efficiency does not contribute significantly to improve energy security. The indexes used in this study can assess diversity of the whole energy structure and the imported energy sources, should benefit to SEA quality and energy security assessment.

Keywords: Strategic Environmental Assessment, Energy Security, Diversity.

1. Introduction

Strategic Environmental Assessment (SEA) is aimed to pre-assess the likely integrated environmental impacts from a policy, plan, or program (PPPs). Unlike a project with specific development content, the assessment scopes of SEA are vague and uncertain. In Taiwan, SEA is included in the Environmental Impact Assessment Act and the SEA Regulation is announced as the basic guideline. Energy policy is one of the listed policies which ought to carry out SEA under the Regulations. Several assessment items are appointed; however, these items cannot reflect the core issue of an energy policy, which is energy security. Energy security equals to national security and should be considered in SEA. Although energy security does not induce direct impacts on natural environment, it does impact significantly on the whole environment.

The SEA Regulation was announced in 2000 but only five cases completed to date. Sustainable Energy Development Framework was proposed by the Bureau of Energy. According to the requirement of SEA Regulations, the Bureau initiated the SEA in 2006 and the draft was completed in 2009. The SEA draft pointed out that the assessment items should be adjusted to specifics of policies to strengthen the relations between assessment items and policies. Thus, additional assessment factors, such as stability, efficiency, and clean of energy policy were suggested to be added.

Energy security is a complex issue and comprises diverse components, such as supply security, consumption security, production security, transportation security, ecological security, environmental security, and so on. Unfortunately, the definition of energy security is not received consensus (Loschel, et al., 2009). Due to the complicated definition, it is hardly to quantify its security level. Some definitions can be found in Bohi and Toman (1996), IEA (2007), Lin (2008), Commonwealth of Australia (2009), and Kruyt et al. (2009). In addition to the Taiwanese experiences, the assessment of energy security for SEA of energy policies is weak and obscure (Noble, 2002; Jay, 2010; Josimovic and Pucar, 2010).

Therefore, the objective of this study is to establish feasible tools to address the impacts of PPPs on energy security. Energy security consists of three important respects, which are adequacy, reliability, and affordability (Commonwealth of Australia, 2009). Due to economic analysis is necessary to examine the affordability of energy policies and more monetary information are required, this study excludes the considerations of affordability and is focus on diversity or dispersion of energy policies as energy security assessment.

2. Material and Method

2.1. Energy Security in Taiwan

Taiwan depends on extremely high imported energy. The dependence on imported energy is up to 99.23% in 2008, in which the dependence on oil is 49.5% and 83.62% of imported oil is from middle-east counties. The heavily high dependence on particular imported regions is a big challenge to conserve energy security. Besides, the imported value of oil occupies 19.35% of the whole imported value due to the increased oil price. It is the first time that the imported value of oil is larger than 10% of GDP in Taiwan. Not only the high dependence on imported energy, but also the high energy consumption is opposite to the international trend which decreases fossil fuel usage. Chang (2004) compared oil supply of six Asia countries with Shannon-Weiner Index and concluded that high risk happened in Taiwan and Philippines. In these two countries, mostly oil is imported from west Africa where politics is unstable. Lin (2008) assessed Taiwanese energy security with economic model and demonstrated the decreased trend of energy security since 2000, because of the high energy intensive business structure. The official annual report addressed energy security with five indicators, including energy dependency on imports, energy dependency on oil, values of energy imports/total imports, oil imports dependency on the middle east, and oil dependency on imports. The major causes to low energy security in Taiwan are the high dependency on imported energy and imported oil.

2.2. Strategic Environmental Assessment in Taiwan

The implementation of SEA in Taiwan is based on the article 26 in Environmental Impact Assessment Act, in which the PPPs with significant environmental impacts should be assessed. The SEA Regulations was announced in 2000 and amended in 2005 and 2006. In the Regulations, ten policies are required to implement SEA. Until December, 2009, only five SEA cases were finished. Many arguments have been discussed, such the listed policies, assessment scope, and assessment tools. Basically, the policy proponent checks whether the proposed policy is listed in the Regulations. If yes, the proponent cooperates with professional agency to produce the SEA report and submit it to official administration. A consult committee under administration will do the final examination and feedback to the policy proponent. The SEA report is the supplement document provided to decision maker. Eight impact aspects are assigned in the Regulations, i.e., environmental capacity, natural ecology and landscape, public health and safety, land resources, water resources, cultural property, international environmental regulations, and society and economy. In each impact aspects, several sub-factors are listed. The final assessment results are expressed as qualitative symbols, ++, +, 0, -, --. The symbols indicate significant positive effect, positive effect, none effect, negative effect, and significant negative effect, respectively.

2.1. Energy Security Indicators

The quantitative indicators for assessing energy security can be divided into two types. One is focus on particular aspect and uses individual indicator, such as the dependency on imported energy or imported oil, the percentage of imported energy, the concentration of energy supply, and so on. The other is integrated index, which combines several concerned aspects of energy security into one integrated index. for example, the energy security market concentration (ESMC) and energy security index (ESI) by International Energy Agency (IEA, 2007), and the Energy Indicators for Sustainable Development developed by International Atomic Energy Agency, which are to assess energy security with considerations of economic, social, and environmental impacts (IAEA, 2005; Vera and Langlois, 2007). Some indicators are incorporated with risk evaluations, such as geopolitical market concentration risk (Blyth and Lefévre, 2004) and risk weight in energy security (Wu et al, 2006).

The energy security should satisfy stable supply and affordable price (IEA, 2007). In this study, the stable supply is particularly considered in SEA and the economic impact on energy price is excluded at this stage. While considering the physical characteristic of energy security, the more vulnerable to physical disturbance means the less energy security. The vulnerability usually comes from less energy sources in energy structure or high dependency on particular sources. The diversification of energy policy is used to demonstrate the physical disturbance. Two commonly indices are developed for assessing diversity, i.e., Shannon-Wiener index and Herfindhal-Hirschman index. The shannon-wiener index is orginially served as a biodiversity measure, combinding the number of species and the proportion of each species. A value of shannon-wiener near to zero means that almost the sample is the same species, implying very low diversity. on the contrary, the great value indicates the species distribute more equally and the diversity is high. the herfindhal-hirschman index is a common meaure of market concentration. it is calculated by summng the squares of the maket share of each firm.

In Taiwan situation, the most important issue on energy security is to increase energy diversification because more than 99% of energy in Taiwan is depended on imported energy. Therefore, indicators to assess energy diversity in energy policy is focused and two indicators are used in this study. Regarding to energy diversity, diversity in national energy structure, diversity in imported energy, and diversity in different energy sources are concerned. Two indicators are able to express the concerned diversity with simple calculation. They are Energy Mix Diversification (EMD) and Energy Imported Diversification (EID). The EMD mimics Shannon Index, considering the number and distributions of energy sources, to evaluate the national energy diversification. The EID further assesses the imported countries of the same energy source and the percentage of energy quantity from each imported country. The EID is able to reveal the imported distributions of particular energy source, such as oil, coal, or natural gas. Due to this indicator is focus on imported energy, high imported percentage of the overall national energy will decrease this indicator significantly. The two indicators share similar concept with Shannon index and ARE easily to use. The required information can be found in public annual statistic report and not necessary on complex computations. Although the core concept is similar, the highlights of the two indices are different. The EMD index focus on diversity of the whole energy structure and the EID underlines diversity of imported energy and diversity of each energy source as well.

The equations of the two indicators are as follows.

$$EMD = -\sum_i p_i \times \ln p_i \qquad (1)$$

$$EID = (1 - \sum_i p_i)(\frac{\sum_i p_i \times I_i}{\sum_i p_i}) \quad (2)$$

where p_i is the percentage of energy type i in the overall energy (%), I_i is the imported diversity of energy type i and calculated by $I_i = -\sum(w_{i,j} \times \ln w_{i,j})$. $w_{i,j}$ is the percentage of energy type i imported from country j.

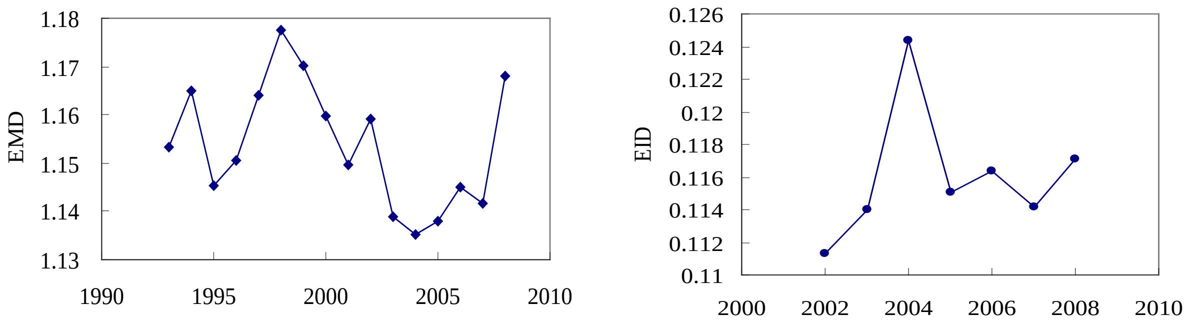
3. Results and Discussion

3.1. Energy security of the current policy

The energy security indicators, EMD and EID, are used to demonstrate the past and current situation in Taiwan. The energy data is from official statistic report.

(1) EMD analysis
The energy sources in Taiwan are classified as seven types, i.e., coal, oil, natural gas, hydropower, nuclear energy, solar and wind power, and thermal energy. The highest diversity occurs when average distribution among the seven energy types, which is 1.95. However, more than 80% of energy is coal and oil. The EMD is ranged at 1.13 ~ 1.18, depicted as Fig. 1(A). There is no significant change in the past 15 years, implying that the energy supply structure does not change, or, not improved.

(2) EID analysis
Except renewable energy, the fossil fuel and nuclear energy are almost imported. In 2008, the coal is imported from five countries and more than 90% is from Australia and Canada. The oil is imported from seven countries and 55% is concentrated in Saudi Arabia and Kuwait. The natural gas is also from seven countries and 65% is from Indonesia and Malaysia. Therefore, the imported diversity of the different energy sources is 0.77, 1.69, and 1.52 for coal, oil, and natural gas, respectively. The performance of diversity of energy type shows that the diversity of oil is better because of the more imported countries and higher distributions. In addition, the percentage of the three energy types to the overall energy is 32.42%, 49.46%, and 9.42% in 2008. Thus, the EID in 2008 is 0.117. The EID trend is as Fig. 1(B). Due to the dependency on imported energy is too high, the EID value is very low.



(A) (B)

Figure 1 The results of (A) EMD index and (B) EID index in Taiwan.

3.2. *Energy security of Sustainable Energy Development Framework*

(1) scenario of energy policy

The lately announced energy policy in Taiwan is the Sustainable Energy Development Framework. In this study, one of the strategies listed in the framework is used to demonstrate the energy security assessment. Many objectives are set in this Framework and one of them is to increase energy efficiency. In this study the objective of energy efficiency is used as energy policy scenario, in which the energy efficiency is increased 2% annually in future eight years and the energy intensity (or energy consumption) is decreased 20% of the level of 2005 by 2015.

The energy efficiency is the ratio of energy production to input, expressed as NT$/ LOE (New Taiwanese Dollar/ litter of equivalent oil). In 2009, the energy efficiency is 113 NT$/LOE and the value will become 133 NT$/LOE in 2017 under the policy scenario. If the production is 1000 NT$, the 8.85 litter of oil is required in 2009; however, only 7.52 litter of oil is required in 2017 according to its higher energy efficiency. Therefore, the 15% of energy will be saved in 2017 if assuming other impact factors are maintained. This means primary energy consumption of 121,333 thousand kLOE in 2009 will decrease to 103,557 kLOE in 2017. The total saved oil is 17,776 thousand kLOE in 2017. The assumed trend of energy efficiency and primary energy is showed in Fig. 2. After translating the policy objective into the detailed energy change information, the information is used to assess the impact of energy security incurred by the policy.

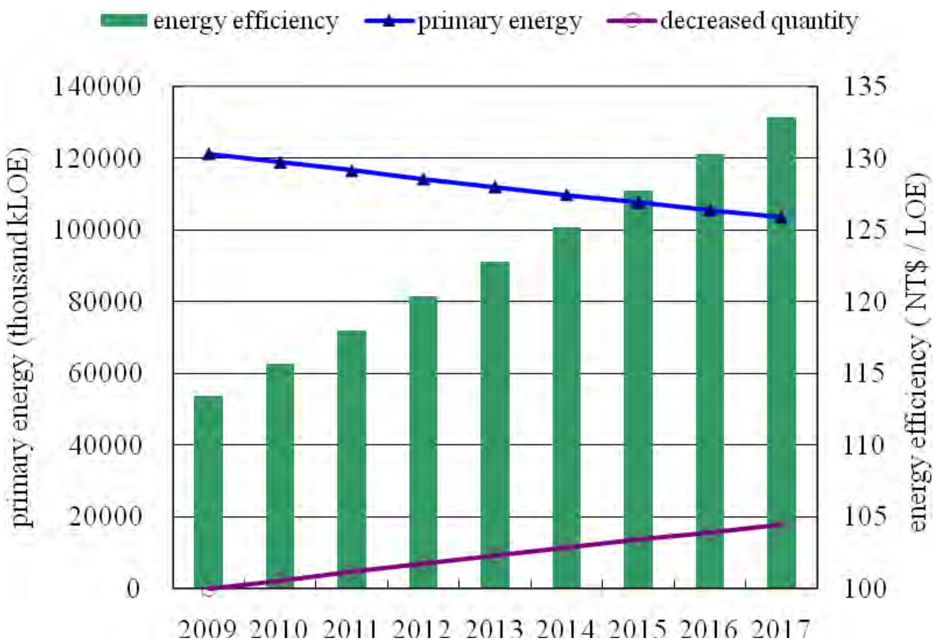


Figure 2 The simulated trend of energy efficiency and primary energy under the scenario of increased 2% of energy efficiency annually in eight years (base year 2009).

(2) EMD analysis

Due to the increased energy efficiency, the total of 17,776 thousand kLOE can be saved in 2017. If the saved energy is contributed to coal and oil savings and the other energy maintains as the same quantity in 2009. The energy structure is then changed as Fig. 3. The percentage of coal is from 34.6% in 2009 decreased to 31.9% in 2017 and the oil is from 45.2% to 44.4%.

The performance of EMD is 1.167 in 2009 and 1.254 in 2017 because of the decreasing percentage of coal and oil. Although the distribution of energy sources is slightly raised because of the improved energy efficiency, the EMD value is still less than Japan and Korea, which is 1.38. The big difference is caused by the high percentage of coal and oil. Even in 2017 scenario, the percentage of coal and oil is summed up to 76.3%. However, this value in Japan and Korea is less than 70%, which implies that the improvement of energy efficiency seems not contribute significantly to energy security and the developments of the other energy are important as well.

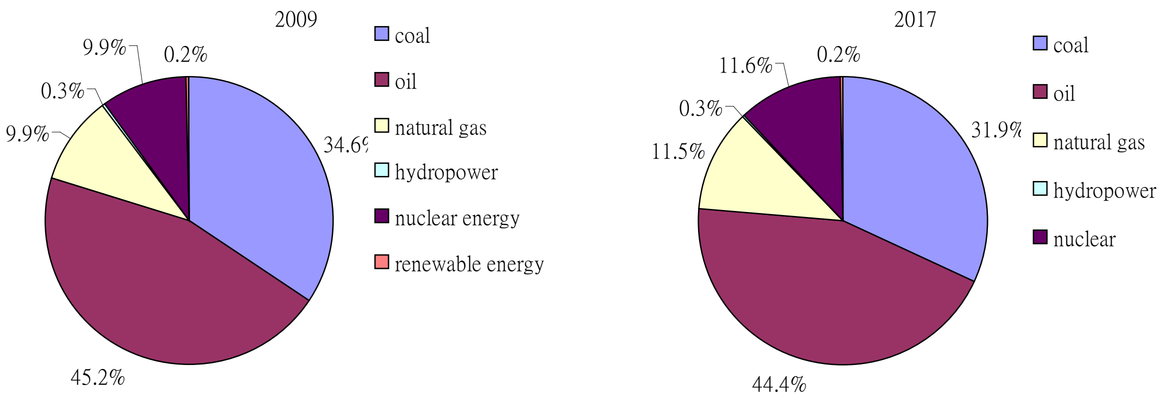


Figure 3 The energy structure in 2009 and 2017

(3) EID analysis
There is no detailed information about the change of energy imported countries under the scenario of improved energy efficiency. Assuming the number and distribution of energy imported countries is the same with that in 2009, i.e., 0.77 for coal, 1.69 for oil, and 1.52 for natural gas. But the percentage of coal, oil, and natural gas to the overall energy is changed, the final EID is therefore from 0.117 in 2009 to 0.164 in 2017. The more diversity energy structure in 2017 results a better consequent EID value as well.

4. Conclusions

Energy security is the core issue of energy policy and should be included in SEA. However, assessing energy security is difficult due to its indistinct definition and no indicators can reflect the complete energy security. The need of a quantitative tool of energy security is obvious in Taiwan; especially applying it in SEA. This study clarifies the physical characteristics of energy security and suggests that diversification can represent the energy security. Two indicators are proper to quantify the diversification, which are energy mix diversification (EMD) and energy imported diversification (EID). The EMD reveals the diversification of the national energy structure. When disperse the dependency on particular energy sources, the EMD will sequentially increase. The EID is an advanced indicator and is able to reflect the imported diversity of a particular energy type.

In Taiwan, the domestic energy production is very low and almost 99% of energy depends on imported energy. The results of EMD and EID show the consistent low energy security. The current energy structure is heavily relied on coal and oil and results in low EMD value. The high percentage of imported energy causes low EID value. Even increasing energy efficiency according to the objective of a newly energy policy, the improvement on energy structure is limited. Unless the dependency on coal and oil is decreased to less than 70%, the energy security would not promote dramatically in Taiwan.

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Have to Re-examine Renewable Energy

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Abstract: In this paper, it was emphasized that the conversion process of renewable energy resource was non-renewable, and energy resources were re-classified as self-consumption-based energy resource which mainly consumed itself and carrier-consumption-based energy resource which mainly consumed carriers. This classification avails to improve energy conversion efficiency and utilization efficiency based on their respective disciplines and mechanisms.
Conventional energy system is established on the basis of self-consumption-based energy resource. And its theoretical, academic and technical contents have been unable to meet the needs of carrier-consumption-based energy resource for technological innovation. Therefore, in the era of vigorously promoting renewable energy resource, the energy theory and technology system corresponding with carrier-consumption-based energy resource must be established and new ways to use energy must be explored corresponding with carrier-consumption-based energy resource conversion mechanism.
We emphasized that it was necessary to set up the new theoretical and technical system of energy to adapt to renewable energy development, which was the key to solve energy problems.
Although the new theory deviates from the conventional view, it's crucial for establishment of new energy science and technology innovation system, and would play a significant role on sustainable development of human society and low carbon technology innovation.

Key words: *Renewable energy, Self-consumption-based, Carrier-consumption-based.*

Nomenclature

E_A *Available energy* .... *j*
E_S *Self energy* .... *j*
η_c *Conversion efficiency*
η_{cc} *Carrier consumption efficiency*
e_{PE} *Index of unit energy environment* .... $ppm{\cdot}j^{-1}$
P_{ep} *Pollution in equipment production process* .... *ppm*
P_{EP} *Pollution in energy production process*.................... *ppm*
E_P *Energy production* .... *j*

1. Introduction—Energy resource and energy

Energy resource has always been a hot debate since the outbreak of oil crises. There are about twenty definitions of energy resource up to now. In The Encyclopedia of Science and Technology, energy resource is defined as the resources from which energy, such as heat, light, electricity and so on, can be obtained. In Encycopedia Britannica, energy resource is a union of all fuels, water, solar, wind, and can be converted into required energy by the appropriate means. Thus energy resource is not equal to energy. Energy resource can be considered as the resources which can be converted into energy. And these resources can't be utilized directly, but be utilized in the form of energy after corresponding conversion. So energy is the outcome of energy resource conversion and not equal to energy resource.

This paper clarified the difference between energy and energy resource through the systematic expatiation and proposed corresponding solution for the deficiency existing in the present energy research. And methods to improve the energy utilization efficiency were proposed through a clear classification of different types of energy utilization in order to clarify each bottleneck of energy utilization efficiency. Therefore, the current low energy utilization efficiency could be improved fundamentally, and the new energy was promoted to become the leading energy resource.

2. Analysis of non-renewability for "renewable energy resource"

The history of human civilization is a history of human utilization of energy resource, and creation of any substance is inseparable from energy resource utilization. The development of human society has experienced three stages [1]: a stage that mainly utilize "renewable energy resource" such as solar, wind, geothermal, water and so forth; a stage that mainly utilize fossil fuels such as petroleum, natural gas, coal, and so on, which are not renewable; and a stage devoting major efforts towards development of renewable energy resource. At the first stage, human used natural energy sources intuitively to do simple work, provide heat and keep warm etc. At the second stage, the invention of steam engine promoted development of industrialization marked as fossil fuels (petroleum, natural gas and coal). Theory and technology system corresponding with energy resource generated gradually. But lack of theory and technology system corresponding with renewable energy resource constrained the development of energy resource. At the third stage, serious environmental problems and energy resource supply issues emerged constantly due to the large-scale utilization of fossil fuels at the second stage. Human is once again faced with the necessity to strongly emphasize the development of renewable energy resource.

In order to meet the demand of industrialized society, the emerging energy resources should be developed in a high efficiency, low consumption, high energy density, sustainable and little environmental impact direction. Therefore the renewable energy resources should be converted into stable energy such as electric power. With respect to high energy-density energy resources, such as oil and coal, most of renewable energy resources are low energy-density energy resources, such as wind, solar, tidal energy resources, they will consume more equipments (also carriers) in conversion process. The conversion efficiency, life, cost, and resources of carriers will determine the utilizing efficiency and the development of renewable energy resource. This is the reason why the renewable energy resource was substituted by fossil fuels at the second stage and couldn't be utilized on a large scale at the third stage [2].
To solve this problem, we proceeded with the substrate of renewable energy resource and explored ways to improve its efficiency through the technological analysis of renewable energy resource.

3. Energy system methodology

3.1. Classification of energy resource by dichotomy

Currently energy resource is classified into fossil energy, renewable energy, nuclear energy and hydropower, etc. in the form of energy resource, rather than in the form of energy resource utilization and conversion. From an objective point of view, some energy resources including fossil energy, nuclear energy and biomass energy are all available through their own consumption, while other energy resources, such as solar, wind, geothermal, ocean energy, etc. are available through carrier consumption. And these two forms of energy utilization and conversion have their own rules and theoretical basis.

When wind energy and solar energy included in renewable energy resource are converted from resource into energy, carriers are needed during the conversion process and the conversion efficiency depends on the adoptive carriers. Herein it can't simply be thought that energy resource is renewable so that the whole process of energy resource utilization is renewable. Because the energy resource utilization efficiency doesn't depend on energy resource itself but depend on the adoptive carriers attributed to the low energy-density. Although this type of renewable energy resource are considered to be renewable but its renewability during the conversion process accompanied by carriers' consumption is untenable. So this type of renewable energy resource can't be entitled as "renewable energy resource". Here we focused on the different determinants in the energy resource utilization process and reclassified energy resource, which conduced to the development of new energy resource and acceptance of new energy resource as the mainstream in this society.

Here we focused on the different determinants in the energy resource utilization process, abandoned the existing classification of energy into renewable energy and non-renewable energy, reclassified the overall energy system, cleared the direction of the new energy development, which could conduced to effective solution of the new energy efficiency bottleneck issues, and acceptance of new energy as the mainstream in this society.

According to the determinant of energy efficiency, energy resource is re-classified as self-consumption-based energy resource which mainly consumes itself and carrier-consumption-based energy resource which mainly consumes carrier. According to the energy resource utilization ways, energy resource is re-classified as fuel type energy resource and non-fuel type energy resource. From the perspective of energy efficiency, the energy efficiencies of self-consumption-based energy resource and fuel type energy resource mainly depend on the substance itself, while the energy efficiencies of carrier-consumption-based energy resource and non-fuel type energy resource low energy-density are mainly determined by carrier ascribed to low energy-density. This classification is conducive to improve energy efficiency more effectively when studying laws and mechanisms, respectively, and to clear the relationship between different types of energy resources, finally clear the development direction of renewable energy resource.

At present, all of the energy resource theories are built on the basis of traditional energy resources. However, these theories have been established before the emergence of new energy resource. And new energy resource here mainly means carrier-consumption based energy resource and non-fuel-based energy resource proposed above.

In other words, these theories can't meet the demand of the existing energy resource technology innovation. And traditional production and living style, and traditional energy resource utilization ways can't pull birth of more rational, more scientific, more efficient, low-cost, new energy resource technologies. Therefore, in this era vigorously advocating the development of renewable energy resource, energy theories and technical systems corresponding with new energy resource should be build up, new energy resource utilization ways consistent with new energy resource conversion mechanism should be explored, and a revolutionary energy resource technology innovation should be developed, finally a new industrial revolution which is different from the previous industrial revolution marked as the steam engine should be activated.

3.2. Life circle analysis of energy technologies

We demonstrated the above view through life cycle analysis (LCA) of the energy utilization. LCA [3, 4] is an approach in which all energy and material inputs and outputs are accounted for in a technology system, and compilation and evaluation of the potential environmental impacts. The assessing object of LCA method is environmental impacts and material conversions caused by the product system or service system. LCA can identify and quantify the energy consumption and waste discharge associated with the assessing object, and it also can assess the caused environmental burden correspondingly. Assessment of the environmental impacts caused by energy consumption and waste discharge can help provide an overview interaction between the product system and environment as complete as possible. It avails to find the timing and means to improve energy utilization efficiency and protect the environment, and provides products and technology criteria. Therefore, LCA can determine the non-renewability of energy utilization process and demonstrate bottlenecks of energy utilization efficiency through energy consumption, which not only proved the correctness of our classification, but also point out how to improve the energy utilization efficiency from the point of an overall view.

Therefore, human must re-examine the "renewable energy resource" problem. Carrier-consumption-based energy resource and non-fuel type energy resource are inexhaustible, clean and pollution- free as the existing substance in nature. They need to be converted into energy in the application process. And carriers must be used in the conversion process. Once these energy resources are converted into energy through carriers, the utilization process will consume carrier materials and give rise to pollution of the production process, coat, efficiency and waste proposal issues, which are critical issues of this energy resource utilization. In order to clarify the impact factors and developing direction of energy resource, the corresponding LCA-type formulas are established shown as below:

$$E_A = E_S \times \eta_C \times \eta_{CC} \quad (1)$$

$$e_{PE} = (P_{ep} + P_{EP}) \div E_P \quad (2)$$

The energy production and costs of energy production in the utilization process can be clarified according to above formulas. Solar and wind energy are chosen as an example. Since solar and wind energy can be greatly influenced by the natural environment and climatic conditions, with instability and uncertainty, in order to improve power quality, new energy storage devices must be set in new energy power generation system so that excess energy is stored when the external energy is sufficient, and lacked energy is complemented when the external energy is insufficient. For example wind generator can store the wind energy through inductive energy storage device and improve the quality of power supply. In addition to the traditional batteries and energy storage inductor, modern energy storage devices have been developed such as super-capacitors and flywheels, etc., but the exploitation of these materials and preparation process has huge energy consumption.

Amorphous silicon cells in solar photovoltaic industry provide an example [5, 6]. The photovoltaic industry chain consists of four parts: silicon material, silicon chips, solar cells, solar energy battery components. Preparation of silicon materials have gone through silicon ore mining, preparation of industrial silicon, the process of preparation of crystalline silicon and so on. Investigation of energy storage systems and examination of issues associated with waste disposal of expired batteries and development of energy storage devices for long-term use must be carried out in order to achieve stability in the independent power generation. At present, solar power plant construction requires an investment which is approximately 7-8 times that of coal [7], the power generation cost of solar electricity is about 8-9 times of coal, and requires much more land area than coal-fired electricity. By this token, the solar power generation technology presents not only high-cost problem but also the problem of consumption of resources, the process of pollution, waste disposal and other issues.

Take wind energy as an example [8], the world's wind power calculation is based on the standard of power generated by the largest wind of annual local detection, known as peak power. However, the maximal wind power of the year couldn't be maintained every day. In fact wind power unit effective power only reach to 20% of peak power, which makes wind energy cost of unit power very high; brings about large quantity of consumption of resources such as converting equipment, fan blades, transmission, generator; causes equipment maintenance and waste disposal problem latterly [9]. Without exception, the utilization efficiency of above energy in the utilization process mainly depends on the energy conversion means, which is the carrier consumption we mentioned above. In other words, this type energy converts through the carrier consumption. So we named this type energy carrier-consumption-based energy.

Here we propose the existing problems of new types of energy, don't oppose vigorously the development of new energy resources, and don't deny classifying energy into the renewable energy resource and non-renewable energy resource, but understand energy resource from another point of view. At the same time due to the shortage of fossil energy, we need to develop new energy resources vigorously. Raising these issues is only for pointing out that the new energy resource developing road is a materials innovation road, technological innovation road, process optimization road.

Through the re-classification of energy resource, developing directions of different types of energy resources can be clarified, e.g. the developing directions of self-consumption based energy resource and fuel type energy resource are the deployment of process and the implementation of energy saving measures; the developing directions of carrier-consumption-based energy resource and non-fuel type energy resource are choose of materials, study of technical principles. Here selection of materials for carrier-consumption-based energy resource mainly includes new materials for energy efficiency improvement and cost reduction etc.

3.3. New energy resource theory and technology system

There is another reason for the difficulty of existing new energy resource technologies to break through. It is that so far no scientific research institutions or scholars could propose a systematic concept and planning for energy science and energy systems, so the real energy discipline has not been established. The so-called discipline has two meanings: the disciplines and branches of knowledge; teaching, research and other functional units, which is relative definition on the teaching and research activities. Here "discipline" partially refers to the latter meaning, but are also relevant with the first meaning. While there are quite a bit researches on the branches of energy resource in the world and there are quite adequate research methods for all kinds of energy resources, the researches on energy system and energy discipline are relatively less, which causes the division between the disciplines, non-shared resources, over-specialization of talent education, narrow range of knowledge, narrow direction of research, overall low benefit and relatively decentralized scientific research especially individual research.

The re-classification on energy resource can't make changes on the nature of energy resource, but is very helpful for the improvement of energy efficiency, the establishment of energy discipline and talent education. For example, for the self-consumption-based energy, the establishment of discipline should be interdisciplinary-based on chemical engineering, energy chemistry, thermal engineering and so on; for carrier-consumption-based energy, the establishment of discipline should be interdisciplinary-based on mechanical engineering, material science, energy biology, energy physics and so on.

Construction of a discipline possesses multiple functions, such as talent education, scientific research, social services, etc. Discipline set up under the right guidance of academic philosophy could develop the discipline of various functions of discipline much better. The establishment of energy discipline is in line with this standard. From the view point of energy classification, it can be analyzed that energy discipline is the intersection of parts of materials science, chemical technology, physics and mechanical engineering etc.

From now on, the systematic energy discipline hasn't been established, which causes a serious split within the disciplines. So, logical relationships between different types of disciplines, discipline characteristics and patterns of development can't be reflected accurately. This situation not only seriously affect the interaction between the cross discipline, integration, resulting in blind comparisons and vicious competition between different disciplines, impeding the normal development of energy disciplines, but also affect the energy talent education. Rational energy talent education is more conducive to the development of energy resource disciplines and the correct development path for energy can properly guide the efficient development and utilization of energy resource. Therefore, we must create the right energy system, adjust the energy disciplines reasonably, and establish the corresponding theoretical basis in order to study its regularity and mechanism. E.g. theoretical system for carrier-consumption-based energy resource may include energy ecology, energy transfer study, energy materials, energy bionics, energy chemical, biological energy, energy physics etc., and its technology system should include collection technology, conversion technology, energy storage technology, using technology and so on.

Discipline construction can promote the development of scientific research and industry and then stimulate the improvement of scientific research level and overall strength. With the social development and technological progress, the discipline construction has been the crucial factor to strengthen internal discipline, enhance the overall academic level of scientific research and promote talent education. In the beginning of establishing a new energy discipline system, the direction of development may not be stable. Therefore, it need to go through a period of adjustment, differentiation, and eventually evolved into a purposeful, organized common action. When this action is recognized by the society, a new discipline comes into being.

4. Conclusions

In this paper, starting from the energy resource, the non-renewability of energy utilization process was proposed on the basis of the exploration of the energy resource and it was pointed out that the existing energy utilization theory could not meet the existing demand for energy technology innovation. Therefore, new energy theory and technology system should be established corresponding with the new energy system and new energy utilization ways should be explored corresponding with the new energy conversion mechanism. So classification of energy resource by dichotomy was proposed and energy was re-classified as self-consumption-based energy and carrier-consumption-based energy. And this viewpoint was demonstrated by the LCA. In conclusion, after effectively addressing these problems, the corresponding energy systems should be established through discipline construction to promote scientific research and industrial development.

Today is accelerating development new energy resources. We must start from the origin of energy utilization and promote new energy resource into the mainstream of energy resources through exploring the origin of energy, principle inquiry, technological innovation, discipline construction and other means, so as to establish a new industrial revolution different from that marked as steam engine.

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Evaluation and Analysis of Renewable Energy Sources Potential in Slovenia and its Compatibility Examination with Slovenian National Renewable Energy Action Plan

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Abstract: Environmental problems and high import dependency from fossil fuels are core problems of the energy policy of the European Union (EU), therefore the EU has committed to increase the share of renewable energy sources (RES) in final energy consumption to 20% by 2020. Individual targets for each EU member must be incorporated in National Renewable Energy Action Plan (NREAP). To evaluate the possibilities for development of sustainable energy industry and for preparation of NREAP, evaluation of future energy needs must be made, national RES potentials must be examined and increase of RES share must be planed. In this paper the energy balance and the consumption structure of energy sources in Slovenia, EU and the World is analyzed. The share and growth of RES in Slovenian energy balance is compared with the average values of EU and the World, with emphasis on examining RES potential in Slovenia. Compatibility of RES potentials with the planed utilization for individual RES potentials in Slovenia is analyzed from economic and technological point of view with environmental considerations taken into account. The purpose is to examine which RES potentials have not been fully exploited and compatibility of measures provided in Slovenian NREAP with the estimated potential of RES.

Keywords: *Energy, Renewable energy sources, Energy Policy, Slovenia, Potentials*

1. Introduction

In the 20th century, dramatic 20 fold increase of energy consumption has been noticed [1]. It is expected that the energy consumption will also rise in the future. The forecast of International Energy Agency (IEA) in its reference scenario estimate, that world energy demand from 2005 to 2030 will rise for approximately 52% [2], while predictions of World energy council estimate double energy demand by 2050 what is comparable to IEA. Other recent estimates suggest that energy demand over the next five years will rise 2.5% annually and after that for 1.5% annually by 2030. Fossil fuels will remain the major energy source, which will cover approximately three quarters of elevated energy needs.

The amount of fossil fuels consumed annually (about 80% of the total energy consumption) is about 7.5 bi llion tons when converted to carbon units (toe). Because the current world population is more than 6.86 billion people, the average consumption of fossil fuel energy by the people of the world at the turn of the century was just a little more than one ton per person. World average in annual energy consumption in 2008 was approximately 1.44 toe per capita. Calculation based on the data in national energy balance [3] shows, that the average consumption of fossil fuels in Slovenia is about 50% higher than the world average while average annual energy consumption in Slovenia is 2.38 toe, which is 65% more than world average what, on this criteria, range Slovenia among developed countries. Energy mixes of the members of EU-27 typically include approximately 60% of fossil fuels. IEA noted that predicted increase of energy demand in the next twenty years will have a s imultaneous influence on increased prices of energy sources and increased green house gas (GHG) emissions. That is why IEA is drawing attention to the problems of fossil fuels consumption and calls for international climate agreement to cut GHG emissions. Continuous increase of energy consumption in Slovenia in the past and the future expectations are not sustainable and energy related emissions are already around 80% of all GHG emissions in Slovenia [4].

Pollution, GHG emissions, rising energy demand and high import dependency of energy are the core of energy problems in EU as well as in Slovenia. That is why RES are seen as a long-term solution and a short-term reduction of the above stated problems. The EU is aware of the issues related to conventional energy sources (CES) and supports the development of RES and sustainable energy. Sustainable energy comprises two key components: energy efficiency (EE) and RES. The investments in EE and RES are highly important since RES causes less or no pollution, enables use of local resources, lowers import dependency and increases EU competitiveness at the same time.

First ambitious goal set in EU in 2001 for the EU Member States, was 12% share of RES in 2010, which is unlikely to be reached. Second goal is represented in 20/20/20 objectives that require 20% of RES in EU by 2020. Specific target for Slovenia is 25% of RES. Achieving this objective is encouraged also with renewable energy Directive (2009/28/EC) that requires Member States to submit NREAP by 30th June of 2010. These plans had to be prepared in accordance with the template published by the Commission, provided detailed roadmaps of how each Member State expected to reach its legally binding 2020 target for the share of RES in their final energy consumption. Member States had to set out the sectoral targets, the technology mix they expected to use, the trajectory they would follow and the measures and reforms they would undertake.

The ever-growing worldwide consumption of fossil fuels and the concomitant emissions as well as the limited availability of fossil fuels, have led to a growing interest in the application of RES, therefore RES potentials must be examined. The increased general awareness of the negative environmental impact of the use of fossil fuels demands sustainable alternative energy sources. To enable further growth of sustainable energy sector, energy consumption and RES share must be examined, that is why we are analyzing and comparing energy consumption and RES share between 2000 and 2010 in Slovenia, EU and the World. We are also examining and evaluating individual RES potential. Total, technical and economic potentials of individual RES and plans of Slovenian energy policy are analyzed and additionally evaluated with our own recognitions and calculations. Our thesis is that potentials of RES are certainly not taken appropriately into account in the Slovenian NREAP that is why we have also tested compliance of RES potentials in Slovenia with NREAP.

2. Methodology

Statistical data presented in the study are gathered on the base of compilation method. Different independent sources (statistical offices, national, international and private studies and analysis, scientific papers and national energy balances) were used. Data of energy consumption, RES share, total, technical and economic RES potentials (exploited and unexploited), barriers of RES exploitation and all others data are statistically analyzed, evaluated and cross-compared.

Comparison energy production and RES share in Slovenia, EU and the world presents situation analysis. Our contribution is identification and combination of data, since individual data from different sources are not comparable because they were obtained by different methodologies. On this basis actual similarities and differences of energy statistics of Slovenia, EU and the world were than examined and cross-compared. In the second part RES potentials of Slovenia are examined. We examined and critically evaluated many existing studies, evaluations and documents. Where the deviations of RES potential between individual studies were large, comparison with our own calculations of RES potentials that was based on characteristics of Slovenia (natural and physical characteristic, theoretical energy conversions) was made. In case of solar potential, our estimation is calculated on the base of average annual solar radiation and multiplied with the total surface of Slovenia and in case of wood biomass potential, our calculation is based on annual natural forest increase and annual forest cut down and supported with the average heat of combustion. Our calculations and synthesis of many different data from different sources and characteristics of Slovenia presents the basis on which we made a comparison and compliance testing with the data and measures about RES potentials and measures written in Slovenian NREAP and national energy program (NEP).

The survey and analysis of Slovenian RES potentials is held on t he basis of currently established economical, technological and environmental acceptability. We assume that technological and economic RES potential will increase in the future due to technological development, internalized external costs and increased prices of fossil fuel but the environmental potential will be reduced because of stricter environmental requirements. Although the study relates to NREAP that also includes calculations and forecasts about heat pumps, whose potentials are not yet fully discovered and liquid biomass that is mostly going to be imported in Slovenia, these two categories are not included in this study.

3. Results and discussion

3.1. Energy consumption in Slovenia, EU and the World

In order to achieve the development of sustainable energy policy all over the world, an international agreement, similar to 20/20/20 objectives, that are obligatory for EU members, is necessary. Gross inland consumption of primary energy in Slovenia compared to EU and World in 2000 to 2009 is presented in Table 1. From table 1 it is also visible that in EU RES share and the production of energy from RES increases more successfully than in Slovenia. Calculation of trend, based on data from table 1, for years 2005 to 2009 has shown that EU-27 is reaching its target of renewable energy sources much faster than Slovenia itself.

Share of RES in Slovenian gross primary consumption is more or less constant from 2000 to 2009. The biggest share of RES in Slovenia belongs to wood and hydroelectric energy. Minor changes in RES share between 2000 and 2009 are mostly a result of hydrological conditions in Slovenia. RES share and energy production from RES is growing slowly; only from 2007, meanwhile RES share in EU-15, EU-25 and EU-27 is growing constantly from 2002. We have also compare Slovenia with the world energy statistic because we surprisingly found some similarities of Slovenia and the world, like later mentioned peak energy consumption or share of RES in world primary energy consumption that is like in Slovenia also more or less constant from 2000 to 2008. These pattern similarities are sometimes even stronger and more visible than similarities with EU pattern, although Slovenia is more similar to EU because it is a developed country above the world average from the energy use, GDP and standard of living point of view. However the world energy production from RES is growing. The cause is that the world growth of energy production from RES is the same as the growth of world primary energy consumption. Energy intensity in Slovenia slightly rose in 2008 and in 2009 it fall back to the level of 2007. Meanwhile EU energy intensity is continually declining since 2003 [5, 6]. Peak of gross primary consumption in Slovenia was in 2008, while EU-15 reached peak consumption in 2005, EU-25 in 2005, EU-27 in 2006 and the world in 2007 [2, 5, 6]. A giant decline in energy production in 2009 can be seen in all analysed objects. This data among others also suggested cooling of economy, especially in most developed countries in EU and could be used as a forecast of economic trends in the near future.

Energy demand in Slovenia exceeds Slovenian production capacity that is why Slovenia is going to import around 50.6% of its energy and energy sources in 2010. S lovenian dependency on energy imports (49% in 2009) is very close to the EU-25 average (51%). Both data shows that Slovenia and EU are highly dependent on energy imports. This dependency that causes economical, political and social vulnerability of EU members must be seen as a challenge and opportunity for sustainable energy policy. Slovenia is going to import 100% of hard coal, anthracite, coke and oil products along with 99.7% of natural gas. Domestic supply in year 2010 is based on lignite, brown coal, hydro energy, wood biomass and electric energy from nuclear power plant Krško [3]. Oil products will cover the biggest share, approximately 47.6%, of imported energy sources [4]. Oil also remains the dominant fuel in the primary energy mix of EU-27 till 2035 [2].

Table 1. Total primary energy supply - TPES (2000-2009) [1, 2, 5, 6, 7].

Slovenia	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
TPES (ktoe)	6360	6749	6820	6931	7129	7307	7318	7336	7749	6990
RES (ktoe)	761	776	716	714	822	774	768	735	845	874
RES share (%)	12.0	11.5	10.5	10.3	11.5	10.6	10.5	10.0	10.9	12.5
EU-15										
TPES (Mtoe)	1454	1469	1502	1497	1530	1552	1552	1544	1527	n.a.
RES (Mtoe)	85	88	85	92	99	103	110	124	130	n.a.
RES share (%)	5.8	6.0	5.7	6.2	6.5	6.6	7.1	8.0	8.5	n.a.
EU-25										
TPES (Mtoe)	1655	1668	1706	1702	1743	1766	1766	1764	1747	n.a.
RES (Mtoe)	90	93	97	95	103	111	115	123	137	n.a.
RES share (%)	5.4	5.6	5.7	5.6	5.9	6.3	6.5	7.0	7.9	n.a.
EU-27										
TPES (Mtoe)	1724	1763	1759	1803	1825	1825	1826	1808	1799	1681
RES (Mtoe)	98	101	100	108	116	121	129	143	151	151
RES share (%)	5.7	5.8	5.7	6.0	6.4	6.6	7.1	7.9	8.4	9.0
World										
TPES (Gtoe)	10.02	10.17	10.23	10.58	11.04	11.44	11.60	12.06	12.00	n.a.
RES (Gtoe)	1.29	1.29	1.31	1.33	1.37	1.41	1.44	1.50	1.47	n.a.
RES share (%)	12.9	12.7	12.8	12.6	12.4	12.3	12.4	12.4	12.3	n.a.

From the energy mix analysis it is clear, that if we can not place our expectations on intensification of nuclear energy, we will need to focus our efforts into the development of renewable energy. Slovenia will have to restrict its attention to those technologies that could be introduced at a significant scale in the near future.

3.2. Estimation, analysis and examination of RES potentials in Slovenia

Because RES are the key element of sustainable energetics, we analysed and examined data about RES potentials in Slovenia. RES potentials are presented in table 2. Presented data and calculations from table 2 are not fully comparable, because they are combined from many different sources and studies of RES potentials in Slovenia that were or at least should be considered in preparing NREAP and NEP and compared with our own calculations. Differences also occur because forecasting RES potentials can not be totally reliable. Indicative prices for RES energy plants are a s ubject of investments in electricity (cogeneration) power plants only. Investments in heating power plants are much lower.

A hydro energy potential (HE) of Slovenia, a high efficiency of hydro electric power plants (HEPP), a very long life (over 100 years) and non-emission operation together with obtained cheap energy should make HEPPs the priority of the Slovenian energy industry. We estimate that the investments in large and small HE should be a priority of Slovenian electricity sector, because HEPP can significantly impact on mid-term replacement of CES. HE in Slovenia allows construction of small HE with additional 100 MW installed power [8, 9]. Small HEPPs also have positive impact on t he decentralization of energy industry and are over 90 % efficient. Technical and economical potential of large HEPP is much higher than small HEPP potential but the construction of large HEPP causes a large local environmental impacts. Meanwhile small HEPPs cause much less environmental strain, can be built in many locations and require relatively small total investments, that is why small HEPPs are attractive also for private capital. Small HEPPs must also be encouraged in rural regions because they present social and economic benefits for rural development. Despite efficiency of HE exploitation can be improved also with renewing and upgrading existing HEPPs, Slovenia is not giving enough emphasis on this measure.

Table 2. RES potentials in Slovenia at the end of 2010 [5, 8, 9, 10, 11, 12].

RES	Total potential (TWh/a)	Technical potential (TWh/a)	Economical potential by 2020 (GWh/a)	NREAP 2020 goal (GWh/a)	Price (million EUR/MW)	Installed (MW)
Hydro	19.4	9.1	6370	923		819
large HEPP		8.6-8.0	6070	837	1.5-2.6	
small HEPP		0.5-1.1	300	86	1.3-3.0	90
Solar	25835.4	8.6-2777.8	139-1300	343	3.0-5.0	17
Wind	15.6	3.1	226-1000	191	1.0-1.4	0
Wood biomass	19.6	2.9-10.1	300-4305	1249	2.0-4.5	115.4
Biogas	47.3	2.8-4.3	265-927	255	3.6	20.5
Geothermal	>5.4	0.6	44.4 - 150	38	4.6	0

Total potential of solar energy potential is approximately 25.84 PWh/year. As we can see from table 2, technical potential is estimated approximately from 0.01 to 2.77 PWh/year [11]. If we would like to achieve the maximum value of technical potential which is 10.8% of total potential, we should cover 10.8% of Slovenia's surface that is why we estimate this as an unrealistic value. However we have been witnessed 300% growth of photovoltaic in year 2009 [12]. High growth is expected also in 2010. The reasons are the current level of operating support and guaranteed purchase price. However reference costs will be 20% lower in 2011 and 30% lower in 2012 therefore moderate growth can be expected in the future.

Wind energy potential in Slovenia is currently totally unexploited. Total installed capacity of wind power plants (WPP) in Slovenia is 0 MW [12] despite the fact that wind is one of the cleanest and fastest growing RES on the world and especially in EU. The usage of WPP is limited due to lack of appropriate geographic locations, as well as the fact that almost 36% of Slovenia is included into NATURA 2000 network. Although construction of WPP represents significant intervention in the environment, we can achieve synergy with nature by thoughtful and sustainable positioning of WPPs, especially in degraded areas near roads. We propose the installation of a few pilot WPPs and the examination of their functioning. The results obtained would facilitate the decisions about new investments in WPPs and critics of environmental organizations which do not support WPPs in Slovenia. We have witnessed some unsuccessful investments in installations of WPP, therefore Slovenia is going to study and analyse proper areas for WPP. Because of the trends of WPP in EU, Slovenia's department for energy is going to make a list of environmentally undisputed areas with sufficient wind that would attract potential investors. This measure will enable faster commercialization of wind energy.

Maximal technical potential of wood biomass estimated in NREAP and NEP seems excessively high. Technical potential is indeed estimated from 2,875 to 10,108 GWh/year [11]. However estimation 2,875 GWh/year covers only wood biomass that can be exploited only in minor energy plants and households, while maximum estimation covers also wood biomass that can be exploited in major energy plants and as co-incineration in thermal power plants. In spite of that, differences in wood biomass potential estimations are significant and very different from our calculation. Annual natural forest increase in Slovenia is 8 million cubic meters and average energy potential calculated from average heat of combustion of eleven different types of domestic Slovenian wood is 2,440GWh per million cubic meters of wood [11, 13]. That means that for achieving maximal technical potential Slovenia should exploit approximately one half of annual forest increase what is almost impossible, because of wood processing industry and current annual cut down that is approximately 3 million cubic meters of wood. Because of that we believe that this estimation is overestimated. Although NREAP goal for wood biomass is ambitiously set, wood biomass increase will have to be well supported for achieving the objective.

Relatively high biogas potential of Slovenia also seems to be overestimated. In similar studies which were not included in the preparation of NREAP and NEP (like the study of BigEast), estimated technical and total potential is much smaller. However, the NREAP goal is not so ambitiously set, because the study made by Agricultural and forestry chamber, that was not included in the preparation of NREAP and NEP, estimates that biogas potential by 2020 is 927 GWh/year [13] which is almost four times more than the NREAP goal is for 2020.

Slovenia currently exports a lot of biological waste to Austria [4]. Instead of this we believe that Slovenia should search for options for bigger domestic exploitation of biological waste. Important emphasis also must be made on cogeneration of heat and electricity and more extended use of landfill gas. Especially problematic is the use of heat from biogas plants, because they are mainly in the areas where not many heat consumers live. Slovenia should also support the cooperation between local farmers and local communities that should become partners in biogas plant investments. This kind of partnership is very appropriate for rural development and for preserving jobs in rural areas that means that positive effects of biogas as a RES are not just a matter of energy policy. Future measures are appropriate, because exploitation of biogas has strong growth. Growth from 2008 to 2009 was considerable 117%. Despite the enshrined measures, the main problem of biomass exploitation, whether to exploit rural areas for food or for energy corps supply remains the same.

Estimated geothermal energy potential of Slovenia differs greatly in different sources and studies. Geothermal energy potential data are collected every 5 years. Last available data are from year 2005, therefore Slovenian geothermal potential can not be accurately estimated. Nevertheless we can say the annual potential is at least 5443 GWh [11].

As it is evident in table 2 comments, NREAP has both good and bad sides and does not only deal with RES potentials but is also a plan for the future state of Slovenian energy sector.

3.3. Key factors for forecasting and planning future energy policy in Slovenia

Whereas the preparation of NREAP is a challenging project, only four members of EU have managed to submit NREAP in time (until 30.6.2010) and six members still did not submit it until the end of 2010. Slovenian NREAP was submitted to EC with minor delay (8.7.2010) which is a result of completion and improvement of the NREAP content. Slovenian energy consumption forecasts and goals are presented in table 3. Calculation of future energy use in Slovenia for 2016, directed with 2006/32/EC, is based on 2006/32/EC directive methodology.

Table3. Forecasting and planning final energy consumption (FEC) for achieving 20/20/20 or 25 objectives [3, 10, 11]

category	**2007**	**2008**	**2009**	**2009** evaluation	**2010** forecast	**2012** forecast (Kyoto)	**2016** objective (- 9%)	**2020** objective (20/20/20)
FEC in Slovenia (ktoe)	4867	5232	4891	4960-5176	4744/ 4927*	5031*	4267 (9%) / 5214*	5232* or "*x*"
RES in FEC in Slovenia (ktoe)	745	780	787	813-849	840/ 872*	941*	1137*	1324* or 0.25 "*x*"
RES share in Slovenia (%)	15.3	14.9	16.1	16.4	17.7	18.7	21.8	25.3
RES share in EU-27 (%)	9.7	10.3	11.0	n.a.	12.0	n.a.	n.a.	20.0

* - NREAP forecast 9% - goal of directive 2006/32/EC

In the table 3 we can see that NREAP plan shows 20/20/20 objectives are achievable at Slovenian and EU level. Because 2020 goals do not prescribe future energy consumption but only the share of RES, we marked energy consumption in 2020 wit "*x*". For 20/20/20 objectives future energy consumption is not so important but it is essential that RES share advocates 25% of "*x*". Especially important and problematic for achieving 25% of RES in Slovenia is raising share of transport [10] that is becoming the biggest problem in meeting Kyoto GHG emission targets as well. The lack of implementation of past objectives can also be seen in NREAP planning. Objective 33.6% of electricity from RES, set for 2010 for example, is planned to be reached (exceeded) only by 2015. In table 3 we can also see that NREAP objective is not planning to lower final energy consumption but to lower its growth. Because smaller and energy efficient use is also the goal of EU and because energy use declined in 2009 [5], mainly because of the economic crisis, we only have to retain it on the current level, what is more favorable than reducing it. That is why this is not a very ambitious goal. NREAP is actually planning to breach 2006/32/EC directive, which directs Slovenia to achieve 9% energy savings relative to the annual average energy consumption of 2001-2005 by 2016. We believe that increased EE and gradual change of consumer habits should be fully included in NREAP, because this brings the best long-term opportunity for smaller and efficient energy use. However it is realistic to expect a smaller growth of energy consumption by 2015 due to economic recovery but this trend must be limited already in the present.

Disregarding Kyoto targets can also be seen. Planed closure of inefficient blocks of thermal power plant could be made in 2012 instead of 2014 [8]. With this measure Slovenia would significantly reduce possible penalty for failing Kyoto targets and improve the basis for the South Africa agreement as a successor to the Kyoto.

4. Conclusions

In the study we have proven that studies and data about RES potentials differ significantly. That makes the estimates about RES potentials and future energy policy goals planning partly inaccurate. We discovered that our calculations about RES potentials are not exactly the same as in NREAP and NEP therefore we are not totally sure about appropriateness of goals and measures set by Slovenian energy policy. Possible cause of differentiation of different studies about RES potential could be inaccurate data, different databases or different methodology of some studies. It is also possible that data presented in NREAP and NEP could be more accurate if more studies and researches about RES potentials would be made. However, all the studies had shown that Slovenia has many unexploited RES potentials, especially hydro, solar and wood biomass potentials, which are appropriate for future exploitation from technological, economical and environmental point of view, therefore they must be particularly stimulated. NREAP goals are ambitiously set and high growth of RES in all four sectors of NREAP is planned. Wood biomass and hydro potential will be increased most of all. Our opinion is that achieving these goals will be the most problematic. We have also noticed the lack of ambitious measures for smaller and energy efficient use, based on cogeneration or threegeneration, that could also be based on the 2006/32/EC directive.

We believe that reduced and efficient energy use is the only solution that leads to the sustainable energetics. Most important is that efficient technologies will be used regardless of the RES and that measures regarding RES and EE will be combined and implemented.

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Regulation for Renewable Energy Development: Lessons from Sri Lanka Experience

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Abstract: The paper examines the key features of the small hydropower development environment in Sri Lanka which led to sector's rapid expansion. The recent development framework of the small hydropower sector was based on the importance of using indigenous resources, recognizing the positive environmental impacts and the avoidance of high cost alternative thermal generation. This framework also recognized the pioneering effort of the developers in site identification by giving rights to develop on a first-come first-served basis. The policy framework was later extended with a renewable energy portfolio standard to achieve 10% of power generation through renewable energy. The standard power purchase arrangements reduced the transaction costs. The feeding tariffs originally based on avoided costs later shifted to cost based, technology specific tariffs encouraging diversification of the renewable energy portfolio. The introduction of net-metering for renewable energy based distributed generation and the limited interventions in the form of green tariffs also assisted the renewable energy development. The paper concludes that the policy and regulatory frameworks and different approaches to implementing them have been mostly successful experiences in Sri Lanka and they would provide useful lessons for similar countries when formulating and implementing related polices, regulations and legal frameworks.

Keywords: *Renewable energy, regulation, feed-in-tariff, avoided cost, net-metering*

1. Introduction

Sri Lanka has a long history of using renewable energy for its power generation dating back to early 20th century when most of the tea plantation companies installed small hydropower plants to provide their electricity needs. Since then, the country's power generation system gradually developed into a large hydropower dominated system until early 1990s when almost 100% of its supplies came from hydropower. With the exponentially increasing demand for electricity and due to limited large hydro resources the country turned to oil based thermal power plants to supply its base-load requirements. The small hydropower development, though impeded until 1980s due to penetration of the national grid and large hydropower domination, became an attraction, with the increasing fuel costs for thermal power generation.

The paper examines the key features of the framework for grid connected renewable energy and in particular small hydropower development in Sri Lanka and how the policy and regulatory interventions assisted the sector's rapid expansion.

2. Policy Environment

2.1. Renewable Energy Development Policy

In the mid 1990s there was a resurgence of the interest in small hydropower development, particularly on the grid connected power plants. The policy environment was developed by the government with the assistance of the Ceylon Electricity Board (CEB) which was the sole purchaser of power generated by outside its own generation system. This process involved, assigning sites for development, licensing and power purchase agreement. Later with the rapid development of the small hydropower sector, the need to facilitate expansion into other renewable energy sources led the government to specifically address these aspects in the energy policy being drafted in 2006/07. From the beginning, the government policy has been to allow the private sector to develop all grid-connected plants up to 10MW.

The Energy Policy and Strategies of Sri Lanka has given due emphasis to the development of both the conventional and non-conventional renewable energy based generation (NCRE) [1]. One of the key policy elements is the promotion of indigenous resources in energy supplies. The relevant strategies have been identified in order to achieve this objective. They are the following

- The use of economically viable, environmentally friendly, non-conventional renewable energy sources to be promoted by providing a level playing field in generation sector development
- Concessionary financing to be sought to implement hydroelectric projects which are not viable under normal commercial terms
- Necessary incentives to be provided to other non-economic non-conventional renewable energy resources where appropriate to ensure their contribution to the energy supply
- A separate facilitation centre dedicated to the systematic planning and promotion of non-conventional renewable energy sources will be established.
- Appropriate steps to be taken to ensure the development and efficient use of non-commercial energy supplies such as biomass.
- Research and development on adopting new technologies and practices to be promoted

The policy has identified small hydropower, biomass power and wind energy as the three leading non-conventional forms of renewable energy sources to be promoted in Sri Lanka for grid connected electricity generation. The Government would endeavour to reach a level of 10% of grid electricity generated to be produced using NCRE by 2015. Though this policy has not yet been formally translated into a renewable energy portfolio standard issued by the regulator, the government and the regulator are taking necessary measures to reach this target.

The government has recognized the principle that the natural resources are public goods and hence the associated benefits need to be passed on to all the citizens in the country. But in the interest of expanding the NCRE technology penetration no resource cost is charged for a period of 12 years from the date of commercial operation. The resource charges will be used to finance incentives for further NCRE development through the Energy Fund. Therefore this recent development framework for renewable energy sources within which the small hydropower sector operates was based on the importance of using indigenous resources while recognizing the positive environmental impacts and the avoidance of high cost alternative thermal generation.

2.2. Institutional Framework

During the initial development phase of the small hydropower sector, CEB was the main institution involved as the sole purchaser of electricity generated by these plants. Central government agencies and provincial and local authorities have been involved in the areas such as land acquisition, environmental clearance and water rights. Once after commissioning the plant, apart from licensing and notifying the annual power purchase tariff determined by CEB, the central government’s role in the sector was minimal.

With the expansion of the small hydropower sector and the interest of the private sector in developing other renewable energy sources, the government strongly felt the need to have a dedicated agency with adequate authority for NCRE resource development. Not only this agency needed to be able to facilitate the process of NCRE development but also it was to have the statutory powers to intervene and overcome barriers. Addressing this requirement the Government passed a new legislation to establish the Sustainable Energy Authority (SEA) in 2007 [2]. The board of directors of SEA has the representation from all important stakeholder state agencies and the private sector. This has enabled SEA to address many of the critical issues within their board meetings.

2.3. Site Selection and Development

The CEB developed the hydropower master plan in 1989 which identified many of the hydropower development sites greater than 1MW capacity [3]. In addition, independent investigations by prospective developers and interested individuals and groups also have led to identification of many sites for small hydropower development including those below 1 MW capacity. The government policy has been to allow private sector to be the sole developer of all the sites below 10MW capacity connected to the national grid. The right to develop each of the sites has been awarded on a first-come first-served basis through a letter-of-intent offered by the CEB, recognizing the pioneering effort of the developers in site identification. Later, in order to avoid excessive delays in developing sites for which the letters-of-intent have been issued, the government decided to impose a time limit for development activities to start and progress. If no progress is made within the timeframe provided the letter-of-intent for the relevant site is withdrawn.

During the development of the grid-connected small hydropower sites, the developers usually respond to the needs of the local population partly advocated by the local government bodies in order to ensure smooth implementation. Such interventions by the developers include those such as construction of paved access roads and bridges in the surrounding rural areas which improve transport facilities for the rural communities. In addition, local manpower and other resources are used to the maximum during construction and operation of the plants.

The off-grid micro-hydropower sites often identified by rural communities have been developed by the community organizations themselves, with the assistance of some non-governmental organizations. The community contributes both in-kind through manpower and material for construction and operation of the plants and in cash. These micro-hydro plants have varying capacities ranging from 5kW to 25kW each serving 25- 200 village households depending on the capacity.

3. Regulatory Environment

The regulatory environment for small-hydropower involves licensing, power purchase agreements and feed-in tariffs. In the initial stages of development the institutions involved in this regard were the Ministry of Power and Energy and the CEB. With the establishment of the Public Utilities Commission of Sri Lanka (PUCSL) in 2003 and the enactment of the Sri Lanka Electricity Act of 2009, the regulatory authority over the small-hydropower sector fell within the purview of the PUCSL.

3.1. Standardized Power Purchase Agreement

In 1997 CEB introduced a standardized power purchase agreement (SPPA) for small grid-connected renewable energy based electricity generating plants less than 10MW. SPPA binds the CEB to purchase power generated by these plants without a limitation at a tariff declared every year. Further, the generator was assured a minimum tariff of 90% of tariff in the first year of its commissioning, throughout the SPPA duration.

3.2. Feed-in Tariffs

3.2.1. Avoided Cost Based

In 1997/98 the government declared that the SPPA tariff would be based on the "avoided cost" principle. The tariff calculated as the three year moving average was published at the beginning of each year. Initially the avoided cost was determined using the long term generation planning model which derives the generation expansion plan for the country for the following 20 years. It is a rolling plan and the calculation methodology captured the long term impact of the addition of renewable energy based small power plants in the overall long term generation plan. Later with the understanding between the CEB and developers the methodology was shifted to the operational planning model used in the system control centre where the short term operational costs provided the key inputs to the calculation process [4].

3.2.2. Project Cost based

In 2007/08 the government took a decision to reexamine the feed-in tariff regime as a part of the new energy policy where specific renewable energy targets are to be achieved by 2015. This process led to the introduction of the technology specific cost based feed-in tariffs for all types of renewable energy based plants which would be developed. Initially these renewable energy sources were limited to small-hydropower, wind and biomass. The tariff is designed to make sure that the developer would always have positive cash flow during the SPPA period. The tariff is revised periodically to ensure gradual penetration of different technologies. This new tariff is expected to encourage wind and biomass based plants which tend to have costs higher than those can be recovered through avoided cost based tariff. The plants already in operation or those in which SPPAs had been signed were given the option to remain in the previous tariff regime or to switch to the new regime.

3.2.3. Green-Power Tariff

In 2008 PUCSL initiated action on the allowing interested consumers to purchase power from identified NCRE based power plants. Though direct power wheeling from the generators to the users has not been legally permitted under the electricity act, PUCSL could encourage green-power consumers to enter into agreements with the generators to pay an additional charge directly for the power delivered while paying the standard consumer tariff to the CEB. PUCSL annually verifies whether the energy delivered to the consumers by such generators would satisfy their annual consumption expectation of green-power as agreed in advance. Accordingly, the final payments are reconciled.

3.3. Net-metering

On the advice of SEA, government and the CEB agreed for net-metering of premises with NCRE based systems connected to the grid in 2009. Though the feed-in tariff is not offered to these systems unless they have an SPPA, these premises can still use the grid as an energy storage. If systems are properly designed, net-metering now opens the door for such premises to be carbon neutral in their power consumption.

3.4. Exemptions from generation license

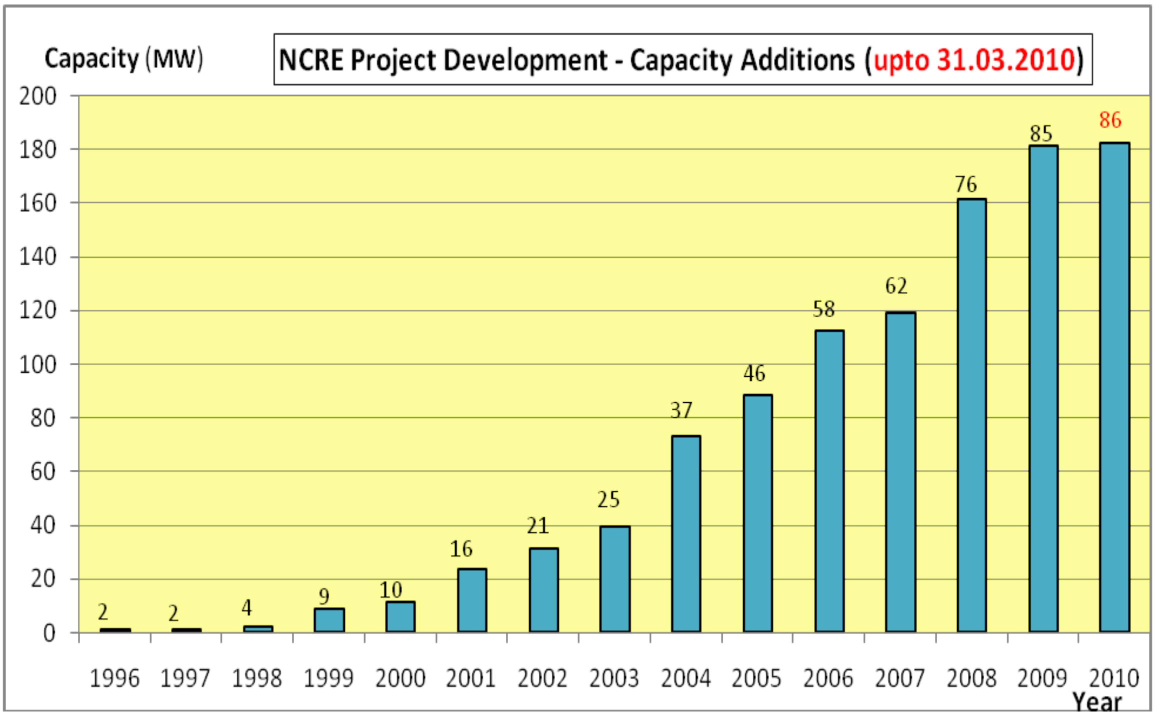
In the initial stages of development, off-grid generators never used to obtain generation (and distribution) license which is required under the law. The authorities ignored this situation considering that the requirements to fulfill for generation license are too cumbersome for the community operated small off-grid systems to fulfill, though operating these systems without a license was in contravention to the Electricity Act. When the PUCSL became empowered with regulatory authority over the power sector in 2009, under the provisions of the Sri Lanka Electricity Act it has been taking steps to exempt off-grid generators from licensing.

4. Analysis and Discussion

4.1. Policy

The government policy of working towards an NCRE development target by 2015 has helped the SEA, CEB and the PUCSL to justify incentives for NCRE development. This can be in the form of direct government subsidies or cross-subsidies in the sector.

The policy of allowing private sector to develop all grid-connected power plants below 10MW and offer of an standardized power purchase agreement with guaranteed unlimited power purchase at a predictable price have encouraged both local and foreign investors to enter into the small hydropower sector. The sector was further attracted by the investors due to the policy of offering sites on a first-come first-served basis which incentivized rapid site identification, investigation and development. The resulting exponential development since 1998 can be seen in figures 1 and 2 where NCRE development up to 2008 has been totally dominated by small hydropower.

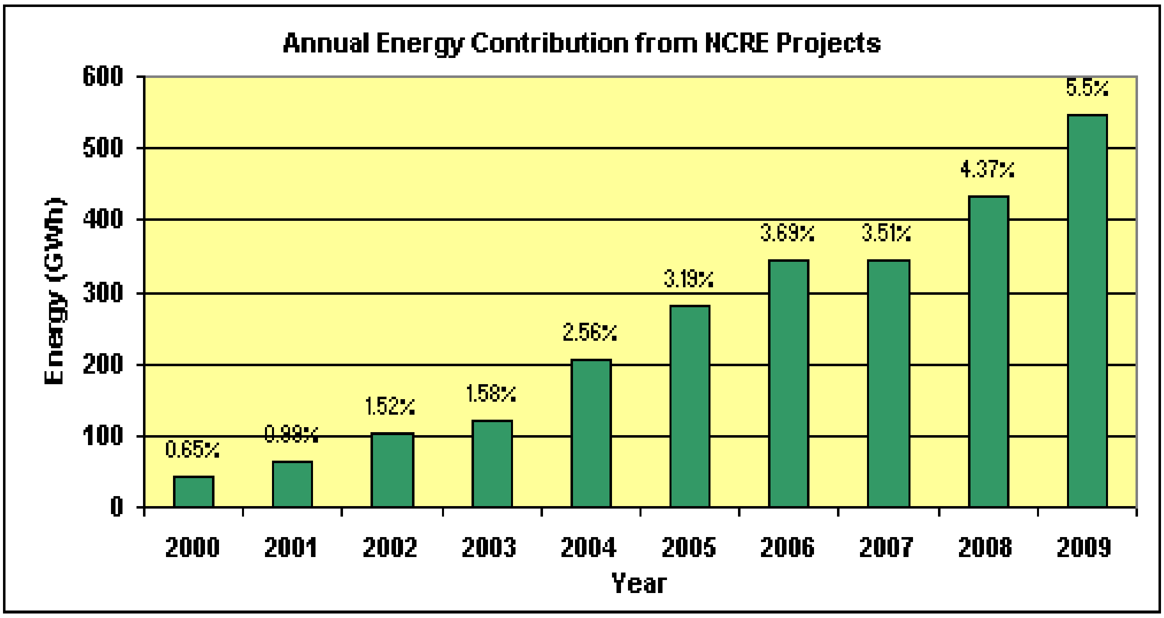


Source: Ceylon Electricity Board

Fig. 1. Total Capacity Additions of Non-Conventional Renewable Energy Based Generation

During the initial stages, the rights to develop the sites were obtained by those who actually wanted to invest in the projects. As the sector development gathered momentum, interested parties used the prevailing policy of site allocation to obtain the right to develop the site and sell the rights to other investors. This created an unhealthy market for letters-of-intent for small hydropower sites which eventually increased the effective project costs and delayed development. This situation was arrested to a certain extent with the introduction of a time limit for development where the investment needed to be in place within a specific time frame.

The optimal capacity of the power plant to be constructed at given site is a function of the investment and the returns it brings based on the hydrological conditions. As a result of the investors being allowed to choose the capacity of the plants to be constructed, the plant capacity became a function of available financing. This has resulted in under-sizing of plant capacity in certain sites leading to an economic loss. This situation could have been avoided if the utility or the SEA carried out an independent assessment and incentivized the developers to construct the plants to their optimal capacity.



Source: Ceylon Electricity Board

Fig. 2. Total Energy Supply from Non-Conventional Renewable Energy Based Generation

4.2. Regulation

The feed-in tariff based on the avoided cost of generation provided significant returns to the investors of small hydropower plants, in the initial phase of development where most of the better sites had been developed. Since during this initial period the avoided cost calculation was based on the long term generation plan, the feed-in-tariff was linked to the most economical generation expansion in the country. But this hardly reflected the actual situation on the ground where the CEB could not follow this plan due to external interventions. This led to the avoided cost calculation being shifted to the operational plan where short term generation schedule was the key input to the calculation. Since the generation system has been suboptimal the avoided cost determined in this manner provided even a higher feed-in-tariff. This environment attracted more investors to the small hydropower sector since even less economically efficient sites could be now developed while the more economically efficient sites led to significantly large returns to the investors. With this approach to feed-in-tariff, the benefit of low cost hydropower was never passed on the final electricity consumer nor it did not assist development of other NCRE sources such as wind and biomass.

With the introduction of the cost based feed-in-tariff the small hydropower sector provided savings which could be used to subsidize other more expensive technologies such as wind and biomass while still providing adequate returns to the investors in small hydropower sector. Also it reduced the financial burden on the government and the final electricity consumers due to addition of these expensive plants.

Green-power transactions facilitated by the PUCSL opened a new approach to supplying green-power to the interested consumers within the existing legal framework where power "wheeling" is not allowed. This enables, particularly green manufacturing which is fast becoming an important export oriented sector, to expand. Net-metering arrangements can further enhance these opportunities for the green-power generation and consumption.

5. Conclusions

The paper discussed the experience in the policy and regulatory environment in the Sri Lanka renewable energy sector. This included the areas such as renewable energy targets, institutional mechanisms, renewable energy site selection and allocation, feed-in tariffs and green-tariffs.

The paper concludes that the policy and regulatory frameworks and different approaches to implementing them have been mostly successful experiences in Sri Lanka. These along with less successful experiences would provide useful lessons for similar power systems in other countries when formulating and implementing related polices, regulations and legal frameworks leading to accelerated development of the renewable energy industry.

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Policy and Strategy aspects for Renewable Energy Sources use in Latvia

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Abstract: Existing Policy & Strategy as well as new tendency in renewable energy sources (RES) use in Latvia will be presented in the paper. The main directions of the energy policy are aimed at improving the security of energy supply of the country by encouraging diversification of supplies of primary energy resources. Creation of competition conditions, promotion of use of renewable and local energy resources and environmental protection also play a substantial role.
In accordance with the Latvian "Law on the Energy Performance of Buildings" environmental and economic considerations, as well as binding regulations of the local government and other regulatory enactments, shall be taken into account in designing buildings, in order to evaluate the possibility to use as an alternative solution in these buildings systems, in which RES are used.
Paper will describe good experience and practice of this Policy and Strategy.
Papers will describe the geothermal energy and solar energy using opportunities in Latvian conditions. Recommendations for new legislation on RES effective and rational use will be presented.
The main directions of the energy policy are aimed at improving the security of energy supply of the country by encouraging diversification of supplies of primary energy resources. Creation of competition conditions, promotion of use of renewable and local energy resources and environmental protection also play a substantial role.
The main objectives of the energy policy are to ensure sustainable accessibility to necessary energy resources and security of supply in order to foster economic growth and improve quality of life; to ensure environmental quality retention and meet the objectives set in the Kyoto protocol of UN FCCC and Latvian Climate Change Program on GHG emissions reduction for years 2005 – 2010.

Keywords: *policy, renewable energy sources*

1. Introduction

The main directions of the energy policy are aimed at improving the security of energy supply of the country by encouraging diversification of supplies of primary energy resources. Creation of competitive conditions, promotion of the use of renewable and local energy resources and environmental protection also play a substantial role.

The main objectives of the energy policy are to ensure sustainable accessibility to the necessary energy resources and security of supply in order to foster economic growth and improve quality of life; to ensure environmental quality retention and meet the objectives set in the Kyoto protocol of UN FCCC and Latvian Climate Change Program on GHG emissions reduction for years 2005 – 2010.

Latvia's total final energy consumption is secured from local energy resources and the flow of primary resources from Russia, the CIS countries, the Baltic countries, EU and other countries. Currently, three types of energy resource making up approximately equal proportions dominate in the delivery of Latvia's primary resources – oil products (mainly petrol and diesel), natural gas and wood-fuel. Like many other European Union (hereinafter – EU) countries, Latvia is dependent on imports of primary resources. Having regard to the reduction of economic activity in Latvia, although consumption fell during 2008.

The share of RES has traditionally been significant in Latvia's energy supply and in 2008 it comprised 29.9% of the total final energy consumption. Rapid growth in final energy consumption and the slow development of RES projects has reduced the RES proportion by 2.6% compared with 2005. In the consumption structure for electricity, the RES segment is made up of hydropower plants, wind power plants, biogas power plants and biomass power plants, as well as cogeneration stations utilising RES. In 2008, RES made up 39.6% of the total final consumption of electricity, with the majority of this, a little over 97%, supplied by large hydropower plants, with the remainder coming from wind power plants, biomass cogeneration power plants and small hydropower plants. RES makes up the largest proportion in the final consumption of heat energy, including district heating, at 42.7%. [6]

The import of fossil energy resources is characterised by large price fluctuations, which does not facilitate the sustainable development of the economy. Latvia's natural gas is supplied by only one country – Russia – Latvia, having regard to the potential of RES available in its territory and the significant position RES already takes in Latvia's current primary energy resource balance compared with other European Union Member States, must attain national energy independence both through promoting measures to increase energy efficiency and increasing the share of local RES in energy, diversifying energy resources and energy supply sources and reducing energy imports. [6]

2. Policy and Strategy for the RES use

2.1. *Energy policy framework documents:*

2.1.1. Guidelines for Energy Sector Development for 2007-2016

The main bases for Energy policy are: The guidelines to ensure security of supply in the country as the main goal of energy Policy. The increasing of self-sufficiency and greater diversification of energy resources supply are the next very important subjects of Energy sector development. Latvia has to search for its own fossil fuels and to increase effective use of renewable sources of energy and energy production in cogeneration (CHP) processes;

2.1.2. Guidelines for Use of Renewable Sources of Energy for 2006-2013

Setting targets for the use of RES are:

- 49.3 % share of RES-E by 2010;
- 8 % share of electricity produced in highly efficient CHP using biomass by 2016;
- 5.75 % share of biofuels in total consumption by 2010;
- 10 % share of biofuels by 2016 (in comparison to less than 2 % in 2006).
- 35 % share of RES in the Energy Balance (in comparison to 28 % in 2007).

2.2. Legal Framework

2.2.1. EU Directives:

- Directive 2001/77/EC on electricity production from RES;
- Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market.
- Directive 2009/28/EC on the promotion of RES usage

2.2.2. National laws:

- Energy Law;
- RES Energy Law (project);
- Electricity market Law;

- Law on the Energy Performance of Buildings;
- Regulations No. 262 on Production of Electricity from Renewable Sources of Energy;
- Regulations No. 221 on Electricity Production in Cogeneration Regime.

2.3. Main support instruments

2.3.1. Mandatory procurement of electricity produced from RES on basis of fixed purchase price formulas

- Regulations No. 262 on Production of Electricity from RES (in force since March 2010);

These Regulations (No. 262) indicated criteria's of produced electricity as compulsory purchase trades. If electricity produced of biomass or biogas in power station with installed capacity over 1 MW, it is possible to get guaranteed fee of set up power.

- Regulations No. 221 on Production of Electricity in Cogeneration Regime (in force since March 2009).

2.3.2. EU Structural Funds

In accordance with the Latvian "*Law on the Energy Performance of Buildings*" environmental and economic considerations, as well as binding regulations of the local government and other regulatory enactments, shall be taken into account in designing buildings, in order to evaluate the possibility to use as an alternative solution in these buildings systems, in which RES are used.

2.3.3. Investments in the energy sector

State support in the energy sector is only given to Projects linked to adjustment of heat supply system. The priorities for the use of EU Structural Funds are listed in the Development Plan; these priorities are sub-divided into measures, which in turn are sub-divided into activities. It is planned to allocate approximately EUR 140 million in the energy sector from the Cohesion Fund in the next Structural Funds utilization period of 2007-2013. This amount will be distributed to measures for increase of efficiency of district heating systems, for development of cogeneration plants that use biomass and development of wind farms in Latvia.

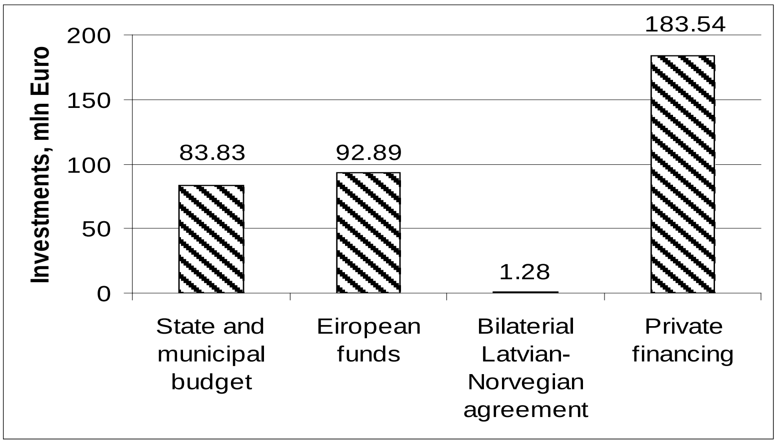

Fig. 1. Potential financial sources for development of RES use (2006-2013)

2.3.4. A feed-in tariff (FiT)

A feed-in tariff involves the obligation on the part of a utility to purchase electricity generated by renewable energy producers in its service area at a tariff determined by public authorities and guaranteed for a specific period of time (generally 20 years). A FiT's value represents the full price per kWh received by an independent producer of renewable energy, i.e. including a premium above or additional to the market price, but excluding tax rebates or other production subsidies paid by the government.

Different tariffs can be defined for different technologies (wind, solar, biomass, etc.) or different countries depending on resource conditions (e.g. solar irradiation). The rate of a FiT is furthermore reduced each year for new installations in order to stimulate decrease in production costs. Feed-in laws have been the primary mechanism used to support RES development in Europe and the US. They have a track record of some two decades and are well established throughout the European Union. At present, they are being applied in 21 EU member countries. While many countries in Europe have introduced a FiT on different levels, only some of them (e.g. Germany) have adopted appropriate rates specifically for PV. Others used inadequate FiT parameters (for instance Austria – too low a ceiling on total installed PV capacity) and thus failed to stimulate significant investor interest.

The feed-in tariff (the mandatory procurement of the energy produced from renewables), a method of support Latvia has chosen, is a straightforward and effective way to reach the renewable targets. This approach is widely used in other member states, too. However, it also bears a number of risks, namely: the procurement price and support timeline is tied to the moment when the energy production equipment becomes operational; and the pricing formula relies on e lectricity prices and fossil fuel prices. A thorough and unbiased analysis of conditions needs to be carried out s well as a calculation of reasonable return on assets. The pace and direction of technological progress needs to be estimated, a hard task. Misjudgements in setting the procurement price and the length of support could go both ways. Truly effective, market-based mechanisms are yet to be found. In Latvia, a quick analysis of the procurement price for the energy produced from biogas or in established hydro-electric power plants reveals overestimates. The quota system favours a closed circle of businesses, whose ties to the political parties are apparent. No wonder the Ruling Coalition Council had to agree on t he pricing principles and quota volumes before the decision was made by the Cabinet of Ministers. Unreasonable procurement pricing undermines the principles of renewable energy use for sustainable development. [7]

2.3.5. Other support mechanisms

In EU countries exist significant variety of support mechanisms. Their main goal is to introduce renewable energy sources into the market and to make them as a c ommon source for gaining electricity. It is commonly admitted that activity of scientific circles and informational campaigns connected with demonstration projects play an important role in the RES development. In case of photovoltaic FiT Tariff is the most important and most effective way in creating development in that branch provided that correct designing of FiT law is submitted.

Investment based support mainly depends on providing investment subsidies, tax credits, and bank loans with beneficial interest rates. Supports mentioned above are significant due to their impact on i nitial market development. Investment based support has importance in case of expensive technologies and currently it is used in many European countries.

Quota schemes (also called Renewable Portfolio Standard - RPS) oblige the producers of electricity and retail provider to attain a specified minimum level of shares RES in its mix. RPS is commonly combined with the Tradable Green Certificates system (TGC). TGC relies on market competition and therefore is unstable in the matter of price. These certificates being the subject of trade contain additional profit for the renewable user of energy. Tradable Green Certificates system does not favor the most future-orientated and ecological technologies of producing green electricity such as photovoltaic and off-shore wind turbine.

Tendering or Competitive Bidding is a transitional mechanism between FiT and RPS. Under a tendering scheme developer of project submits his own proposal and indicates the wholesale price he would like to get for the produced electricity. The one, who offers the lowest production costs of every kWh, will be able to sell electricity for the lower price and will enter a contract which guarantees that electricity will be bought over a defined period of time.

2.4. New Energy Policy

The first proposals are submitted to the Ministry of Economy of Latvia. Some recommendations for the new legislation on effective and rational use of the RES:

- there is a well-established national support scheme for production of electricity from RES – mandatory procurement applicable to electricity production in wind-, hydro-, biomass- and biogas PP;
- with regard to the RES, we convinced to reach a balance between electricity demand and supply potential from local Power Plants by years 2011 – 2012;
- to further develop and implement support schemes for highly efficient cogeneration and use of renewable energy resources in the power generation;
- to improve facilitation activities for bio-fuel production and consumption;
- to implement energy efficiency measures;
- to actively participate in EU and other international R&D projects;
- as a major challenge we regard the upcoming renewable energy policy development on the EU level and the ambitious individual target for Latvia – 42 % by 2020;
- to develop pilot projects and implementation.

2.4.1. New Latvian Policy on RES

Overall, the national renewable energy policy is to promote their use, respecting environment and achieving CO_2 emission reduction. The main renewable energy policy objectives to be achieved is as follows

- Electricity production of RES is 49,3% of all produced electricity in 2010;
- Renewable energy must be at least 37% in total energy balance;
- The share of biofuels of all marketed transport fuel should be 5,75% in 2010.

The aim of the Government policy is to achieve the balance between electricity demand and supply potential from Power Plants by years 2011-2012;
The goal is to promote maximum energy efficiency measures and supply of the power plants that use local fuels and renewable sources of energy in the high-efficiency co-generation cycle.

The remaining part of the required supply capacity will be diversified to other fossil fuels, to prevent over-dominance of natural gas.
During the development of cogeneration plants, energy from renewables will increase power capacity potential of transmission and distribution systems. Two support tools have been selected for this purpose:

- compulsory purchase at a specified price, whether in terms of all Latvian electricity consumer payment in proportion of consumption;

- Renewable sources of energy promote the development of cogeneration power plants earmarked for investment in the power structure, the purpose of EU structural funds.

For improvement of RES use and promotion of the development of biomass cogeneration, it is expected to attract the means of EU Structural Funds and support of Cohesion Fund. Till the year 2016 it is expected to attract 8,1 million LVL from the State Budget and 27 million LVL from EU Structural Funds.

RES exploitation strategy is closely connected with the introduction measures of energy efficiency. RES policy includes an integrated approach to energy efficiency issues.

2.4.2. RES Law (project)

Aims and Objectives

Aims of the Law:

- to promote local RES production, use and export;
- to determine stable long term investment environment for production, usage and export of local RES support;
- to contribute reducing technologies of the greenhouse effect and gas emission;

Law challenges to achieve goals:

- Till the year 2020 increase the RES usage in gross final consumption up to 40% and continue to gradually increase it;
- to promote openness and accessibility of information on energy scope;
- to establish administrative procedures in RES production and usage;
- to determine the support measures for local RES production and usage.

2.4.3. National goals of RES use

Law enforcement is a specific period till the year 2020 to achieve the following percentage of gross in RES usage:

- till year 2012 not less than 34,08%;
- till year 2014 not less than 34,82%;
- till year 2016 not less than 35,93%;
- till year 2018 not less than 37,04%;
- till year 2020 not less than 40%.

2.4.4. Republic of Latvia National Renewable Energy Action Plan for implementing Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC by 2020.

The action plan ‘Latvia’s national renewable energy action plan’ stipulates indicative targets for the share of RES in each type of final energy consumption, to foster the fulfillment of the common objective pursuant to Directive 2009/28/EC, taking into account the potential RES available and usable in Latvia. Having regard to the potential of economically usable RES available in Latvia, the main types of usable RES will continue to be solid biomass, mainly wood, as well as biogas, wind power and hydro power. [6]

2.6. North Vidzeme Biosphere Reserve as a good practical experience

The administration of the North Vidzeme Biosphere Reserve (NVBR) has completed erection of the Environmental Education and Information Centre with a potential area of 675m^2 in the town of Salacgriva. This centre is expected to provide local residents, businesses, municipalities and state institutions with information about the natural assets of the reserve as well as about protection of natural resources and the use of innovative solutions in the regional development. By now, a project of the environment-friendly building in the Biosphere Reservation (BR) on the north of Latvia (Vidzeme) has been accomplished. The BR covers the area of Salacas River − a temperate forest zone characteristic of the Baltic Sea coastal ecosystems. Its land area is 4577km^2, with the population of about 80 000 people. Half its area is covered by forests and 15% by wetlands. The reservation includes 167.5 km^2 of the Gulf of Riga coastal aquatorium. The Environmental Education and Information Centre building were completed in 2009. The relevant project was funded by the European Economic Area and Norwegian Government Financial Mechanism. The Centre will serve as a model for the use of environment-friendly renewable energy. According to the project, the heating-and-cooling equipment was installed for geothermal energy use and solar collectors – for preparing hot water. Energy savings through compression modular equipment were used in the reverse cycle heating of the building and solar collectors − for hot water production up to 90 MWh/ year. As a result, the following was achieved:

- CO_2 reduction (taking fossil fuel use as the basis) − 56.6 tonnes / year.
- Number of holes drilled for space heating and cooling − 11;
- Solar collector's area for production of 500 l hot water − 18 m^2.

Such systems are highly efficient, therefore they were selected with the aim to reduce the management costs of Environmental, Education and Information Centre. Although there are some Backlogs, however system works and functions in full.

3. Conclusions

Recommendations for RES effective use were prepared upon the realized projects and analyses of the National RES Policy and Strategy.
Within the frame of the State Research Program's Project ''Research and development of the renewable energy resources production and consumption technologies for climate changes generated by energy sector mitigation'' suggestions were worked up also for rational RES use.

The action plan provides for guidance towards the more extensive use of local RES in Latvia, noting the measures to be taken to attain the target prescribed in Directive 2009/28/EC, implementing sustainable development, conserving environmental quality and contributing to the reduction of greenhouse gas emissions, increasing Latvia's energy self-sufficiency, ensuring the sustainable utilisation of Latvia's natural resources and the socio-economic benefits of their utilisation. Support mechanisms for generating energy from RES that operate more successfully than previous ones must be established, not only for electricity but also for heating and transport fuel. [6]

The EU has stepped up efforts to harmonize policies on the promotion of the use of energy from renewables in all member states by defining legally binding policy principles for the renewable energy promotion measures and setting individual renewable energy targets for each of the countries. Despite that, Latvia's renewable energy support policy, particularly the mandatory procurement scheme for the energy produced in power plants using renewables, is an area with an unstable legal framework, susceptible to frequent fluctuations in political opinions and interests, which often are not based in the country's economic and welfare considerations. The New RES Law is prepared to approval. The Law will improve the current situation of RES in total, as well as will prevent confusion.

In the recent years, Latvia's energy policy practice was marked by inconsistencies and the lack of socio-economic reasoning, which allows, in some cases, to suspect influence of lobbyists on the development of legal framework. Examples of that trend are the aforementioned frequent changes in the mandatory procurement regulation and the feed-in pricing formula, which is politically motivated rather than based in thorough economic reasoning. In the energy sector, is the lack of flexibility in the mandatory procurement scheme, which is meant to promote the use of renewable energy resources. The inflexibility may lead to situations when support schemes follow the letter of the EU directives, but not the spirit. The quota system supports the renewable energy target (49.3%) on paper, but the structure of the system does not prevent the situation when the businesses with the procurement rights do not set up the planned renewable energy plants whilst the businesses that would be willing to do so have no access to the quotas.

The Environmental Education and Information Centre fulfilled its function as to promoting the state's comprehension of the importance of the RES use. Investments involved in the project were an economically viable option; besides, the realized project helps to reduce the yearly maintenance costs. As a result of the project it has become clear that the energy independence of Salacgriva from imported energy resources is an invaluable and nationally important issue, which could be as a model to several European Union countries. The project also includes informational events that promote the advantages of using renewable energy for heating; this especially concerns heat pumps in combination with solar collectors.

As one more example of good experience, must be mention Institute of Physical Energetics (IPE). It is leader for solar energy research and development in Latvia. Achieved solar energy is used for IPE hot water supply. Solar energy polygon could be used not only as auxiliary heat supplier for IPE, but also as an education and training polygon for new specialists - students, PhD students, etc.

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New and Renewable Energy Policies of Jeju Island in Korea

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Abstract: This study provides information on the energy status of Jeju Island in Korea (located at south of the Korean Peninsula), including general demographics, primary energy consumption and energy consumption by source, energy consumption by sector, power generation, and new and renewable energy.
The purpose of this study is to establish a regional sustainable energy supply system and to promote new and renewable energy industries throughout Jeju. Although Jeju, and Korea in general, already have some renewable energy development, there is strong demand and desire to greatly expand the level of renewable energy adoption. Jeju will not only expand the solar and wind industries, but also pursue bioenergy, geothermal power, hydropower, stationary and mobile fuel cells, ocean energy, and waste energy.
Jeju's regional energy planning is based on the *Energy Basic Law* established in 2006. Specifically, these programs have included policies supporting loans for purchase of renewable energy infrastructure, subsidies for renewable-based facilities, the 100 thousand green homes program, subsidies for solar thermal development, subsidies for local government investment in green technology, certificate programs, training programs, feed-in-tariffs, the formulation of new companies specialized in new and renewable energy, and regulations for mandatory use of new and renewable energy in new public buildings.

Keywords: *Jeju Island, Renewable Energy, Energy Policy*

1. Introduction

Energy use is a primary component of daily life. It is the basic to economic development and modernization. Energy consumption is also related to physical comfort and military strength. This fossil fuel-based lifestyle triggers some problems, such as economic instability, environmental pollution and hazards, and global warming. For economic instability, if the economic system of a country is based upon fossil fuels, the amount and price of fossil fuels, especially oil, will directly influence economic development and stability.

Regional energy planning is an extremely important component of any future development goal. Not only is it important for regions to know how development will unfold in their own jurisdiction, but also understand how development will unfold in nearby jurisdictions that are inherently linked to their own. Many times regional energy planning can capture specific development goals that are not achievable through national- or international-level policy. It is because of the localized framework in which regional energy plans are developed that they are able to focus on region-specific goals and accomplish tasks that are sometimes overlooked at the national level. In many areas of the world, regional energy plans have been under development for many decades and have become increasingly utilized since the 1990s.

The purpose of this study is to discuss the establishment of a regional sustainable energy supply system and to promote new and renewable energy industries throughout Jeju. Renewable energy development is an integral part of energy sustainability. Various forms of renewable energy can be exploited for electricity generation, with hydro and wind power currently dominating the renewable energy economy. Wind power is already competitive compared to fossil fuels in terms of cost of generation, and it has been shown that risk assessments favor this type of energy.

2. Basic Information

2.1. Overview of Energy Status in Jeju

This section provides information on the energy status of the Province of Jeju, including general demographics, primary energy consumption and energy consumption by source, energy consumption by sector, power generation, and new and renewable energy as shown in Tables 1 to 6. This information will be used at a later point in this paper to assist the analysis of the energy, environmental, economic, and social components of Jeju's energy framework.

Table 1. Area, population and gross regional domestic product (2006)

	Area (km^2)	Population (1,000)	Population Density (persons/km^2)	GRDP (2005, current price, billion Won)
Korea	99,678	49,268	497.8	817,811.9
Jeju	1,848	560	303.9	7,663.9

Table 2. Primary energy consumption (2006) (Unit: 1,000TOE(Tonnage of equivalent energy))

	Total	Coal	Petroleum	LNG	Hydro	Nuclear	Others
Korea	233,372	56,687	101,831	32,004	1,305	37,187	4,358
Jeju	1,149	-	1,120	-	-	-	29

Table 3. Total energy consumption by source (2006) (Unit: 1,000TOE)

	Total	Coal	Petroleum	City gas	Electricity	Heat energy	Others
Korea (%)	173,584	22,660 (13.1)	97,037 (55.9)	18,379 (10.6)	29,990 (17.3)	1,425 (0.8)	4,092 (2.4)
Jeju (%)	924	0	653 (70.7)	3 (0.3)	249 (27)	0	19 (2.0)

Table 4. Energy consumption by sector in Jeju (Unit: 1,000 TOE)

Criteria	Total	Coal	Petroleum	City Gas	Electricity	Heat energy	Others
Total	924	0	653	3	249	0	19
Industry	209	0	130	0	78	0	2
Transportation	359	0	359	0		0	
Residential/ Commercial	302	0	151	3	146	0	2
Public & others	54	0	14	0	25	0	15

The purpose of Jeju's mid- and long-term Roadmap is to establish a regional sustainable energy supply system and to promote new and renewable energy industries throughout Jeju. Korea already has some experience with renewable energy; as of June 2008, 100 thousand homes have adopted solar power systems, accounting for almost 22 MW of photovoltaic power and an additional 8.4 MW is planned for power generation. Solar thermal water heating systems have also been in use since the 1970s, but have experienced technical setbacks. Wind power has also experienced some development with 192 MW of wind power installed by 2007 in Korea.

Table 5. Power generation (2006)

	Generation Facilities (MW)	Generation (MWh)
Korea	65,514	381,180,710
Jeju	631	2,073,144

Table 6. New & renewable energy (2006)

		Korea		Jeju	
		Capacity	Production(TOE)	Capacity	Production(TOE)
Total		-	1,249,920	-	16,012
Wind		78,941kW	59,728	3,210kW	9,196
Solar Power		22,322kW	7,756	427kW	296
Solar thermal		24,314m^2	33,018	269m^2	770
Geothermal		10,007RT	6,208	70RT	28
Bio	Total	-	274,482	-	2,861
	Biofuel	141,597t/y	53,346	-	--
	Biogas	30t/h	77,390	-	--
	Others	-	143,746	4,133t (RDF)	2,861(LFG, RDF)
Fuel cells		270kW	1,670		-

2.2. Energy Development at a National Level

Much of Jeju's positive attitude towards renewable energy comes from the overall Korean desire to achieve sustainability. In Korea's 2008 *National Energy Basic Plan*, goals were set to achieve a 46 percent energy efficiency improvement for newly installed energy and nearly fivefold increase in new and renewable energy by 2030. It is planned to expand photovoltaic power by 44 times, from 80 to 3,504 MW; wind 37 times from 199 to 7,301 MW; bioenergy 19 times from 1,874 to 36,487 G cal; and geothermal 51 times from 110 to 5,606 G cal. Further, there are plans to introduce a renewable portfolio standard (RPS) with mandatory obligation for public buildings, and a *1 Million Green Homes* program supporting wind, ocean, and bioenergy sources of energy. Lastly, the plan seeks to increase investment in research and development (R&D) for wind, fuel cells, and solar power.

Achieving Korea's goals will require an investment of 111.5 trillion won ($93.3 billion USD) by 2030. A large portion of this funding will go towards basic R&D, including the development of specific technologies such as Si PV (Silicon based Potovolatics) by 2015, thin Si PV and CIGS(Copper-Indium-Gallium-Selenide based Potovoltaics) by 2015, and organic PV by 2020. For wind power, goals are to develop 2 MW by 2010 and 5 MW by 2016 with a strong emphasis on wind turbines in urban areas, deploying by 2010. Solar thermal goals are the most aggressive, vying for 10 kW of generation by 2012 and 200 kW by 2013.

Specific policy initiatives include market- and private-driven plans such as a RPS by 2012 including new and renewable energy for public and private buildings; and a major increase in the role of local government. Further, Korea seeks a large increase in private investment through policies including removal of market barriers, an increase in flow of public information, development of new industrial codes, and development of human resources.

3. Regional New and Renewable Energy Pane

Jeju's regional energy planning is based on the *Energy Basic Law* established in 2006, which consists of: (1) energy demand projections; (2) measures to provide reliable energy supply; (3) the new and renewable energy plan; (4) measures relating to carbon emission reductions; (5) district heating development; (6) development of new energy resources; and (7) other energy issues necessary for the region. Specifically, these programs have included policies supporting loans for purchase of renewable energy infrastructure, subsidies for renewable-based facilities, the 100 thousand green homes program, subsidies for solar thermal development, subsidies for local government investment in green technology, certificate programs, training programs, feed-in-tariffs, the formulation of new companies specialized in new and renewable energy, and regulations for mandatory use of new and renewable energy in new public buildings.

Although the development of the 10 MW wind farm in Haengwon(located in Jeju Island) is a noteworthy accomplishment, the wind farm accounts for only 1 percent of Jeju's electricity demand. Another project, the *Green Village Project*, includes 57 households powered by PV electricity, producing 160 thousand kWh/year and accounting for 75 percent of the households' loads. Excess peak electricity is sold back to the grid, thus turning some profit for the homeowners in wind Green Village. However, these projects account for a very small portion of total energy consumption and thus renewable energy development is needed to a much greater degree.

The prospects for new and renewable energy development in Jeju are promising, since 60 percent of the national wind potential is concentrated in Jeju Island if its offshore areas are included. As such, Jeju plans to build 500 MW of wind generating facilities by 2020, accounting for 20 percent of Jeju's total electricity demand at that time. Jeju plans to achieve this level of growth by concentrating on self-generating facilities located close to the end-users and limiting the development of large-scale facilities. Jeju will also consider the development of transmission lines between the mainland and the island, allowing for transmission of excess generation or sale of generation at a competitive rate.

Geothermal development will face barriers of high cost, but is applicable for large-scale projects. Comprehensively, Jeju hopes that the 20 percent target for wind power can be achieved sooner than planned. In the meantime, Jeju will deploy large geothermal generation plants to complement the intermittency of wind and solar power. Landfill gas plants will also provide additional renewable energy. Hydrogen power is a longer-term prospect, but a hydrogen refueling station is already being considered at the site of the Haengwon wind farm for the purpose of introducing a hydrogen car by the end of 2009.

3.1. Wind Power

Jeju has outlined basic goals to foster increased wind power development in the province by maximizing its wind potential for future energy resources. In 2050 produce 440.8 thousand TOE (936.2 MW) potential energy by wind power, accounting for 30 percent of renewable energy supply.

Jeju's public and private investment projects for wind power seek to develop 936MW of wind capacity by 2050 according to the following schedule: 289MW in 2013, 565 MW in 2020, 809MW in 2030, and 936MW in 2050. Out of 809 MW in 2030, 609 MW is scheduled to come from the off-shore wind development. As of 2007 the installed wind capacity in Jeju was only 34MW. As of the end 2008, the installed capacity of wind power in all of South Korea was 236MW.

Jeju Island's first demonstration project for wind power generation was planned by the Korean Government's Ministry of Trade, Industry and Energy and the Korea Institute of Energy Research (KIER), and started operating in February 1995 (CADDET, 1998). In 2003 the first major wind farm was installed in the island. Local government administration has enjoyed broad autonomy while the public support for environmental conservation increases.

For these reasons, Jeju has good prospects to develop renewable energy sources, including wind power.

Jeju has outlined goals to meet 30 percent of its renewable energy with wind power by 2050. The above global trends in wind power development combined with Jeju's excellent wind potential suggest that Jeju could have more than 30 percent of renewable energy supply from wind power. According to the Roadmap, 60 percent of Korea's national wind potential is concentrated at Jeju Island including its offshore areas. This potential should be exploited to the furthest degree possible. In most applications, wind power is least expensive form of renewable energy and Jeju should pursue this technology as its flagship renewable technology.

3.2. Geothermal Power

Jeju has outlined basic goals to foster increased geothermal energy development in the province, especially through building geothermal facilities located close to the industrial sites. In 2050 produce 220.5 thousand TOE (130.1 MW) of energy by geothermal power, accounting for 15 percent of total renewable supply.

This project involves a trial development of geothermal electricity and heating and cooling services for large-scale industrial parks in Jeju. This project will involve the attraction of private capital as well as a feasibility study on a 10MW geothermal plant. The benefits of this project include the development of a true fossil fuel-free city which relies entirely on renewable energy. This will likely prove to have environmental and economic benefits for the businesses located in the industrial park.

In Korea, hydrogen fuel cells, PV, and wind power have been selected as the main areas of development (IEA, 2004). For geothermal energy, Korea has just begun to develop its geothermal resources, and the technology has not been implemented on a large scale. Compared with other countries it is evident that geothermal use in Korea is considerably less than other similar regions. As such, the government should devote greater resources to developing advanced geothermal resources, especially in geographically-promising areas like Jeju.

Geological conditions and economic costs are two crucial limitations for geothermal energy development. Jeju island has abundant geothermal potential and has annual investment plan from year 2008 to 2011. Therefore, geothermal energy could play a significant role in Jeju's renewable energy future.

3.3. Solar Power

Jeju has outlined basic goals to foster increased solar power development in the province. Solar power, especially PV, is currently being heavily researched both in academia and in the industrial sector. Solar power is a broad term that covers many different types of energy production. Among these are photovoltaics (PV) and different types of solar thermal such as solar hot water and large scale solar thermal power. Jeju could build solar power plants by using surplus property within wind farms. A summary of the goals, as discussed in Jeju's Roadmap, is provided here. In 2050 produce 110.1 thousand TOE (449.7 MW) of energy by solar PV power, accounting for 7.5 percent of total energy supply. In 2050 produce 36.8 thousand TOE (681,482 square meters) of energy by solar thermal power, accounting for 2.5 percent of renewable energy supply.

By 2030, the target of Jeju's renewable resources in total will account for 30 percent of the energy supply. Since Jeju island has a high degree of solar insolation, it is projected that solar PV will account for 8 percent and concentrated solar thermal plants will account for 2 percent.

The use of solar power technologies in South Korea is becoming increasingly important to meet the growing needs of energy and address the shortage of energy resources. In addition, electricity generated through renewable energy sources has been aggressively promoted because energy prices are soaring and awareness of environmental issues is increasing. To facilitate more extensive adoption of solar power electric generation, Jeju launched programs and incentive policies aimed at increasing solar energy supply, such as direct funding of solar installations, the green home project, and the construction of the solar power plant. Further, Jeju will create a desalination plant using solar energy, which in effect advances both desalination and solar technologies.

3.4. Biomass and Biofuels

Jeju has outlined basic goals to foster increased biomass development in the province. R&D will be conducted to develop vehicle technology in order to accommodate biogas industry. By 2030, 25 percent of diesel consumption will be replaced with biodiesel (BD20 blend). In 2050 produce a total of 10 thousand TOE (9,479 net cubic meters) of energy by biogas. In 2050 produce a total of 136.9 thousand TOE (161,000 kiloliters) of energy by biofuels. In total, biomass will account for 10 percent of renewable energy supply.

The biofuel projects involve the construction of biodiesel production and supply facilities from 2007 to 2010 and secondly, bioethanol production and supply facilities from 2010 to 2012. The biodiesel(feedstock is Rapeseed Oil) project will have an installed production capacity of 3.4 million gallons (13,000 kiloliters) per year. The bioethanol project will have an installed capacity of 22.1 million gallons (76,000 kiloliters) per year and will produce and supply bioethanol by using discarded citrus for processing.

The biogas projects involve the creation of a biogas facility using livestock manure and other organic waste sources. The goals are to treat organic waste at a rate of 100t/day and produce biogas at 11,000 m^3/day and organic fertilizer at 20t/day. The project will have a total investment of US$362 million (420 billion Won).

3.5. Hydrogen and Fuel Cells

Jeju has outlined basic goals to foster increased hydrogen development in the province. The goal is to provide a hydrogen economy through a focus on hydrogen technology. In 2050 produce 514.4 thousand TOE (455 MW) of energy by fuel cells, accounting for 35 percent of renewable energy supply.

This project involves the construction of a test and evaluation research center for hydrogen and fuel cells. Construction of the research center will have a total budget of US$31.9 million (37 billion Won) (from the Central Government) and had been constructed from 2005-2008 by the Korea Institute of Energy Research. Secondly, the project involves a monitoring project for commercialization of the hydrogen fuel cell vehicle supply. The monitoring project will have a total budget of US$82.8 million (96 billion Won) and will be undertaken from 2008-2010 by the Central Government and Hyundai Motors. This project will include the construction of two hydrogen stations and operation of four hydrogen-electric vehicles (three sedans and one bus). The primary benefit of this project is the development of an integrated system of fuel cells and hydrogen which is produced from domestic renewable energy resources.

The hydrogen source in Jeju could be electrolysis. The electricity of the power needed to electrolysis is wind power. As mentioned before, Jeju has a large potential of the wind power even the electricity consumption of the province is small. The idea to using hydrogen in Jeju is based on surplus wind power which cannot be used due to quality of electricity when it connected to the grid line.

3.6. Specific Development Targets

The Korean central government aims to increase the share of new and renewable energy in electricity generation to 11 percent of total energy demand by 2030 (National Energy Basic Plan in 2008). In response to these goals, Jeju pursues the development of six leading new and renewable projects, including projects for wind, geothermal, solar, biodiesel, bioethanol, biogas, and hydrogen.

Mid- and long-term projections of electricity demand show an annual growth rate of 2.5 percent for Korea and 2.4 percent for Jeju to 2020. The annual growth rate of primary energy in Jeju will be 2.2 percent during 2007-2016; then 1.5 percent during 2017 to 2030; and then 0.7 percent during 2031-2050. Wind power generation will experience rapid growth, accounting for 9 percent of electricity demand in 2011, 17 percent in 2015, and 28 percent in 2020. Renewable energy in total will account for 10 percent in 2013, 20 percent in 2020, 30 percent in 2030, and 50 percent in 2050. By 2030, wind energy will account for 50 percent of total renewable generation, solar will account for 8 percent, concentrated solar thermal plants will account for 2 percent, geothermal 15 percent, bioenergy 10 percent, and fuel cells 15 percent as shown in Table 7.

Table 7. New and renewable energy supply targets by energy source(Unit: 1,000TOE)

Year	2007	2013	2020	2030	2050
Wind	16.0(90.4%) 34 MW	136.2(70%) 289 MW	266.4(60%) 565.8 MW	380.8(50%) 808.8 MW	440.8(30%) 936.2 MW
Solar Power	0.34(1.9%) 1.36 MW	17.4(8.9%) 71.1 MW	56.6(12.7%) 231.2 MW	60.9(8.0`%) 248.7 MW	110.1(7.5%) 449.7 MW
Solar thermal	0.046(0.2%) 848m^2	2.1(0.1%) 38,889m^2	10.0(2.3%) 185,185m^2	15.2(2.0%) 281,482m^2	36.8(2.5%) 681,482m^2
Geothermal	0	7.7(4.0%) 4.5 MW	44.4(10%) 26.2 MW	114.3(15%) 67.4 MW	220.5(15%) 130.1 MW
Bio energy	1.3(7.3%)	30.2(15.5%)	44.4(10%)	76.1(10%)	146.9(10%)
Fuel cells	0	1.0(0.5%) 0.88 MW	22.2 (5%) 19.6 MW	114.3(15%) 101.1 MW	514.4(35%) 455 MW
Total	17.7	194.6	444.0	761.7	1,469.5

3.7. Annual Investment Plan('09-'13 1st step Project)

The Annual Investment Plan for 2009 to 2013 is the first step in a larger scheme. The plan has a total budget of US$718.8 million (833 billion Won). Details on the allocation of the budget are provided in Table 8.

Table 8. Jeju's annual investment plan (Unit : Million Won)

	Total	'08	'09	'10	'11	'12	'13
Total	833,100	101,610	207,527	57,028	178,855	149,040	139,040
Central Government	53,067	5,700	27,767	4,800	4,800	5,000	5,000
Jeju	44,153	7,800	22,953	3,200	3,200	3,500	3,500
Private Investment	627,255	30,500	143,820	41,000	160,855	130,540	120,540
Research Institute	108,625	57,610	12,987	8,028	10,000	10,000	10,000

4. Conclusions

The Roadmap has clearly identified the energy demand and supply up to the target year (2050). The target year of choice is an important component of the regional energy plan. The Roadmap's proposed rates of the development of new and renewable energy sources correlate to each decade and are interestingly proportional as shown in Table 9. Jeju aims for 20 percent new and renewable energy share in 2020; 30 percent in 2030; and 50 percent in 2050. Achieving a 50 percent renewable energy contribution will require aggressive and smartly-crafted policy intervention.

Table 9. Overview of new and renewable energy supply targets in Jeju(Unit : 1,000TOE)

	2007	2013	2020	2030	2050
Primary energy demand	1,708	1,946	2,220	2,539	2,939
Renewable energy	17.7	194.6	444.0	761.7	1,469.5
Renewable share (%)	1%	10%	20%	30%	50%

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Renewable energy policy in Turkey

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Abstract: This study aims to explore the availability and potential of renewable energy sources in Turkey and discuss the government policies and economic aspects. Turkey is a country which has the highest hydropower and wind energy potential among European countries. Current energy policy of Turkey primarily aims to maximize geothermal, wind and hydropower potential of the country in next 15 years. In Several incentives were developed for electricity generation from renewable energy sources by the publication of Law No. 5346 in 2005. The most important ones are: ease of land acquisition and feed-in-tariffs which promises purchasing of electricity generated by legal entities with a price of 5-5.5 €c/kWh. Since Turkey is a European Union (EU) candidate its laws and regulations must be compatible with EU. As the legislation in EU member states is investigated it is apparent that Law No. 5346 should be restructured. This should include: (i) redetermination of feed-in-tariff amount according to type and capacity of renewable energy source, (ii) taking installed capacity into account instead of reservoir area for hydroelectric power plants as renewable energy source, (iii) making detailed Environmental Impact Assessment (EIA) report obligatory for renewable energy plants. The emphasis has been given on hydropower and wind energy. The renewable energy policy of Turkey has been compared with the advanced economies in Europe like Germany and Norway

Keywords: *Renewable energy, EU policy, Turkey.*

1. Introduction

Energy is one of Turkey's most important development priorities. Hence, utilization of domestic renewable energy sources is of vital importance for Turkey to reduce its dependence on foreign energy supplies, provide supply security and prevent the increase in greenhouse gas emission. Turkey's energy policy targets to increase the current share of renewable energy which is 20% to 30% in coming years. Turkey has quite miscellaneous energy resources including hard coal, lignite, oil, hydropower, natural gas, geothermal, wood, animal and plant wastes and solar. However, utilization of these resources is not adequate to meet the demand of the country. The energy demand of Turkey has been growing more rapidly than the energy production since it is a socially and economically developing country (Fig. 1).

Insufficient government efforts have forced Turkey to increase its dependence on foreign energy supplies. Instead of sufficiently promoting the usage of domestic energy resources and taking necessary precautions governments has relied highly on foreign energy supplies.

Thus, for example, the share of natural gas by the year 2005 as a thermal power plant fuel reached to 60% though Turkey has insufficient natural gas reserves [1]. It was reported that 74% of Turkey's total energy demand was met by imported energy in 2007. In Turkey, natural gas and electricity prices for residential and industrial use have increased by almost 8 and 7 times, respectively between 1999 and 2010. Thus, renewable energy sources have become a challenging alternative to fossil fuels for the country. In this study, current situation of renewable energy sources was investigated in detail and energy policies applied in Turkey was scrutinized by taking EU policy into account. The promotion of electricity from renewable energy sources (RES) is a high European Union (EU) priority.

The RES Directive (2009/28/EC) concerns electricity produced from non-fossil renewable energy sources and it states that the share of renewable energy in the total energy consumption of the EU must increase to %20.

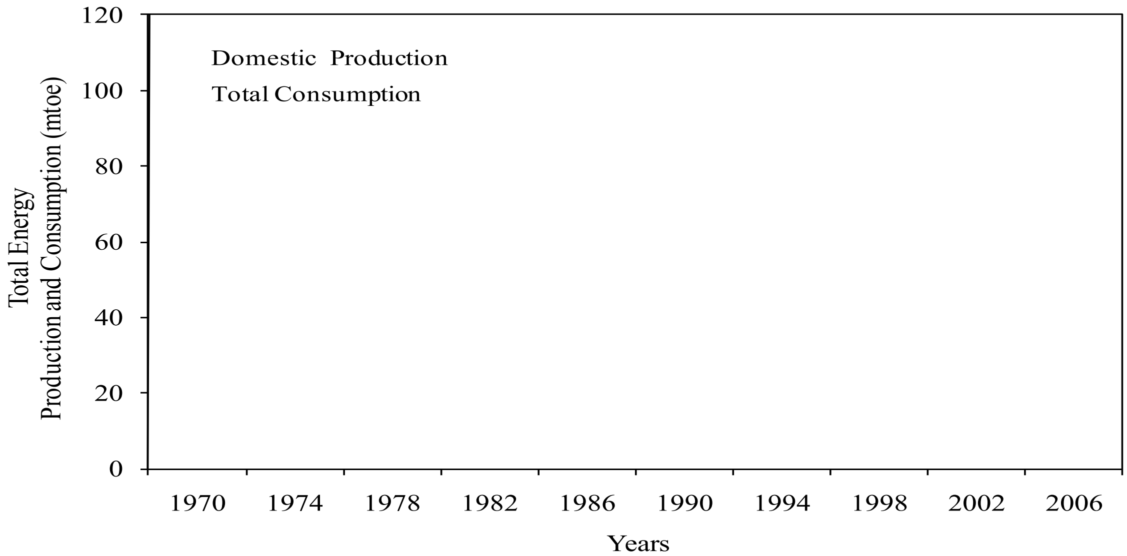

Fig. 1. Trends in total energy production and consumption of Turkey between 1970 and 2006 (data source: [1]).

2. Current Energy Trends and Economic Profile of Turkey

Monopoly of public sector was finished in 1982 in Turkey and private sector was allowed to build power plants and sell the electricity generated to Turkish Electricity Administration. The first law (Law No. 3096) that formed the frame for the participation of private sector in electricity industry was published in 1984. This law constituted the legal basis for private entrepreneurs to build new generation plants by means of Build-Operate-Transfer (BOT) contracts. Law No. 4283 (Law on Building and Operating of Electricity Generation Plants by BOT Model and Regulation of Energy Marketing) which provided the participation of private sector in building and operating of energy plants inured in 1997.

Turkey has become one of the biggest economies around Europe and the world within last 30 years with rapid increase in population and industrialization. According to International Monetary Fund (IMF), by the year 2008, Turkey was 15th biggest economy of the world and 6th biggest economy of Europe with a GDP (based on purchasing power parity) of 915.4 billion USD. In addition, average annual growth of GDP (based on current prices) is 4.3% in last 20 years [2]. Economic growth and increase in population, of course, has brought more energy demand. Annual growth rate and population increase projections show that this trend will continue in coming years. In addition to a number of forecast models developed for Turkey, current authors also proposed a model based on fuzzy logic methodology to forecast gross electricity demand of Turkey [3]. In the model proposed gross electricity demand was predicted only using GDP data. The fuzzy logic model proposed has showed that there is a direct relationship between GDP and gross electricity demand. This finding is also consistent with the literature. Mahadevan and Asafu-Adjaye (2007) stated that for electricity importing countries there is a mutual causality between GDP and energy consumption.

3. Renewable Energy Potential of Turkey and Current Situation

Turkey is quite a rich country in terms of renewable energy potential. Turkey has a significant hydropower and wind energy potential with its coastal line of 7200 km and an average elevation of 1132 m . Turkey's wind energy potential is primarily focused in Aegean, Marmara and Mediterranean regions from higher to lower, respectively. Since Turkey's geological structure has volcanic origin the existence of more than 600 hot water sources whose temperature reach almost 100°C makes the country very rich in terms of geothermal energy. By the year 2009, hydropower, wind, geothermal and wastes (biogas +biomass) is used in electricity production (Table 1).

Table 1. Potential of renewable energy sources in Turkey and current situation in 2009.

Type of Energy	Technical Potential (MW)	Economical Potential (MW)	Installed Capacity (MW)[a]
Hydropower	54,000	42,000	14,553
Wind	114,000	20,000	802.8
Geothermal	1,500	600	77.2
Wastes (Biogas +Biomass)	-	-	81.2
Solar	56,000	-	-

[a]Data source: [5]

Although Turkey has the highest technical hydro and wind power potential in Europe, only very small portion of this potential is used when compared to those countries (Table 2). It can be easily seen that Germany, Spain and Austria is leader countries in developing their wind power potential. This is mainly due to incentive policies that government of these countries implement towards promoting the utilization of renewable energy sources.

Table 2. Comparison of wind and hydropower potential of Turkey to some European countries.

Country	Land Area ($x10^3$ km^2)	Technical Hydropower Potential (TWh/yıl)[a]	Technical Wind Power Potential (TWh/yıl)[b]	Developed Hydropower Potential by 2006 (%)[c]	Developed Wind Power Potential by 2006 (%)[c]
Turkey	781	216	166	20.5%	0.1%
Norway	324	200	76	59.7%	0.9%
Sweden	450	100	41	72.8%	2.4%
France	547	100	85	56.3%	2.5%
Italy	301	105	69	35.2%	4.3%
Austria	84	75	3	46.5%	57.4%
Switzerland	41	43	1	71.9%	1.5%
Spain	505	66	24	38.8%	95.9%
Germany	357	25	24	79.6%	128.0%
England	244	3	114	153.3%	3.7%

Data sources: [a][6], [b][7], [c][8]

4. Assessment of Renewable Energy Policies in Turkey in EU Policy Perspective

Renewable energy sources have gained importance in last decades due to growing energy demand. It can clearly be seen that policies applied by governments towards the utilization of renewable energy sources have a pronounced importance on the promotion of the utilization of these resources. Thus, though their financial and environmental disadvantages, incentive policies and privileges foster the utilization of renewable energy sources. In this context, it is considered that the increase of the utilization of renewable energy sources strongly depends on government policies.

A total of 64 countries are supporting electricity generation from renewable energy sources and 45 countries are offering purchase guarantee by feed-in-tariffs for electricity generated from renewables in the world by the year 2009 [9]. As a result of these policies installed capacities of solar battery and wind power plants increased by 6 and 2.5 times, respectively. For example, after the publication of Renewable Energy Law in Germany in 2000 electricity generation from wind and solar energy in 2007 increased by 5 and 50 times, respectively.

Turkish government primarily targets to increase the share of renewable energy sources in electricity generation to at least 30% while decreasing the share of natural gas below 30%. In this context, Turkish government has planned to make the required changes in Law No. 5346 in 2010 to (i) utilize the whole economically feasible hydropower potential in electricity generation, (ii) utilize the whole economically feasible wind energy potential in electricity generation, (iii) provide full utilization of economically feasible geothermal energy potential of 600 MW, (iv) encourage and expand the utilization of solar energy for electricity generation until 2023. In order to achieve these targets Turkey needs to increase the installed capacities of hydropower and wind power plants to 20000 MW and 19200 MW, respectively within the next 15 years [10].

Since Turkey is an EU candidate its laws and policies are expected to be consistent with those of EU. In terms of energy production EU is promoting electricity production from renewable energy sources to decrease energy import and reduce greenhouse gas emissions throughout the union. Main instruments used in promoting renewable energy in EU are; purchase guarantees by feed-in-tariffs, quota applications and energy tax exemptions. In Turkey first promotion instrument towards electricity generation from renewable energy sources was the publication of Electricity Market Law (Law. No. 4628) in March 2001. In the context of this law, individual and corporate entities built electricity generation facilities from renewable energy sources having maximum installed capacity of 500 kW were exempted from licensing obligations and setting up a company. Moreover, by this law Energy Market Regulatory Authority (EMRA) was founded and private sector entrepreneurs were allowed to build and operate power plants by taking out a license from EMRA. In May 2005, Law on the Utilization of Renewable Energy Sources for Electricity Generation (Law No. 5346) was published in official gazette in Turkey. Renewable energy sources included in the context of this law were; wind, solar, geothermal, biomass, biogas, wave, stream energy and tide, channel, SHP or hydropower production facilities having a reservoir area less than 15 km^2. Some incentive mechanisms were introduced to Turkish market for electricity generation from renewable energy sources by Law No. 4628 and 5346. These mechanisms can be classified as licensing, land appropriation and purchase guarantee by a constant feed-in tariff. Table 3 presents the details of these mechanisms developed in Turkey. Even though these mechanisms were introduced in Turkey markets they are still inadequate when compared to EU countries leading the utilization of renewable energy sources. For example, Germany offers different feed-in tariff amounts for different energy sources specified in German Renewable Energy Law (Table 4). Nevertheless, in Turkey, a feed-in tariff of 5.5 €c/kWh is applied without taking energy source into account and any installed capacity limitations. This issue is considered to cause a serious confliction to EU.

Table 3. Incentive mechanisms offered to individuals and corporate entities by Law No. 4628 and 5346.

Incentive Mechanism	Incentives
1) Licensing	a) Installed capacity of 500 kW are exempted from licensing and setting up a company b) Only 1% of the licensing cost is paid by corporate entities applied to get a license and these entities do not pay annual licensing cost for the first eight years. c) Priority is given for system connection.
2) Land Appropriation	a) Real properties which are either regarded as forest or the private property of Treasury are leased or right of easement or usage permits are given to such properties. b) 85% discount is applied to rent, right of easement and usage permits and Forest Villagers Development Revenue, Forestation and Erosion Control Revenues are not demanded during the first 10 years.
3) Purchase Guarantee	a) Government guarantees to buy electricity generated for 10 years offering a feed-in tariff amount of 5-5.5 €cent/kWh.

Table 4. Feed-in tariff amounts specified in German Renewable Energy Act 2009.

Type of Energy	Feed-in Tariff Amount
Hydropower	12.67 €c/kWh, P<500 kW; 8.65 €c/kWh, 500 kW<*P*<2 MW 7.65 €c/kWh, 2 MW<*P*<5 MW
Wind Energy	9.2 €c/kW, in the first five years after the installation 5.02 €c/kW
Solar Radiation	43.01 €c/kWh, P<30 kW; 40.91 €c/kWh, 30 kW<*P*<100 kW 39.58 €c/kWh, 100 kW<*P*<1 MW 33 €c/kWh, *P*>1 MW

Publication of Renewable Energy Law in Turkey had a clear effect on hydropower development (Table 5) as well as on the installed capacity of wind power which increased from 20 MW to 802 MW between 2005 and 2009 (Fig. 2). Hydropower potential increased by 15% in 2007 as compared to 2006 and planned plants increased by 4 times in the same year. Furthermore, planned installed capacity increased by 7% in 2007 as compared to 2006 and most of the projects at that year was composed of SHPs [11]. Fig.3 presents the status of hydropower energy in Norway and in Turkey. Norway is a country nearly produced its total electric energy from hydropower. But 22.2% of its hydropower potential is not used in order to preserve protected areas [12]. On the other hand in Turkey, the hydropower policy is based on to develop its all hydropower potential which is not complying with the EU Water Framework Directive. However in the country, ecologically sensitive sites should be preserved like the example of Norway.

Table 5. Progress in hydropower plants after the publication of Renewable Energy Law in Turkey ([13], [14]).

	In Operation (2006)	In Operation (2007)	Under Construction (2006)	Under Construction (2007)	Planned (2006)	Planned (2007)
Number of projects	142	148	40	158	573	977
Installed Capacity (MW)	12788	13306	3197	6564	20765	22260
Energy (GWh/yıl)	45930	47590	10518	23620	73851	79177

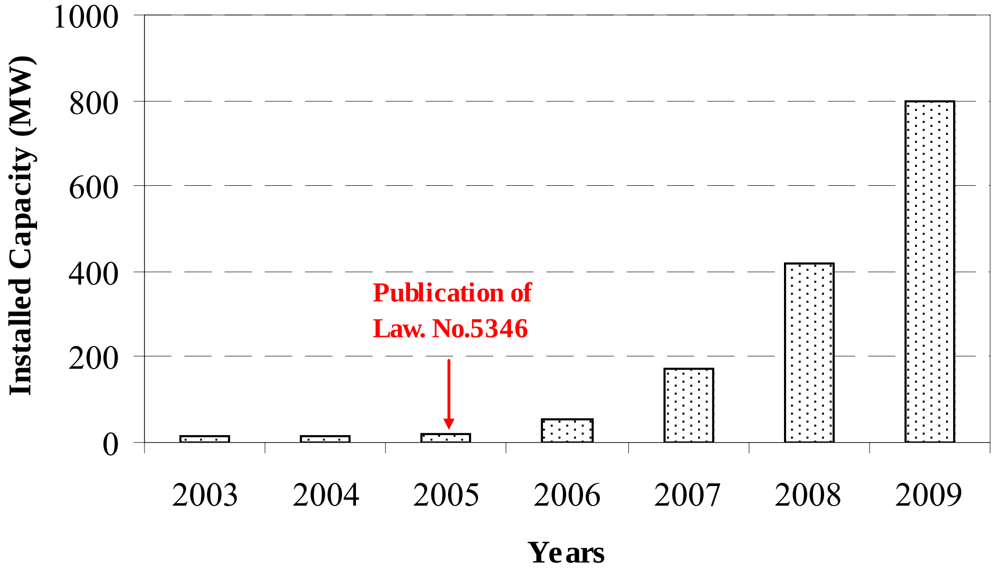

Fig. 2. Progress in installed capacity of wind energy in Turkey between 2003 and 2009.

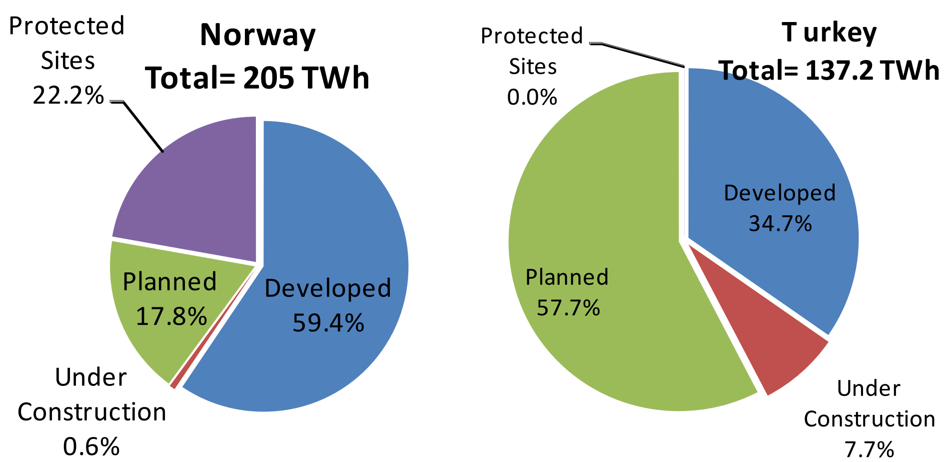

Fig.3 The total hydropower production in Norway and Turkey at the end of 2007 (Data sources: for Norway; [12] and for Turkey; [11]).

5. Conclusions

In this study, availability and potentials of renewable energy sources in Turkey was evaluated as well as the effectiveness of government policies focused particularly on Renewable Energy Law (Law No. 5346) and its compatibility to EU policy. Even though Law No. 5346 contradicts with EU legislations, its effect can be clearly seen immediately after it w as published. Nevertheless, conflictions of Renewable Energy Law (Law No. 5346) published to increase the utilization of renewable energy sources with EU policies creates serious obstacles to achieve this target. First confliction is, on the contrary to EU, the constant feed-in tariff amount offered in Turkey without taking capital investments of specific energy sources into account. Second issue considered as a confliction is that hydropower plants with a reservoir area less than 15 km^2 are considered within the definition of renewable energy defined by Law No. 5346, thus shifting private sector interest from SHPs to big hydropower plants. This issue is handled differently in EU in a way that governments take installed capacity of power plants into account and plants with lower installed capacities get higher amount of incentive. The last issue considered as another contradiction to EU legislation is that no detailed Environmental Impact Assessment (EIA) report is required in the construction of power plants utilizing renewable energy sources in Turkey. However, in EU, the organizations such as Europe Investment Bank investigate the probable harms of a project to the environment while considering financing it [15]. This is a serious confliction as more and more attention is being paid to environmental issues in EU as well as the world.

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Energy and sustainability: public perspectives on what are the issues, who should address them and how

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Abstract: In this work we present the results of a Q -study aimed to systematically represent lay-people's perspective on energy and sustainability issues. Especially we explored lay-people' perspectives on what are the overriding issues related to energy, (e.g. energy security and environmental crisis) as well as which actors are responsible to address these issues. In this context we elicited people's opinions on contested alternative technologies (e.g. nuclear power, wind energy, hydrogen). We were able to identify tree different environmental perspectives and a non-environmental one. Despite interesting common points (e.g. mistrust in the government) the data show dissimilarities in the perception of how the future energy system might look like. The main divergences turn around the employment of nuclear energy and in general of large scale decentralized system vs. small scale one. Although the presence and the distribution of the results in the larger population it is still to further enquire we retain the results useful for policy makers and practitioners involved in the designing, the decision making or implementation phase of new technologies to achieve energy sustainability as well as in the communication activity with the large public.

Keywords: *Lay-people's perspectives, Energy, Sustainability, Q-methodology,*

1. Introduction

Challenges like climate change, energy security or air pollution require a long-term strategic decision making where different policies are designed and implemented today to develop the sustainable energy system of tomorrow. These strategies will change the shape of the current system by supporting certain technologies and promoting certain behaviors (e.g. less car use, more solar panel installations in households).

Ideally these strategies result from the negotiation of the different actors' perspectives in the policy arena. We can define a perspective (or frame [1]) as a constellation of values, beliefs, assumptions and interests, which determines not only the problem that matter but also the boundaries of the solution space. Given that no perfect solution is possible, these strategies reflect the negotiated priorities, values, the issues that should be solved (e.g. energy independence or carbon emission) and how (e.g. biomass, nuclear energy or bicycles).

However this negotiation process is not isolated within the boundaries of the policy arena, but is affected by more or less stable exogenous factors like cultural or technological innovation. A relatively unstable and influential exogenous factor is public opinion, which can affect the process by determining the discussion agenda or by giving more power to certain actors in the arena [2].

In this context we aimed to explore people's opinion on energy related issues, controversial technologies (e.g. biomass, hydrogen or nuclear energy) and other non technical solutions. Especially we aimed to explore how people look at the issue, if and how they construct the problem boundaries and thus define the solution space (perspective thus as a combination of beliefs on what are the problems, who is responsible to solve them and how).

The research aims are resumed in the following research questions: *What are the lay people's perspectives on energy related issues? How are these perspectives agreeing and/or conflicting?*

We expected that divergences in the acknowledgement of the issues and responsibilities by the public would have led to the preferences towards different technologies. Moreover we expected to find other perspectives beside the largely explored environmentalism. Similarly to the environmentalism we expected these other perspectives to lead to the preference (or rejection) towards the different technologies but for different reasons.

Aiming to understand the line of reasoning behind the preferences we opted for a qualitative research method, rather then a quantitative one. After a brief description of the chosen method (section 2) we will present the results of the study (section 3) and discuss them in section 4. We reserved some considerations in the conclusive section (section 5).The study, which is an ongoing research, has been designed to be an intercultural project in two countries: the Netherlands and Italy. For the sake of clarity, in this paper we will be presenting and discussing only the results from the Italian work.

2. Methodology

To pursuit our research scope we chose for the Q-Methodology, which combines qualitative and quantitative techniques to make explicit the different perspectives on a certain topic [3] [4] [5]. The Q-methodology was thought to be particularly suitable to overcome the possible lack of knowledge on the technical aspects of the topic or the absence of a preexisting opinion in the respondents. In fact in a Q-study the subjects are asked to assess a set of sentences through a *likert* scale (for example agree vs. disagree) but in the context of an interview. We thought the sentences, formulated as opinions, would have facilitated people to give reactions at least on the sentences themselves. Moreover, unlike conventional R-surveys in a Q-sort the sentences are not considered singularly but rather ranked and put in relation one to each other. The respondents are asked to distribute the sentences written on small cards in a predefined grid accordingly to how much they agree or disagree with them. The task of ranking is enriched by comments and explanations on the different choices. In this way through a Q-sort (a particular disposition of the cards) it is possible to build up and organize in a structure the personal point of view, even if it was not present before. In other words, the Q-method can either elicit an existing perspective or help in constructing one.

In a second quantitative phase all Q-sorts are statistically related and grouped in shared perspectives. Given the nature of the statistics used, the q-methodology doesn't require big samples, as far as the sample guarantees a sufficient variety of perspectives. This technique hence does not aim to give a representatives distribution of the opinions among the population (such an opinion pool) rather to disclose the variety of perspective on a certain topic and dig into them [4]. The "extreme" positions are frozen as cardinal points between which everybody will than distribute their opinions.

The use of statistic helps the researcher to process more information at the same time and can reveal unexpected results when combining the subjects' profiles. The comments collected during the interviews are used to reconstruct the narratives. Contrarily to a conventional quantitative analysis, the perspectives are enriched with useful qualitative data about the "how" and the "why" certain variables are related. The interpretation of the links among variables derives directly from the point of view of the interviewees and not from the free interpretation of the researcher.

A Q-study entails different steps. Firstly it is necessary to record and resume all the variety of opinions and beliefs that represent the *flow of communication* object of the study. In our case we organized 7 focus groups[1] for a total of 49 people interviewed covering different age and background. We asked people to discuss about what are the main problems related to energy production and consumption and which actors are responsible to do something about it. The entire flow of communication has been reduced into 40 s entences (a sample of them is showed in table 2), which have been chosen to represent the variety of perspectives rather than for their frequency or relevance.

In the second step of a Q-study the respondents (the P-set) are asked, in the context of a single interview, to dispose the sentences written on 40 small cards in a predefined grid, with the shape of a quasi normal distribution. As in qualitative studies the P-set is selected so to represent the maximum variety of perspectives. In our case, we started by collecting the environmentalist's perspectives by interviewing people belonging to association or companies working in the sustainability field but also people living in the countryside and having solar or photovoltaic panels. Starting from few of these people we continued contacting people by snowballing: each interviewee was asked to put us in contact with somebody who thought similarly and someone who thought very differently. With the snowball method we contacted up to the 5th level of interconnection. As a further control variable we looked for people with very different political preference. In this way we got to a P-set of 36 subjects whose characteristics are resumed in table 1. Together with the task of disposing the cards into the grid the subjects were asked to comment the cards and explain the reasons behind their disposition.

Table 1 Socio-demographic characteristics of the Italian P-set. The subjects are all living in the province of Ancona, in the center of Italy. We organized the data dividing the P-set in subgroups according to the political preference. We show the average age (∏) and its standard deviation (Δ); gender (M=male; F=female) and the education level measured in years (high-school degree or less =13y; bachelor degree=16y; master degree or more+18y)

Socio-demographics →	Age		Gender		Education (in years)		
↓ Political preference	∏	Δ	M	F	≤13y	16y	≥18y
Left (PC, 5Stelle,SeL)	29	11	5	2	1	2	4
Center-Left (PD)	46	14	3	4	-	-	7
Center (non specified)	41	10	1	3	-	1	3
Center-Right (PDL-UDC)	40	11	3	2	1	-	4
Right (FN, exAN, LN)	39	13	6	1	3	1	3
No preference	39	13	3	3	3	1	2
TOTAL	39	14	21	15	8	6	22

The last step of a Q-study is the data analysis. With the PQMethod program, we performed a centroid factor analysis and we ortognally rotated the 7 resulting factors through the varimax. To perform the Q analysis we selected four of the seven the factors, which had the Eigenvalues higher than 1.4 of and at least four subjects loading purely (subjects highly correlating only with one of the four factors). The selected factors explained alone the 55% of cumulated variance and are presented in section 3.

3. Results

Through statistic analysis we identified four different factors representing four shared perspective on the matter of energy related issues. Recalling the qualitative information collected during the interviews we reconstructed the narratives of the factors. We also labeled each factor with a title resuming the core of the perspective.

In the following sections (3.1 to 3.4) we resume in few lines the main points of the logics behind the different factors.

3.1. Factor 1 the hopeless environmentalist.

Whatever problem there is with energy (like climate change, pollution or overconsumption) the point is that nobody cares about. People don't care, the newspapers don't talk about these things, the Government does nothing, the technologies are ready but there is a powerful lobby that is blocking their venue in the market. The only way out is that future generation will become more responsible in energy consumption. Therefore education since the primary school is the key solution. Nuclear should not be implemented, because of the waste, because it's dangerous, because it is hold. The decentralization of the energy production is a good idea, so to avoid the transport energy and to keep multinational's hands off the energy. Off-grid houses, usage of urban waste or biomass to produce energy, small-scale renewable energy plants, this is how the future should look like.

Table 2 Example of the 40 sentences composing the set of cards that people have been asked to q-sort in a scale from -5 to +5. On the right side of the table we can see the ranking value of each sentence per each of the 4 factors identified.

	Factors			
Sentences	1	2	3	4
I am a climate-skeptical. I don't think climate change is an issue. There are even scientists that say that it is a normal process and that it has nothing to do with our energy consumption.	-3	-1	0	-5
Humans are more important than nature, we are on top. We should satisfy our needs, but not completely disregard the nature.	-1	-4	3	-2
The majority of oil comes from political unstable countries. We would have a serious problem if the Middle East would close the tap of oil. We should not depend on them.	2	4	5	1
I wish it would be possible to completely independent from the electric grid. I would prefer producing the energy at home on my own.	3	-3	3	2
Maybe we could come back in doing things locally, also energy. It would be nice to produce energy locally and not to transport it	4	-2	2	4
Nuclear energy is good way to solve the issues related to energy.	-4	2	2	-4

3.2. Factor 2, the practical environmentalist

This factor underlines the socio-political aspects of the issue. The real problem is the uncontrolled consumerism: the overconsumption is an issue in itself. This overconsumption is also bringing issue with the energy like the environmental problems: human being is part of the nature and we have to respect it since everything we do against nature will backfire on us anyway. Noteworthy in this perspective the environment is intended as the landscape, the air-quality thus the local natural resources rather than the global issues like climate change. The overconsumption may also lead to less availability of energy and in anyway it is unacceptable to depend on other countries for our energetic needs, especially if they are politically unstable, totalitarian and culturally outdated like the Middle East.

From this perspective the government is incapable of handling this situation, although it should have only a marginal role. The mistrust in the government is compensated by the trust in the liberal market: the change will come from down-up, when the people consume less and better, new sustainable products will diffuse in the liberal market. The Government should support this chain through education, which makes of people responsible consumers.

Concerning the solutions, decentralization is not the future, nor the local production and certainly not the independent houses. Decentralizations means too much responsibility on people and it would be impossible for them to mange all this. Centralized production and the use of existing infrastructure: that is the key. Nuclear is a good compromise: it can increase our energy independence in an economically viable way without harming too much the environment. Using urban waste to produce energy is indeed a good idea, since it solves two problems in one (i.e. where putting the waste and energy availability) while using potential food might be an issue (table x.4.3).

3.3. Factor 3 No to no - Yes to progress, the futuristic citizen

This is the economic and technical focused perspective. The real issue is not the environment: climate change is a natural process and the human activity is too small to have any effect on it. Pollution? We are much more aware of our environment now than in the past and definitively air was more polluted during the industrial revolution than nowadays.The reality is that we need energy for everything we do. We cannot come back to stone-age and consume less: the progress lead us to an increase in the quality of life, we cannot go back! We are at the top of the chain, therefore we have to find a way to have enough energy to satisfy our needs, of course without completely disregard nature. Developing countries are their energy consumption, but in the end energy availability is not a problem: we don't know which technological surprise science holds for us in the future.

The focus of the issue with energy is at the geo-political level. The worries are not for the increasing consumption of developing countries, which means more people pulling the corner of the same blanket, but rather the energy dependence issue. Particularly it is not seen favorably the dependence from Middle East countries (but also from Russia) for our energy supply. For these issues people cannot do a lot. The government should take instead a key role, not only by giving the guidelines, but also giving clear directives to people on what to do. In this discourse technology has a central role. For example if hydrogen is the future, we should go for it. What ever change in the system or in people behavior is needed to realize the future it should have to be pushed top-down, promoted or even imposed if necessary. An example is the smoking-ban. People might be not so open-minded or lack of long-term vision and therefore block the progress.

Progress and technology will give us the solution and it is not possible to say always no to any new technology, like the incinerators or hydrogen. Why not having hydrogen at home or in a car?! What is scaring of new technologies? Terrorism? Why no to nuclear energy? Why no to Methane? Say yes to progress.

3.4. Factor 4 the liberal environmentalist.

From this perspective the current (over)consuming model is leading our society nowhere. We should consume less and better. For instance we should consume locally. This doesn't hold only for seasonal-local food but also for the energy sources. Although technology can help us no technical fix is possible: we need to change our behavior, that is why education to sustainability is so important.

The responsibility of making our world more responsible is equally divided among the different actors: it is true that industry consume and pollute a lot, but we buy their products. We should stop to blame the industry or China for pollution. Also the Government has limited power, since it is a complex international issue, with delicates geopolitical balance.

The government can help with taxation or monetary incentives and especially with education, since a real change cannot come without a deep awareness. The change should be realized bottom-up: the responsible and aware consumers will pull the market, the companies will invest in research and better technologies will be developed. Decentralization is definitively the way to go, so using waste or biomass to produce energy? OK, but these are buffering solutions not the future. In the future we should produce less waste rather than count on them for our energy supply! Nuclear is a 30 years old question, and the answer is NO! (x.4.5)

4. Discussion

In the previous section we described the narratives resuming the four identified perspectives on energy issues and sustainability. The Eigenvalues of the factors are higher than 1.4 and they explain alone the 55% of cumulated variance, both values indicating rather strong results.

The Hopeless, the Practical and the Liberal environmentalist (factors 1, 2 and 4) substantially share an environmental position especially if compared with the Futuristic citizen (factor 4) that instead focuses on the geo-political and technical aspects of the issue minimizing the environmental crises. The three perspectives sharing the environmental focus however, give different meanings the word "environment": from the global aspects of climate change (the *liberal* and the *hopeless environmentalist*) to the aesthetic view of the natural surroundings (the *practical environmentalist*). The fourth perspective (the *futuristic citizen*) claims also the need of a change but in the name of progress rather than a supposed environmental crisis.

The responsibilities of this change are distributed in a different way in the four perspectives: some see the need of a top-down change, with clear indication of what to do, since citizens do not have a long-term view nor enough knowledge. From another perspectives, sustainability can come out of the liberal market as far as people want it: through a bottom-up change the citizens/consumers pull the market by changing their consuming behavior.

As we hypothesized, the four lines of reasoning drive to different vision of the future energy system. It is noticeable the clear-cut anti-nuclear position of environmentalists (the *liberal* and the *hopeless*) as well as the pro-nuclear position of the other two perspectives: the practical environmentalists see nuclear energy as an inevitable necessary compromise, while the futuristic citizen welcome it as any other alternative technology. Although everybody seems to be in favor of the diffusion of the renewable and alternative energy sources, in different measure wind, solar, biomass but also urban waste there is a clear distinction of their role in the future energy system. The decentralization of the energy production, i.e. communities and single individuals producing energy, is seen as a key change from the environmentalists (the *liberal* and the *hopeless*). At the opposite side is the other environmentalist sub-group, the *practical environmentalist,* which sees decentralization as an excess of responsibility on lay-people, while centralized production system should guarantee lower cost of energy and security of supply. The *futuristic citizen* instead seems to give a different meaning to the (de)centralization: the production of energy will be with but not limited to local/individual systems because this is the direction that technology is taking.

Last, we would like to underline an interesting pattern observed in our data: an apparent coherence (but not statistically proven) between the perspective and the political preference. In our sample the *futuristic citizen* seems to be consistent with a *rightist* political perspective; the *liberal environmentalist* compatible with a *leftish* one; the *centrists* (center left and center right) divided themselves among the *hopeless* and the *practical* environmentalist.

5. Conclusion

We started this work asking two questions, formulated in section 1 of this paper as: What are the lay people's perspectives on energy related issues? How are these perspectives agreeing and/or conflicting? We hypothesized that differences in looking at the issue would have led to a divergence in defining the solution space and thus what is acceptable or not from the lay-people's point of view.

We performed a Q-methodology study, which combines qualitative and quantitative techniques to identify the different perspectives and the agreeing/conflicting points. Through this methodology we were able to identify the nuances among the three identified environmental point of views, i.e. the difference meanings given to the word "environment" and the different attitudes towards the issue, i.e. hopeless. Remarkably we identified a fourth non-environmental perspective, which is, to the best of our knowledge, still unexplored in the literature.

According to our results these different frames correspond to different solution space demarcation, e.g. different ways of looking at the future. The hopeless and the liberal environmentalist, these who look at the global environmental issues, claim for a deep societal change. This change is expressed also in a revolution in the current energy system, where the energy is locally produced and managed by people's organization. The same deep change is claimed as well by the other environmental group but it is expressed in a completely opposite way: a business as usual but clean. At the implementation level, the futuristic citizen surprisingly comes in the middle: for different reasons they envisage a combination of the two. If the data result to be externally valid, a special attention should be given in the communication, firstly distinguishing which kind of environmentalist are addressed and secondly by taking into account that other frames are in audience that would also step onboard but for different reasons.

Interestingly but not surprisingly, the data suggest a possible political conflict around the energy issue. Notably political preference and solutions space seem to be strongly related a priori, since few political parties in the Italian political arena have a cl ear program on the topic energy and sustainability.

However, being a qualitative study we are careful in claiming a systematic relationship among frames, solution space and political preference. These aspects could find a (dis)confirmation in a quantitative study. Concerning the external validity of the data, many authors [3] [4] claim that the Q-methodology is capable of disclosing the variety of perspective by means of small samples provided that the latter offers a sufficient variety of way of thinking. However, given the difficulties in our work to identify a priory the "sufficiency" of the variety, it would be interesting to verify how stable are the data and if and how these perspectives are distributed in the larger population.

In conclusion we underlie that according to our results, other frames beyond environmentalism justify the shift towards a new energy system in lay-people perspective; in addition, different frames seam to lead to the preference towards different kind of future energy system (especially concerning the implementation of centralized vs. decentralized systems and the employment of the primary energy sources, like nuclear power.), this aspect deserve further research to be (dis)confirmed. Future research will address the definition and the distribution in the larger population of the above-described frames and solution spaces (i.e. technology preference and policy acceptance). We think that the results can be used by policy makers and practitioners both in the designing and decision making process as well as in the communication phase.

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[i] Six focus groups were conducted with Dutch participants, while one was conducted with Italians (living in the Netherlands from less than 4 years). It might be argued that organizing the focus groups in the Netherlands might have led to overlooked some important issues from the perspective of the Italians. However, during the interviews, we asked to the Italians interviewee if some important aspects were missing. Only one over 36 remarked that a sentence about the "future threat of a war among nations because of energy depletion" was missing. The same topic raised up during the Italian focus group and during the coding was classified under the geo-political topic and thus included in the sentence "The majority of oil comes from political unstable countries. We would have a serious problem if the Middle East would close the tap of oil. We should not depend on them". In this light we think that the 40 selected sentences are indeed representing the main points of the energy related issues including a sufficient variety of point of views.

Performance of Jatropha biodiesel production and its environmental and socio-economic impacts - A case study in Southern India

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Abstract: In India expectations have been high on production of biodiesel from the oil-crop Jatropha. Jatropha is promoted as a drought- and pest-resistant crop, with the potential to grow on degraded soil with a low amount of inputs. These characteristics encourage hope for positive environmental and socio-economic impacts from Jatropha biodiesel production. The purpose of this study was to explore the performance of Jatropha biodiesel production in Southern India, to identify motivational factors for continued Jatropha cultivation, and to assess environmental and socio-economic impacts of the Jatropha biodiesel production. 106 farmers who have or have had Jatropha plantations were visited and interviewed regarding their opinion of Jatropha cultivation. The result indicates that 85 percent of the farmers have discontinued cultivation of Jatropha. The main barriers to continued cultivation derive from ecological problems, economic losses, and problems in the development and execution of the governmental implementation of the Jatropha programme. The Jatropha characteristics were overrated, and the plantations failed to provide income to the farmer. A common factor for the farmers who continued Jatropha cultivation was that they had the economic means to maintain non-profitable plantations. As the Jatropha programme was not as successful as expected, the expected positive environmental and socio-economic impacts have not been realized.

Keywords: *Household interviews, Drivers and barriers, Land use, Rural development.*

1. Introduction

Jatropha Curcas (Jatropha) has been regarded as one of the most promising crops for securing energy supply and for socio-economic development in developing countries. Jatropha is a small tree or large bush that develops fruits containing seeds with an oil content of 32 to 40 percent, which can be transformed into biodiesel [1]. Promoters of Jatropha argue that the biodiesel from Jatropha does not compete directly with food production since the whole plant is toxic and hence non-edible. More importantly, the potential of Jatropha to grow on degraded soil and its resistance to drought and pests enable cultivation on land that is not suitable for food production [2]. The characteristics of Jatropha have raised expectations for positive environmental and socio-economic impacts from biodiesel production.

India is one of the countries that have had high expectations on production of biofuels for secured energy supply and sustainable environmental and socio-economic development. In 2003 the Indian government declared a National Mission on Biofuels, to drive large-scale implementation of biofuel production. The National Mission on Biofuels stated a five percent blending target of biodiesel in conventional diesel, with a 20-percent blending target for 2012 [2]. The Planning Commission for the National Mission on Biofuels announced that Jatropha was found to be the most suitable biodiesel crop for the stated energy, environmental, and socio-economic purpose, and initiated a programme for Jatropha implementation [3]. The Planning Commission estimated land areas needed to achieve the blending target and identified land areas available and suitable for Jatropha cultivation.

2. Description of the study and methodology

This study was performed during the spring of 2010 with the purpose to explore the performance of Jatropha biodiesel production under prevailing energy and agricultural conditions in Southern India. The focus was to identify motivational factors for continuation and termination of Jatropha cultivation and to assess environmental and socio-economic impacts of the Jatropha biodiesel production.

To address the purpose, semi-structured interviews with farmers in the states Andhra Pradesh and Tamil Nadu who have or have had Jatropha plantations were performed with the aid of a translator. Questions regarding the socio-economic situation of the farmers, the performance of their Jatropha plantations, and their reasons for continuing/discontinuing cultivation were asked. Farmers targeted for participation in this study were respondents from a field study performed in 2005-06 by researchers from the Indian Institute of Science in Bangalore which focused on gaining knowledge on the performance of Jatropha plantations in Southern India and the socio-economic status of the Jatropha farmers. Additional farmers were added to the sample during the process to get a more complete picture of Jatropha cultivation within the two states.

The total number of respondents was 106 (77 in Andhra Pradesh, 29 in Tamil Nadu), where 54 were a part of the previous study. A distinction was made between the respondents depending on the ownership of their land, dividing them into three groups; private farmers, community land, and industry/research land. The majority of the respondents were private farmers, having ownership rights to their land or having land assigned specifically to them by the government to sustain their livelihood. Apart from the interview respondents government officials, scientific researchers, and other concerned actors contributed to understanding of the subject through informal discussions.

Three limitations made within the study need to be acknowledged. Geographically the field study was limited to the two states Andhra Pradesh and Tamil Nadu. Regarding the exploration of the performance of Jatropha biodiesel production the study mainly focused on the cultivation stage, since the production process in the studied districts had often not reached further stages. When analysing the results private farmers have been in focus due to that one of the objectives of the study was to assess the socio-economic impacts of Jatropha cultivation.

3. Results

The results of the field study provide information on the performance of Jatropha cultivation, and information on socio-economic status of Jatropha farmers was needed for understanding and further interpretation of the results. For knowledge on socio-economic status the private farmers were asked basic questions regarding landholdings, size of household, occupation and education level. The results indicate that Jatropha farmers commonly have small landholdings and low level of education, and that the economic situation is stronger among Jatropha farmers in Tamil Nadu than in Andhra Pradesh.

3.1. Implementation of Jatropha

The initiation of large-scale Jatropha cultivation was driven by the government through national and state government agencies, and within the states the different district governments were encouraged to design and initiate implementation programmes for Jatropha plantation. The National Mission on Biofuels stated that investments in the implementation of biodiesel production should have been made by the government, for example by using already existing poverty alleviation programmes.

The implementation in the studied districts was driven mainly by agricultural and rural departments of the government, but in some cases also by local NGOs and private companies. A majority of the respondents, 74 percent in Andhra Pradesh (57 of 77 respondents) and 90 percent in Tamil Nadu (26 of 29 respondents), state that the idea of initiating Jatropha plantations came from a government agency.

To promote plantation of Jatropha to farmers the local governments announced incentives in the form of free Jatropha seedlings, financial subsidies, subsidised agricultural facilities, bank loans and promises of future income from the plantations. The involved farmers were also promised information and training in cultivation practices.

3.2. Continuation and termination

The field study shows that a majority of the interviewed farmers discontinued cultivation of Jatropha; 85 percent of the farmers (90 of 106 respondents) discontinued cultivation and 15 percent (16 of 106 respondents) continued, with or without maintenance of the plantations (see Fig. 1).

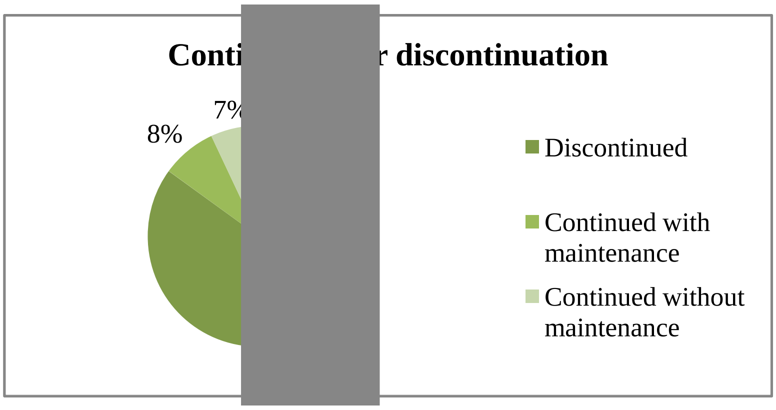

Fig. 1. Percentage of the total number of respondents who have discontinued or continued (with or without maintenance) cultivation of Jatropha.

3.3. Drivers

The field study shows that only 15 percent of the interviewed farmers (16 of 106 respondents) have continued cultivation of Jatropha. Of the continuing 16 respondents nine have continued with maintenance of their plantations and the other seven respondents have stopped maintaining their plantations but have not removed the plants in order to use the land for other purposes. Reasons mentioned for keeping plantations or parts of plantations without maintenance and with no expectation on outcome are costs for removal of the plants and not having any plans for alternative uses for the land.

Drivers to continued Jatropha cultivation mentioned by the farmers were divided into three categories: economic, ecological and implementation (see Fig. 2). Drivers mentioned were hope for future economic possibilities, that the Jatropha plants have a positive effect on other plants, that the plants have survived even if the plantations are not maintained and that the plantations were implemented and kept for demonstration purposes. Each farmer could mention more than one driver.

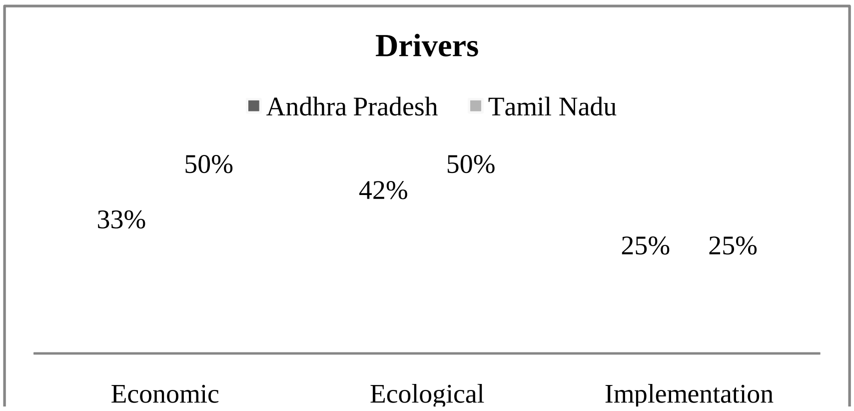

Fig. 2. Percentage of the respondents from both states who mentioned drivers within each of the three categories.

The number of continuing farmers is small, they work under different agricultural and economic conditions and have a variety of reasons for keeping their plantations, and there are no clear differences between drivers mentioned by farmers in Andhra Pradesh and farmers in Tamil Nadu. Hence it is difficult to draw any general conclusions on the drivers for continued cultivation of Jatropha. What can be noted is that all farmers who have kept and maintained their plantations have the economic means to maintain non-profitable plantations. In the case of private farmers or companies who have continued they all have other sources of income and incomes from Jatropha are considered additional. Where non-private actors have continued cultivation, the plantations are undertaken and continued for the purpose of demonstration or research and are not privately funded.

3.4. Barriers

The main reason for choosing Jatropha for the large-scale programme for biofuel production was its agricultural characteristics: the suitability for cultivation on barren and fallow land, the low demand for inputs, and the resistance to pests and drought. Experiences from plantations clearly show that Jatropha production has not been able to meet the high expectations, 85 percent of the interviewed farmers (90 of 106 respondents) have discontinued cultivation of Jatropha.

The farmers were asked about their reasons for not continuing cultivation of Jatropha and mentioned a wide range of barriers to cultivation. These barriers were divided into five main categories: economic, ecological, market, knowledge, and implementation, where barriers within the ecological category were most frequently mentioned (see Fig. 3). The main barriers within the ecological category are connected to problems for Jatropha to grow and yield under poor conditions; 54 percent of the respondents (57 of 106 respondents) state water scarcity and climatic problems as barriers, and 11 percent (12 of 106 respondents) mention insufficient yields. In the economic category the most mentioned barriers are insufficient income from the plantations and cost for labour. The respondents also experienced barriers derived from the implementation of the Jatropha programme; the most mentioned barriers within the implementation category are lack of support from the government or other actor that initiated Jatropha cultivation, and that promises made in the initial stage had not been fulfilled. Some of the reasons mentioned are closely connected, sometimes it is difficult to distinguish one single barrier since one problem mentioned may be the root of another. For example, if low or no income is mentioned as a barrier to continued cultivation, this lack of income may be due to low yields caused by water scarcity.

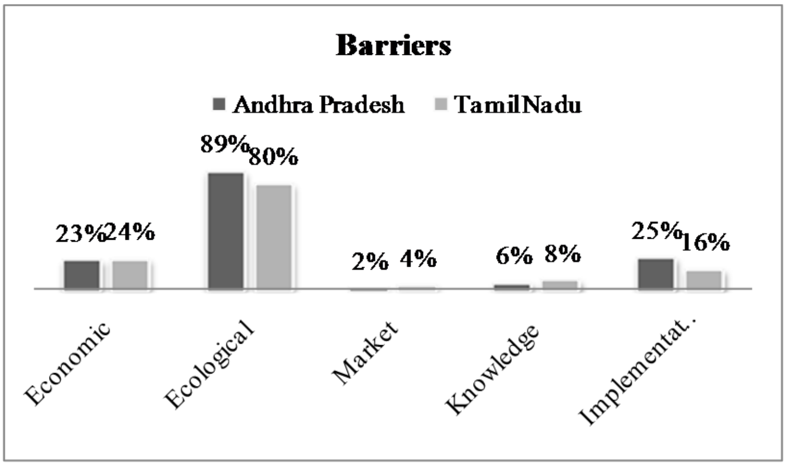

Fig. 3. Percentage of respondents from both states who mentioned barriers within each of the five categories.

3.5. Inputs

Jatropha was promoted as a crop that could survive and yield on barren land without inputs of water and fertilizers. Jatropha's drought resistance provided an opportunity for farmers on rainfed lands, who had been suffering from drought and had not been able to gain yields from their land. But under harsh rainfed conditions Jatropha plantations failed to yield and could often not even survive. The single largest barrier to continued cultivation of Jatropha mentioned by the interviewed farmers was water scarcity. It seems that inputs of both water and fertilizers are needed for survival of the plantations on poor soils. 70 percent of the interviewed farmers (74 of 106 respondents) mentioned that they have been using some kind of irrigation system, and 25 and 32 percent used chemical and biological fertilizers, respectively. Note that these figures do not take amount and frequency into consideration. However, even with inputs Jatropha failed to give satisfying yields.

3.6. Insufficient yields and incomes

One of the most important barriers to continued cultivation of Jatropha was the low or non-existing economic returns from the plantations. In most cases there was no or very low yield, and hence no incomes from harvests to cover the cost for the plantation. 6 percent (5 of 77 respondents) in Andhra Pradesh and 55 percent of the respondents (16 of 29 respondents) in Tamil Nadu harvested seeds from their plantations. The resulting amount of dry seeds from these 21 respondents who harvested ranged from 2.5 to 2470 kgs/ha/year, where only two of the respondents reached more than 370 kgs/ha/year, while the yield suggested by district initiators ranged from 2470 to 12355 kgs/ha/year [4]. Adding to the financial problems many farmers substituted Jatropha for other crops and experienced loss of income from these crops.

3.7. Jatropha plantation details

Jatropha was promoted as a plant that could be cultivated on wasteland, not suitable for cultivation of other crops, to avoid competition with food production. In Andhra Pradesh, 78 percent of the land used for Jatropha was regarded by the respondent as cropland, 17 percent was wasteland or barren land, four percent of the land was used for grazing, and one percent was considered forest land. In Tamil Nadu 93 percent of the land used for Jatropha was cropland, three percent wasteland/barren land, and three percent was used for grazing. In total, 82 percent of the interviewed farmers in the two states planted Jatropha on cropland, which was previously used to grow a variety of food crops that were removed for plantation of Jatropha. However, to consider land as cropland does not necessarily mean that the land is high-quality arable land since there are often discrepancies in what is regarded as cropland depending on who defines it.

In general the Jatropha plantations in both states were kept for a short period of time. Out of the farmers who have discontinued Jatropha cultivation no respondent have kept their plantation for more than 5 years, a majority discontinued within three years, and 33 percent already within one year. The results indicate that the respondents in Andhra Pradesh in general kept their plantations for a shorter period of time than the respondents in Tamil Nadu.

4. Discussion

The results from the field study have provided a picture of the performance of Jatropha cultivation and the experiences of the Jatropha farmers. However, the interviews did not always provide a clear picture of the reasons to problems experienced in the field, and further discussion is needed for understanding of these problems.

4.1. Insufficient yields

One of the main problems encountered during Jatropha cultivation is the failure to reach satisfying yields. To some extent the explanation can be that the expectations on Jatropha characteristics, such as drought resistance and ability to grow on degraded soils, have been too high and that cultivation under poor conditions has failed. But experiences in the studied districts show that even if inputs are applied and plantations are properly maintained the yields have not reached expected levels. The field study has failed to provide any explanation to this problem. When questioned about reasons for yields failing, neither farmers, researchers, nor government officials were able to provide clear answers. They have mentioned reasons such as unsuitability of soil and climate or poor maintenance. One theory, provided during an informal discussion with a representative of an institute involved in Jatropha research, is that cross-pollination by air has created hybrids of different Jatropha varieties that do not possess the agricultural characteristics of *Jatropha Curcas*. This would mean that what the farmers actually grow on their fields is not *Jatropha Curcas* but a variety that is not as resistant and high-yielding as the intended crop.

4.2. Plantation life time

When discussing failing yields, one important aspect to consider is the life time of the Jatropha plantations. Jatropha is not producing any economic yield the first three years, but most farmers have removed their plantations within three years after planting, hence before the time when economic yield could be expected. Furthermore, 33 percent of the farmers removed their Jatropha plantations within one year after planting. This may affect the total perception of yield failure, since the plantations could possibly have yielded if maintained for a longer time. However, most of these farmers cultivated Jatropha under poor conditions and as plantations on similar lands in the area have failed, it is uncertain if this aspect has a significant effect overall.

One explanation for the early removal is that farmers could not afford to maintain plantations without any additional sources of income. Without maintenance, the plantations were in bad condition, which made it hard to expect that a good yield would ever be reached. Another explanation may be in the guidelines for implementation of the Jatropha programme. These guidelines provided the opportunity to implement plantations under already existing poverty alleviation programmes. As a consequence, a large part of the targeted actors were poor and marginal farmers. People living in poverty are constantly in acute need of cash to sustain their livelihood, and many farmers accepted to start Jatropha plantations just to get access to the financial subsidies and loans promised in the implementation programme. The farmers received seedlings to start their plantations, but in most cases other subsidies failed to reach the farmers. Without income, poor farmers could not afford to maintain their Jatropha plantations. With government subsidies or loans it could have been possible for farmers to keep their plantations until the time economic yields could be expected. A prerequisite for this is that the farmers are aware of details regarding yield expectations and the stages of the plantation development.

4.3. Effects of the planning and implementation of the Jatropha programme

Many of the problems seem to root in poor planning and implementation of the national Jatropha programme. It is common practice in the studied districts to make a technical assessment and present a scientific protocol before the release of new crops to ensure compatibility with prevailing conditions. In the case of Jatropha no trials were made, instead district level authorities trusted information from the national and state level, and provided this to the farmers. If studies under prevailing conditions had been made prior to implementation, the inability to meet the expectations on Jatropha´s agricultural characteristics could have been discovered and the government departments could have avoided promotion of an unsuccessful crop to the local farmers. Pre-studies could also have allowed for better-performing varieties to be developed. Better information on Jatropha and its characteristics would have enabled better extension services to the farmers, and the farmers need not have been insufficiently knowledgeable about maintenance and use.

Another problem rooting in poor implementation is lack of government support to Jatropha farmers. The National Mission on Biofuels stated that investments in the implementation of Jatropha production should be made by the government. This would be ensured by subsidies and loans to the farmers. From the interviews it is clear that the incentives promised during the implementation programme often did not reach the farmers. The majority of the farmers received free seedlings as promised. Only 39 percent of the private farmers (37 of 96 respondents) received some kind of support apart from free seedlings. Many farmers mentioned lack of government support or unfulfilled promises as barriers to continued cultivation of Jatropha.

4.4. Land use and competition with food production

One of the main reasons Jatropha was chosen for the biofuel programme was that it would not compete with food production. The Planning Commission identified land areas available and suitable for Jatropha plantation. The identified land areas were on land classified as wasteland, not suitable for cultivation of other crops, to avoid competition with food production. Still, 82 percent of the farmers (87 of 106 respondents) removed plantations of food crops for Jatropha, or planted it on land which is suitable for other crops. One reason for this could be a gap in perception of what is considered wasteland; the government targeted farmers on land they classified as wasteland, while the farmers viewed it as cropland. The reason could also be that economic incentives, promises of higher incomes and pressure from the district authorities pushed farmers to substitute Jatropha for their food crops. The district authorities may have been influenced to implement Jatropha on cropland due to lack of information on the National Mission on Biofuels and pressure for fast implementation from national and state governments. In 2008, the Indian government announced a new biofuel policy that further emphasized some of the issues that were criticised in the National Mission on Biofuels, among these the competition with food production.

5. Conclusions

85 percent of the interviewed farmers have discontinued cultivation of Jatropha due to poor performance. Jatropha biodiesel production was advocated based on the idea that Jatropha could be cultivated on degraded or barren land, that demand for inputs was low, and that the crop was resistant to drought and pests. Experiences in the field show that Jatropha has failed to survive and/or grow on poor soils and that a majority of the farmers planted Jatropha on cropland. The plantations have not been able to tolerate drought as well as expected, and pest attacks have occurred in several cases. Farmers have experienced that the crop requires inputs for survival and growth and have used irrigation, fertilizers, manure, and pesticides. Even when planted on fertile land and provided inputs, Jatropha did not produce a sufficient yield. Problems experienced in the field can be related to the planning and implementation of the Jatropha programme where a major problem is that the implementation was not preceded by studies of cultivation under prevailing conditions. A major problem experienced by the farmers is that they have not received subsidies and other support that was promised during the implementation process.

The Jatropha programme was expected to have positive socio-economic and environmental impacts. However, 82 percent of the farmers planted Jatropha on cropland, which entailed competition with food production. Instead of gaining additional income from Jatropha plantations, farmers experienced financial losses and reduced income. Further, as only small amounts of Jatropha biodiesel was produced, the positive impacts on environment and energy security was not realized.

In Southern India there is still on-going research on Jatropha and hope for Jatropha biodiesel production, but more scientific knowledge on Jatropha characteristics is needed, and development of high-yielding and resistant varieties is required, for Jatropha to become a successful biodiesel crop.

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PURE - Public Understanding of Renewable Energy

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Abstract: Public understanding of science PUS is a central concept among science communicators. Public understanding of renewable energy PURE is proposed as an important sub-concept of PUS. The aim of our paper is to interest and invite renewable energy scientists to join a PURE research project. Four separate important questions for a PURE research project can be identified: (A) Is PURE important? (B) Which issues of PURE are the most important ones, according to renewable energy scientists? (C) What understanding of renewable energy has the general public today, worldwide? (D) How to achieve PURE?

Keywords: *Public understanding of science, PURE, Renewable energy, science communication, science centre.*

1. Introduction and Definitions

Public Understanding of Science is today an established concept. There is even since 1992 a scientific journal with this name. The concept is usually referred to as *PUS*. Bauer [1] has given a 3-fold definition of PUS: (1) "Debunking of superstitions, half-knowledge, complete and utter ignorance, misunderstanding and mumbo-jumbo, and virulent memes that give rise to anti-science." (2) PUS is to "improve science literacy, to mobilize favourable attitudes in support of science and new technology, to increase interest in science among young people and other segments of society, and to intensify public's engagement with science in general and for the greater good of society." (3) "PUS considers common sense as an asset" and PUS research should "chart out the public controversies arising from new developments and in different regions of the world" exemplified by "the impact of the climate of opinion on knowledge production."

During the planning of Sweden's first science centre The Futures' Museum, one of the authors (Broman) gave seven reasons for creating a science centre [2], slightly revised [3]: (1) Give an insight that science is understandable. (2) Awaken curiosity. (3) Give people the courage to experiment. (4) Facilitate public understanding of science. (5) Provide preparedness to withstand superstition and pseudoscience. (6)Amuse and entertain. (7) Provide aesthetic experiences. The reasons have been described in some detail in English elsewhere [4]. Reason (4) is in line with Bauer's definitions (2) and (3), and reason (5) coincides with Bauer's definition (1).

Underlying the statements is the notion that PUS is important, which scientists happily believe, and we of course agree, but it is not as simple as that. There are e.g. so many different sciences (which in turn are divided into many disciplines). A rather popular notion is that "science" is that same as "natural sciences", but that is not the case. Again citing Bauer, science also "includes engineering and medicine, the social sciences and humanities, old and new disciplines with clear boundaries, but also ... fuzzy transdisciplinary techno-sciences." But maybe all different disciplines are not equally important that the public understands?

It is also vital to identify target groups, since some may be more important than other. Loosely defined target groups frequently mentioned are young people (in the world of science centres often restricted to the "7-eleven group" of elementary school children), voting adults, and decision makers. Other interesting groups may include teenagers, refugees, religious fundamentalists, senior citizens, people living in villages as well as cities, just to name a few.

It is also important to identify groups of science communicators. As an example, The European Science Communication Network ESCOnet, 2005-8 developed and conducted a series of workshops on science communication training aimed at young post-doc researchers [5].

Since renewable energy is our main interest, the authors have decided to investigate a sub-set of PUS, namely public understanding of renewable energy PURE. The remainder of this article attempts to give a starting point of a potential research project on PURE. The main questions are "is PURE important?" and, if the answer is *yes*, "how could PURE be achieved, and which means of achieving PURE are potentially useful?"

2. On the Importance of Public Understanding of Renewable Energy

There are several reasons why public understanding of renewable energy might be important. Four of them are these:

(1) The earth is a lonely planet in a vast space, not as crowded as the impression one gets from science fiction movies. For humans to move from a destroyed earth to another hospitable planet is just impossible.

(2) The earth is a planet alive with a dead sister and a dead brother. Venus is too hot for life due (also) to too much greenhouse gas, while Mars is too cold due (also) to too little greenhouse gas.

(3) Anthropogenic influence on the world's climate, in particular climate warming due to release of greenhouse gasses like carbon dioxide CO_2 and methane CH_4 is generally agreed upon among [6].

(4) One major source of greenhouse gases is combustion of fossil fuels, which has to be replaced by increased energy efficiency and large-scale worldwide dissemination of appropriate technologies for harnessing renewable sources of energy.

A reasonable conclusion is that public understanding of renewable energy is important. An important task of a research project on PURE would be to identify pros and cons in this respect. There are also several attendant questions: What do professionals - researchers, planetarians, teachers - say? How interested is the public - and different target groups - in renewable energy, and what do they already know? Which disciplines in renewable energy science are more important than others? A very crucial role exists of common people in the success of this objective of large scale harnessing of renewable sources of energy, since as adoption as well as design, developing, manufacturing etc, would require their participation.

3. How Could Public Understanding of Renewable Energy be Achieved, and which Means are Potentially Useful?

There are of course several different channels that can be and are used in conveying attitudes towards and knowledge of renewable energy subjects: Newspapers, TV programs, books, interactive exhibits in science centres, lessons in the school. Different media certainly attract different target groups. One of the tasks for the project to find out is of course how science centres with interactive exhibits can be used for the envisaged purpose i.e. PURE. It is even not possible to judge all centres the same - it is of course a great difference between large science centres (like Nehru Science Centre in Bombay, Cité de Science and Technologie in Paris or Exploratorium in San Francisco) and small ones (like Ekohuset in Strömstad and Molekylverkstan in Stenungsund; both Sweden).

As has been shown by several authors, among them Franck Pettersen in a master thesis [7], is that a combination of watching a planetarium show and doing experiments related to the show is very useful. (Planetariums used to be devoted basically to astronomy using a classical opto-mechanical star projector. Increasingly, planetariums today concentrate on edutainment shows with astronomic content, using all-dome video technique. Shows related to climate change and its solutions would be easily produced using modern planetarium projectors and would fit nicely under the planetarium dome.) Here are two other voices on interactivity:

Michael Spock, former Director of *Boston Children*'s *Museum*, borrowed the Chinese philosopher Confucius' proverb as a motto for the museum: I hear and I forget, I see and I remember, I do and I understand (cited in [8]).

William Glasser wrote [9]: We learn 10% of what we read, 20% of what we hear, 30% of what we see, 50% of what we both see and hear, 70% of what is discussed with others, 80% of what we experience, and 95% of what we teach.

An important component of achieving PURE is likely to be interactivity and hands-on experience, and useful environments for this are science centres. Some examples of this are shown elsewhere [10] in photographs from the Teknoland outdoor science centre 2000-2001: Yourself a Sundial, Toddlers' Teknoland, Solar Energy Surfaces, The Greenhouse, and The Solar Heated Chess Board.

3.1. Popular Education of Renewable Energy through IASEE and ISREE

International Association of Solar Energy Education IASEE started in December 1989. In September 1990, IASEE became the International Solar Energy Society ISES Working Group on education (see e.g. [11]). Also since 1991, IASEE has arranged a series of symposiums, International Symposium on Renewable Energy Education ISREE, held every or every second year, sometimes as part of the biennial ISES Solar World Congress. At each symposium, between 10 and 30 papers were presented. Most papers have dealt with education in schools and at university level, and certainly school children and university students are important target groups, but here we will concentrate ourselves on the general public.

One of the 1991 ISREE papers presented was *On the Need for Solar Energy Education* [12]. In this paper, elementary and secondary school education, vocational training, university courses, educating decision makers, and educating the general public are treated. An excerpt from the paper reads (slightly edited):

> EDUCATING THE GENERAL PUBLIC
>
> Ordinary people are the ultimate utilizers of energy from the sun and accordingly need basic knowledge in how to make use of this new technology and be motivated to use it. A number of ways to educate large populations are readily available. Some proven examples:

Mass media. This includes newspapers, weekly magazines, radio, and TV. You address professional journalists, and if you manage to teach them some basic facts, they will frequently make o good job in popularizing what they have learned.

Exhibitions. We have built both Science Centre exhibitions (1986 and 1990 on solar measurements for the Futures' Museum in Borlänge, Sweden) and travelling exhibitions (Alternative Energy 1976, Solar Energy Exhibition 1989 [13]). The educational value of an exhibition is greatly improved if it provides hands-on experiences.

Another kind of exhibition is the trade fair with commercial and institutional exhibitors. Such fairs can range in size from the one hundred m^2 or so of exhibits that accompany SERC's Solar Energy Days to the multi-acre exhibition of the UN Conference on New and Renewable Energy Sources of Energy in Nairobi 1981. Such fairs contain up-to-date technological information for many categories of visitors and should be made available both to professionals and to the general public.

Lectures, etc. General admission popular lectures sometimes attract good-size crowds, especially if arranged as debates or panel discussions, or if a well-known speaker is featured. Lectures can also be video-taped, and can, with appropriate solar powered equipment, be shown just about anywhere (see [14]).

Community college courses. These are excellent in giving interested individuals more-than-basic knowledge. The aim of such courses can even be that every participant builds his own solar collector (see [15]).

Another paper at ISREE'91 dealt with renewable energy education and training in an Egyptian village with a programme consisting of public presentations, group discussions, simple solar kits, children competitions, technical training workshops, exhibits with working models, working systems, video-training systems, and a communal library [14].

A regional training workshop was held in Libya in December 1990 with the objective of familiarizing women in developing countries with renewable energy development and technology; the workshop was presented at ISREE'92 [16].

A community college type of educating people that is popular in Sweden is called study circles. A typical study circle consists of a circle leader - the teacher - and 5-10 participants. Especially during the 1990ies, knowledge about solar heating was spread in many locations in Sweden in this form, where each study group built a solar heating system at one of the participants' house, using a popular build-yourself solar collector kit; this was presented at ISREE'93 [15]. A thorough investigation of this kind of education is a case study done by Henning [17].

The importance of public understanding of renewable energy was dealt with at ISREE'02 [18]. In this paper, a result from SAS [19] was cited:

> The study *Science and Scientists* (SAS) asked ten thousand (10 000) 13-year old pupils in 21 countries:
>
> *"What do you want to learn about?"*

"New sources of energy - sun, wind"
was among the 25% least popular answers, and it was much less popular among girls than among boys.
* Why is it so?
* Should we do something about it?
* If so, how?

<u>* Why is it so?</u>
Pupils - and adults - are interested in scientific and technological subjects for a number of reasons:
* Economical reasons
* Usefulness
* Interesting, fun
* Relevant

Renewable energy obviously does not meet these requirements! At ISREE'02, the rhetorical question *Should we do something about it*" was answered with a *Yes*! followed by *If so, how?* and a try to answer [18]:
* Visibility of renewable energy is important
* The school is important
* Media are important
* Exhibitions, Science Centres and Science Parks could be used to meet people of all ages.

Experiences from using science centre exhibits in educating the general public on renewable energy were presented at ISREE'03 [10].

3.2. Renewable Energy Dissemination at Village Level

A large proportion of the Earth's population is rural, and their quality of life could be improved at the same time as their impact affection on climate is decreased by introduction of renewable energy utilization at village level: "Low carbon technology for low-purchasing power people." This includes a multitude of technologies and education of users is therefore critically important. A good example is dissemination of family size biogas plants in India - to date 4 million units and the aim to increase the number of plants to 12 million.

Another example: Electricity for light has quickly become affordable by the development of low-cost white high-intensity low-energy light emitting diodes (LED). Mobile phones are spreading rapidly also among rural people in developing countries, and these are effectively charged using the same small not-so-expensive photovoltaic (PV) modules used for powering LED lamps.

When educating rural people, it should be understood that many people live below the poverty line and that illiteracy is common. It is not always easy as the following example may illustrate [20]. Egyptian authorities wanted in the early 1980ies to implement solar collectors for water heating in a rural area. The farmers however refused to use them for from their point of view good reasons. In an earlier campaign in the same area, authorities had tried to introduce family planning, and the local people suspected that this new technology was just another attempt to decrease their fertility.

4. A PURE Research Project Proposal

As obvious from the preceding chapters, we have for several years been interested in public understanding of renewable energy. We believe however that presently this concept is more important than ever. An interdisciplinary and international science communication project on public understanding of renewable energy is proposed with the hub at Strömstad Academy (www.stromstadakademi.se) in Sweden. It should include both research on the importance of PURE and on the impact of different methods to achieve PURE including determining which methods are best adapted for different target groups.

This means that different target groups have to be approached from renewable energy specialists and energy policy makers to school teachers [21], engineering students [22] and different kinds of end-users. A variety of methods, such as questionnaire studies, interviews and focus groups, should be considered.

We have made a start by supervising Science Communication master students and teacher students at Dalarna University during the last decade. Some of them have written their theses on the impact of experimenting with renewable energy at science centres on school pupils in ages 6 to 18. One example is the thesis of Harahsheh [23], indicating a measurable impact on 15-yr. old pupils on their attitude towards renewable energy.

There is however much more that need to be done. A possible start could be a questionnaire distributed world-wide to a well-defined target group (such as visitors to science centres) aiming at finding out the present level of public understanding renewable energy. We would also like to know how renewable energy scientist grade different topics in PURE.

Please contact us if you would like to participate in the PURE project. The corresponding author's email address is found at the top of the article.

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Potential Renewable Bioenergy Production from Canadian Agriculture

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Abstract: Agriculture has the potential to supply large amounts of biomass for renewable energy production from residues from traditional crop production and from dedicated energy crops. This renewable energy production has significant potential to contribute to the reduction of GHG emissions in the energy sector by using ethanol and biodiesel to displace petroleum based liquid fuels and direct burning of biomass to displace coal for generating electricity. To quantify this biomass potential, we used the Canadian Economic and Emissions Model for Agriculture to estimate renewable energy production from biomass and the impact on agricultural production. We used two scenarios: the first scenario that looks at a combination of market incentives and mandates, and a second scenario that looks at only market incentives. The results show that: in the markets and mandates scenario, biomass production is higher, both ethanol and electricity are required to take place and land use change occurs. Agriculture has significant potential to generate biomass for energy under different scenarios, the incentive mix can have a large impact on the type of bioenergy produced, there is significant potential for GHG emission reductions and there is potential for unintended GHG effects, such as the increased clearing of land for crop production.

Keywords: *Bioenergy, Policy, Agriculture, Greenhouse gas emissions, Land use change*

1. Introduction

For several years, countries have been expanding their production of renewable energy from biomass [1-3]. To date in Canada, most renewable energy has come from grains and oilseeds to supply first generation biofuels. In Canada and elsewhere, significant research is underway on the uses of cellulosic biomass, such as residues and dedicated energy crops to expand the biomass supply available for renewable energy production [4-6].

Climate change is an important issue to governments around the world [7-8]. The effort to reduce net emissions of GHG in Canada could have major implications for Canadian agriculture. Renewable energy production has the potential to contribute to GHG emission reductions by displacing GHG intensive sources of energy. Based on previous analysis [9], the largest potential for agriculture to contribute to reduced GHG emissions is to provide bioenergy feedstocks that would substitute for fossil fuels. However, the use of biomass for renewable energy can have unintended consequences, such as land use change, which could increase GHG emissions from agriculture. Further, the use of biomass for renewal energy has implications for food availability.

Increasing renewable energy production from biomass can be accomplished by mandates that require their use or market incentives, such as a carbon price that rewards emission reductions and is technology neutral. There has been extensive work done at Agriculture and Agri-food Canada (AAFC) on the implications of using biomass for renewable energy. This paper will present results from two illustrative forward looking scenarios that will allow us to examine the impacts of using a combination of market incentives and mandates on biomass production and renewable energy production compared to using only a market based incentive. It will conclude with a discussion of results and highlight areas for future areas of research.

2. Methodology

We used two scenarios that represent possible outcomes for market and policy conditions that could be present in 2017. We then used the Canadian Economic and Emission Model for Agriculture (CEEMA) to estimate how different policy scenarios will affect resource utilization, GHG emissions and bioenergy production.

2.1. Canadian Economic and Emissions Model for Agriculture (CEEMA)

CEEMA is composed of two models – the Canadian Regional Agriculture Model (CRAM) which assesses the regional resource use implications and the Greenhouse Gas Emissions Module (GHGEM) which assesses the GHG emissions associated with these resource changes (Figure 1). The CRAM component of CEEMA was also enhanced to have a limited ability to clear land based on land availability estimates from a mapping and remote sensing overlay exercise.

2.1.1. The Canadian Regional Agricultural Model (CRAM)

CRAM is the main analytical tool used to assess the economic impacts and resource utilization patterns resulting from the scenarios examined. CRAM is a static partial equilibrium model of the Canadian agriculture sector. While CRAM does not give information on the growth of the sector over time, it can provide a very detailed before (baseline) and after (scenario) snapshot of the agriculture sector. CRAM incorporates all of the primary production for both crops and livestock, and also includes some processing activities, such as oilseed crushing, production of biofuels form grains and oilseeds, dairy and livestock slaughter. CRAM is spatially disaggregated across 55 regions in Canada.

For the purpose of this analysis, CRAM used AAFC's 2008 Medium Term Outlook to generate a baseline for the agriculture sector in 2017. This 2017 baseline already includes expectations about the state of the domestic and international biofuels market and assumes that Canada has met its existing target that ethanol replace 5% of gasoline and biodiesel replace 2% of diesel fuel and heating oils [10].

2.1.2. The Greenhouse Gas Emissions Module (GHGEM)

The GHGEM is a spreadsheet based accounting model that translates changes in resource utilization, as determined by CRAM, to GHG emission estimates. It contains modules to estimate direct and indirect GHG emissions from production of crops and livestock. The three greenhouse gases that the model provides estimates for are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) [11]. The emissions can be broadly grouped into the following categories: emissions from farm level activities, emissions that are indirectly related to the farm level activities, emissions from induced economic activities, and emissions from other agro-ecosystem related land use [12].

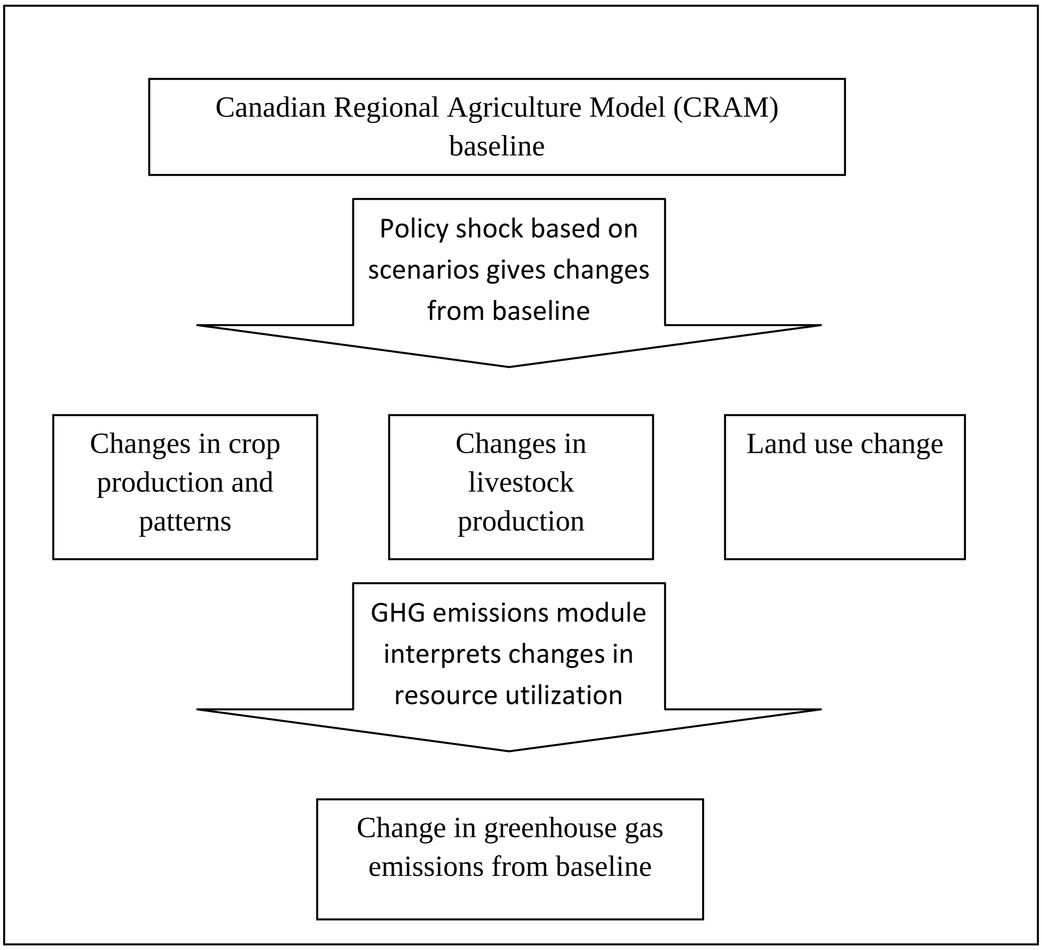

Figure 1. Structure of CEEMA

2.1.3. Land availability estimation

We also enhanced CRAM to have ability to clear land for new agricultural production based on land availability estimates. We estimated the area of non-agricultural land on soils with agricultural potential by examining the intersection of soil capability maps and land cover maps. Soil capability for agriculture maps for most of the southern parts of Canada were created through interpretation of detailed soil maps and aerial photographs under the Canada Land Inventory program (Department of Regional Economic Expansion, 1969) and are available in digital format (Natural Resources Canada, 2008). These maps were intersected with land cover maps derived through classification of 30-metre Landsat satellite imagery by Agriculture and Agri-Food Canada (2008). This data was then used to populate CRAM with information on which regions had land that could be cleared of forest or shrub cover for crop production [13].

2.2. Scenarios

Two scenarios were used. Each scenario is drawn from a family of scenarios that were used for previous analysis. Each scenario allows for the use of corn stover, cereal straw, hybrid poplar and perennial grass for renewable energy production. These scenarios were intended to be illustrative as opposed to prescriptive, given the uncertainty related to what will be the actual policy and market environment in 2017 [14].

2.2.1. Scenario I: "Markets and mandates" scenario

The "Markets and Mandates" scenario is drawn from a family of scenarios that were originally developed to examine the effects of various future renewable energy targets and market conditions on the Canadian agriculture sector. The scenarios consisted of a combination of market drivers and mandates that impact the production of renewable energy. The main renewable energy options in the scenarios are liquid fuels for transport and electricity for the displacement of coal power. Although we considered a range of oil prices, carbon prices, and mandated renewable energy targets, for this paper we are drawing on the scenario with the following characteristics:

Table 1.Policies assumptions in "Markets and mandates" scenario

Market incentives		Mandates		
Oil price ($/bbl)	Carbon price ($/Mg CO_2 eq.)	Ethanol (% of gasoline)	Biodiesel (% of petroleum diesel)	Electricity (% of coal based energy substituted)
120	50	20	8	20

This scenario contains the highest oil price, carbon price, and mandated renewable fuel use. We also required that 50% of ethanol must come from cellulosic biomass.

2.2.2. Scenario II: "Markets only" scenario

The markets only scenario is drawn from a family of scenarios that were developed to look at the impact of a technology neutral carbon price to provide an incentive for renewable energy production. The scenarios looked at the impact of a $10, $30 and $50 CO2e price on the agriculture sector. This scenario did not assume a specific oil price but it is built into the scenario that implementing a carbon price will put some upward pressure on the overall price of energy from fossil fuels. This results in an oil price of roughly $80/bbl. For the purpose of this paper, we will be drawing on only the results from the $50 carbon price scenario.

3. Results

3.1. Biomass production

Biomass production is higher in the markets and mandates scenario. The mandates require that a minimum amount of renewable energy be produced that, in turn, requires the production of large amounts of biomass for various source (Figure 2). Total biomass production in the markets and mandates scenario is 37.3 MT compared with 20.6MT in the markets only scenario.

In both cases the biomass supply is dominated by residues, and the distribution of biomass production among the various types of biomass is relatively similar.

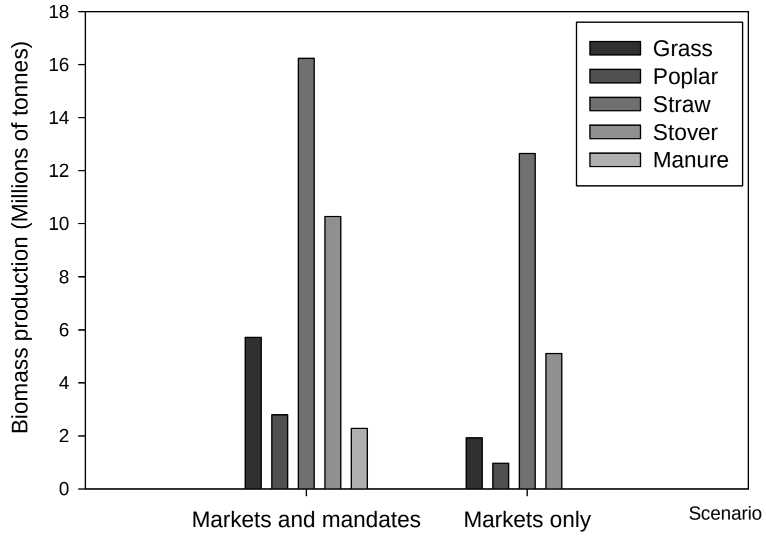

Figure 2. National biomass production by scenarios

3.2. Bioenergy production

In the markets and mandates scenario the production of both ethanol and electricity are required to take place. Production of electricity only takes place due to the mandates, as the higher oil price for ethanol out-competed the effect of the carbon price on electricity production for biomass. In the markets only scenario where the only driver is the carbon price, nearly all of the biomass produced is used to offset coal based electricity as there is far greater emission reduction potential associated with reducing use of coal compared to gasoline.

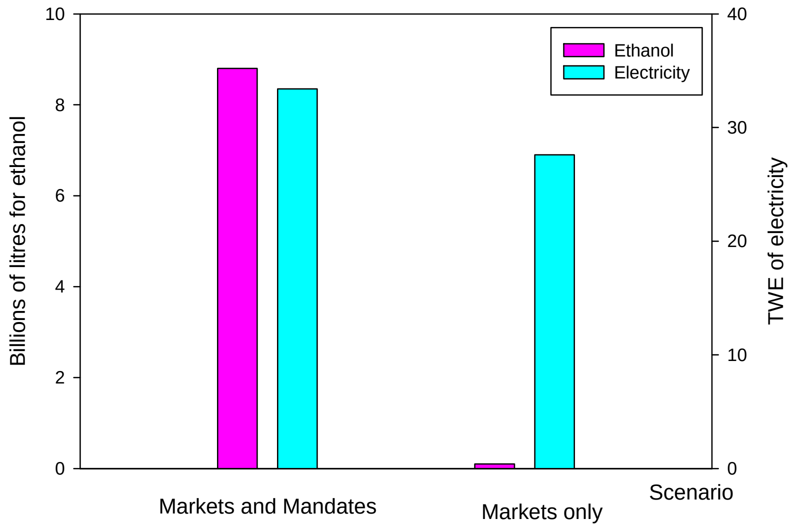

Figure 3. Renewable energy production by scenarios

3.3. Land use change

Land use change occurs only in the markets and mandates scenario. Because this scenario places very high pressure on the agricultural land base to supply biomass, additional land comes into production. Overall 319 kHa would be cleared in 2017 for agricultural production, representing a 1% increase in land available for cropping. There is no land use change observed in the markets only scenario.

3.4. Greenhouse gas emissions

Emissions reductions in the energy sector are much greater than the emissions savings in the agriculture sector (Figure 4). Almost all the emissions reductions in the energy sector are accomplished from the use of biomass to offset coal. Very little emissions reductions are associated with ethanol use.

It should be noted that because of the land use change in the markets and mandates scenario overall emissions can significantly increase. Emissions from land use change could reach 181 MT CO_2e (lower if biomass removed during clearing is used), overriding any initial positive benefit associated with bioenergy production. Over time continued emission reductions from bioenergy production can potentially offset the initial release of carbon, but this will only take place after several years and these future emission reductions are not reflected in the results presented above.

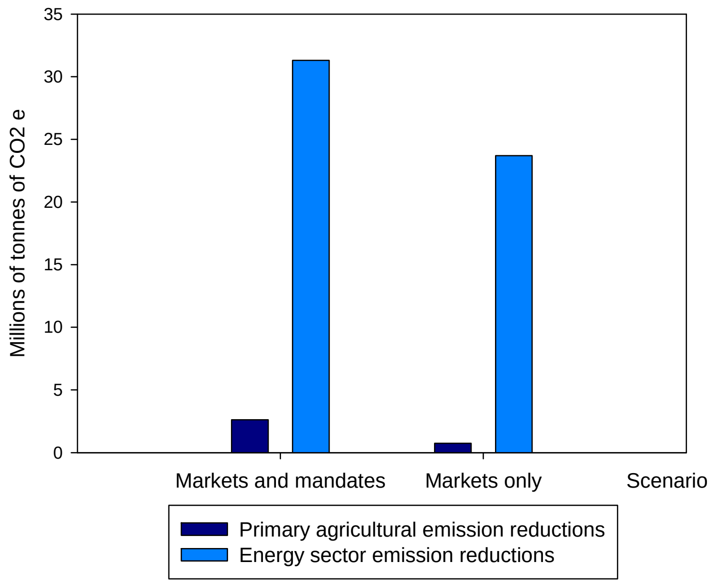

Figure 4. Emission reductions related to bioenergy production

4. Discussion and conclusions

4.1. Biomass production and impact on agricultural commodity production

In both scenarios, the majority of the biomass production comes from the use of residues. Residues generally outperform dedicated energy crops due to the fact that they are a by-product of crop production only require harvesting, nutrient replacement, and transportation costs. As residues come from existing land already under the production of traditional crops they do not have to compete for land the way dedicated energy crops do, and since residues already come from existing land, their use requires less land be used exclusively used for renewable energy production. To meet Canada's current bioenergy target of 5% ethanol and 2% biodiesel that is expected to come from grains and oilseeds, 5% of cropland would be required to provide the necessary feedstock. In the markets and mandates scenario with 20% ethanol, 8% biodiesel and 20% coal displacement this would increase to 16% of cropland used exclusively for bioenergy, not including the impact of increased corn imports from the US. In the markets only scenario, because electricity accounted for almost all the bioenergy produced there was no increase in the use of grains for first generation biofuels. There was some expansion in the production of dedicated energy crops but this amounted to only 7% of cropland as most feedstock came from residues and did not impact traditionally commodity production. Through the diversion of land from traditional commodity production can place additional pressure on the overall system's ability to supply agricultural commodities; the shifts in Canadian production are not expected to impact world commodity prices.

4.2. Renewable energy production

While the distribution of biomass production in the two scenarios is relatively close, the production of renewable energy is not. When incorporating the effects of mandates and a higher oil price, there is a much stronger tendency to produce ethanol from biomass. When looking at the impact of only a carbon price and no mandates, the results show that biomass production is used mainly to displace coal electricity. Mandates require specific renewable energy outputs to be met while the use of market based instruments allows the market to allocate resources.

4.3. GHG reductions

In our modeling framework, GHG-reducing activities will benefit from the carbon market. For example, producing liquid biofuels from grains and biomass, as well as electricity from biomass are assumed to generate GHG reductions that add value to the production activity relative to the strength of their emission reductions. In this analysis using one unit of biomass for coal electricity displacement generated roughly 10 times the benefit of using that same unit for ethanol to displace gasoline. The impact on soil organic carbon with the production of additional perennial crops was also incorporated but it had a relatively small impact compared to the downstream benefits from renewable energy production.

Canada has about 10 million ha of land that has potential for agriculture that is currently and predominantly under shrubs or forest. If the scope of GHG considered in the policy does not include emissions from this clearing this land and land use change occurs, then the emission from that clearing could result in a large initial increase in emissions and it would time for emission reductions from bioenergy to drive the system to being a net contributor to GHG reductions.

4.4. Other considerations and future areas of research

There are other items that are not addressed in this paper such as the longer term impact of residue removal on soil erosion and the broader interaction with the forestry sector. These are important items for future research that will need to be carefully considered related to the large scale production of biomass from residues and dedicated energy crops.

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Drivers and barriers to rural electrification in Tanzania and Mozambique – grid extension, off-grid and renewable energy sources

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Abstract: Mozambique and Tanzania are countries with very low rural electrification rates – far below 5 % percent of the rural population use electricity. The pace of rural grid electrification is slow and for most remote areas access to the national electricity grids will not occur within a foreseeable future. Off-grid (decentralized) electricity grids are seen as a complement and fore-runner to the national grid, making electricity available many years in advance and creating demand and a customer base. Most off-grid systems are supplied by diesel generators which entail unreliable and costly electricity. Alternative off-grid energy sources exist in the region, such as biofuels, wind, micro-hydro and solar PV; but there are significant barriers to adoption, adaptation and diffusion of such RE-based technologies. In this study, the specific drivers and barriers for rural electrification and off-grid solutions in both countries are explored across a stakeholder spectrum. It is part of a larger research effort, undertaken in collaboration between Swedish and African researchers from natural, engineering and social sciences, aiming at an interdisciplinary assessment of the potential for an enhanced utilization of available renewable sources in off-grid solutions. By qualitative methodology, data was collected in semi-structured stakeholder interviews carried out with ten national level energy sector actors. Findings illustrate country-specific institutional, financial and poverty-related drivers and barriers to grid and off-grid electrification, as perceived by different energy sector stakeholders.

Keywords: *Rural Electrification, Off-grid Systems, Renewable Energy, Africa, Drivers and Barriers*

1. Introduction

There is little doubt that access to and use of electricity is a benefit to people, not only in the current electricity-dependent world but also in developing rural areas. While electricity may not bring development on its own it is a highly desired commodity and a prerequisite to rural development in long term perspective [1] [2]. In the first industrial countries massive electrification was initiated in the 1880's, to be completed only decades after the World War II; a huge effort backed by powerful institutions. The challenge is now to spread the same technologies in emerging economies with often very different institutional, cultural and financial conditions. One such region is sub-Saharan Africa where the electrification level is minute – especially in rural areas.

In this study, the current and future prospects for rural electrification (RE) in Mozambique and Tanzania are assessed in terms of drivers and barriers for RE through grid extension and off-grid solutions; based on interviews with key stakeholders from government, international donors, private sector and civil society in both countries carried out during 2010. The aim is to conduct a cross-sector analysis of country specific drivers and barriers to successful RE and use of renewable energy sources (RES) in off-grid systems, as perceived by stakeholders influencing the development in each country. Both countries have very low RE levels and there is a long history of Swedish bilateral partnership within the energy sectors. The analysis reveals important drivers and barriers at national and local level, some of which are not addressed in literature reviewed. The paper starts with a description of current conditions for RE in sub-Saharan Africa. Thereafter, the electricity sub-sectors of Tanzania and Mozambique are outlined followed by a section on method. The results for each country are presented and discussed, followed by conclusions.

1.1. Prerequisites for rural electrification in sub-Saharan Africa

In any country the construction of electric grids to distribute power in rural areas is an infrastructure assignment carrying huge expenses, not less so in most African countries where existing infrastructure is rudimentary. In Africa and elsewhere, RE has largely been the responsibility of the public sector, which in the African context generally implies a large influence from donors. In comparison with industrial countries and own ambitions, RE in Africa has been progressing at a slow pace. In order to speed up the process and involve the private sector as encouraged by the World Bank, many African countries have in later years taken on energy sector reforms, strategies which have yet not shown intended results [3]. The large distances and low incomes make distribution expensive and rural customers financially unattractive to private sector investors.

Expenses associated with vast distance could be met by decentralized grids in wait of full grid coverage. Such off-grid approaches for supplying electricity in remote areas are frequently powered by diesel generators which are dependent on fuel transports for operation, and generate a comparatively higher running cost. An alternative to diesel powered off-grid are available renewable energy sources (RES). In sub-Saharan Africa the potential of RES is high [4] and particularly micro hydro power and solar photovoltaic (PV) have been utilized so far. Due to the low population density and geographical distances, RES are often the least-cost alternative and financing instruments like the Clean Development Mechanism can become an important driver for RES in both countries [4, 5].The extensive pan-African literature covers progress and constraints of such RES based off-grid implementations [6] [7] [8]. Moreover, development programs have addressed the use of PV systems, solar home systems (SHS), in rural households which have resulted in an internal market for these technologies in some countries. The SHS trend is accompanied by a substantial impact assessment literature. Rural area energy transition is not unproblematic and several barriers have been identified – both regarding RE in general and regarding the use of RES in off-grid in particular. An earlier literature review [9] identified barriers within the following areas: institutions and stakeholders performance; economy- and finance; social dimensions; technical system and its management; technology diffusion and adaption; and rural infrastructure.

1.2. Rural electrification in Tanzania

Tanzania's current electricity generation relies heavily on hydropower; secondary sources are domestic natural gas and imported oil. In 2008 the total power generation capacity was 1100 MW. The transmission grid covers a minor part of the country leaving out most areas, particularly western and southern regions. District capitals and other important centers are supplied by diesel generators. The RE level is currently 2% (2009). There is an outspoken intention to utilize the prominent availability of RES, in particular for enhancing RE [10]. Still, there is little use of RES for electricity generation and only 13 % of the disbursed budget 2008/2009 was used for RE and RES altogether (corresponding to 1/3 of what was used for the gas and petroleum sector).

The Tanzanian power subsector, under the Ministry of Energy and Minerals, is dominated by the public agency Tanesco (Tanzania Electric Supply Company). An energy sector reform has taken place during the last decade, leading to the enactment of the Electricity Act in 2008 [10]; private sector is now encouraged to take an active role within the sector and a regulatory oversight of the tariff system is ensured by the EWURA (Energy and Water Utilities Regulatory Authority), established in 2006. The responsibility of RE has been transferred from TANESCO to the Rural Energy Agency, REA, which became operational in 2007. REA is responsible for facilitating RE which is done by supporting applicants (public, NGO or private) with grants for organizational learning and for capital investment (normally covering up to 30% of the project). Other important actors are donors, who provide major parts of the energy budget, NGO's (primarily TaTEDO) and international consultants.

1.3. Rural electrification in Mozambique

In Mozambique the electricity generation is heavily dominated by the 2075 MW hydro power station Cahora Bassa, situated in the north western part of the country. Cahora Bassa, a few smaller hydropower stations and a back-up coal power station supply all electricity to the national grid. The lion share of electricity from Cahora Bassa is exported to neighboring countries but transmission lines reach the largest cities and some towns. Since the country is stretching over enormous distances transmission losses are significant and the power supply becomes fragile in the outskirts of the grid. Numerous diesel generators have been allocated to supply smaller and remote districts. In difference to Tanzania the country has endured a long lasting civil war, ended in 1992. Since then the efforts in grid extension have been significant; still the RE level was below 2% in 2007.

EdM (Electricidade de Moçambique) is the governmental utility responsible for electrification (generation, transmission and distribution) in Mozambique, but a restructure is considered. EdM buys most of its distributed electricity from the Cahora Bassa dam to low costs which somewhat complicates competition and introduction of other energy sources. The private sector, however, are free to contribute. EdM carries out RE by extending the national grid and the tariff is regulated by the Ministry of Energy. Another public institution is FUNAE (National Fund for Rural Electrification), founded in 1997 and strongly supported by donors, in practice responsible for rural off-grid electrification mainly using diesel generators and solar PV systems. Like in Tanzania, foreign consultants play an important role both in development of national strategies and project specific planning. In Mozambique very few NGO's are involved in RE.

2. Method

The study was conducted during eight weeks of field work in Tanzania and Mozambique in January-March 2010. By qualitative methodology data were collected through interviews with stakeholders. The interviews addressed six themes: (1) current state of the electricity infrastructure in rural areas; (2) institutional and socioeconomic drivers and barriers to RE; (3) productive uses of electricity; (4) potential for off-grid and renewable energy systems; (5) local participation in electrification processes; and (6) impact from electricity on people's lives. The themes were based on a review [9] of mostly African-related peer-reviewed literature (results presented in Table 2 alongside interview results). The interviews were recorded (unless circumstances made this impossible) as sound files. The interviews were semi-structured, i.e. asking open-ended questions, using an interview guide, and considering the professional experience of the respondent [11]. This paper presents the findings from 17 interviews carried out with government staff, donors, consultants and NGOs. The respondents were selected based on their influence in and experience of RE processes. Some interviews are with two or three respondents at the time. Our analytical strategy is based on theoretical propositions [12] and the concepts of 'drivers' and 'barriers', which are commonly found in the management literature, but are also commonly used by stakeholders in the field, as to signify factors that enhance or hinder the wished-for development.

The interviews have been transcribed and then analysed using the Atlas.ti software for qualitative data analysis. Each interview is read through and then all meaning units (quotations) are sorted into subcategories (e.g. "communication problems"), that are part of categories (e.g. "barriers for RE") which are in turn related to the themes. This type of analysis combines a deductive analysis (categories are based on the themes of interest) with inductive analysis (subcategories emerge from the material) in an iterative process [11]. The software then allows for analysis of e.g. specific categories, subcategories and Boolean queries. The result is a cross-sector mapping allowing for comparison between various perspectives, organizations and between countries.

Some methodological weaknesses should be pointed out. First and foremost, the analysis is limited in scope both in terms of number of respondents and time allocated in each interview. The respondents are in general very knowledgeable in their area and much more can be learnt from each stakeholder. For practical reasons, only one interview was held with each respondent, implying that the analysis reflects what stakeholders found relevant at a specific point in time. However, the format of semi-structured interviews allows for respondents to reflect on their own answers and bring up additional aspects even if not asked for. Second, there is always a risk of misunderstandings, due to lacking language skills. Interviews were held in English and translated by local interpreter when necessary. Further, information given must be assessed critically as respondents may lack knowledge or hold subjective perceptions that are inaccurate in some areas. Such weaknesses are addressed through triangulation of findings. It also matters if there are sensitive issues to which respondents are unwilling to answer. The question of biases in interviews, the concepts of reliability and validity (coming from quantitative science) are discussed in length in literature and take on a slightly different meaning for this type of analysis [11]. In this study, trustworthiness of results is sought by two researchers searching for inconsistencies and comparing findings to existing literature.

3. Results

3.1. Indicated drivers and barriers for rural electrification

Results of identified barriers and drivers are shown in Table 1 and 2 respectively, and discussed in section 4. The respondents' reflections regarding the potential for renewable energies are not included in the tables but presented in the following section (3.2.).

3.2. Respondents' reflections regarding the potential of renewable energy sources

Among the renewable energy sources known to be available in the region micro/pico hydro power were evidently the source most appreciated among respondents. In Mozambique most respondents and in particular the EdM were very enthusiastic about the potential of micro scale hydro for off-grid applications (notably, no larger expansion of hydro power have been undertaken since colonial time in the country). Apart from hydro power EdM showed little interest for renewable sources. In Tanzania the potential exploitation of new hydro power resources, including micro scale, was greatly advocated by Consultant A who also stated that hydro power expansion in Tanzania are being successfully counteracted by the gas lobby. Hydro power has the strong benefit of higher capacity than e.g. solar PV while the flipside of the coin are the seasonal droughts that in particular have affected Tanzania. Regarding wind power there were little support in both countries, with skepticism related to costs and fluctuations. However, wind power got some support from Tanesco's research division. Solar PV is used for off-grid electrification in both countries still it was referred to as generally expensive and of low productive use. Regarding geothermal energy conversion Consultant A reported that a previous assessment has indicated good resources but low political interest.

Table 1. Identified barriers or constraints to successful RE in general (B) and to off-grid electrification in particular (b) extracted from stakeholder interviews and Africa-related literature (L). Tanzania: 1=Tanesco, 2=REA, 3=TaTEDO, 4=Donor, 5=Consultant A. Mozambique: 6=EdM, 7=FUNAE, 8=Donor, 9=Consultant B, 10=Consultant C. Number of interviews: i-iii.

Identified barrier	Source										
	L	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
		iii	*ii*	*i*	*ii*	*i*	*iii*	*ii*	*i*	*i*	*i*
Institutions and stakeholder performance											
Low institutional quality	B				B	B	B				B
Inadequate planning capacity	B	B			B	B			B		
Organizational structure and strategies	B					B					
Lack of co-investments (rural develop.)	B					B					
Lack of private sector involvement	B		b		B						
Incompatible donor policies						b					
Top-down management in energy sector				b	B	B	B				
Economy and finance											
Tariff system and connection fees	B		b		B	B					
Subsidies	B		b		B						
Insufficient rural financial institutions	B		b		B						
Poor rural market and low productive use	B	B	b		b		B		B	B	B
Admin. costs in small off-grid systems	B									B	
Compensation (in land acquisition)		B									
Lack of consistency between RE projects		B									
High costs of diesel		B		b			b	b		B	b
Donor dependency					B	B	B		B	B	
Social dimensions											
Poverty and low household affordability	B	b	b	b	b	B	B				
Gender issues	B			b							
Problems in local participation and theft	B								B		B
Lack of local engagement						b		b			
Change of mind among costumers								b	B	B	
Technical system and local management											
Lack of access to skilled personnel	B		b							B	b
Weak maintenance culture	B			b		B				B	b
Low capacity of solar PV systems	B					b		b			
Low access to required components	B	B					B	b			
Low generation capacity						B	B		B		B
Technology diffusion and adaption											
Unwillingness of behavioral change	B		b	b							
Users' low awareness of techn. potential	B										
Lack of local entrepreneurship						B	B				
Rural infrastructure											
Scattered population	B	B				B	B	b	B		
Limited rural infrastructure (roads etc.)	B					B					
Long distance transmission							B				B
Traditional houses (electricity prohibited)					b	B					
Devastating cyclones										B	
Nature reserves and national parks					B	B	B				

Table 2. Identified drivers to RE in general (D) and to off-grid electrification in particular (d) extracted from stakeholder interviews. Tanzania: 1=Tanesco, 2=REA, 3=TaTEDO, 4=Donor, 5=Consultant A. Mozambique: 6=EdM, 7=FUNAE, 8=Donor, 9=Consultant B, 10=Consultant C. Number of interviews with each organization: i-iii.

Identified driver	Source									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	iii	*ii*	*i*	*ii*	*i*	*iii*	*ii*	*i*	*i*	*i*
Policy and poverty mitigation ambitions										
Governmental policies and subsidies	D	d	d	D	D	D	d	D		D
Political campaigning	D					D			D	
Donor push / support			d	D	D			D	D	
Pushing from individuals in gov. agencies					D					D
Private sector involvement										
Market incentives	D	d							D	
Churches		d			d					
Social responsibility in private sector						D				
Niche market for certain energy systems								D		
Local demand										
Increasing demand (industry, households)	D	d	d			D	d	D		D
Grass-root organizing				D		D	d			
Off-grid RE creates demand for grid ext.					D					D
Other										
Need of increased sustainability in grid						D		D		
Promotion of renewable energy / CDM				d					d	

4. Discussion and conclusions

According to stakeholders, the main drivers for RE in Tanzania are political priorities.
Tanzania confronts challenges both at the national and local levels, while no references are made to important actors at the intermediate level. Tanesco is considered the main actor but with major financial and organizational problems. According to donors and consultants, lack a of planning at government level is a main issue, causing inefficient implementation and financing problems – in fact only a minor part (14%) of available funds for energy projects in 2008-2009 were disbursed on time. The opening up for private sector involvement is considered a driver but so far little private investment is taking place in RE. Low return rates, political setting of tariffs and a weak customer base in rural areas makes RE unattractive. Tanesco and REA both use economical potential and productive energy use as indicators for RE planning, still, much would be gained if RE projects would also be accompanied with complementary infrastructural investments according to experienced consultants. Among local barriers, most stakeholders mention poverty and low population density – the latter having huge impact on both distribution and transmission costs. Despite low tariffs (that are financially unviable), rural customers find it difficult to afford connection and subsidies are often used to overcome this barrier. To find a level appropriate both for satisfying consumers and encouraging private sector incentives in the energy sector is difficult. For off-grid, all stakeholders agree that diesel generators are costly and unreliable, but where grid extension is not economically feasible, off-grid solutions are necessary for political goals to be attained.

Also in Mozambique, political ambitions are considered the main driver for RE, for social and economical reasons. EdM regard RE as means to slow urbanization, providing better health care and education, and lower birth rates in rural areas. The lack of industry poses a barrier as

RE is not commercially viable and in comparison to Tanzanian agencies the emphasis on prevalent economical potential and productive use are seemingly not used as a strong indicator of where to direct RE. New generation is needed; Mozambique is depending on the large hydro plant Cahora Bassa and long distances leave most of the country without power. Another recognized barrier is that private actors find it hard to compete with Cahora Bassa's cheap electricity. The energy sector is top-down oriented and donor dependency creates problems in budgeting; the budget becomes more of a wish-list than a planning instrument. Diesel generators are very common for small-town electrification and rural off-grid systems but very costly and unappreciated. There is a good hydro potential but virtually no expansion have been implemented since colonial times. FUNAE has a major mission carrying out off-grid throughout the country but is still a rather limited and new organization. Off-grid barriers are high costs of diesel, logistics (incl. spare-parts), and communication with costumers due to bad infrastructure. For sustainable off-grid solutions, a technical support system is needed to facilitate maintenance, and most probably there are huge benefits waiting in micro hydro power. Local people's engagement is important but variable, according to FUNAE, impacting off-grid system sustainability. Along the coast, the occurrence of cyclones destroys infrastructure and impedes investments.

In comparison, the two countries face similar challenges with low population densities, weak customer bases, large distances and inadequate infrastructure. While domestic actors regard social demand as an important driver for RE this view is less pronounced by the foreign actors who rather regard the (lack of) economic demand as a barrier. At the national level, both countries rely on external funding for RE, but low institutional capacity and quality – both countries suffer from corruption and politically motivated but economically unviable plans– hinder efficient implementation and use of funds. There is political recognition that grid extension needs to be complemented by off-grid solutions, but the responsible agencies are yet to become fully operational.

The drivers and barriers identified in this study are largely corresponding to those in the literature, as can be seen in Table 2. However, the problems associated with donor dependency and how this impacts budgeting and implementation comes out as important constraints for both countries, which is not discussed in any detail in the RE literature. Institutional weaknesses are often discussed in terms of bad governance, but in Tanzania the lack of correspondence between local realities and donor criteria for RE projects also create institutional barriers. In this study it further found that traditional building techniques (using mud and grass) in rural areas slow down connection rates; a barrier not previously emphasized. All stakeholders turned out to share a view on diesel generators as expensive and unreliable. Here, appropriate RES could assist but the interest among stakeholders is weak. A barrier with certain relevance for the region is the reported lack of complementary services and co-investments to accompany RE. Here, Tanzania seems to have taken more account of recognizing other rural development when carrying out RE. In sum, our results support earlier findings but complement with country-specific drivers and barriers. To be remembered, importantly, RE takes decades to implement even in the wealthiest country; due to strong political ambitions, donor support and an accumulating experience among stakeholders the rate of electrification is keeping up in both studied counties.

The methodological weaknesses are primarily due to time constraints and a follow up on sector development over the coming years would improve credibility of finding. This study provides an assessment of drivers and barriers to RE that is broader in scope and more detailed than earlier writings, and provides an excellent basis for cross-country comparison and in-depth studies for each country. It is also valuable for stakeholders, such as donors, consultants and policy makers, to gain overview of challenges to address.

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Renewable energy policies implementation drivers and barriers for Abu Dhabi

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Abstract: Climate change and fossil fuel depletion are the main drivers for the recent focus on finding alternative energy resources. Renewable energy (RE) is an obvious choice to reduce carbon dioxide and other pollutants contributing to global warming. However, the high cost of RE technologies is the main obstacle facing the diffusion of RE power generation, therefore economical and political intervention is inevitable. In the United Arab Emirate (UAE) population and economic growth are the main reason of a fast increase of energy demand, leading to two problems, first the UAE has one of the highest carbon footprint in the world and second, the fast depletion of its main energy generation resource – fossil fuel, which highlights the need to establish a RE sector. In this study, literature reviews are conducted covering 61 countries focusing on their efforts to adopt RE resources in the power generation sector as well as policies implemented by their respective governments and decision makers. Furthermore, we investigated the applicability of the main RE policies implemented worldwide in the Abu Dhabi - the capital of the UAE- context. As a result of our analysis, we recommend to apply a mixed policy of Feed-in-Tariff (FIT) and the Quota system for RE electricity generation in order for the UAE to meet its 7% target by 2020.

Keywords: *Renewable Energy, Renewable Energy Policy, Masdar Initiative*

1. Introduction

Climate change and fossil fuel depletion are the main drivers for the recent focus on finding alternative energy resources. Renewable energy (RE) is an obvious choice to reduce carbon dioxide and other pollutants contributing to global warming. However, the high cost of RE technologies is the main obstacle facing the diffusion of RE power generation, therefore economical and political intervention is inevitable. These interventions usually include legislation, incentives to investment, energy generation targets, guidelines for energy conservation, strategies to stimulate the energy industry, and taxation [1]. Economic support policies that encourage investments in new technologies that promote the adoption of RE have been implemented in many countries. In particular, a variety of economic support policies for RE has been developed and implemented mainly in Europe and the USA. These policies include: Quotas, Feed in Tariffs (FITs), Bidding or Tendering, Tax incentives, and Subsidies.

In the Unite Arab Emirate (UAE), population and economic growth are the main reason for the fast increase of energy demand, leading to two problems, first the UAE has one of the highest carbon footprint in the world [2] and second, the fast depletion of its main energy generation resource – fossil fuel, which highlights the need to establish a RE sector. To address these issues, in this work we study the fundamental requirements to introduce relevant RE polices as a first approach to promote RE use in the UAE. In 2008, the first RE policy set by UAE government -at least seven percent of the emirate's power generation capacity will come from RE sources by 2020- provided a critical missing piece of the UAE‘s overall strategy in energy and sustainability. This policy marks the start of new energy era in the UAE; nevertheless, this policy does not state the mechanism of how to achieve this target.

This paper will first introduce the key features of the different (RE) policy options. Second, it will present a comparative analysis of the RE policies mechanisms as well as summarizing the requirements for their successful implementation. Third, the findings from the 61 surveyed countries focusing on RE technologies, capacities and policies are presented. Finally, the challenges and existing constraints for the development of RE Policy in Abu Dhabi are presented and discussed. The paper concludes with summary and recommendations.

2. Background

Even though it is widely agreed that support schemes need to be put in place to promote the use of RE, there is almost no consensus as to what are the best RE policies to use. In the following we introduce the different policy options including their respective advantages, disadvantages and recommendations for successful implementation.

Feed-in Tariffs (FITs), are performance-based regulation incentives aimed at increasing the adoption of RE sources. The term "feed-in tariff" derives from the German Stromeinspeisungsgesetz of 1990, which literally translated means "electricity feeding-in law." Germany implemented the Electricity Feed-in Law (1991) in order to create a market for renewable electricity by offering providers a fixed but attractive price for the recovery of generation costs and since then it stands as the paradigmatic example of effective FIT regulation [3].

Renewable Portfolio Standard (RPS), Renewables Obligation (RO), Mandatory Market Share (MMS) policy or Quotas are the different names given to a similar set of incentives for RE in various countries, RPS in USA, RO in UK, MMS in China and renewable quotas in European countries [4]. The shared theme of all these incentives is that the government sets a percentage of electricity to be generated by renewable sources, assigns an actor, such as electricity users, suppliers or generators, to meet the specific percentage and penalizes those who fail to meet their goals. These mechanisms are essentially market based and they are designed to achieve a cost-efficient generation of RE [5]. Quotas are presently applied in a number of countries around the world. The RPS in Texas has been very effective due to good local resource, presence of tax credits and strong penalties for non-compliance [6]. Although they have resulted in a growth of renewables in most countries, they have not achieved the same success as the FITs in Germany and Denmark [7].

Centralized Bidding or Tendering systems are one of the major policies for promotion of RE in the electric power sector. These mechanisms have been applied in the early stages of RE development in UK and are presently employed for wind power in China under the name of concession program [8]. As the name implies, the policy mechanism works by calling for bids from investors for RE projects. It is essentially a market-based policy, which strives to develop RE projects at the least possible cost. The policy of bidding for RE contracts was first started by UK in the form of Non Fossil Fuel Obligation (NFFO) in 1990. This policy was then discontinued in 1998 when it was realized that NFFO was not able to achieve required implementation of RE. In 2002, it was replaced by Renewables Obligation (RO). The other major example of a bidding system is the Chinese Concession System for wind power development. The system was started in 2003, and fifth bidding round was completed in December of 2007 [8]. Chinese RE Law of 2005 makes provisions for implementation of FITs, quotas and bidding systems [4].

Tax Credits is one way to lower the costs of RE through market compensation. The main types include investment, and production tax credits. They are largely used in Europe, USA, Japan, and India as well. Investment Tax Credits can cover the cost of the RE system itself, or even the total cost of the installation. Investment Tax Credits can prove to be useful at the early stages of the technology, where there are high costs, or at times when utilities are being deployed on remote areas. They aid lowering the level of risk involved and the costs of investing in RE technologies [9]. In the United States, businesses receive a 10 percent tax credit for purchases of solar and geothermal RE property, subject to certain limitations. Some U.S. states have Investment Tax Credits of up to 35% [10].

The high upfront investment cost of renewable makes them unattractive choices for investors. Removing this barrier by reduction in the initial capital outlay by consumers for RE systems is accomplished through direct ***subsidies or rebates***. These subsidies are used to share the initial capital cost of the system, so that the consumer sees a lower price [10]. Subsidies have been used by many countries for stimulating growth in RE sector. A combination of investment subsidies, low-interest loans, net metering and public education has resulted in an early success of PV in Japan [9]. Similar subsidies have been employed in many countries for RE development. In most cases, they are used in combination with other RE support mechanisms. This is in stark contrast with investment tax credits, which tend to favor large companies with greater tax liabilities [6].

In general, RE policies can be grouped into two categories, *Investment Focused Policies*, e.g., Rebates/Subsidies, Investment Tax Incentives and Bidding/Tendering, *and Generation Based Policies*, e.g., FITs, Quotas and Green Credits [11].

3. Current state of Renwable Energy and lessons learned.

When put in an international comparative perspective the UAE is found to be far behind the world's leaders in RE. Yet, the recent move of introducing an RE sector is an unprecedented initiative in the region that might play an important role in setting the stage for similar decisions by other comparable countries. We conducted a comprehensive analysis of the current state of RE in order to identify RE policy trends to help inform potential adaptation of RE initiatives in new projects or countries. The analysis was performed by reviewing RE data of 61 countries mainly focusing on RE technologies, capacities and policies implemented by the different countries. For demonstration purposes, Table 1. summarizes a selection of 7 countries out of the 61 studied as geographical representations to their regions; the table covers the following categories: RE policies, targets, projects, produced electricity and installed capacities.

As a result of this study, here, we highlight the main finding of the analysis based on the data from the 61 countries analyzed as follows: Europe is dominating the RE scene, since more than 50% of all countries that uses RE projects are European followed by Asia, America and finally Africa. Furthermore, most of the European countries use hydroelectric and wind power and very few use geothermal energy. This can be explained by the fact that hydro and wind are the most abundant energy source in Europe and geothermal energy is the least used energy source and this is due to the immaturity of most of the state of the art geothermal technology solutions.

Table 1 summurizes the RE policies, targets, RE sources used and their installed capacity of 7 countries

			RE Target		*RE Projects*			
Country	*RE Policy*	*RE mechanism*	*Primary energy*	*Electricity*	*Type*	*Electricity Produced*	*Installed Capacity*	*Reference*
China	FIT since 2005		15.4% by 2020	21% by 2020	Small hydro		60 (GW) as of 08	[12, 18, 20, 21, 23]
	Public investment	A total of USD731 million is allocated to support biogas			Wind	0.20%	26.01 (GW) as of 2009	
	Capital subsidies and grants	A subsidy of (USD2.93)/W to support the BIPV system installation.			Solar PV		0.3 (GW) as of 2009	
	Quotas, Energy tax, PCB, Tax credits							
Germany	FIT since 1990	Investment support for solar PV	18% by 2020	12.5% by 2010	Small hydro		1.4 (GW) as of 2008	[7,13, 14,15, 16, 17,20]
	Investment tax credit	Parts of the revenue of energy taxes finance RES			Wind	6.40%	25.78 (GW) as of 2009	
	PCB				Solar PV	1%	9.83 (GW) as of 2009	
	Net metering				Geothermal		0.006 (GW) as of 2008	
	Capital subsidies and grants	Only in exceptional cases 30% of invest.			Biomass	4.40%	4 (GW) as of 2008	
	Energy tax	Eco-tax on conventional electricity			Concentrated Solar Power		1.5 (MW) as of 2009	
	Public investment and Loans	R&D support			Hydropower	3.30%	4.7 (GW) as of 2008	
India	FIT since 1993		20% by 2020	12% by 2012	Small hydro		2 (GW) as of 2008	[12, 14, 18, 20, 24, 25]
	Quota system			15% by 2020	Wind	1.60%	10.93 (GW) as of 2009	
	Energy Investment Tax	Wind Power: per good. Biomass: total exemption			Solar PV		0.12 (GW) as of 2009	
	Capital subsidies and grants	For small hydro up to 25 (MW).			Biomass	0.20%	2.1 (GW) as of 2009	
					Hydropower	15%	32.892 (GW) as of 2009	
Japan	FIT	FIT for Solar PV		1.63% by 2014	Small hydro		3.5 (GW) as of 2008	[14,18,20, 21,22,]
	Capital subsidies and grants	Solar PV household subsidy			Wind	0.20%	2.21 (GW) as of 2009	
	Public investment and loans	National stimulus Package of 22 billion USD			Solar PV	0.20%	2.6 (GW) as of 2009	
	Green Certificate Trading				Geothermal	0.30%	0.54 (GW) as of 2008	

			RE Target		*RE Projects*			
Country	*RE Policy*	*RE mechanism*	*Primary energy*	*Electricity*	*Type*	*Electricity Produced*	*Installed Capacity*	*Reference*
	Quotas				Hydropower	7.50%	27.759 (GW) as of 2009	
UAE	Quotas, Bidding and Subsidies			7% by 2020	Solar PV		10 (MW)	[26]
					Solar thermal		100 (MW)	
UK	RO since 2002	TGC as part of RO scheme	15% by 2020	10.4% by 2010/2011	Small hydro		0.173 (GW) as of 2008	[7, 13, 14, 17, 19, 20]
	Public investment and Loans	R&D and offshore wind support. A total 10.4 billion GBP for low carbon economy.		15.4% by 2015/2016	Wind	1.30%	4.05 (GW) as of 2009	
	Energy Tax	Tax exemption for electricity from RE.			Solar PV		0.032 (GW) as of 2009	
	FIT, Quotas and NFFO				Biomass	2.80%	1.368 (GW)	
					Hydropower	2.30%	1.513 (GW)	
US	RO			20% by 2030	Small hydro		3 (GW) as of 2008	[13, 14, 18, 20, 21, 22]
	FIT since 1978				Wind		35.159 (GW) as of 2009	
	Energy Tax	Production of Tax Credit-extension			Solar PV		0.824 (GW) as of 2010	
	Public investment and Loans	30 billion $ in loan guarantee for RE projects as of 2009			Geothermal	0.40%	3.10 (GW) as of 2009	
	Tax credits	Payment in lieu of tax credits for investment on RE			Biomass		8 (GW)	
	Capital sudsides and grants				Concentrated Solar Power		188 (MW) as of 2009	
					Hydropower	6.30%	95.0 (GW) as of 2009	

Among all the RE projects in the studied countries, wind, hydro and biomass were found to constitute the biggest share of RE installed capacity, where Wind installed capacity ranges between 35-10 GW in the US, China, Germany and India, Hydropower ranges between 95-27 GW in the US, Russia, Brazil, China, India and Japan, and finally Biomass reaches up to 70GW in Costa Rica"

On the policy front, approximately 70% of the 61 countries are applying feed-in tariff policy which portrays it as an effective policy to encourage the use of RE sources. This wide use of FIT is due to its several advantages that include: offering investment security and market stability as well as it being very effective in increasing the amount of electricity generated from RE sources such as wind and solar.

As a whole, the most used RE source is hydroelectric energy. This suggests that, in general, hydro energy is the most abundant energy in comparison to the other projects such as geothermal, solar PV, solar thermal and biogas. All the countries that have more than 30% RE targets to be fulfilled between 2020 and 2050, has mainly wind and hydro projects where the hydro projects have the highest installed capacity.

An example of a successful RE implementation story, Costa Rica is already producing 99% of its electricity from renewable sources which makes it the first carbon-neutral country in the world.

4. Renewable Energy Policy in Abu Dhabi

The only operating RE solar PV plant in Abu Dhabi is the 10 MW plant in Masdar City which is also registered as a CDM project for carbon credit purposes. The 10 MW plant, consisting of 87,777 panels (50% thin film and 50% crystalline silicon) is projected to generate 17,500 MWh of clean energy each year (with a single kWh of clean energy being the carbon-offset equivalent of 0.8 kg depending on an area's network and its energy-producing source). The cost of kwh produced in the 10 MW PV plant is 48 US cents (2009).

4.1. Existing Barriers for the Development of RE

In [27], Patlitzianas made an overall review of the existing barriers that can impede the development of RE in the Gulf countries and including the UAE. The barriers of the UAE are grouped into three main categories: market technology, policy legislation, and cost. All of these categories are related to infrastructure and institutions. As a conclusion, the authors argue that the barriers that unfairly discriminate against RE are mainly the lack of commercial skills and information, the absence of relative legal and policy framework, the high initial capital costs coupled with lack of fuel-price risk assessment, as well as the exclusion of environmental externalities in the cost.

4.2. Toward a Comprehensive RE Policy for Abu Dhabi

Currently Abu Dhabi Government has set a target that 7% of its electricity generation to come from renewable sources. Solar power is the most favorable source of RE for Abu Dhabi. The 10-MW PV solar plant is already installed and operating, and supplying power to Masdar City operations and connected to the existing Grid. It is a small amount of electricity generated but its success opens the market to have individuals, private builders and property owners to consider RE technologies.

As a result of our analysis, we recommend to have a mix policy between Fee-in-Tariff (FIT) and Quota system in order to share the RE electricity generation. Currently, the Abu Dhabi government through the Abu Dhabi Executive Affairs Authority (ADEAA) is reviewing the energy policy in general and electricity generation in particular in conjunction with all the actors. In order to ensure that this policy is effective we need to take many things into considerations:

1. There has to be continues political support to encourage the adoption of RE.
2. Through the Masdar Initiative, the main RE technologies that can comply with the policy mechanism are Solar and Wind (mainly off-shore). The market has to develop the most effective options.

3. Must ensure that the electricity provider, ADWEC, buys the electricity generated from RE sources. Transco, the power transmission company, provides the grid connection of all RE sources.
4. Develop a trading mechanism between RE generators and ADWEC.
5. Using a Guarantee of origin certificates is a good example to use as a proof of generation and compliance under a more controlled environment.

5. Conclusion and recommendations

Abu Dhabi, with the Masdar Initiative, is regarded as a pioneer in its efforts to promote RE in the Middle East region especially in Gulf States that share similar characteristics such as abundance of solar resources and oil rich economies that can support such an initiative. The paper listed the RE policies and mechanisms for many countries in addition to their different RE technologies and installed capacities. One thing to notice is that UAE (Abu Dhabi) has a policy target of 7% RE share of electricity generation by 2020 but there are no additional legislations or mechanisms to promote power generation such as feed-in tariffs, renewable portfolio standards, capital subsidies or grants, investment tax credits, sales tax or VAT exemptions, green certificate trading, direct energy production payments or tax credits, net metering, direct public investment or financing, and public competitive bidding.

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Barriers to and Drivers of the Adoption of Energy Crops by Swedish Farmers: An Empirical Study

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Abstract: Since the Swedish government and the EU intend to encourage farmers to expand energy crop production, knowledge of the factors motivating adoption decisions is vital to policy success. Earlier studies have demonstrated that important barriers to farmer adoption of energy crops include converting from annual to perennial crops and from traditional crops or production systems to new ones. Economic motivations for changing production systems are strong, but factors such as values (e.g., aesthetics), knowledge (e.g., habits and knowledge of production methods), and legal conditions (e.g., cultivation licenses) are crucial for the change to energy crops. This paper helps fill gaps in the literature regarding why farmers decide to keep or change a production system. Based on a series of focus group interviews with Swedish farmers, the paper explores how farmers frame crop change decisions and what factors they consider most important. The main drivers of and barriers to growing energy crops, according to interviewees, are grouped and discussed in relation to four broad groups of motivational factors identified in the literature, i.e., values, legal conditions, knowledge, and economic factors. The paper ends by discussing whether some barriers could be overcome by policy changes at the national and European levels.

Keywords: *Climate change, Energy crops, Farmers' incentives, Drivers, Barriers*

1. Introduction

The national goal of converting the Swedish energy supply from fossil fuel to renewable energy has been made more urgent by the climate change debate and a general emphasis on the sustainable development concept. As a member of the European Union (EU), since 2007 Sweden has been subject to an overall binding target of making its energy supply 20% renewable by 2020 [1]. Reducing total national emissions by producing more energy-related products or energy crops on traditionally agricultural land, i.e., "energy farming" [2], is one of the highlighted changes. At present, approximately 2% of Sweden's arable land is used for energy production [3]. Several studies indicate that energy crop production from the agricultural sector will play a more important role in the future [4,5]. The Swedish agricultural sector produced 1–1.5 terrawatt hours (TWh) of energy in 2006 [5, 6]. It has been calculated [7] that the agricultural sector could produce 15–30 TWh, depending on economic and political measures, and the Federation of Swedish Farmers (LRF) has committed to increasing energy production to at least 5 TWh in the near future [8]. A high potential for increased energy crop cultivation has also been identified at the European level [2,9]. At the same time, the problematique inherent in using limited land resources to produce renewable energy in a situation of high commodity prices and continuously growing world population should not be underestimated.

Currently, 13 energy crops are available to Swedish farmers [10], each with particular cultivation opportunities and restrictions and sets of drivers and barriers. The three most extensive energy crops currently produced in Sweden are straw (a by-product), oil crops, and wheat, each covering 15,000–25,000 ha [10]. Earlier studies of conditions for land use change at the Swedish and international levels have demonstrated the importance of economic incentives in encouraging individual actors to change production or land use [11,12]. In the Swedish case, economic evaluations of investment in energy crop production produce contradictory results. Despite the potential profit, existing subsidies, and considerable farmer interest in energy crop cultivation [11], the extent of energy crop production in Swedish agriculture is limited [13,14]. Earlier studies have likely been too focused on purely economic incentives, which alone cannot explain farmer behaviour concerning the conversion to energy crop production. This leaves a knowledge gap regarding the involved social, cultural, institutional, and environmental issues, and how they are seen from the perspective of society and individual actors [9].

To address this knowledge gap, we had previously reviewed the scientific and gray literature dealing with *why* farmers decide to stay with or change a production system, and what motivational factors serve as drivers of or barriers to specific crops [10]. The review indicated that, although economic incentives to change the production system are strong, factors such as values (e.g., aesthetics), knowledge (e.g., habits and knowledge of production methods), and legal conditions (e.g., property rights and cultivation licensing) may also be crucial for production system change [10]. However, no empirical, explorative study of this matter has yet been carried out.

This paper builds on our earlier analysis of motivational factors as described in the literature, adding the findings of an empirical study of the conditions necessary for farmers to engage in energy crop production, which can serve both climate change mitigation and adaptation purposes. The specific research questions are: i) What drivers of and barriers to energy crop production, from the farmers' perspective, can be empirically identified? ii) How do these relate to the factors identified in the literature? The results will enhance our knowledge of *why* farmers choose to change their land use, including motivational factors. In terms of increasing energy crop production – a Swedish government goal – our analysis can provide a basis for policy decisions regarding enhancing drivers and removing barriers.

2. Motivational factors as drivers and barriers

Studies of the public understanding of environmental issues have identified a frequent gap between peoples' opinions and their actions – an "attitude–behaviour divide" (see, e.g., [15,16]). Even though actors may be knowledgeable regarding environmental issues, they may not always act in ways that contribute to environmental sustainability [17]. The reasons for this vary, but one possible explanation is that many environmental problems are characterized by complexity and uncertainty; they are often global in nature and their effects may be distant in time and space [16, 18].

Many studies focus on a single crop [19,20] or a particular aspect of energy farming [21]. Very few studies take a more integrated view of a wider range of crop alternatives and motivational factors relevant to the farmer considering energy farming. Rosenqvist et al. [19], for example, statistically analysed the characteristics of individual farmers who have adopted salix cultivation, and compared this group with a strategic sample of farmers who have not. The only more holistic study we found in the surveyed literature was that of Paulrud and Laitila [11], who use a methodologically strict and quantitative approach (i.e., a choice experiment) to investigate a limited number of motivational factors affecting a limited number of crops. Building a more comprehensive understanding of what affects farmers' adoption of energy crops calls for a more explorative and qualitative approach. Hence, it is important to contextualize attitudes, i.e., to analyze not only actors' stated opinions, but also the barriers preventing people from acting and the drivers encouraging them to do so [16,17].

To understand the contextual factors that restrain and enable farmers' actions, it might be useful to distinguish between *proximate causes* and *underlying driving forces* of individual land use change decisions [12,22]. Proximate causes are the motivational factors directly experienced by land users, such as an available market's increased demand for a product driving a change in land use or decreased dependence on subsistence farming due to off-farm income-generating activities. Underlying driving forces are indirect and more process oriented, such as climate change or expanding national/regional markets.

Our previous review of the literature dealing with the motivational factors guiding farmer decisions to engage in energy crop production identified four broad groups of motivations relating to values, legal conditions, knowledge, and economic factors [10]. Along with these, a variety of more specific factors was found that may serve as drivers of or barriers to individual farmers considering the adoption of certain energy crops. The analysis indicated that, although several studies have been undertaken, we still lack knowledge of the various groups of motivational factors and how they are assessed by individual farmers. More specifically, we lack knowledge of the direction of the motivational factors associated with various crops, the relative strengths of these factors, whether different strata of farmers assess motivational factors differently, and the precise identity of the proximate causes and underlying forces.

This paper represents a preliminary attempt to fill this knowledge gap. We aim to identify a wide variety of barriers and drivers discussed by Swedish farmers during four focus group interviews, dealing not with the adoption of specific crops, but with the motivational factors affecting whether or not one engages in "energy farming". These barriers and drivers will be discussed in relation to the four broad groups of motivational factors mentioned above, i.e., values, legal conditions, knowledge, and economic factors [10].

3. Methodology

This study builds on four focus group interviews involving 21 Swedish farmers, 20–70 years old, in 2010. A focus group is a group interview in which a small number of participants is brought together to discuss a specified issue under the guidance of a moderator who preferably assumes a low-key position [23]. The comparatively free form of discussion occurring in focus groups enables the researcher to uncover aspects of the chosen topic that were not anticipated but were spontaneously raised in the discussions and thereby proven to be important to the participants. Focus groups were chosen for this study since they offer a research method well suited to generating a rich understanding of participants' beliefs and experiences [24]. Moreover, focus group methodology enables analyses of what participants bring to the group; focus groups constitute "thinking societies in miniature" [25], in which the process of joint meaning-making may be studied in action [26]. Focus group methodology is well suited to studying socially shared knowledge as it is constructed, expressed, and negotiated in a group [27]. Nevertheless, like all research methods, focus groups have their limitations. Their purpose is not to draw statistical conclusions that are generalizable to a general population [28]. Instead, focus groups provide in-depth insight into particular topics, insight that can productively be combined, for example, with survey research.

Each interview started with a discussion of climate change and of the information sources used by the participating farmers to learn about this issue. This part of the interview is not analyzed here, but will be used for other purposes in the K3 project. The last 30–45 minutes of the focus group interview were designed as a participatory exercise in which farmers were asked to mention factors that they saw as facilitating or impeding their adoption of a certain energy crop (one annual and one perennial). The factors were written down on cards, and participants were then asked to rank them in order of importance [29]. In the discussions, we used four example crops: wheat for energy production, hemp, salix, and hybrid aspen, of which two are annual (wheat and hemp) and two have a turnover time of more than 20 years (salix and hybrid aspen). Despite the use of specific example crops, the discussions were framed in general terms as dealing with the drivers of and barriers to energy farming.

4. Results

As shown in Table 3, the four groups of motivational factors mentioned by farmers during the focus group discussions include numerous aspects and conditions affecting decisions to begin growing energy crops. In Table 3, these are grouped into the four categories of motivational factors identified by Ostwald et al. [10]. In several cases, the same factor may serve as a driver of adopting an annual crop and a barrier to adopting a perennial crop, or vice versa.

5. Discussion, conclusions, and ideas for further research

Table 3 indicates that many of the factors identified in the literature review were mentioned in the focus groups. Legal factors, however, were not mentioned by the participating farmers as having any motivational impact. Knowledge factors, which were not mentioned that often, served mainly as barriers.

Value-driven motivational factors include environmental concerns, which seem to serve mostly as drivers of the adoption of both annual and perennial energy crops. The food versus energy antithesis and the heritage aspect served as very strong barriers to adopting perennial energy crops. This was particularly so in Group 1, comprising farmers in a forest area, who described adopting such crops as a “crossroads” choice that would undo the work of generations of ancestors who have striven to keep the fields clear to enable food production. To some extent, the food versus energy antithesis also served as a barrier to annual crop adoption, as it was seen as unethical to “burn food”. From this perspective, annual energy crops were slightly less bad than perennial crops, as they at least kept open the option of growing food crops in the near future. Moreover, lifestyle issues such as workload and curiosity served as drivers of the adoption of perennial energy crops.

Economic factors were, together with the value-related factors, those most often mentioned in the groups. In particular, the issue of flexibility was discussed thoroughly by all groups, mostly as a barrier to the adoption of perennial energy crops and a driver of annual crops. The inflexibility of the “crossroads” choice of perennial crops focused on the long turnover time of these crops as well as the difficulty of reconverting to annual crops after harvesting the perennial crop. The potential for better risk management by applying a portfolio perspective to the farm’s “crop basket” (identified by Berg et al. [4]) was also mentioned. Moreover, issues of profitability, subsidies, output value in relation to input costs, and other more straightforward economic aspects were also mentioned, particularly by Group 4, which consisted of relatively young farmers in an intensive farming area.

Table 3. Empirically identified barriers, B, and drivers, D, for farmers adopting energy crop production. Each B or D indicates that a factor was mentioned at least once in each focus group.

Identified factors	<1 year turnover	>20 years turnover	Typology of factors
VALUES			
responsibility for nearby environment	D	B	environmental concerns
destroying nice views	D	B	
wildlife refuge (in open landscapes)		D	
preserve cultural landscape	D	B[2]	
environmentally friendly		D	
low negative environmental impact		D	
grow food for the world	BB	B[2]	food vs. energy
potential food becomes energy	B		
producing either food or energy	D		
not usable for other purposes (food)	B		
honour/dishonour ancestors	D	B	tradition/ heritage
“culture” = cultivation	D	B	
fun to try something new		D	fun, curiosity
curiosity		D[2]	
less work, more leisure time		DDD[2]	work load
good timing with other crops		D	
KNOWLEDGE			
too little knowledge		BB	knowledge
well-known crop	D		
not the optimal energy crop (input/input ratio)	B		
ECONOMY			
flexibility	D	BBB	flexibility
destroys field drainage, etc.	DD	BBB[2]	
“crossroads” choice	D	B	
market flexibility (many buyers)	D	BD	
contract (if food wheat price goes up, you lose)	B	D	
unclear political ambitions + long-term perspective	D	B[2]	
lack of flexibility + too little knowledge	D	B	
not such a long turnover time		D	
global wheat trade reduces the risk of unexplainable price price fluctuations	D		
short term – easier to plan	D		
if land is available/marginal land	B[1]D	DD	available land
no available land	BB[1]	B[2]	
unsuitable for soil type/intensive farming region		B	
profitability	BB[1]DD	DD[2]	other factors
subsidies	D	D	
soil degradation	B	B[2]	
(no) need for special equipment	D	B	
rational production		D	
low inputs (labour and agrochemicals)	B	D	
lower quality specifications compared with those of food wheat	D		

[1] Hemp
[2] Hybrid aspen

Moreover, our results have implications for policy formulation in general and for climate change communication and extension service to farmers in particular. In terms of the time and energy spent discussing the different types of motivational factors, value and economic factors were clearly regarded as the most important by participating farmers. In fact, value-related issues seemed to constitute the basis of individual identity – "what it is to be a farmer" – functioning as a filter or background for other factors, including economic ones, which were always assessed in relation to this identity. Hence, in discussing the potential for energy crop production, advisors and authorities must understand farmers' interpretative frames, i.e., what determines how they interpret and understand such messages, and in which agricultural setting they conduct there trade. There is also a clear divide between how various motivational factors serve as either drivers or barriers when annual or perennial energy crops are discussed. New policies to promote energy farming must take this into account, and design specific policy components for specific types of crop so that the overall policy package is coherent in terms of its motivational effects on farmers' decisions.

This paper has presented the results of a preliminary analysis of four focus group interviews of a planned sequence of eight. The following issues will be explored in an upcoming analysis of the present material, complemented by four additional focus groups to be held in 2011:

Firstly, the motivational factors identified here are mainly analyzed with regard to their direction, i.e., whether they serve as drivers of or barriers to the adoption of annual and perennial energy crops. Analyzing the ranking of the identified factors and any correlations between them to establish a hierarchy of importance would improve our qualitative understanding of what affects farmers' adoption of energy crops. Preliminary results indicate that value-related factors are at least as important as economic factors.

Secondly, the motivational factors discussed here were identified from the perspective of individual farmers and the decision contexts that face them when considering converting to energy crop cultivation. The factors all directly influence the outcome, but often they stem from trends and developments on a national or even global scale. The distinction between proximate and underlying forces [12] may sharpen the analysis considerably.

Finally, the increased cultivation of energy crops can be seen as a way society can adapt to climate change by reducing greenhouse gas emissions. Clearly, the opportunities created by increased national and global demand for energy crops enhance risk management and portfolio thinking for farmers, who can benefit from a wider choice of crops when deciding whether to stay in traditional food production or convert to energy crops. These and other adaptation possibilities for individual farmers also merit investigation.

Future quantitative studies, i.e. surveys, could productively explore the relative and absolute importance of various motivational factors to different strata of farmers (e.g., depending on age, type of land tenure, and location).

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The Chinese Grain for Green Program – assessing the sequestered carbon from the land reform

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Abstract: Grain for Green Program was launched in China as a national measure to control erosion and increase vegetation cover in 1999. With a budget of 40 billion US dollar, the program that targets cropland and barren land has today converted over 20 million hectares of land into primarily tree-based plantations. Even though the design of the program includes a category of energy forest only a negligible part is planted as such (0.61%). The majority of the land converted is for protection (78%). The use of these plantations in the future is however unclear and a hypothesis of energy substitution is valid.
In this paper, we try to estimate the overall carbon that has been sequestered due to the program by using official statistics from the program and by calculating it according to mainly three different approaches; calculations made on I) net primary production, II) figures from IPCC's greenhouse gas inventory guidelines, and III) mean annual increment. We also highlight several of the uncertainties that are associated with the program and the estimations.
The result shows that conversion of cropland and barren land generated carbon sequestration over its 10 first years ranging from 222 to 468 million tonnes of carbon, with the IPCC approach yielding the highest estimate whereas the other two approaches had more similar outcome (around 250 million tonnes of carbon). Uncertainties associated with the assessment lies within the use of growth curves not designed for the particular species and their different locations, actual survival rate of the plantations, and discrepancies in figures concerning the program (e.g. area, type, survival rates) at different levels of authority (from national to local). The carbon sequestered in the biomass (above and below ground) from this program is equivalent to 14% (based on median of all three approaches) of China's yearly carbon dioxide emissions due to fossil fuel use and cement production.

Keywords: *Land-use change, Mitigations impact, Plantations, Carbon sink, Bioenergy.*

1. Introduction

As China continues its rapid rate of development, dealing with the massive and growing emissions of greenhouse gases (GHG) (6.5 mega tones of carbon dioxide (tCO2) in 2007 corresponding to 22% of the global total) the country will be vital in the context of global climate change [1]. Afforestation and reforestation have become important measures in China to slow down the wind and water erosion. In 1999 the Chinese government introduced the Grain for Green Program (GGP) also known as Slope Land Conversion Program [2] or The Conversion of Cropland to Forest and Grassland Program [3]. The large-scale afforestation under the GGP will result in a large amount of new forest and hence enhance the carbon sequestration capacity in the terrestrial ecosystems. With this quick background setting the objectives of the paper are to i) estimate how much carbon the program has sequestered, ii) how a national assessment can be conducted and the potential strengths and weaknesses it holds, and finally iii) what the potentials are to use the biomass produced as an energy substitute for fossil-fuel.

2. The program and the setting

The GGP feature the conversion of steep-sloped and degraded cropland and barren land to forest and grassland by millions of small landholders in 25 provinces, municipalities and autonomous regions (Fig. 1). The primary targeted area of the GGP was the basins of the Yellow and Yangtze River. The Loess plateau located in the upper and middle reaches of the Yellow River is a part of this area. It is well known for severe soil erosion and degraded land. Over 60% of the land suffers from various degrees of soil erosion as a consequence of unsustainable use and degraded vegetation cover, as well as the presence of deep, loose yellow soils [4]. The GGP mainly focuses on steep slopes that seriously threaten to degrade the water quality in the rivers.

Figure 1.Grain for Green Program coverage in China (yellow) indicating the sensitive areas around the Yellow River and Yangtze River.

3. Methods and materials

To estimate the carbon in the trees planted under the GGP information on area, location of plantation and the locations physical characteristics, species, increment per year and survival rate were needed and collected from forestry statistics and national and province level and scientific literature. To estimate the carbon sequestration performance of the programme we assumed a baseline of what plausible would happen in the absence of the implementation. Due to the targeted soils' degraded character with high erosion and unsustainable agriculture we assume the carbon sequestration would be equal to zero of negative. The carbon pools included in the calculation was above and below ground biomass with the latter as a ratio of 0.26 of the former [5].

The total carbon stock for the different regions, i.e. provinces, is calculated according to equation 1:

$$C_{Total} = \sum_{j}\left[\sum_{i}(A_{i,j} \times C_j \times (Y - i))\right] \qquad \text{Equation 1}$$

where $A_{i,j}$ (ha) is the converted cropland for region *j* in year *i*. *Y* is the year the study was conducted, i.e. 2009. This means that the trees planted in year i=2008 has been growing for 1 year. C_j (tonnes carbon (ha yr)$^{-1}$) is the carbon increment per hectare and year fitted for the climate conditions of each for region *j*. The time frame used is from 1999 to 2008/2009. The amount of land converted is presented in Fig. 2.

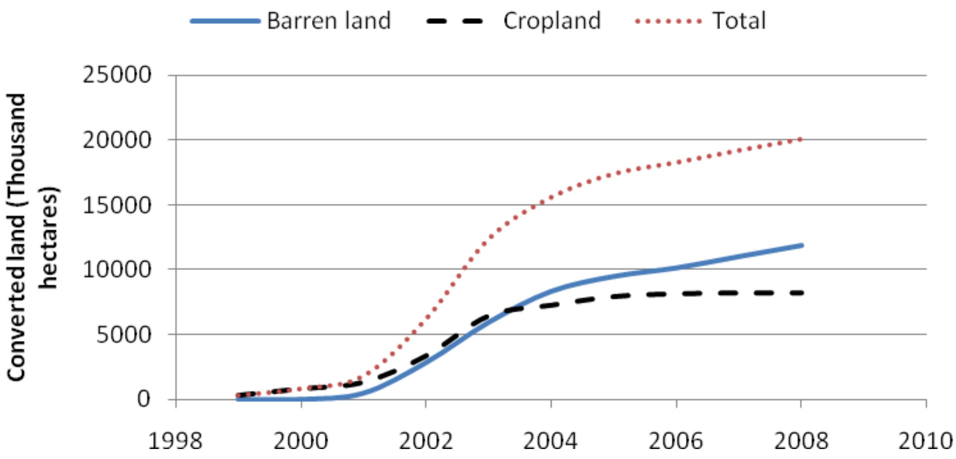

Fig 2. Total accumulated converted cropland and barrenland area 1999-2008, data missing for barren land 1999-2000 (Administration 1999-2008).

Three different values were used to assess the carbon in the terrestrial vegetation in GGP. 1) Net Primary Productivity (NPP), 2) Intergovernmental panel on climate change (IPCC) Guidelines for National Greenhouse Gas Inventories (GNGGI) and, 3) mean annual increment (MAI). Two of the NPP values were derived from China specific studies [6], [7] and one on global average [8]. IPCC default values i.e. in the lower accuracy level Tier 1, were used for natural and managed forest [9]. MAI values are primarily derived from a national assessment [10] or when missing a global value of 1.6 tC/ha/yr [11] was used.

4. Results

4.1. Carbon sequestered under GGP

The total area of barren land converted is larger than the area of cropland converted. Because of this the result of carbon sequestrated by barren land conversion is also larger as can be seen in Fig. 3. The highest value for cropland and barren land conversion is 468 million tonnes carbon (MtC) and the lowest value is 222 MtC. There is a large difference, 246 MtC, between the highest and the lowest values.

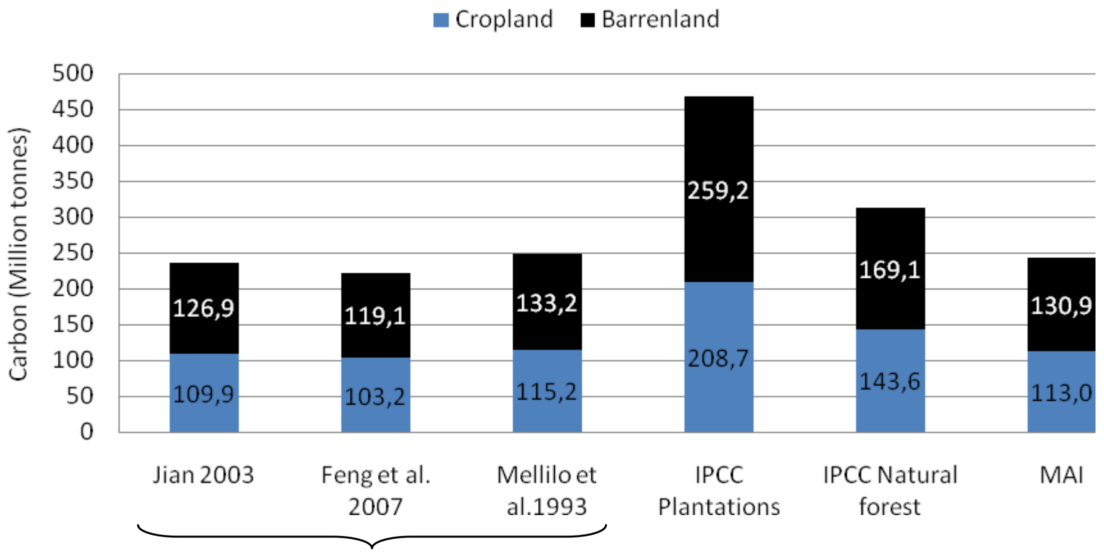

Fig 3. Total amount of carbon sequestrated by conversion of cropland under the GGP 1999-2008 (tonnes).

The reason behind the high value of the IPCC plantation figure can be that the default values are assessed for heavily managed systems including rotation.

4.2. Saptial differences in carbon from GGP

In most provinces the carbon sequestration under barren land and cropland is almost equally large, barren land being a little larger (Fig. 4). Only Xinjiang, Qinghai, Shaanxi, Sichuan and Jilin have larger carbon sequestration through cropland conversion than through barren land. Sichuan has the largest value, 31.7 MtC while Tibet has the lowest, 209 thousand tC.

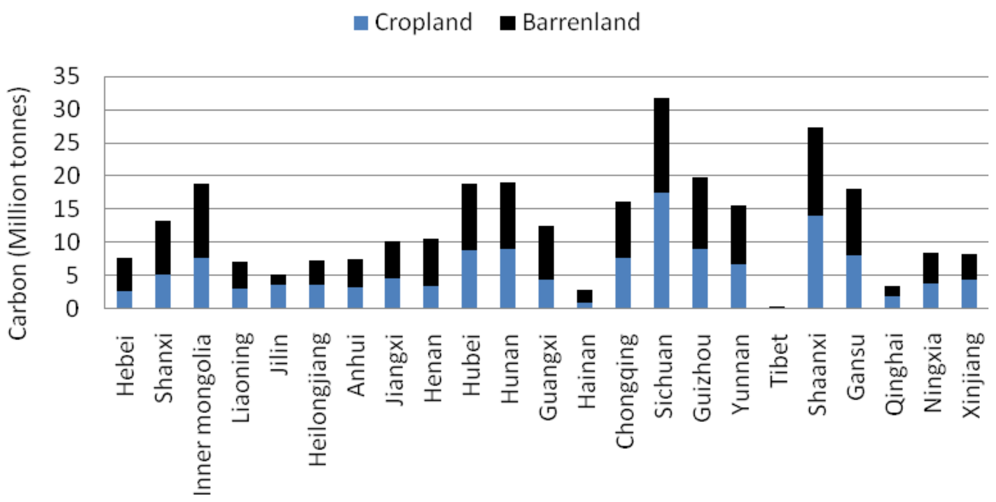

Fig 4. Average amount of carbon sequestrated by conversion of cropland 46.4% and barren land 53.6% under the GGP 1999-2008 per province (Million tonnes).

4.3. Sequestration level and potential impacts

From this 20 Mha plantation program the sequestering rate has been ranging from 222 to 470 MtC with a median on 246 MtC. This would mean that the annual sequestration range from 22-47 MtC/yr with a median on 25 MtC. Or if taken on a hectare basis, a carbon content of

11-23 tC/ha, which indicates a low productivity. Taking the median of 246 MtC it corresponds to 14% of the carbon emitted only in the year of 2009.

5. Discussion

There are large differences in figures depending on the biomass growth used in the model; differing up to 103%. This is due to assumptions on regional differences, species growth patterns and management impacts. Further, the different species and place of planting is crucial for the outcome. Also, the actual area that has been converted differs between sources ranging from 20 to 32 Mha, where we have chosen the lower value from the China forestry yearbook.

Since the legislation behind the GGP states that the forest planted may not be harvested until over-matured there are low potential to grow fast rotational energy forests on the land converted by the GGP. Further, the legislations defines only 0.61% of the forest planted as 'energy forest' whereas as much as 78% of the forest planted are for protection and most of these species are not suitable for usage as bio-energy. Hence, the potential for bio.energy for the forest planted within GGP is low. This is further evident when looking at the amount sequestered carbon that is fairly low, ranging from 11-23 tC/ha .

In order to make the estimation more accurate it would be interesting to collect province specific data regarding the species used and province specific biomass growth rate for all provinces. This would make the estimation more accurate since biomass growth is strongly dependent on local factors such as soil quality, thinning, irrigation and fertilization.

Another way to obtain more accurate results would be to divide the converted land into smaller areas that has a homogenous climate. By doing so better approximations of the biomass growth rates could be obtained by relating the growth rate to the climate.

6. Conclusion

- The carbon sequestrated by the conversion of cropland and barren land under the GGP ranges between 222.3 and 467.9 MtC. The median is 246 MtC while the mean is 289 MtC. With IPCC's approach for natural forests the amount of carbon sequestrated by the conversion of cropland and barren land between 1999-2009 is 312 MtC.

- 246 MtC sequestrated between 1999-2009 corresponds to 14% of the total carbon emitted from Chinas carbon emitted in one year (2009).

- The potential for bio-energy from the forest planted due to the Grain for Green program is low since the part of trees planted that are suitable for bio-energy is low and since the legislations prevents harvesting of the forest until over mature.

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How would renewables fair if a return to planned electricity markets was introduced?

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Abstract: For nearly all their history, modern renewables have had to fit into electricity systems that otherwise operate using the model of competitive wholesale markets and retail competition for consumers. Renewables' costs are generally too high for utilities to choose them in preference to other generation technologies. However, there is wide agreement that fossil fuel generation has to be phased out in favour of technologies that produce low levels of greenhouse gas emissions. There have always been question marks about whether the free market model for electricity would be sustainable but doubts are now beginning to emerge from an unexpected quarter and much more influential quarter, the pioneers of liberalised electricity markets, Britain. In December 2010, the British government published a White Paper on its proposed reforms to the electricity market that are widely expected to see foresee a much more interventionist approach. However, the British government also has a strong policy to promote new orders for nuclear generation and concerns have been expressed that the market reforms will be designed to favour nuclear power at the expense of renewables. This paper reviews previous policies in Britain to promote renewables and examines options available in a more planned electricity system.

Keywords: *Electricity liberalisation, renewable obligation, feed-in tariff, carbon market, capacity auction.*

1. Introduction

For nearly all their history, modern renewable generation technologies have had to fit into electricity systems operated using the liberalised model of competitive wholesale markets and retail competition for consumers. Their costs are too high and, for some options, the technologies are not mature enough for utilities to choose them in preference to other generation technologies. However, there is wide agreement that fossil fuel generation has to be phased out in favour of technologies that produce much lower levels of greenhouse gas emissions. As a result, it has been necessary for governments to override the markets in various ways to stimulate investment in renewable.

In Britain, there is now recognition that there are fundamental problems with the electricity market that will require a return to a more planned approach. In December 2010, the British government published a White Paper that set out its initial thoughts on market reforms. The situation in Britain is complicated by the strong policy, supported by all three major parties, to promote nuclear power, overtly as a way to reduce greenhouse gas emissions.

2. Why have electricity markets failed?

In February 2010 when the British government and the energy regulator both reported major problems with competitive electricity markets, they implied there were two main problems: that the market would not build sufficient new renewable capacity; and that the market could not be relied on to ensure there was enough overall capacity to ensure demand would be securely met.

The British Energy Minister, Ed Miliband, told the Times[1]:

[1] The Times 'Labour prepares to tear up 12 years of energy policy' February 1, 2010, p 37

> The Neta system [the British wholesale market], in which electricity is traded via contracts between buyers and sellers or power exchanges, does not give sufficient guarantees to developers of wind turbines and nuclear plants. He said that one alternative would be a return to "capacity payments" - in which power station operators would be paid for the electricity they generate and also for capacity made available. The idea of such payments is to give greater certainty to investors in renewables and nuclear energy.

A day later, Ofgem stated[2]:

> 'The unprecedented combination of the global financial crisis, tough environmental targets, increasing gas import dependency and the closure of ageing power stations has combined to cast reasonable doubt over whether the current energy arrangements will deliver secure and sustainable energy supplies.'

And

> 'There is an increasing consensus that leaving the present system of market arrangements and other incentives unchanged is not an option.'

Neither argument is convincing. The mechanisms to get renewables built inevitably took them out of the main market and if these mechanisms did not work, it was not the fault of the market, it was in the design of these policies, as is argued below. On the more general point of supply security, it is hard to know why this has come up as an issue now. The market model has always relied on the wholesale market price being high enough that sufficient capacity will remain on-line to ensure supply security and that market signals would be seen early enough to stimulate sufficient new capacity to meet demand growth and replace old plant. So far this has proved the case in Britain and supply security has been maintained although it is arguable this has been the result of market imperfections rather than the efficiency of the market [1]. There are a large number of new power plant projects that could be on-line within five years, albeit mostly gas-fired, so there would seem to be no reason as to why doubts on supply security should arise now.

Thomas [1] argues that the faults are more fundamental and would apply even if there was no need to replace fossil fuel plants with low-carbon generation. He argues that: if wholesale markets became truly competitive, investment in new capacity would be intolerably risky; retail competition inevitably disadvantaged small consumers and within small consumers, the poorest consumers; and the costs of competition are bound to outweigh any conceivable benefits.

3. Renewables in competitive markets

In Britain, renewables have been supported through two separate mechanisms, a capacity auction system from 1990-98 financed by the Fossil Fuel Levy (FFL) through the Non-Fossil Fuel Obligation (NFFO) and from 2002 onwards a Renewables Obligation (RO) system. A Feed-In Tariff system was introduced in 2010 but only for much smaller sources than are covered in, for example, Spain and Germany. Each of these mechanisms has had its

[2] Ofgem (2010)'Action needed to ensure Britain's energy supplies remain secure' Press release R5, February 2010.
http://www.ofgem.gov.uk/Media/PressRel/Documents1/Ofgem%20-%20Discovery%20phase%20II%20Draft%20v15.pdf

advantages and disadvantages. In principle, all could be used in a more planned system so it is important to examine their record.

3.1. The NFFO

The NFFO was an accident born of the failure to privatise the nuclear power sector in 1990. The nuclear power plants were placed in a new publicly owned company, Nuclear Electric. The operating costs of the existing nuclear plants were found to be about double the expected market price for electricity so to allow the company to continue trading, a subsidy had to be introduced. 10 per cent of all consumer bills, the Fossil Fuel Levy (FFL) was allocated to this subsidy raising about £1m per year. The European Commission judged this an unfair state aid to nuclear power and required that it be phased out by 1998.

Nearly all of the FFL was paid to Nuclear Electric. For political reasons, a small proportion of this, rising from 0.5 per cent of the subsidy in 1990/91 to 8 per cent in 1994/95 was allocated to renewables and this was disbursed through capacity auctions [2]. A total of five auctions were held. Typically, the auctions would specify the amount of capacity that would receive subsidies and could also be targeted at particular technologies, for example, waste-to-energy. In terms of prices, the results were impressive with the last auction in 1998 producing an average successful bid of £27/MWh compared to £75/MWh in 1990.

However, the completion rate on the successful bids was very poor. This was partly because of difficulties in obtaining finance and planning consents, and problems of equipment supply. The time limit on the FFL imposed by the European Commission meant also that projects could only receive subsidies for a short period of time up to 1998 when the FFL had to be phased out. In 1996, the FFL for nuclear was abolished and remained at a much lower level until 1998 specifically to subsidise renewables. Because subsidies for renewables were allowable under European Union law, it was possible to extend to 15 years the period for which subsidies could be given and this meant that for the final auction, much longer contracts of 15 years could be awarded to successful bidders rather than the contracts up to 1998 that had applied previously.

3.2. The Renewables Obligation

There was a hiatus from 1998 to 2002 while the government considered how to replace the NFFO. In April 2002, the British government announced that a Renewable Obligation (RO) on electricity retailers would be introduced. This effectively requires them to source a given percentage of their electricity from renewable sources. The level was set at 3 per cent in 2003, rising to about 10 per cent in 2010 [3]. Companies that fell short of their target percentage are required to ‘buy out’ their obligation at 3p/kWh (rising annually with inflation). The funds raised are redistributed to the suppliers that complied with the obligation using certificates. The RO was expected to force electricity retail companies to meet their obligation as cheaply as possible to ensure their tariffs remained competitive.

There have been a number of problems with the RO [4]. First, the design of the penalties means that if all the companies fall short of the target, none of them is financially or competitively disadvantaged. The cost of the buy-out may be judged preferable to the risk and extra cost of building new renewable facilities. Given the structure of the British electricity market, under which all the major electricity retailers are owned by the six large generation companies, the RO is also a barrier to entry for new generators. The retail arms of the ‘big six’ companies will generally have a strong incentive to either own or control the resources they contract and will be able to prevent entry by new renewable generation companies.

3.3. Feed-in tariffs

Feed-in tariffs (FITs) have been highly effective, for example, in Spain and Germany, at rapidly expanding renewable capacity and, given the poor rate of installation of renewables in the UK, this has led to pressure to adopt FITs in the UK. In 2008, the UK Energy Act [6] introduced provisions for FITs and in April 2010, FITs were introduced, but only for installations with a capacity of 5MW or less. This scheme can clearly only have a limited impact and seems focused mainly on households. It is too early to assess how successful it will be yet. Elsewhere, experience suggests that the key to successful use of FITs is to set the fixed tariffs at a level that is high enough to stimulate investment but not so high as to lead to wasteful over-investment with larger than necessary public subsidies.

3.4. Review of experience to date

While Britain has probably the best renewable resource base in Europe, at least with current technology, it has one of the poorest rates of installation and costs have been high [4]. The evidence that costs are high is particularly damning given the emphasis with the two main policies, the NFFO and the RO, on market mechanisms as a means to minimise the cost to consumers.

4. The Future

In the next decade, the requirements for installing renewable generation will be massively increased. Under the RO, British electricity retailers are required to source about 10 per cent of their *electricity* from renewables. Under the European Commission's '20-20-20' targets, Member States would need to source 20 per cent of their *energy* from renewable sources. Given that in the UK, electricity makes up less than 20 per cent of final energy consumption, meeting this target would require a massive increase in installation rates. Even if we assume that half of these renewables would not be used for electricity generation (e.g., bio-fuels), this would require that renewable generation capacity would have to increase more than 5-fold in less than a decade.

It would seem that cost-minimisation can no longer be the dominant policy force. Clearly, electricity needs to remain affordable, especially if we are going to require that it substitutes for direct use of fossil fuels, for example, in space-heating and transport, so cost has to remain an important consideration. However, future generations will not be impressed if we fall well short of the '20-20-20' target no matter how cheap the renewables we do build are.

The major unknown is the attitude of the British government to nuclear power. Nuclear proponents claim that nuclear power is the only feasible way to meet such ambitious targets as the '20-20-20' policy. Nuclear is claimed to be a proven, low-carbon, base-load source that can be deployed in large numbers with no resource constraints that cannot be overcome.

Its detractors, apart from the well-rehearsed arguments on safety, proliferation and waste disposal, dispute that it is as low-carbon as it is portrayed and they are concerned about the extent of uranium reserves. The designs now available for order have yet to be demonstrated. They also claim that nuclear's costs are far higher than governments promoting it acknowledge and that rates of installation for nuclear programmes worldwide have almost invariably fallen far short of the rates forecast. To illustrate the two latter points, they note that estimated construction costs of the latest generation of plants has increased from US$1000/kW less than a decade ago to US$6000/kW and if history is a good guide, outturn costs will be even higher. On installation rates, when President Bush launched the US Nuclear

2010 programme in 2002, the assumption was that one or two new reactors would be in service by 2010. It seems likely that the first reactor under this programme will not be finished much before 2020 and many of the utilities that expressed interest in the programme are now dropping out. Nevertheless, the British government is convinced that a rapid expansion of nuclear power will be the main tool for Britain to reduce its fossil fuel usage.

A number of mechanisms have been mooted in Britain to encourage renewables (and nuclear) development.

4.1. Capacity payments

These were mentioned by the Energy Minister in his February 2010 announcement so it seems likely they are in the mind of officials at the energy ministry (now the Department of Energy and Climate Change, DECC). Capacity payments would be paid to generation sources simply for being available to generate and would clearly be an advantage to potentially base-load sources, but would be of little or no value to intermittent sources such as wind, wave or solar. They would be a particular advantage to nuclear power however, which because of its rigid cost structure is vulnerable to market price variations.

However, the logic of capacity payments would seem to be that they should be targeted at peaking capacity. The annual loading of such plant is highly variable depending on weather and demand, and, for several years, a peaking plant whose availability is needed for supply security might earn little or no income from sale of electricity. A capacity payment sufficient to cover its fixed costs would give plant owners a strong incentive to keep such plant on-line. If a base-load source is not earning enough money to cover its costs from sale of electricity this suggests either that there are market defects or that that source is simply uncompetitive.

It should also be noted that from 1990-2002, the British electricity market design included a type of capacity payment. However, this was continually manipulated by the generators to increase, unfairly, the level of payment they received.

4.2. Fixing the Carbon price

The idea of fixing the carbon price came up in the context of the 2008 UK White Paper on nuclear power [5]. According to this, for nuclear power to be economic, using even the government's highly optimistic figures, the carbon price would have to be at least €36/tCO_2. It may have been that this was simply the easiest way for the British government to maintain the illusion that nuclear power was an economic option that companies would choose unprompted if some enabling measures were introduced. A centre piece of the British policy since then has been that no public subsidies would be offered to induce the construction of new nuclear capacity. However, the discussion of the Carbon price was seen by many as an indication that the British government was considering putting a floor on the Carbon price at a level that would make nuclear power economically viable. A Carbon price floor would also provide a more secure income stream for all renewable options, but whether it would be sufficient by itself to ensure that renewable capacity was built is far from clear. The same reservation applies equally to nuclear power.

In practice, the Carbon price is set in the European Union's Emissions Trading Scheme (EU ETS). Britain cannot choose arbitrarily to fix the Carbon price unless it exited the EU ETS and set a floor Carbon price for a new British Carbon market, which does not seem likely to be politically viable. Alternatively the Carbon price could be fixed if the EU ETS was substantially changed to include a floor price for the whole of Europe.

Few would argue that the EU ETS has worked well and the Carbon price has remained low, far below the levels seen by the British government as being necessary to make nuclear power viable. Whether simply giving up on the market entirely to creatively find ways of reducing greenhouse gas emissions by fixing the Carbon price is necessary is far from clear.

4.3. Energy efficiency

Clearly, reducing demand substantially would make the 20 per cent target much easier to achieve. An aggressive programme of energy efficiency measures would also have other policy pay-offs. Britain now has a serious problem of 'energy poverty', a condition under which a household is required to spend more than 10 per cent of their household disposable income on buying energy for the house. This has risen, as energy prices have increased from about 7 per cent of households in 2002 to more than 20 per cent in 2010. A programme of energy efficiency measures targeted at low income households would have major welfare benefits, would be likely to create large numbers of new jobs in the construction sector. It might also allow existing welfare payments, such as the winter fuels allowance under which all pensioners receive a sum of the order of £300 every December as a contribution to their energy bills.

5. Conclusions

5.1. Political considerations

It is arguable that it was always an illusion that a free market for electricity was feasible except in the few years around the turn of the century when fossil fuel markets were over-supplied and the extent of the challenge posed by climate change had not been fully assimilated at the highest policy level. Renewables are, in general, some way, in terms of cost and technological maturity from the position in which it can be left to the market to order them.

If this is the case, the announcements from the British government of concerns about the electricity market should not have been a shock not because of what was said but because Britain is seen as the pioneer, advocate and most successful implementer of electricity markets.

The European Union is in an even more difficult position than the UK. It bought into the rhetoric of electricity markets fully and has spent more than 15 years trying to impose essentially a copy of the 'British Model' on Member States. In the process it irreversibly dismantled structures and companies which, while far from perfect, had delivered reliable affordable electricity for many decades. For the Commission to admit that this effort was all misconceived will be politically difficult. However, the Commission cannot escape the reality that a free market electricity system is not feasible. A likely outcome is that what will emerge is a 'Frankinstein's Monster' of a system with a veneer of competition, but which in reality is subject to strong centralized planning with inadequate regulation.

5.2. Practical options

The capacity auction mechanism under the NFFO, and the Renewables Obligation and the European Union Emissions Trading Scheme have all suffered from serious design issues that meant that none worked as planned. It is hard to say whether, with better design, these could have been effective or whether it is the fate of all market mechanisms, no matter how attractive in principle, to fail in practice, often through manipulation by the companies.

However, if the '20-20-20' targets are a necessary and viable target, we may not have the time for more experiments with market mechanisms. We will also not have the luxury of cherry-picking only cheap renewable options, such as on-shore wind, we will have to pursue more expensive renewable options.

Feed-in tariffs remain the option with the best track-record of bringing large quantities of renewables on-line. They can also be tailored for a variety of sources with different prices on offer for different technologies.

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Investment in Wind Power & Pumped Storage in a Real Options Model – A Policy Analysis

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Abstract: Promoting renewable energy has been a key ingredient in energy policy seeking to de-carbonize the energy mix and will continue to do so in the future given the European Union's high ambitions to further curb carbon emissions. A wide range of instruments has been suggested and implemented in various countries of the EU. A prominent policy promoting investment in renewable technologies is the use of feed-in tariffs, which has worked well at large scale in e.g. Germany, but which has only been implemented in a very limited way in countries such as the UK. Being subject to environmental uncertainties, however, renewables cannot be seen in isolation: while renewables-based technologies such as wind and solar energy, for example, suffer from uncertain loads depending on environmental conditions, hydropower allows for the storage of water for release at peak prices, which can be treated as a premium (partially) offsetting higher upfront investment costs. In addition, electricity prices will respond to changes in electric capacity in the market, which is often neglected in standard investment models of the electricity sector. This paper contributes to the existing literature of real options approaches to electricity investment by investigating the specific characteristics of renewables and their associated uncertainties in a stylized setting taking explicitly into account market effects of investment decisions. The prices of the model are determined endogenously by the supply of electricity in the market and by exogenous electricity price uncertainty. The inclusion of market effects allows us to capture the full impact of public incentives for companies to invest into particular technologies.

Keywords: *Real Options, Energy policy, Renewables, Market effects.*

1. Introduction

According to the International Energy Agency (e.g. [1]), Norway's electricity production is almost exclusively based on hydropower. However, the potentials for large-scale hydropower has been almost exhausted over the past and in the pursuit of meeting emission reduction goals without compromising the security of energy supply, the Norwegian government has been promoting other renewable energy sources such as hydro- and wind power. The latter is particularly attractive for Norway, as it enjoys both high wind speeds and a long coast line.

Within the European Union the most common policy to encourage the installation of renewable capacity has been feed-in tariffs to date. This works such that producers receive a fixed price for the supplied electricity, which exceeds expected market prices. Often these tariffs decrease over time. The policy for the promotion of Norwegian wind power has been an investment subsidy before the project has started. Even though it had been planned to – jointly with Sweden - introduce a market arrangement for electricity certificates to substitute for these investment subsidies from 2007 on, these plans had to be postponed until after 2010. Under this arrangement, as outlined in [2] consumers will have to buy a certain amount of certificates for their electricity bought and eligible power plants will yield certificates for the electricity producers which can be sold. Policymakers then decide upon the type of electricity production, which should be eligible, and on the respective amount of certificates. This way the countries can exploit the renewable resources and distribute the burden on the producers in the most efficient way and the aggregate quota will thus be attained at a lower total cost compared to feed-in tariffs or quotas.

[3] use a real options approach taking into account the uncertainty from certificate price fluctuations to estimate the amount of new renewable capacity coming online under such a joint Swedish-Norwegian electricity certificate scheme. In this study, we want to focus on the current policy of investment subsidies. In addition to the policy context, another factor that we want to take into account in our analysis is the intermittency of wind power, which has tended to make it an unattractive option next to fossil-fuel-fired generation options [4]. In a related study, [5] explored how the integration of energy storage with individual wind turbines could smooth out the wind speed fluctuations. Their results for different types of wind conditions illustrated that short-term wind power fluctuations could be substantially reduced.

Several studies over the past few years have further looked into technologies to realize such benefits and pumped-storage wind-hydro plants, which use reservoirs to store water previously pumped up with wind power, have been found to be profitable under particular circumstances [6]. Especially on islands, where wind potentials are high, pumped-storage wind-hydro plants have been found to be a promising option, with larger islands offering potential for even more profitable investments, where wind-hydro could even serve as base-load (e.g. [7], [8]).[1] Finally, a number of ancillary benefits add to the attractiveness of the technology. These include, inter alia, that the stored water can in emergency cases be used for consumption, irrigation, and to fight fires, etc. Also, wind-hydro plants are almost carbon-free in terms of emissions. Finally, the wind-hydro plant can contribute substantially to grid stabilization by acting as a swing producer (consuming in off-peak times to pump up the water and generating during peak times). Most of the studies reviewed above have found that pumped-storage wind-hydro plants generally only become profitable at high electricity prices or significantly improved design and efficiency combined with high wind speeds. In this paper we want to explore the profitability of such a system both in Norway, but also in Germany considering the impact of uncertainty on investment decisions. Uncertainty emanates from two sources in our study: the development of the electricity price, which can additionally also be influenced by new capacity additions, and the intermittency of wind, which leads to a fluctuating load and thus uncertainty in profits. We therefore want to explore pumped-storage wind-hydro plants to stabilize profits from wind. While this might appear like an attractive solution for particular demonstration cases, it has to be kept in mind that such equipment is extremely costly and it is questionable whether the premium from profit stabilization would make up for this deficiency and whether therefore public funding should rather be directed at R&D targeted at cost reductions in the first place.

We adapt the real options model presented in [9] in order to capture all these elements to answer the research questions outlined above and apply it to the German and Norwegian market situations to get a picture of the profitability of pumped-storage wind-hydro plants in the respective countries. The model focuses on the plant and its operation and abstracts from problems of integrating wind power into the grid, which is why the results have to be interpreted with caution.

2. A Real Options Model for Wind Power Investment with Pumped Storage

2.1. Model formulation

In this section we formulate the model that will be used for the analysis in section 3. We study the profitability of the wind technology combined with pumped storage when compared

[1] This is attractive for small and isolated electricity production systems, which does not apply to Norway.

to the standard wind farms. The investor tries to find the investment strategy that maximizes expected profits during the planning period. He can decide whether and when to construct new electricity generating capacities. There are two possible technologies available: a standard wind farm (referred to as wind) and wind combined with pumped storage (referred to as wind + hydro). The assumptions underlying the model formulation can be summarized as follows:

1. The decisions can be made only once a year, the planning period is finite (*T* years).
2. The total number of power plants that can be built is limited to *n*, where only one power plant can be built during one year.
3. The load factor of both technologies is assumed to be uncertain, which leads to the annual electricity production being uncertain. Therefore, the annual electricity supply of both technologies is assumed to be equal and is denoted by q_t^w, which is modeled in each year as an independent random variable with known distribution.
4. The supply of the investor is given by the maximum quantity as $q_t^w(n_t^w + n_t^h)$, where n_t^w, n_t^h denote the number of wind and wind + hydro power plants built by the investor prior to year *t* respectively. The aggregate supply Q_t in year *t* is given by
$$Q_t = Q_0 + Nq_t^w(n_t^w + n_t^h)\,, \qquad (1)$$
where Q_0 is the quantity supplied by firms that do not invest during the planning period and the quantity produced by plants outside the planning period, i.e. which already existed in t=0. *N* is the multiplier of the new investment. This represents the assumption that the new investment in the market is of the same structure as the one chosen by the investor.
5. The electricity price in year *t* (P_t^e) is assumed to depend both on income and demand in the current year and is subject to exogenous shocks, i.e.
$$P_t^e(Q_t, X_t) = Y_t^{-\varepsilon_i/\varepsilon_p} Q_t^{1/\varepsilon_p} X_t \qquad (2)$$
where Y_t is the disposable income in year *t* and $\varepsilon_i, \varepsilon_p$ denotes the income and price elasticity respectively. X_t is the exogenous shock, which is assumed to be an independent random variable with known distribution for each *t*.
6. As has been already explained in section 2.1, wind when combined with pumped storage is able to affect the timing of supply and thus to benefit from the price fluctuations within a year. Thus the average price of electricity per kWh sold by a wind + hydro combination is higher than that of a standard wind. This is represented in the model by the price premium *p*, which denotes the price increment in percentage of the yearly electricity average price at the market.
7. The capital costs are annualized, representing a situation where the overnight construction costs are covered by a loan with the annualized capital costs being the yearly installments of such a loan. The O&M costs depend not only on the number of the power plants of the individual technologies, but also on the electricity supply in the given year, Therefore the yearly costs $c(n_t^w, n_t^h, q_t^w)$ of the investor are a function of n_t^w, n_t^h and q_t^w. The yearly income of the investor can be calculated as
$$\pi(n_t^w, n_t^h, q_t^w, X_t) = P_t^e(Q_t, X_t)q_t^w(n_t^w + (1+p)n_t^h) - c(n_t^h, n_t^w, q_t^w)\,. \qquad (4)$$

Under these assumptions the investor's problem can be formulated as

$$
\begin{aligned}
&\max_{u_t^w, u_t^h} \quad E[\sum_{t=0}^{T-1} \frac{1}{(1+r)^t} \pi(n_t^w, n_t^h, q_t^w, X_t)] \\
&n_{t+1}^w = n_t^w + u_t^w && t = 0, \ldots, T-1 \\
&n_{t+1}^h = n_t^h + u_t^h && t = 0, \ldots, T-1 \\
&n_0^w = 0, \quad n_0^h = 0 && \\
&n_t^w + n_t^h \le n, \quad u_t^w + u_t^h \le 1, && t = 0, \ldots, T-1 \\
&u_t^w \in \{0,1\}, \quad u_t^h \in \{0,1\} && t = 0, \ldots, T-1 \\
&q_t^w, X_t - \text{random variables with known distribution} && t = 0, \ldots, T-1
\end{aligned} \tag{5}
$$

where r is the subjective discount rate, n_t^w, n_t^h are the state variables, u_t^w, u_t^h the control variables that are binary and represent the decision of the investor to invest in year t into a wind/wind + hydro power plant respectively.

The resulting problem is a stochastic optimal control problem in discrete time with all the underlying variables being discrete in each time step. Thus it can be solved by recursive dynamic programming. The solution is then the optimal control in terms of feedback control telling the investor the optimal action for each time step and each possible state in that time.

To analyze the impact of the individual features of the model (impact of climate policy, wind load uncertainty), this output is further processed. In the results section, two indicators of the optimal control are usually reported: the mean amount of wind + hydro farms that are built within the planning period, and the value of the firm. The mean value of the firm is directly given by the value function in the first year that is derived by the dynamic programming. For the average number of wind + hydro plants, Monte Carlo simulations are used. Future load and price shocks are simulated and for each simulation the feedback optimal control is used to extract the decision realized in that simulation. These decisions are then used for the calculation of the average investment into wind. In addition, these can be used to calculate the sum of the discounted profits over the planning period in each simulation, which gives us a distribution of the value of the firm as well. For the application, the values of the individual parameters have to be estimated, the functional forms and the remaining data still have to be specified. This is explained more in detail in section 2.3.

2.2. Data

In our paper the investment decisions of the producers are exemplarily surveyed in the countries Germany and Norway. The producers can choose between a farm of wind power plants and a farm of wind power plants in combination with a hydro pump storage plant. Both investment opportunities are adjusted so that the maximum output per year is the same. Furthermore the ratio of the size of the wind farm respectively the combination of wind farm and hydro pump storage in Norway and Germany is equal to the ratio of the size of the two electricity markets (Q_0). [9] calculate the optimal size of the pump storage plant in relation to the wind farm and derive the ratio of 1:3. We use this ratio together with their estimate for the electricity loss caused by the pump process in the hydro pump storage plant of 0.1128 to calculate the setting of the combination. The cost estimates we use are taken from the 2010 [10] and summarized in Table 2. To derive the costs in € rather than US$, we used the exchange rate given in the IEA report [10] of 0.68 and the same measure (average exchange rate of 2008) for the translation of € into Norwegian Kroner at 8.22 (OECD, 2010 [11]).

Table 1 Cost Data

		Yearly production	Ann. Capital Costs / Plant	Variable Costs (O&M + Fuel + Permit expenses)
Wind	Germany	25,916.9 GWh/a	275.9 Mio. €/a	24.90 €/a
	Norway	6,120.5 GWh/a	535.8 Mio. NK/a	204.78 NK/a
Wind + Hydro	Germany	25,916.9 GWh/a	543.1 Mio. €/a	32.08 €/a
Pump Storage	Norway	6,120.5 GWh/a	1,054 Mio. NK/a	263.78 NK/a

Source: calculated from [10] IEA, 2010.

The load factor of the wind plants is assumed to be normally distributed around a mean of 23% (according to [11]) with a standard deviation of 6% (as estimated for Europe in [12]). There is a huge amount of literature estimating the demand and its elasticity for electricity. Two often cited survey articles in this stream are Dahl (1993, [13]) and Espey and Espey (2004, [14]). Together they analyze some 84 articles with estimations of the elasticity for electricity. For modelling our price process, we rely on the basic model to keep the analysis transparent. The elasticities are thus estimated as follows:

$$\ln Q_t = \varepsilon_p \ln P_t^e + \varepsilon_i \ln Y_t + x_t \tag{6}$$

with x_t denoting the error term. The articles also calculate mean values of the estimates found in the analyzed articles for equation (6). The authors report an interval with the mean price elasticity of demand ε_p at -0.80 and the mean income elasticity ε_i at 0.93. The estimations using the form in (6) exactly estimate the price process used in our model described given by equation (2). For the stochastic shock (error term in (6)) we assume a normal distribution with mean 1 and standard deviation of 0.2 (which is approximately the size of the variance of the error term when estimating equation (6) with our underlying data). We model the disposable income using a starting value Y_0 from 2009 and the average annual growth rate y of the last 20 years (1990 – 2009). As the firm has no investments at time $t=0$ we take the actual total gross electricity generation of 2009 as the original supply in the market Q_0 and assume that respectively the big electricity producers of a country simultaneously take the same decisions. The data is summarized in Table 2.

Table 2 Price Process Data

	Y_0	y	Q_0	N
Germany	2,445.5 Bio. €	0.0288	577,380 GWh	4
Norway	2,264.3 Bio. NK	0.0389	136,353 GWh	5

Source: EUROSTAT (2010), OECD (2010) [11].

The considered planning period T is chosen as 30 years and following the standard assumptions in this stream of literature, we assume a discount rate r of 0.05. Each firm is allowed to invest a maximum of four times. Note from the data that the difference between the “Germany case” and the “Norway case” lies in two characteristics: the size of the market and the electricity price process (and the underlying parameters).

3. Model Results and Policy Analysis

3.1. Price Premium

An investment into the combination of a wind farm and a hydro pump storage plant conveys the following characteristics: a) the (uncertain) output of the wind farm is the same as without the hydro pump storage, but b) the producer now has the opportunity to save some output if the prices are low and sell the output plus the saved electricity if prices are high. Thus c) on average the producer earns a higher price per unit of output, i.e. he receives a price premium for having the opportunity to postpone the selling of current production. This premium has to outweigh the d) investment costs for the hydro plant, the variable (O&M) costs of running the hydro pump storage plant and the (small) loss of output through the storage process. Figure 1 shows the average number of investments into the combination at the end of the planning period for different levels of price premia. One can see that only with a price premium as high as 70% in Germany and 75% in Norway the combination gets relatively profitable and the producers invest into it at least once. To get the maximum average number of investments a premium of at least 115% would be needed in Germany and 150% in Norway. Such high differences in the average price per output unit cannot be realistic. E.g. [15] calculated the optimal operation and size of a wind-hydro power plant combination. They found the yearly average per unit profits of the combination to be 20.12% higher than the per unit profits of an equally sized wind farm. Thus, we can conclude that today the investment into a combination of a wind farm and a hydro pump storage plant without public support is not profitable for a producer compared to only investing into a wind farm.

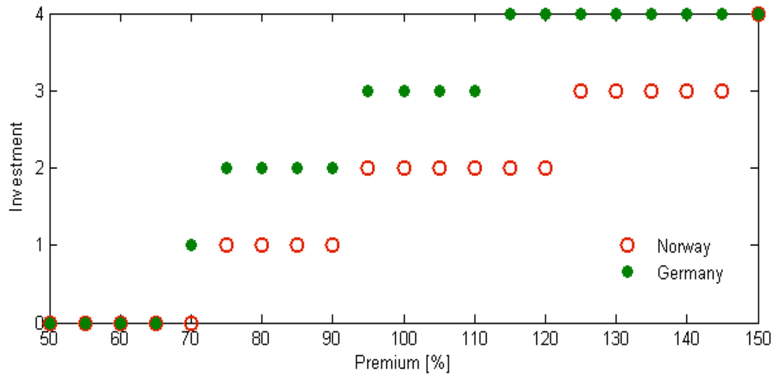

Figure 1: Average investments into wind-hydro at the end of the planning period for different levels of price premia

Two factors we do not consider in our study are grids and economies of scale. One can think of the additional costs surrounding the transmission of the electricity from the wind farm to the pump storage plant and back into the system as an increase in the variable costs of each produced unit. These costs are higher the farther the wind farm is away from the pump storage plant or in the periods (high-peak vs. low-peak) during which the electricity is transported. Thus, a large fraction of the literature shows that the combination is most profitable on small islands and could even serve as base-load on larger islands (see e.g. literature review in Anagnostopoulos and Papantonis (2007) [6]). In our framework, taking into account the costs grid adjustments would increase the threshold premium needed to make the combination relatively profitable. Economies of scale work in the other direction. So a bigger wind farm or e.g. an already existing bigger hydro pumped storage plant can produce the electricity at lower per unit costs, which will result in a lower threshold premium.

3.2. Investment Subsidy

Due to the positive externalities of the combination, i.e. for example stored water can in emergency cases be used for consumption and irrigation, etc, it makes sense for a country to support the investment into these combinations. E.g. Norway supports the investment into the combination by paying a subsidy on the investment costs before the project starts. This subsidy would need to be high enough to make up for the difference in the premium needed (as seen in the chapter before) and a realistic premium.

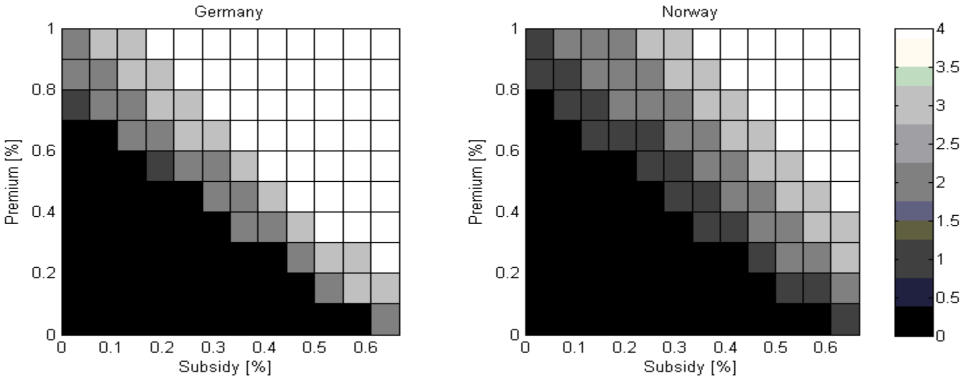

Figure 2: Average investments into wind-hydro at the end of the planning period for different levels of capital cost subsidies.

Figure 2 shows the average number of investments into the combination at the end of the planning period for different levels of capital cost subsidies. The different areas are shown for a variation of price premia between 0% and 100%. For realistic premia values (i.e. between 10% and 30%) the threshold subsidy to trigger at least one investment into the combination in Germany and Norway lies between 35% and 50%. To get the maximum average number of investments a subsidy of up to 70% in Germany and 90% in Norway would be needed. In general, one can see that the investment activity of the producers is much more sensitive to an increase in the subsidy in Germany than in Norway. This can be explained by the relatively higher threshold level needed to trigger investments in the Norwegian market, i.e. prices start relatively lower in Norway due to the relatively higher already installed capacity in t=0 in Norway. Afterwards the follow-up investments happen later due to the higher number of big firms investing at the same time and the higher (in absolute terms) price level. Since in our framework we compared the investments into wind farms and the investments in a combination of wind power with hydro pump storage plants, the introduction of a likely Swedish-Norwegian tradable green certificates system, which would affect both types of plants symmetrically, would in general not change our results. The results would only change if policy makers would allocate different amounts of certificates to units of electricity produced by wind or water plants and categorize the electricity produced by the hydro pump storage plant as electricity generated by water rather than by wind. In that case the result in our framework would be a decreased (if the allocation is in favor of water; increased otherwise) threshold premia. Producers will earn an uncertain but positive additional amount per unit produced.

4. Conclusion

This paper has presented a model for the economic evaluation of the adoption of a hybrid technology combing wind power and hydro pumped storage. We have chosen the market situation in Germany and Norway as case studies and explicitly accounted for uncertainty about the development of the electricity price and the market effects of new capacity additions, the intermittency of wind leading to a volatile load and the policy of an investment subsidy. While the stabilization of profits and its raise by a premium from being able to sell at peak prices might appear attractive, our study shows that without substantial public support the technology is not profitable and will not be adopted for realistic premia. If grid stabilization, CO_2 mitigation and other objectives than profit-maximization enter the objective, there is thus a case of intervention to promote this type of technology.

Apart from the conventional policy measures ranging from feed-in tariffs to investment subsidies, another important dimension recommended to policy makers for consideration is the investment into R&D to decrease the costs and increase the efficiency of the technology in general. Rather than supporting investments today with relatively high costs compared to other green technologies, this can prove to lead to a faster diffusion of the technology at lower cost. Further research should also try and include factors that have not been considered explicitly in this analysis: grids, economies of scale and – in the case of Norway – the planned green certificate system.

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Grid-Connected Renewable Energy in China: Policies and Institutions in a Socialist Market Economy

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Abstract: Chinese policies and institutions for the deployment of renewable electricity are only partially compliant with what is internationally recognized as "best practice"; and divergences from the optimal policy and institutional model are frequently interpreted as obstacles to renewables in China. Much as a political economy perspective has aided understanding of why Chinese economic reforms were partial and unique, the contextualization of Chinese policies and institutions for renewables in the broader picture of China's political economy (said contextualization being the purpose of this paper) might help explain why those policies and institutions diverge from best practice. Further, given that China proved successful in promoting its economic growth with partial and unique reforms, the partiality and uniqueness of its renewable policy and institutions need not impede the rapid development of renewable electricity. Our analysis combines a review of specialized literature and the business press with semi-structured interviews held with relevant actors in policy, business, and research related to renewable energies.

Keywords: *Renewable energy, Policies, Institutions, Political Economy, China.*

1. Introduction and methodology[1]

There is an extensive literature that describes the particularities of China's political economy, as well as, in many cases, the impact of said political economy on socio-economic performance. These are usually studies that deal with quite broad views of political economy as well as with broad outcomes (such as economic growth). Nevertheless, one observes less emphasis in trying to relate the features and performance of more specific economic sectors (e.g. renewable energy) to the particularities of the Chinese political economy. Instead, when looking into concrete economic sectors, it is not uncommon for specialists to analyze China by applying concepts and theoretical models developed for other realities. Also not uncommonly, the fact that Chinese regulations do not fit nicely into such concepts and models leads observers to pessimistic expectations on Chinese performance.

In this paper, we look into the Chinese grid-connected renewable energy (GCRE) sector as an exercise in overcoming the mainstream de-contextualization of the analysis of Chinese policies and institutions when it comes to specific economic sectors. To be more concrete, we attempt to explain why Chinese policies and institutions do not nicely fit into the "best practice" model, in view of China's principles for decision-making. Whereas such model could be portrayed as a sector-specific description of a Liberal Market Economy (LME), Chinese policies and institutions for GCRE more resemble the sector-specification of what could be termed a Socialist Market Economy (SME); more concretely, policies and institutions are informed by three principles of decision-making particular to the Chinese political economy: gradualism, developmentalism, and socialism.

Our analysis combines a review of specialized literature and the business press with semi-structured interviews held with relevant actors in policy, business, and research related to renewable energies. Interviews were conducted at: departments of the Government of Spain;

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Chinese public research centers; institutions for international cooperation in energy and the environment; and multinational companies operating in China.

2. Policies and institutions for GCRE: "best practice" and the case of China

There is an extensive literature describing sets of policies and institutions[2] that foster the deployment of renewable energy (and GRCE in particular). Such collections of prescriptions are scattered, appearing mostly in professional reports and policy handbooks published by energy organizations or associations (see for example GWEC, 2005; IEA, 2007 and 2008; IREC, 2004; World Bank, 2008; WEC, 2004).

In a previous paper (García, 2010), we assembled a systematic collection of the policy and institutional prescriptions posited in these reports as "best practice"; also characterizing such prescriptions as a sector-specific description of a particular kind of capitalism, sometimes termed LME, as in Hall and Soskice (2001). In particular, the model consists in: (1) policies that eliminate economic barriers to renewables (barriers to investment related to insufficient revenue or excessive cost) by leveling the playing field of renewables vis-à-vis fossil fuels, as well as by implementing support mechanisms that compensate for high costs, limited access to finance, and insufficient demand; and (2) institutions that eliminate non-economic barriers (barriers to investment related with institutions) by ensuring good governance on the part of the State and corporate competition. In other words – in terms closer to those describing LMEs – policies consist in regulations that intend to facilitate private investment via the perfection of market mechanisms; and institutions consist in liberal-market institutions, which would also facilitate investment. See a detailed summary of the "best practice" model in Table 1.

Also, the aforementioned paper (García, 2010) discussed the extent to which China's policies and institutions for GCRE fit into the "best practice" model, concluding that they do so only partially and imperfectly. China's policies diverge from best practice insofar as: negative externalities of fossil fuels are not compensated for (as with a coal tax); regulations do not incentivate feeding power into the grid, but instead focus on installing capacity (China's renewable portfolio standard does not refer to actual power fed into the grid but to installed capacity; and the tender system for wind that prevailed until 2009 had no provisions to ensure generation and transmission); remuneration levels are low and duration of tariffs is short (be they tariffs set in tenders, in local licenses, or through FITs); regulations do not include enough provisions for the reduction of tariffs over time, necessary for the promotion of cost-reducing innovations; and PPAs do not ensure connection. Meanwhile, concrete divergences in institutions include the following: general legal insecurity; complex and lengthy red-tape; unpredictable policy instruments (insufficient stability and transparency); insufficient competition in generation due to market concentration, a high market share remaining in public hands, and limits to foreign presence; and restrictions to innovation in manufacturing brought about by barriers to external trade and to foreign investment. See Table 1.

[2] Policies here refer to those rules offered by public authorities as the preferred course of action toward a desired outcome; and institutions refer to structures of economic actors (governmental or corporate) and the mechanisms that influence those actors and relations between them.

Table 1. Summary of "best practice" for the deployment of renewables, and the Chinese divergence from "best practice"

	Policies and institutions for renewables in the "best practice" model	**Elements typical of a liberal market economy**	**Chinese divergences with "best practice"**
Policies to overcome economic barriers	Elimination of coal subsidies	Perfection of markets: role of government is to, with an arm's length approach, eliminate market distortions and compensate for market failures	Negative externalities not fully compensated for
	Compensation for the negative externalities of fossil fuels (pollution…)		
	Remuneration for the positive externalities of renewables		
	Compensation for high initial costs (mandated market policies): quantity-based and price-based schemes		Regulations focus on installed capacity rather than power generation Remuneration levels are low, and duration of tariffs is short
	Increased access to capital: fiscal and financial aids		Regulations do not include enough provisions for reduction of tariffs
	Ensuring sufficient demand (PPAs)		PPAs do not ensure connection
Institutions to overcome non-economic barriers	General legal security	Liberal-market institutions: role of government is to set formal and predictable (stable, non-discretionary, and transparent) rules that are effectively enforced; and to ensure low barriers of entry and competition	General insecurity and uncertainties
	Capable bureacracy: coordination and cutting of red-tape		Incomplete coordination, and complex and lengthy red-tape
	Quality of regulations in renewables: specific, legally binding targets, and predictable instruments		Targets not compulsory, and instruments lacking stability and transparency
	Competition and technology-friendly policies in generation: unbundling, absence of oligopolies, openness to FDI		Limits to competition in generation (market concentration, public ownership, and barriers to foreign entry)
	Competition and technology-friendly policies in manufacturing: openness to external trade and FDI		Limits to innovation (barriers to foreign trade and entry)

Source: Author's design.

3. China's policies and institutions for GCRE in light of principles of policymaking

We contend that singularities in Chinese policies and institutions for GCRE are better understood in light of the overall framework of the Chinese political economy or, more specifically, of the general principles of decision-making in China[3]. We use authoritative secondary sources, as well as insights obtained in interviews, to identify those factors that might help understand the partiality and uniqueness of the Chinese fit into "best practice". In doing so, we stress the importance of gradualism of reforms, developmentalism, and socialism in explaining most particularities of Chinese GCRE's policies and institutions.

Gradualism in Chinese economic reforms has been widely documented[4], with reforms being implemented incrementally and also experimentally. Addressing electric sector reform in particular, Ma and He (2008) and Chen (2010) describe how the transformation of policies and institutions has moved gradually and incompletely toward those of a market system. Various interviewees for the present study described Chinese policies in renewables as being implemented slowly, and through experimentation and trial-and-error (author's interviews). Indeed, many of the aforementioned divergences from "best practice" in the promotion of renewable electricity can be explained in light of gradualism, such as for instance: increasing but still insufficient taxation of coal; the focus on promoting installed capacity before focusing on efficiency as the goal of either mandated market policies or financial incentives; the increasing but still insufficient remuneration and duration of mandated market policies (whether tenders, independent projects, or even FITs); and increasing but incomplete regulation and enforcement of PPAs[5]. Also, institution building is clearly underway, and the following institutional barriers could be seen as the result of gradualism: general legal insecurity; fragmentation of the bureaucracy; targets that remain non-binding; insufficient regulatory details in the REL and its provisions; increasing albeit insufficient wholesale competition, or the preeminence of public ownership in generation. Finally, experimentation can be seen in the wide range of policies implemented: China uses (or has used) most of the policies in the toolbox, also experimenting with institutions – for instance, frequent modifications of incentives to foreign participation in generation or manufacturing.

Nevertheless, interpreting obstacles to renewables in view of gradualism might suggest that there is but one single path for policy- and institution-making for GCRE, which China is following, however slowly. But – as Naughton (1996) and Rawski (1999) indicated – gradualism implies not only that China crosses the river by groping for stones, but that it might be unclear what is on the other side (what the regulatory goals are). If so, the fit of Chinese GCRE policies and institutions with "best practice" might remain forever partial. Also, because other institutional forces, beyond transition, shape Chinese policies and institutions for GCRE, divergences from what is considered an optimal framework for investment could perpetuate[6]. From among such forces, we highlight developmentalism and socialism[7].

[3] For a comparison of how political economy factors (in particular, principles and power structures informing policymaking) explain differences between China, India, and Brazil in reforming electric utilities, see Rufín et al. (2003).
[4] See, for instance, McMillan and Naughton (1992), and Naughton (1996).
[5] Although the amendment to REL introduced in December 2009 specifies the fine to be payed by non-compliant grids, some analyses contest that rather than making connection requirements simpler and stronger, the amendment barely modifies REL, or even complicates its directives (see http://www.chinaenvironmentallaw.com/2009/12/28/chinas-renewable-energy-law-amendments; last accessed 12 December 2010).
[6] That there is no convergence into a single policy and institutional model, even when countries might share the same discourse and general pro-market trends, is stressed in Rufín et al. (2003) for reforms in the electric sector.
[7] Together with Chinese traditional culture, development and socialism are identified by Ogden (1989) as the three core values informing decisionmaking in China.

We contend that the Chinese State exhibits elements of developmentalism that help explain some of the uniqueness of China's policies and institutions for GCRE. As in the paradigmatic cases of Japan or South Korea[8], in China: (1) economic policy has developmental goals; (2) development is deemed as necessary for political legitimacy and stability; and (3) development is to be achieved by means of the State's involvement in the mobilization and allocation of resources. On similar grounds, McNally and Chu (2006) argue that China is another case of a developmental state, although a "diffuse" one, insofar as the central government merely sets the overall incentive and policy framework.

First, the Chinese government is widely recognized to have developmental goals, in the present century with an emphasis on equitable and sustainable growth – an emphasis embedded in the idea of Scientific Development. We should also stress that China shares with prototypical developmental states an emphasis on development goals attached to a somewhat lesser emphasis on rules: concreteness and transparency of regulations are not necessary for development[9]; and ideology can be set aside when deciding regulation, opening the door to pragmatism, flexibility, and eclecticism in the choice of policies and institutions.

Bringing the developmental state to electricity and renewables, there are very diverse non-renewable-energy goals embedded in China's decisions regarding renewables. Goals include energy security (limiting oil imports, avoiding black-outs), socio-economic development (developing local industry, providing employment, lessening rural-urban inequalities and consequent migration…); and environmental protection (diminishing local pollution, as well as emissions of greenhouse gases) (Martinot and Li, 2007; author's interviews). In fact, the delay in using feed-in-tariffs and the early favoring of tenders might reflect the growth imperative insofar as the latter instrument kept prices lower than the FIT system would (Lema and Ruby, 2007).

We have also found an emphasis on goals vs. regulations in Chinese policies and institutions for GCRE. Several interviewees noted the relevance of REL, not for the (few) regulatory details included in that law, but for the signal it sent of Beijing's commitment to pursuing renewable-related goals. In regard to pragmatism, and referring to reforms in the electricity sector, Rufín et al., 2003, see this as an element of Chinese ideology informing the particularities of such reforms.

Second, China's developmentalism is frequently seen as the means to preserve its political regime. Changes in policies and institutions are not in conflict with the preservation of the political system, but reforms are instead conducive to development, and therefore necessary to such preservation. For the case of electricity and GCRE, Yeh and Lewis (2004) argue that the electric sector reform was not an embrace of competitive market models, but the "creative, dynamic response to a set of technical and economic constraints on the one hand, and the political imperative to stay in power on the other. This logic of reform motivates the strategic decision to increase electricity production in order to meet current demand and fuel future economic growth. Such growth, in turn, is part of a larger effort by the party-state to maintain legitimacy by channeling potential citizenship demands into consumption and thus pacifying newly middle-class consumers" (Yeh and Lewis, 2004: 464). Similarly, it is arguable that if Chinese policies and institutions for GCRE do not fit into "best practice", it is because these are not an advancement toward the perfection of electricity markets and the creation of

[8] Frequently cited references on the Developmental State in Japan or South Korea are Johnson (1982) and Amsden (1989).
[9] See Johnson (1982) for a portrayal of the importance of the executive vs. the legislative in the Japanese developmental state.

market-friendly institutions. Rather, they are the necessary response to diverse development needs that, if unattended, could lead to a loss of legitimacy of China's political regime.

Third, the policy and institutional instruments to achieve developmental goals are not strictly those of a liberal market economy, but closer to those of developmental East Asia (World Bank, 1993). Essentially, these include a wide array of non-market-distorting instruments, as well as instruments that do distort resource allocation. In other words, the role of the State in China is not one of creating and perfecting markets, or of ensuring that the proper market institutions are in place, but rather to control these in search of the aforementioned developmental goals (Huang, 2008; McNally, 2008[10]). Involvement of the State in the allocation of resources is exerted via a range of mechanisms that extend from indicative planning to industrial policy and direct ownership of companies. Indicative planning can be seen, in general, in China's Five Year Plans; and, in the case of GCRE, in documents such as the National Medium and Long-Term Development Plan for Renewable Energy in China. Also, the corporatization of state owned enterprises (SOEs) was not simply a gradual move toward privatization, but an attempt to create national-scale holding companies where "state ownership was in a controlling position, to develop large-scale enterprises across territorial and product sector lines, introduce advanced technology, create new products, and work toward achieving international competitiveness. Although it was unstated, this was essentially the model of the huge Korean enterprise groups" (Yabuki and Harner, 1999: 42). In other words, the most recent advancements in industrial reforms demonstrate mixed elements of industrial policy (an effort to nurture certain industrial sectors) and public ownership as means to achieve developmental goals. The tender system for wind (delays in implementing FITs), low remuneration, and other aforementioned limits to foreign competition in power generation (not to mention in distribution) are better understood in light of China's intentions to preserve and nurture public control and even ownership over strategic sectors.

Finally, socialism also informs policymaking and institution-building in China. Some even see gradualism and experimentation as the result of the inherited socialism: in particular, of "communist ideology, nationalistic ambitions, (…), and less opposition from interest groups" (Ma and He, 2008: 1699). And the ongoing prevalence of socialism, even after thirty years of reform, is observable in the official branding of China's economic regime as Socialism with Chinese Characteristics, or in the endorsement, since 1993, of a SME. This system, simply put, entails public ownership (dominating in key sectors) while at the same time having all entities participate within a market system. Also, the SME includes a desire for self-reliance, no longer understood as autarchy but via strategic integration in the global economy (Liu, 2007). Under Mao's Socialism, the State combined government and business roles, and that was also the case for the electricity sector (Ma and He, 2008). Under current Socialism, the government and business roles have been split into different government agencies, to the point where (starting in 2003 according to Ma and He, 2008) public entities in charge of the electricity business have been "corporatized", but not privatized. Also, as already stated, the desire to preserve public ownership might explain many of the policies and institutions described for China's GCRE: delays in implementing FITs, the possibility of keeping remuneration low and tariff duration short, uncertainties in law implementation, and all other difficulties for private and/or foreign competitors in electricity generation.

[10] McNally (2008), who indicates that "China's industrial capitalism remains heavily shaped by the hand of the state" (McNally, 2008: 116).

4. Conclusions

This work has looked into China's grid-connected renewable energy (GCRE) as an exercise in overcoming the mainstream de-contextualization of the analysis of Chinese policies and institutions when it comes to specific economic sectors. To be more concrete, we have reviewed how Chinese policies and institutions do not nicely fit into a "best practice" model; and we have tried to explain such imperfect fit by virtue of China's principles for decision-making: gradualism, developmentalism, and socialism.

We have found that gradualism helps understand most of China's particularities in policies and institutions for GCRE, such as, among others, negative externalities that are not fully compensated for, remuneration levels and tariff durations that grow gradually, increasingly secure PPAs, gradual specifications and predictability of regulations, or a paced opening to competition. Developmentalism, in turn, explains, for instance, the multi-faceted goals of GCRE policies and institutions (these including energy security, environmental, and socio-economic goals); the lack of details and unpredictability of regulations; and all limitations to competition – insofar as competition could endanger industrial policy or public ownership. Finally, socialism also helps understand any measures favoring public corporations (from the delay in using FITs to regulatory uncertainties).

Further research would be necessary to determine: (1) whether there are more elements of the Chinese political economy that should be taken into account in order to better understand the departure of China's policies and institutions for GCRE from "best practice" (certain procedures of decision-making, such as fragmented authoritarianism, decentralization, and government-business coordination, may deserve special attention); and (2) whether the fact that gradualism and partiality of overall economic reforms have not been obstacles to China's economic growth and development should lead us to consider the gradualism and partiality around the application of "best practice" in GCRE as more of an opportunity than an obstacle.

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Policies and Institutions for Grid-Connected Renewable Energy: "Best Practice" vs. the Case of China

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Abstract: A consensus seems to have emerged around what constitutes "best practice" in policymaking and institution-building for the deployment of grid-connected renewable energy (GCRE). However, this consensus, found scattered throughout reports and policy papers, or in the discourse of policymakers and businesspeople, has yet to be systematized. And still, an implicit "best practice" model does seem to exist, against which national cases are frequently assessed, being portrayed as "good" or "bad" for the deployment of renewables in view of, respectively, convergences and divergences from the model. In this paper, we attempt to systematize what are frequently considered the best policies and institutions for renewable electricity. We also seek to portray the prevailing model as a sector-specific description of the policies and institutions present in liberal market economies. Subsequently, we explore the case of China, arguably not a liberal market economy, where policies and institutions coincide with "best practice" only partially and imperfectly, even following enactment of the nation's Renewable Energy Law (REL) in 2006.

Keywords: *Renewable energy, Best practice, Policies, Institutions, China.*

1. Introduction and methodology[1]

There is an extensive literature describing policies and institutions that foster the deployment of renewable energy. To our knowledge, there has been no academic effort to systematically collect the policy and institutional prescriptions posited in diverse sources as "best practice"; such is our current intent. Furthermore, given the diversity of national economic systems, even within market economies, we aim to compile those policies and institutions that constitute a "best practice" model in a way that reveals this model as a sector-specific description of a particular kind of capitalism, sometimes termed "liberal market economy" (LME, as in Hall and Soskice, 2001).

Next, we present China as our case study, whose policies and institutions fit the "best practice" model only partially and imperfectly, even following enactment of a Renewable Energy Law (REL)[2] in 2006. When judged against the model, Chinese particularities appear to be imperfections, or even obstacles to the deployment of renewables. Since the overall Chinese economic system arguably does not fit the definition of an LME, this case study shows: (1) the need for further research in order to determine whether Chinese particularities are indeed imperfections, or simply the sector-specific manifestation of an alternative variety of capitalism; and (2) the need to question the "best practice" model, insofar its prescriptions might be valid only for certain political economies (those of LMEs).

Our analysis combines a review of specialized literature and the business press with semi-structured interviews held with relevant actors in policy, business, and research related to renewable energies. Interviews were conducted at: departments of the Government of Spain; Chinese public research centers (Chinese Academy of Social Sciences, Energy Research

[1] The author would like to acknowledge the financial support of a *Becas Complutense-Del Amo* grant, as well as the insights provided by John Zysman and Steven Vogel, and various doctoral students at University of California, Berkeley.
[2] See the REL at: http://www.ccchina.gov.cn/en/NewsInfo.asp?NewsId=5371 (last accessed November 23, 2009).

Institute, and Pekin University); institutions for international cooperation in energy and the environment; and multinational companies operating in China.

2. Common views on the policies and institutions needed for GCRE[3]

2.1. Overcoming economic barriers to GCRE: policies for the creation of markets

Economic barriers are those high costs and/or insufficient revenues that prevent greater investment in the deployment of renewable technologies. The purpose of policy, according to the guidelines published by relevant international actors (cited below), should therefore be to remove, or compensate for, such obstacles, thus making renewable technologies competitive vis-à-vis traditional alternatives. As we shall see, the economic barriers identified in the specialized literature are basically obstacles that derive from market distortions or failures that, once removed, allow renewable technologies to move towards market competitiveness.

In particular, governments should aim at: (1) "leveling the playing field for renewables" (IEA, 2007:9); and (2) introducing support instruments for an increasingly cost-effective deployment of renewable technologies. Leveling the field entails the elimination of market distortions that favor traditional sources over GCRE: elimination of subsidies to conventional fuels, plus internalization of negative and/or positive externalities. But even if the playing field is leveled, the deployment of GCRE encounters other economic obstacles which "continue to be financially costlier for the investors in renewable power plants than conventional generation" (World Bank, 2008:47). The most cited include: the higher initial cost of installing generating capacity in GCRE; more restricted access to capital; and insufficient demand. Overcoming these obstacles would be achieved by mandated market policies (World Bank, 2008; REN21[4]), financial incentives, and actions to ensure demand.

Regarding mandated market policies, the usual classification establishes that schemes are either quantity-based (basically renewable portfolio standards, RPS, and tender procedures) or price-based (feed-in tariffs, FITs[5], and feed-in premiums). Meanwhile, financial incentives for deployment would aim to promote investment by lowering the costs of such investment, via financial and fiscal aids (grants, loans and loan guarantees, tax credits, etc.). Finally, and regarding demand for GCRE, the clearest recommendations are to ensure grid access and to institute Power Purchase Agreements (PPAs). Although there has been much debate over instrument effectiveness – especially between price-based and quantity-based mechanisms – the latest recommendations (IEA, 2008; World Bank, 2008) underline the importance, not so much of the choice of a particular instrument, but of how an instrument is implemented. In particular: (1) these schemes should be fine-tuned for each renewable technology; (2) remuneration for each technology should be sufficient to ensure profitability – IEA sets minimum levels of remuneration at USD 0.070/kWh for wind, and at USD 0.080/kWh for biomass; (3) the schemes should be of long enough duration to recover investment and ensure profitability; (4) any financial support to renewables should be designed to ensure that both investment and efficiency are achieved, in order to "move technologies quickly towards market competitiveness" (IEA, 2008:23); and (5) production-based supports are preferable to supports to investment, or to installed capacity, since they reward the desired outcome.

[3] This discussion is mostly based on IEA, 2008; GWEC, 2005; IREC, 2004; WEC, 2004; World Bank, 2008; and author's interviews (mostly Western interviewees, since these agreed upon most of what constitutes "best practice").
[4] See: http://www.ren21.net/RenewablesPolicy/PolicyInstruments/RegulatoryPolicies/tabid/5623/Default.aspx (last viewed November 23, 2010).
[5] We understand feed-in tariffs as tariffs that are fixed and equal for any generating company.

2.2. Overcoming non-economic barriers: developing market-friendly institutions

Guidelines on how to promote the use of renewables also focus on the need to eliminate non-economic barriers, which some studies identify as particularly damaging to the development of renewables. Non-economic barriers, at the risk of simplification, consist of features of the institutional framework that prevent greater investment in an increasingly cost-effective deployment of renewable technologies. The purpose of policy, therefore, should be to remove institutional barriers that impede the good functioning of markets.

In systematizing the diverse lessons in this arena, we find that: (1) Regarding government-related institutions, it is proposed that "good governance" prevails by way of general legal security, a capable bureaucracy, and predictable regulations for renewables; and (2) regarding corporate-related institutions, prescriptions include low barriers of entry and competition, as well as a technology-friendly corporate structure. It is proposed that State institutions should first tend towards the development of an overall (not only in energy) regulatory framework that is conducive to market transactions. WEC (2004) refers to the non-observance of property rights as a barrier to renewables; and IREC (2004) identifies as detrimental the absence of "transparent and enforced (…) anti-corruption policies and regulations" (IREC, 2004:7). Second, there are calls for a capable, coordinated bureaucracy; even for "joint policy-making and priority setting between energy ministries and rural development, health, education, water, environmental, and other ministries" (IREC, 2004:11). A capable bureaucracy also entails well-trained officials, and fewer administrative hurdles. Third, regulations around renewables should have specific institutional features: goals should be concrete, formally specified, and binding; policies should be long-term and stable, follow pre-established rules, and be simple and transparent. In sum, rules should be predictable: policy effectiveness for deployment "is more affected by the perceived investment risk on renewables projects than on their potential profits and/or costs" (IEA, 2007:11).

Regarding corporate structure, the "best practice" lessons proposed by the literature relate closely to electricity sector reforms. First, production and transmission should be unbundled in order to avoid oligopolies and achieve wholesale competition. Sometimes implicit in the pro-competition rationale, and clearly stated by most Western interviewees, is the need for room for foreign participation, as this could bring about technology and skill upgrades.

2.3. The "best practice" model as a sector-specific description of an LME

Here we show how the "best practice" model fits into a broader set of policies and institutions present in an LME. Beginning with policies to overcome economic barriers, the very goal of fostering (private) investment through market-incentives presumes the existence of an LME, where investors are atomized companies making decisions in view of costs and revenues. Note that both major sets of prescribed policies restrict a government's role to perfecting the functioning of markets: leveling the playing field explicitly entails the need to eliminate market distortions and compensate for market failures; and support mechanisms are not meant to be part of industrial policy, but should compensate for economic disadvantages of GCRE vis-à-vis fossil fuels arising from market distortions. Regarding institutions to overcome non-economic barriers, the goal is an institutional environment that motivates (private) investment. The prescribed institutions basically reflect those of an LME: the role of government is to set and enforce formal and predictable "rules of the game", so that corporations may freely "play" in the market with no major uncertainties and/or discrimination. Thus do prescriptions include legal security, a capable bureaucracy, and predictable regulations, plus low barriers of entry to both domestic and foreign participation.

The perfecting of markets through arm's length policies and the setting of formal, predictable regulations both fit well into the standard role of a State within an LME. In such a system the State plays an arm's length role while setting competition requirements that prevent coordination between companies. Also, corporate competition in an LME entails that technology transfers occur through market mechanisms, such as hiring or joint ventures (Hall and Soskice, 2001). In similar fashion, the "best practice" model calls for competition or foreign participation as a source of innovation or technology transfer (assuming that these will not be coordinated). Also, LMEs include financial systems with short-term horizons, like those in the "best practice" model (a financial system delinked from the State and non-financial corporations, and unwilling to take long-term risks).

3. Chinese policies and institutions for GCRE[6]: divergences from "best practice"[7]

3.1. Policies for the creation of markets?

As for leveling the playing field for renewables vis-à-vis traditional technologies, Cherni and Kentish (2007) describe how the usual market distortions favoring traditional technologies apply to China. The fact that the average tariff paid to coal-fired power generators is at 0.050 USD/kWh[8] somehow reflects the low cost of producing electricity with coal (for comparison, see below for tariffs paid for renewable sources). A revamped tax on coal is being discussed, but the uncertainties around such tax reform are still many[9]. However, China does implement all the aforementioned support-to-deployment instruments: mandated market policies, financial incentives, and support for demand. But as we shall detail, imperfections in implementation (with respect to "best practice") are significant.

Within quantity-based mandated market policies, China has implemented a renewable electricity standard: all generating companies with installed capacity above 5MW are required to have an installed capacity of renewable energy of at least 3% of total by 2010. Note that this obligation refers not to actual power fed into the grid, but merely installed capacity, which, as some interviewees indicated, results in around 30% of the installed capacity for renewable electricity remaining dormant. Another quantity-based system for GCRE is a tendering system, which prevailed in the case of on-shore wind between 2003 and 2009 and has recently begun to operate for solar. During this period, five national tenders for wind concessions were carried out by the National Development and Reform Commission (NDRC). Winning prices fell between 0.055 and 0.080 USD/kWh; and concessions were for 25 years, but the fixed tariff was guaranteed for the first 30,000 full load hours of operation (GWEC, 2005). Because low remuneration levels and the short duration of fixed tariffs proved insufficient for profitability (Lema and Ruby, 2007; author's interviews), foreign investors were barred from winning these tenders. Remuneration was either below or scarcely above what IEA (2008) identifies as a threshold for deployment of wind power (0.070 USD/kWh), and even below the price set for wind in China before the tender system (Lema and Ruby, 2007); also below what some studies have cited as the threshold for profitability (0.082-0.102 USD/kWh, according to Li et al., 2006). Moreover, the 30,000-hour duration of the tariff corresponds to about half of a wind park's life (author's interviews). Finally, the winning of a concession does not necessarily imply that the project will generate and feed

[6] Many particular policies and institutions will refer only to onshore wind power, given the lag in regulation for other renewable electricity sources, as well as their still-marginal presence in the Chinese installed capacity mix.
[7] Here we use "author's interviews" as a reference to interviewees, be they Western or Chinese, as long as there was a major coincidence in opinions. Otherwise we make disagreements explicit.
[8] All data will be provided in USD. Conversions are made at an exchange rate of 6.8 RMB per 1 USD (December 2009).
[9] Author's interviews and press articles: http://uk.reuters.com/article/idUKTOE62O02R20100325; http://www.eeo.com.cn/ens/Politics/2010/03/29/166354.shtml (last accessed November 23, 2010).

electricity into the grid (REN21, 2009). Apart from national tenders, all wind projects below 50MW are to be approved at the provincial level[10], with specific licensing criteria set locally. According to REN21 (2009), tariffs set for provincial development projects have been between 0.075 and 0.099 USD/kWh, close to what IEA (2008) considers a minimum for deployment and below the estimated threshold for profitability (Li et al., 2006).

Regarding price-based mandated market policies, there is a FIT for biomass, set at the price of coal plus 0.036 USD/kWh for 15 years (RELaw Assist, 2007); and a FIT for wind was established in July 2009, ranging from 0.075 USD/kWh to 0.089 USD/kWh. There are expectations that a FIT for solar will follow, to be set between 0.160 and 0.220 USD/kWh[11]. Given an average coal price of 0.050 USD/kWh, the premium set for biomass raises its FIT to an average of 0.086 USD/kWh, scarcely above what IEA (2008) considers the minimum tariff for policy effectiveness. The FIT for wind also falls very close to the IEA's minimum tariff[12]. Furthermore, although the FIT does set prices slightly above most tariffs resulting from national concessions, it departs little from the average remuneration of independent projects negotiated locally. As with tendering or the independent project systems, the fixed tariffs for wind apply to 30,000 hours of operation, or about half the life of a park. Finally, provisions for the reduction of tariffs over time have been thus far specified only for biomass.

As for financial incentives, we find in China both financial support and fiscal aids. A very recent example of financial support is that solar PV generation projects above 500MW have been eligible, since July 2009, for the enhanced "Golden Sun" project, which includes a 50% subsidy for all investment[13]. The REL itself, in Article 25, dictates that "financial institutions may offer preferential loan with financial interest subsidy" to projects in renewables. On the fiscal side, there are tax reductions, the most relevant being the 50% cut in the VAT tax rate for electricity generated by wind (Lema and Ruby, 2007). Article 26 of the REL also includes tax benefits to renewables. In any case, financial support is frequently given to the manufacturing and development of installed capacity, but with scarce incentives to production, efficient use of resources, or quality improvements and cost reductions (Cherni and Kentish, 2007). Finally, China implements certain demand-enhancing schemes. Transmission companies are obliged to provide each facility with connection to the grid, at the connection point closest to the generator; and, under PPAs, they are obliged to purchase all renewable electricity. Nevertheless, grid companies may prove reluctant to comply with rules: grid companies suffer losses from the purchase of renewable power at fixed tariffs (Cherni and Kentish, 2007). Also, even when generators are provided with connection points, these may be too far from the point of generation[14]. Finally, the grid simply lacks the technical requirements for connecting increasing volumes of renewable electricity (author's interviews). In 2008, as a result of difficulties in connection, and coupled with the fact that the RPS applies to installed capacity and not dispatched power, a significant portion of installed wind capacity remains unconnected to the grid (author's interviews).

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[10] See China's "Administrative Provisions for Renewable Energy Power Generation" (http://www.martinot.info/China_RE_Law_Guidelines_2_NonAuth.pdf; last accessed November 23, 20010).

[11] Press article: http://www.renewableenergyworld.com/rea/news/article/2009/08/ldk-solar-signs-500-mw-pv-project-deal (last accessed November 23, 2010).

[12] IEA (2008) notes that even remunerations well above the minimum might not be effective, if not coupled with the removal of non-economic barriers.

[13] Press article: http://solarglobalgreen.com/pg/blog/justin/read/1278/china-golden-sun-project-aims-to-speed-construction-of-solar-farms (last accessed April 28, 2010).

[14] China's "Administrative Provisions for Renewable Energy Power Generation" (http://www.martinot.info/China_RE_Law_Guidelines_2_NonAuth.pdf; last accessed November 23, 2010) indicates that "the connection system should be built by the power grid enterprises at their own costs", which according to business interviewees does not imply that this is the case over the entire length of the line.

3.2. Market-friendly institutions for renewables?

Concerning institutions related to the State, and general legal security, empirical studies, together with our own interviews, show that foreign companies are discouraged by general regulatory uncertainty in China. As for the capability of the bureaucracy to design, implement, and enforce goals and instruments for the promotion of renewables, coordination has increased since the centralization of energy regulation into new public entities (Lema and Ruby, 2007), such as the National Energy Administration (NEA) or the State Electricity Regulatory Commission (SERC). But a multiplicity of stakeholders continues to prevail, posing at least three problems. First, it brings uncertainty to the degree that the *de iure* or *de facto* responsibilities of each government organism are unclear[15]. Second, even under the umbrella of Beijing's determination, fragmentation assists the designs of public players disinterested in the development of renewable electricity. For example, Ma and He (2008) explain how Chinese local officials have been historically evaluated according to economic growth, de-prioritizing compliance with environmental regulations. Third, in relation to the multiplicity of stakeholders, there exists in China a multiplication of bureaucratic procedures. As to the quality of policies around renewables, we find that the Chinese government does indeed have specific targets for renewable electricity, as demanded by the "best practice" literature (see for instance NDRC's National Medium- and Long-Term Development Plan for Renewable Energy in China, 2006-2020). Nevertheless, according to Ma and He (2008), those targets are weak insofar as they are not compulsory. Also, China seems not to rank particularly high regarding predictability of policy (resulting mostly from regulation being stable, rules-based, and transparent). For instance, when it comes to clarity and transparency of rules, we see that REL includes very few regulatory details; and other renewable energy legislation in China also lacks specificity (Cherni and Kentish, 2007; IEA, 2007; author's interviews). In particular, there are critiques to the uncertainties around tariffs, connectivity and PPAs (negotiated case-by-case), grid upgrades, and enforcement measures.

We now turn to the corporate structure for renewable electricity. Electrical sector reform included the separation between government and business operations, as well as the unbundling of generation and transmission. Also, an independent regulatory and supervisory agency (the SERC) was established. In any case, reforms in the sector are widely perceived as unfinished, mostly in that free entry and competition are restricted, both in terms of transmission/distribution and generation. Regarding transmission, the State Grid and the Southern State Grid are essentially monopolies, as well as monopsonies, in their respective regions. Also, regulations regarding connection and PPAs are not rigorously enforced, probably because of the limited regulatory capacity of SERC vs. NDRC, and SERC's limited authority over the transmission companies, given the administrative ranks of SOE managers, which parallel those of the government officials at SERC.

In the area of generation, public and private companies are allowed to compete with the "big five" state corporations that resulted from the 2002 unbundling of the State Power Corporation (SPC). But competition is hindered by industry concentration, public ownership and control, and barriers to foreign competition. The latter not only restrict overall competition but also limit the technology and know-how utilized in development and generation. The five big holding companies own nearly 40% of total generation assets[16] and produce about half of China's electricity[17]. Much of the remaining assets belong to other

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[15] See Cherni and Kentish, 2007; Lema and Ruby, 2007; Ma and He, 2008, about the limited authority of SERC vs. NDRC.
[16] Information on asset ownership is as of 2006, and according to Ma and He (2008).
[17] Information on production is from the Energy Information Administration of the United States, at http://www.eia.doe.gov/cabs/China/Electricity.html (last accessed November 23, 2010).

companies administered by the central government (10%) or by local governments (45%). The "big five" power companies, which traditionally generate electricity with coal, also dominate the renewable power sector. For instance, under the national tender system for wind development, all winners but one have been "big five" subsidiaries (Lema and Ruby, 2007). And seven wind mega-projects planned for construction will be led by China's "big five"[18]. Moreover, the "big five" are SOEs, and since most other generation assets are controlled by central or local governments, any semblance of market-like competition is hindered further. At the same time, foreign competition in development and generation remains marginal: foreign companies (including joint ventures) produce about 6% of total electricity in China; and out of the 12GW installed in wind in 2008, about 95% belonged to Chinese capital, with most of the remaining 5% belonging to joint-ventures, and only a marginal share being wholly foreign-owned (author's interviews). The scant presence of foreign developers and generators might be explained by policies already reviewed, which deter foreign investment (author's interviews; RELaw Assist, 2007): (1) the fact that foreign companies could not win concessions through national tendering; (2) low remuneration and short duration for all incentive schemes; and (3) the fact that foreign projects are allowed a debt-financing percentage below the 80% permitted for domestic projects. Other policies and institutions also reviewed could conceivably deter the entry of any company, but foreign competitors especially: grid access and PPAs that are time-consuming and difficult to negotiate; the general departure of the Chinese legal and contractual framework from Rule of Law principles; administrative hurdles in licensing procedures; institutional weaknesses of the policies for renewables; etc. (Cherni and Kentish, 2007; author's interviews).

In manufacturing, both industry concentration and the market share of Chinese companies are lower than in power generation. In wind, prior to 2004 there were fewer than five manufacturers of wind-power components. By the end of 2008, wind turbine manufacturers numbered 70 (REN21, 2009). Nevertheless, the three biggest manufacturers dominate, with over half the market[19]. Among those 70 companies making turbines in China, more than 50 are Chinese-owned, eight are joint ventures, and nine are foreign-owned. But the presence of foreign capital in manufacturing has decreased over time: in 2004 the domestic market share for wind turbines was 18% (GWEC, 2005); the 2008 share for domestic and joint-venture companies was 75% (REN21, 2009). And in view of certain recent government incentives, it is likely that Chinese companies will continue to increase their market share. For instance, all majority Chinese-owned domestic manufacturers will be awarded up to $88 per kW for their first 50 wind turbines certified and connected to the grid; also, Chinese companies will apparently benefit most from the aforementioned mega-wind farms project[20]. Foreign production of equipment faces some difficulties. Frequently mentioned policies include the 70%-local-content standard for wind turbines, and the turbines' import duties structure: in 2000, a 12% tariff for turbines (3% for components) was re-introduced. Also, compared to domestic companies, foreign manufacturers face restrictions (some related to policies and institutions described). Examples of discriminatory policies include: the tendering system for wind, which favors turbine price over quality; subsidies for Chinese companies only; and the very recent "buy Chinese" policy wherein projects financed by the economic stimulus package must seek government permission before buying foreign goods and services.

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[18] Press article: http://www.chinadaily.com.cn/cndy/2009-07/07/content_8385497.htm (last accessed December 10, 2009).
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4. Conclusions

A consensus seems to have emerged, among Western organisms and practitioners, around which policies and institutions are best for GCRE. We find that the "best practice" model basically amounts to a sector-specific description of an LME: policies should consist in regulations that facilitate private investment via the perfection of market mechanisms; and institutions should be market-friendly, also to facilitate investment. In China, arguably not an LME, we have encountered policies and institutions for GCRE that have moved toward the described prescriptions, but gradually and only partially. Although the accuracy of the details presented in this paper may suffer from the rapid pace at which Chinese regulations evolve, general imperfections here mentioned will likely prevail in the medium term.

As stated, when measured against the "best practice" model, China's particularities appear to be obstacles to the deployment of renewable technologies. But, seen in a wider perspective – that of China not fitting into the definition of an LME – further research would be necessary to determine whether Chinese particularities are indeed imperfections, or simply the sector-specific manifestation of an alternative (non-LME) variety of capitalism. Moreover, the fact that China has proven quite successful in GCRE should lead us to question the "best practice" model, insofar its prescriptions might be valid only for certain political economies.

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Expansion of the Swedish Elcert certificates system to the Netherlands: a cost-benefit analysis

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Abstract: This paper investigates the net benefits of adjusting the Dutch renewable electricity support system from a feed-in premium (FIP) scheme into a hybrid renewable portfolio standard (RPS), i.e. an RPS on top of, and well-integrated with, the existing FIP. The alternative scenario envisages, moreover, the establishment of a joint support scheme with Sweden on the basis of the existing Swedish Elcert certificates system. The paper benchmarks the costs of the alternative renewable electricity support scenario against the baseline FIP scenario. A major limitation is the exclusion of network impacts. Moreover, the analysis of the economic impacts in Sweden is limited to distributional effects. The aggregate welfare impact for the Netherlands is robustly positive. In both countries major winners and losers are identified.

Keywords: *Hybrid RPS schemes, Joint support schemes, Bottom-up harmonisation of national support schemes*

1. Introduction

The paper draws on an ongoing study by the Energy research Centre of the Netherlands, ECN, into the social costs and benefits of readjustment of Dutch renewable electricity support from a feed-in premium system (FIP) into a FIP in combination with a renewable portfolio standard system (RPS), hereafter referred to as *a hybrid RPS system*. The RPS is endorsed by certificates (Elcerts), issued on behalf of qualifying renewable generators. The latter sell their certificates to electricity suppliers and certain end-users, who have to prove compliance with the mandatory RPS target with Elcerts. The RPS target implies that a certain calendar-year-specific minimum % of electricity deliveries (suppliers) or consumption (end-users) has to be sourced from qualifying renewable generation technologies. Some of these technologies need more support to become competitive on the electricity market. The FIP regulations may provide additional technology-specific support to the latter technologies, contingent on government decisions. The hybrid RPS system concept as a basis for EU support harmonization was introduced at meetings of a CEPS/ECN Task Force [1].

This paper focuses on a two-country hybrid RPS as an example of bottom-up harmonization of the (envisaged) national support schemes for RES-E (renewable electricity). The Netherlands and Sweden are considered to launch a joint hybrid RPS on the basis of the existing Swedish Elcert certificates system. The EU Renewable Energy Directive (RED), 2009/28/EU allows such bottom-up harmonization subject to certain conditions. It is to be an application of 'joint support schemes', i.e. one the 'cooperation mechanisms' in the RED.

The key driver towards potential market-based joint support schemes is to achieve higher cost-effectiveness in target compliance by capitalizing on the gains from trade. Expanding the domain of a well-designed joint support scheme may lead to a reduction of total RES-E generation costs to achieve the sum of the national RES-E targets[1] of the participating countries [2],[3].

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[1] *The RED sets mandatory national targets for the share of renewables in final energy consumption.*

The goal of this paper is to evaluate the economics of a Dutch-Swedish joint hybrid RPS support scheme from a Dutch societal perspective. Towards that aim, it compares the latter support scheme as the alternative scenario with the existing Dutch FIP system as baseline. In the alternative scenario, the existing Dutch FIP system, henceforth referred to with the Dutch acronym SDE, is retained in the Netherlands in a fully compatible way with the joint hybrid RPS support scheme.

The baseline scenario consists of a continuation of the existing national support schemes: the Dutch SDE scheme and the Swedish Elcert certificates scheme respectively. The alternative joint hybrid RPS on suppliers is presumed to be launched as from the start of year 2014. Part of the additional RES-E consumed in the Netherlands might be produced by qualifying Swedish RES-E generators.

The analysis considers primarily the vantage point of Dutch society. Even so, it investigates distributional effects on major stakeholder categories in both the Netherlands and Sweden.

This paper is structured as follows. First the methodology is succinctly explained (Section 2). Research results are shown in Section 3. Section 5 winds up with conclusions.

2. Methodology

2.1. Baseline scenario background

2.1.1. Baseline scenario

To date, the SDE is the Dutch government's main subsidy instrument in support of the deployment of renewable electricity. It is a feed-in premium system, granting technology-specific production subsidies for renewable generators. It is attempted to set the SDE premium for an installation of a certain SDE category commissioned in a certain calendar at such a level to cover the so-called 'financial gap' without overcompensation.

The so-called *base rate* for an installation's SDE premium is determined by the installation's anticipated RES-E generation cost with some *adjustment factors*. Part of the anticipated premium is paid at regular intervals on the basis of actual production. After each calendar year settlement of last year's SDE subsidy is based on the difference between the base rate and last year's average baseload price. However, an electricity *price floor* and a corresponding maximum SDE subsidy rate is determined upon closure of the SDE subsidy contract.

Adjustment factors relate to:

- Insurance costs: to provide some hedge against the risk for the RES-E operator that the electricity price drops through the set electricity price floor.
- Transaction costs: anticipated transaction costs to sell electricity (especially for SDE categories with many small-scale RES-E operators).
- System imbalance charges: applicable for wind power, and PV.
- Profile costs: applicable to intermittent sources assuming a non-negligible share in the electricity fuel mix (relate to the downward 'merit order' effect on the power price and to the technology-specific time profile of electricity production which may yield below-average or above-average baseload prices).

The electricity price floor implies a non-negligible risk to the investor and his financers. If the electricity price is to drop below the set electricity price floor, the SDE subsidy rate will not suffice to provide full coverage of the 'financial gap' that needs to be bridged to render the RES-E power plants concerned financially viable. In practice, the adjustment rate for insurance against this risk does not give complete solace.

2.2. Baseline scenario design

The baseline scenario is taken from [4], a study also used for the design of the Dutch Renewable Energy Action Plan. The baseline scenario assumes an intensified continuation of the SDE feed-in premium scheme, so that a 35% in gross energy consumption will be achieved by 2020 completely based on (45 TWh) inlands renewable energy generation. Furthermore, the SDE is supposed to become financed through a surcharge on the electricity bill instead of being paid by government finances. As such, the SDE forms the basis for a stable investment climate, where energy companies can plan new renewable energy investments years in advance. This stable investment climate is a necessity for reaching high levels of renewable electricity in the short time period up to 2020.

The wind power capacity grows to 6000 MW onshore in 2020 and 6000 MW offshore slightly thereafter. Co-firing of biomass in coal fired power plants is supported through subsidies, and is projected to reach on average up to 20% co-firing, on energy basis, for all coal fired power plants in operation. The economic co-firing potential in 2020 is foreseen to be around 10 TWh. The baseline scenario includes a significant rise in electricity production from stand-alone biomass installation, up to 7 TWh in 2020. No options are limited by budget ceilings, except for solar PV. Figure 1 below indicates the total RES-E production, differentiated by technology, for the period 2012-2020.

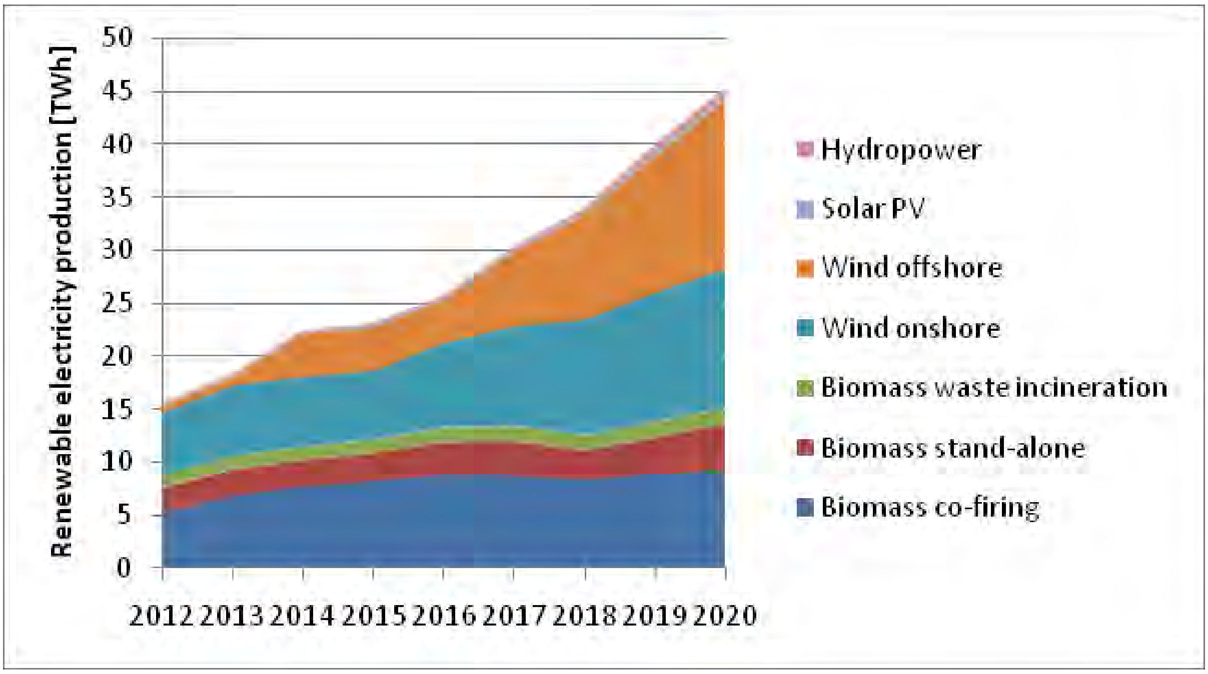

Fig. 1 Baseline scenario: Dutch RES-E production [TWh].

For reasons of containing the modeling complexity, we have refrained from accounting for the (in practice very small) negative impact of changes in the SDE surcharges on power demand.[2]

2.3. Alternative scenario background

The alternative RES-E stimulation scenario is predicated on the presumed realization of a joint support scheme with Sweden as per 1 January 2014. The basic idea behind such a scheme is that within a certificates-based joint RPS support scheme, in principle, each of the participating countries has the right to introduce additionally at the national level supplementary support measures. (Changes in) supplementary support measures can be adopted in close bilateral government-to-government consultation and in a way that is supportive to the well-functioning of the joint Elcert certificates market. In the case of the Netherlands this will be the existing SDE support scheme. The joint support scheme will be integrated into the SDE regulations.

In the absence of the SDE high-cost marginal Dutch RES-E generation options, notably offshore wind, would determine the – in that case potentially very high – Elcert price. Hence, given the steeply rising Dutch RES-E supply curve, supplementary Dutch support to high-cost renewable generation options is warranted to contain windfall profits in both the Netherlands and Sweden. Moreover, it provides an additional instrument to limit the net import volume of Elcerts from Sweden, should the joint Elcert market and the Swedish RES-E sector show signs to become overstretched.

The Swedish RPS, called "the electricity certificate system", requires all electricity suppliers and certain electricity users to purchase Elcert certificates equivalent to a pre-set target proportion of their respective electricity demand, set for each calendar year of the Swedish RPS scheme. The scheme became operational as per 1 May 2003 and is scheduled by law to last until the end of year 2030. Its main stated purposes are to help increase the production of renewable electricity and reduce emissions of greenhouse gases.

Information from the Swedish Energy Agency ([5], [6]) suggests that from both an effectiveness and a cost efficiency criterion, the Swedish RES-E support scheme appears to function well. The Swedish support scheme is well on track to meet its pre-set RES-E deployment objectives. RES-E support cost hover around €ct 3 / kWh of qualifying RES-E.
In a previous ECN study Sweden has been identified as the best fit for a joint hybrid RPS support scheme with the Netherlands [7]. Besides the well functioning of the Swedish support scheme, major reasons include:

- The quite diverse portfolios of RES-E resources between Sweden and the Netherlands, making for a large *gains from trade* potential.
- The scope for additional RES-E production in Sweden at relatively moderate cost on top of complying with Sweden's RES target in 2020 as laid down in the Renewable Energy Directive. In contrast, the Netherlands is only to meet its 2020 RES target completely inlands at quite high cost. This further strengthens the potential for win-win trade.

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[2] *For the same reason, the (small) negative impact of (changes in) the cost of Elcert certificates to be borne by suppliers/end-users on power demand has been disregarded likewise.*

2.4. Alternative scenario design

We assume that differences in market conditions facing RES-E project developers under the baseline and alternative scenario respectively, small differences in technology-specific generation costs will occur. Because of space restrictions, we refer to [8] for specific production costs for different production categories for both the SDE and RPS systems and further explanation of underlying cost factors.

It is assumed that the launching date will be beginning of 2014.[3] As explained in [8] certain regulatory costs have been assumed for the Dutch public sector, CertiQ as the Dutch Elcerts issuing and tracking agency as well as RES-E generators and suppliers. We note that the in practice important benefits of improved Elcert market functioning as a result of market domain expansion [3] have not been captured in our modeling exercises.

Our main modeling assumption regarding the evolution of the Dutch RES-E generation are the following ones. As a result of net import of Elcerts from Sweden corresponding to about 9 TWh in 2020, Dutch RES-E generation is projected correspondingly less than under the baseline scenario. This refers especially to high cost options wind offshore and (in the Netherlands) biomass stand-alone. In Sweden the extra 9 TWh are projected to be generated by primarily wind onshore.

3. Results

The cost-benefit analysis results are succinctly explained below. Once more we refer to [8] for more details.

3.1. The Dutch societal perspective

The annual cashflows of (positive or negative) net benefits to the Dutch economy of the alternative scenario over and above the baseline scenario are shown in Table 1. Positive (negative) figures indicate lower (higher) costs for the alternative support scheme than the corresponding baseline cost. The overriding factor determining the overall impact for the Dutch economy are the strongly positive net savings on differential RES-E cost to the Dutch economy. The savings on lower production by high-cost marginal RES-E generators in the Netherlands are dominating the extra costs of net import of Elcert certificates from Sweden. Also the projected slightly lower per unit technology-specific generation cost are relatively modestly explain these results.

Table 1. Shift to Alternative III: RPS SE - Annual incremental net benefits to the Netherlands [€$_{2010}$ million].

	2013	2014	2015	2016	2017	2018	2019	2020
Savings on differential RES-E cost		217	234	275	281	459	633	805
Savings on imbalance cost of wind power		0	0	0	0	6	14	21
Regulation cost public sector	-20	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
Regulation cost CertIQ	-1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Regulation cost suppliers and RES-E generators	0	-1	-1	-1	-1	-1	-1	-1
Total (€ million)	**-21**	**214**	**232**	**272**	**278**	**464**	**645**	**824**

[3] *In practice, even in a smooth preparation process it might not be earlier than in 2015 or 2016.*

Table 1 (cont.)

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
757	698	629	612	629	568	522	497	329	280	275	198	55	-50	-153
21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
776	**718**	**648**	**631**	**648**	**587**	**541**	**516**	**348**	**299**	**294**	**217**	**74**	**-30**	**-134**

To bring out the more near-term impact of a change from the baseline scenario to the alternative scenario, we calculated the projected NPV of differential cash-flows for the period 2013-2020. More structural trends can be observed from the projected NPV pertaining to the period 2013-2035 and its difference with the one pertaining to 2013-2020. For the purposes of this study application of a *real* discount rate[4] of 2.5% would seem appropriate. Reasons are the relatively modest size of non-diversifiable project risks, whilst the cost risks of RES-E tend to be counter-cyclical with respect to macro-economic business cycles. In showing the sensitivity of the results to the discount rate applied, we have applied a 0% and 5% discount rate as well.

The resulting NPV values are shown in Table 3. Applying the recommended 2.5% discount rate, our projections indicate that a shift in 2014 from the baseline support scheme to the alternative one would reduce, in the period 2013-2020, the costs of RES-E support to the Dutch society by 2.4 billion Euros (at prices of year 2010). The resulting cost reductions for Dutch RES-E market stimulation as measured against the baseline benchmark are set to continue after 2020 reaching an aggregate level of 4.2 billion Euros in the period 2021-2035, whilst the projected upshot for the total analysis period 2013-2035 is 6.6 billion Euros saved on RES-E market stimulation. These results are insensitive in nature to the choice of discount rate within the (rather wide) 0-5%/a interval.

Table 3. Net benefits from a Dutch socio-economic perspective of a shift in year 2014 from the prevailing SDE support scheme to a joint hybrid Renewable Portfolio Standard support scheme with Sweden (RPS SE).

Net present value in 2010 (€$_{2010}$ billion)							
Period		2013 - 2020			2013-2035		
Discount rate		0 %/a	2.5 %/a	5 %/a	0 %/a	2.5 %/a	5 %/a
Alt.Scen.	RPS SE	2.9	2.4	2.0	9.0	6.6	4.9

Source: authors' projections

3.2. Distributional effects upon Dutch stakeholders

Apart from the relatively limited cost to the *public sector* for introducing and supervising the demand-side RPS system, the shift to such a support scheme is budget-neutral. The distributional effect for CertiQ is slightly positive as this agency will be charged with the task of operating the Elcert certificates tracking system in the Netherlands, in close association with its Swedish counterpart. High-cost RES-E generators are set to be strongly adversely

[4] *A real discount rate is roughly equal to the projected nominal discount rate applicable to projected cashflows in current prices minus the projected rate of general price inflation. Our cashflow analysis is based on cashflows at a constant general price level of year 2010, i.e. "at prices of to-day". The recommended nominal discount rate with a projected rate of inflation of 2% would be for the present study: ≈ 2.5% + 2%, i.e. ≈ 4.5%.*

affected, whilst biomass co-firing thermal power plants will gain to a lesser extent. Also other non-RES generators stand to gain: they may fill part of the gap resulting from lower RES-E production volumes and benefit from a according to our modeling results very small upward power price effect as well. Power consumers are poised to lose initially but are indicated to win as from year 2019 to an increasing extent with savings on SDE cost surcharge on their electricity bill as the dominating underlying factor.

3.3. Distributional effects upon Swedish stakeholders

Exercises with the COMPETES model suggest that net Dutch imports of Elcerts up to a level of about 9 TWh is to lead to a maximum upward effect of the Elcert price of €ct 1.1/kWh to a level of €ct 3.49/kWh in 2020, after which year this upward effect will gradually dissipate. Remarkably the resulting extra RES-E production in Sweden is poised to have a much stronger downward effect on the average baseload price in Sweden, than the corresponding reduction in the RES-E production expansion in the Netherlands will have on the average Dutch baseload price in opposite (upward) direction. Differences in network topology, robustness and flexibility (also on the demand side) of the respective power network systems and the size of interconnections to evacuate surpluses and import national power deficits might be undercurrents of this result.

A strong winner will be the *Swedish RES-E sector* at large, most strongly the Swedish onshore wind sub-sector. The drop in baseload power prices in Sweden is good news for power users and bad news for notably *power generators that do not qualify for Elcerts* (including operators of pre-2003 hydro power plants). On average, qualifying generators will be more than compensated by extra revenues from Elcert sales. Assuming a zero price elasticity of power demand exercised by unprivileged consumers, the overall effect of the Alternative III scenario on Swedish power consumers can be disaggregated into the following underlying effects:

- A negative effect on account of the at least initially significantly upward reacting Elcert price. Contingent on company market strategy and competition circumstances on the Swedish retail market, Swedish suppliers will pass through their costs of acquiring Elcerts to comply with the Elcert system target more or less completely to their customers on a *pro rata* basis. The size of the effect depends on the Elcert price reaction and on the system target.
- A positive effect on account of the reaction of the wholesale market and its knock-on effect on the power price on retail market. This combi-effect regards all final power users.
- With a strong caveat for the crudeness of our modeling simulations of the Swedish distributional effects – our modeling outcomes suggest that the second effect is the dominant one. If this result can be confirmed indeed by more profound research, this will be good news for Swedish electricity consumers.

4. Conclusions

The main conclusion is that the Dutch economy would gain in a robustly positive way from the introduction of a joint hybrid RPS support scheme with Sweden. In the Netherlands, the largest distributional effects fall upon RES-E generators, other generators, and power consumers. On aggregate, Swedish renewable generators applying qualifying technologies for participation in the Elcert system are set to be clear winners and other Swedish generators clear losers. Less robust indications suggest that Swedish consumers may benefit.

Our quantitative analysis has focused on those effects that can be quantified with a fair amount of robustness. For example, in our quantitative analysis we have refrained from taking recourse to sweeping, speculative assumptions on the nature and volume of external effects of specific 'innovation pathways', the innovation dynamics of inter-technology competition, the strategic value of bottom-up harmonisation of national support schemes, etc. A major limitation is the exclusion of network impacts. Moreover, more elaborated research is needed to analyse the impacts of the joint Dutch-Swedish support scheme considered here on the Swedish economy.

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Proposal of a framework for the selection of renewable energy technology systems in Africa

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Abstract: Energy is essential for economic development in Africa. The current electrification figures show that countries in sub-Saharan Africa are facing major challenges in reaching positive economic growth and supplying basic energy services to rural communities. Prior to this study a comprehensive framework of factors to select renewable energy technologies did not exist. The purpose of this research was to develop such a framework and to validate it by means of empirical analyses. A triangulation of methodologies including a literature analysis, focus group, Delphi study and case study was used to determine the framework of factors. This paper presents the final framework that includes both the thirteen criteria and measures to be used for the selection of renewable energy technologies in Africa. The paper further recommends the critical documentation that must be created for each competing technology.

Keywords: *Renewable energy technology selection, Developing countries, Sustainable energy, Selection criteria, Framework of factors*

1. Introduction

Energy is essential for economic development in Africa [1]. The current electrification figures show that countries in sub-Saharan Africa are facing major challenges in reaching positive economic growth and supplying basic energy services to rural communities [2]. Sustainable energy technologies are available and can be used to great effect in Africa to alleviate this problem [3]. Sustainable energy technologies can also contribute to job creation [4]. The implementation of renewable energy technologies in sub-Saharan Africa to date, however, has not always been successful due to both technical and non-technical factors [4-9]. Prior to this study a comprehensive framework of factors to select renewable energy technologies did not exist. The purpose of this research was to develop such a framework and to validate it by means of empirical analyses.

2. Methodology

A triangulation of methodologies was used to determine the framework of factors [10]. The analysis of the literature investigated renewable energy technologies and their application, the challenges in renewable energy technologies for implementation in Africa, and the selection methods in the fields of project, portfolio, programme and technology management. This was followed by a focus group [11, 12] with three experts,[13] in which thirty eight factors that need to be taken into account during the selection of renewable energy technologies in Africa were identified [13]. The factors identified by the focus group were confirmed and the eleven most applicable factors were selected through a two-round Delphi study [14-16]. Finally, case studies on the implementation of renewable energy technologies were undertaken in three countries [17, 18]. These case studies confirmed the eleven factors identified during the Delphi study and identified a further two factors that were added to the framework [19].

3. Results

The final list of factors, factors identified during the focus group, the Delphi study definition of each factor as well as the important issues for each factor identified in the case studies, is shown in Table 1.

Table 1. Framework of thirteen final factors to consider for sustainable, renewable energy technology selection in Africa

Factor description	Focus group identification	Delphi study definition	Important issues for each factor from case studies
Technology factors			
Ease of maintenance and support over the life cycle of the technology	Maintenance/ support	Security of supply is enhanced. It also implies that spares are affordable and can be easily acquired.	Quality of the installations, the maintenance plans, the training of technicians, maintenance training for users, keeping maintenance simple and adapting the technology to the specific environment
Ease of transfer of knowledge and skills to relevant people in Africa	Transfer of knowledge and skills	Transfer of knowledge and skills to the community involved. Dedicated personnel to run the facility are required.	Identification of stakeholders to train; methods of skills transfer applicable to the environment; quality of training; and formalization of skills transfer.
Site selection factors			
Local champion to continue after implementation	Local hero – champion to continue after implementation	Facilitators of the technology exist which will ensure that the facility will continue after implementation.	Local champions must be identified during technology selection, their responsibilities must be clearly defined and they must be aware of the long term implications of their role
Adoption by community	Passion/ ownership/ buy-in/ adoption by community, responsibility	Community adopting the technology, accepting ownership, demonstrating buy-in and taking responsibility	A determination must be done of the capacity of the population to adopt the new technology, the benefits of the new technology must be determined and communicated to the community and that measures must be in place to ensure client satisfaction
Suitable sites ready for pilot studies	Pilot study site selection issues	Pilot studies are necessary to demonstrate technology to decision makers	Selection of pilot sites is very important and valuable; pilot sites must be selected in such a way that they will be accessible for demonstration purposes to the community
Access to suitable sites can be secured	Not applicable	Access for implementers to sites where the technology can be implemented must be secured up front	Determine priorities of population; set implementation targets; identify site criteria; and identify site
Economic/ financial factors			
Economic development	Economic development (community eventually able to pay), economic	Economic development translates into (a) the community being able to pay for services and (b) economic sustainability	Income generation, cost and time saving and national income and savings all contribute to economic development

Factor description	Focus group identification	Delphi study definition	Important issues for each factor from case studies
	sustainability		
Availability of finance	Available budget – the finances to support a project	The determination of the required budget and the availability of finance for this budget are addressed here. The type of finance whether debt, equity or grant must also be taken into account.	Finance can be facilitated by implementing payment methods which are applicable for the households, as for example, bartering and that finance methods must be in place before the technology can be implemented on a large scale
Achievability by performing organization			
Business management	Proper project management	The performing organization having the business management capacity and procedures in place to ensure that the implementation of technology can be done successfully	Which business management skills should be transferred, how the skills are to be transferred and what to do in the short term when the skills of the organization are lacking
Financial capacity	Financial capacity	Both the administrative capacity to manage finances and the ability to deliver, given the payment conditions.	Financial capacity for performing organizations can be problematic at the outset but that various methods can be used to alleviate the financial capacity required by the performing organization.
Technological capacity	Capacity	The performing organization has the correct technology necessary for implementation of the project at their disposal.	Technological capacity is directly related to quality. Quality assurance must be enforced; regulation of performing organizations and the dictating of standards also contribute to quality installations.
Other factors			
Government support	Regulatory financial incentive, tax regimes must be supportive" and does it fit under national priorities	Governmental support has been obtained for the technology	In the first place, the government must be aware of the new technology and support its implementation. If the government is also prepared to assist in the implementation, success of implementation is further enhanced.
Environmental benefits	Environmental impact assessment	The implementation of the technology will have a positive impact on the environment	Environmental benefits may include: decrease in the release of greenhouse gasses; protection of fragile ecosystems; halting soil erosion; halting desertification; prevention of fresh water pollution.

The focus group used the nominal group technique to identify 38 factors that need to be taken into account for the selection of renewable energy technologies in Africa and classified these factors into six categories.

The Delphi study was conducted over two rounds with the purpose of confirming and prioritising the factors identified during the focus group. The Delphi questionnaires were sent to experts (both academics and practitioners) in the field of renewable energy, with the emphasis on Africa.

In the first round, respondents were presented with the factors identified during the focus group and then asked to: comment on the classification of factors; comment on the description of factors; provide additional factors that were overlooked during the focus group; and provide a preliminary rating of the factors identified during the focus group in terms of feasibility, desirability and importance of considering these factors during the selection of renewable energy technologies in Africa. At the end of the first round Delphi the factors were regrouped into four categories.

In the second round of the Delphi study, the respondents were presented with a summary of the comments and ratings supplied in the first round and were then asked to supply new ratings in terms of feasibility, desirability and importance. The results were analysed. Eleven of the factors were rated by the experts to be feasible, highly desirable and highly important when selecting renewable energy technologies in Africa.

The eleven factors identified in the Delphi study were then used to generate the framework for the eight case studies which were conducted in the following three African countries: Rwanda; Tanzania and Malawi. The sources of evidence used included interviews, documentation and observation. The case studies confirmed that the eleven factors identified during the Delphi study are important for the selection of renewable energy technologies in Africa. Two additional factors were also found to be important and the wording of one of the factors was changed.

In conclusion, the thirteen most important factors that need to be considered for the selection of renewable energy technologies in Africa have been collated into a framework.

4. Discussion and/or Conclusions

The critical documentation that must be generated before renewable energy technologies are selected in Africa is shown in Table 2. The issues that have been identified in this study that must be addressed for each of the factors are also shown.

Table 2. Critical documentation for selection of renewable energy technologies in Africa

Description	Quality plan	Maintenance plan	Technology plan	Human resource plan	Financing plan
Technology factors					
Ease of maintenance and support over the life cycle of the technology	Standards, monitoring, evaluation, corrective action, responsibility, warranty	Operator maintenance, technical maintenance, spares	Adaption of technology	Responsibility for maintenance	Maintenance funding model
Ease of transfer of knowledge and skills to relevant people in Africa				Local skills levels, operator training and manuals, technical training and manuals, responsibility, quality, stakeholders, skills transfer	Skills transfer funding model
Site selection factors					
Local champion to continue after implementation				Identification of local champions	
Adoption by community			Capacity determination, benefits determination, information distribution, adoption probability		
Suitable sites ready for pilot studies			Selection of pilot sites		Pilot site funding model
Access to suitable sites can be secured			Priorities of population, implementation targets, site criteria identification		
Economic/ financial factors					
Economic development					Income generation, domestic cost and time

Description	Quality plan	Maintenance plan	Technology plan	Human resource plan	Financing plan
					savings, national income saving
Availability of finance					Initial investment donor funding, loan availability and rates, government support
Achievability by performing organization					
Business management				Capabilities of current organizations, business skills training, interim measures	
Financial capacity				Administrative capacity of performing organizations	Capital outlay requirements, capital outlay funding
Technological capacity	Quality assurance responsibility; technical guarantees	After sales service	Technological capacity of performing organization, regulation of standards for technology	Manufacturing training, installation training, maintenance training, refresher courses, quality training, technical backstopping	Financial incentive for quality
Other factors					
Government support			Government acceptance and support; energy policies, legislation and standards		Relief on taxes or duties; funding or subsidies; licensing
Environmental benefits			Environmental benefits of technology		

The critical documentation can be used at various levels and by various organizations to select the most appropriate renewable energy technologies for implementation in Africa. The critical documentation must be completed for each competing technology. The technology that performs the best in terms of addressing all the issues for all of the factors can then be selected. By using the framework proposed in this study, selection of renewable energy technologies can be done with the assurance that the most important factors for the successful implementation of these technologies have been taken into account.

The successful implementation of renewable energy technologies in Africa will lead to the improvement of the lives of the population in Africa, will increase their productivity and quality of life, and will contribute towards the alleviation of poverty and the empowerment of women and children. African children who have sustainable access to energy will be better educated and thus be better future leaders.

Further work is required to implement the factors into a selection method for example the analytical hierarchy process or analytical network process.

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Biofuel sustainability: relationships between the directive 2009/28/EC and scientific research

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Abstract: With the aim to reinforce the sustainability of biofuel production the EU directive 2009/28/EC has recently introduced a set of criteria aiming to reduce environmental effects of uncontrolled biofuel production. The criteria introduced by the directive define a procedure to compute the Green House Gases (GHG) emission of biofuel production based on the Life Cycle Analysis (LCA) approach. Nevertheless, although this approach is quite consolidated in some production systems, it represents a novelty in the biofuel sector. Using the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis in this paper it is compared the approach introduced by the directive with the main results emerged from a selection of papers, on the same subject, published in international journals in the last five years. The main results show as the new approach and the calculation method adopted could be a positive guideline for a better assessment of GHG emission at European level. However, some aspect could improve the efficiency of the new directive. Indirect land use change, functional unit and the involvement of other environmental impacts are some of the aspects that should be considered in order to refine the directive calculation method. Moreover, the paper highlights how it is fundamental to establish a right trade-off between LCA application and bureaucratic constraints for economic agents operating in biofuel production chain.

Keywords: *Biofuel sustainability, Life Cycle Analysis, Directive 2009/28/EC*

1. Introduction

Biofuels are considered one of the best alternatives to mineral oil derivatives in the transport sector, so their production and consumption are highly supported by the political framework, especially in Europe and in the United States. Although biofuels cover a small part of total energy requirement, the increasing demand could make doubtful their real sustainability, especially considering that feedstock production takes place in different countries around the world. In this regard there is a broad debate from which emerge several opinions: sceptical positions on the usefulness of biofuels (e.g.: Koonin, 2006; Odling, 2007; Righelato and Spracklen, 2007); judgements and criticisms (e.g.: Fargione *et al*., 2008; Melillo *et al*., 2009); encouraging considerations on future prevision related to the develop of the second-generation biofuels (e.g. Tilman *et al*. 2006; Fargione *et al*., 2008). The debate still remain open and the opinions on the effectiveness of a biofuel policy are not always in agreement (e.g. Kennedy, 2007; Robertson *et al*., 2008; Fargione, *et al*., 2008). From a conceptual point of view reasoning on biofuel sustainability pass through the definition of what basis utilize to discriminate which of them are sustainable and then identify the sustainable policy framework for biofuel development. In this regard it could be useful to decompose the question into two elements: the first, technical, seeks to understand whether biofuels are sustainable products, while the second, institutional, it is dedicated to understand whether the implemented policy framework to promote biofuels is sustainable.

These two aspects support each other: it is politically correct to promote the biofuels use only if they prove to be technically sustainable (in particular if the goal of the political action is precisely the sustainability), on the other hand, not having the absolute certainty that such products are sustainable, or that the production methods are sustainable, the policy action can orient economic operators to those supply chains able to demonstrate their sustainability by using rules, certifications system or other effective evaluation methods.

In line with the existing implemented policy framework for biofuel development and with the aim to reinforce the sustainability of EU biofuel production the directive 2009/28/EC has recently introduced a set of criteria aiming to reduce environmental effects of uncontrolled biofuel productions incorporating technical patterns into institutional framework. The criteria introduced by the directive define a procedure to compute the Green House Gases (GHG) emission of biofuel production based on t he Life Cycle Analysis (LCA) cradle-to-grave approach. Nevertheless, although LCA approach is quite consolidated in some production systems, it represents a novelty in the biofuel sector. Using the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis in this paper it is compared the approach introduced by the directive with the main results emerged from a selection of papers, on the same subject, published within international journals during the last five years.

2. The SWOT analysis applied to the LCA approach of the directive 2009/28/EC

From a theoretical point of view the SWOT analysis is an evaluation methodology that assess the possibility for a subject to achieve a goal highlighting strengths and weaknesses of the subject and the opportunities and threats that can occur from his setting, in respect to the goal. In order to analyse possible benefits, problems, opportunities and limits that can occur in the application of the LCA in the biofuel sector as regulated form the recent directive 2009/28/EC on the promotion of the use of energy from renewable sources, in this paper strengths and weaknesses are pointed out by comparing the directive with the institutional framework, while opportunities and threats are highlighted examining the technical aspect emerged from a literature review concerning the LCA methodology applied to biofuel sector.

2.1. Strengths and Weaknesses

Strengths and weaknesses of the application of the directive are deduced from the analysis of the relationship between the content of the directive and the political objectives that European Union aim to achieve through a sustainable development of biofuels sector. From a conceptual point of view to identify strengths and weaknesses the paper analyse the three major objectives of the EU biofuel policy (energy security, climate change mitigation and rural development) in respect to the principal sector involved by the application of the directive such as biofuel sector, energy sector, agricultural and food sector, environment and rural development. Within this contest strengths and weaknesses are presented considering that what in the directive can be helpful to reach these objectives has been considered strengths, while problems about biofuels development that the directive can not solve has been treated as weaknesses.

2.1.1. Strengths

Before declining the different aspects that could be classified as strengths it is important to highlight some general concepts having a positive impact on the institutional framework. Before the adoption of the directive the EU political framework in support of biofuel developments were only related to production incentives both on the supply and demand side. Among the different policies implemented in the EU to stimulate biofuel supply, we recall the directive 2003/96/EC on energy taxation, the energy crop premium and the non-food set-aside payment. While on the demand side, we recall the directive 2003/30/EC on the promotion of biofuel use, which fixed a share of biofuel blends equal to 2% of the overall consumption of gasoline and diesel in transport for the end of 2005, rising to 5.75% in 2010. Moreover, the directive here examined (2009/28/EC), has increased the European biofuel target to 10% by 2020. This political framework has had a great impact on production: from 2005, the first biofuel target year of the directive 2003/30/EC, to 2009, the EU-25 biodiesel production rose to 184%. In the same period biodiesel production capacity increased from 4.2 to 20.9 million tons, the equivalent of an increment of 395% (EBB, 2010).

Considering the uncontrolled development of biofuel production, the adoption of the directive with sustainable constrain for biofuel production and use can be viewed as the only way for the prosecution of the European biofuel policy. In this regard, one of the more significant strengths of the directive is that it is highly innovative and in line with the European political action, that is largely based on the enhancement of sustainability goals. Moreover the new framework imposed by the directive forces Member States to monitoring the environmental, economical and political problems related to biofuels production and consumption, providing new basis for consciously decisions.

In respect to the biofuel sector the new target fixed by the directive, equal to 10% of renewable energy in transport sector by 2020, is set up in a more clear framework able to demonstrate and communicate the real sustainability of biofuel products. This new scenario could stimulate institutional investors that could be attracted by the ethic aspect of sustainable biofuel and in the same time also new investors can look at biofuel sector with a growing interest in relation to the reduced risk related to a more controlled supply chains, as a consequence of the application of the LCA approach.

Also the agricultural and food sector is indirectly involved by the directive, indeed it allows a double counting of energy produced by waste, residues and lingo-cellulosic biomass. Trough this mechanism the second generation of biofuels are promoted and then, the so criticized conflict between food and non food use of feedstock, should be attenuated.

From the environmental point of view two related aspects can be considered as strengths. First, the directive fixes a minimum level of GHG reduction, so the environmental benefit can be assured, second the calculation method for the GHG emission is fixed and equal for all EU Member States, reducing technical disagreement in emissions assessment and consequently market asymmetry and trade distortions.

2.1.2. Weaknesses

As for the strengths patterns, also for the weaknesses can be formulated some general considerations related to the adoption of the directive. If the innovative character of the directive is analysed as a strengths pattern, from a conceptual point of view it could be also viewed as a limitation, indeed it is possible that it can be incomplete and inexact.

Monitoring of environmental, economic and political aspect imposed to Member State is not sufficient to control these problems, in the directive there are not specific interventions able to manage indirect land use change, fluctuation in commodities prices and food insecurity. However, it is admitted that these problems are very complex and their management required more knowledge. Through the National Action Plan the directive encourages the processing sector and the biofuel consumption, but does not highlight any specific intervention in support of farmers. The sustainable standard introduced with the adoption of the directive could be viewed as a constrain in the commercial relation, European imports restriction imposed on non sustainable biomass and biofuels could stimulate international trade partners to introduce non tariff barriers on other relevant products for European community. Another general weaknesses is related to the methodology adopted for the calculation of the GHG reduction, indeed the directive suggests two different approaches, analytic and concise, that could produce different results.

In respect to the implication related to the biofuel sector the introduction of the mass balance system, as a method for the traceability of the products, does not appear completely clear. This unsettled contest opens the interpretation and application of the directive liable to a lobby activity from processing and trader agents reducing the efficiency of all the system.

With reference to agricultural and food sector it is possible to underline that no specific and direct interventions are considered to reduce food no food conflict, so the promotion of sustainable biofuels could not be enough to reduce this conflict. Moreover within the directive there are not specific actions devoted to promote biofuels supply chains in rural areas. Finally, with regard to energy sector, although the contribute of biofuel development to energy security is, at the moment, in absolute value limited, their development do not contribute to energy security. Indeed the feedstock necessary for biofuels production in the next future will continue to be imported from extra EU country, making null the contribute of biofuel sector to the energy independency goal, simply the question shifts from fossil fuel to food commodity. Indeed, the Commission itself expects an increasing flow of imports of biomass for biofuel use. Moreover, these latter questions appear in contrast with the recent publication of the proposal reform of the Common Agricultural Policy for the period past 2013, where one of the three main objectives is directed to revaluate the European food security.

2.2. Opportunities and Threats

In this article the opportunities and threats related to the adoption of the directive are investigated in respect to the technical pattern, looking up weather biofuels are sustainable products in respect to their GHG emission within the contest of LCA approach. In order to highlight the most widespread problems the paper has compared the methodology proposed by the directive with the main results, on the same topics, emerged from a literature review. The paper has considered fourteen articles relative to the LCA application in biofuels sector published on international journals during the period 2004 to 2010.

The articles considered span from general reports where authors compare several LCA with the aim to underline the origin of the variability in the results obtained to very critical articles that explain conceptual mistakes in LCA structure and proposing new methods to assess biofuels sustainability.

In the following it is itemized the main criticisms of LCA application to biofuel sector emerged from literature review:

- definition of the system boundaries of LCA analysis; system boundaries should be consistent with the goal of analysis, because outputs are greatly affected by the numbers of steps considered in supply chain examined (Feng *et al.*, 2008; Gnansounou *et al.*, 2009; Quirin *et al.*, 2004; Rowe, 2009; Singh *et al.*, 2009).
- definition of the reference systems; to obtain reliable results of GHG reduction, it is relevant to have clearly defined reference systems as regards fossil fuels, alternative uses of biomass, uses of co-products substitutes (Cherubini *et al.*, 2009; Gnansounou *et al.*, 2009; Quirin *et al.*, 2004).
- choice of functional unit; functional unit should be consistent with the system boundaries considered. The same biofuel can appear sustainable using one functional

unit and not sustainable using another (Cherubini *et al.*, 2009; Gnanosunou *et al.*, 2009; Quirin *et al.*, 2004; Singh *et al.*, 2009).

- choice of input considered; when the inputs considered are different, biofuel sustainability could appear different within the same system boundaries (Rowe, 2009).
- data quality and representativeness; data used in LCA could be *out-of-date* or little representative, a particular phenomenon could be difficult to measure, so data could not be reliable. Moreover the data used could be significant only for local condition considered and then not replicable in different context (Cherubini *et al.*, 2009; Chiaramonti and Recchia, 2010; Larson, 2006; Menichette and Otto, 2008; Quirin *et al.*, 2004; Rowe, 2009).
- assessment of another environmental impacts; CO_2 emissions are always assessed, but other GHG are also important, besides other possible impacts, like acidification or eutrophication, could occur during biofuels production (Delucchi, 2004; Larson, 2006; Menichette and Otto, 2008; Quirin *et al.*, 2004).
- efficiency of energy conversion; it is important to consider the energy efficiency of engines and conversion plants. Indeed, with high engine efficiency emissions are lower (Delucchi, 2004; Larson, 2006; Menichette and Otto 2008; Rowe, 2009).
- consideration of fuels/biofuels mixtures; technical features of mixtures affects emission levels (Croezen and Kampman, 2009; Gnansounou *et al.*, 2009)
- effects of agricultural residues removal; the removal of agricultural residues for producing biofuels could affects the level of CO_2 emissions, so this effect should be assessed and considered (Cherubini *et al.*, 2009).
- choice of allocation method; different allocation methods of GHG emissions between biofuels and co-products cause different results (Chiaramonti and Recchia, 2010; Gnansounou *et al.*, 2009, Larson, 2006; Luo *et al.*, 2009, Menichette and Otto 2008; Quirin *et al.*, 2004; Rowe, 2009; Singh *et al.*, 2009; Wang *et al.*, 2010).
- consideration of direct land use change; this phenomenon is highly relevant because it can cause CO_2 emissions or savings, so LCAs should consider it (Cherubini *et al.*, 2009; Delucchi, 2004, Gnansounou *et al.*, 2009; Larson, 2006; Menichette and Otto, 2008).
- consideration of indirect land use change; like the preceding point (Cherubini *et al.*, 2009; de Gorter and Tsur, 2009; Feng *et al.*, 2008; Gnansounou *et al.*, 2009; Menichette and Otto, 2008).
- conceptual mistake of LCA; (de Gorter and Tsur, 2009; Delucchi 2004; Feng *et al.*, 2008).

In the following the LCA calculation methodology proposed by the directive has been compared with the main aspect emerged by the literature review just detailed. Where there is consistency there is an opportunity, while where the directive shows a lack of precision there is a threat.

2.2.1. Opportunities

- Within the directive the system boundaries is defined by the cultivation of biomass and by the use of biofuels in cars, this approach is in line with the well-to-wheel approach recommended in literature for LCAs of biofuels for transportation;
- the directive fixees which inputs must be considered in calculation of GHG emissions, while in the literature there is not an agreement about this choice;

- the directive provides default values of GHG emissions, this data are representative of the typical European supply chains and, furthermore, they are conservative; in this way it should be an agreement in assessments at European level, while in literature the approach is not univocal;
- allocation method adopted in the directive is energy allocation; in the literature this approach does not appear as the best method, but is admitted that is almost exact; besides, energy allocation is more easy to perform;
- direct land use change is considered in the calculation methodology proposed by the directive, indeed it provides an equation to assess consequent GHG emissions or savings.

2.2.2. Threats

- the calculation methodology of the directive regards only a reference system relative to fossil fuels, while there is not a reference system for co-products and alternative uses of biomass;
- the functional unit fixed by the directive is mega joule of energy content, while it should be kilometre driven by cars in order to be consistent with the system boundaries;
- the directive does not consider other environmental impacts like acidification or eutrophication;
- the directive calculation method for GHG emission considers only energy efficiency of biomass processing, while does not consider the cogeneration processes;
- features of fossil fuels/biofuels mixtures are not considered in the directive;
- indirect land use change is not considered in the directive calculation method.

3. Conclusions

In this paper the directive 2009/28/EC has been analysed with the aim to find possible benefits and complications that his application could involve. Directive has been studied using the SWOT analysis conceptual structure, that identifies Strengths, Weaknesses in relation to the institutional framework and Opportunities and Threats in respect to literature review on LCA application to biofuel sector. The main result of the analysis allow to highlight the innovative feature of the directive and how its implementation could facilitate policy maker to reach the main goal of the European biofuel policy, promoting production and consumption of really sustainable biofuels. This scenario could stimulate the entry into the market of new ethical investors attracted by a r eal sustainable sector. However, some relevant aspects are not completely resolved like the relationship between biofuel development and fluctuation in commodity prices or the definition of the role played by rural area. On the other hand, from a technical point of view, some positive aspects with a certain importance are emerged too like, for example, the definition of default value for GHG emissions for all the EU, reaching an agreement in assessments at European level or the definition of the inputs to be considered in the calculation method. On the contrary the directive uses a functional unit that does not appear in line with the literature examine and, moreover, does not consider indirect land use change. Overall, considering that the directive is highly innovative, the presence of some weaknesses and threats can be considered normal. A deeper investigation would be useful to improve the efficiency of the EU biofuel policy.

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Which factors affect the willingness of tourists to pay for renewable energy?

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Abstract: This study presents insights into the determinants of tourists' intention to pay a premium for accommodation in a hotel with renewable energy sources. The empirical analysis is based on the estimation of binary logistic regression models. Four subsets of independent variables were used in this empirical analysis, namely: (*i*) demographic factors, (*ii*) economic variables, (*iii*) past experience with regard to renewable energy sources and (*iv*) variables regarding environmental awareness and information dissemination. Empirical results suggest that middle-aged people are probably more willing to pay for their stay in a hotel using renewable energy. In general, men are more likely than women to pay extra money for accommodation in a "green" hotel. However, the results suggest that marital status and educational level are not statistically significant factors in the willingness to pay more. Rather, environmentally-conscious and adequately informed tourists are more willing to pay for renewable energy than others. Our analysis is focused on intention because we expect that those people willing to pay for staying in a green hotel are a potentially relevant market segment for developing sustainable tourism in Greece.

Keywords: *Tourists, WTP, Renewable energy*

1. Introduction

Contrary to fossil fuels, the intensive use of renewable energy is inextricably linked to zero greenhouse gas emissions. Thus, the penetration and implementation of renewable energy projects is one of the major goals of European countries in their quest for achieving sustainable development. However, the use of renewable energy sources is strongly related to public acceptance.

Previous studies have focused on attitudes towards green energy and on acceptance of renewable energy sources (Ek, 2005; Roe et al, 2001; Mallett, 2007; Jodert et al., 2007 Zoellner et al., 2008). Others have examined the intention of hotel customers to stay at a green hotel employing the theory of planned behaviour (Han et al., 2010; Han and Kim, 2010). In general, consumers who are more receptive to environmental products, and choose to purchase them, are willing to pay more for environmental benefits. Empirical studies have also focused on the amount that consumers are willing to pay by way of premium for renewable energy investments and the role of socio-demographic determinants in the case of Italy (Bollino, 2009) and Korea (Ku and Yoo, 2010).

Several studies have been conducted on the issue of renewable energy penetration in Crete (NTUA, 1992; Vamvuka and Tsoutsos, 2002). Crete hosts one-fifth of all tourists visiting Greece. More than 50% of all renewable energy projects in the Greek islands are implemented in Crete (Michalena and Angeon, 2009). The willingness of Crete's residents to pay for renewable energy sources was investigated by Zografakis et al. (2010).

The aim of this study is to examine the determinants that affect tourists' intention to pay more for their stay in a hotel using renewable energy sources. For this purpose, we employ cross-section data from the largest Greek island, Crete. Unlike previous studies, we chose tourists because we expect tourists willing to pay for a stay in a green hotel to be a potential market segment important for the development of sustainable tourism on the island.

The paper proceeds as follows: Section 2 presents the methodological issues and the data used in the empirical analysis. Section 3 presents the empirical results, while the conclusions of the analysis and policy implications are discussed in Section 4.

2. Methodology

The research provides some insights into the determinants that affect tourists' positive attitude towards renewable energy. The empirical analysis is based on a cross-section data set. We carried out an extensive survey of 400 tourists during their summer holidays in Crete in 2009, using the random stratified sampling method. In particular, we distributed 100 questionnaires in each of the fourth prefectures of the island (Chania, Rethymno, Heraklion and Lasithi). The survey was conducted using a structured questionnaire and personal interviews. Given the purpose of our study, we interviewed tourists at hotels (Veal, 2006). We chose hotels at random taking into account the official hotel directory. The response rate was 80% and the survey resulted in a data set of 320 tourists. As a prerequisite, the respondents were above 18 years of age and income-earners.

Empirical results are based on the estimation of logistic regression models. Logistic regression (sometimes called the logit model) is used for predicting the probability of an event occurring by fitting data to a logit function. Logistic regression is a useful way of describing the relationship between one or more independent variables (e.g. age, gender, etc.) and a binary response variable, expressed as a probability, that has only two possible values (such as willingness or unwillingness).

In our case, under the binary logistic model, the estimated value of the dependent variable is interpreted as the probability that a tourist will pay more for accommodation in a "green hotel", as identified by the values of the explanatory independent variables. Thus, binary logistic analysis enables us to measure the impact of each variable on a tourist's intention to stay in a hotel using renewable energy sources. Four subsets of independent variables were used in this empirical analysis, namely: demographic factors, economic variables, past experience with regard to renewable energy sources, and variables regarding environmental awareness and information dissemination. Therefore, in the empirical study, we employed the following expanded specification for a tourist's willingness to pay more for accommodation in a "green" hotel:

$$W_i = b_o + b_1 A_i + b_2 A2_i + b_3 MPg_i + b_4 K_i + b_5 D_i + b_6 Ird\,e_i + b_7 D_i + b_8 E_i + b_9 Rhx\,e_i + b_{10} Sp_i + b_{11} Ria_i + b_{12} E_i + u_i \quad (1)$$

where WTPi is a binary variable indicating whether the tourist *i* is willing to pay extra for hotel accommodation using renewable energy sources or not; specifically, the variable takes the value 1 when the tourist is willing and zero otherwise[1]. $Gender_i$ is a dummy variable accounting for 1 if the respondent is male and zero if female; Age is the respondent's age;

[1] To be more precise, we asked "Are you willing to pay extra for hotel accommodation with RES?" (Yes/No). A similar question format was followed by (Dalton et al., 2008) in Australia. Jun et al. (2010) had also performed contingent valuation methodology employing dichotomous choice questions.

$Age2_i$ is the square of the respondent's age; $Married_i$ is a dummy variable taking the value 1 if the respondent is married and zero otherwise; Kid_i is a dummy variable accounting for 1 if the respondent has children and zero otherwise; $Degree_i$ is a dummy variable accounting for 1 if the respondent has completed undergraduate studies and zero otherwise; $Income_i$ is the respondent's monthly private income in euros; $Days_i$ is a quantitative variable indicating the average duration of a hotel stay while on holidays; $Expense_i$ is a quantitative variable expressing the average holiday cost per person; $Rhome_i$ is a dummy variable accounting for 1 if the consumer has already implemented an energy conservation system at home and zero otherwise; $Satisf_i$ is a dummy variable expressing the tourist's satisfaction with a previous stay in an energy-conserving hotel (yes: 1, 0: otherwise); $Rinf_i$ is a quantitative variable expressing awareness of renewable energy sources; $Envin_i$ is a dummy variable accounting for 1 if the respondent is aware of global environmental problems and zero otherwise; and u is an error term. The empirical results from the estimation of Eq. (1) are presented in Section 3 of this study.

Table 1 summarizes the expected sign for bi coefficients of Eq. (1). In particular, it is assumed that the people most likely to pay more for accommodation in a hotel with RES are those with a positive previous experience with the implementation of energy-conserving practices. Therefore, the expected sign for variables “Rhome” and “Satisf” is positive. We also assumed that adequately informed consumers are more likely to participate in eco-friendly actions. Thus, a positive relationship should be expected between “Rinf” or “Envin” and willingness to pay. In addition, previous studies reported that higher income groups are more willing than others. Higher income groups tend to spend more money on vacations. Thus, we also expected a positive sign for “Expense”. On the other hand, it may be difficult for these groups, who have longer vacation periods, to pay a premium for environmental purposes. In this case, the expected sign for the variable “Days” is negative. Although, it is difficult to predict the impact of demographic characteristics on the decision to pay more for accommodation in a hotel with RES, it is expected that highly educated consumers are more prone to support energy-conserving actions. Thus, a positive sign is expected for the variable “Degree”.

Table 1. Expected sign of the variables specified in the empirical binary logistic regression

Designation	Expected sign	Designation	Expected sign
Gender	+/-	Days	-
Age	+/-	Expense	+
Age2	+/-	Rhome	+
Married	+/-	Satisf	+
Kid	+/-	Rinf	+
Degree	+	Envin	+
Income	+		

3. Results

In this section we present the results of the statistical and econometric analyses to estimate the profile of ‘green’ tourists. As ‘green’ tourists we define those consumers willing to pay extra for accommodation in a hotel using renewable energy sources.

3.1. Descriptive Statistics

From the sample of 400 tourists in question, 53.1% were women and 46.9% men. Most respondents were between the ages of 31 and 50 years (36.9%); 18.1% were between 25 and

37 years, 12.8% between 51 and 71 years and 29.7% between 18 and 24 years. As regards the educational level, 60.9% were university-educated. The majority were employees with 40% working in the private and 21.9% in the public sector, whereas 14.1% were freelancers. The tourists' average monthly private, non property-related, income was €1,400, with a large percentage of monthly incomes being no higher than €500 (17.5%). The income of 3.4% of tourists varied between €800 and €1,100 and 22.2% declared having an income above €2,000. 34.4% of tourists were married. The majority (32.8%) reported holiday expenses between €251 and €500; 25.3% between €751 and €1000 and 7.8% over €1,500. As shown in figure 1, 45% of tourists were willing to pay more for accommodation in a hotel with renewable energy sources. As to the vacation's purpose, the vast majority of respondents (92.2%) reported recreation and the rest professional reasons. Next, interviewees were asked about their past experience with renewable energy sources. In particular, 71.3% of tourists had previously implemented an energy conservation project at home, and only 25% were satisfied with their past accommodation at an energy-conserving hotel.

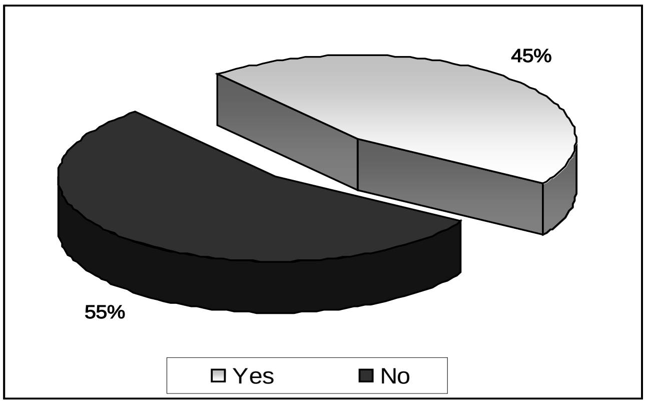

Fig. 1. Willingness to pay for accommodation in a hotel with RES

3.2. Logistic Regression Analysis

Several interesting results were obtained from the empirical estimation of Eq. (1). Table 2 summarizes the empirical results of the logit equation's estimated coefficients with respect to the willingness to pay extra for accommodation in a hotel using renewable energy sources. Statistically non-significant variables were omitted from model II. The final results for explanatory variables of tourists' willingness to pay are set out in the last column of Table 1, Model III. All the estimated coefficients of the explanatory variables presented in the final model have the expected sign and are statistically significant at a level of 5% or 1%. Estimated standard errors are corrected using White Heteroskedasticity. The Hosmer and Lemeshow statistic is one of the most reliable tests of model fit for binary logistic regression. The overall percentage of correct predictions for the final estimated model (model III) is 72.8%. The p-value 0.721 uses the Hosmer and Lemeshow Goodness-of-Fit Test with n-2 degrees of freedom. We are not able to reject the null hypothesis that there is no difference between the observed and predicted values of the dependent, implying that the model's estimates adequately fit the data. A p-value less than 0.05 indicates a good fit for a binary logistic regression model.

As follows from Table 2, men are more willing to pay extra than women, at a 10% level of significance (Model I & II). However, we didn't find any statistically significant relation between family status ("Married" and "Kid") and willingness to pay more for staying in a "green" hotel.

Age is a statistically significant factor in the willingness to pay more for accommodation in a hotel with renewable energy sources, at a 5% level of significance. Indeed, it is estimated that younger tourists are less willing to pay extra than middle-aged tourists. However, the negative sign of the estimated coefficient for the variable 'Age2' implies that age positively affects the dependent variable, but at a decreasing rate - reaching a maximum at 53 years of age

$$\frac{\vartheta(b_1"AGE"+b_2"AGE2")}{\vartheta"AGE"} = b_1 + 2b_2"AGE" = 0.106+2*(-0.001)*"AGE"=0.$$

In particular, for all tourists under the age of 53, an increase in age will positively affect the probability of paying more to stay in a green hotel. The importance of age on willingness to pay for RES was also reported by Dalton et al. (2008), who performed a frequency statistics analysis.

Table 2. Estimated binary logistic regressions of tourists' willingness to pay more to stay in a hotel with renewable energy sources (yes: 1 no: 0)

Independent variables	Model I	Model II	Model III
Constant	-2.910*** (4.460)	-2.967*** (6.146)	-1.269** (4.032)
Gender	0.279* (1.715)	0.308* (1.656)	
Age	0.106** (2.619)	0.104** (3.361)	0.020** (4.136)
Age2	-0.001** (2.266)	-0.001* (2.390)	-0.001** (2.481)
Married	0.154 (1.204)		
Kid	-0.017 (0.002)		
Degree	0.090 (0.103)		
Income	0.135 (1.230)		
Days	-0.045* (1.839)	-0.065** (3.938)	-0.070** (4.500)
Expense	0.001 (1.577)		
Rhome	0.796*** (8.085)	0.796*** (8.187)	0.703*** (6.691)
Satisf	0.074** (4.076)	0.069** (3.669)	0.075** (4.443)
Rinf	0.273*** (4.715)	0.273*** (5.018)	0.288*** (5.758)
Envin	0.662** (3.033)	0.635** (2.980)	0.610** (2.873)
- 2 Log likelihood	393.541	395.512	399.677
Nagelkerke R Square	0.282	0.325	0.360

Note: ***, *, represent levels of significance at 1% and 10%, respectively. Wald statistics are presented in parentheses. Standard errors are corrected using White Heteroskedasticity.

As expected, the longest-staying respondents were also the least willing to pay more, at a 5% level of significance (Model I & II). Educational level is also included in the first model, indicating that there is a positive, but statistically insignificant relation, between higher education and willingness to pay. Generally, tourists with a positive past experience at an energy-saving hotel are more likely to be willing to pay extra for their accommodation in a hotel implementing renewable energy projects, at a 5% level of significance. Accordingly, those tourists who have not previously adopted an energy conservation project at home are less likely to pay more for staying in a “green” hotel than others, at a 1% level of significance. As Bollino (2009) mentioned, those consumers who have a positive attitude to renewable energy technologies, will be prone to pay a surplus.

As far as economic parameters are concerned, the estimated coefficients for income and holiday expenditure are (as expected) positive, but not statistically significant. These results may explained by the following three parameters: (i) the economic uncertainty that influences consumers’ decision making process (ii) the fact that consumers stated preferences vary over time depending on their experience or knowledge and (iii) the hypothetical nature of the contingent valuation question and the fact that and consumer may value different public goods (Wang and Whittington, 2005). In contrast to the above-mentioned conclusion, the empirical results indicate that there is a positive, statistically significant, relation between information dissemination on renewable energy sources and willingness to pay, at a 1% level of significance. This result is in line with Roe et al. (2001) study for U.S. electricity consumers. Accordingly, environmental awareness about global environmental problems positively affects the probability of paying more, at a 5% level of significance. Zografakis et al. (2010), had also pointed out that high awareness levels or energy saving behavior resulted in a positive attitude for renewable energy sources.

4. Discussion and Conclusions

This paper has focused on providing insights into which factors affect tourists’ willingness to pay for renewable energy sources in Greece. The empirical results suggest that middle-aged people and men are more likely than others to pay a premium for accommodation in a hotel with renewable energy practices. This study also shows the importance of information dissemination and environmental awareness in the willingness to pay for renewable energy sources. In particular, past experience, environmental awareness and information dissemination are strong, statistically significant, factors that positively affect tourists’ willingness to pay for accommodation in a green hotel. Bearing in mind that tourism is considered to be Greece's “heavy” industry, it is important for enhancing sustainable development that hotels embrace renewable energy technologies. Accordingly, policies aimed at increasing consumer acceptance of green hotels can contribute to the adoption of sustainable lifestyles. As tourists become more sustainable consumers, the impact of tourism on the environment is limited. In this context, investigating the socioeconomic profile of tourists willing to pay a premium would have multiple useful policy implications. In particular, in the business sector, green hotel managers could expand their market share by focusing their advertising campaigns on those less willing to pay for renewable energy sources. Thus, green advertising can enhance a hotel's economic viability by increasing tourist demand. On the social level, renewable energy projects in hotels can contribute to environmental protection. However, further research is needed to achieve this goal in the tourism sector. Specifically, more analysis is needed on how information feedback can influence a tourist’s actual choice in favour of a green hotel, rather than relying solely on self-reported intentions to pay more for one. More importantly, there must be an emphasis on the various barriers that tourists report when it comes to accepting to pay more for renewable energy sources. In the case of willing tourists, research is needed on economic or other incentives for paying more and achieving sustainable behavioral consumption patterns.

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A dynamic hypothesis for developing energy-efficiency technologies in housing industry

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Abstract: The UK target to significantly reduce CO_2 emissions from housing has been challenged by the fact that 80% of the UK housing stock existing in 2030 has already been built. Energy-efficiency technologies for existing housing are developed in attempt to meet this target, e.g. fabric upgrades, ventilation systems, etc, but the interrelationship between the technical and social aspects of using these technologies is not fully understood. From the household perspective, a clear financial case in addition to other intangible benefits should exist to create high demand for these technologies. On the other hand, many technological interventions are still in the development stage and according to the technology diffusion theory there will be a delay in adopting these technologies on the expected scale. This study will use system dynamics modelling to investigate the relationship between the supply and demand of energy-efficiency technologies for existing housing. A dynamic hypothesis will be set to analyse the interrelationships among the controlling variables of technologies development over a period of time. This paper introduces the main structure of the study and discusses the technique adopted to model the identified dynamic hypothesis.

Keywords: *Energy-efficiency technologies, System dynamics*

1. Introduction

The housing industry in the UK is experiencing its transition period from traditional to energy efficient. The call for energy efficient houses has been intensified in the light of the high demand for energy. The growth of energy prices increases the pressure on householders to find solutions to the energy bills, and on the industry to develop more energy efficient technologies for houses. The introduction of UK targets to reduce CO_2 emissions has also a great effect on both the householders and developers. In the UK, approximately 26% of CO_2 emissions are attributable to the domestic sector[1]. At least 70% of the UK housing stock that will be present in 2050 have been already constructed before year 2005[2]. Therefore, modifications to the existing housing are essential to meet the targets of the UK Climate Change Bill. However, it is not only energy efficiency technologies that will achieve the CO_2 emissions target, but the changes to occupants' behaviour will also have a great influence to accommodate these modifications.

Despite the growing development in Energy Efficiency technological interventions, the uptake of these technologies is not great enough to show that there is a significant reduction in energy consumption and CO_2 emissions. Among the reasons for this market failure might be that the costs and benefits of refurbishment options are often complex to determine[3]. Achieving the target of CO_2 emissions will require large investments in the stages of energy generation, transmission, conversion and end-use, together with measures to control demand. Oreszczyn and Lowe[4] indicated that this necessitates the need for research to help formulate and evaluate policy, to measure progress, and to help industry to deliver.

2. Methodology

A previous study, 'TARBASE'[5], investigated a number of technologies in the field of end use technology, building fabric and energy supply technologies to achieve reductions in CO_2 emissions. Three intervention sets were identified with their effect on CO_2 emissions attributable to two selected dwelling types, namely; 'comprehensive', 'complete', and 'limited' intervention sets. A Whole Life Cost (WLC) approach has been conducted to investigate the cost implications for the uptake of these intervention sets by householders. The study concluded that there is no clear financial case over a 25 year horizon for householders to invest in the proposed interventions. The results also revealed the need for new policy approaches to overcome the financial and non-financial hurdles for a mass uptake of Energy efficiency technologies[6]. This paper builds on the results of TARBASE and investigates in a wider context the development and diffusion of energy efficiency technologies for housing. Variables affecting different policies to reduce CO_2 emissions such as subsidy, rising energy price, R&D investment from the industry, etc. are considered. Technology diffusion theory reveals that technological development and implementation includes a long delay to be fully diffused. In addition, effective implementation of technological innovations requires an understanding of the complexity underpinning the process and the inherent uncertainty about the actual performance of low energy housing[4]. The adoption of innovative technologies also requires reliable performance indicators to be employed to ascertain the condition of such processes. Models that simulate the implementation of new technologies need to consider the effect of experimentation, iteration and refinement of activities that are reliant on volatile information[7, 8]. These models should consider that many variables are time dependent and/or carry a high level of uncertainty. It is understood for example that the efficiency of new technologies is expected to rise by further development and experience in use. In addition, it must be stressed that the emissions savings are only realized when behavioural change accompanies the technological deployment.

Different motivational frames might alter the appraisal of costs and benefits related to a specific pro-environmental behaviour. Understanding the needs satisfied by the purchase of an energy efficient technology would allow their costs to be compared to the cost of other purchases satisfying other needs[9]. It is more likely that only a part of the family budget currently allocated for household improvements would actually be spent on energy efficiency improvements, even for those informed individuals with strong pro-environmental attitudes. Additionally, there is no financial incentive associated with the investment if reduction in utility expenditure (at current energy process) is taken as the sole benefit. The deployment of deep cut intervention sets are likely to result in other benefits, such as improved comfort and increased asset value of the property. It is feasible that when all benefits are aggregated, financial incentives will appear for householders and this needs to be explored further[5, 9].

In conclusion, the emissions reduction targets required to address the climate change agenda are only likely to be met through a combination of demand and supply side interventions. Identifying technological solutions for achieving a reduction in UK domestic dwellings is complex. Assumptions have to be made regarding for instance construction, occupancy and occupant behaviour in order to define the baseline for assessment of technological interventions which themselves are often interdependent. This would suggest that stressing the ethical or environmental appeal of an energy saving technology will only have limited effect if the technology is perceived by the consumer as having a high capital cost. In response to the challenge posed by this complexity, a System Dynamics (SD) based model is proposed in this research. It can investigate policies that affect the development and diffusion of energy efficiency technologies related to the housing industry during its transition period, considering both the demand and supply sides. SD modelling can identify the causal structure underlying the behaviour of complex systems, simulate the behaviour of time dependent variables and assess the usefulness of different energy policies such as energy tax and R&D subsidy for diffusing energy efficiency technologies.

SD modelling involves the following steps[10]:

1. Articulating the problem to be addressed
2. Formulating a dynamic hypothesis or theory about the causes of the problem
3. Formulating a simulation model to test the dynamic hypothesis
4. Testing the model output to satisfy the purpose
5. Designing and evaluating policies for improvement

Based on the relevant literature and data available from TARBASE, the proposed SD model was developed as a hypothetical model. This paper discusses the first two steps of the model development. Further development, requiring additional data, will build a comprehensive SD model.

2.1. Problem Articulation

The problem in hand is not only about the typical process of technology diffusion, but also about the effect of the pressure to reduce CO_2 emissions and the social and economical implications of using these technologies. Therefore, this step in modelling will identify the major controlling variables of technology diffusion and the effect of using these technologies on CO_2 emissions. In addition, the reference mode of the system behaviour will be identified. Reference mode is the graphical representation of the system behaviour over a period of time. This can be based on historical or pre-defined/required behaviour. The optimum behaviour of the system occurs if the pattern of the demand for house upgrading follows the same pattern of the diffusion of the technological intervention sets. Therefore, the technology diffusion theory will help identifying the reference mode of the demand for house upgrading. The time period assumed for the study is to 2050, when the CO_2 emissions reduction target is set.

2.1.1. Technology Diffusion Theory

Diffusion process is the methodology of adopting an innovation by members of a certain community. Rogers[11] categorizes the five stages of the diffusion of innovations as: knowledge (awareness), persuasion (interest), decision (evaluation), implementation (trial), and confirmation (adoption). Over the time of the diffusion process, new individuals adopt the innovation while others might reject it. Four factors were identified that influence adoption of an innovation, namely: 1) the type and need for innovation, 2) the communication channels used to spread information, 3) time period of diffusion, and 4) the nature of the community to whom innovation is introduced. Technology adoption rate always follows an S-curve that represents the length of time required for a certain percentage of community members to adopt the technology[11], as shown in Fig. 1. There are categories of adopters: innovators, early adopters, early majority, late majority, and laggards. This pattern of technology adoption will be used for the purpose of modelling as "reference mode of diffusion", which for this research will be the reference mode of "demand for house upgrading". The demand for house upgrading will be investigated from the perspective of householders, industry, and government. Individuals usually adopt an innovation if it has some attributes, namely: (1) the innovation has some relative advantage over an existing one, (2) the innovation is compatible with existing values and practices, (3) the innovation is not too complex, (4) the innovation has trialability (i.e. can be tested for a limited time without adoption), (5) the innovation offers observable results.

Various models have been developed in order to simulate the typical diffusion of technological innovations. For example, Veneris[12] developed a SD model which takes into account various diffusion patterns modelled via differential equations. The model did not consider that technology development is dynamic as there is always development or improvement over the time of diffusion all along the S-curve. Therefore, the S-curve is actually made up of a series of S-curves of different sections of a population adopting different versions of technologies. It did not also simulate the effect of the pressure to reduce CO_2 emissions and the social and economical implications of using these technologies

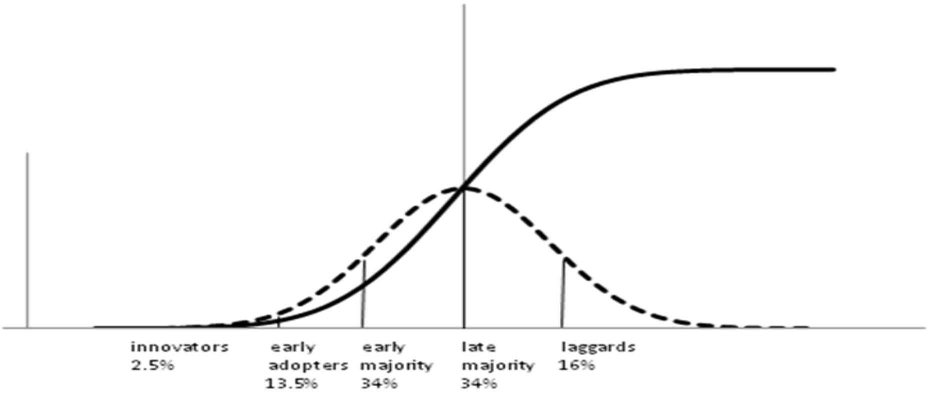

Fig. 1. Innovation adoption rate (Rogers[11])

The other main reference mode required for this model is for the rate of CO_2 emissions reduction. The target set for the year 2050 will be used as a guidance reference mode in this model (further data is required to refine this mode in a more accurate rate). Fig. 2 suggests that the linear emissions reduction rate since 1970 was 7.5 M t(CO_2)/decade. This would achieve a 60% reduction in CO_2 emissions from UK buildings by 2050. To achieve the 80% reduction adopted by the UK government in 2009, a faster rate of reduction (around 10 Mt(CO_2)/decade) might be needed[4].

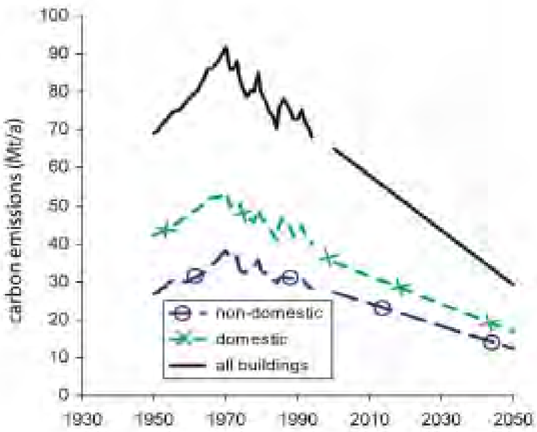

Fig. 2. Domestic and non-domestic carbon emissions to 1994 with trajectories to 40% of 1990 emissions in 2050 (reported in Oreszczyn and Lowe [4])

2.2. Formulation of the dynamic hypothesis

A dynamic hypothesis is set to explain the behaviour of the system and the relationships among its variables that develop its reference mode. Four mapping tools were used to develop this hypothesis, which are: Subsystem diagram, Model boundary chart, Causal loop diagrams, and Stock and flow maps. As this paper aims only to introduce the hypothetical model, the Stock and flow maps will not be presented.

2.2.1. Subsystem diagram

Fig. 3 classifies the architecture of the studied system into a number of subsystems. Each subsystem is mainly controlled by a certain variable, as illustrated by the variable name in each box of Fig. 3. The main control variables of each subsystem and the interactions between each other will be identified on the causal loop diagrams. For example, the actual proportion of dwellings using the intervention sets is used to measure technology diffusion. The other identified variables influence this measurement, namely; Rate of technology change, Unit energy consumption, R&D Investment, and CO_2 emissions. A number of feedback loops have been identified that control the subsystems behaviour, namely; Technology change loop, R & D loop, Consumption loop, and Emission loop. These loops will be studied and simulated to show how the system behaves under different conditions and policies.

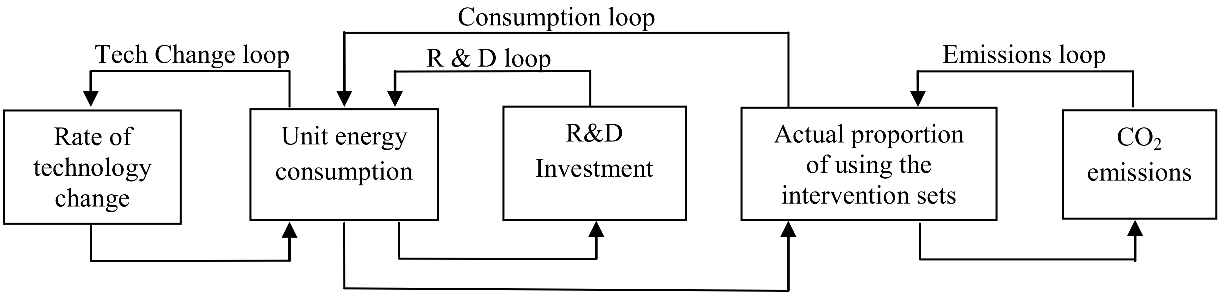

Fig. 3. Model sub-systems

2.2.2. Model boundary chart

The chart identifies the scope of the model by classifying the variables into endogenous, exogenous, and excluded variables, as shown in Table 1. This classification is essential to identify the model boundary in terms of the type of each variable and the relationships among variables.

The current version of the model excludes the interest rate on saving/investing the cost of house upgrade assuming that they will balance the effect of inflation on all expenses. The variables considered for the selection of intervention sets are: energy price (economical factor) and CO_2 emission (environmental factor) and R&D investment as financial support. Other variables influencing technological developments such as market impact or other new ways of house upgrading are excluded. The exogenous variables have great impact on the endogenous structure but their behaviour will be included from one single relationship for the purpose of this model.

2.2.3. Main Causal Loop Diagram (CLD)

For each of the above subsystems, a CLD is developed. The main CLD for the adopted model (Fig. 4) shows how the variables are related to each other. The resulting reinforcing loops and balancing loops will be discussed next.

Table 1. Model boundary chart

Endogenous	Exogenous	Excluded
• Actual use of intervention sets	• Energy tax	• Inflation rate
• Average CO_2 generation rate per until energy need	• Other cost of house upgrade	• Interest rate
• Effect of technology on unit energy consumption	• Reference energy price	• Other factors to influence selection of sets
• Average energy production price	• Government subsidy	• Effect of competition on technology change rate
• Average unit energy consumption	• Intangible effects	
• Indicated house upgrade demand		
• Average energy demand		
• R& D investment		
• Effect of cost on house upgrade		
• Indicated unit energy cost		
• House value		
• Industry revenue		
• Technology change rate		
• Actual energy consumption		
• CO_2 emissions		

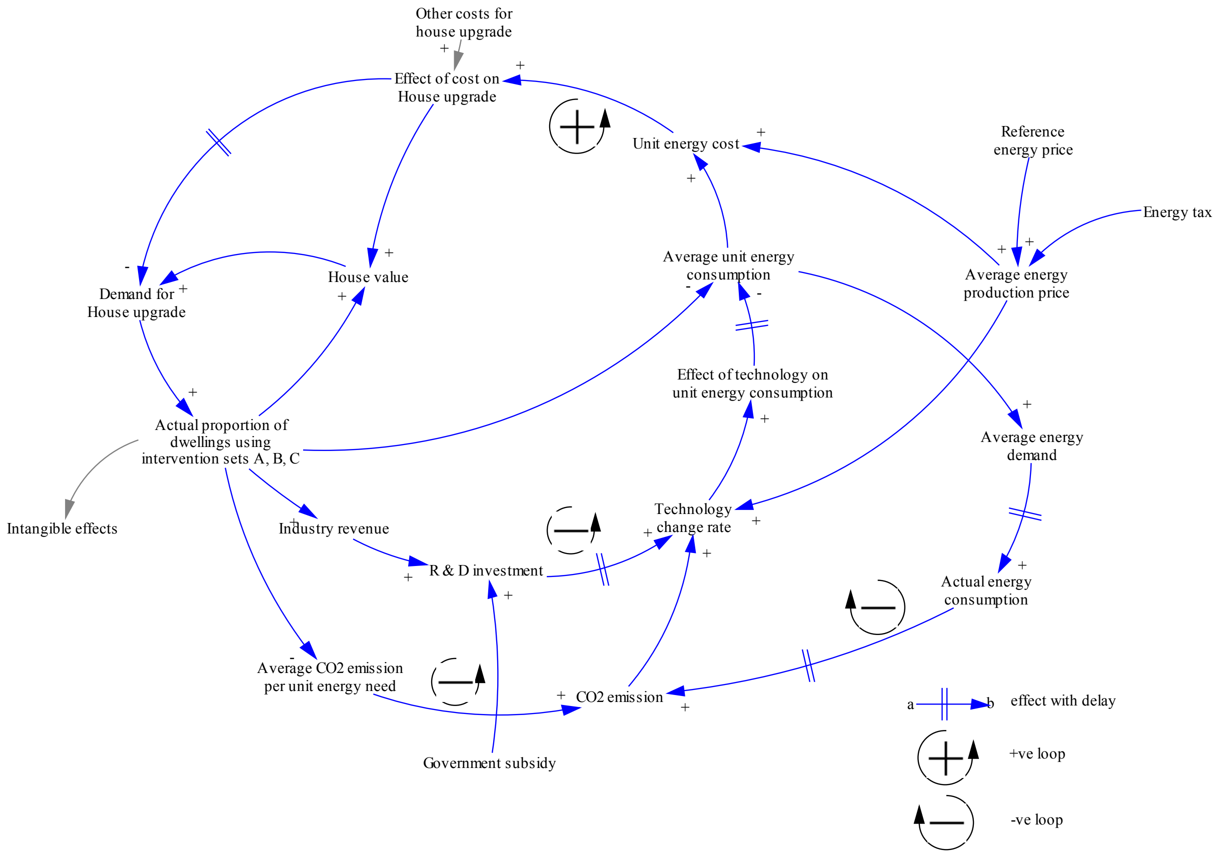

Fig. 4. Main Causal Loop Diagram

3. Results

The model variables and the causal relationships among them are defined. Positive signs are given to parallel relationships, while negative signs are for inverse relationships. The structure of system variables and relationships may create feedback loops. The polarity of a feedback loop (i.e., positive or negative) is identified by summing the polarities of the relationships among its variables. Loops with an odd number of negative relationships are negative. Loops with an even number of negative relationships are positive. Variables within positive loops will continue to increase indefinitely, therefore positive loops are self-reinforcing. Variables within negative loops will stabilize over time, therefore negative loops are self-balancing. Feedback loop structures, once identified, are translated into stock-flow diagrams to enable the SD simulation. The simulation part is beyond the scope of this paper. Clearly, the degree of details at which a CLD is defined strongly influences the success of this approach, and considerable care should be taken to develop it right.

3.1. Consumption loop (+ve loop)

Improving average unit energy consumption by increasing the actual proportion of using intervention sets; [Average unit energy consumption – unit energy cost – Effect of cost on house upgrade – Demand for house upgrade – Actual proportion of using intervention sets A,B,C - Average unit energy consumption]. Energy efficiency improvement can be measured by the reduction in the Average unit energy consumption, which reduces the unit energy cost and subsequently the effect of cost on hous e upgrade, which leads to an increase in the demand for house upgrade. High demand for house upgrading will increase the use of intervention sets, which in turn decreases the average unit energy consumption.

3.2. R&D loop (-ve loop)

R&D Investment results in reducing the unit energy consumption; [Average unit energy consumption – unit energy cost – Effect of cost on house upgrade – House value – Demand for house upgrade - Actual proportion of using intervention sets A,B,C - Industry revenue – R & D investment – Technology change rate – Effect of technology on unit energy consumption - Average unit energy consumption]. R&D investment is increased by input from industry and government sources. The higher ratio of industry revenue from selling more intervention sets, the higher dedicated funds for R&D. This will lead to more advanced technologies that reduce the average unit consumption.

3.3. Emissions loop (-ve loop)

The increasing use of the technology intervention sets will reduce CO_2 emissions; [Average unit energy consumption – unit energy cost – Effect of cost on house upgrade – Demand for house upgrade – Actual proportion of using intervention sets A,B,C – average CO_2 emissions per unit energy need – CO_2 emissions - Technology change rate – Effect of technology on unit energy consumption - Average unit energy consumption].

3.4. Technology change loop (-ve loop)

While the increase in the Average unit energy consumption might increase the actual energy consumption and the CO_2 emissions, but this in turn will accelerate the rate of technology change; [Average unit energy consumption – Average energy demand – Actual energy consumption – CO_2 emissions - Technology change rate – Effect of technology on uni t energy consumption - Average unit energy consumption].

The double lines shown on some links indicate the expected delays in realising a significant effect of one variable on the other, such as effect of technology development on application (the average unit energy consumption). These delay relationships are important to understand the behaviour of the system and the estimated time to measure the effect of the technological intervention sets during the transition period. There are a number of variables (on the gray arrows) which are modelled as exogenous inputs or policy variables based either on d ata series of reality or using some reasonable assumptions. By definition, these exogenous variables may influence the model behaviour but are not part of the main causal loops.

4. Conclusions

The diffusion of energy efficiency technologies for housing, considering both the demand and supply sides, has been investigated in this paper. Modelling the diffusion process using SD principles shows that various relationships within the process are developed that can help achieving the target of CO_2 emissions. The developed CLD with negative feedback loop will have a systemic resistance to undesirable outcomes within the system. However, a positive feedback loop will cause instability to the system performance. Therefore, when implementing changes for variables in a positive feedback loop, all other variables should be monitored to ensure that undesirable outcomes are controlled. Further analysis is required to validate the system behaviour against the identified reference modes.

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Swedish building policy and the manufacturers of single-family houses in the county of Dalarna. A collaboration for the future goal of the improvement of energy efficiency?

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Abstract: Sweden's goal is to reduce the use of energy per heated unit area in dwellings by 20 percent by 2020, and by 50 percent by 2050. To fulfil these goals, Sweden's dependency on electricity and, in particular, the large use of electricity for heating must be taken into account. The aim of this article is to study the effects of the Swedish building regulations from 1 January 2010, with regard to improving energy efficiency. The article follows the energy policy revision through policy documents and interviews.

The political goal of reducing both the annual electrical energy and the maximum instant power for heating is, on the whole, fulfilled by more efficient heat pumps. The study also shows that, in spite of the stricter building regulations for electrically heated houses, the standard of insulation required for the building to fulfil the building regulations is dependent on the heating and ventilation systems installed in the house. These changes towards more stringent requirements are also counteracted by there not being the same requirements for the existing housing stock.

Keywords: *Building policy, Energy efficiency, Manufacturers of single-family houses, Electrically heated houses.*

Nomenclature

A_{temp} the temperate area of the building ………………………………..m^2

HRV exhaust and supply air ventilation with heat recovery.............................dimensionless

1. Introduction

The energy used in the built environment constitutes 40 percent of the total energy use in Sweden. Consequently, a more efficient use of energy within the built environment is one of the most important means of achieving sustainable community development and fulfilling the environmental and climate goals. [see also 1, 2].

Sweden's goal is to reduce the demand of energy per heated unit area in dwellings by 20 percent by 2020 and by 50 percent by 2050 [3]. To fulfil these goals, Sweden's dependency on electricity and, in particular, the large demand of electricity for heating must be taken into account. Sweden has the largest number of heat pumps of the member countries of the E U. In 2008, almost 40 percent of single family houses in Sweden were heated completely or partially by heat pumps. [4, 5]. But the Swedish building regulations for electrically heated houses became stricter in 1 January 2010. The new building regulations concern the use of energy and power demand for new construction. The focus is partly on the supplied energy, i.e. purchased energy per m^2 floor area, and partly on limiting the maximum power demand of electrically heated houses [6].

The aim of this article is to study the effects of the Swedish building regulations from 1 January 2010, with regard to improving energy efficiency. The research question is if the revised building regulations from 2010, regarding energy use and power demand for new buildings, have resulted in changed building construction and/or a choice of alternative heating systems.

2. Theory and Methodology

Evert Vedung considers that different outcomes follow an intervention by the government, for example taxation laws or state subsidies. By outcomes he means what happens when the specific intervention reaches those who Vedung calls final recipients– that is the individuals or groups which are the goal for the intervention – and the final recipients' action caused by the public intervention. Three different types of intervention can be distinguished: the immediate, the intermediate and the final result [7]. We use a model which focuses on goals and fulfilment of goals, called a side effect evaluation. The evaluation focuses on the goals, and if the interventions have resulted in the fulfilment of the set goals [7]. According to Evert Vedung, two questions have to be asked in order to study this. These are: do the results correspond to the agreed goals for the interventions? And, if so, does this depend on the intervention?

A qualitative method makes it possible to reach an understanding of people's behaviour in relation to the surrounding environment (Merriam 1994:46). The housing companies' accounts have been followed during a three year period from when the building regulations were being framed until they were in force. During the autumn 2009 and the spring 2010, 10 representatives from manufacturers of prefabricated, single-family houses[1] were interviewed. They have their head offices and production in the county of Dalarna. The interviews focused on the house manufacturers' reasoning and how they acted during the period of transition from 1 February 2009 until 1 January 2010. After the building regulations came into force, follow-up interviews were carried out with the house manufacturers during the spring 2010 [see also 8]. Further analysed material is from group discussions from 2007, when researchers from Dalarna University and house manufacturers discussed heating systems which the companies could consider [see also 9].

3. The building regulations after 2010: u-values, power and energy use.

During the last 30 years there has been a change in households' choice of heating systems in Sweden. Owners of single-family houses have changed from using oil fired boilers to using more district heating, heat pumps and bio-fuels [10]. But the energy use per m^2 heated area for new built premises and dwellings has, on the other hand, been constant from 1993 to 2005. An explanation which was given before the revision of the building regulations in 2006 was the lack of a requirement for improvement of energy efficiency [11].

The building regulations on energy management from 1 Jan 2010 concern permanent residences, and not vacation homes. The regulations imply, above all, a tightening up of the requirements for newbuilt, electrically heated houses with both an energy requirement and a power requirement. Even houses with waterborne electric heating and heat pumps are now classified as electrically heated if the installed power demand exceeds 10 W/m^2. For buildings

[1] The definition prefabricated, single-family housing companies includes three different groups: 1) companies which manufacture houses according to the client's requirements (customer adapted houses), 2) housing companies which produce standard houses, and houses according to the client's requirements, and also 3) housing companies which only manufacture standard houses (Fredling & Sellin 2003).

with other methods of heating there are no tightening up of the requirements[2]. There are even somewhat less stringent requirements in the north of Sweden because there are three different zones instead of the previous two climate zones (see table 1). An electric immersion heater or electric boiler is, however, almost always used as a temporary reserve in single-family houses, which is true, for example, for houses with solid fuel boilers. This means that, in principle, all houses would be classed as electrically heated, and only houses with district heating would be omitted. For this reason there is an exception in the building regulations which says that "the electric power in a solid fuel appliance, which is installed to be a temporary reserve, is not counted if the solid fuel appliance is constructed for permanent operation" [6]. During this period the importance of flexible heating systems is also emphasised and the opportunity for flexibility in new building encouraged [12].

The three climate zones are: the most northerly, climate zone I (the counties of Norrbotten, Västerbotten and Jämtland), with an alleviation in the requirements for houses which are not heated by electricity, compared with earlier requirements. Climate zone II consists of the central parts of Sweden, including the county of Dalarna, the region which is in focus in this article[3]. Climate zone III comprises of the southern parts of the country.

The building regulations are based on the building's specific energy demand (see table 1) which is the energy use of the building divided by A_{temp}[4]. The energy use of the building is the energy which is used for heating and domestic hot water, and also that part of the electricity supplied to the property which is related to the requirements of the building. This means all permanently installed equipment within, under, or on the outside of the building. Pumps, fans, cooling machinery and heating cables are included if they supply the building[5]. When fuel is used, the amount of fuel and its calorific value is used to calculate the energy demand. Energy from solar collectors and solar panels, and also free cooling which is taken directly from the ground is not included in the energy use of the building [6].

[2] According to The Swedish Board of Housing, Building and Planning's instructions all buildings shall be classified as electrically heated if the installed electric power demand for heating is greater than10 W/m^2.
[3] Climate zone II includes the counties of Västernorrland, Gävleborg, Dalarna and Värmland
[4] A_{temp} is the area of all the floors, including stairs and shafts, for the spaces which shall be heated to over 10ºC. A garage within the building may not be included in A_{temp}, but its heating requirements shall be included in the energy use of the building (Boverket 2008,p.35).
[5] Fixed lighting in common areas shall be included but not lighting in gardens and on external footpaths. Neither shall electricity for other uses, for example as engine pre-heaters and car coupé heaters, be included. Electricity which is used for comfort cooling shall be adjusted upwards by a factor of three for houses which are not electrically heated (Boverket 2008).

Table 1: Requirements for specific energy use and power demand for buildings from 1 January 2010 [6]

Climate zone	Form of heating	Maximal specific energy use [kWh/m^2·year]	Maximal installed electric power [kW]	Overall heat transfer coefficient [W/m^{2}K]
I	Electricity, addition when A_{temp}>130 m^2	95	6 +0,035(A_{temp}-130)	0,40
	Other	150	-	0,50
II	Electricity, addition when A_{temp}>130 m^2	75	5 +0,030(A_{temp}-130)	0,40
	Other	130	-	0,50
III	Electricity, addition when A_{temp}>130 m^2	55	4,5 +0,025(A_{temp}-130)	0,40
	Other	110	-	0,50

4. The building regulations; problems and opportunities

When researchers from Dalarna University talked to different housing companies during the summer and autumn of 2007, it was evident that there was concern and speculation on how the building regulations on the improvement of energy efficiency would finally be framed and what this would mean to them. One of the people interviewed said that ”there is a proposal, which is being circulated for comments, and which has been postponed a number of times, which says that heat pumps will be classified as electric resistance heating. It has been circulated time and time again and no-one knows when it will be introduced”. But it is clear, the informant said, that the government and the Swedish Board of Housing, Building and Planning want to tighten up the requirements and reduce the use of energy in newbuilt houses (housing manufacturers, group discussion 1).

The housing manufacturers were interviewed during the autumn 2009, which is during the period of transition which started in January 2009. Therefore they had access to the revised wording and the opportunity to digest the changes presented and form a strategy to allow their production to fulfil the requirements for the improvement of energy efficiency. But as 2009 was a period of transition and the regulations did not come into force until 1 January 2010, some housing manufacturers were still ambivalent on how they would deal with the new regulations, and what change would materialise in the end. During 2010, the questions on how they should fulfil the Board of Housing, Building and Planning’s requirements have ceased.

4.1. Insulation thicknesses and tightness

One change which the interviewees presented was additional insulation in walls and roofs. There are companies which increase insulation from 195 mm to 240 mm, but there are also companies which keep the thinner insulation and change from air source heat pumps to ground source (rock) heat pumps instead. Most of the interviewees said that a relatively easy measure for improving energy efficiency was thicker walls. One of them said that their manufacturing process was constructed so that further insulation could be added without much trouble and therefore it is not expensive (interview 2)

One of the interviewees emphasised that more insulation and a thicker wall is less a question of saving energy than of a psychological effect. He said ”the saving in energy by constructing a thicker wall is not as great as you think (interview nr 1). He also considered that there was a limit to wall thicknesses as they take up far too much of the floor area if they are too thick. The floor area is limited in prefabricated single-family houses because the transport from the factory to the building owner is by lorry, and they want to limit the number of lorries. A larger house means more lorries, which in turn leads to higher house prices (e.g. in interview 3).

There is a requirement for a limited average heat transfer coefficient in the Swedish Board of Housing, Building and Planning’s building regulations (BBR) 2010. This is that the house shall not have a higher average heat transfer coefficient than 0,4 W/m^2K for electrically heated houses and 0,5 W/m^2K if the house has other methods of heating [13]. However, according to Persson and Heier (2010), the requirement for the average heat transfer coefficient is so low that it does not have any practical significance. It is principally the energy and power requirements which set the limits for the insulation standard of the house [14]. There is no specific requirement in BBR on the tightness of the building envelope, only that it shall be sufficiently tight to fulfil the energy and power requirements. The house companies pointed out that if the house purchaser chose to buy the house from them, but selected another company to erect the house, it is the house purchaser, in his role as commissioner of a building project, who is responsible for the building envelope having the required tightness to fulfil the energy requirements. This is an obligation which the interviewees thought could be neglected because the house purchaser was not aware of his/her responsibility (interview nos 7).

4.2. Choice of heating systems

There are many different parameters to be considered when choosing a heating system[6]; living area, size of supplementary areas, ventilation, acceptable noise level, economy etc. [9]. The choices open to house manufacturers and house purchasers in Sweden are different types of heat pumps, district heating and bio-fuel boilers or bio-fuel stoves. Solar collectors can be included in all these systems.

In the autumn 2009, the companies were very confident that the air and ground source heat pump manufacturers would improve their products and the products’ energy generation, and thereby simplify the work with energy management and the possibility of fulfilling the requirements of the Swedish Board of Housing, Building and Planning (interviews 1, 2, 5 among others). One of the interviewees expected a great change in the production of heat pump products and, according to him, the heat pump suppliers have done ”a really good job” (interview 1). During the interviews it was pointed out that one air source heat pump company has become more interesting to the market because of its technology, an improved exhaust air heat pump, and because of the changed building regulations (interviews 6, 4). It is a company which has existed for almost 10 years and has increase its sales from about 30 heat pumps per year to 600 per year (Henning 2009).

The house manufacturers’ customers seldom or never choose pellet boilers or pellet stoves Solar heating is also often rejected. The house manufacturers emphasise that bio-fuels are troublesome because they take a lot of space and need a lot of work. They say that the people who are interested in the environment install solar heating (interview 4,5,7). To make the

[6] A heating system is not always included in the house sale; if this is not the case the customer can be responsible for the installation him/herself.

disadvantages of pellets and solar heating clear the house manufacturers often emphasise the advantages of air source heat pumps and ground source (rock) heat pumps, for example that they are economical and easy to handle (interviews nr 5,2).

In this study it seems as though the changeover from the traditional exhaust air heat pump, which has the lowest investment cost but the highest total cost, to the improved exhaust air heat pump [7] took place because the requirements were changed, not because it was, in fact, also financially profitable [15]. The product has existed for a number of years, but the company increased its sales substantially after the revision of BBR in 2010. The new regulations originate in an aim to reduce electrical heating and increase the use of bio-fuels [3, 11] However, Persson and Heier (2010) show that the revised building regulations mean that the choice of a bio-fuel, in this case pellets, needs the supplement of an exhaust and supply air ventilation with heat recovery (hereafter called HRV system). On the other hand ground source (rock) heat pumps fulfil the Swedish Board of Housing, Building and Planning's energy requirements without HRV. Ground source (rock) heat pumps also have an advantage, as the possibility of omitting HRV means a lower investment cost. The interviews show that a low investment cost is an advantage when choosing a heating system for the new house.

4.3. Current and future changes

The companies could see opportunities in this energy political goal and in current, as well as in possible future, changes in the building regulations. An example of this is one of the companies which has bought a company which produces low energy houses. They want to take part in, and at the same time follow, a new market with low energy. Therefore, the company has invested in a show house where the building envelope and heating system with heat storage is different from their other standard houses. The show house has extra well insulated walls, solar collectors and district heating and also three storage tanks (total of 750 litres) [16].

However, according to the interviewees, these changes towards more stringent requirements are counteracted by there not being the same requirements for the existing housing stock. There are not the same constraints in spite of the fact that the heating of the existing housing stock requires more energy (interviews nos 2,4,7). One of the interviewees makes the effect of these unequal requirements clear when he says that the stringent requirements for newconstructed dwellings can lead to too high prices for some of the prospective house owners. They choose to buy an older house instead (interview 1).

The interviewed manufacturers that produce vacation homes sold within the region of Dalarna, also have to adjust to the requirements specified for permanent homes. This is because even thought the vacation homes are not affected by the energy requirements in the government building regulations, Malung –Sälen municipality has started to insist the vacation homes follow the same requirements as permanent homes. This is because new buildings in Malung – Sälen municipality is manly of vacation houses which have similar designs to permanent houses and therefore similar energy demands. If these do not follow the more stringent energy regulations, the energy demand will increase and may require an increase in the capacity of the power distribution net. (interview 4,5 and a politician from Malung-Sälen).

[7] An improved exhaust air heat pump is an electrically driven heat pump which cools the exhaust air to approximately -15° C, and also makes use of heat from condensation of the humidity in the air.

5. Conclusions

If we use Evert Vedung's concepts and model, this study shows that the immediate outcome of the Swedish Board of Housing, Building and Planning's building regulations from 2010 regarding the improvement of energy efficiency is, in some cases, an improvement of the building envelope, in particular supplementary insulation of the walls, but above all a changeover from an exhaust air heat pump to either an improved exhaust air heat pump or a ground source (rock) heat pump.

The intermediate outcome is that prospective house owners choose to buy an older house with a high energy consumption instead of a new with less energy demand. The changes towards more stringent requirements are counteracted by there not being the same requirements for the existing housing stock. Prospective house owners choose to buy an older house instead of a new one, because of higher prices caused of the stringent requirements for new constructed dwellings. To make it attractive for a prospective house owner to build a house it is also important to focus on regulations concerning the existing building stock and energy use.

The intermediate outcome is also a question of increased performance of exhaust air heat pumps and the effects of this. Increasing insulation was not always a result of the Swedish Board of Housing, Building and Planning's energy requirements. The requirements could be fulfilled with the help of a more efficient air source heat pump instead. A parallel can be drawn between this study and a Norwegian study on state intervention and house manufacture. The Norwegian study shows that state regulations are regarded as an indication of the least which should be done and the smallest possible changes are carried out [17]. It is interesting, though, that in contrast to the manufacturers, Malung-Sälen municipality requests more than what is defined in the building regulations. The vacation houses are being used mainly during the winter and are the same size as permanent houses[8] the interviewed emphasized the importance of having the same requirements for all the new built houses. That is to prevent for instance the need to expand the power distribution grid.

The final outcome of this study is that the new building regulations do not automatically lead to better insulated houses. The conclusion is that it is sufficient to change from an ordinary exhaust air heat pump to an improved exhaust air heat pump or a ground source heat pump. A trend, where heat pumps and (electrically heated) passive houses continue to dominate Swedish house production means that the housing stock is becoming more and more based on electric heating. It is true that the houses fulfil the requirements in the building regulations, but, at the same time, they increase the problem of high power loads during the winter which demand great flexibility in production capacity.

The building regulations focus on reducing the households' bought energy instead of climate impact. From a regional and vacation houses perspective this is interesting, because the log house industry feels that its work and normally bio-fuel heated houses are threatened**.** From a climate perspective it can be discussed if a log house built and heated with wood from the region is not preferable to a low energy house built in concrete and heated with a ground source heat pump [see also 18].

[8] For example, the average size of the houses produced by one of the manufacturers was 120 $m^{2.}$ (interview 6)

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Promoting renewable energy and energy efficiency in Central Africa: Cameroon case study

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Abstract: Central Africa owns important renewable energy potential. This important potential is still suffering from poor development. The main cause of the poor use of renewable energy is the poor commitment and dedication of governments who have not taken the necessary measures to boost the sector. Thermal plants are hence among other solutions planned or under construction. The purpose of this paper is among other things aiming at ensuring that the renewable energy resources of Central Africa are known and are subject to be used optimally. The work also shows availability of renewable energy sources and suggests actions to promote and sustain its development. Based on the knowledge of the Central African energy sector, this paper will identify actions for improved access to sustainable, friendly, affordable energy services to users as well as a significant improvement of energy infrastructure in Central Africa and the promotion of renewable energy and energy efficiency. The work will show the potential for solar, biomass and hydro while showing where available the level of development. Then identified obstacles for the promotion of clean energy will be targeted. Finally, suggestions will be made to help the countries develop a vision aiming at developing good clean energy policy to increase the status of renewable energy and better contribute to fight against climate change. Cameroon case study will be examined as illustration. We will use several documents from institutions in the region and abroad, and maps when available.

Keywords: *Renewable energy, Potential, Central Africa, energy policy, Cameroon*

1. Introduction

Central Africa owns important renewable energy potential, namely hydro, solar and biomass. This important potential is still suffering from poor development up to the point where the sub region is still abundantly using the fossil energy as main power source. The main cause of the poor use of renewable energy is the poor commitment and dedication of governments who have not taken the necessary measures to boost the sector. This issue will also be addressed. Since the region is experiencing power shortage, thermal plants are among other solutions planned or under construction. This solution currently under implementation in Cameroon and other countries in the region, is not environment friendly and hence is not a long term solution.

2. Methodology

The work shows availability of renewable energy sources and suggests actions to promote and sustain its development. Based on the knowledge of the Central African energy sector, this paper will identify actions for improved access to sustainable, friendly, affordable energy services to users as well as a significant improvement of energy infrastructure in Central Africa and the promotion of renewable energy and energy efficiency.

The work will show at first the potential for the three primary energy sources which are solar, biomass and hydro while showing where available the level of development. Then identified obstacles for the promotion of clean energy will be targeted. Finally, suggestions will be made to help the countries develop a vision aiming at developing good clean energy policy to increase the status of renewable energy and better contribute to fight against climate change. Cameroon case study is very interesting because the country has a great renewable energy potential and can develop and export energy to neighboring countries.

The state of art in energy sector in Cameroon will be made. Based on ongoing projects and strategic documents adopted by the country, directions towards which actions will be made will be suggested. From the overview of institutional structure reform of the Cameroon power sector and assessments, specific suggestions based on the weaknesses of the institutions will be made for the enhancement of the renewable energy and hence sustain energy access and security in general and in remote areas in particular, where the fight against poverty is more difficult. We will use several documents from institutions in the region and abroad, and maps when available.

3. General information on Central Africa

Central Africa (Cameroon, Central African republic, Gabon, Republic of Congo, Chad, Equatorial Guinea, Democratic republic of Congo) is situated between latitude 13° south and latitude 22° north, longitude 8° East and longitude 22 East.

Central Africa is endowed with an abundance of renewable energy resources but the region is still looking forward to facing the challenge of harnessing its resources effectively and efficiently. There is still a vast dependence on fossil fuels and biomass. The use of fuel wood for lighting and cooking is still very familiar in the region given the poor income of populations. This negatively impacts the environment and causes infant mortality from acute respiratory illness associated with the inhalation of wood smoke. Approximately 1.6 million people die every year because of indoor air pollution - that's one death every 20 seconds [1]. This indicates that there is a need to develop efficient, sustainable and safe technologies to relieve population from such a burden.

4. Renewable energy potential in central Africa

4.1. Hydro potential

These countries own important hydro potential. Although 3.4 GW has already been developed, above 100 more GW of hydro power still remain untapped with an economically feasible hydropower potential above 900 TWh. Given the importance of the hydrographic network, tidal energy can also be envisaged, as well as ocean energy along the guinea golf.

Table 1 Thermal power, hydropower potential and development in Central Africa: source: [2] and [3]

COUNTRY	Gross theoretical hydropower potential (TWh/year)	Under operation in 1999 (MW)	Technically feasible (TWh)	Thermal plants
CAMEROON	294	725	115	300
GABON	80	170.2	32	210
DEMOCRATIC REPUBLIC OF CONGO	1397	2440	774	NA
CONGO	50	89	NA	
CENTRAL AFRICA REPUBLIC	NA	19	3	24
EQUATORIAL GUINEA	NA	1	NA	28
CHAD		0	0	37

4.2. Wind potential

According to GEOS-1 satellite measures from NASA [**Error! Bookmark not defined.**] from july 1983 to june 1993, the wind potential of the region is poor within the equator. Chad is the only country with an average speed above 5 m/s throughout the country, allowing the possibility for wind development.

4.3. Geothermal potential

Some hot water sources are identified in the region, but detail study for the assessment of the geothermal potential have not yet been done so far in Central Africa, although one important volcano (mount Cameroon) is still in activity. The eastern part of the Democratic Republic of Congo might have important geothermal potential since it is part of the Indian Ocean ring of fire.

4.4. Solar Potential

Africa is situated from one side to another at the Equator level, hence making this continent one of the sunniest in the world. Based on the data from Solar Radiation project (SoDa) [4], the lowest daily mean radiation ranges from around 4 kWh/day/m² (wet forest) to above 8kWh (dry desert in Chad). The modified map below from SoDa shows the average solar radiation of the region. It appears that Central Africa has a great solar potential.

4.5. Biomass Potential

Central Africa holds up to one-quarter of the world’s tropical forests. This forest is the second largest tropical forest in the world after the Amazon forest. Its mosaic of ecosystems regulates local climate and the flow of water. The forest covers an important area, from the Albertine Rift (Rwanda, Burundi, Uganda) to the Gulf of Guinea (Equatorial Guinea, Gabon, Cameroon) and harbors a variety of forest. It’s one of the place where wild dense forests can still be found in the world with an area around 500 million acres, spanning the boundaries of Cameroon, the Central African Republic, the Democratic Republic of Congo, Equatorial Guinea, Gabon and the Republic of Congo.

Inadequate and improper forest management practices is a threat to the long-term viability of these forests, significantly reducing their economic potential and resulting in negative social and environmental impacts. Over 50 percent [5] of the Congo Basin's forests are under commercial logging leases. Despite several sustainable forest management programs, Central Africa tropical forests are disappearing at an alarming rate.

5. The energy sector in the region

The energy sector differs from one country to another, depending on the available potential. Some countries have liberalized the sector and others are still on the way to doing it. Each country has its own energy sector management and regulations. The countries are still looking forward to having transborder regulations. This will for instance facilitate grid interconnection and sustainable management of energy sources. All the countries have developed important thermal plants.

6. Energy efficiency

The issue of energy efficiency is suffering from poor information and dissemination on energy efficiency technologies. The contributions in Central Africa should mainly be oriented towards building capacities and information dissemination on energy efficiency technologies. The grand objective of this initiative is to lighten the economical burdens of the countries in the region thereby improving the life quality. Due to the reason of affordable prices, most of the countries are using, less efficient equipment notably in their industry, transportation or household sectors (generator, wood, petrol…). Most of such equipment, which can be second-handed (from developed countries), obsolete or of inefficient technology (non efficient stoves, incandescent light bulb…), is less efficient than the latest models being used to date and thus consumes more energy. These inefficient apparatuses often produce more air pollutants that can cause environmental destruction and threat of contracting serious diseases for people.

Many countries in Central Africa are oil producers. The availability of fossil fuels is hence not an important issue. The energy efficiency technology could help reducing the negative environmental impact of human activities by decreasing the consumption of fossil fuels, and thereby yielding the same results as the renewable energies. Actions should be undertaken to ameliorate and sustain the Energy Intensity, defined here as the ratio of the total energy consumption to the Gross Domestic Production (GDP), to a level below 0.5 (developed countries between 0.2 and 0.3).

Introducing high efficiency technologies into Central Africa will be foreseen to lighten their economical burden by reducing the total conventional fuel consumption, electricity bills and the high deforestation level, and thus improving their productivity. Given the high level of biomass consumption (80% household energy in Cameroon [6]), energy efficiency will be foreseen to lighten the desert encroachment and thus climate change.

The issue of implementing hybrid renewable energy system can also be envisaged, namely solar/hydro/biomass/wind.

7. Barriers to renewable energy and efficient energy implementation

There are significant barriers to the further implementation of renewable energy that need to be addressed. The key issues include the following:

- Biomass, hydro, solar and wind energy technologies remain expensive (high capital costs), compared to firewood, charcoal, petrol and gas energy supplies,
- Poor long period support of renewable energy projects (till reaching profitability)
- Lack of consumer awareness on benefits and opportunities of renewable energy solutions.
- Poor decentralized solutions for energy services (generation, distribution…)
- Financial, legal, regulatory and organizational barriers need to be overcome in order to implement renewable energy technologies and develop markets.
- Lack of specific access to key energy infrastructure such as the national electricity grid,
- Poor availability of funds for development of renewable energy
- Poor organization and sector institutions

8. Suggestions

8.1. Vision

The region needs to develop a vision leading to strategies and programs. This should be politically sustained in order to mitigate the poor leadership and poor renewable energy and energy efficiency policy formulation in the sector. In order to sustainably fight against climate change, strategic action plans should be developed or reviewed where available to fit with clean development mechanism. This should be done through capacity building and capacity enhancement of stakeholders in the region.

Central Africa in general is suffering from a poor vision on the issue of renewable energy and energy efficiency. Very few countries have developed a vision on this issue and other are still looking forward to doing it. The strategies and programs exist in some countries. They should match the vision and meet the targets.The region should identify the long term perspective action on the issue of promoting renewable energy and energy efficiency. Where there is no vision on this issue, it is important to focus on stakeholder's capacity to define and adopt a long-term perspective on renewable energy and energy efficiency. If need be, capacity building and/or capacity enhancement should be prior to the formulation of the vision.

In order to meet the renewable energy and energy efficiency targets, effective leadership is a key issue for the attainment of the targets within Central Africa. At national and regional levels, political authorities should be involved and support the action. This would lead to the generation of champions.

Other important points are:

- enforce energy policy at the regional level,
- promote and develop power trade and ancillary services,
- increase access to clean energy to populations and reduce poverty,
- create a free regional energy market and improve energy system reliability and quality of supply in the whole region.
- initiate pilot projects funded to help develop the market for sustainable energy,
- create favorable regulatory and policy frameworks,
- Promote innovative finance and business models to activate the private sector,
- develop and support policy-maker networks at regional level with initiatives in the field of energy efficiency, sustainable energy regulation, renewable energy and regional regulatory board
- disseminate mirroring of well-reasoned input

8.2. Enabling environment

Given the purchase power of the population and the economic constraints, renewable energy requires an enabling environment for its promotion. As mentioned above, the renewable energy initial capital cost is high compared to conventional energy sources. This can only lead to making them commercially uncompetitive in the short to medium-term. To overcome this situation, specific actions need to be taken at several levels, namely fiscal, financial, social and legislative levels. This includes commitment and dedication of actors for a good leadership and encouragement of champions. National and international bodies hosting development agencies based in each country should also work together to attain the promotion of renewable energy and energy efficiency targets. Full implementation of free trade within Economic Community of Central African States (ECCAS) will facilitate regional programs and collaboration among states.
Addressing the human resource issue is a key point for attaining the objectives. The region experiences poor human resources in the field of designing, evaluating and implementing renewable energy and energy efficiency projects. Good governance and good regulation in the sector are also very important for promoting and enabling environment for scaling up investments and mobilizing public and private initiatives.

The real potential and benefits of all renewable energy sources is still to be assessed. Because some studies are not done or not fully done, the costs for developing renewable energy tend to be very high and there is a reluctance to invest in what are sometimes considered to be risky investments.

8.3. Role of financial instruments

The profitability of renewable energy is subject to discussion in a market driven energy economy. To address this issue, many countries in Europe have adopted different specific renewable power generation approaches (feed in tariff, certificates, fixed tariff). In order to achieve the target, the introduction of renewable energy technologies into a market driven energy economy will require the allocation of funding to assist in overcoming the initial high capital cost. It could be done through government bodies, private institutions sustained by government or simply through dedicated funds (budgetary allocation, subsidies, incentives...). The process should be stopped as soon as the renewable energy technologies become competitive and are driven by market forces alone.

Other actions to be undertaken are:

- Establishment of a good organizational framework and robust energy policy and strategy
- Public sensitization
- Promotion of efficient techniques and marketing strategies (4Ps)
- Knowledge management and networking with other partners and projects, governmental and private sector partnership

9. Cameroon case study

Cameroon power sector heavily relies on hydropower with 721 MW of Hydro schemes over the total installed capacity of above 1000MW. According to the World Bank Investment Climate Assessment, limited access to reliable electricity is among the 5 top obstacles to doing business in Cameroon. It is estimated that the lack of reliable energy services is costing Cameroon close to 2% of the gross domestic product growth. In order to rehabilitate existing power station, as well as transmission and distribution networks, the electricity utility AES SONEL recently secure a EURO 260 million loan financing for its five year investment program. In order to secure energy supply for the country, the Government of Cameroon commissioned a least cost power sector development plan (PDSE 2030) which is on the way to being updated. Given the time needed for the studies, development and funding of hydro plants, the country has been obliged to take emergency measures based on thermal solutions to cover current and foreseen energy shortages in the short term. If the funding doesn’t follow, emergency measures taken for electricity production might become permanent, producing more than one million tons of carbon dioxide per year.

9.1. Main current and future thermal plants

From 2004 to 2011, thermal plants capacity from fossil energy has been multiply by four. Several thermal plants are permanently under operation. The most important are the Limbe thermal plant and the Yassa thermal plant with an installed capacity of 85 MW each. The construction of Kribi thermal plant (gas) with a capacity of up to 300 MW is ongoing. To meet energy shortage foreseen in the country in the short term, the Government plants plans to develop up to 100 MW additional thermal capacity in the cities of Bamenda (20 MW), Ebolowa (10 MW), Mbalmayo (30 MW) and the capital city Yaounde (40 MW). To face the growth of the demand estimated above 50 MW per year, important reforms and midterm development plans have been done. As demonstrated above, renewable energy is far from being the first solution for addressing energy shortage issues in Cameroon.

9.2. Institutional reform

Prior to the current status, electricity was supplied in Cameroon by a single vertically integrated company that had the responsibility for production, transmission, distribution and retail sales. The country established a sector regulator (ARSEL), a rural electrification Agency (AER) and also created the Electricity Development Corporation (EDC) which, as Government of Cameroon's asset holding company, is responsible for the management of public sector assets in the power sector, in particular hydropower assets, as well as the regulation of power flows. Nowadays, more than 20 texts govern the sector which is liberalized since 1998. The aim of liberalization was to attract private sector investments to help the country develop its power sector. The generation, transmission, distribution and sales of power are submitted to concession agreement, license or authorization, declaration regime, free regime and the special regime for rural electrification.

9.3. Renewable energy promotion

No specific action dedicated to the promotion of renewable energy has been undertaken so far. Programs for efficient stoves are ongoing for energy efficiency but many other issues still to be addressed. The country also has a rural electricity fund for the promotion of rural electricity. The formulation of strategic actions to boost the energy sector in all parts of the country is still ongoing in the Ministry of Energy and Water. The promotion of renewable energy and energy efficiency is among these actions. But given the poor experience of the stakeholders, pilot projects should be initiated and disseminated.

9.4. Identified regulatory barriers to renewable energy

Challenges (regulatory and others) to sustainable energy in Cameroun include:

- The restructuring of the electricity utility AES-SONEL mission;
- The establishment of connection charges and tariffs from renewable sources;
- The update and implementation of low cost solutions and safety standards for rural electrification;
- The encouragement of the ongoing policy for entrepreneurs willing to enter the electrical service contracting business;
- The consolidation of the provision of incentives to encourage entry of new electricity retailers in cities and rural areas through rural electrification fund;
- The promotion of energy efficiency
- The dissemination of bests practices.

The mission of the electricity utility should be restructured to encourage energy from renewable sources, through attractive connection charges and feed in tariffs. In order to boost the sector, the rural electricity fund should promote the development of hydro and solar plants where need be and disseminate information about champions.

9.5. Weaknesses of the institutions

The country will be experiencing in the future for the first time a true management of new operators, for only two licenses are granted so far. All the projects are currently facing poor visibility on the issue of feed-in, transport and tariffs. The electricity regulatory agency (ARSEL) created in the framework of liberalization hence has limited experience.

For each of the ongoing projects, there will be specific negotiations if necessary measures concerning regulations are not taken in time. The sector is also suffering from a lack of transborder regulation for interconnection among countries, because Cameroon can be a net electricity exporter. Options for encouraging decentralized solutions in remote areas are currently ongoing through rural electricity fund, but the experience is still limited. To address these issues, Cameroon is developing several strategic action plans. The promotion of renewable energy and energy efficiency hence still has a long way to go.

10. Conclusion

Central Africa is a region with great renewable energy potential, a place were almost all renewable energy sources can be found. The region owns the first hydro potential of the continent, the second tropical forest in the world and an important solar radiation all year long. Despite the great renewable energy potential, the region is experiencing very poor renewable energy and energy efficiency promotion. Although some actions are ongoing, more specific actions in the region are needed at several levels. Suggestions have been made to help the region develop a good vision to address the issue and take the necessary measures at all levels for promoting renewable energy and energy efficiency.

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The impact of the GB Feed-in Tariffs and Renewable Heat Incentive to the economics of various microgeneration technologies at the street level

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Abstract: England, Scotland and Wales planning regulations require zero carbon homes by 2016. This can be expected to accelerate the uptake of microgeneration technologies. To incentivise small low-carbon generators the UK Department of Energy and Climate Change (DECC) proposed two new systems: the Feed-in Tariffs (FIT) and the Renewable Heat Incentive (RHI). This paper investigates the impact of these two systems on the carbon performance and the economics of various microgeneration technologies under two scenarios: (a) at the single dwelling level and (b) a local microgrid at the street level. The economic implications of combining a number of houses to form a local microgrid are assessed and expressed in terms of percentage of capital investment outstanding. The paper concludes that the current structure of the FIT and RHI does not incentivise microgeneration technologies according to their carbon performance and does not favour street-level schemes such as the one investigated in this paper. However it is sufficient to drive the market forward.

Keywords: Microgeneration, Microgrid, FIT, RHI, Residential, Renewables, Economics

1. Introduction

England, Scotland and Wales planning regulations require zero carbon homes by 2016 [1]. For large-scale residential developments, this implies the use of biomass combined heat and power (CHP) systems with potential contributions from photovoltaics or solar thermal systems. Micro wind power is unlikely to be suitable for the majority of developments due to the poor wind resource in the urban environment [2]. Smaller-scale developments and notably individual houses will be dependent on a combination of microgeneration technologies to meet their demand in heat and electricity. Undoubtedly the main barrier to the microgeneration technologies to date has been the high capital costs. In order to support and incentivise small low-carbon generators, the Department of Energy and Climate Change (DECC) in the UK proposed two new systems: The Feed-in Tariff (FIT) and the Renewable Heat Incentive (RHI).

A zero carbon home as defined in the "Code for Sustainable Homes", takes into account energy efficiency usage within the boundaries of the house. However, Department of Communities and Local Government (DCLG) recognise that there may be cases where it is not reasonable to expect zero carbon to be achieved through on site measures alone [3]. This means that policies will set out a series of solutions that can deal with the emissions that cannot be dealt with on the site of the development ('allowable solutions').

This paper considers a slightly less restrictive definition of the "zero carbon home" where various microgeneration technologies are directly connected to and operating for small-scale developments of fewer houses than would be typical for a developer-driven housing development (Figure 1). The impact of linking a number of houses at the street-level to the economics of various microgeneration technologies is investigated and compared with the economics for the single house case.

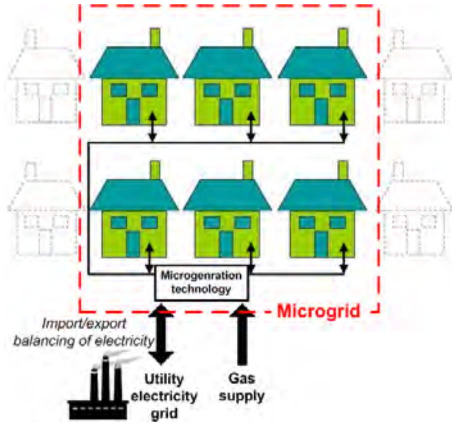


Fig.1 Conceptual combined thermal and electrical microgrid at the street level

2. Assessing the thermal and electrical demand of a residential housing cluster

For the prediction of the thermal heating demand (space heating and domestic hot water) the dynamic simulation package *TRNYS* [4] was used. Figure 2 illustrates the relationship between the main parameters used in *TRNSYS* to predict the thermal demand.

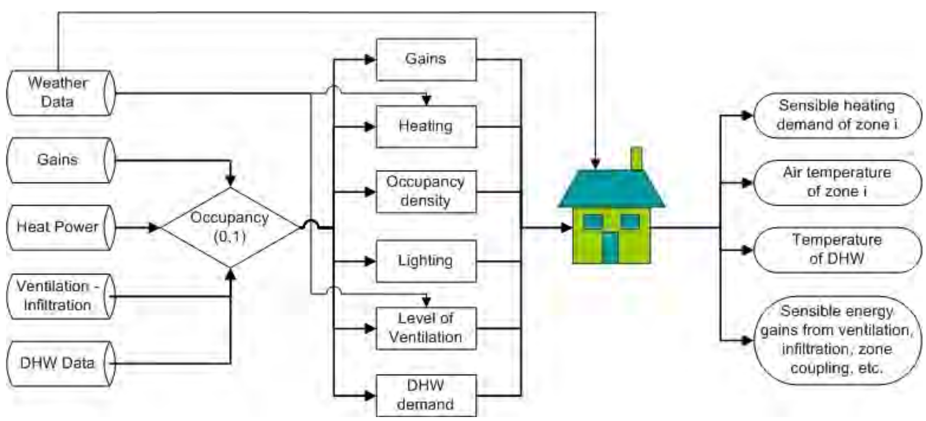


Fig. 2 Schematic illustration of the main signal flows used in TRNSYS for predicting the thermal demand

2.1. Space heating demand

The study considered a notional detached house constructed post-1965, which essentially represents ~17% of the total UK building stock [5]. Three user occupancy profiles were used: (a).Retired couple, (b).Professional working couple and (c).Family with 2 children.

2.2. Domestic hot water demand

Load profiles developed by Ulrike and Klaus [6] were used for the domestic hot water demand. Domestic hot water data and occupancy profiles were synchronised with a Fortran routine developed within *TRNSYS*, effectively operating as a load buffer [7].

2.3. Electrical demand

For this study real data was used for the generation of the electrical demand profiles; this had the form of five-minute interval data from an eco-home development of 9 low energy houses in Havant, near Portsmooth, UK [8]. Three datasets were chosen from the Havant trial to represent the three occupancy profiles in this study. Table 1 summarises the demand levels for the three occupancy profiles and the cluster of 10 houses.

Table 1. Demand profiles in kWh for the 3 occupancy profiles and the cluster [7]

	Retired couple	Working couple	Family	10 house cluster
Space heating	12,178	8,161	10,287	118,008
DHW	3,006	3,002	5,230	36,706
Electrical	2,800	3,500	4,000	33,700

3. Clustering approach - Microgrids

The energy consumption of ten detached houses was modelled. Detached houses were chosen as they are a common house type of the UK building stock, accounting for more than 20% of the total UK building stock [5] and they are more likely to adopt any of the technologies considered in this study due to the availability of space as required by some technologies.

The clustering of ten houses at the street level to form a local microgrid was chosen as the basis of this study to assess any potential financial benefits. The reasons for adopting such an approach are:
(*a*) Smoother demand profile with less distinctive peaks, for both heat and electricity, maximizing the local use of the energy generated. More continuous thermal demand is expected to result in fewer losses from the thermal storage and buffer tanks and less volatile electrical demand is expected to result in lower levels of electricity export.
(*b*) Increased thermal load, allowing CHP technologies to operate under better regime.
(*c*) Proportionally smaller peak demand of a cluster compared to a single dwelling, which translates to smaller total installed capacity for the microgeneration technologies.
(*d*) Lower capital and maintenance costs for the microgrid compared to the single house.

The short proximity of the houses within the residential cluster implies a small electrical network, where distribution losses may be ignored. The heat network was assumed to be equally small and highly insulated, therefore heat losses were also considered to be negligible.

4. Microgeneration technologies

Four types of microgeneration technologies were considered and modelled in *TRNSYS* at the single house level and the street-level microgrid [7]: Solar thermal, Photovoltaics (PV), Ground Source Heat Pumps (GSHP) and Combined Heat and Power (CHP).

4.1. Solar thermal

A typical active, indirect, flat plate solar thermal system of 4.4kW_p capacity was modelled for the single house and the street cluster (x10). A 300 litre stratified thermal storage tank was assumed per house. For the street-level cluster the same thermal storage tanks were assumed to be linked, essentially operating as a common thermal storage.

4.2. Photovoltaics (PV)

A monocrystalline PV module of 1.8 kW_p manufactured by Suntech Power [9] was modelled for each house, requiring 13m^2 total roof area [7]. The main limiting factor for sizing the PV system was the available roof space with right orientation and the minimum shading. This size is of a typical domestic application which may vary from $1.5kW_p$ to $2kW_p$ [10]. For the 10 house cluster the PV arrays were linked to form a local microgrid. Each house within the cluster was connected to a local distribution grid, allowing electricity to be transferred from one house to another and excess generated electricity to be exported to the utility grid.

4.3. Ground Source Heat Pumps (GSHP)

A single ground source heat pump system per dwelling was modelled to meet the space heating demand. To maximise the heat pump's thermal performance, heat storage was also considered. For intervals where heating demand could not be met by the heat pump, a backup boiler delivered any heat shortfall. GSHPs were modelled for 45°C output temperature, essentially modelling high temperature underfloor heating and low temperature radiators. For the single house a GSHP of $6.4kW_p$ rated heating output was modelled, whilst for the cluster at the street-level two large heat pumps of $32.6kW_p$ rated output each operating in series were considered [11].

4.4. Combined Heat and Power (CHP)

In terms of using fuel more efficiently, the concept of a CHP system was considered. Small CHP systems are commonly high heat:electricity ratio systems (>3:1) and as stated in the government's standard assessment procedure (SAP) [12], are assumed to be heat-led, meaning that they are allowed to operate only when there is demand for heat. On the grounds of economics, the installation of a CHP unit with a secondary back-up boiler would be unattractive. CHP units were therefore examined as an alternative to condensing gas-fired boilers.

For the single house a stirling engine micro-CHP system from Whispergen [13] was modelled, whilst for the residential cluster two options were investigated:

(a). a mini CHP operating as common facility for the microgrid and;
(b). three CHP units of different capacities ($7kW_{th}/1kW_e$, $14kW_{th}/5.5kW_e$, $30kW_{th}/15kW_e$) operating in series to provide the same peak thermal and electrical output as the single mini-CHP ($51kW_{th}/21.5kW_e$).

A thermal storage tank of 150 litres per dwelling was considered. Multi-stage operation involves the problem of scheduling the CHP devices operating in series. For this reason a heuristic, greedy construction algorithm was designed and incorporated in the CHP model.

5. Feed-in-Tariffs (FIT) and Renewable Heat Incentive (RHI)

In order to support and incentivise small, low-carbon generators and also make low carbon generation more cost effective to communities and householders, the UK Department of Energy and Climate Change (DECC) proposed two new support systems: the FIT and the RHI. With the FIT and RHI the UK Government introduces clean energy cash-back for renewable electricity and heat. Table 2 presents the tariffs for generated electricity and heat as proposed by DECC.

For electricity generation technologies, electricity exported to the national grid will be incentivised by an extra $3p/kWh_e$.

Table 2. FIT and RHI generation tariffs for the UK, as proposed by DECC in February 2010

	FIT or RHI tariff (p/kWh)	
	Single house	**Cluster**
Solar thermal (kW_{th})	18.0	17.0
PV (retrofit) (kW_{el})	41.3	31.4
GSHP (kW_{th})	7.0	5.5
CHP (kWh_{el})	10.0	0

6. Results

At the first step, the carbon emissions from the 10-house cluster were estimated for the business as usual scenario (BaU) of a 90% efficient condensing boiler and electricity from the national grid. The BaU carbon footprint was then compared with the carbon footprint after deploying the microgeneration technology at (A) the individual house level and (B) the microgrid level. Results are summarised in Table 3 and clearly illustrate the improved carbon performance of the microgrid. It should be noted that micro-CHP for the single dwelling was the only technology with poorer carbon performance than the BaU scenario. PV system for the microgrid achieved a higher utilisation factor of the generated electricity, with 6% lower import and 15% lower export. However, in terms of carbon performance, the two schemes were equivalent as the system effectively displaces electricity with the same carbon intensity as the electricity imported. CHP's improved carbon performance for the microgrid was mainly due to lower electricity import from the national grid (13% for the mini-CHP unit and 24% for the 3 CHPs in series). For the carbon emission analysis a carbon intensity factor of 0.19kgCO_2/kWh was used for natural gas and 0.43kgCO_2/kWh was used for electricity imported from the UK national grid [12].

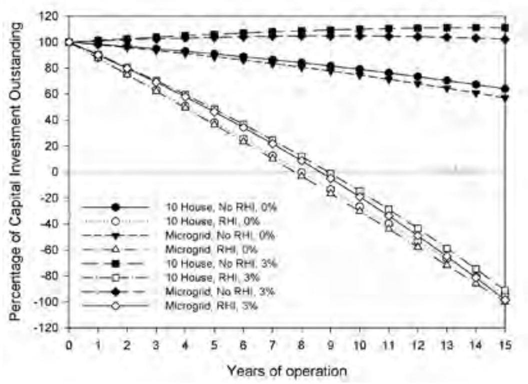
Table 3. Estimated tnCO_2 savings per annum compared with the BaU scenario

Tones CO_2 saved compared with BaU	**Solar thermal**	**PV**	**GSHP**	**micro-CHP**	**1 mini-CHP**	**3 CHPs in series**
10 non linked houses (A)	3.8 (48%)	8.0 (54%)	10.3 (41%)	-2.2 (-4.7%)	-	-
Microgrid (B)	4.3 (55%)	8.0 (54%)	11.5 (46%)	-	7.0 (15%)	7.8 (17%)
Difference (A-B)	0.5	0	1.2	-	-	-

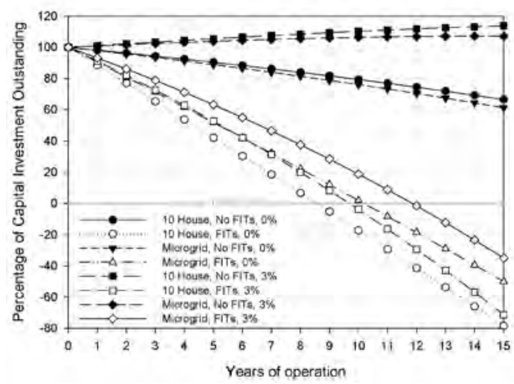
The costs of the generated energy from each technology were estimated for a 15-year period, for the 10 non-linked houses and for the microgrid. The impact of the FIT and RHI schemes was assessed for each technology. For each case, both 0% and 3% interest rate was investigated for the capital investment. The prices used for gas and electricity were: 5p/kWh for gas and 16p/kWh for electricity (£1=100p) assuming a 3% annual increase over the 15 year period. Figure 3 illustrates the predicted cost of ownership for all the microgeneration technologies assessed in this paper.

For solar thermal the single house system was priced at £3,000 with maintenance cost £50 per annum to cover engineering inspections. For the microgrid the total investment, including the piping to connect the houses, was priced at £36,000. Without the RHI support the savings achieved by the system were negated by the interest rate and the system's economics diverged. Taking into account the RHI tariffs, the system achieved a financial break-even after 10 years of operation. Financially the microgrid scheme performed better, achieving 10% greater savings on energy bills compared to the 10 non-linked houses.

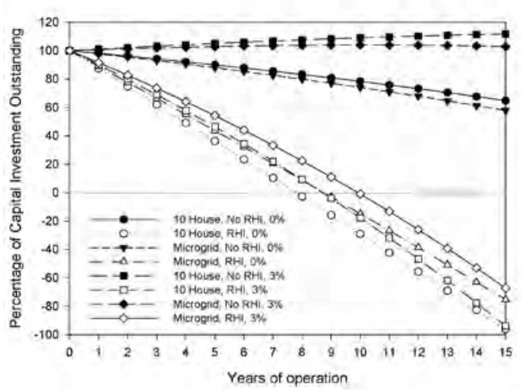
The main benefit of forming a microgrid when considering PV, was the increase of local utilisation of the electricity generated by the system. With the current FIT structure, the PV microgrid scenario was predicted to have worse performance than the standard single-house installations. Due to the very high tariff for generation and the additional export tariff, savings from the avoided import were insignificant compared to the savings due to generation. Assuming 3% interest rate, the financial payback period was predicted to be ~10.5 years for the 10 non-linked houses and ~13 years for the microgrid. Assuming no FIT the microgrid performed marginally better than the single-house case. The capital cost used for the analysis was



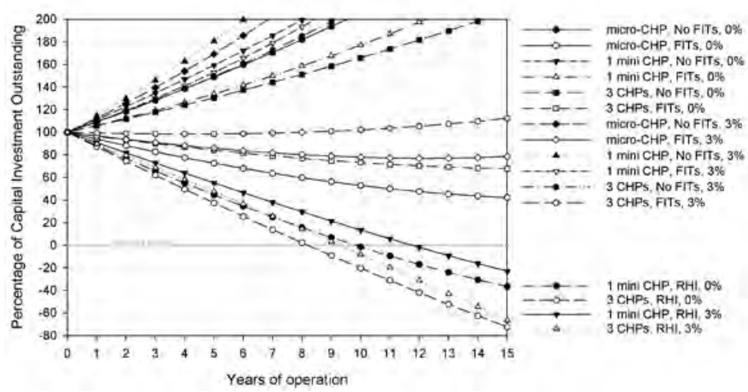
a. Solar thermal



b. Photovoltaics (PV)



c. Ground Source Heat Pumps (GSHP)



d. Combined Heat and Power (CHP)

Fig. 3 Cost of ownership profile for all microgeneration technologies considered in this study, assuming a 3% annual increase in the energy prices.

£4,500 per kWp installed and an annual OPEX of 2% of the initial capital cost was assumed for maintenance and the replacement of the system's inverter.

The improved carbon performance of the microgrid with GSHP systems was also followed by improved financial performance. With the current RHI tariffs microgrid was estimated to perform better than the 10 non-linked houses, with payback periods of ~9.5 and ~11 years respectively, despite the lower tariff offered for larger systems. Without the RHI support, all systems were far from the financial breakeven point. The capital cost assumed for the GSHP system was £1,000 per kWp [14] installed and a 1% maintenance cost was allowed for an annual inspection.

CHP units were examined as an alternative to boilers; hence the economics were calculated against the BaU scenario of a 90% efficiency condensing boiler, priced at £900 per unit with an annual maintenance cost of £50. Capital costs used were £26,000, £45,000 and £50,600 for the micro-CHP scheme, the mini-CHP scheme and the 3 CHPs in series respectively, including the heat piping network. A 2% of the capital cost was allowed for annual maintenance. As seen in Figure 3d, none of the three CHP schemes modelled reached the financial breakeven point within 15 years of operation, even when taking into account the current FIT. It should be noticed that despite its poor carbon performance, micro-CHP performed financially better, followed by the 3 CHP units in series and then the mini-CHP operating for the microgrid. The lower part of Fig. 3d illustrates a hypothetical scenario where the communal CHP units are supported through the RHI scheme. A price of 3.5p/kWh_{th} would be required for these systems to reach the financial break-even point after 8-10 years of operation assuming 0% interest rate, whereas when a 3% interest rate was assumed breakeven took an additional 2 years.

Figure 4 shows a summary of the financial performance of all the microgeneration technologies considered for the residential cluster at the street level, with the current FIT and RHI tariffs, assuming 3% annual increase in energy prices and a 3% interest rate for the capital investment. It is shown that CHP technologies can not be economically viable if not incentivised. Current support for solar thermal, GSHP and PV proved to be sufficient to drive the market forward, even for the case of a 3% interest rate for the capital investment.

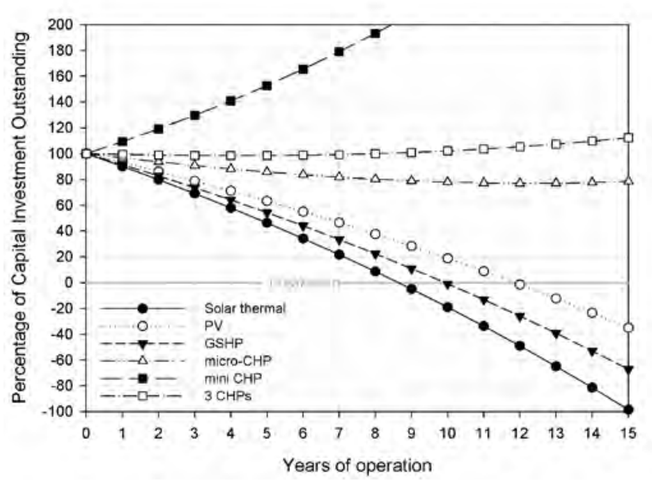


Fig. 4 Cost of ownership profile for all microgeneration technologies for the residential cluster, under the current FIT and RHI structure, assuming a 3% annual increase in the energy prices and 3% interest rate for the capital investment.

7. Conclusions

This paper investigated the impact of the UK FIT and RHI tariffs on the economics of various microgeneration technologies when they operate as common facilities for a cluster of houses at street level. It was shown that the carbon performance of these technologies was not followed by similar financial performance. A comparison between the individual house level and the cluster of 10 linked houses showed that there are potential carbon benefits and better matching of the generation-consumption profile. In some cases, however, the benefits are almost negated by the current FIT and RHI structure, due to the lower tariffs offered for larger installations and because of the high tariff offered for generation which overshadows the financial benefits from local consumption/avoided import. For this work, linked microgeneration technologies have been regarded as one larger installation, but financial benefits could further increase if each unit could be incentivised individually. The clustering approach proved to benefit CHP technologies more than any other, delivering 7-8tnCO_2/year per cluster. With no support from the Government such schemes were not predicted to reach the financial breakeven point within their lifetime. As heat-led processes they could be supported through the RHI scheme. With a generation tariff of 3.5p/kWh$_{th}$, CHP technologies could breakeven financially after 8-12 years and proliferate in the residential sector.

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The Parameters used in Multiple Criteria Decision Making Methodologies for Drafting out Renewable Energy Sources Support Schemes

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Abstract: The increasing environmental concerns and energy issues required for a sound design of decision patterns increased the parameters to be considered in deciding and developing an efficient energy strategy through the optimisation of support schemes for renewable energy technology. The correct identification and evaluation of the decision making parameters leads amongst others to correct political decisions for maximising the benefit of investment cost, social and environmental gains and improvement of technologies. The paper is focussed in analysing the parameters to be used in a Multiple Criteria Decision Making method and in suggesting a ranking scale for the parameters to be ued in drafting their weights. Fourteen parameters were selected and analysed. The analysis is contacted through literature review, personal communication with key personnel and through questionnaires.

Keywords: *Renewable Energy Parameters; MCDM Methods; Renewable Energy Policy.*

1. Introduction

Energy planning and support methodologies have been developing through the years for supporting decision makers to evaluate conflicting alternatives and derive a way to come to a compromise in a transparent process. Very common methods used in energy planning are the Analytic Hierarchy Process (AHP), PROMETHEE, ELECTRE, Multi Attribute Utility Theory (MAUT) and in order to validate a result more than one of the methods can be used.

During the70's and 80's, the increasing environmental concerns and energy issues changed the design of decision patterns so as to include the environmental and social implications in energy planning. This caused an increase in the parameters to be considered in deciding and developing an energy strategy. The paper discusses the parameters used in decision making for drafting out Renewable Energy Systems (RES) support schemes and through the outcome of questionnaires suggests the parameters' rankings to be used in further developing their weights. The first part lists a number of indicative parameters briefly explaining them and the second part deals with the questionnaires results.

2. Methodology

A literature review has been conducted in identifying the most commonly used parameters. The study in ranking the parameters and identifying their weights is carried out through literature review, personal communication with key personnel and the fulfillment of questionnaires. The outcome of this paper draws out conclusions regarding the major parameters to be used along with indicative suggested weights. The correct identification and evaluation of the decision making parameters leads amongst others to correct political decisions for maximising the benefit of investment cost, social and environmental gains and improvement of technologies.

3. Indicative Parameters

The parameter evaluation has to provide tools of judgment for decision makers (DM), which must verify the consistence of choices with the expectations of the DM and with the needs of the other involved actors. A number of criteria can be developed to best suit the alternatives and decision makers' familiarity with the alternatives and the criteria. In this chapter, criteria that could be used in deciding the best mix of RES subsidy scheme are examined.

Generally, the parameters used in each country and for each RES technology may vary, however, in general the parameters to be used should be:

- compatible with political, legislative and administrative situation (willingness, level of cooperation of governmental departments and political parties);
- consistent with the local technical and economic condition, which depends on the local capacity of managing the innovation both at technical and financial levels (availability of technology, cost factors, maturity);
- consistent with energy demand predictions (projection of final energy consumption may affect greatly the decision outcome since it will affect the aggressiveness of the support schemes);
- compatible with the existing environmental and ecological constraints (International agreements can shape the final classification of the alternatives).

The parameters to be used should be agreed on and accepted by all the actors involved in the decisional process. A list of potential parameters is presented below:

3.1. Maturity / reliability

A mature technology can be defined as a technology that has been in use for long enough and most of its initial faults and inherent problems have been removed or reduced by further development [1]. Another key indicator of a mature technology is the ease of use for both non-experts and professionals. The judgment is expressed within the range of 1-4. A rank order is applied, with increasing preference from 1 to 4, as follows: (1) technologies that are only tested in laboratory; (2) technologies that are only performed in pilot plants; (3) technologies that could be still improved; (4) mature technologies, close to reaching the theoretical limits of efficiency [2]. Popp, et al. 2010 expressed the necessity in evaluating the maturity of renewable energy technologies for drafting future energy policy and developing efficient support schemes.

3.2. Market maturity

This criterion is an estimation of the market availability and the status in the penetration process of a given technology and the materials and services associated with the considered action [3]. A Judgment scale provided by Becalli et.al. 2003 is the following: (1) not present on the market at least in a experimental stage; (2) pilot plants; (3) start of market availability; (4) market availability of the technology for less than 10 years; (5) market availability of the technology for more than 10 years.

3.3. Consistence of installation and maintenance requirements with local technical know-how

The evaluation of this criterion is oriented to a qualitative comparison between the complexity of the considered technology, and the capacity of local actors of ensuring an appropriate installation and operating support. The technology maturity and market maturity are highly correlated with this criterion since the market availability for installation and maintenance requirements depends on them. The following qualitative scale of ranking is used: (1) insufficient technical background for installation/maintenance; (2) middle technical background for installation/maintenance; (3) great technical background for installation/maintenance [2].

3.4. potential / Climatic conditions

Unlike fossil fuel technologies, the efficiency of renewable technologies is generally very site specific. Thus, it would be expected that photovoltaics in the UK would incur a higher cost per kWh than countries located at lower latitudes such as Cyprus. In general, the geographical potential can be considered as the energy flux theoretically extractable in areas that are considered suitable and available for energy production i.e. in areas which are not excluded by other incompatible land cover/use and/or by constraints set on local characteristics such as elevation and other land characteristics [4]. This criterion is only concerned with the geographical potential of a certain region. The scale to be used is not in the form of energy output but a use of a more general linguistic scale is more appropriate. The scale proposed considering the available renewable energy technology, is as follows: (1) Almost no potential; (2) Very low potential; (3) Low potential; (4) Medium potential; (5) High potential; (6) Very high potential.

3.5. Continuity and predictability of performance

In assessing renewable energy it is important to know the conditions of continuous operational patterns. This condition is often a characteristic of a given technology and does not indicate a factor of unreliability. For example the output performance of photovoltaic is more predictable than the one of windpower. As of 2008, Germany produces between 1500 and 7700 GW h/month depending on wind conditions. This makes traditional scheduling of power generation for the day ahead very unsure [5]. The judgment of this parameter can be expressed according to the following scale: (1) unpredictable and not continuous operation; (2) predictable but not continuous operation; (3) predictable and continuous operation.

3.6. Value of energy output

Possible future revenues from investments in RETs are crucial for facilitating an economically viable period of heavy installations that is needed to fulfill the new environmental goals. The costs are the initial investment and the operational and maintenance (O&M) costs [6]. To evaluate the profits of renewable energy projects without including any of the policy support mechanisms, the following equation can be used for the value of energy output (VEO).

$$VEO = E[XsmPsm + XcmPcm] \qquad (1)$$

where E is the monthly energy output by the renewable system, Xsm is the percentage of energy sold in the spot market, Xcm is the percentage of energy sold in the contract market, Pcm is the contract market price and Psm is the spot market price.

3.7. Value of environmental benefits (VEB)

Renewable energy sources, which are often (but not always) carbon-free, are among the technology options available to reduce carbon emissions in the electricity sector [7]. Governmental policies regarding environmental protection and emission reductions are amongst others mainly based on the promotion of RET. The VEB can be calculated using two scenarios, the renewable energy certificates and the certified emission reductions scenario.

3.7.1. *Renewable energy certificates (REC)*

In REC, the benefits can be defined as the value of the energy output and the RECs revenue. One REC represents the environmental attributes associated with one MWh of electricity from renewable energy technologies.

3.7.2. Certified emission reductions (CER)

The CER is based on the Clean Development Mechanism of the Kyoto Protocol. The registered CDM project obtains one CER for each 1 ton of CO_2 reduced by the project. Besides, the sale of CERs represents an additional source of project income. However, the development of a CDM project generated extra costs for the project developer, also known as transaction costs. These costs are related to the formalization and validation of the CDM project, as well as the monitoring and verification of the emission reductions.

3.8. Environmental benefits of the reduction of pollutant emissions

With a direct price for emissions—via either an emissions tax or a tradable emissions permit system—the fossil fuel sector has an incentive to lower its emissions rate until the marginal cost of reduction equals the emissions price [8]. In order to have a synthetic index, the score can be expressed through the following qualitative scale of values: (1) very high emissions, when each category is relevant; (2) high emissions, when at least two of the categories are relevant; (3) middle emissions, when at least one category is relevant; (4) low emissions, when all the emissions category are insignificant or do not exist.

3.9. Land requirement

This criterion represents one of the most critical factors for the intervention site, especially where the human activities are relevant factors of environmental pressure. A strong demand for land can also determine economic losses, which are proportional to the specific value of the site and the possible attendant alternative needs. An approximate scale can be as follows: (1) high land requirements and significant landscape alternation that can limit future growth of the area; (2) high land requirements and significant landscape alternation that has no affect on future growth of the area; (3) middle land requirements and landscape alternation; (4) low land requirements and landscape alternation; (5) no land requirements and landscape alternation [9].

3.10. Sustainability according to other environmental impacts

Landscape impact, acoustic emissions, electro-magnetic interferences, bad smells, and microclimatic changes are evaluated. A synthetic judgment can be expressed through the following scale: (1) very high intensity impacts; (2) high intensity impacts; (3) middle intensity impacts; (4) low intensity impacts; (5) not existing impacts. This parameter can be considered highly subjective since it includes impacts such as landscape changes. While large dams and wind farms change the landscape significantly, people might argue whether the change is positive or negative.

3.11. Labor impact

An estimation of labor potentials due to employment of RET can be used. Additional direct and indirect employment and the possible indirect creation of new employment must also be assessed. The following linguistic scale can be used: (1) low employment occurring only at the installation process; (2) low employment that will provide further jobs during the maintenance of the RET; (3) medium employment during installation and maintenance; (4) high employment during installation however low during the maintenance of the RET; (5) high employment both during installation and maintenance.

3.12. The net present value (NPV)

At present, for most of the RET, the investment costs, along with the risks of renewable energy, remain high [10]. The NPV calculation relies on the initial investment, the total accumulated cash-flow and the discount rate. The cash-flows are the costs and the benefits associated to the project. The benefits taken into account are the value of the energy output (VEO) and the value of the environmental benefits (VEB). The following scale is an indication of the investment's profitability. (1) NPV < 0 not a profitable investment; (2) NPV $= 0$ not gain and not loss; (3) NPV > 0 added value [11].

3.13. Distribution cost

Modern small scale generation plants with standardized modular design are competitive, less capital intensive, more efficient, quicker to build and have more sophisticated control technologies for operation and transmission networks. [12]. However, this parameter is highly location correlated and each project case should be examined accordingly. A general linguistic scale can be used: (1) High cost for connection to the grid lowering significantly the NPV; (2) Medium cost for connection to the grid with impact on the NPV; (3) Low cost for connection to the grid with minimal impact on the NPV.

3.14. Compatibility with political, legislative and administrative framework

It is of high importance for governments to realize that RETs with high fixed but low variable costs can provide price stability and a good hedge against the risk of fuel price volatility [13]. Many countries are pursuing greater use of renewables. However, there is little agreement on what policies are most effective in promoting renewables, or even in what it means for a policy to be 'effective.' The goal of RE policy appears simple: to get more renewables in place. However, a closer look reveals that there are in fact many goals that renewables are intended to accomplish. Renewables can be seen as a way to reduce carbon emissions, to promote industrial development, to decrease fossil fuel imports, and meet other policy goals. Each of these goals leads to a different set of programs and technologies. [14]. The examined criterion assesses the qualitative relevance of the above considerations, with regard to government support, the tendency of institutional actors, and the policy of public information. The overall value judgment is expressed in the following way: (1) absent; (2) middle; (3) high.

4. Sampling of Parameter weights using questionnaires

Questionnaires were used in finding an approximation of the weight for each parameter. The questionnaires asked the responders to rate the importance of each parameter from a scale of one to ten. Moreover, the following information was collected from each responder: (a) Educational background; (b) Occupation and position; (c) Familiarity with renewable energy sources. The questionnaires were given to a range of professionals consisting of university lecturers, business consultants, mechanical and electrical engineers, environmental scientists, civil engineers, IT consultants and engineers, researchers, accountants and economists. Questionnaires were not handed to a specific group of responders but rather to a wide range of professionals employed in a wide spectrum of the Cypriot economy. As expected the range of answers varied considerably according to the responders' educational background and familiarity with RET.

4.1. Familiarity of the responders

The familiarity of each responder for RET was also recorded (Fig. 1). The responders were asked to give their subjective judgment on how familiar they are with RET using a scale of one to ten (legend of Fig. 1) where 1 is representing "not familiar at all" and 10 representing "an expert". About 28% of the responders answered that they are somewhat familiar (number six), and only about 1% answered that they considered themselves experts.

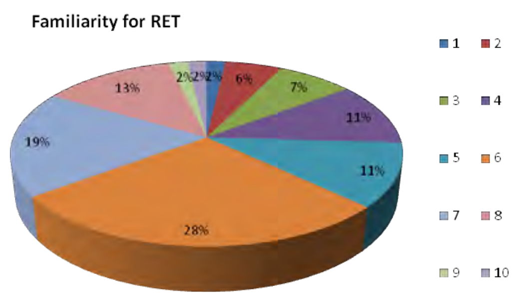

Fig 1. Familiarity of responders for RET

4.2. Responders view

An analysis has been conducted using the responders' view without taking into consideration their knowledge and familiarity as regards the RET. The results (Fig 2) reveal that the highest ranked parameter and in turn the most important one that should carry the highest weight in a multiple criteria decision making model is the "Potential/climatic conditions".

Fig 2. Responders' view

Using the above rankings incorporating the responders' answers for each parameter, we can deduct the weight of each parameter. It is suggested to use the percentage values since it will give a more precise indication of the closeness of each parameter's weight.

Responders' high rank for the "Potential / Climatic conditions" parameter reveals the relation this parameter has on all the other parameters in question. We can say that the effect of this parameter reflects on other parameters such as the value of energy output and in return the "net present value" and the "Value of environmental benefits (VEB)", the market maturity and in return to the local technical know-how for installation and maintenance requirements, the continuity and predictability of performance, land requirement and the compatibility with political, legislative and administrative framework. Though the "Environmental benefits of the reduction of pollutant emissions" is ranked second, parameters that address other environmental issues such as "Sustainability according to other environmental impacts" and "waste treatment" are ranked in much lower positions. The "Value of environmental benefits (VEB)" parameter is ranked third which can be contributed to the fact that the parameter is expressed in monetary terms which is easily translated to direct benefits of the individual investor.

Using the weighted sum method and then multiplying by each rating according to the responder's answer, the final results are better adapted to suit the familiarity with the ratings given. The parameter regarding "Potential / Climatic conditions" is still ranked first indicating its importance in drafting an energy policy regarding the promotion of renewable energy sources. Thus, if we were going to use this parameter in a decision matrix then it should have one of the highest weights. The "Environmental benefits of the reduction of pollutant emissions" is still ranked second and the "Value of environmental benefits" is still on the third position. The change is noticed when accessing the "Continuity and predictability of performance" which is now ranked seventh while VOE is sixth showing a higher importance. The "Local technical know-how for installation and maintenance requirements" is ranked one place higher; this might be due to the fact that the responders with higher familiarity give more emphasis on the technological aspect of RET

5. Conclusions

When assessing the parameters to be used in a Multiple Criteria Decision Making problem, one should define the problem as thoroughly as possible and examine the parameters in detail. In deciding the optimum mix of renewable energy sources to be implemented, a multidimensional approach should be used. Most of the parameters concerning this decision are correlated and an advantage of one alternative in a specific parameter will result in a higher ranking for other alternatives too.

The outcomes rely on a great degree on responder's answers which may lead to misleading results since the answers are subjective. When analyzing the results and viewing the outcomes we can note that the parameters concerned with environmental issues were amongst the higher ranked parameters. However, recycling and reusing in Cyprus is still in its infancy as a practice of the Cypriot citizen. The social desirability bias can lead to wrong rankings of the parameters and to misleading outcomes. The above results however, are a good indication of the parameters rankings and even if we consider that the results are highly affected by the social desirability bias we can view them as an indication of society's point of view on the parameters.

The responders' views reveal great similarities on drafting the weights for the parameters. The differences occur mainly to each responder's familiarity. Familiarity combined with the educational background and occupation can give a more precise inside into each parameter's weight. However, in order to be more precise in the determination of the final weights, the input of all high level officials taking part in the decision making process should be taken into consideration.

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Windpower contribution to sustainable development in Brazil

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Abstract: Global electricity consumption rose exponentially over the last decades powered by fossil fueled thermal power plants. In comparison, Brazil relies on large hydroelectric plants to generate most of its electricity. Nevertheless, the share of thermal electricity generation in Brazil has increased because thermal power can balance the seasonality of the hydroelectric based system and is cost competitive. Regardless its great wind potential, the use of this technology in Brazil is still timid. The country had only 835 MW of installed windpower capacity until November 2010, or 0.75% of its total. An aggressive wind power deployment has been constrained by its cost until recently. However, windpower has potential to act as a complementary energy source to hydropower during dry seasons, and its development could displace thermal power plants. This paper aims to quantify potential greenhouse gas (GHG) emission reductions and jobs creation in three different scenarios of wind energy development up to 2019. In the baseline scenario, windpower will create over 93,000 jobs and reduce up to 96 million tones of CO_2 by 2019. In comparison, a massive windpower deployment scenario, , foresees the reduction of up to 176 million tones of CO2 and the generation of more than 225,000 jobs, most of them in the manufacturing sector. Therefore, wind power is an important alternative for promoting sustainable development in Brazil because it reduces GHG emissions and creates green jobs.

Keywords: *Wind power, Wind industry, Jobs, Sustainable development, Brazil*

1. Introduction

Over the past years concerns on climate change left the scientific and environmental spheres and got strong social and political engagement. The establishment of carbon markets, coupled with international oil price volatility, stimulated a rapid development of renewable energy (RE) generation technologies [1]. RE generation systems are free of harmful emissions and their energy sources are ubiquitous. In comparison to other RE windpower stands out because despite its small share in the global electricity market, it was subject to a rapid growth in recent years [2].

A turning point for windpower development in Brazil was the renewable energy incentive program (Proinfa) of the Ministry of Mines and Energy, established in 2002. However, the high energy costs for wind projects compared to traditional and other renewable energy sources precluded a massive deployment of this energy technology. The realization of dedicated windpower auctions in 2009 and 2010 attracted more projects, making windpower more competitive with traditional fossil fueled power plants.

The Brazilian electricity mix encloses a significant share of hydropower. In 2009, this energy source was responsible for 85% of the total domestic electricity supply [3]. Windpower development in Brazil is unique because in the Northeast region, which contains approximately 50% of the Brazilian wind resource, besides high average wind speeds, its availability complements the hydrologic cycle [4]. Therefore, windpower can be used to match the power loss during the hydropower offseason displacing thermal power plants that are currently balancing the electricity supply [5].

Windpower could contribute in various ways for sustainable development (SD). Developing a clean RE source helps maintaining the low greenhouse gas (GHG) emission factor of the Brazilian grid. Moreover, the establishment of a domestic industry brings in innovation and the development of new indigenous technologies, in addition to new job positions [6], which become relevant as a response to economic crisis and sensible investments in RE must be evaluated according to this yardstick [7].

Nevertheless, the exploitation of the windpower potential depends on long term policies that facilitate the deployment of this RE source. Despite the recent success, the existing medium and long term official energy supply scenarios do not foresee a significant increase in the share of this energy source [8].

The current work aims to evaluate potential benefits and quantify the avoided emissions and the employment generation potential of windpower development in Brazil. Initially we carry on a brief review of the present state-of-the-art of windpower in Latin America (LA) and Brazil. Next, we assess the potential of this RE source in Brazil and we evaluate its contribution to SD and energy security in the country. Finally we compare different scenarios, which are based on official data and a massive windpower development vision.

2. Windpower in Brazil

Forecasts prepared by the Global Wind Energy Council (GWEC) consider LA as a promising windpower market due to its sizeable wind potential and increasing energy needs in the region [2]. In fact, since the beginning of the century, various countries in the region have implemented policies to support the development of RE, including windpower [9]. Over the last years, a timid growth was observed in the share of windpower in LA in comparison to Europe, North America, and Asia. In 2009, the installed capacity in LA doubled from 653 MW to 1,274 MW. However, until August 2010, only two countries were responsible for a significant share of windpower in LA. Brazil and Mexico were responsible for 44% and 29% of the total installed power in the region, respectively [10].

According to a recent GWEC assessment, Brazil has the largest windpower market potential in LA due to its large remaining wind resources, the ability to complement hydropower generation, and the possibility of hosting wind equipment manufacturing plants. Moreover, the country is considered as a future equipment supplier to the region [2].

Although the first wind turbine was installed in Brazil in 1992, in Fernando de Noronha Island [11] the share of windpower in the Brazilian matrix became noticeable only after 2006 with the first Proinfa results. A total of 54 wind projects totaling 1.4 GW of installed capacity were supported by the Program [12], which was instrumental to the expansion of windpower in Brazil. Presently, Proinfa supported facilities are responsible for 95% of the installed windpower capacity in Brazil, or 835 MW up to December 2010 and yet, its contribution corresponds to less than 1% of the total power capacity of the country.

Other milestone that has contributed to the installation of the wind manufacturing industry in the country was the 60% minimum requirement share of domestic equipments in wind projects [13].

Until 2009, the cost of the windpower based electricity was still a barrier to its expansion. The average electricity price of Proinfa projects in 2007 was in the range of $119 to $135 per MWh, depending on the individual capacity factor of each one [14]. Up to this point, windpower was considered unfeasible and not competitive despite the considerable potential that was revealed in the first national assessment at 143 GW [15].

The turning point was due to a conjunction of good policies and global market conditions. In 2009, the first auction fully dedicated to windpower was commissioned. Possibly due to great availability of wind resources in areas with low population density, the variation of the exchange rate, and the economic crisis in 2008-2009, a significant supply of equipment was available and both domestic and international companies were led to invest in the Brazilian market. In August 2010, a second windpower auction took place, along with other RE sources in which, wind energy competed with small hydroelectric plants (SHP) and biomass cogeneration projects. For the first time wind energy prices ($73/MWh) were below other RE prices [16]. Additional 6 GW of windpower projects were enabled to participate in the auction [17], and certainly most of these will be hired in future.

Considering the projects assisted by Proinfa and by the latest auctions, more than 5 GW of windpower will be added to the Brazilian grid by the end of 2013. It is more than the current 0.8 GW but still far away from the total indigenous potential. Currently the country uses around 0.5% of its potential. If windpower electricity trade in dedicated auctions persists, the expansion trend continues and costs decrease over time. In the future windpower could occupy a significant share of electricity generation and complement the current hydro-thermal system.

In comparison to major future hydroelectric projects in the Brazilian Amazon, windpower resources are closer to energy load areas along the coast line (figure 1), and major transmission lines of the national grid [18]. Therefore, transmission costs and losses associated with windpower are smaller than the ones associated with large expected hydroelectric projects.

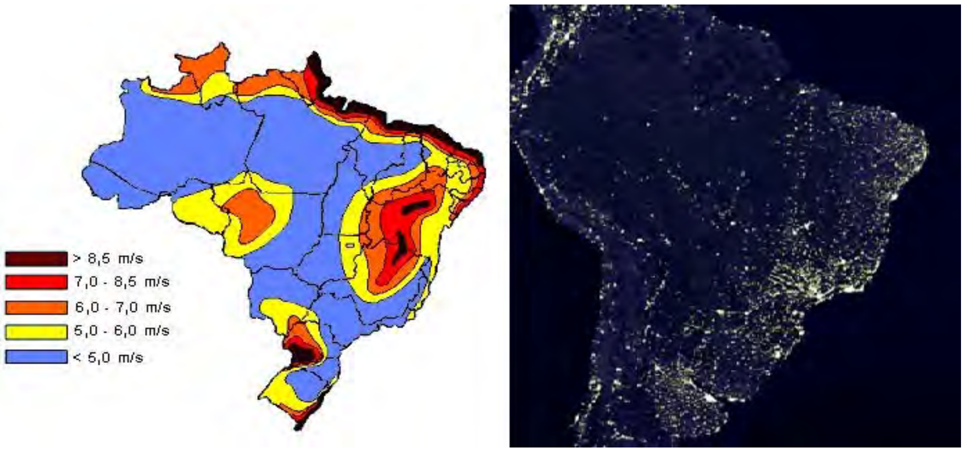

Fig. 1. Wind resources at a 50m height in Brazil [19] and its correlation to urban areas [20]

In summary, windpower that was considered unfeasible just one year ago is nowadays, not only competitive with other alternative energy sources, but also with traditional fossil fueled based electricity generation technologies. The turning point in Brazil was due to a conjunction of good policies and global market conditions. As a result, low impact windpower projects are a real supply option to meet power needs.

2.1. Complementarity between wind energy and hydroelectricity

RE face various difficulties such as high cost and resource intermittency. To increase the performance of RE, diversified complementary sources should be spatially and seasonally combined. Traditionally, thermal generation plants are used to support systems based on renewable sources. In recent years, alternative energy sources have been contemplated for this role [21]. This phenomenon can be observed in Brazil.

The share of renewable sources in the Brazilian energy matrix corresponded to 47% in 2009, well above the world average. Moreover, hydropower comprises 85% of all electricity supply in the country, and additional 5% comes from other RE sources [3]. The hydroelectric system encloses several large reservoirs, capable of multi-year regulation.

Nevertheless, due to environmental concerns, most of the future dams in Amazonia will be run-of-river hydroelectric plants, with lower dams [8], leading to further reliance on climatic conditions. Thus, because wind resource availability in the Northeast of Brazil complements hydrologic regimes, it could lead to optimal use of reservoirs [4]. Indeed, windpower might displace part of the fossil fuel based electricity generation, reducing pollution and maintaining the high share of RE in the Brazilian matrix.

2.2. Economic benefits of windpower deployment

Both climate and RE policies will change the way economies are currently structured. Climate change consequences may negatively affect the economy in most countries, especially the ones in which the contribution of vulnerable sectors, such as agriculture, plays an important role [22].

Investing in a low-carbon economy creates risks and opportunities. On the one hand, a few studies show that in the long run subsides in RE in Germany have led to high costs with few or no benefits to the economy [23,24,25]; on the other hand, most economy-wide studies show positive economic outcomes from investing in low-carbon technologies [7,26,27].

According to Fankhauser et al (2008) [28], the most important benefit from climate and RE policies is innovation, which demands technical change adapted to a new market structure. The quest for new technologies and processes increases the demand for skilled labor, and countries that position themselves as leaders in low-carbon technologies might become key exporters. Over the past few years, Brazil has attracted various wind turbine manufacturers (e.g. Enercon, Impsa, GE), and due to the fast growing market, might become an exporter to other LA countries.

In periods of low economic growth, as the one seen in the financial crisis in 2008-2009, unemployment rates tend to grow, and so does the concern about job loss related to large amount of subsides invested in RE [7]. In fact, employment generation driven by RE promotion has been disputed, especially in the United States [28].

2.2.1. Green Jobs

According to the United Nations Environmental Programme (UNEP), green jobs are work in various activities that contribute to preserving or restoring environmental quality. Most studies reveal that RE is more labor-intensive than fossil fuel-based power generation [27,29,30]. Hence, the substitution of RE for fossil fuels leads to a positive net effect on employment. In Brazil, the creation of new jobs, due to windpower development, should be compared with the creation of jobs due to the development of concurrent alternatives such as hydro.

Nevertheless, based on the available information about green jobs generation, global employment in the RE sector was above 2.3 million in 2006. Brazil is one of the most significant RE employer, with 500,000 jobs on the biomass sector. In contrast, globally, wind energy generated 300,000 jobs up to 2006, and it is expected that employment in this sector will reach 2.1 million in 2030 [22]. Most of these jobs are located in manufacturing, according to the level of domestic production of equipments [30].

3. Methodology

To quantify GHG emissions reductions and job generation in the wind sector, we used a baseline scenario up to 2019, developed by the Ministry of Mines and Energy. Based on that scenario, and the recent growth of the wind energy market in Brazil, we developed two alternative scenarios, one moderate and one optimistic. The scenarios have the following characteristics (Figure 2):

a) Scenario A, or Baseline Scenario, foresees an installed wind capacity of 6 GW by the end of 2019 [8];
b) Scenario B, or Moderate Scenario, estimates a raise of 50% in the installed capacity up to the end of the period, resulting in 9 GW, based on expectations of the Brazilian Wind Energy Association (ABEEolica) of 10 GW in 2020 [31];
c) Scenario C, or Optimistic Scenario, predicts annual hiring of 1.5 GW in exclusive windpower auctions, to be installed from 2013 onwards. By the end of the period, 14 GW of windpower capacity will be commissioned.

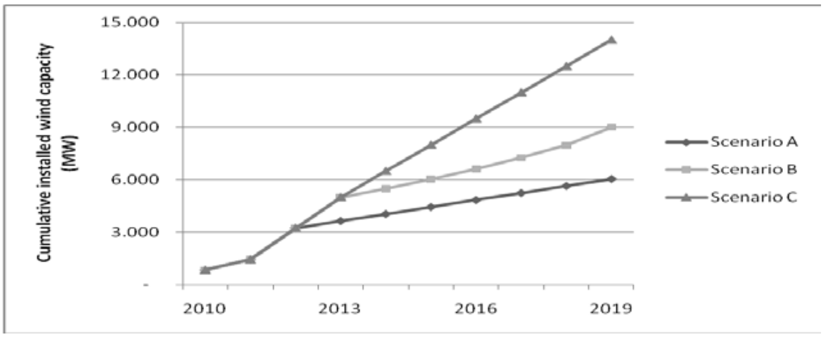

Fig. 2. Installed capacity in the years 2010-2019 in the three proposed scenarios

For estimating job creation, a multiplier provided by the Economical and Social Development Bank (BNDES) which estimates in 15 jobs/MW in manufacturing and construction and 0.4 jobs/MW in operation and maintenance of wind turbines [32]. These figures refer to total jobs, accounting direct and indirect employment over the supply chain.

For estimating potential GHG emission reduction, we considered that windpower displaces fossil fired power plants using natural gas and coal, the main thermal sources foreseen in the long-term national energy plan. Emission factors were taken from the International Energy Agency report, published in 2009 [33]. Emission reductions were estimated over the period between 2011 and 2020.

4. Results

Scenario A results in up to 96 million tons of CO_2 reductions between 2011 and 2020 and yields 93,850 jobs, out of which, 83% are in the manufacturing and installation of wind farms.

Scenario B emission reductions are 34% greater than scenario A, which mitigates up to 129 million tons of CO_2 and generates over 143,000 jobs, 85% in manufacturing and installation.

The most optimistic scenario foresees a reduction up to 176 million tons of CO_2 - 83% higher than in scenario A - and the employment of more than 225,000 people, 87% of them in manufacturing and installation.

According to the Brazilian Inventory of Anthropogenic Emissions and Removals of Greenhouse Gases, published in 2010 by the Ministry of Science and Technology, in 2005 the electricity generation, transmission and distribution emitted about 52 million tons of CO_2 [34]. Scenario A suppressed 28% of the baseline emissions, while the scenario C reduces annual emissions by 65% in 2020.

5. Conclusions

Wind energy is a source experiencing rapid growth worldwide. Following the trend, although timid, windpower market has rapidly developed in Brazil after Proinfa and mainly after the wind dedicated auctions of 2009 and 2010. Further expansion of the industry depends on continued support for RE in the country e.g. frequently auctions plus the inclusion of RE in medium and long term energy expansion plans.

This study shows the potential contributions that a significant expansion of wind capacity during this decade could bring to the country's sustainable development. The use of wind energy as a substitute for fossil-fuel power plants reduces up to 28% GHG annual emissions in the electricity sector in the year 2020, based on the year 2005, in the scenario proposed by the government, while a scenario of intense deployment displaces up to 65% of these emissions.

The development of the wind industry brings several benefits such as innovation and technology transfer, and possibly the emergence of Brazil as a production center for wind equipment in Latin America. Nevertheless the more significant effect is the creation of 93,000 to 226,000 green jobs by 2019.

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Wind Electricity Generation in Three States of India: Policies and Status

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Abstract: Many state governments in India rely on wind energy generation (WEG) to overcome chronic electricity shortages. This paper provides a citizen's view of WEG in India, in the backdrop of (a) the ever-rising national demand for primary energy, (b) the national electricity policy, and (c) wind energy policies in its three highly industrialized states – Tamil Nadu, Maharashtra, and Gujarat. Data from public domain such as the web-sites of government departments is used. Each state has increased its share of WEG with incentives for investment in this sector. The remarkable increase in installed capacity for WEG over the past years has not led to a proportionate increase in the kWh of wind power generated. The unbridled growth in this sector has pitted farmer activists against wind energy companies. A stampede for commissioning large wind farms can potentially destroy local ecosystems through changes in land use patterns. Few studies have been made in India to address such socio-economic concerns. Policies of doling out excessive incentives for MW-scale under-utilized wind farms that feed inefficient grids must be reconsidered. The people of India must receive direct tangible benefits from WEG for it to be a truly clean option of green energy for them.

Keywords: *Government, Policy, Status, Capacity, Utilization*

1. Introduction

Energy-starved India faces many challenges to sustain the remarkable growth in its GDP witnessed over the past decade. The consumption of manufactured products and services has sharply increased with a rise in disposable incomes, and its people expect better living conditions. Ambitious projects are underway to upgrade the nation's infrastructure, to transform India into another economic superpower. To meet these expectations, India's electricity generation capacity must be significantly increased from its current gross value of 164.8 GW [1]. Demand for primary commercial energy, which grew at an average annual rate of 6% during 1981-2001, is expected to grow more rapidly in the future [2].

1.1. Background

Energy policies world-wide are giving an increasing importance to clean sources of energy. A UN-panel has recommended an 85% cut in global greenhouse gas emissions (GHGE) from year-2000 levels to prevent the ill-effects of global warming. India currently produces about $1/4^{th}$ of the world's annual per capita emissions of 4.48 $t{\cdot}CO_2e$ (tonnes of CO_2 equivalent). During the last G-8 Summit, India agreed to work with other major economies in identifying a global goal for reducing GHGE [3]. Critics opine that India has compromised its policy of rejecting legally binding limits on its GHGE, and any caps would affect its future developmental plans. An 85% cut may force India to lower its emissions to < 0.2 $t{\cdot}CO_2e$.

1.1.1. India's energy and electricity demand scenario

With only 0.4% of the globe's proven reserves of crude, India accounts for 2.8% of the world's total oil consumption. To fuel a booming transport sector, 70% of its oil requirements are imported at huge costs to the exchequer. Large imports of LNG too are required to supplement indigenous production. As the numbers of vehicles in India grow, oil and LNG imports will follow suit. Food items and essential commodities became pricier when oil prices peaked in 2008. Unprecedented high inflation levels, attributed by policy makers to oil market economics and India's growth story, have stretched the budgets of many families.

Global petroleum price increases will pose concerns for India as she copes with her apparently insatiable demand for crude oil. Another facet of India's energy concerns is that growing numbers of new vehicle buyers are opting for compact electric vehicles (EV) which can be re-charged easily using a domestic electrical socket, and several manufacturers are catering to this new demand. The road use policy currently requires no license, registration, or taxes for such EV. With improved affordability, many Indians are buying air-conditioners and electrical appliances that were, not long ago, considered items of luxury. As the numbers of EV, TV-sets and washing machines in use grow, enormous demands are placed on India's already scarce power supply. Several Indian cities experience daily power outages, inconveniencing its citizens and many small and medium business enterprises.

1.1.2. National electricity policy (NEP)

India aims to augment its power generation capacity by 100 GW during the 10^{th} (2002-07) and 11^{th} Plan periods (2007-12), besides improving the annual per capita energy availability to 1 MWh [1]. In 2005, a national program was launched to electrify all villages and make electricity accessible to all households by 2012, through a mix of grid-connected, standalone systems and isolated lighting technologies. The NEP also aims to overcome chronic shortages in meeting peak electricity demand, besides ensuring efficient and reliable supply of power of specified standards at affordable prices.

1.1.3. The way forward with renewable energy

India has a large under-exploited potential for hydro-power generation, confined to certain geographical locations. She currently produces limited amounts of atomic energy for civilian use, due to her foreign policy leanings towards nuclear fuel exporting nations. Although the recent (and controversial) Indo-US nuclear agreement assures fuel supplies and reactor equipment, India has far to go before nuclear power overtakes fossil fuel power generation. To eradicate chronic electricity shortages, and compete in a carbon-sensitive global economy, India must go in for decentralized renewable energy (RE) technologies. Decentralization is essential for reducing transmission and distribution (T&D) losses in the existing grid networks. In the present centralized set-up, maintenance shut-downs, grid failures, and strikes impact vast areas of densely-populated India. Decentralization would also promote power production using locally available resources; such as biomass and wind [4].

1.2. Purpose of the study

Several policies have been formulated by successive governments that offer fiscal incentives to the users of RE. Over 25 years ago, India launched a national program for the assessment of her wind resources to promote WEG. As one outcome, 233 sites with an annual average wind power density (WPD) > 200 W/m^2 have been identified thus far. Many such sites are in the industrialized states of Tamil Nadu (TN), Maharashtra (MH) and Gujarat (GJ). Estimates suggest a gross potential of 48.6 GW of wind power for the entire country, with TN (5.5 GW), MH (4.6 GW), and GJ (10.6 GW) among other front-runners in this category [5].

There are many functional, and many more upcoming, WEG projects within India. This study attempts to assess (a) whether the current policies that aggressively promote WEG have yielded any significant addition to the overall power generation scenario, and (b) whether there has been any alleviation in chronic electricity shortages as a consequence. This study is limited to ascertaining the policies for, and status of, WEG in the states of TN, MH, and GJ, which have witnessed a boom in wind energy installations in the past few years. When juxtaposed with other concurrent policies relating to power production and supply, it is hoped that a more holistic view of WEG within India would emerge.

1.3. Methodology of the study

Data has been sourced from the web-sites of central and state agencies involved in WEG, which in most cases tended to be in fair consonance. Reports on electricity shortages, energy policy and WEG in the print media (e.g. national-level newspapers), and reports by reputed non-governmental agencies, have been utilized. Data obtained from web-sites is referenced by mentioning the date of access (DoA).

2. State-wise electricity scenario and wind energy generation

2.1. In Tamil Nadu

Located in peninsular India, TN experiences both the monsoons: south-west and north-east. The state's annual per capita power consumption is nearly 1 MWh. Its major WEG sites are near the *Western Ghats* and (to a small extent) along its coastline. From 1986-93, 120 WEG units totaling 19.4 MW were installed. By 2009, the total installed capacity (IC) for WEG was 4.288 GW, against a gross power generation capacity of 10.214 GW [5, 6].

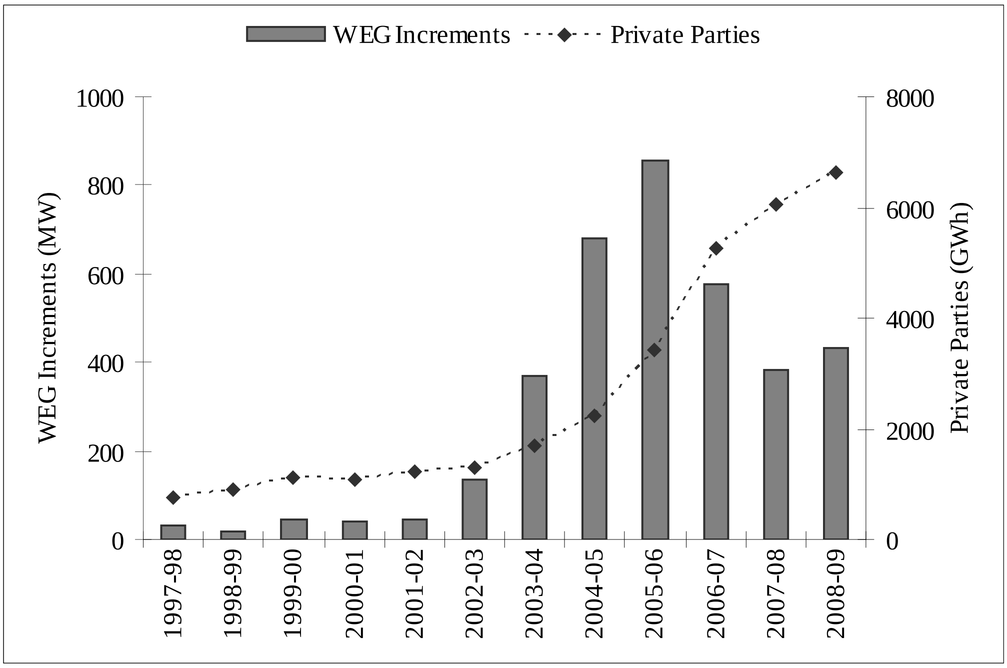

Fig. 1. Increments to WEG, and contributions to WEG by privately-owned units, in Tamil Nadu [6].

The state inducts independent power producers (IPP) into its WEG program. The state electricity board (TNEB) charges the IPP a fee of Rs. 2.575mn (million) per MW installed, plus more if creation and maintenance of T&D facilities by the TNEB is opted for. The IPP have to execute a 15-year power purchase agreement with the TNEB. In 1995-96, the IPP were paid Rs.2.25 per kWh by the state, with a 5% annual increment. Currently, Rs.3.39 is offered based on the recommendations of the state electricity regulatory commission (SERC), in view of the rising capital, interest and maintenance costs. Contributions to WEG from private parties are shown in Fig. 1. In recent years, there is a decline in the augmentation of TN's WEG capacity (see Fig. 1). Saturation of existing sites may be one reason. Investors have also shifted to MH and GJ which offer competitive prices (refer Table 1).

Table 1. State-wise wind electricity generation policies [7].

Policy Item	Tamil Nadu	Maharashtra	Gujarat
(a) Captive use of WEG	Allowed	Allowed	Allowed
(b) Wheeling charge rate	5%	2% + 5% for T&D losses	4%
(c) Buy-back (Rs./kWh)	3.39 (fixed)	Levelized tariff (refer [7])	3.56 (fixed)
(d) Third party sale	Allowed	Allowed	Allowed
(e) Other incentives	None	Off-take facilities, road, loans	Excise exemption

2.1.1. Electricity crisis in Tamil Nadu

Since late-2007, serious electricity shortages plague TN. Over the past decade, the state has pro-actively sanctioned investments into its information technology, automobile and manufacturing sectors, all clustered around its capital city Chennai. Spurred by such policy, demand for electricity has grown every year. It is reported that while the peak demand touched 9.5 GW on some days, the generation was only 6.7 GW [8]. According to industry experts the electricity crisis would continue for another 3-4 years [9]. To tide over shortages, the TNEB formulated policy changes to curtail consumption. A 40% cut imposed in the permitted power consumption by industries effectively crippled operations in many automobile ancillaries, farming and fishing industries all over TN. Textile industries are reportedly worst-hit, with machines requiring a 2-2.5 hour interval after restart to attain their full capacity, each time they are tripped by the erratic power supply. Automobile manufacturers are reported to have diverted their orders elsewhere, instead of sourcing products from within the state [10].

2.1.2. Status of wind electricity generation in Tamil Nadu

Plots of IC and "workable" (available) capacity (WC) for WEG on the 15th day of each month are shown in Fig. 2, based on daily TNEB reports [11].

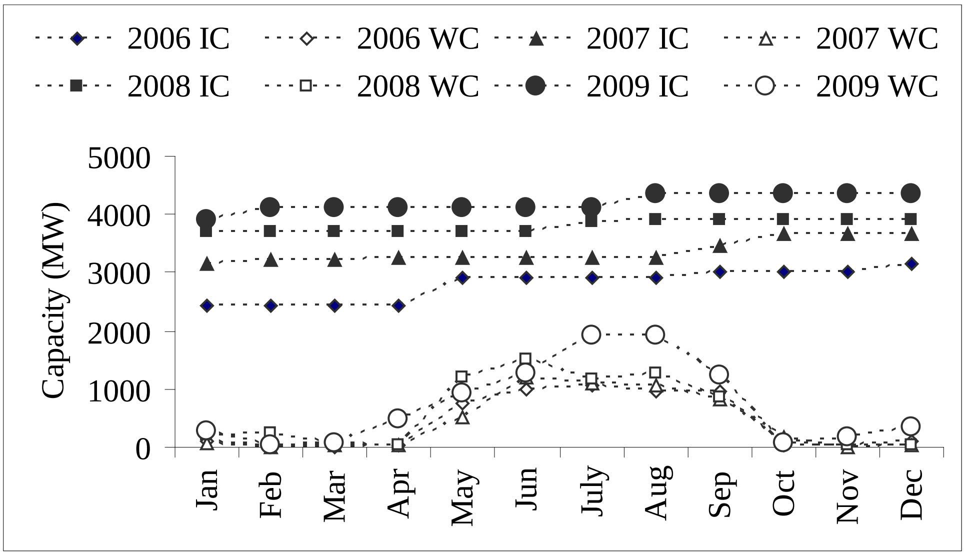

Fig. 2. WEG in Tamil Nadu: Monthly variations in installed and workable capacities [11].

Only one day's data was chosen as being representative for an entire month because several electronic reports were missing or were corrupted. Besides, the number of figures and data being presented here had to be limited. The following can be observed from Fig. 2: (a) From Jan. 2006 to Dec. 2009, there has been an 80% increase in the IC for WEG, and (b) WEG is significantly more during May to Sep., compared to the other months of each year. The May-Sep. averaged generation was 950 MW (in 2006), 942 MW (2007), 1204 MW (2008), and 1451 MW (in 2009). When the above seasonal averages are normalized by the corresponding IC for WEG, the figures reveal that the capacity utilization factor (CUF) was 0.33 (in 2006), 0.29 (2007), 0.32 (2008), and 0.36 (in 2009). Although the IC has substantially increased during 2006-09, the available capacity has remained steady at roughly 33% of the IC, and that too during these five months in a year. During the remaining months, the CUF of the WEG units are extremely small numbers.

One reason for the low utilization could be the wind patterns: if monsoons fail during a particular year, it is the wind conditions that are blamed. But WEG in TN has suffered not just because the winds play truant. Even with favorable winds, only 5.25bn (billion) kWh could be generated, as against a possible 8.25bn kWh. It is claimed that due to inadequate evacuation facilities for wind electricity, losses to the tune of 0.8-0.9 GW arise, and that the TNEB prefers to shed load. In southern TN, out of the IC of 2.21 GW for WEG, only 1.2 GW are generated [12]. Due to the poor off-take policies, wind power producers in TN claim they have lost close to Rs.9bn, and Rs.45bn worth of their investments lie idle. The TNEB counters that the IPP install a unit every six months, but it takes nearly 12 months to build new transmission lines. Connecting remote wind farms to the grid is not easy when the lines have to pass over private lands.

2.2. In Maharashtra and Gujarat

2.2.1. Maharashtra

Within MH, thermal and hydro-power plants having a total IC of almost 10 GW are owned and operated by the state. Nearly 1.8 GW of power is produced by IPP. During the 1990s, the state was embroiled in a dispute over the Enron-Dabhol power project which was supposed to provide nearly 2 GW of gas-based power. That project did not take-off as expected. More recently, MH has faced acute shortages to the extent of 5-6 GW in meeting peak demands. The state has generally had a poor record of managing T&D losses in its electricity networks.

In an effort to showcase the viability of WEG, the state has installed demonstration projects totaling 11.09 MW. These and other favorable policies of the state towards WEG have attracted investments close to Rs.105bn. From a mere 190 MW in 2000-01, nearly 2.1 GW of wind power projects had been set up by 2010 [13]. Many older units of 250 kW operating at 30 m above ground (250 kW, 30 m) were replaced with 1 MW, 50 m units to exploit the higher WPD and realize lower investment costs per MW. Yearly increments to WEG capacity have been declining, though. The state added 545 MW in 2005-06, 485 MW in 2006-07, and 268 MW in 2007-08. It has targeted to add 600 MW to its WEG capacity each year from 2008-09, to achieve a cumulative capacity > 4.1 GW by 2012. A 1 GW wind farm, the largest of its kind, is currently under erection in the state.

To promote wind farm development, the govt. allows the use of state-owned wastelands which are leased out to private developers for 30 years at market rates. For other incentives offered, refer Table 1. But all is not well with wind power projects in MH, as revealed in a status paper which claims that though 1.76 GW of WEG units were installed by 2008, their combined annual generation was only 1.8bn kWh [14]. CUF increased from a mere 8.6% in 2000-01 to 11.7% in 2007-08, after touching 19.2% in 2003-04. That article also points out that investors are not interested in WEG and have merely invested in these facilities to gain from the accelerated depreciation and tax benefits offered by the govt. There have been other independent reports of developers clashing with locals, over issues of land acquisition.

2.2.2. Gujarat

Thermal and hydro-power, are the mainstays for electricity generation in this state. The IC for power generation is 9.6 GW, with nearly 1.5 GW in projects under development. IPP provide close to 3.7 GW. The demand for power is expected to grow to 14 GW by 2011-12. This was one state that was comfortably placed as regards electricity supply [15], but the situation has changed due to coal and LNG shortages [16]. Endowed with a long coastline, GJ receives the south-west monsoon winds almost head-on. The state set up its first WEG demo unit in 1986. Later, more units were installed totaling 16.3 MW. In 1993 the state govt. declared an incentive program inviting private-sector participation, and from 1993-98 investments in WEG boosted the IC to 150 MW. In 2002, the govt. revealed a new policy, and WEG capacity grew by 220 MW till Nov. 2006, reaching 570 MW by Mar. 2007. It is reported that these units generated close to 455mn kWh in 2006-07. In 2007-08, new capacity additions of 616 MW were made and the total IC for WEG rose to 1.2 GW [17]. For the 11th Plan period, the state proposes to add nearly 4 GW of capacity to WEG. The Indian Railways plans to invest Rs.700mn for a 10.5 MW wind farm in the state. Power so generated is proposed to be wheeled away for railway electric traction – an unlikely prospect. Although the state now ranks next only to TN and MH in terms of the IC for WEG, the CUF of the units in operation are a measly 8% [18].

3. Discussion

On one hand, it may be said that the rapid growth in India's WEG sector has been facilitated by several incentive-laden policies which make investments into WEG very attractive for investors. On the other hand, it may be said that when incentives are geared to attract investments rather than improve the utilization of existing WEG units, such projects could become conduits to launder money. A study has alleged a nexus between monopolistic wind turbine makers and cash-rich investors, to avail of the huge (80%) depreciation benefits offered to WEG units during their first year of operation besides tax holidays and a slew of other duty cuts [14]. If this were the case, investors would care less whether the installations have poor CUF, or whether they remain idle. The same report also claims that business dealings in wind energy are opaque, and that the true costs of capital are unclear. Instead of reducing, based on economies of scale, costs of WEG units have reportedly gone up from Rs.40mn to Rs.60mn per MW over the years. Agreements exist to sell wind electricity to grids, third parties, or use for own consumption. Very few records are available in the public domain on how much wind power is actually delivered to the grid. Rules prescribe a certain percentage of wind electricity produced to be supplied to a grid, but enforcement is lax and the miniscule quotas are usually exhausted by other sources of green energy. The SERCs must make daily reporting of WEG mandatory for all IPP and state electricity boards.

Land acquisition for wind farming has affected many vulnerable farmers reeling under repeated crop failures and loans from usurers, and families coping with farmer suicides. There are reports of coercive methods being adopted for land grabbing by middle-men representing wind farm developers [19]. Villagers are promised monetary compensation and other benefits in return, but most promises never materialize and the sellers find their position a lot worse afterwards. Govt. policies must insure that land, instead of being sold, is leased out to wind farm companies and fair market rents are paid to the lessors. Large-scale removal of trees and forest cover to erect wind farms affects the livelihood of villagers dependent on these natural resources. They languish in poverty and darkness with noisy wind turbines for company, and whatever little power the units generate is wheeled away to the cities.

Besides rapid industrialization, other factors contribute significantly to the India's widening electricity deficit. Many political parties in India, at the centre and in the states, have used provision of free electricity for farming as a poll plank. Income from agriculture qualifies for federal income-tax relief too. Such policies have led to write-offs of huge debts owed by farmers to the state electricity boards. The provision of free power for farming has an adverse cascading effect. During droughts, farmers use electricity to pump out ground-water for irrigation. These pumps run endlessly, deplete the ground-water table and increase soil salinity. With power available for free, shortages notwithstanding, farmers neither conserve the precious ground-water nor the electricity. Illegal connections, faulty meters, lax monitoring, and T&D losses allow for gross under-recoveries of electricity consumed. Revenue losses stifle genuine investments in the power sector and promote an indifference towards electricity conservation. In many instances, power is simply wasted when consumers deliberately choose not to switch off. Extravagant lighting for political gatherings, cine-artiste shows, mega-bucks night-time cricket tournaments, etc. has become a routine affair.

Instead of viewing WEG as a panacea for their ailing power sector, Governments could frame policies to award discounts on electricity bills to consumers who (a) reduce their electricity usage, and (b) maintain it thereafter within a certain threshold. Such incentives can be offered with ease since billing is nowadays computerized, allowing for the processing of long-term electricity usage patterns. Governments must implement policies that offer cash discounts for the purchase of CFLs and LEDs for domestic lighting. Such products continue to be prohibitively expensive for many, who opt instead for inefficient incandescent bulbs.

4. Conclusions

Policies for, and status of, wind electricity generation (WEG) in three major states of India are explored. The policies of the various state governments to promote WEG have led to a spree of investments in this sector. But the spectacular increase witnessed in the recent past in the installed capacity for WEG has not necessarily translated into a mitigation of electricity shortages in these states. Existing units face problems relating to under-evacuation and grid integration, and operate with poor capacity utilization factors. Very little credible information exists in the public domain on the actual power delivered by wind farms to the electricity grids, the true costs incurred, and the incomes generated. The liberal incentives offered are possibly being misused by investors for pecuniary benefit. In order to change this situation for the better, governments must revise their relevant wind energy policies to remove loop-holes. Instead of promoting a headlong rush into WEG projects with further sops, govt. policies must reward generation and optimum utilization of the existing units. One way would be to increase and strictly regulate the percentage of wind power supplied to the grids by the IPP, and not to yield to demands for more concessions from the wind energy lobby. Novel applications of wind electricity to suit Indian requirements must be thought of. Instead of MW-scale grid-connected units, smaller-scale solar-assisted decentralized WEG units that can be installed at community levels must be promoted. Electricity so produced can be used to provide metered back-up for residential use, street lighting, or water supply. The use of wind electricity for decentralized applications such as battery-charging, water treatment and purification, and production of compressed air must be explored. WEG must be matched properly with demands of an appropriate kind, in order to maximize the benefits.

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Managing the diffusion and adoption of renewable energy technologies in Nigeria

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Abstract: Increments in the price of oil in 1970s have brought many countries in search of alternative energy sources which will not cause harm to their entire environment as like fossil fuel does. The only available energy source that is capable of providing perhaps without harm to the environment is renewable energy. Renewable energies are important to an energy supply portfolio as they contribute to the world energy supply security, as well as to reducing dependency on the use of fossil fuel. They also contribute to mitigating greenhouse gases. The diffusion and adoption of a new technology such as renewable energy technologies needs the proper understanding of the environment as well as the existing sources of energy in the area. This paper investigates the current status of energy production and the potential of renewable resources in Nigeria. These investigations were carried out by analyzing the available policies and barriers toward the promotion of using renewable energy technologies in Nigeria. These barriers include political issues, environmental issues, technical issues, as well as economic and social issues.

Keywords: *Innovation, Renewable energy, Diffusion and adoption.*

1. Introduction

Nigeria is one of the countries with high potential in energy resources; the country is blessed with both fossil energy resources such as natural gas, coal and crude oil, and renewable energy resources such as biogas, biomass, solar energy and many more.

Energy is claimed to be one of the essential inputs for socio-economic development (Brew-Hammond, 2010). It is then clear that the connection between energy and the millennium development goals (Parcaco and Takada, 2004) make it more necessary to address the issue of energy problem in Nigeria, most especially electricity generation and distribution (Brew-Hammond, 2010; Karekezi, and Majoro, 2002; Modi, 2004; Porcaro and Takada, 2004). Therefore, the provision of a constant power supply is the sign of a developed economy. A nation with unstable power supply risks keeps losing potential investors and development (Okoro and Chikuni, 2007). Nigeria is blessed with natural resources; therefore every Nigerian should have access to electricity. For this to materialize there is only one question which needs a quick answer: how can it become reality? The inability of the Power holding of Nigeria to supply Nigerians with adequate electricity has severely affected many sectors of the economy such as manufacturing industries, mining, agricultural production, and households.

This paper will be looking at (1) the current status of energy production in Nigeria, most especially electricity. The policies promulgated by the energy commission of Nigeria will be reviewed, to see which of these policies are in support of the diffusion and adoption of renewable energy in Nigeria. (2) Potential of renewable energy resources in Nigeria will also be reviewed. Nigeria is a country which is blessed with abundant natural resources which includes renewable energy resources such as biomass, solar, biogas, etc. With all these resources in place, Nigerian still depends heavily on the use of fossil fuel for electricity generation.

2. Genesis of electricity production in Nigeria

Electricity generation in Nigeria dates back to 1896, which was the first time of generating electricity in the city of Lagos with a capacity of 60KW. After the first generation, an arm of the then government was established under the jurisdiction of the public works department (PWD) with the responsibility of electricity supply in Lagos. Later, 1950 a central body called the Electricity Corporation of Nigeria (ECN) was established in order to integrate electricity power development and make it more effective (Okoro and Chikuni, 2007).

In complement the work of Electricity Corporation of Nigeria, a new body called Niger Dam Authority (NDA) in charge of dam construction and maintenance, both on the river Niger and in other places within the country. In 1972, both ECN and NDA were merged to become an entity called National Electric Power Authority (NEPA) (Okoro and Chikuni, 2007). The two organizations were merged in the hope that their merger would result in the improvement of production and distribution of electricity power supply throughout the whole country, which would reduce excessive spending on both organizations; and that it would result in the utilization of available resources such as human, financial and other to the electricity supply throughout the country (Okoro and Chikuni, 2007:52).

The above two bodies then metamorphosed into the National Electric Power Authority (NEPA) which then later transformed into the Power Holding Company of Nigeria (PHCN). The Power Sector Reform Bill was signed into law in March 2005 to enable private companies' participation in electricity generation, transmission, and distribution (Okoro and Chikuni, 2007:52). The bill split PHCN into eleven distribution firms, six generating companies, and a transmission company, all of which will be privatized. The bill is yet to become operational due to opposition from the labour unions.

The Energy Commission of Nigeria (ECN) is the only apex government organ empowered to carry out overall energy sector planning and policy implementation, as well as to promote the diversification of energy resources through the development and optimal utilization of all, including the introduction of new and alternative energy resources like solar, wind, biomass and nuclear energy (The Energy Commission of Nigeria, 2010).

2.1. Position of energy in Nigeria

Nigeria is an energy rich country as stated above, also rich in human resources with a total population of 140.4 million by the 2006 population census, with an annual population growth rate of about 2.8% (Akinbami, Ilori, Oyebisi, Akinwunmi, and Adeoti, 2001). Logically, with all of these abundant energy resources, it is expected that Nigerians should have sufficient and sustainable energy, but the reverse is the case. The national energy use trend reveals a dichotomy between urban and rural households, due to the nature of energy forms consumed in Nigeria, specifically commercial energy such as petroleum products, natural gas, coal, and electricity, and non-commercial or traditional energy, like fuelwood and other biomass.

The Manufacturer Association of Nigeria (MAN) claims that about 60 million Nigerians now own power generating sets for their electricity, using generators of varying sizes with diesel as their sources of fuel, which is not environmentally friendly. The same numbers of people spend a staggering N1.56 trillion ($13.35million) to fuel their generators annually (The Energy Commission of Nigeria, 2010). In his own contribution, Mr. Steven Dimitryer a senior private specialist at the World Bank notes that 'Nigeria experiences the worst electricity crisis among its contemporaries, which underscores the nightmarish generation, distribution and supply in the country' (The Energy Commission of Nigeria, 2010). Electricity is the most important infrastructure bottleneck in Nigeria, most of the industries in Nigeria experience power outage and about 85% of these industries own generators as an alternative source of power generation (ECN, 2010). Presently, about 10% of rural households and 40% of the country's total population have access to electricity in Nigeria (Mbendi.com, 2011).

3. Renewable energy resources in Nigeria

With respect to this paper, the renewable energy sources in Nigeria that will be considered are hydropower, solar energy, wind, and biomass energy.

3.1. Hydropower

Like every other renewable energy source, hydropower has tremendously contributed to the world energy supplies. The current world capacity of hydropower in 2004 was 2810 TWh and is projected to be 4903 TWh by 2030 with growth of 1.8% per year, although the share will still remain at 2% of the world energy supplied (IEA, 2007).

There is high potential for hydroelectricity generation in Nigeria: the current hydropower plants contributed about 29% of electricity generation to the nation total power supply (Aliu and Elegba, 1990; Sambo, 2005), while all the rest is coming from fossil fuels. The resources for hydroelectricity, unlike other types of renewable energy resources, require only a flow of power over a period of time added up to an annual energy (Boyle, 2004). The availability of rivers and natural falls mean that Nigeria has the potential to provide the needed amount of electricity to revitalize the economy. Total hydropower resources potential exploitable in Nigeria is estimated to be 11,000MW (Sambo, 2005).

3.2. Small hydropower

Small hydropower in Nigeria refers to small hydropower generation with a capacity of 1-10 MW. Nigeria is blessed with large rivers along with some natural falls. Nigeria's rivers have the capacity to generate about 11,000 MW of electricity, of which 19% are currently being developed. Existing hydropower plants in the country need rehabilitation due to lack of adequate maintenance (Aliyu and Elegba, 1990; ECN, 2010). There is no standard definition which size of hydropower is small or large, but Table 1 shows classification of ranges of hydropower along with their capacity.

Table 1. Classification of Hydropower Range (adopted from Aliyu and Elegba,1990) .

Range of Hydropower	Capacity of Range (MW)
Large	>100
Medium	15-100
Small	1-15
Mini	0.5-1
Micro	<.05

3.3. Solar energy

Nigeria is a country with abundant solar resources with an annual average daily sunshine of 6.26 hours, ranging between 3.5 hours along the coastal area and about 9.0 hours on the far northern border (Bala, Ojosu, and Umar, 2000). Approximately 5.08 x 1012 KWh of energy can be received in Nigeria per day from the sun with an efficiency of 5%. This amount of energy is able to produce 2.54 x 106 MWh of electricity from solar energy (Sambo, 2005). Solar energy can be utilized in every part of the country, most especially for rural domestic use and for power supply to remote areas where electricity is still not provided.

3.4. Wind energy

Wind is another free gift to the nation. Its intensity depends on the location of the country. Nigeria is situated within a low to moderate wind zone. Windmills were successfully used in the 1960s, especially in the northern part of Nigeria such as Dundaye village in Sokoto State for pumping water from the borehole. They were also used in Garo, near Kano, for supplying water to notable places such as a school, dispensary and to some houses (Anyanwu and Iwuagwu, 1994). All of these old windmills still exist in their different locations, but they are not working any more due to poor maintenance.

3.5. Biomass energy

Resources for biomass in Nigeria can be found in wood, animal waste obtained from agriculture, forestry, municipal and industrial activities and also from aquatic biomass, forage grasses and shrubs. Fuelwood constitutes 37% of the total energy demand in Nigeria. 95% of this fuelwood is consumed by households (Energy Commission of Nigeria, 2005). Figure 1 below indicates the share of fuelwood compared with other types of energy sources.

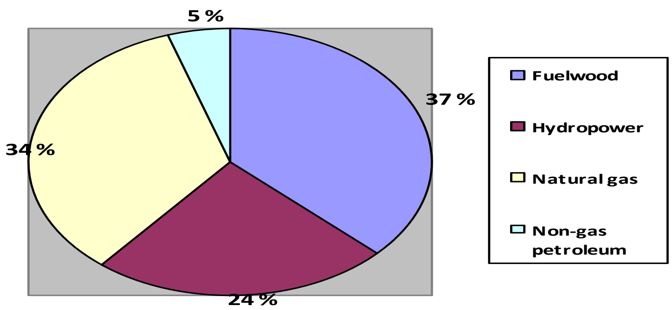

Figure 1. Share of fuelwood compared with other types of energy sources. Data source (ECN, 2005).

3.5.1. Biogas

The amount of waste generated in urban areas alone is capable of generating substantial electricity for the populace within the environment. This waste can be transformed into biogas. Biogas is a mixture of about 60 to 70% methane (CH_4), 23 to 38% carbon dioxide (CO_2), about 2% hydrogen (H_2) and some traces of hydrogen sulphide (H_2S). Biogas is produced by a process known as anaerobic digestion in the absent of oxygen. This gas can be used in cooking and lighting, as well as for agricultural and industrial production.

The use of biogas is fast spreading all over developing nations, particularly in countries like China, Indian, Taiwan, and Philippines (Akinbami et al., 2001). Biogas production units do exist in the sub-Saharan Africa, with a capacity ranging from less than 100 cubic metres to a larger digester of production capacity of greater than 100 cubic metres (Akinbami, et al., 2001).

The use of biogas is not yet pronounced in Nigeria, but some notable work on it is in progress, which is still at the research stage. The current capacity of digesters in Nigeria ranges between 10-20 cubic metres. These are produced by the Sokoto Energy Research Centre (SERC) and use cow dung, human excreta and piggery waste for biogas production (ECN, 2005; Akinbami, 2001).

4. Managing renewable energy technology in Nigeria

The development of a nation's economy is said to be an indication of how well energy is utilized along with the conversion of available energy resources to useful energy technologies

(Sambo, 2005). In order to ensure optimal, adequate, reliable and secure supply of energy to, and its efficient utilization in the country, it is important to put in place a harmonized, articulate and comprehensive energy policy to support the appropriate energy technologies for the country.

Before now, existing policies in the energy sector have been those of the separate energy sub-sector, that is, electricity, oil and gas and solid minerals. There have also been energy-connected policies developed in sub-sectors whose activities are strongly dependent on those in the energy sector. These include transportation, agriculture, science and technology and environment, among others. The sub-sectoral policies, however, reflect the individual sub-sectoral perspectives. ECN, (2003) realized that there is a need to have an integrated energy policy which will guide future energy related sub-sectoral policy developments, in order to avoid policy conflicts which may otherwise arise.

4.1. Nigeria's energy policy and objectives

The overall driving force of the energy policy objectives in Nigeria has been the optimal utilization of the nation's energy resources for sustainable development. These policy objectives and implementation have been carefully defined with the notion that energy is crucial to developmental goals and that government has a prime role in meeting the energy challenges facing the nation, most especially the electricity stumbling block. In addition, the nation's dependence on oil can be reduced through the diversification of the nation's other energy sources, aggressive research, development and demonstration (RD & D), human resources development and many more. Each of the energy sources in Nigeria has its own policy which forms the overall policy of the nation.

4.2. National Policy position toward the diffusion and adoption of renewable energy in Nigeria

Stated below are some of the significant elements in national policy toward diffusion and adoption of renewable energy in Nigeria (ECN, 2003).

i. Harnessing hydropower potential available in country for electricity generation, also paying attention to the development of the mini and micro hydropower schemes.

ii. Exploitation of the hydropower resources in an environmentally sustainable manner and encouraging private sectors and indigenous participation in hydropower development.

iii. Promoting the use of alternative energy sources to fuelwood by developing an appropriate technology to use wood chips rather than the direct use of wood.

iv. Aggressive use and integration of solar energy into the nation's energy will be done, by developing the nation's capability in the utilization of solar energy as well as monitoring worldwide development of solar energy technology. To enable the use of solar energy as complementary energy resources in the rural and urban areas.

v. Developing wind energy resources and integrating them with other energy resources to form a balanced energy mix. It will as well involve taking necessary measures to ensure that wind energy is harnessed at a sustainable cost to both suppliers and consumers in the rural areas.

vi. Developing local capability in wind energy technology and applying it in areas where it is technically and economically feasible.

vii. Harnessing non-fuelwood biomass energy resources and integrating them with other energy resources. Also promoting efficient methods in the use of biomass energy resources.

Increasing the percentage of the contribution of hydro electricity to the total energy mix is yet to be achieved in the country; the survey carried out in harnessing hydropower is yet to be put into effect. Most of the rural areas in the country are still experiencing blackout due to the absence of electricity, while the current hydropower has in one way or the other contributed to ecosystem damage preventing fishermen from getting their daily bread. Furthermore, the maintenance of those available hydro electricity generating plants in the country is far below standard as a result of poor management of the whole system.

About 60% of Nigeria's population is highly dependent on fuelwood for cooking and other domestic uses. The use of fuelwood arises as a result of lack of appropriate cooking methods. This is not limited to the rural environment alone: even people in the urban area use it as well. It is discerned that the rate of fuelwood consumption far exceeds the replenishing rate, which has resulted in environmental setback. Therefore, the use of innovative ways of cooking is urgently needed both in the rural areas and the urban areas in order to curb the results of global warming.

Rogers, (1995:5) defined diffusion as the process by which an innovation is communicated through certain channels over time among the members of a social system. The rate of diffusion and adoption of renewable energy is very low in Nigeria, as a result of heavy dependence on the use of fossil fuel, since the nation's economy solely depends on the exportation of crude oil and gas. Innovation in the Nigeria energy system needs foreign investors to boost her energy sector: Nigeria's position as one of the lowest consumers of electric power per capita in Africa remains a big issue. Figure 2 shows Nigeria consumption of electric power per capita ranking among some selected countries in Africa.

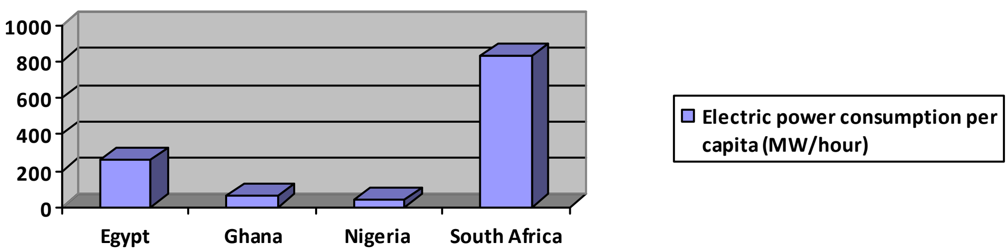

Figure 2. Per capita electric power consumption of some selected countries

4.3. Barriers to diffusion of renewable energy technologies (RETs)

Painuly, (2001:75) argues that there are many barriers 'that have prevented penetration of RETs'; some are discuss below.

4.3.1. Political issues

First and foremost, there should be stability and transparency in the political environment of Nigeria, with the notion of creating a country of a stable political atmosphere which will attract investors. Complete reform of the current policy on electricity generation and distribution should be overhauled to create a fair way for the whole group of stakeholders in the emerging power sectors within and outside Nigeria. Right now, there are some parts of the country which urgently need attention when it comes to investment, such as the Niger Delta area. Establishing viable projects within these areas will not be an easy task, since this region is somehow controlled by the rebels. Other parts of the country with similar political instability issues should be addressed in order to give ways to investors.

4.3.2. Environmental issues

When planning for the type of innovation for diffusion and adoption, the government should consider the environmental impacts of the technology before adoption. Also the area where it will be used should be taken into consideration: for example a community with less people should not be allowed to have a gigantic project unless the community is a supply power for other areas. More so, a city with high level of industrial waste should be denied of having similar project to avoid polluting the city together with the inhabitants. Also the use of heavy duty generator fuel with diesel should be discouraged.

4.3.3. Technical issues

The worst problems facing most of the power plants in Nigeria at present are technical issues. Inadequate maintenance of existing power plants has led to an insufficient electricity supply. There is a lack of standards, codes, and certification. The educational system of the country is too broad and the curriculums are not tailored to the need of the environment at large.

4.3.4. Economic and social issues

It is very appropriate to provide substantial capital for the promotion of renewable energy systems in Nigeria, if the government really wants consumers to have access to electricity that is affordable and available. This capital should have a defined time frame to ensure efficiency improvement in renewable energy technology and the enhancement of the nation's power industries. Therefore, in order to make electricity available to consumer, it will require utilization of the renewable energy resources in the country.

5. Conclusion

Energy is as an essential commodity for nation building, Nigerians deserve a constant supply of electricity. This paper has highlighted the genesis of electricity in Nigeria, as well as the potential of renewable energy in the country. It was identified that about N1.56 trillion ($13.35million) were spent on the fueling of generators as a result of lack of available sustainable electric power to both private and corporate users. Dependence on the use of fossil fuel couple with low per capita consumption of electricity and barriers have a contributed greatly to the low rate of diffusion and adoption of renewable energy technologies in Nigeria

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Shifting the policy paradigm of solar photovoltaic and other renewable energy technologies supply in rural Ghana

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Abstract: Energy, inter alia, other structures, have been sine qua non to socio-economic development, enhancement of rural production and food security, improvements in healthcare and standards of living in human societies. Currently, while energy can help extricate rural societies in the developing world from poverty and augment development, they can only be realised through the implementation of effective energy policy approaches. Employing instruments from both qualitative and quantitative methods to analyse data gathered from two solar PV projects' sites in Ghana as case studies, the paper explores the interface between the policy approaches that have been used for the supply of electricity to rural Ghana, and the energy needs of these rural communities. The paper concludes that, due to the prevalence of poverty among rural societies in Ghana and other parts of the developing world, energisation and not electrification, is the optimal policy paradigm that will underpin rural socio-economic development and the adoption of renewable energy technologies (RETs).

Keywords: *Rural Electrification, Renewable Policy, Energisation*

1. Introduction

The positive interconnectivity between energy and the plenary human development dates back to the beginning of human existence. Energy, inter alia, other structures, have been *sine qua non* to socio-economic development, enhancement of rural production and food security, improvements in healthcare and standards of living in human societies. Unequivocally, therefore, energy has a pivotal role to play in the attainment of the goals of the twined global development paradigms: *sustainable development* and the 'Millennium Development Goals' (MDGs), despite the non-explicit mention of energy in any of the MDGs. The argument is that, communities, both rural and urban, will be well placed to achieve both social and economic prosperity and poverty alleviation once they have access to effective, reliable and affordable modern energy services (The EU Energy Initiative, 2006; Bawakyillenuo, 2009). Conversely, the upshot in the absence of adequate, affordable, reliable and safe modern energy services is stunted socio-economic development - a manifestation of poverty (Department for International Development, 2002). The International Energy Agency (IEA) (2002), corroborated the importance of energy in the socio-economic fabric of rural areas, by outlining the adverse effects of its non-existence: "[the] lack of electricity exacerbates poverty and contributes to its perpetuation, as it precludes most industrial activities and the jobs they create" (p.33). It has been estimated that an additional 700 million people worldwide will need to be provided with reliable and affordable modern energy services by 2015, in order to meet the MDG poverty reduction target (Flavin and Aeck, 2004).

Notwithstanding the importance of energy in fostering development, globally, about 1.6 billion people are without access to modern forms of energy especially, electricity, while 2.4 billion people rely on traditional biomass fuels for their energy needs (DFID, 2002; Flavin and Aeck, 2004; Niez, 2010). Predominantly, these people are found within the rural areas of developing countries especially, Sub-Saharan Africa and South Asia (Duke et al, 2002; Niez, 2010). For instance, more than 83% of Africa's rural population is without electricity, with an incremental figure of 92% in Sub-Saharan Africa (Bawakyillenuo, 2009). In a similar vein, traditional biomass fuels account for about 70-90% of primary energy supply and up to 95% of the total consumption in some African countries (Karekezi, 2002).

The original approach, and still, the dominant in the supply of electricity to rural areas in the developing world, is centralisation, which involves the distribution of power from the grid (Bawakyillenuo, 2009). Almost all Sub-Saharan African countries follow this centralised grid-based strategy in rural electricity supply. An alternative approach, which has been favoured by many individuals, nations and organisations, is the decentralised approach: the usage of decentralised sources of energy generation technologies particularly, 'new' renewables (micro hydropower, solar PV, wind, biofuel, solar thermal electric and geothermal), diesel-engine generator set or hybridisation of any of these energy technologies. The hyper support for the latter approach notably, the utilisation of 'new' renewables, emanates from their environmental benignity, modularity, least-cost advantage on a life-cycle basis compared with grid and diesel generators. Using life-cycle accounting and externalities associated with energy systems as the yardsticks, renewable energy technologies are cost-competitive as well as reliability-competitive with conventional energy sources in many applications including, off-grid electrification with solar photovoltaic (PV), solar photovoltaic pumping (PVP) irrigation systems etc., (IEA-PVPS T9-07, 2003; Flavin and Aeck, 2004).'New' renewables also have the potentials to offset the vulnerability of developing countries to oil price spikes, reduction in both import dependence burden on foreign exchange (Radulovic, 2005; Flavin and Aeck, 2004). However, it is still quite elusive with respect to whether the use of both approaches (centralised and decentralised) in the supply of electricity to rural populations, always have the desired effects on them.

Predicating the argument on analysed data from two solar PV projects' sites in Ghana as case studies, this paper explores the interrelationship between the policy approaches that have been used to supply electricity to rural Ghana, and the energy needs of these rural communities. In particular, it examines the extent to which these policy approaches have helped serve the energy needs of these communities after solar PV and other RETs were incorporated in the Rural Electrification Programme (REP). It concludes with recommendations for the energy policy approaches that could be the panacea to poor rural communities' needs in Ghana and other developing countries.

2. Rural electrification versus energisation – a contextual account

Energy encompasses light, heat, mechanical power and electricity from various sources of fuels - fossil fuels and renewable energy sources (DFID, 2002). The need or desire for energy, therefore, is a 'derived demand' from the demand for varied energy services – cooking, water heating, lighting, refrigeration, water pumping for productivity, transport, communications, etc. Rural electrification and energisation are two different sources providing these energy services.

Rural electrification has been defined diversely. However, the points of divergence are centred on the approaches (centralised, decentralised or both) used in the supply of the electricity. For instance, some observe rural electrification to be the extension of the central grid to rural areas. Conversely, rural electrification has been viewed as the process by which access to electricity is provided to households or villages in isolated or remote parts of a country irrespective of the approach (Niez, 2010). Characteristic of rural electrification in the developing world is the emphasis on lighting service to the exclusion of cardinal services especially, productivity (DFID, 2002). Although lighting enhances off-farm productive activities, on the whole, rural electrification programmes are usually devoid of responding holistically to the energy needs of the rural poor. Many rural electrification programmes are top-down in approach. Often, huge sums of money are spent to extend grid to selected rural areas without any consideration to the availability of adequate generation capacity (Ramakumar, 2007).

The concept of energisation on the hand is very holistic. It embraces electrification, and emphasises on the provision of the composite varied energy services, based on the needs of the rural beneficiary communities. Unlike rural electrification, the central theme of energisation focuses on matching the needs of end-users of energy services with available resources (Ramakumar, 2007). Therefore, notwithstanding the approaches (centralised, decentralised, or both) used to supply energy services to beneficiary communities, the existence of such services are usually fulfilling the expressed energy needs of the communities, hence, will have more support from them. In other words, the delivery of energy services through energisation programme follows the bottom-up approach.

3. Geography, energy perspectives and socio-economic issues of Ghana

Surrounded by Cote D'Ivoire, Burkina Faso, Togo and the Atlantic Ocean, Ghana is between 4^0 and 12^0 degrees north latitude, and longitude 30^0W and 1^0E. The climatic conditions range from warm and relatively dry along the southeast coast, hot and humid in the southwest, and hot and dry in the north. With an approximate population of 22.4 million, coupled with an estimated annual growth rate of 2.7%, 54 and 46 percent are rural and urban respectively (Bawakyillenuo, 2009).

Ghana, abounds with renewable energy resources (hydro, solar, wind, biomass, etc), and has a considerable amount of oil deposit in the off-shore. The country's energy consumption is estimated at 6.6 million tonnes of oil equivalents (TOE) with an estimated per capita consumption at 360 kilograms of oil equivalent (KOE). Traditional fuels constitute 59% of the total consumption, whilst petroleum products and electricity account for 32% and 9% respectively. Though with majority of the population in the rural areas, an inverse relationship exists concerning access to modern sources of energy between the urban and rural areas. About 17% of the total rural population, and only 5% in the rural population of the northern part of the country, have access to electricity, juxtaposing with 77% access in the urban area (Bawakyillenuo, 2009). The lighting and cooking energy services' needs of the rest of 83% are derived from traditional fuels - kerosene, candles, dry cell batteries, oil lamp, etc (ibid). Modern energy services for productive activities especially, cottage industries, irrigation farming, etc., are either non-existent or negligible in these rural areas (Bawakyillenuo, 2007).

In response to the Economic Recovery Programme (ERP) of the 1980s, the Government of Ghana instituted the National Electrification Scheme (NES) in 1989 principally, as the tool for the extension of the grid to the nooks and cranny of the country, especially all district capitals, towns and villages exceeding 500 inhabitants, over a thirty-year period (1990-2020) (Abavana, 2004). The Self-Help Electrification Project (SHEP) was later initiated to complement NES: it makes provisions for communities within 20km radius of existing 33 KV or 11 KV sub-transmission line to speed up their electrification projects, once they secure all poles for the low voltage network with 30% of houses wired. In 2001, the Government of Ghana mainstreamed solar PV and other renewable energy technologies in the REP.

With respect to the economy, Ghana has approximately twice the per capita output of poorer West African countries, with an estimated per capita GDP at $2,600 in 2006 (CIA World Factbook - Ghana, 2007). Agriculture (farming, rearing and fishing) is the mainstay of the economy, accounting for 37.3% of GDP (2006) and 60% workforce; followed by the service sector with 25% workforce; and industry – 15% percent (ibid). The rural economies within the three belts of the country (coastal, middle and northern) are fundamentally based on rain-fed agriculture, 90% of which is peasant-based. In the coastal belt, fishing is the main occupation followed by livestock rearing; in the middle belt with bimodal rainfall regime, crop farming predominates, followed by livestock rearing and fishing; and in the northern belt with a unimodal rainfall regime, crop farming and livestock rearing are the main economic activities. The northern belt (the two solar projects' zone) is frequently subjected to poor yields and food shortages, because of the single rainfall regime, climate variability and lack of facilities to undertake complementary farming activities in the dry season. Though richer than other poorer West African nations, poverty is still pervasive in the rural areas of Ghana, since rain-fed agriculture is the main occupation. Incidence of poverty is quite acute in the rural areas, accounting for 84% of Ghana's poor – the northern belt ranks the highest in poverty.

4. Wechiau and Bunkpurugu/Yunyoo's PV solar household system (SHS) projects

The two case studies were carried out through field survey in 2005 by the author as part of his PhD thesis' fieldwork. The projects are the Government of Ghana/Spanish Government off-grid solar PV rural electrification project in Wechiau in Wa West District (1998) and the UNDP/GEF/Ghana Government Renewable Energy Service Project (RESPRO) in Bunkpurugu/Yunyoo District in 1999. The goal of the Wechiau project was to assess the social, economic and technical performance of solar PV as an instrument for rural electrification in off-grid communities. The project comprised of a battery centre and PV/SHSs, with the implementing body being the Ministry of Energy (MOE). The financing mechanism used to supply the PV/SHSs to customers was the fee-for service. While customers paid a flat installation fee of ¢100,000 cedis (US$ 13.92), users of both the 50Wp and 100Wp modules paid ¢15,000 (US$2.09) and ¢25,000 (US$3.48) monthly tariffs respectively. The Wechiau project was managed by two formal indigenous groups after its implementation (i.e. operators of the battery charging centre and a solar committee) with different responsibilities. Operators of the battery charging centre were tasked with charging of batteries commercially, passing the fees charged onto the solar committee, and undertaking basic servicing of the installed PV/SHS. The solar committee on the other hand, was to collect the monthly tariff from the users on behalf of the MOE and deposit it at the bank.

Implemented from 1999 to 2004, the main aim of RESPRO was to initiate the development of a commercial market for renewable-based electricity services in rural Ghana, with an initial emphasis on PV/SHS. An individual customer could apply for one of two PV/SHSs, 50Wp and 100Wp. Because the main market model was the fee-for-service, customers paid a ¢250,000 (US$34.86) installation fee and ¢90,000 (US$12.55) six months advanced tariff for 50Wp SHSs before installation was carried out. On the other hand, customers wanting 100Wp SHSs paid a ¢500,000 (US$69.72) installation fee and 150,000 (US$20.91) six months advanced tariff. Six months after installation, customers began paying monthly tariffs - ¢15,000 (US$2.09) for a 50Wp system and ¢25,000 (US$3.48) for a 100Wp system. A default in paying the tariff for three months resulted in the removal of the system. RESPRO was implemented by a subsidiary unit of the MOE, which was formed through the secondment of some of its personnel. Personnel included a national co-ordinator in Accra, two engineers and six field technicians, who were responsible for the installation and maintenance of the solar PV systems.

5. Methodology

Data for this paper were gathered using, documentary gathering of energy policy literature of Ghana; formal and informal interviews with three PV technicians who worked on the two PV/SHS projects, three officials at the Ghana's energy ministry; the administering of households questionnaires to twenty PV/SHS users, twenty non-PV/SHS users and four cottage industrialists. Of particular importance were the incorporation of the Likert scale of measurement and a weighting system based on ranked choices, in the questionnaires. In the application of the Likert scale, respondents indicated the strength of agreement or disagreement on series of statements. In the case of the weighting system, a defined ranking scale (1, being the least, and 10, the maximum) was used, and respondents were asked to indicate their preferences/choices on a set of energy related issues having recourse to this scale. As a result, the total responses for a particular choice are multiplied by its position in a descending order, and the weights are then summed up to reveal the relativity in choices. The various themes addressed in the questionnaires were: the socio-economic features of PV/SHS adopters and non-adopters, sources of the various energy services in the rural areas, factors underpinning the adoption and non-adoption of PV/SHS, knowledge on energy policy, etc. Content analysis, Statistical Package for Social Scientists (SPSS) and Excel were the analytical tools. A limitation of this paper is the small sample size. However, this is catered for, as emphasis is on policy analysis and not statistical significance or econometric analysis.

6. Results

Results of the processed data are presented in the below figure and tables. Also, manifest in the results are the following associated features of the two PV/SHS projects: most of the rural dwellers did not adopt the PV/SHSs; withdrawal of qualified technicians after the projects' implementation phases; malfunction of majority of the installed PV/SHSs; lack of maintenance services after the projects' implementation phases.

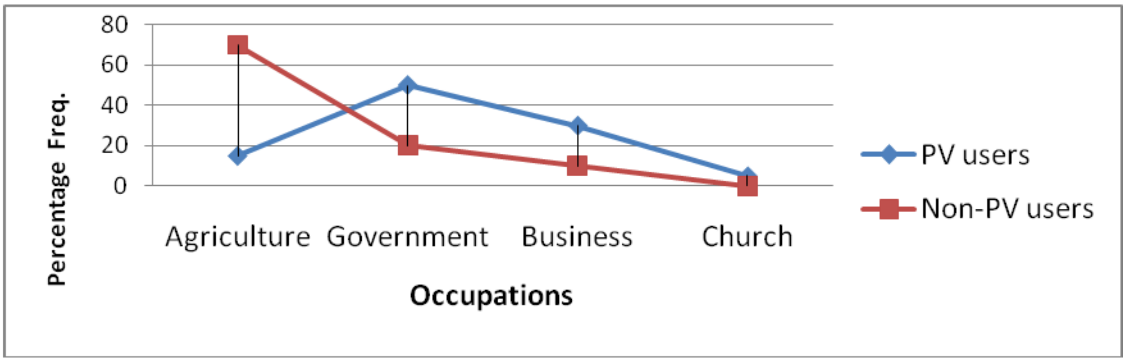

Fig. 1. Occupations of respondents (40) with and without PV/SHS at the two case study areas

Table 1. Main uses of PV/SHS by beneficiaries (20) in the two case study areas

Uses	Frequency	Percent
Lighting	20	100
Entertainment	15	75
Business	4	20
Cooking	0	0
Education	7	35
Agriculture	0	0

Table 2. Reasons for the non-adoption of PV/SHS by non-users (20) in the two case study areas

Reasons	Number	Percent
Expensive	20	100
Prefers grid	12	60
Inaccessible	10	50
Lack of PV know-how	9	45
Unreliable	8	40

Table 3. Relative importance of various energy services to PV/SHS users and non-users

	Lighting		Agriculture (irrigation)		Cooking		Entertainment		Cottage industry	
Ranking (1...5)	PV users	Non users	PV users	Non users	PV users	Non users	PV users	Non users	PV users	Non users
Very important	9	2	2	10	5	5	7	2	2	6
Important	6	4	2	6	5	7	5	2	3	4
Somewhat important	3	5	3	3	4	5	5	0	4	4
Less important	2	5	4	1	3	1	3	6	6	4
Least important	0	4	9	0	3	2	0	10	5	2
Weighted score	82	55	44	84	66	72	76	40	51	68

Succinct explanation to the survey results in the figure and tables above is advanced. Figure 1, reveals the lopsidedness of the occupational characteristics between PV/SHS adopters and non-adopters: agriculture forming the main occupation of majority of non-adopters of PV/SHS and vice versa; and government work (civil service), the main occupation of majority of PV/SHS adopters and vice versa. The most important services from PV/SHS according to beneficiaries are lighting and entertainment (Table 1), while uses for agriculture are non-existent. Non-adopters of PV/SHS see cost, preference for grid and inaccessibility to PV/SHS as the main reasons for their non-adoption of PV/SHS (Table 2). Table 3, also depicts a very disparate rankings between users and non-users of PV/SHS. Lighting, followed by entertainment, dominate the weighted scores by PV/SHS users, with agriculture the least. Inversely, agriculture, followed by cooking and cottage industry are the highest weighted scores by non-adopters of PV/SHS, with entertainment the least.

7. Discussion and conclusion

Critical analysis of the survey results, the socio-economic attributes of the rural people in Ghana and the energy perspectives of the country in tandem, raise key interrelated issues: accessibility to, and affordability of modern energy services by rural people; and the congruity/incongruity of Ghana's energy policy direction with the needs of the rural people.

7.1 Accessibility and affordability

Conjointly, accessibility and affordability are some of the key issues that emerged from the analysis of data for this paper. As indicated in the results section, a key feature of the case studies is that, most inhabitants in the PV/SHS projects' communities did not adopt the technology - a phenomenon that intertwines with accessibility and affordability etc. Accessibility dimension is particularly depicted in Table 2, whereby 10 out of the 20 non-users of PV indicated inaccessibility as one of the reasons for their non-adoption of the technology. Six people out of the 10 that indicated inaccessibility were civil servants and business people, who could not adopt the solar PV/SHS before the projects ended. Notwithstanding the social group that pointed out inaccessibility as the hindrance, poor access to modern energy services is profound in rural Ghana as well as most rural societies in the developing world (Bawakyillenuo, 2009). With respect to the affordability trajectory, Table 2 reveals that cost (expensiveness) is a key factor to the non-use of PV/SHS, while Figure 1 depicts the occupation of majority of these non-users to be agriculture. The lack of affordability of PV/SHS by these non-users is highly correlated with the features of their occupation – rain-fed agriculture, which creates abject poverty among them (see section 3). Enhancing their affordability level can only be made possible by an increase in their incomes, hence, the need for concrete policies on productivity as well as financing. For example, it has been noted that 50 percent of rural households in the developing world will still be unable to afford solar PV even with the use of credit and fee-for-service financing models (Bawakyillenuo, 2007, citing Jacobson, 2004).

7.2 Ghana's energy policy direction vis-à-vis the needs of rural communities

Analysis of the energy policy documents and survey results reveal the unidirectional nature of the energy policy of Ghana in general, as well as on 'new' renewables. Emphasis on these technologies, especially PV (the only renewable technology in application in Ghana), is electrification. The onset of PV utilisation was premised on the fact it was virtually impossible to electrify certain islands on the Volta Lake and remote areas via the grid (Abavana, 2004). The uni-focus nature of policy towards these 'new' renewables is buttressed by the main uses of PV/SHS by beneficiaries in the two study areas (Table 1). While lighting and entertainment services predominate the uses, direct application of motive power from PV for agricultural purposes are non-existent. This policy slant on 'new' renewables on the one hand, and the survey results in Table 3 on the other hand, bring out the incongruity between the policy and the energy needs of rural dwellers. The non-users of PV/SHS, who are predominantly peasant farmers, and riddled with poverty, place more value on energy services that will boost agriculture, cooking and cottage industry. Arguably, such energy services have the overall impact of increasing income levels. The choices by PV/SHS users (who are the middle class and the minority in the rural areas), however, contrast with those of the non-users. The choices of PV/SHS users are not far-fetched because, their occupations can afford them certain amount of disposable incomes, which are enough to propel them up the rungs of the energy ladder (i.e. the desertion of the application of kerosene and dry cells to the utilisation of electricity from modern energy technologies). It is an established fact that, higher incomes enhance the ability to afford more energy (DFID, 2002).

The flagship outcome of this paper is that, the focus of energy policy in Ghana, even with the incorporation of RETs is that of electrification (lighting) – a faltered policy strategy, because it does not address the composite and core energy services needs of poor rural communities. Electricity is not always the most appropriate form of energy services to the poor (DFID, 2002). Irrespective of numerous solutions advanced by scholars and organisations for the expansive dissemination of RETs especially, PV in rural areas of developing countries, findings of this paper affirm that their slow adoption process and sustainability boil down to the disregard for appropriate policies measures. Effective policy structures act as stimulants to PV/SHS dissemination (Bawakyillenuo, 2009).

As a result of the prevalence of poverty among rural societies in Ghana, and for that matter the developing world, energisation is the optimal policy trajectory for these areas. Through this policy approach, energy services needs of various social and income groups are met via the conduction of needs assessment in a 'bottom-up'' approach, rather than a 'top-down' (a common element with electrification). Thus, two alternatives for parties interested in clean lighting services will be available – PV/SHS and solar lantern; the former, more costly than the latter. But, also available is PVP or hybrid of wind pump/PVP for productivity (irrigation agriculture, cottage enterprises, etc), to individuals and groups wanting to augment their production. These energy services that are geared towards productivity are the bedrock to extricating rural people from poverty. The reasoning is that, the application of such productive energy services can create a virtuous growth cycle among poor rural societies; and this cycle will in turn motivate them to crave for other energy services such as lighting, entertainment, education, etc. In other words, the application of energy services for production (irrigation and other cottage industries) can increase incomes, and the ripple effect of such an increase is the ability to afford other modern energy services.

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Measures to Promote Adoption of Residential Photovoltaic Systems

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Abstract: The purpose of this paper is to clarify the effects of a combination of electricity rates, the price of the electricity generated with a photovoltaic (PV) system, and a subsidy when a government aims at achieving a certain level of PV-system adoption. A microeconomic model based on classical demand theory is made. The case is mainly analyzed where the amount of PV-generated electricity is different from household to household while the amounts of electricity consumption and budget as well as utility functions are identical. Other cases are also mentioned. It is shown that a household prefers a higher PV-generated electricity price with a higher electricity rate to a higher subsidy if any one of the following conditions is satisfied with other things being equal: (1) it will have a relatively large amount of PV-generated electricity if it installs; (2) it has a relatively large amount of budget; or (3) it has a relatively small amount of electricity consumption. Furthermore, other things being equal, the difference in utility functions has no effect on the preference. This suggests, though the mixed effects of these conditions are not examined, that a combination optimal for a household does not always optimal for another.

Keywords: *Residential Photovoltaic System, Feed-in tariff, Subsidy*

1. Introduction

There will be several measures to promote adoption of residential photovoltaic (PV) systems. One is that a government subsidizes a household to install the system. Another one is that the electricity generated by a PV system is purchased by an electric utility. Moreover, the retail rate of electricity will influence a household's economic situation and affect the decision to install the system. Accordingly, three parameters, an electricity rate, a price at which the PV-generated electricity is purchased by a utility, and a subsidy for installation, play a role in increasing the number of system-installed households. A government generally has control over these parameters. The purpose of this study is to obtain information available when a government sets them.

Most of existing studies addressing relevant issues are empirical or simulation ones calculating the value of PV systems or a break-even point, a combination of the parameters that makes it pay a household to install the system. For example, Mills et al. (2008) examine empirically the impact of electricity rate design on the economic value of PV systems for commercial customers in California. Carley (2009) shows using a two-part probit model that interconnection standards and RPS policies significantly increase the likelihood that a customer will adopt distributed generation capacity in the U.S. Rigter et al. (2010) determine the cost of PV system and obtain the optimal feed-in tariff by net present value analysis with Chinese data. Black (2004) shows that PV system installation is financially feasible under government incentives, net metering, high electricity rates, and other conditions in terms of rate of return, increase in property value, and cash flow.

These studies show the three parameters play an important role but do not deal with interrelations among them explicitly. This paper aims at filling this gap. I employ a different approach based on classical demand theory, in which consumers make decisions about purchases of goods by maximizing utility subject to budget constraints. Interestingly, to the best of my knowledge, the problem has not been investigated this way. I make a microeconomic model, examine efficient combinations of the parameters when a government intends to make a given number of households install the system, and analyze the payoffs of the relevant parties such as system-installed households, no-system households, and an electric utility.

I identify the locus of an electricity rate, a PV-generated electricity price, and a subsidy on which a government can make a given number of households install the system. The utility levels of a system-installed household and a no-system household are calculated and the utility maximization point for each household is identified. This will make some contribution to the discussion on how the electricity rate, the PV-generated electricity price, and the subsidy should be set from an equity point of view.

2. Methodology

A microeconomic model is set up. Since rational consumers will optimize decisions on purchasing PV systems based on their usual lifespan of 10-20 years, all quantities and monetary values employed in the model are set forth in terms of a fixed system lifespan.

Consider N households with a market consisting of three goods: electricity, PV systems, and a composite of conventional goods. N is sufficiently large. The government has a target of installed systems in n of N households.

Since the price elasticity of demand for electricity may be very low, we assume that if electricity rates change, household electricity consumption, x, will remain constant. Each installed PV system produces e units of electricity. It is assumed that $x > e$.

All monetary value is normalized without loss of generality such that the price of the composite good is 1. The price of a PV system, which includes the prices of PV generation equipment and installation, is denoted by K and is constant.

In the model, a single electric utility, a government-regulated monopoly, supplies electricity to all households. Electricity rates may therefore be understood to be set by the government. For analytical simplicity, we assume the electricity rate to be a single, variable rate. Let c represent the cost of generating a unit of electricity for the electric utility. Suppose the conventional electricity rate is set at c.

Let y represent the budget of a household. The sum of the budgets of all households is denoted by Y. Funds for the subsidy are raised by taxation. It is assumed that a household must pay a tax according to its income, that is, the budget. Let S be a subsidy for a household with an installed system. Then the tax rate for each household should be nS/Y.

Let the quantities of PV systems and composite goods purchased by a household be denoted by q_1 and q_2, respectively, with q_1 taking one of two values, 0 (no PV system installed) or 1 (PV system installed). Let the utility function be denoted by $u(q_1, q_2)$. We exclude utility obtained from electricity consumption. A household can do without a PV system since it can purchase all the electricity it consumes from the electric utility. Hence, it is plausible that the installation of a PV system can be valued in terms of finite quantities of the composite good. Thus, we define a function $v(q_2)$ such that the utility level at point $(0, q_2)$ is equal to that at point $(1, q_2 - v(q_2))$ on the r-p plane, i.e., $u(0, q_2) = u(1, q_2 - v(q_2))$. In other words, function $v(q_2)$ indicates the opportunity cost of installing the system in terms of the quantity of the composite good. It is reasonable to assume that $v(q_2)$ should satisfy $0 \le v(q_2) \le q_2$. $v(q_2)$ is twice differentiable and that it holds that $0 < v'(q_2) < 1$ and $v''(q_2) < 0$. This implies that the larger the budget of a household, the higher the value of a PV system to that household, but the smaller the incremental value.

3. Results

There are many variables to be considered, *e*, *x* and *y* as well as $u(q_1, q_2)$ and $v(q_2)$. It is difficult to deal with them simultaneously, so we focus on *e* in subsection 3.1 and then mention how to deal with the other variables in subsection 3.2.

3.1. Different amounts of PV-generated electricity

Suppose that household *i*'s amount of PV-generated electricity is e_i. It is assumed that $e_i > e_j$ for all *i* and *j* such that $i < j$. It holds $N > \sum_n e_i / e_n$ since *N* is sufficiently large. It is assumed that for any household *i*, $v(y - cx) < K - ce_i$ and $v(y - r_0 x) \geq K - r_0 e_i$ for some sufficiently large r_0. The meaning of this assumption, as shall become clear, is that if the electricity rate and PV-generated electricity price are both *c* when $S = 0$, no household will install PV systems, and that if both are r_0, all households will install systems.

The budget of household *i* increases practically from $(1 - nS/Y)y - rx$ to $(1 - nS/Y)y - rx + S + pe_i$ if it installs a PV system. This is equivalent to the situation in which the budget remains at the same level $(1 - nS/Y)y - rx$ while the price of PV systems decreases by $S + pe_i$. Hence, the budget constraint of household *i* is $(K - S - pe_i)q_1 + q_2 \leq (1 - nS/Y)y - rx$.

Since households maximize utility subject to the budget constraint, household *i* installs the system if $v((1 - nS/Y)y - rx) \geq K - S - pe_i$ and does not if $v((1 - nS/Y)y - rx) < K - S - pe_i$. Therefore, the necessary and sufficient condition for exactly *n* households to install the system is that the two inequalities $v((1 - nS/Y)y - rx) \geq K - S - pe_n$ and $v((1 - nS/Y)y - rx) < K - S - pe_{n+1}$ hold simultaneously. It will be shown step by step that there exists a combination (r, p, S) that satisfies the following equation:

$$v\left(\left(1 - \frac{nS}{Y}\right)y - rx\right) = K - S - pe_n . \tag{1}$$

Eq. (1) guarantees that exactly *n* households install the system.

3.1.1. Controls of price and rates

We first analyze a special case, where $S = 0$. Let us make the arguable assumption that as the electricity rate rises, it becomes more favorable for a household to install a system and generate electricity itself, rather than purchase it if the PV-generated electricity is purchased at the electricity rate. In other words, it holds that $v(y - rx) - (K - re_i)$ is increasing in *r*, i.e., $xv'(y - rx) < e_i$.

Lemma 1. There exist r_1 and p_1 that uniquely satisfy Eqs. (2) and (3), respectively.

$$v(y - r_1 x) = K - r_1 e_n , \tag{2}$$

$$v(y - cx) = K - p_1 e_n . \tag{3}$$

Proof. These are shown from the assumptions $v(y-cx) < K - ce_i$, $xv'(y-rx) < e_i$, and $v(y-r_0x) \geq K - r_0e_i$.

Suppose the government chooses the lowest *r* for any *p* or the lowest *p* for any *r* to make exactly *n* households install systems.

Lemma 2. The *r* and *p* set by the government must satisfy the following equation:

$$v(y-rx) = K - pe_n \ . \tag{4}$$

Proof. The curve defined by Eq. (4) on the *r*-*p* plane connects points (c, p_1) and (r_1, r_1), and is strictly upward-sloping (Fig. 1). Hence, there exists a unique solution *r* for any *p* that satisfies Eq. (4), and vice versa. A point on the curve represents the lowest *r* for any *p* or the lowest *p* for any *r* that satisfies the two inequalities.

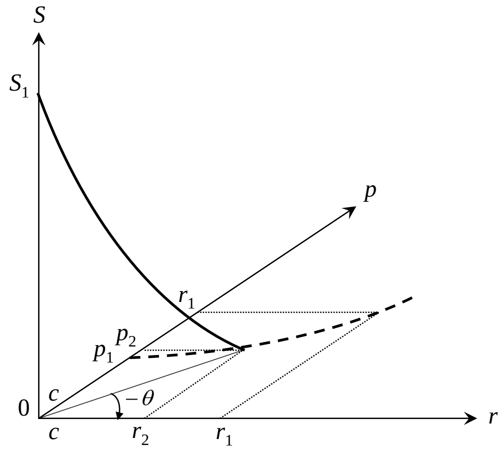

Fig. 1. The curves guaranteeing that exactly n households install the PV system in the r-p-S space. The dashed curve corresponds to the case where there is no subsidy. The solid curve corresponds to the case where a subsidy is introduced with the electric utility being compensated for the costs of purchasing PV-generated electricity.

The utility levels of system-installed household *i* and a no-system household, and the profit of the electric utility, are as follows, respectively:

$$u(1, y - rx - (K - pe_i)) \ \ (i = 1, \cdots, n), \tag{5}$$

$$u(0, y - rx), \tag{6}$$

$$(r-c)Nx - (p-c)\textstyle\sum_n e_i \ . \tag{7}$$

The government may make its decisions in determining *r* and *p* that the electric utility should be compensated for the costs of purchasing PV-generated electricity. Namely, the profit of the utility (7) is set at zero:

$$(r-c)Nx - (p-c)\textstyle\sum_n e_i = 0 \ . \tag{8}$$

This forms a straight line containing point (c,c) on the *r*-*p* plane. Solving simultaneous equations (4) and (8) for *r* and *p* we obtain the solution (r_2, p_2) shown in Fig. 1.

3.1.2. Controls of subsidy for households

Next we analyze another special case, where $r = p = c$.

Lemma 4. There exists a unique solution, S_1, that satisfies Eq. (1) when $r = p = c$. The government chooses S_1.

Proof. $v((1-nS/Y)y - cx) - (K - S - ce_n)$ is strictly increasing in *S*, and negative if $S = 0$ and positive if $S = (r_0 - c)Yx/(ny_n)$. Therefore, there exists a unique solution S_1.

3.1.3. Controls of price, rates, and subsidy

Now we return to a general case. Suppose that the electric utility is compensated for the costs of purchasing PV-generated electricity, that is, Eq. (8) holds.

Proposition 1. The curve defined by simultaneous Eqs. (1) and (8) is convex and connects points $(r_2, p_2, 0)$ and (c, c, S_1) in the *r*-*p*-*S* space (Fig. 1). The government chooses the *r*, *p*, and *S* on the curve.

Proof. See Appendix 1.

The utility levels of system-installed household *i* and a no-system household are as follows, respectively:

$$u\left(1, \left(1 - \frac{nS}{Y}\right)y - rx - (K - S - pe_i)\right) \quad (i = 1, \cdots, n), \tag{9}$$

$$u\left(0, \left(1 - \frac{nS}{Y}\right)y - rx\right). \tag{10}$$

The combination (r, p, S) that maximizes the utility of each household is obtained by maximizing the quantity of q_2 subject to simultaneous Eqs. (1) and (8). Let us investigate such a combination.

Proposition 2. For system-installed household *i*, the optimal combination is $(r_2, p_2, 0)$ if $e_i \geq \sum_n e_i / n$. Specifically, the optimal combination is $(r_2, p_2, 0)$ for household 1. On the other hand, for system-installed household *n* and no-system households, the optimal combination is (c, c, S_1).

Proof. See Appendix 2.

Proposition 2 implies that if a household will have a relatively large amount of PV-generated electricity with a PV system, it prefers $(r_2, p_2, 0)$, while if it will have a relatively small amount of PV-generated electricity, it prefers (c, c, S_1).

3.2. Modeling differences in budgets, electricity consumption, or utility functions

First, suppose the amount of budget of household *i* is y_i while *x* and *e* are constant. To take into account that as a budget increases, installing a PV system becomes easier, we assume that $y_i > y_j$ for all i and j such that $i < j$. We can then do an analysis similar to the case considered above and show if a household has a relatively large budget, it prefers $(r_2, p_2, 0)$, while if it has a relatively small budget, it prefers (c, c, S_1).

Next, suppose the amount of electricity consumed in household *i* is x_i, where $x_i > e$, while *e* and *y* are constant. As the amount of electricity consumption increases, the budget for purchasing a PV system and the composite good decreases, and therefore installing a system becomes more difficult; to take this into account, we assume that $x_i < x_j$ for all *i* and *j* such that $i < j$. Then a similar analysis can be done and it is shown if a household has a relatively small amount of electricity consumption, it prefers $(r_2, p_2, 0)$, while if it has a relatively large amount of electricity consumption, it prefers (c, c, S_1).

Lastly, we consider the case in which utility functions are different from household to household. Suppose household *i* has a utility function $u_i(q_1, q_2)$, while *e*, *x*, and *y* are constant. Assume $u_i(q_1, q_2) > u_j(q_1, q_2)$ for all *i* and *j* such that $i < j$ for any (q_1, q_2) and define a function $v_i(q_2)$ such that $u_i(0, q_2) = u_i(1, q_2 - v_i(q_2))$ and $v_i(q_2) > v_j(q_2)$. The analysis in this case can also be done in the same way. In this case, it is shown that any combination (r, p, S) guaranteeing exactly *n* households install the PV system bring about the same level of utility to each household regardless of PV system installation.

4. Conclusions

In this paper, I have analyzed the relationship between an electricity rate, a PV-generated electricity price, and a subsidy to achieve a certain level of PV system installation, and examined the impact on the utility of households.

I found that a household prefers a higher PV-generated electricity price with a higher electricity rate to a higher subsidy if any one of the following conditions is satisfied with other things being equal: (1) it will have a relatively large amount of PV-generated electricity if it installs a PV system; (2) it has a relatively large amount of budget; or (3) it has a relatively small amount of electricity consumption. Furthermore, other things being equal, the difference in utility functions of households has no effect on the preference.

The results imply that welfare distribution varies depending on the parameter settings even if a fixed number of households install PV systems. This is because each household has its own amounts of PV-generated electricity, budget, and electricity consumption and utility function. Hence, it will be difficult to set parameters with which every household is satisfied. It then may be a policy option that a menu consisting of a combination of an electricity rate, a PV-generated electricity price, and a subsidy for installation is offered to households. This may relieve unfairness to some extent.

In the model, each effect of the amounts of PV-generated electricity, budget, and electricity consumption and utility functions was investigated separately but the mixed effect of them was not. Investigating the mixed effects is very important particularly when a government practically determines the value of each parameter. An analytical approach used in this paper may be difficult to apply directly but the formulation can be used if, for example, a simulation method is used.

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Appendix 1: Proof of Proposition 1

The curve defined by simultaneous equations (1) and (8) connects $(r_2, p_2, 0)$ and (c, c, S_1) in the *r*-*p*-*S* space. First, we show the curve is strictly downward-sloping. Define θ as the angle formed by the line (8) and the *r*-axis on the *r*-*p* plane (Fig. 1). Then it follows that $\cos\theta = \sum_n e_i / A$ and $\sin\theta = Nx/A$, where $A = \sqrt{(\sum_n e_i)^2 + (Nx)^2}$. We are allowed to show the proposition with respect to the curve obtained by rotating the original curve define by (1) and (8) around the *S*-axis by $-\theta$. The obtained curve is on the *r*-*S* plane:

$$v\left(\left(1 - \frac{nS}{Y}\right)y - \left[c + (r-c)\frac{\sum_n e_i}{A}\right]x\right) = K - S - \left[c + \frac{Nx}{A}(r-c)\right]e_n . \qquad \text{(A1)}$$

The slope of the tangent is as follows:

$$\frac{dS}{dr} = -\frac{[Ne_n - v'(r,S)\sum_n e_i]x/A}{1-(n/N)v'(r,S)}, \qquad \text{(A2)}$$

where $v'(r,S) \equiv v'((1 - nS/Y)y - [c + (r-c)\sum_n e_i / A]x)$.

This is strictly negative due to the assumption $Ne_n > \sum_n e_i$, and thus the curve is strictly downward-sloping. Hence, there exists a unique solution *r* for *S* and vice versa that satisfies simultaneous equations (1) and (8). The government will choose a point on the curve since points on the curve represent the lowest *r* for *S* or the lowest *S* for *r* that satisfies the two inequalities.

It can be verified that the second-order differential d^2S/dr^2 is always positive since $v''(q_2) < 0$. Hence, the curve is convex in the *r*-*p*-*S* space.

Appendix 2: Proof of Proposition 2

We are allowed to prove Proposition 2 with respect to the rotated curve around the *S*-axis by $-\theta$. First, I deal with system-installed household *i*. The quantity of q_2 when $q_1 = 1$ is as follows:

$$\left(1-\frac{n}{N}\right)S+\frac{\left(Ne_i-\sum_n e_i\right)x}{A}(r-c)+y-K-(x-e_i)c \quad (i=1,\cdots,n). \tag{A3}$$

The points giving a fixed amount of q_2 form a straight line on the r-S plane. The quantity of q_2 is always increasing in r due to the assumption $Ne_n > \sum_n e_i$ and in S, too. The slope of the line giving a fixed amount of q_2 is obtained from (A3).

$$\frac{dS}{dr}=-\frac{\left(Ne_i-\sum_n e_i\right)x/A}{1-n/N} \quad (i=1,\cdots,n). \tag{A4}$$

This is strictly negative due to the assumption $Ne_n > \sum_n e_i$. The difference of the absolute values of slopes (A4) and (A2), which is denoted by $F_i(r,S)$, follows:

$$\begin{aligned} F_i(r,S) &\equiv \left[\frac{\left(Ne_i-\sum_n e_i\right)x/A}{1-n/N}\right]-\left[\frac{\left(Ne_n-v'(r,S)\sum_n e_i\right)x/A}{1-(n/N)v'(r,S)}\right] \\ &= \frac{x}{A}\cdot\frac{Ne_i-\sum_n e_i-(N-n)e_n-\left(ne_i-\sum_n e_i\right)v'(r,S)}{(1-n/N)\left[1-(n/N)v'(r,S)\right]} \end{aligned}. \tag{A5}$$

The sign of $F_i(r,S)$ is positive if $e_i \geq \sum_n e_i/n$. Then, the optimal point is $(r_2, p_2, 0)$ for household i since the utility is increasing both in r and S. For household n, the optimal point is (c, c, S_1) since $F_n(r,S)<0$. Note that if $i<j$, i.e., $e_i > e_j$, the absolute value of dS/dr of household i is larger than that of household j from Eq. (4).

The proof for a no-system household is done similarly. We obtain the quantity of q_2 when $q_1=0$ as a function of r and S:

$$-\frac{x\sum_n e_i}{A}(r-c)-\frac{n}{N}S+y-cx. \tag{A6}$$

This is always decreasing both in r and S. The slope of the line giving a fixed amount of q_2 for a no-system household is obtained from (A6):

$$\frac{ds}{dr}=-\frac{x\sum_n e_i/A}{n/N}. \tag{A7}$$

This is negative. The difference of the absolute values of slopes (A7) and (A2), which is denoted by $G(r,S)$, is as follows:

$$\begin{aligned} G(r,s) &\equiv \left[\frac{x\sum_n e_i/A}{n/N}\right]-\left[\frac{\left(Ne_n-v'(r,S)\sum_n e_i\right)x/A}{1-(n/N)v'(r,S)}\right] \\ &= \frac{x}{A}\cdot\frac{\sum_n e_i-ne_n}{(n/N)\left[1-(n/N)v'(r,S)\right]} \end{aligned}. \tag{A8}$$

This is always positive. Therefore, the optimal point is (c, c, S_1) since the utility is decreasing both in r and S.

The new course of FITs mechanism for PV systems in Italy: novelties, strong points and criticalities

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Abstract: The paper deals with the new course of the Feed-in Tariffs mechanism for photovoltaic systems that will start from January 1, 2011 in Italy with the actuation of the Government Decree DM 06/08/2010. After a short introduction on Feed-in Tariffs and Net-metering in Italy, the paper focuses the attention on an economical comparison between the incentives established by the Government Decree DM 19/02/07, ended on December 31, 2010 and those introduced by the DM 06/08/2010. The economical comparison is based on three indexes: the Pay Back Period, the Net Present Value and the Internal Rate of Return, characterizing the investments done for the realization of the photovoltaic systems. In particular, simulations show how the new Decree significantly penalizes the architectural integration, that represents a strongly criticism of the new incentive policy.

Keywords: *Renewable Energy Resources, PV systems, Feed-in Tariffs, PBP, NPV, IRR*

Nomenclature

F	*FIT value*	€/kWh
$c_{kWh,t}$	*the electricity price at the t^{th} year*	€/kWh
u	*percentage of maintenance cost*	%
C_0	*initial investment cost*	€
C_{add}	*yearly insurance cost*	€
i	*Weighted Average Cost of Capital (WACC)*	%
N	*lifetime of the investment*	year
NPV	*Net Present Value*	€
IRR	*Internal Rate of Return*	%
PBP	*Pay Back Period*	year
E_t	*Energy produced at the t^{th} year*	kWh

1. Introduction

In 2001 [1], the EU has officially recognized the need of promoting Renewable Energy Sources (RES) as a priority measure since their exploitation contributes to environmental protection and sustainable development and makes it possible to meet Kyoto [2] targets more quickly. The latest evidence of the diligence of the European countries in promoting the use of RES is the European Council Directive 2009/28/EC [3], targeting an objective of 20% as contribution of the RES on the total European energetic consumption in 2020. Such a bond represents, without doubts, a challenging goal, that will be able to be reached only with an effective RES incentive policy and with a concrete effort towards the improvement of the energetic efficiency of these sources.

Photovoltaic (PV) had a higher grow rate in the last decade with respect to the other RES-based systems. The data reported by Nomisma Energia [4] show how, among all the RES-based technologies, PV expected to contribute a major share of renewable energies in the coming decades.

PV technology is still very expensive and its development is strongly connected to incentive policies promoted by national governments and encouraged by the EU, which is striving to ensure the PV industry remains competitive on the worldwide market.

The most common incentive mechanism in Europe, adopted by 15 countries, is represented by Feed-in Tariffs (FITs) [5]. It involves the obligation on the part of an electric utility to purchase electricity generated by renewable energy producers in its service area paying a tariff determined by Public Authorities and guaranteed for a specific time period.

In Italy FITs mechanism has been introduced in 2005 with a Government Decree [6] and has been changed during the years through another Government Decree in 2007 [7] and arriving today, with the Decree of the Ministry of the Economical Development 06/08/2010 [8], at its third version.

The purpose of this work is to highlight the novelties of the last Decree, and the differences with the previous one and to examine the effects of this new course on the diffusion of photovoltaic in Italy.

2. Feed-in Tariffs in Italy

FITs mechanism obligates an utility to purchase electricity generated by PV systems in its service area, paying a tariff determined by the public authorities and guaranteed for a specific time period. The value of a FIT represents the full price received by an independent producer for any kWh of electric energy produced by a PV system.

Different tariffs are defined for different countries, depending on resource conditions and socio-political situation. In Italy, since 2005 various Government Decrees have defined a support system that allows the producers to have recourse contemporary to FIT and Net-metering for PV installations with rated power not over 200 kWp [6,7,8].

Net-metering is a support strategy that allows the customers to offset their electricity consumption with small-scale RES over an entire billing period using it at a different time than it is produced, without considering when the power is consumed or generated and storing their energy in the Utility's grid. With Net-metering the energy produced and injected in the grid has the same economical value of the energy sold by the Utility to the customers.

Over 200 kWp, the customer could choose if selling the whole electric energy produced by the PV system to the local Utility or if using part of this energy for its own consumptions.

In this case the support system is composed by two terms:

- a FIT for the whole electricity produced by the PV system;
- a value for the electricity produced by the PV system which can be used for the own consumption (with a saving in the electricity cost) or partially or totally sold to the local Utility at a price established by the Italian Authority for Electric Energy and Gas.

Therefore, while in the other countries the FIT is paid only for the energy effectively sold to the Utility, in Italy, for 20 years, the producer receives a FIT for the whole produced electric energy and a payment for the part of electric energy sold to the Utility.

A new Decree of the Ministry for Economical Development in 2007 (DM 19/03/2007) simplified the procedure to obtain the incentive and changed the FITs values distinguishing among Field installed or not integrated in building, Partially Integrated in Building and Building Integrated PV Systems [7].

Today, thanks to the success and to the experience done with the DM 19/03/2007, the Italian Government has emitted the DM 06/08/2010, that replaces the previous one, introducing new rules and new tariffs for PV systems in Italy starting from January 1, 2011 [8].

The main differences introduced by the new Decree deal with the classification of the PV systems and the values of the related FITs. The new classification is the following:

- in buildings PV systems;
- building integrated PV systems with innovative characteristics;
- concentration PV systems (CPV);
- PV systems with technological innovation;
- other PV systems.

The characteristics of the PV systems with technological innovation and the related FITs will be established with a further Decree.

Tables 1 and 2 report the FITs values, respectively, for building integrated PV systems with innovative characteristics and for CPV (categories not contemplated by the previous Decree).

Table 1. FITs in DM 06/08/2010 for PV systems integrated with innovative features.

Rated power range (kW)	FIT (€/kWh)
$1 \leq P \leq 20$	0.440
$20 < P \leq 200$	0.400
$20 < P \leq 5000$	0.370

Table 2. FITs in DM 06/08/2010 for PV concentration systems.

Rated power range (kW)	FIT (€/kWh)
$1 \leq P \leq 200$	0.370
$200 < P \leq 1000$	0.320
$1000 < P \leq 5000$	0.280

Table 3 reports the values of the FITs stated by the 2007 and by the 2010 Decrees in the period may-august 2011.

Table 3. FITs in DM 19/02/07 and DM 06/08/10.

Rated power range (kW)	DM 19/03/2007			DM 06/08/2010	
	Not integrated (€/kWh)	Partially Integrated (€/kWh)	Totally Integrated (€/kWh)	PV in buildings (€/kWh)	Other PVs (€/kWh)
$1 \leq P \leq 3$	0.384	0.422	0.470	0.391	0.347
$3 < P \leq 20$	0.364	0.404	0.442	0.360	0.322
$20 < P \leq 200$	0.346	0.384	0.422	0.341	0.309
$200 < P \leq 1000$	0.346	0.384	0.422	0.335	0.303
$1000 < P \leq 5000$	0.346	0.384	0.422	0.327	0.289
$P > 5000$	0.346	0.384	0.422	0.311	0.275

PV systems are considered in the category "PV systems in buildings" if they are installed according with particular modalities proposed by the DM 06/08/10; if the PV systems do not fulfill these modalities, they must be included in the category "Other PV systems".

With reference to the previous classification, inside the category "PV in buildings" are, therefore, included some totally integrated PV systems and almost the totality of the partially integrated PV systems; in the category "other PVs" are included field PV systems, not integrated PV systems and some of the partially integrated PV systems.

Only with reference to the PV systems typologies of the previous classification and belonging to the new ones, in Table 4 the FITs percentage variation between the old and the new decree are reported.

Table 4. FITs percentage variations.

Rated power range (kW)	Not integrated (other PVs) (%)	Partially Integrated (other PVs) (%)	Partially Integrated (PV in buildings) (%)	Totally Integrated (PV in buildings) (%)
$1 \leq P \leq 3$	- 9.64	- 17.77	- 7.35	- 16.81
$3 < P \leq 20$	- 11.54	- 20.30	- 10.89	- 18.55
$20 < P \leq 200$	- 10.69	- 19.53	- 11.20	- 19.19
$200 < P \leq 1000$	- 12.43	- 21.09	- 12.76	- 20.62
$1000 < P \leq 5000$	- 16.47	- 24.74	- 14.84	- 22.51
$P > 5000$	- 20.52	- 28.39	- 19.01	- 26.30

The analysis of the percentage variations puts into evidence that the new FITs mainly penalize totally integrated PV systems with respect to the not integrated ones.

3. Methodology

In the following the previous Decree and the new one are compared, simulating different characteristics of the sample PV systems, in order to explore the possible situations in which the two Decrees give place to different values of the economical indexes.

The economical analysis is performed by calculating, the cash flow, the PBP, the NPV and the IRR of the investment done for realizing the PV systems.

The cash flows depend on several factors such as the equivalent hours produced, the FITs value, the gain for the avoided bill cost, the maintenance and management costs, etc.

All these factors can be translated into cash flows C_t^* by means of the following equation obtained by adding algebraically all the costs C_i and all the profits P_i related to the generic i[th] year:

$$C_t^* = \sum_i P_{i,t} - \sum_i C_{i,t} = F \cdot E_t + c_{kWh,t} \cdot E_t - u \cdot C_0 - C_{add} \qquad (1)$$

In order to carry out a realistic analysis, the cash flows are annualized using the classical expression according to [9]:

$$C_t = \frac{C_t^*}{(1+i)^t} \qquad (2)$$

Equation (2) allows to obtain the equivalent present value of the cash flow of the t[th] year, knowing its nominal value[1].

[1] For example, in the case of i=5%, a cash flow C_t*=1000€ produced at the 10[th] year is equivalent to 614€ at year 0.

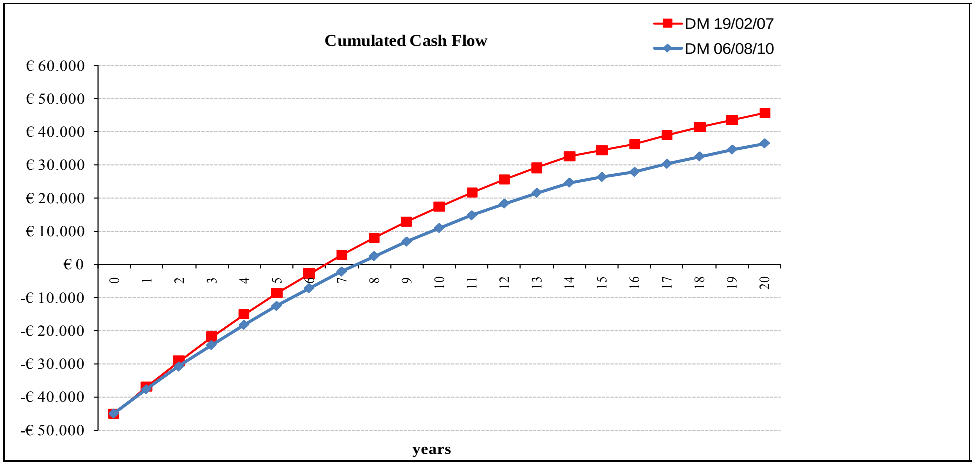
The NPV and the IRR indices are defined by the following expressions [9]:

$$NPV = \sum_{t=1}^{N} \frac{C_t^*}{(1+i)^t} - C_0 \quad ; \quad C_0 - \sum_{t=1}^{N} \frac{C_t}{(1+IRR)^t} = 0 \qquad (3)$$

4. Results

General data:
Yearly reduction of the photovoltaic production: 1%; Electricity price at year 0: 0.15 €/kWh; Coefficient evaluating the maintenance and management cost: 1%; WACC: 3%

First case: 10 kW PV system
Classification according to DM 19/02/07: Not integrated – FIT Value: 0.364 €/kWh
Classification according to DM 06/08/10: Other PVs – FIT Value: 0.322 €/kWh
Initial investment cost: 45000 € - Yearly production at year 0: 14730 kWh

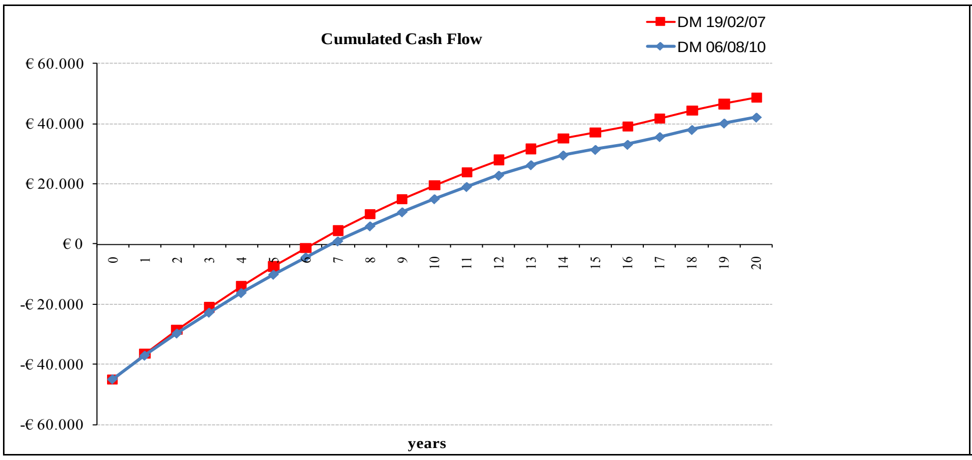


DM 19/02/07 FIT
PBP: 6.5 years
IRR: 10.2%
NPV: 45664 €

DM 06/08/10 FIT
PBP: 7.5 years
IRR: 6.7%
NPV: 36492 €

Fig. 1. Cumulative cash flow – Case 1: 10 kW Not integrated-Other PV system.

Second case: 10 kW PV system
Classification according to DM 19/02/07: Partially integrated – FIT Value: 0.404 €/kWh
Classification according to DM 06/08/10: PV in buildings – FIT Value: 0.360 €/kWh
Initial investment cost: 45000 € - Yearly production at year 0: 14730 kWh

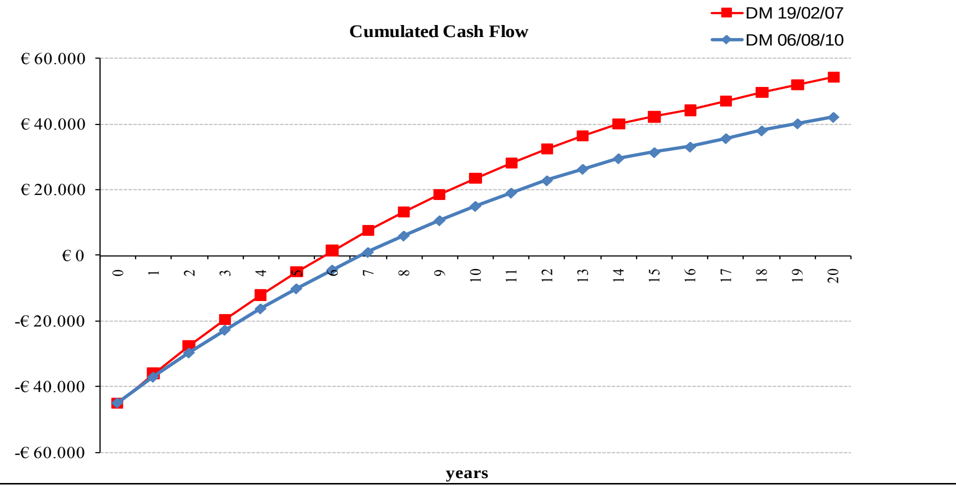


DM 19/02/07 FIT
PBP: 6 years
IRR: 11.2%
NPV: 48597 €

DM 06/08/10 FIT
PBP: 7 years
IRR: 8.9%
NPV: 42102 €

Fig. 2. Cumulative cash flow – Case 2: 10 kW Partially integrated-In buildings PV system.

Third case: 10 kW PV system
Classification according to DM 19/02/07: Totally integrated – FIT Value: 0.442 €/kWh
Classification according to DM 06/08/10: PV in buildings – FIT Value: 0.360 €/kWh
Initial investment cost: 45000 € - Yearly production at year 0: 14730 kWh

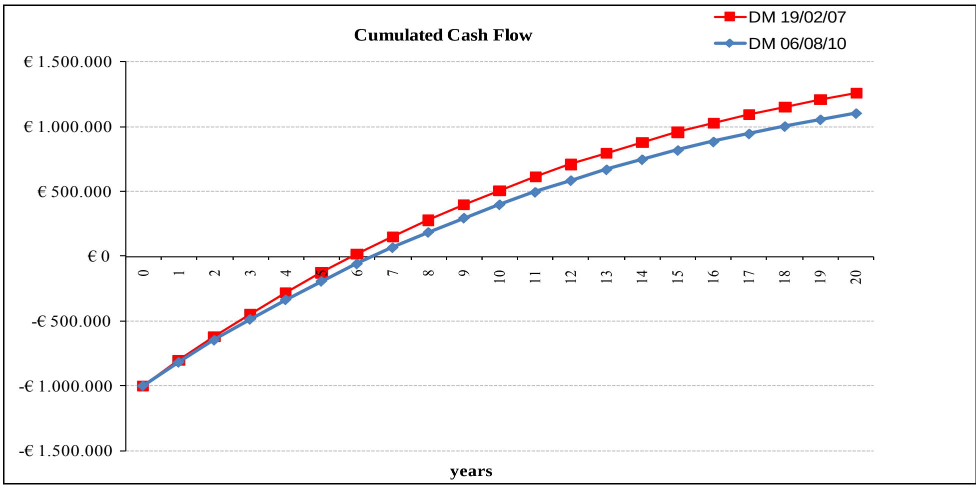


DM 19/02/07 FIT
PBP: 5,8 years
IRR: 13.1%
NPV: 54206 €

DM 06/08/10 FIT
PBP: 6,9 years
IRR: 8.9%
NPV: 42102 €

Fig. 3. Cumulative cash flow – Case 2: 10 kW Totally integrated-In buildings PV system.

Fourth case: 250 kW PV system
Classification according to DM 19/02/07: Not integrated – FIT Value: 0.346 €/kWh
Classification according to DM 06/08/10: Other PVs – FIT Value: 0.303 €/kWh
Initial investment cost: 1000000 € - Yearly production at year 0: 268250 kWh

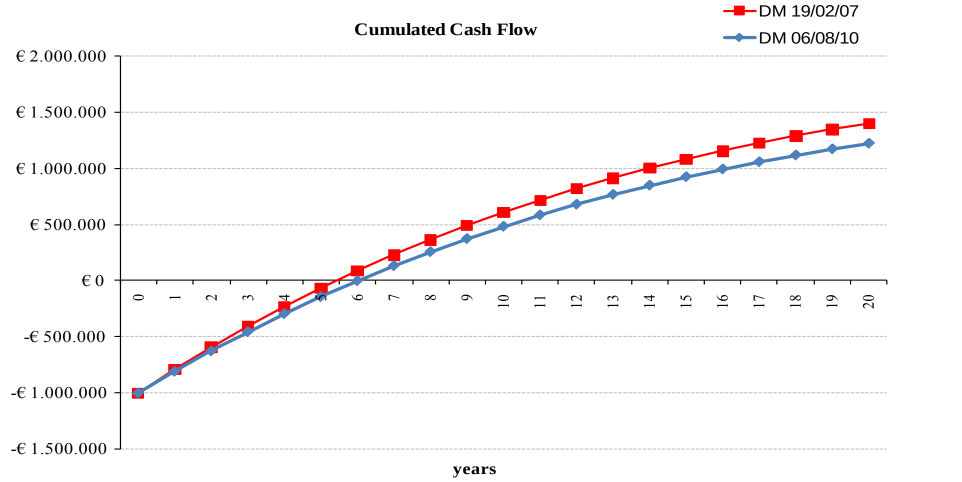


DM 19/02/07 FIT
PBP: 6 years
IRR: 13%
NPV: 1270172 €

DM 06/08/10 FIT
PBP: 6.5 years
IRR: 10.7%
NPV: 1101484 €

Fig. 4. Cumulative cash flow – Case 1: 250 kW Not integrated-Other PV system.

Fifth case: 250 kW PV system
Classification according to DM 19/02/07: Partially integrated – FIT Value: 0.384 €/kWh
Classification according to DM 06/08/10: PV in buildings – FIT Value: 0.335 €/kWh
Initial investment cost: 1000000 € - Yearly production at year 0: 268250 kWh

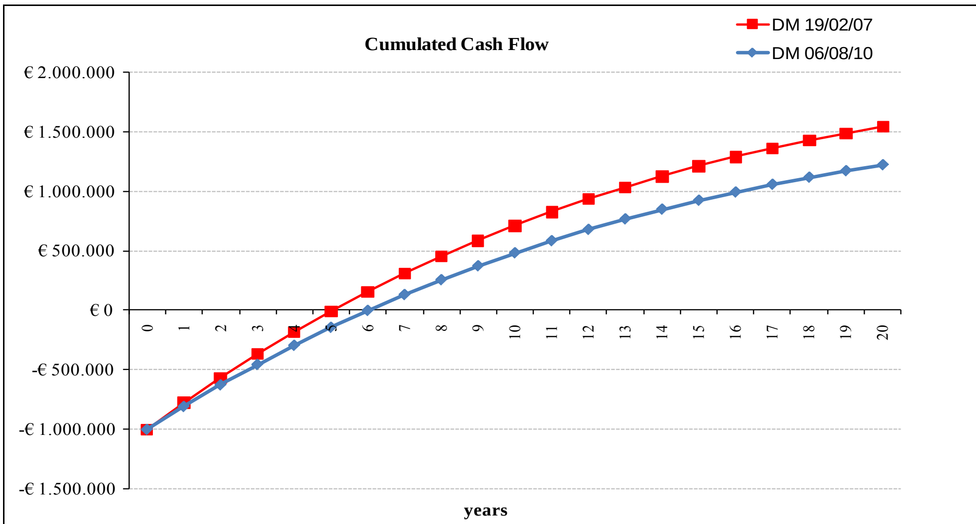


DM 19/02/07 FIT
PBP: 5.5 years
IRR: 14.9%
NPV: 1400409 €

DM 06/08/10 FIT
PBP: 6 years
IRR: 12.4%
NPV: 1219177 €

Fig. 5. Cumulative cash flow – Case 2: 250 kW Partially integrated-In buildings PV system.

<u>Sixth case: 250 kW PV system</u>
Classification according to DM 19/02/07: Totally integrated – FIT Value: 0.422 €/kWh
Classification according to DM 06/08/10: PV in buildings – FIT Value: 0.335 €/kWh
Initial investment cost: 1000000 € - Yearly production at year 0: 268250 kWh



DM 19/02/07 FIT
PBP: 5 years
IRR: 16.8%
NPV: 1540645 €

DM 06/08/10 FIT
PBP: 6 years
IRR: 12.4%
NPV: 1219177 €

Fig. 6. Cumulative cash flow – Case 2: 250 kW Totally integrated-In buildings PV system.

5. Discussion and Conclusions

Simulations show that in the transition from the DM 19/02/07 to the DM 06/08/10:

- PBP increases and IRR and the NPV indexes decreases of about one year in all cases;
- The most significant variations are in the case of Totally integrated PV systems that, with the new Decree, are considered PV systems in building as the major part of Partially integrated PV Systems;
- The differences between economical indexes evaluated are higher for PV systems with lower rated power.

This last consideration, together with the fact that the new FITs have been decreased mainly for totally integrated PV systems, puts into evidence that the new Decree significantly penalizes the architectural PV integration.

This items represents a strongly criticism of the new incentive policy, because it seems to not adequately promote the reduction of the visual impact of PV systems with traditional components.

Really, the new Decree also considers, as above mentioned, PV systems with innovative components for total building integration, for which higher FITs values are established; in the present work these PV typologies have not been analyzed due to the fact that precise indications for their characterization are still lacking. A possibility of improvement, leading to higher incentives for building integrated PV system, can come from the definition of these characteristics, operated so as to include the higher number of situations of architectural integration accepted by the DM 19/02/07.

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Channelling Norwegian hydropower towards greener currents: The challenge of conflicting environmental concerns?

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Abstract: Nearly 100 percent of electricity used in Norway stems from hydropower, but no further large-scale production is politically viable. There is however increased interest in hydropower as both a supplement to the national energy supply and as provider of balance within the European energy system. Interest focuses on: (1) increased pumping and storage; (2) upgrading of existing hydropower installations; and (3) small-scale hydro production. Such measures are also considered as climate-change mitigation. As a fourth developmental path there are also alternative processes aiming at reinforcing environmental concerns in existing hydropower, not least by revising granted licenses. These processes coincide with a reinforced focus on biodiversity. This dual environmental challenge is also enhanced by Norway's follow-up of the EU Directive on renewable energy (RES) and the EU Water Framework Directive (WFD). In this context, we here assess current political and regulatory practice in Norway, focusing on the status of environmental concerns, and the challenges Norwegian hydropower policy faces by the implementation of the EU Directives. The policy challenge is manifest as 'trade-offs' among hydropower priorities at both the strategic and project-specific levels; and is further enhanced by lack of clarity as to the ultimate impact of the relevant EU Directives.

Keywords: *EU, Renewable Energy Directive, Water Framework Directive, Norwegian hydropower, policy, governance, Environmental Policy Integration (EPI), trade-off*

1. Introduction

Nearly 100 % of electricity consumption in Norway stems from hydropower. Since 2001 it has been politically stated that the 'era of new large-scale hydropower constructions is over' **[1]**. At the same time, there is an increased interest for hydropower as a way of meeting national climate change commitments and to sustain the national power balance. Furthermore, there is an increased interest for extending the export potential of hydropower 'balance' to Europe, given the increased intermittent renewable (wind) power production in the EU. In parallel, there is growing concern over the environmental status of Norwegian water courses. Norway is committed by the former and current EU Directives on renewable electricity and energy (RES) (adopted in 2001 and 2008, respectively), as well as the EU Water Framework Directive (WFD; adopted in 2000) **[2] [3].** [1] The directives clearly involve 'trade-offs' among competing concerns for security of energy supply; climate change; biodiversity; and improved water quality.

In this light, there are *in principle* three major options for further development of hydropower in Norway: (1) extend the potential for pumping and storage to increase capacity for balancing; (2) refurbish and/or upgrade existing power production; and (3) promote small-scale hydropower. The third option can also be related to the first, since upgrading can entail increased storage capacity. Furthermore, with respect to environmental concerns for the water courses, there is a fourth 'path' which implies a stronger regard for environmental concerns in

[1] While not assuming the full responsibilities of EU membership Norway participates fully in the EU internal market, as well as being involved in related EU policy areas. This is since 1994 regulated through the Agreement on the European Economic Area (EEA).

the formal processes for revising licenses for existing facilities – with possible modifications and reductions in the production volume.

Referring to these four *developmental paths*, the present paper begins by assessing current political and regulatory practice for hydropower in Norway, focusing on the status of environmental concerns, and the emerging challenge of trade-offs between climate-change and biodiversity. The paper then goes on to discuss the challenges met by the implementation of the EU WFD and RES Directives. The empirical data are based on an ongoing research project on the political and regulatory framework for hydropower, and the related follow-up at the project level. This includes insights from four recent case studies **[4] [5] [6]**.[2]

As a conceptual approach to the analysis, we employ the notion of *Environmental Policy Integration* (EPI), which is an increasingly valuable tool for dealing with the potential synergies and trade-offs related to the goal of sustainable development. As indicated, any further development of hydropower in Norway involves competing economic, social and environmental concerns. Article 11 of the 'Principles' of the treaty of the European Union states that: 'Environmental protection requirements must be integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development'**[7]**. Our analysis is guided by the meaning of this stricture within the context of the academic discourse on EPI **[8]**.

In the following section, we present the analytical and methodological approach. Section 3 presents the main features of the current Norwegian political and regulatory framework, as well as the challenges raised by the EU RES and WFD Directives. In section 4 we discuss how these challenges have been met – and can be assumed to be met in near future, given the established national framework. And in section 5 we provide our conclusions.

2. Analytical framework

The challenge of integrating environmental concerns into economic and social policies is a key focus of the EPI approach. De-coupling economic drivers from environmental degradation is particularly crucial to achieve 'sustainable development' **[9]**. According to a principal interpretation of EPI, environmental concerns should be accorded 'principled priority' in order to reduce the degradation of the life-sustaining capacities of affected ecosystems **[8] [9]**. In the present context, EPI provides a basis for analysing trade-offs between environmental and other concerns relevant for hydropower, from policy strategies down to specific projects. Several mechanisms for applying EPI principles have been explored and analysed in Europe during the last twenty years **[10] [11]**.

Applying EPI principles to the further development of hydropower in Norway, we begin by identifying the *trade-off processes*- and *arenas* where different actors pursue different interests and concerns. A trade-off process in this context is understood as the decision-making procedures in place for resolving conflicts of interest in specific hydropower arenas at both the strategic and project-specific levels.

[2] The research project *Governance for Renewable Electricity Production* (GOVREP; 2009-12) focuses on policies and regulations for renewable electricity in Norway and Sweden. The project is part of the Norwegian Centre for Environmental Design of Renewable Energy (CEDREN), and is co-funded by the Norwegian Research Council, Statkraft and Agder Energy Production.

Such conflicts generally arise when hydro power production is assessed vis-à-vis measures to improve the environment, particularly since strong environmental measures often imply changes in the discharge of water, often affecting established energy production. The challenge of integrating environmental concerns also depends on the perspective employed. Are the concerns addressed at the European, national or local level of analysis? The underlying assumption here is that a European perspective will imply a stronger priority of climate-change mitigation over more local environmental concerns, including biodiversity. However, biodiversity is also a global challenge and entails international commitments.

It is in this light that we aim to identify and assess factors that condition the prioritization and application of environmental concerns. Context-specific studies of this kind are also decisive in order to supplement the traditional techno-economic approach of understanding the phase-in of new energy production **[12]**.

3. The political-regulatory framework for integrating environmental concerns in Norwegian hydropower production

Given its dominant role, hydropower is a crucial part of the general energy policy strategy in Norway. The public management of water courses began as early as 1887 with legislation which is still valid, though frequently revised and amended. The first Protection Plan for Watercourses was adopted in 1973, followed by three additional plans plus a supplement (1980, 1986, 1993 and 2005). In 1981 the Parliament adopted a Master Plan for Water Resources which ranks watercourses according to economic and environmental dimensions as well as the degree of expected political controversy. The Plan has since become the central reference for hydropower development.

Licenses for hydropower production are granted on the basis of both a general Energy Act (covering all forms of energy production and distribution) and more specific legislation on water regulations and water resources (two legal acts)**[6]**. In addition, there are several laws pertaining to the protection of water course environment directly relevant for hydropower.[3] Although these laws do not imply unalterable environmental requirements, they do provide important factors that must be considered in relation to licensing, and changes in licenses.

The four developmental paths for hydropower in Norway (as stipulated above), must, therefore, be based on the general strategic framework put forth in the Master Plan and protection plans, as well as more specific legislative requirements. With respect to *pumping and storage*, however, a more substantial exploitation of this potential in a European perspective is still not accounted for in any existing plan. The existing legislative framework applies, though questions can be raised as to whether this is sufficient given new challenges as to the need for stronger coordination between different licenses within the same watercourse system, most particularly with regard to affected environmental concerns.

The *refurbishment and upgrading* (R/U) of existing installations has been encouraged by political signals, being perceived as environmentally sound as it contributes to increased hydropower with lower environmental impacts than traditional hydropower production since

[3] Although the environmental focus in the water legislation traditionally is related to the local environmental context, there is an increasing focus on biodiversity following from international commitments. In particular, a Biodiversity Law was adopted in 2009, and there is also a specific protection regime for the salmon: The Law on Salmons and freshwater fish, together with regulations for protected salmon rivers and fjords. This also constitutes the Norwegian follow-up of international commitments for the preservation of salmons.

new physical interventions are not required. No overall target for R/U (or for any other aspect of hydropower generation for that matter) has been set at the national level. Licenses for R/U are granted within the legislative framework referred to above.

Small-scale hydropower (up to 10 MW installed capacity) has also been increasingly encouraged by both national and regional authorities, not least as a way of providing new economic activity and income for rural areas. Although guidelines for the planning and impact assessment of small-scale hydro projects at the county level were adopted in 2006, there is no overall national plan. Licenses for small-scale hydro projects are granted directly from the NVE, without additional approval from the MoPE. Another important development in the regulatory framework is a parliamentary decision from 2005 which allows the construction of small-scale projects below 1 MW to be constructed within protected water courses.

Efforts to improve the environmental standard of existing hydropower projects in regulated water courses constitute an important means for improving the water course environment in Norway.[4] Processes where trade-offs are being practiced include: (1) The *revision of licenses* – where the main objective is to rectify earlier regulatory initiatives which mainly emphasized the provision of electricity as a welfare benefit with little concern for environmental impacts. (2) The *revision of regulations affecting water discharge.* This includes licenses containing specific conditions and requirements, such as the protection of salmon. In such cases the particular condition stipulated has more leverage than other concerns, but is still weighted in relation to the consequences of restricting the hydropower production. (3) Finally, with direct relevance for newer licenses (after 1973), it is also possible to reinforce environmental measures applying more general standards, as long as the net energy output is not reduced.

In all of these processes the Norwegian licensing authority (the NVE), is authorized to coordinate related assessments and trade-off processes. The actual importance of the affected concerns will, however, vary from case to case as a consequence of the character of the process itself, as well as the case-specific context. Important aspects of these processes also involve actors at the regional and local levels. The management of hydropower is, however, characterised by sectoral fragmentation, as reflected by the different laws and plans mentioned above. The NVE, together with the Ministry of Petroleum and Energy (MoPE), manage and administer the laws concerning hydropower resources and the related licensing procedures. The Protection Plans, the Master Plan and the laws concerning nature protection and land use planning are, on the other hand, managed by the Ministry of the Environment (MoE) and the Directorate for Nature Conservation (DN).

Furthermore, in a number of cases related to hydropower development, particularly large-scale hydropower plants, the NVE provides only recommendations, whereas the MoPE makes the final decision, which in some cases must also be approved by the Parliament. In the course of these processes, divergences between the ‘MoPE’- and ‘MoE-segments’ often materialise, based on their different mandates.

[4] The four case studies conducted as part of the GOVREP project, focus on different processes of changing the conditions in already granted licenses; the opportunities for integration of environmental concerns, and the trade-offs being made at different levels of governance[4] [5]: (1) Iveland: Upgrading of an existing hydropower plant; (2) Laudal: Revision of regulation of water currents concerning a special condition requiring protection of the salmon stock; (3) Suldalslågen: Revision of regulation of water currents in order to balance the hydro power production and the protection of the salmon stock in a more optimal manner, and (4) Aura: General revision of conditions in a granted license.

3.1. Follow-up of the EU Directives

It is within this general 'policy landscape' that new international commitments – on both climate-change and biodiversity – must be adapted and reconciled. The *EU Directive on the promotion of renewable energy (RES),* adopted in 2008, sets national, binding targets covering electricity, heating/cooling as well as biofuels, and is part of the EU's climate policy strategy **[2]**. The EU RES Directive is, however, still not (as of December 2010) formally adopted by Norway. Due to the extent of Norway's renewable energy resources (both hydropower and wind power), one expects that the EU will require an ambitious national target for Norway (through the EEA Agreement) **[13]**. Related to this process, Norway is currently negotiating with Sweden in order to establish a common scheme for tradable certificates for renewable electricity, and a protocol stipulating the principles of the system was signed by the two countries in December 2010. These efforts build on similar, but failed, negotiations in 2006 **[14]**.

A major objective of the *EU Water Framework Directive (WFD*) is to identify water courses where constructions or operations have affected the ecological status **[2]**. In such cases, one speaks of 'highly modified water courses'; for which the objective is to achieve 'good ecological potential' (as distinguished from a 'good ecological status' for 'purer' water courses) **[2]**. In principle, all water courses affected by larger hydropower activities are considered to be highly modified. The WFD was adopted in 2000, but the inclusion in the EEA Agreement was delayed and Norway did not start implementation before 2006. By focusing on 29 pilot areas Norwegian authorities aimed at coordinating their initial follow-up with the common EU implementation. The EU WFD Directive has stimulated a debate on the future usage of water resources, and the implementation of the Directive has evoked conflicts of interest between energy production and nature conservation in Norway.

The 'complete' Norwegian follow-up is to be coordinated with the second phase of the EU implementation plan, that is 2010-15. This will provide a more complete picture of the effect of the WFD in Norway. The River Basin Management Plans and Programmes of measures (as stipulated by the Directive) related to the first phase were approved by the Government in June 2010 **[15]**. An important part of the Norwegian follow-up is the general principle that concrete measures must be based on sectoral legislation. In general, this means that the NVE continues to coordinate the license processes for hydropower as before, only now being 'informed' of the regional water management plans. The environmental goals of the plans are, therefore, only to be considered along with other existing laws regulating water courses.

4. What is the role of environmental concerns?

As indicated in section 3, Norway's hydropower policy has traditionally been based on a strategic framework which can be characterised as a 'trade-off arena' at the national level. In recent years, the Master Plan's ranking of potential projects based on specific criteria can also be associated with Norway's ambitions on sustainable development (SD). The issue of trade-offs among the three dimensions of SD – economic, social and environmental – is thus increasingly difficult to resolve at both the political-strategic level and in relation to individual projects. Given a general lack of specificity in the Master Plan for hydropower, however, the actual assessments of trade-offs are primarily taking place at the local-regional project level. This has been confirmed by the four case studies of the GOVREP project **[4] [5]**.

Another important finding from these case studies is that environmental concerns must be viewed as compatible with economic interests if they are to be accommodated at all **[4] [5]**. In particular, in relation to revision of regulation of water discharges (Suldalslågen, Laudal) economic interests related to the salmon stock (fishing, tourism) entailed protection measures, including restrictions of the hydropower power production **[4] [5]**. At the same time, in other cases, the focus on economic interests has led to the priority of increased hydropower production, whereas biodiversity-related environmental concerns have been offered only limited attention **[4] [5]**. Hence, although environmental concerns constitute the point of departure for many revisions of existing licenses and installations, pro-environment trade-off's are not stipulated in advance.

Economic concerns also seem to be decisive for small-scale hydropower: The main driver here is clearly a general concern for sustained economic development in rural areas **[6]**. Small-scale hydropower is, however, mentioned as a relevant factor in Norway's most recent climate-change policy strategy **[16]**. Small-scale hydro is also promoted as environmentally benign because no reservoirs are needed, in contrast to large-scale hydro projects. Small-scale initiatives do not, therefore, represent an option for an increased RES balancing of the European energy market. Further, small-scale installations have a number of potentially negative impacts on water course environments, not least due to the high and increasing number of installations. Again, we see no evidence in our studies of overall trade-offs among these partly contradictory objectives **[6]**.

The potential effects and impacts of increased pumping and storage in relation to European energy production has not yet been assessed, nor included in the climate-change policy strategy. Norwegian politicians increasingly refer to this option, however, as a climate-policy measure. Pumping and storage is also seen as an alternative way of fulfilling Norway's impending target under the EU RES Directive. Thus far, however, no public figures have been supplied as to the potential of these and other 'new RES' sources for Norway's obligations under the EU Directive.

R/U initiatives have, however, been framed as a climate-change mitigation option, although not specifically in relation to the overall national climate-change policy strategy. In an R/U project studied within GOVREP (Iveland) the 'climate-argument' was employed to justify the upgrading of the installation **[4]**. This reflects a perception of R/U cases as contributing to an overall reduction of greenhouse gas emissions by hydropower supply. Once again, however, no overall target for R/U has yet been stipulated.

The most relevant SD trade-off processes are thus conducted at a project level within the framework of an outdated Master Plan. More recent national policy targets for climate change, biodiversity and improved water management have thus far not been substantially affected by the national-strategic trade-off decisions. This is most clearly illustrated by the implementation of the WFD Directive. The follow-up here has thus far not resulted in – or been directed by – any overall national objectives, although the process has contributed to a strengthened focus on environmental concerns in water course management and development. In the years to come, the WFD will, nevertheless, require a broader environmental input to the assessment of hydropower projects. As shown in the GOVREP case studies, however, the eventual effect of this input will probably vary from case to case, and from process to process **[4] [5]**.

Finally we can mention that, by examining the regional management plans conducted during the first phase of the WFD follow-up, one is struck by the comprehensive mapping and assessment of the different factors leading to highly modified water courses **[6]**. At the same time, however, no clear provisions as to the further development of hydropower – with eventual direct impact on specific projects – are stipulated by the plans. The main approach is to delegate the responsibility for the formulation of mitigating measures to the energy-sector authorities. Together with the Government's decision to treat environmental concerns primarily in relation to the licensing of hydropower projects – and to only 'be informed' as to the implications of the regional water management plans – the situation clearly reinforces an impression of a relatively passive and incremental Norwegian follow-up of the WFD.

5. Conclusion: The overall status of environmental concerns

The traditional project-specific approach to trade-offs in relation to Norwegian hydropower development reflects a generally 'robust' approach. The environmental dimension is, however, of more recent and increasing importance as a crucial factor in hydropower licensing and development. In addition, both climate-change mitigation and biodiversity are increasingly important national concerns; but, at the same time, concerns that increasingly will conflict with each other. Whereas climate-change will figure more prominently at the strategic level, biodiversity concerns will generally be activated more strongly at the local level and related to specific projects. No overall assessment or specific guidelines exist at to the management of these complex 'trade-off' challenges. The challenge is manifest in growing confrontations between protagonists for stronger environmental concerns and protagonists of more hydropower; and is being directly incorporated into the different mandates of environmental and energy authorities. A stronger focus on biodiversity, and new efforts of establishing a more sector-encompassing water management through the implementation of the WFD, has not altered the relative positions of the responsible agencies thus far. The setting of a new EU-related national RES target, has the potential to induce changes which can reinforce the need to develop hydropower, and thereby lead to even stronger conflicts with biodiversity. The final act in the shaping of Norway's water management system, as well as the future of Norwegian hydropower in an EU energy context, is thus strongly dependent on the follow-up of both the RES and WFD Directives. Whether at the level of national energy-climate strategy, or specific regional-local waterpower projects, the issue of 'trade-offs' is the name of the Norwegian sustainable-development game.

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Small Hydropower Development and Legal Limitations in Thailand

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Abstract: The northern region of Thailand which consists of the Ping, Wang, Yom, and Nan river basins has potential for small hydropower development. The Ping and Wang River Basins are used as case studies. Apart from technical aspects such as electricity generation, engineering and economic aspects, the socio-economics, environment, law and regulation, and stakeholder involvement aspects are also taking into consideration. There are 64 potential projects in the Ping River Basin. The overall electricity potential is about 211 MW with annual power generation of about 720 GWh. For the Wang River Basin, there are 19 potential projects with about 6 MW and an annual power generation of about 30 GWh. However, most of these potential projects are located in forested areas with legal limitations. The various types of forests can result in different levels of legal obstacles. Therefore, the procedure required for permission is varied and is dependent on both the desired development and the forest in question. The laws and regulations related to project development in forested areas are reviewed and are summarized on a case by case basis in a way that is easily understood and accessible for others to use as a reference for other areas. The suggestions for policy adjustments with environmental friendly consideration are also discussed.

Keywords: *Hydropower development, legal limitations, forested area*

1. Introduction

Hydropower is one of the few renewable and clean energy sources. According to the Thailand 15 year power development plan for 2008 to 2022 (Power Policy Bureau, 2010), the total hydropower potential from every region in Thailand is about 328 MW.

This power is generated from 3 different categories of hydropower plants: the Royal Irrigation Department (RID)'s water resources project about 168 MW, small hydropower contributes about 154 MW, and from very small hydropower plants, about 6 MW of power. Among the regions in Thailand, the northern part of Thailand has a very high potential for small hydropower development due to its steep slope topography. However, the suitable sites for small hydropower development are usually in forested areas with legal limitations. Various types of forests present different levels of legal obstacles. There are many laws and regulations that prohibit project development such as the B.E. 2484 (1941) Forest Act, the Ministerial Regulations Number 16, B.E. 2498 (1955), the B.E. 2504 (1961) National Park Act, the B.E. 2535 (1992) Wildlife Reservation and Protection Act, and the B.E. 2507 (1964) National Reserved Forest Act. Therefore, the procedure required for permission is varied and is dependent on both the desired development and the forest in question. In the past, no one has summarized or categorized the means to develop projects in forested areas, especially for the case of hydropower and the case when project sites involve more than one type of forested regions.

The objectives of this research are to analyze the laws and regulations related to project development in forested areas and to summarize on a case by case basis in a way that is easily understood and accessible for others to use as a reference for other areas. The suggestions for policy adjustments with environmental friendly considerations are also discussed. The small hydropower development sites in the Ping and Wang river basins which are the two main river basins in the northern part of Thailand are used as case studies.

2. Methodology

Supriyasilp et al.(2009a) have reviewed laws and regulations related to project development in forested area and have classified the forested areas into three groups based on type of regulations. Each law and regulation has a specific procedure.

The first type are those forests which are protected by law, such as state forests, national parks, wildlife conservation areas, no-hunting areas, national reserved forests, and environmental protection areas. The laws related to the forest in this type are 1) the B.E. 2484 Forest Act, 2) the Ministerial Regulations Number 16, B.E. 2498, 3) the B.E. 2504 National Park Act, 4) the B.E. 2535 Wildlife Reservation and Protection Act, 5) the B.E. 2507 National Reserved Forest Act. If the area involves the B.E. 2484 Forest Act or the Ministerial Regulations Number 16, B.E. 2498, then the project can be developed. If the area involves the other laws, then the project development in the area is prohibited. However, there is exception for the B.E. 2504 National Park Act and the B.E. 2507 National Reserved Forest Act. Under the article 19 of the B.E. 2504 National Park Act, the project or any activities can be done within the area if it is done under the cooperation with the national park. However, the benefit of the project should be used for the purpose of the national park only. For the areas which fall under the B.E. 2507 National Reserved Forest Act, the project can be done by the government agencies using the procedure under article 13.

The second type of forests is those provided by Cabinet Resolutions. This type of forest involves various laws and regulations regarding catchment quality and land use prohibition**.** By status, cabinet resolutions are not laws. But it is the government's policy that all governmental units abide by the cabinet resolutions. According to the Cabinet Resolution of 28 May B.E. 2528 (1985) which concerns the criteria for judging the quality of catchment and measures for land use (along the Ping and Wang Rivers), the area announced as the catchment quality class 1A and 1B is prohibited for all types of project development. This area is reserved as the source of the river. Regarding the Cabinet Resolution of 15 May B.E. 2533 (1990), which concerns permission to use land in the forest areas, the area defined as the conservation area (zone c) cannot be used by a private agency. A government agency can implement a project in the area but must do an environmental impact assessment first.

The third type of area include areas such as parks, arboretums, and state forestry plantations of all kinds including those commemorating the members of the royal family, areas in preparation to be national parks, wildlife breeding and protection areas and areas where hunting is prohibited.

The principles that should be kept in mind when considering the forested area with legal limitation can be summarized as follows.
1) If it is prohibited by law, with no provision for exception, go by the law. When time is needed in the process of annulling/invalidating the law, avoid using the disputed area altogether.
2) If the law has provision for exception, but there is cabinet resolution prohibiting permission, a move to make changes to the resolution must be done first.

3. Case studies and application

3.1. Study areas

The Ping and Wang river basins are selected as case studies. The Ping river basin covers about five provinces namely Chiang Mai, Lamphun, Tak, Kamphaeng Phet, and Nakhon Sawan. It originates in the Pee Pan Nam mountain range in the Chiang Dao district, Chiang Mai province. After passing the town of Chiang Mai, it flows through the provinces of Lamphun, Tak, and Kamphaeng Phet. At the confluence with the Nan River at Nakhon Sawan (also named Paknam Pho in Thai) it forms the Chao Phraya River. The area of the Ping River Basin is approximately 34,856 km^2. The total length is 740 km. The Wang river basin is smaller than the Ping river basin. It covers most areas of the Lampang province. The watershed area is about 10,793.57 km^2 with the total river length of 460 km. The Wang River flows through Lampang province and meets the Ping River at Tak province.

3.2. Potential hydropower development projects

The National Research Council of Thailand (NRCT) has provided funding for the study of potential hydropower development in Thailand. According to the recent research on the study of potential sites for hydropower development in the Ping and Wang river basin (Supriyasilp et al., 2009b; Supriyasilp et al., 2010), there are 64 and 19 potential projects in Ping and Wang river basin, respectively. The Ping river basin has a much steeper slope than the Wang river basin and therefore, it has more potential projects than the Wang River Basin. Moreover, the very small projects which provide installed capacity less than 100 kW are neglected for the hydropower potential analysis in the Ping River Basin. For the Ping river basin, the overall electricity potential is about 211 MW with annual power generation about 720 GWh. For the Wang River Basin, the electricity potential is about 6 MW and the annual power generation is about 30 GWh.

The hydropower schemes in the studies of hydropower development in the Ping and Wang river basins are classified into three types: low head Q based (LHQB), waterway (WW), and dam with storage (DwS) or reservoir type. When analyzing the power capacity, amount of water flow and head of water are two major factors to be considered. The Q in LHQB type stands for discharge or amount of flow per unit of time. The head is a vertical change in elevation between the headwater level and the tail water level excluding loss. The LHQB type is usually applied when the head is low and the amount of flow is large such as in the lower reach and major tributary. The WW type is also called the diversion type or run-of-river type, which part of water is diverted from the main stream to the facilitated channel through the penstock to the turbine. In DwS type, a dam is built to store river water as a reservoir. Following a specific operation rule, water may be released either to meet electricity needs or to maintain an appropriate reservoir level.

Supriyasilp et al. (2009b) has classified the potential sites for the analysis into 6 categories based on the available data and development practices in power generation evaluation. The details of each group are as described as follow.

Group I: The new sites in main river.
For the Ping River, there are many sub watershed and several tributaries. The major tributary usually gives large amount of flow with low head. Thus, the hydropower scheme in this group is the LHQB type. However, the hydropower development in this group is limited since Thai communities are usually situated along the river because the main occupation of the Thai people is agriculture. Even though, nowadays the way of life has changed to be more

industrialized, the preference of a place for living is still near the river. Therefore, there are a lot of communities along the way of the Ping River. Only two potential sites were found in this group to avoid the serious impact on the communities. For the Wang River, there is no project under this group.

Group II: The existing reservoirs
There are several existing reservoirs in Thailand. Most of them are the responsibility of the Royal Irrigation Department (RID). These reservoirs are mainly used for irrigation. They are also considered for hydropower potential development in order to increase the value added of the water in the reservoir. There are three potential sites in each river basin that fall within this category. The hydropower scheme in this category is considered as DwS type.

Group III: The sites in previous studies
Several organizations related to the development of energy such as Electricity Generating Authority of Thailand (EGAT) have studied on the potential sites to develop hydropower projects. In the past, the large dam construction was usually obstructed by the people in the area and the non-government organizations (NGOs). The sites found in the previous studies are also considered in the study of Supriyasilp et al. (2009 and 2010) but need to be reanalyzed on the amount of flow and cost of construction in the engineering and economic aspects. The hydropower scheme in this group is DwS type. There are four sites in this category in the Ping river basin.

Group IV: The sites studied by the Department of Alternative Energy Development and Efficiency (DEDE)
There are 12 sites for the Ping river basin and no sites for the Wang river basin found in the study of the DEDE. Most sites in this group were located in minor tributaries which had a steep topography. All of them are WW type.

Group V: The sites in water organization's development plan.
The sites in this group are from the development plans of relevant water organizations such as the RID and the Department of Water Resources (DWR). The water resource development projects in these plans mainly aim for irrigation purposes. Thus, the analysis has been done under the concept of adding the power capacity to the projects and generating electricity as a by-product. This introduces the value added of the projects and makes the projects more feasible to develop. The hydropower scheme in this group is DwS type. There are 23 sites for the Ping river basin.

Group VI: The new sites from major tributaries
Apart from the sites in group I, the sites in this group have just explored and examined other than previous studies. The study process was started from the site selection. There are 9 WW sites and 11 DwS sites found for Ping river basin, while there are 7 WW sites and 9 DwS sites for Wang river basin.

4. Discussion

Table 1 shows the legal limitations for each potential site in the Ping and Wang river basin based on forested area type. For both river basins, none of the sites is within the forested area type 3. Most of the sites involve more than one type of forested area and more than one law in each forest type. The procedures are summarized in 6 categories as follows. Even though the categories are illustrated based on the Ping and Wang cases, they can be applied as the references for other project development in forested areas.

Category I: the site involves the area announced by the Cabinet Resolution concerning the catchment quality class 1A and 1B. The resolution for that area has to be removed first before one can follow the steps to request use of that area for other laws.

Category II: the site involves the area announced by the Cabinet Resolution as zone C. The environmental impact assessment has to be done for the project development at that site. The process usually takes time.

Category III: the site involves the National Park Act. Under article 19 of the B.E. 2504 National Park Act, the project or any activities can be done within the area if it is done under the cooperation with the national park. However, the benefit of the project should be used for the purpose of the national park only.

Category IV: the site involves the Wildlife Protection Act. Project development in this area is prohibited.

Category V: the site involves the Reserved Forest Act. The project can be done by the government agencies using the procedure following article 13 of the Act.

Category VI: the site involves the Forest Act. The project can be done following the Ministerial Regulations Number 16, B.E. 2498. Therefore, if the project is in category VI only, the procedure is easiest among all categories.

Even though the technical aspects such as electricity generation is important, engineering and economics aspects, the socio-economics, environment, law and regulation, and stakeholder involvement aspects should also be taken into consideration. The sites in group 3 can provide the most installed capacity. However, large dams have to be constructed. This can cause a lot more impacts to the environment comparing to the DwS in other groups, which dam's size is much smaller. The sites in group 1 have low interest rate of return (IRR) and high electricity generating cost (Supriyasilp et al., 2009b). Therefore, the sites in group 1 and 3 are not preferred.

Among the groups, the sites in group 2 seem to be the most preferable due to less legal limitations. Also their environmental impacts are less than the other groups since they already have a reservoir. Group 5 involves less laws and regulation than group 4 and 6. Therefore, they are more preferable. The sites in group 4 and 6 involve more than one type of forested area. There are two sites in the Ping river basin in Category IV, which is prohibited. Most of the sites involve with the Cabinet Resolution 1A (category I) and zone C (category II) together with either the National Park Act (category III) or the Reserved Forest Act (category V).

Table 1. Laws and regulations related to each potential site.

Site no.	Group	HP scheme	Installed capacity (kW)	Annual energy production (GWh)	Forest by laws				Cabinet resolution	
					F. A.	NP. A.	WP. A.	RF. A.	1A/ 1B	Zone C
P1	1	LHQB	100	0.6				●		
P2	1	LHQB	700	4.3	●					
P3	2	DwS	2,000	6.1	●					
P4	2	DwS	110	0.8				●		
P5	2	DwS	257	2.1				●		
P6	3	DwS	77,000	104.5				●	●	●
P7	3	DwS	26,000	55.1				●	●	●
P8	3	DwS	8,000	58.6				●	●	●
P9	3	DwS	8,000	25.9	●					
P10	4	WW	13,600	49.6		●		●	●	●
P11	4	WW	628	3.6				●		
P12	4	WW	930	4.1				●	●	●
P13	4	WW	1,600	7.8				●	●	●
P14	4	WW	90	3.8				●		●
P15	4	WW	1,051	5.3				●	●	●
P16	4	WW	1,447	7.1		●		●	●	●
P17	4	WW	1,450	6.8				●		●
P18	4	WW	1,322	7.0		●		●		●
P19	4	WW	164	0.8		●		●	●	●
P20	4	WW	760	3.8		●		●	●	●
P21	4	WW	417	2.1				●	●	●
P22	5	Plan DwS	1,043	7.1		●		●	●	●
P23	5	Plan DwS	11,058	59.3				●	●	●
P24	5	Plan DwS	2,218	9.3				●		
P25	5	Plan DwS	883	1.4	●					
P26	5	Plan DwS	1,413	2.0				●		
P27	5	Plan DwS	142	0.3				●		
P28	5	Plan DwS	1,457	2.0	●					
P29	5	Plan DwS	761	1.4				●		
P30	5	Plan DwS	674	1.3				●		
P31	5	Plan DwS	721	1.1				●		
P32	5	Plan DwS	333	1.2				●		
P33	5	Plan DwS	113	0.5	●					
P34	5	Plan DwS	982	8.6		●		●		
P35	5	Plan DwS	129	0.9		●				●
P36	5	Plan DwS	2,495	8.2	●					
P37	5	Plan DwS	107	0.4	●					
P38	5	Plan DwS	169	0.5	●					
P39	5	Plan DwS	812	6.7				●		
P40	5	Plan DwS	99	0.4		●		●		
P41	5	Plan DwS	429	1.5				●		
P42	5	Plan DwS	2,052	8.2				●		
P43	5	Plan DwS	5,026	43.8		●		●		●
P44	5	Plan DwS	114	0.9				●		

Table 2. Laws and regulations related to each potential site (con't).

Site no.	Group	HP scheme	Installed capacity (kW)	Annual energy production (GWh)	Forest by laws				Cabinet resolution	
					F. A.	NP. A.	WP. A.	RF. A.	1A/ 1B	Zone C
P45	6	DwS	2,000	12.4				●	●	●
P46	6	DwS	1,500	9.3		●		●	●	●
P47	6	WW	300	1.9		●		●		●
P48	6	DwS	1,000	6.1				●	●	●
P49	6	WW	600	3.6				●	●	●
P50	6	WW	300	1.8				●		●
P51	6	DwS	1,100	6.7				●	●	●
P52	6	WW	600	3.6				●	●	●
P53	6	WW	300	1.8				●	●	●
P54	6	DwS	1,000	6.1				●	●	●
P55	6	DwS	5,300	32.2				●	●	●
P56	6	DwS	300	1.8				●		
P57	6	WW	200	1.2				●		●
P58	6	DwS	1,800	10.8				●	●	●
P59	6	WW	1,600	9.6				●	●	●
P60	6	DwS	3,200	19.2				●	●	●
P61	6	WW	2,500	15.0				●	●	●
P62	6	WW	3,300	19.8				●	●	●
P63	6	DwS	2,800	16.8			●		●	●
P64	6	DwS	2,200	13.2			●			●
W1	6	WW	20	0.12	●				●	
W2	6	WW	20	0.12		●		●	●	●
W3	6	WW	230	1.38		●		●	●	●
W4	6	WW	30	0.18		●		●	●	●
W5	6	DwS	200	1.19		●		●	●	●
W6	6	DwS	370	2.21		●		●	●	●
W7	6	DwS	170	1.01		●		●	●	●
W8	6	DwS	140	0.83		●		●	●	●
W9	6	DwS	10	0.06		●		●	●	●
W10	6	DwS	20	0.12		●		●	●	●
W11	6	DwS	20	0.12		●		●	●	
W12	6	WW	10	0.06				●	●	●
W13	6	DwS	10	0.06				●	●	●
W14	6	WW	50	0.3				●	●	●
W15	6	WW	30	0.18				●		●
W16	6	DwS	10	0.06		●		●	●	●
W17	2	DwS	2,300	6.22				●		●
W18	2	DwS	2,200	15.92	●					
W19	2	DwS	50	0.07				●		

F.A= Forest Act; NP.A.= National Park Act; WP.A.= Wildlife Protection Act;
RF.A= Reserved Forest Act; P1= site no. 1 in Ping river basin; W1=site no.1 in Wang river basin

5. Conclusion

Legal matters present the main obstacle for small hydropower project development in the Northern Region of Thailand. The preferable site usually involves more than one type of forested areas. This paper has summarized the laws and regulations related to hydropower development in forested areas and has suggested the means to develop potential hydropower sites by classifying them into 6 categories. It is recommended that to promote the hydropower development, three issues have to be taken into consideration. First, the laws and regulations have to be systematically reformed so that they are consistent with each other and up to the country's present situation. Second, the issue about project ownership stated in the law has to be reconsidered. The community and private sector should be able to take part in the investment and receive benefits from selling electricity. Regarding the community's investment, people in the community would feel that they are the owner of the resources and as a result would have an incentive to take proper care of the resources. However, the regulation reform for this issue has to be done carefully by considering the concept of balancing the benefits of energy and the detriment to the environment. Lastly, the regulation limiting the use of electricity within the park area should be revised. The excess electricity from the park can then be used to support the national grid.

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Reducing our emissions while achieving good status of our water bodies – is it possible? Swedish hydropower in the limelight

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Abstract: The conflict between climate change mitigation and ecosystems functions is highlighted in the implementation of two EU directives; the renewable energy directive (RES) and the water framework directive (WFD). This paper examines the Swedish implementation of the RES and WFD and possible outcomes in light of the setup and functioning of the present concession system of hydropower in Sweden. The paper discusses the degree of policy coherence of the present and foreseeable outcomes of the directives and suggests some possible policy alternatives to increase coherence in the implementation of the twin objectives.

Keywords: *Renewable Energy Directive, Water Framework Directive, Sweden, hydropower, coherence*

1. Introduction

"In reality we are talking about two goal conflicts. On one hand the renewable energy directive and the water framework directive where demands on increased minimum flow and bypass channels for fish could lead to decreased production of renewable energy. It is also a conflict between two environmental issues, local biodiversity conservation and [global] climate change."

This view regarding the conflict between renewable hydropower production – which is seen as a crucial step in reduced emissions of greenhouse gases – and biodiversity conservation of the river and its surroundings appears in one or another way among various stakeholders connected to the hydropower sector in Sweden today. This twin objective of reducing the emission of greenhouse gases and halting biodiversity loss was already addressed in a formalized way by the adoption of the Swedish Environmental Quality Objectives in 1999. The implementation of the Renewable Energy Directive (RES) and the Water Framework Directive (WFD) has increased the pressure for action to reach these objectives which for many stakeholders appears to be contradictory.

The RES and WFD are EU directives that have to be implemented in the member states of the EU. The RES sets the target of 49% renewable energy of gross final consumption in Sweden by 2020 from a level of 39.8% in 2005. This important level of renewable energy production is to a large extent possible thanks to the high level of hydropower production in Sweden which in 2008 ascended to 69 TWh [1]. The installed capacity has been relatively stable over the past decade, although production fluctuates with precipitation patterns. The WFD has the overarching goal that no water body is to experience a decrease in water quality and that all water bodies should reach good status or good potential by 2015 with the possibility of extension until 2027. A number of quality elements – including biological, hydromorphological and flow regime – have to be fulfilled in order to achieve the required status of the water bodies in a member state. The significant level of hydropower production in Sweden is one important factor leading to many rivers in Sweden at present not reaching the level good status or potential required by the WFD. The high level of hydropower production in Sweden which is positive for the fulfillment of the RES therefore simultaneously makes it harder to reach the requirements of the WFD.

In light of this potential conflict the present paper is focused on the Swedish implementation of the RES and WFD and possible outcomes in light of the setup and functioning of the present concession system of hydropower in Sweden. The paper will in the final part discuss the degree of policy coherence of the present and foreseeable outcomes of the directives and suggest some possible policy alternatives to increase the synergy and coherence in the implementation of the twin objectives.

2. Methodology

The methodology that has been used is document analysis as a first step to identify important issues and possible contradictions that could come from the implementation of the RES and WFD and the functioning of the Swedish governance system of hydropower. The primary data for analysis has been gathered from review and analysis of management and policy documents and literature on the subject. Insights from this step informed the questions that were brought up during semi-structured interviews with relevant stakeholders engaged in the hydropower governance system. Interviews have been conducted with representatives from the four largest hydropower producing companies and representatives from the main authorities dealing with the implementation of WFD and RES in Sweden such as the Swedish Energy Agency and River Basin District Authorities. The lack of centralized and accessible data has limited the analysis of outcomes of actual hydropower concession reviews which would have strengthened the analysis.

Literature on policy coherence has been used to provide a frame with which to analyze arguments raised by the actors and possible outcomes of the implementation of the directives and to what extent they are coherent. Policy coherence is focused on the outputs, implementation and outcomes of different policies and the way they interact. Policy coherence can be viewed as two or more sets of policy objectives that have objectives, instruments and implementation practices that are free from contradictions and have a logical order and clarity [2].

3. Results

The passing of the Energy and Climate bill in 2009 the government can be seen as a major step towards the fulfillment of the RES since it aims at creating a third leg of electricity production from wind and combined heat and power production largely run on biofuels [3]. To achieve this the same bill sets a national planning frame of 30 TWh for wind power and a production goal level of the renewable energy certificates to 25 TWh for 2020. Apart from wind, solar and biofuel production certain types of hydropower production do receive renewable electricity certificate such as production from new plants, plants with an installed capacity not exceeding 1.5 MW and increased production from existing plants. In 2008 production from hydropower plants receiving certificates amounted to 2.6 TWh out of a total of 14.2 TWh [4]. Although hydropower is not identified as an area of priority for expansion to reach the RES goals it is clear that in practice hydropower production does contribute a fair bit in the quota fulfillment partially as a result of the design of the renewable electricity certificates. Due to the old age of the existing hydropower stations there is also quite some potential for efficiency increases from refurbishments that will take place in the coming years. There are calculations pointing towards a potential of 3 TWh increased production simply by replacing existing turbines and generators and modifying the water intake of the stations [5].

As part of the implementation of the WFD water bodies affected by hydropower stations in Sweden are being classified as Natural, Heavily Modified (HMW) or Artificial depending upon the extent of alteration of the water body or if it has been created for the purpose of electricity production. Natural water bodies are required to reach the environmental quality standards Good Ecological Status (GES) while heavily modified and artificial water bodies need to reach the less strict quality standard Good Ecological Potential (GEP). All water bodies in connection to hydropower stations with more than 10 MW potential have in the initial management round been given the status HMW. This adds up to roughly 200 dams in connection to hydropower stations that together represent 10% of the total number of hydropower stations that produce about 97% of the total of hydropower electricity [6]. These same water bodies have been given the general status moderate ecological potential which means that improvement measures should be required to reach GEP [7]. The extent and type of improvement measures needed to reach GEP is still not decided by the responsible River Basin District Authorities (RBDA). There are however indications that physical changes, such as construction of bypass channels, and changes to the flow regimes might be necessary. Bottenhavet RBDA have for example specified that they expect at least 55 new bypass channels to be constructed in hydropower and lake regulation dams in the coming years [7]. The changes required to reach GEP are specified in the program of measures that are created by the RBDA every six years. These programs of measures are targeted at public authorities who have the same tools – mainly supervision and review of concession and general regulation – as before the implementation of the WFD. The purpose is to make sure that the environmental quality norms are met in the water bodies adjacent to the hydropower stations [8].

The final step of implementation of both efficiency increasing measures of hydropower stations and changes required to reach GEP or GES in adjacent water bodies will normally go through the existing concession system of hydropower in Sweden. Hydropower concessions – which specify the conditions and restrictions of operations – are granted in a court of law, have legal force and unrestricted validity in time. This means that general regulations cannot limit the original freedom given in a concession while the operator has to stay within the restrictions of the same. No significant changes are allowed without a corresponding change to the concession which requires a new judicial process. Extended refurbishments which for example increase the water intake capacity of the turbines or increase the drop of the water require a change to the original concession. The vast majority - 88% - of hydropower concessions in force today have been given according to the 1918 Water Law or older [9]. An important number of these concessions allow full appropriation of the water flow for power production. In the case of stations with more than 10 MW potential this is allowed in the majority of cases while it is less common in smaller hydropower stations. Supervision of a given concession by the authorities will therefore often not lead to improved water quality of the adjacent water bodies.

The option that is left for significant changes to the hydropower stations with the current concession system is therefore a judicial trial of the change or a judicial review of the original concession. A judicial trial of a change to the hydropower station is a limited process where only the proposed change is examined by the court while the original concession stays largely unchanged. A judicial review is a more thorough process where the original concession is examined in light of the current Environmental Code and often leads to requirements of minimum environmental flow and in some cases bypass channels. When an old concession is up for review the operator has to tolerate a loss of up to 5% of the water flow for fish and environmental interests without compensation. The initiator of a judicial trial process has to pay the costs of all involved parties, the court process and the necessary investigations that form the basis of a ruling. When a review is initiated by public authorities in favor of general interests the same rules apply except that the operator pays its own costs for participating in the process. A judicial process to change or review a concession is a very complex process where many stakeholders participate and where the nature of the process opens up many possibilities to protract the process if it is in the interest of either of the involved actors. A court ruling can for example be appealed to a Court of Appeal and in the final instance the Supreme Court. A single case can therefore take many years to solve if there is disagreement between the involved actors. One of the most protracted litigation processes in Sweden relates to the Stornorrfors hydropower station where it took 46 years for the parts to agree on appropriate compensatory measures for the damage caused to the fish stocks. For the court process to be effective and lead to a satisfactory result at a reasonable cost it is therefore vital with prior agreement between the involved actors [10]

At present the possibility of reaching prior agreement is limited since the main actors involved have very divergent interests. Hydropower operators risk losing energy production and up to 5% revenue from a concession review since the old concession in most cases allows for more generous appropriation of the water than a reviewed concession would. It is therefore in the economic interest of operators to try to limit the amount of reviews that are initiated and carried through. At the same time the authorities responsible for environmental issues have an interest in trying to maximize the amount of reviews that are carried out to update as many concessions as possible to be in line with the demands of the Environmental Code of Sweden. Currently the main authority responsible for environmental interests in hydropower concession trials is trying to create court practice that a petition from an operator for a judicial trial due to a change for an extended refurbishment requires a review of the original concession. The issue is not that the extended refurbishment will cause an unacceptable impact in itself but rather if the hydropower stations should have a modern concession or be allowed to continue with old concession that are not in line with the demands of the Environmental Code. With such a practice the operator would also have to shoulder the costs of the process as the initiator. Currently there are various ongoing concession trial processes where this issue is being deliberated.

As a result of the functioning and incentives in the concession system and operators and authorities following lines of action that are logical in light of their interests the Swedish concession system is currently working rather slowly and ineffectively. About 2/3 of the resources invested for restoration of water bodies are required for the process and only 1/3 goes to actual physical changes and improvements [10]. Between 1999 and 2009 a total of 73 hydropower concessions out of 3727 have been reviewed which amounts to about 2% of the total [9]. From interviews with operators it is also clear that the full efficiency gains from refurbishments of hydropower stations is not always reached since operators at times opt for a more limited refurbishment to avoid a protracted judicial process that could lead to a review of the original concession. The actions in court from both sides seem to have led to a rather antagonistic situation which became obvious from comments by a representative from one of the responsible authorities. "They [one of the studied energy companies] have stated that they do not intend to spill a single drop of water for environmental causes. I do not see why we should enter into negotiations with them". In interview, at a different time, the responsible hydropower manager of the concerned company also had strong feelings on the subject "My opinion is that what they [the responsible authority] is doing…appears to be some sort of vendetta against the energy companies in cooperation with the Swedish sport fishing association"

The current functioning of the hydropower concession system therefore leads to results where the full efficiency gains from hydropower refurbishments are not always reached. This limits hydropower's share of the fulfillment of the RES objectives in Sweden. At the same time the slow functioning of the concession system makes it highly unlikely that it will be able to implement necessary changes emanating from the implementation of the WFD if the requirements for reaching GEP and GES require significant changes to a large part of existing hydropower stations.

4. Discussion and conclusions

At the strategic policy level there is a relatively high coherence between the implementation of the RES and WFD since the focus in Sweden lies almost exclusively on expansion of wind power and biofuel production to reach the mandatory level of renewable energy production. The integration of up to 30 TWh of intermittent wind power also seems to be possible to balance with 80% of the existing hydropower capacity which indicates that balance capacity in the Swedish electricity grid is not a limiting factor in the selected path to reach the RES targets [11]. The renewable energy certificate is however constructed in such a way that it gives a push for hydropower production as well and we have seen that around 18% of the increase in renewable electricity production to date comes from hydropower production increases.

At the level of implementation, that is at the project level, there is however a risk of some policy contradiction in the implementation of the WFD and RES since measures to improve the water quality could require a certain amount of water flow for bypass channels and minimum environmental flow in the rivers. There is however an important potential to increase the coherence by combining the measures for improved status of the water with extended refurbishments which would allow for higher production of renewable electricity despite of using a smaller share of the water. There is therefore a potential for win-win solutions where the increased efficiency of the hydropower stations could allow for both measures to improve the water quality and increased hydropower production or at least limit the production loss from measures to improve the status of the water. The results in this paper however clearly indicate that the current concession system and the behavior of the main actors involved in it makes it highly unlikely that such synergetic fulfillment of both the RES and WFD will take place.

One of the main barriers for the effective functioning of the system is the economic risk that operators face when engaging in a concession trial or review process since such a process could lead to a 5% loss of energy production and revenue. A possible policy alternative to remove this barrier could be to create a general insurance scheme from which resources could be taken to fully compensated operators from changes emanating from a concession review. By creating a general insurance scheme that all operators are required to participate in a common source of finance would be created that can be used to fully compensate concerned operators from changes to their concessions in a review process. Operators would in this case not have an incentive to protract review processes nor limit the amount of concession reviews that are carried out. Such an insurance scheme could be obligatory for all hydropower producers and consist of a sum of up to 5% of the production value of hydropower in Sweden which is the established limit in the Environmental Code of production loss that operators are required to bear.

With a more effective functioning of the concession system – and with the operators fully compensated for any energy losses in reviews – operators would be more inclined to realize extended refurbishments, requiring concession reviews, which would yield higher efficiency gains in the refurbished hydropower plants and increased renewable electricity production than today. An important part of the energy loss that could results from diverting water for biodiversity requirements if it is necessary to achieve GEP could in this case be compensated for by increased efficiency gains from extended refurbishments of the hydropower stations. The total loss of potential renewable energy production in Sweden would with such a solution be significantly less and it is even probable that the net result would be an overall increase in hydropower production if the space for water improving measures is restricted to up to 5% for hydropower stations that have concessions according to the 1918 water law or older.

There is also an additional source of finance possible for the costs that the operators have to shoulder from review of concessions which comes from the renewable energy certificates. The overarching goal of the renewable electricity certificate is to "establish a more ecologically sustainable energy system in Sweden" [4]. At present this is focused solely on increased production of renewable electricity but with only slight changes it could also work in favor of improving the status of water bodies in Sweden. This would be possible by introducing a requirement that hydropower plants need to possess a reviewed concession according to the Environmental Code and WFD to be entitled support from the renewable electricity certificates scheme. Such a modification would increase the coordination between the WFD and RES and work towards the fulfillment of the twin environmental objectives of CO2 reduction and biodiversity conservation necessary for a more ecologically sustainable energy system.

Research on a global scale is pointing towards the increasing urgency of action both in terms of CO2 reduction and biodiversity conservation which leaves us little option than to tackle the two issues simultaneously [12]. The policy suggestions made in this paper are therefore aimed at improving the ability of the Swedish concession system of reaching synergetic and effective solutions in the hydropower sector that can provide solutions to both environmental challenges.

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