Renewable Energy Innovation Policy - Lithuanian Case

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ABSTRACT

In order to tap the diverse renewable energy potential and substitute fossil fuel- and uranium-based energy production, a wide variety of technologies is required. However the development of new RE technologies is often meeting resistance and facing difficulties. The report analyses the possibility to introduce advanced renewable energy technologies into the Lithuanian energy system. Lithuania is highly (~90%) dependent on imported fossil and uranium resources, thus utilisation of local RE sources is a necessity for one of many reasons – to ensure security of energy supply. However, the existing conventional energy technologies have "moulded" the technical, institutional and behavioural surroundings into the fossil fuel and uranium technological regime. The regime is resisting the shift towards renewable energy technologies and makes it difficult to introduce innovative RE technologies into the Lithuanian energy sector.
The report is analysing the reasons behind the dependency of the energy system on once chosen fossil and uranium path and seeks for a governmental strategy for Lithuania to become an innovator of advanced renewable energy strategy. The suggested innovation policy approach – strategic niche management – is described and analysed using the case (example) of advanced biomass gasification technology introduction into Lithuanian energy system. The conclusions present a tentative (methodological) framework for RE innovation policy in Lithuania.

PREFACE

This report is prepared during the 10th semester of Sustainable Energy Planning and Management Master Program, at Aalborg University. The overall theme of the report is promotion of renewable energy innovations, with a focus on Lithuanian case.

The idea to study renewable energy development issues in Lithuania came naturally. The interest in Sustainable Development in energy sector has arisen during my Thermal Engineering studies in Vilnius Gediminas Technical University in Lithuania. Learning about the success factors for the development of renewable energies in Denmark, Germany and other countries give raise to a question: why such positive development seems not possible in my home country – Lithuania? And it has been an interesting and meaningful theme to study.

During the investigation of the Lithuanian energy sector and renewable energy regulations a number of persons have been very helpful by providing valuable input for the report during interviews. These persons are Mr. Vidmantas Jankauskas (Chairman of National Control Commission of Prices and Energy), Mr. Povilas Balciunas (Director of the Centre of Renewable Energy Technologies at Kaunas University of Technology), Mr. Algimantas Zaremba (Director of Energy Department in Ministry of Economy), Mr. Evaldas Piesliakas (Head of Energy Development Division in Ministry of Economy), Mr. Juozapas R. Jarmokas (Head of Energy Conservation Programme Directorate in the Energy Agency), Mrs. Edita Milutiene (Founder of ATEIK), Mr. Remigijus Lapinskas (President of LITBIOMA). I would very much like to thank these persons for having a conversation with me. Last but not least, this report could not have been written without support and indispensable help from Lars, also by proofreading the report and correcting my Lithuanian-English into Danish-English – thanks to you.

Copenhagen, June 2006

Erika Zvingilaite

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List of acronyms and abbreviations

ATEIK	Renewable Energy Information Consultation Centre
BIG/CC	Biomass Integrated Gasification/ Combined Cycle
CHP	Combined Heat and Power
DEM	Danish Energy Management a/s
DH	District Heating
EU	European Union
EUBIA	European Biomass Industry Association
EUR	Euro – the official currency of the European Union
FE	Final Energy
GDP	Gross Domestic Product
HPP	Hydro Power Plant
HPS	Hydro Pump Storage
IEA	International Energy Agency
INPP	Ignalina Nuclear Power Plant
KTU	Kaunas University of Technology
kWh	kilowatt hour
LAAIF	Lithuanian Environmental Investment Fund
LEI	Lithuanian Energy Institute
LITBIOMA	Lithuanian Association for Biofuel Producers and Suppliers
LR	Republic of Lithuania
LSSSF	Lithuanian State Science and Studies Foundation
LSTA	Lithuanian District Heating Association
LT	Lithuania
LTL	Lithuanian currency - Litas
mill	million
MW	megawatt
NAP	National Greenhouse Gas Emission Allocation Plan
NCC	National Control Commission for Prices and Energy
NEEP	National Energy Efficiency Program
NES	National Energy Strategy
OECD	Organisation for Economic Co-operation and Development

PE	Primary Energy
PPP	Purchasing Power Parity
PSO	Public Service Obligation
PV	photovoltaic(s)
PVO	Public Voluntary Organisation
RE	Renewable Energy
R&D	Research and Development
RES	Renewable Energy Source(s)
RES-E	Electricity from Renewable Energy Source(s)
RET	Renewable Energy Technology
RET-E	Renewable Energy Technology for Electricity production
SNM	Strategic Niche Management
TGC	Tradable Green Certificate
toe	tone oil equivalent
TPES	Total Primary Energy Supply
USD	United States dollar
USSR	Union of Soviet Socialist Republics (Soviet Union)

Introduction

"You cannot solve a problem using the same thought process that created it."

Albert Einstein

This report analyses the relevant problem of introducing innovative technologies in a sector of economy (or a firm) when the environment is not favourable or is even resistant to the innovations. Development of new technologies from the idea to a prototype and further to a product requires a special kind of management – management of attention (Kemp et al. 1998). However, often innovations are met with lack of interest or even opposition. This implies that there are no open entries for a new technology in an existing system or organisation, where efforts are directed towards improving existing technologies. This is generally true for the energy sector, which is locked–in to the existing conventional [1] technologies and is resisting the introduction of more advanced renewable energy (RE) technologies.

More specifically, this report examines the Lithuanian energy sector and the renewable energy situation in the country. The energy system in Lithuania is characteristic by the nuclear power plant, and the infrastructure adapted to it. The nuclear plant together with several large thermal power plants forms the large-scale powerful energy structure, which seems to be particularly resistant to adoption of advanced renewable energy technologies. The report studies the reasons behind the resistance and is looking for possible ways for penetration of new RE technologies into the existing energy structures in Lithuania.

But why should new renewable energy technologies be developed in Lithuania?

The advantages of renewable energies are generally accepted and undeniable: reduction of adverse environmental effects from energy production, increase in security of energy supply, utilisation of local resources increases local value added etc. Lithuanian energy supply is by 90% dependent on imported fossil (natural gas, oil, orimulsion etc.) and uranium fuels, for the most part from the only supplier – Russia. The imported fuel (most importantly – natural gas) price is constantly rising and such high dependency on imported energy resources puts the security of energy supply in the country in jeopardy.

Lithuania has committed to achieve, that before the year 2010 renewable energy will amount to 12% in primary energy consumption and 7% in the balance of consumed electricity in the country. Thus the development of renewable energy consumption in the country is positive. However, more advanced RE technologies are usually imported from other countries to Lithuania. Such approach does not foster innovations of renewable energy technologies and does not enhance the national innovation system taking into account that Lithuania in general is lagging behind when it comes to innovations and

[1] Mainly large-scale fossil fuel and uranium technologies.

production of high technologies. It is important for Lithuania to build up an innovation program and become a front runner in developing advanced RE technologies instead of following the footsteps of others by importing the technologies. Otherwise, in the future, having more ambitious environmental and renewable energy targets, it might be that the dependency on imported energy resources is being (to some extend) replaced by a dependency on imported renewable energy technologies. Furthermore, the advantages of developing a domestic RE technology industry are the possibility to export advanced energy technologies instead of importing and thus achieve a positive effect on the national trade balance along with increase in local value-added of energy production, and the creation of additional work places etc.

Generally speaking, a variety of advanced renewable energy technologies should be developed worldwide. There is a risk that, if the world will not have enough advanced renewable energy technologies developed, then the more ambitious environmental and renewable energy objectives of the future will seem not possible to meet. Development of a variety of RE technologies is also important in order not to lock-in to a dead-end technology. By choosing and developing a certain technology, other alternatives are locked out and a certain technological path is being selected. However, due to uncertainties of technological innovation process, the selected path might be a dead end. In that case technologies with larger potential have not been developed, and a certain dependency on the technology has already been created, which can make it even harder for alternative technologies to enter at a later point in time. The example of such a dead end can be development of nuclear technology – *"... the nuclear path as a whole was a detour that has delayed and prolonged the introduction of modern renewable energy technologies"* (Sanden & Azar 2005). Lithuania is one of the countries, continuing on a nuclear power path and practically disregarding the importance of renewable energy technology development in the country.

The forces of socio-technical fossil fuel and uranium inertia in the Lithuanian energy system are creating a number of difficulties and lock the doors for the introduction and development of advanced RE technologies. The purpose of the report is **to develop an innovative policy programme suggestion for finding or creating a way in for new renewable energy technologies, by overcoming the difficulties and using existing possibilities, to penetrate into the Lithuanian energy system.** In other words the research question is – ***How should renewable energy innovation policy in Lithuania be created in order to become an innovator of RE technologies?***

Part 1 of the report is dedicated to a more thorough development of the problem which raises the above research question, and to analysis of the existing difficulties and possibilities for introduction of innovative renewable energy technologies into the Lithuanian energy sector.

The purpose of Part 2 is to answer the research question. This is done by analysing the technological innovation theory and proposing the strategic niche management approach for RE innovation policy. The technological scenarios for utilisation of real[1] renewable resource potential in Lithuania are not available for the report. Therefore the strategic niche management RE policy approach for Lithuanian case is described by analysing an example – introduction of proposed biomass gasification technology for small-scale combined heat and power production.

Conclusions are summarising the findings of the research, based on the purpose of the report and the research question, and formulate a proposal for niche approach-based renewable energy innovation policy framework in Lithuania.

[1] Physically available rather than currently technically and commercially feasible.

RESEARCH METHODOLOGY

The purpose of this section is to explain the research flow and the red thread of the report, to present the limits of the scope of the research and to describe the investigative approach and methods used.

THEORETICAL APPROACH AND THE REPORT STRUCTURE

The goals of the report is to analyze the current RE situation and RE possibilities in Lithuania and to formulate a preliminary proposal for innovative policy framework in Lithuania in order to become a progressive country in developing advanced energy technologies for utilization of local renewable energy sources. More specifically, to recommend a governmental strategy for commercializing biomass gasification technology for distributed electricity production. My focus in the report is on renewable electricity, although the investigation often expands to include heat and fuel sectors as they are interrelated parts of the Lithuanian energy system.

The investigation starts with an underdeveloped research question, when it comes to problem formulation. I begin with a tentative premise, that initiatives to develop new, advanced renewable energy technologies in Lithuania are poor and the existing policy measures do not encourage technological innovations in the field of renewable energy. Additionally, I assert, that a number of new renewable energy technologies should be developed and the country should become one of the front runners in manufacture of such technologies e.g. technologies equivalent to the highest local renewable energy potential.

The further steps of the investigation, that also correspond to the structure of the report, and the relations between the steps (the parts of the report) are shown in Figure 1 and explained below.

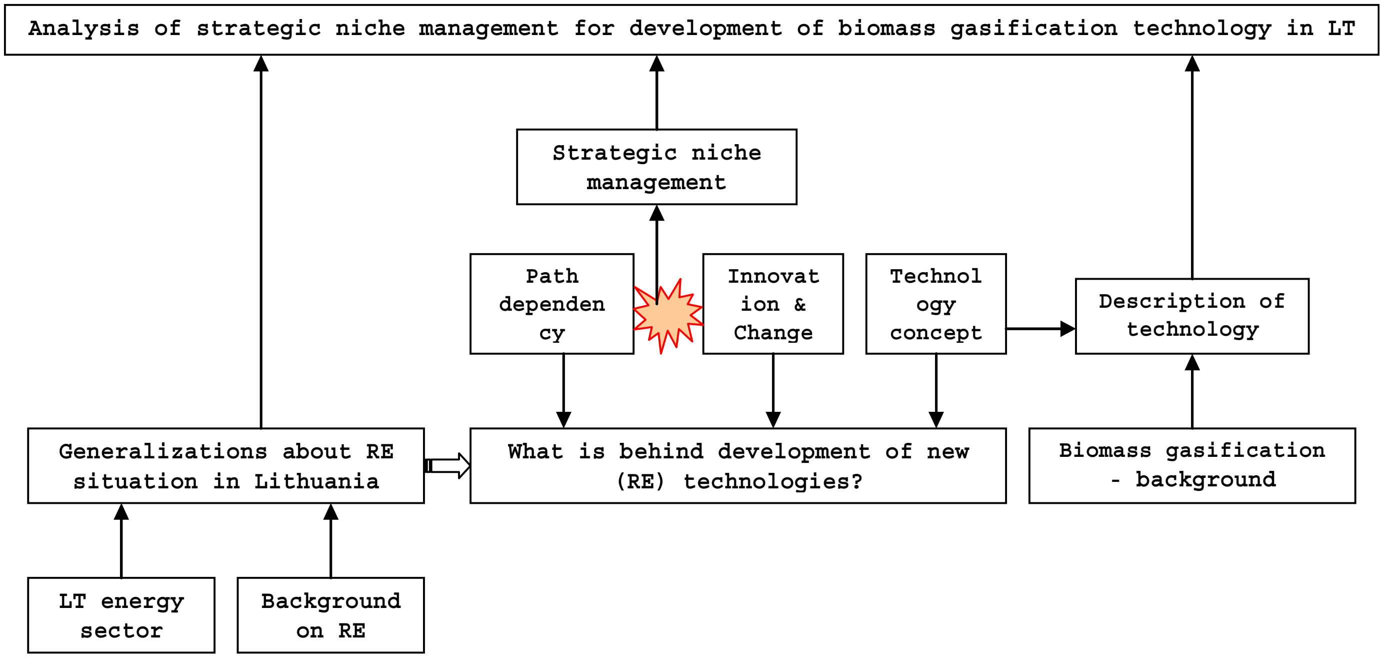

Figure 1Theoretical approach and the report structure

Firstly, I look at the **background on renewable energies**, for more profound understanding of how and which political, economic and technological challenges of today's energy systems can be met by renewable and indigenous resources, what are the barriers for introducing technologies for utilization of these resources and how can they be overcome. This step also provides the conceptual background and forms the standpoint for looking at, analyzing and **evaluating (or generalizing on) the situation of renewable energies in Lithuania**. Clearly, for this evaluation, the **energy sector in Lithuania** is overviewed in order to depict a complete picture of existing favourable and unfavourable conditions for increased renewable energy use in the country and to be able to asses the national RE policy measures against the backdrop of energy reality in the country. These two steps enable to validate the initial presumption that development and innovation of advanced RE technologies in Lithuania is practically not happening and is not encouraged by governmental measures. This validated hypothesis also forms the research problem, which further raises the research question – ***how should renewable energy innovation policy in Lithuania be created in order to become an innovator of RE technologies?***

In order to answer the research question I first look into **what is behind the notion of technological innovation and development**, namely the **concept of technology** and **innovation process**. When a technology is adopted and becomes embedded into the existing technological, economic, political and social/cultural environment a technological regime is formed, which can be referred to as the reason behind **technological path dependency**. Technological path dependency means a difficulty to develop innovations if they imply radical[1] changes in existing technological regime(s). The understanding of the mechanisms behind technological path dependency (technological regime) opens the eyes towards mechanisms, behind the barriers to introduce new, renewable energy technologies. As the importance of developing a number of new RE technologies is undeniable, the way to overcome this **conflict** of path dependency and innovations, requiring changes in the path, has to be found. Here the suggested strategy is **creation and management of niches**, as local, protected breeding spaces for new renewable energy technologies, where they could get a chance to develop and mature. This is primarily suggested as a strategy for governments for development of innovative policy frameworks for advanced renewable energy technologies.

As a potential advanced renewable energy technology that could be adopted and further developed in Lithuania I suggest **biomass gasification technology** for combined heat and power production in gas engine. The description of biomass gasification provides the background of the processes and techniques of biomass gasification as well as application possibilities and advantages of this technology. Using the case (or the example) of biomass gasification-based CHP plant adoption I further **analyze the suggested niche creation and management strategy** as the way to form an innovative policy framework for development of advanced renewable energy technologies in Lithuania. The use of the biomass power gasifier case enables to be more concrete in analyzing the real life issues that niche management policy instruments should address, and identifying the actors and their roles for niche creation and management. The development of advanced biomass technology in Lithuania corresponds to the renewable energy resource that is considered to have a high potential and to the important part of the countries economy and traditions – agriculture. For that reason biomass gasification technology for combined heat and power production seems to be a good technology to start the innovation policy program for renewable energy technologies and to illustrate that adoption of advanced RE technologies is manageable. On the other hand a niche creation for another new technology e.g. photovoltaic technology would probably meet stronger resistance as an alien technology and might need different niche management strategies. Hence only the main principles of the analyzed niche for biomass power gasifier would be applicable for a general RE innovation policy framework in the country. Nonetheless, the analysis of a concrete technology case helps closer analyse the niche formation strategy as a strategy for RE technology innovation policy in Lithuania.

Finally, the conclusions on the findings of the work, summarising the goal of the report and answering the research question, are formulated. In addition, the implications of the research methodology to the report are discussed, and directions of further research are suggested.

[1] The notion of radical technological change is explained in Part 2, section 2.1.

RESEARCH METHOD

By describing the method of the research in this report, I will attempt here to explain my view on the research carried out and the methodological role of different parts of the report.

The project starts with an idea – for Lithuania to become a developer of advanced renewable energy technologies. The idea clearly needs more understanding during the research. For that reason the performed research can be seen as composed of two deductive research cycles (cf. Figure 2) – first cycle is for a better understanding of the problem, related to the initial idea (Part 1), and second cycle is for developing recommendations in order to realize this idea (Part 2). Each of the cycles starts with initial **theory**, which helps to develop a **hypothesis**, and then the **observations** of reality and subsequent development of **empirical generalizations** complete the picture of the analyzed subject.

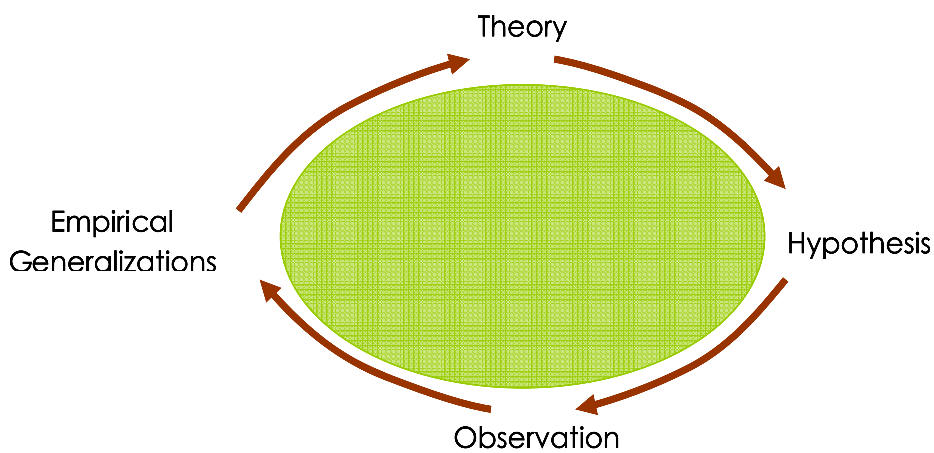

Figure 2 Deduction – from theory to empiricism (Kræmer 2003)

The deductive cycle in Part 1 is completed in order to validate the initial idea of the research. It starts with a general (theoretical) view on renewable energy advantages and the success factors for increased adoption of renewable energy technologies in a country. Further, the hypothesis, that, *although, development of a variety of RE technologies in Lithuania is important for a number of reasons, there is no RE innovation policy, and adoption of new RE technologies is not taking place*, is verified. The verification takes the form of empirical generalizations about the RE situation in Lithuania, which are developed on the grounds of theoretical provisions and observations such as analysis of documents, quantitative data and interviews. Basically, this cycle is a verification and development of the research problem formulation.

In Part 2 the deductive cycle starts with a theoretical view on technology, innovation and technological change. Next, based on the theoretical considerations, I develop a hypothesis – the assumption, that strategic niche management is a possible strategy for a (Lithuanian) government to manage introduction and further development of advanced but not yet mature RE technologies. Then, I carry out observations in form of the analysis of the supposed (theoretical) niche creation and management for introduction and further development of biomass gasification-CHP system in Lithuania, when suggested technology application site is a small-scale district heating company. Further I derive generalizations on the manageability and advantages of proposed niche strategy in Lithuanian context. It should be noted that the performed tentative analysis of biomass gasification-based small scale CHP plant adoption in a district heating plant is seen as the analysis of a simulated situation or an example, rather than a case study. The purpose of this analysis is to explore and develop a more profound understanding of what processes, actors and issues the strategic niche management for advanced renewable energy technologies might include.

Generally speaking, the analysis of the Lithuanian energy sector settings and the study of the possibility to develop renewable energy innovation policy can be viewed as a case study of the development of policy framework for the innovation and diffusion of new RE technologies through the strategy of niche creation and management. The generalized findings of the analysis of this country-case might provide the theoretical insight for analyzing the creation RE innovation policy framework in other contexts than Lithuanian settings.

DATA COLLECTION METHODS

During the investigation I have used multiple data collection techniques and information sources, but the primary methods and sources include traditional collection of "**hard" or written information** and **interviews** with a number of actors, related to the subject of the research. Here I will elaborate on the information collection methods and sources in order to explain, how different data have contributed to the research and subsequently to the report.

The written information sources are as follows:

- Scientific articles form energy related journals and books. They played an important role in establishing the initial research idea and were used for theory triangulation – multiple sources for theory description and different approach perspectives in order to enhance the rigor of the work. Articles on Lithuanian energy sector served as concentrated sources of quantitative and qualitative information about the energy system.
- Statistical reports and homepages of departments of statistics are the sources for quantitative data, used mainly for the analysis and evaluation of the energy sector in Lithuania.
- Legal documents, such as Lithuanian laws on different sectors of the energy system, governmental provisions etc. were thoroughly analyzed in order to present a complete picture of the policy measures for support and promotion of renewable energy use.

Interviews with actors from Lithuanian energy sector were carried out for a number of reasons – in order to clarify the information collected from written sources, to get additional non-written or publicly inaccessible information, to get the insiders' view on (renewable) energy issues, to obtain insights for analysis of norms and beliefs of energy sector actors in Lithuania and for the purpose of data triangulation. It should be noted that the choice of actors interviewed might had been influenced by my as a researchers personal preconceptions, such as that actors in favour of renewable energies would be more open and engaging in the interview and discussion about the current (renewable) energy situation in Lithuania. That might have excluded certain actors e.g. producers of fossil fuel-based energy. I attempted to interview actors having different roles in the energy sector (policy-makers, researcher and private sector actors), and responsible for or influencing the development of renewable energy technologies c.f. Table 1.

Table 1 The interviewed actors

<table>
<tr><th>Name</th><th>Position</th><th>Role</th><th>Principal message</th></tr>
<tr><td>Mr. Vidmantas Jankauskas</td><td>Chairman of National Control Commission of Prices and Energy</td><td>Policy-maker</td><td>Market principles should be used for promotion of renewable energy use. RE can not replace conventional energy</td></tr>
<tr><td>Mr. Povilas Balciunas</td><td>Director of the Centre of Renewable Energy Technologies at Kaunas University of Technology</td><td>Researcher</td><td>There is a large number of alternative technological possibilities for energy production, however policy-makers are not interested</td></tr>
<tr><td>Mr. Algimantas Zaremba</td><td>Director of Energy Department in Ministry of Economy</td><td>Policy-maker</td><td rowspan="2">Renewable energy is promoted enough for achieving the target agreed with EU, government can not define which technologies should be developed, RE technologies are unreliable</td></tr>
<tr><td>Mr. Evaldas Piesliakas</td><td>Head of Energy Development Division in Ministry of Economy</td><td>Policy-maker</td></tr>
<tr><td>Mr. Juozapas R. Jarmokas</td><td>Head of Energy Conservation Programme Directorate in the Energy Agency</td><td>Policy-maker</td><td>Lithuania does not have large RES potential, advanced technologies are expensive and electricity consumers would not be willing to pay more</td></tr>
<tr><td>Mrs. Edita Milutiene</td><td>Founder of private voluntary organization – Renewable Energy Information Consultation Center (ATEIK)</td><td>Non-profit private actor</td><td>There is a low interest in renewable energy in the society, as well as among policy-makers and researchers</td></tr>
<tr><td>Mr. Remigijus Lapinskas</td><td>President of Lithuanian Association for Biofuel Producers and Suppliers (LITBIOMA)</td><td>Private actor</td><td>There is considerable biomass energy potential; however some legal obstacles should be removed. Biomass energy resources are primarily for heat production, electricity will be produced by nuclear power plant</td></tr>
</table>

It should be noted that the interviews took place as conversations or even discussions and the prepared questionnaires served only as guidelines. The main reason for this type of interviews was the wide range of information along with norms and beliefs of actors that I intended to find out.

In addition to the written sources of information and the interviews, observations of developments in Lithuanian energy sector as well as previous experiences in analyzing this sector of Lithuanian economy have contributed to the information on which the research of renewable energy development in Lithuania is based.

The collected information is displayed and interpreted in the report in a form of descriptions, assertions, analysis and comparison of quantitative data, as well as interpretation of qualitative data. The theories, in the report serve also as frameworks for interpretation of the obtained information.

The approach and methods of the research, the data collected and actors interviewed as well as the interpretation and analysis of collected data has obviously influenced the course and outcomes of the study.

One of the major limitations lays within the fact, that the study uses the qualitative flexible approach to the research. This means that the research can be characterised by the evolving design. The course of the study is influenced by the involvement in data collection as well as availability of data and information. The unavailability of data on the real physical potential of renewable energy resources in Lithuania and consequent absence of technological scenarios for utilisation of the existing potential have naturally determined the character of examination in the report. Consequently, the course of the study as well as the findings and final recommendations are more methodological and tentative, rather than analysis of possibilities and concrete proposal for policy measures to implement the actual renewable energy technical scenarios.

Other limitations of the research are considered to be: absence of more elaborated quantitative analysis; the consideration of only one approach for RE innovation policy – technology specific strategic niche management approach; the choice of actors for interviews might have been influenced by personal preconceptions; the absence of tradition to discuss the issue of renewable energies in Lithuania resulted in the limited feedback from the interviewed actors on the possible technological RE scenarios and on the idea of niche approach-based RE innovation policy in the country, and other limitations, related to the methods of information analysis.

The further reflections on, how the investigation has been carried out and its implications for the report will be provided when concluding on the findings of the report.

Part 1 BACKGROUND AND THOROUGH PROBLEM FORMULATION

The first part of the report is dedicated to the description, analysis and evaluation of the renewable energy situation in Lithuania and the subsequent more thorough formulation of already presented problem and research question.

It is important to foster different new renewable energy technologies, however innovation and adoption of advanced RE technologies in Lithuania does not have favourable economic, political (regulatory) and social conditions and consequently is virtually not happening. Such initial research approach and presumption will gain grounds in this part.

The elaboration of the start-idea requires a better understanding of the different aspects of renewable energies. What are the benefits of the use of RE sources in comparison to currently dominating fossil and uranium-based energy production – why is it important to foster development of such technologies? The knowledge of key success factors and possible barriers for adoption and diffusion of renewable energy technologies is important for analysis of the existing renewable energy situation in Lithuania, which is described next in this part of the report. The description of dominating energy resources, technologies and actors in the Lithuanian energy sector reveals among other issues the current status of the country in terms of renewable energy use. The future ambitions and possibilities for introduction of additional RE capacities are also defined by policy goals and instruments for promotion of renewable energies in the country.

Thus the first research cycle explains how difficult it is to introduce advanced renewable energy technologies into the Lithuanian energy sector and why, as well as what possibilities (if any) there are to introduce such technologies. The upcoming study of renewable energy issues and analysis of the energy situation in Lithuania forms the foundation and motivation for the analysis of the implementation of the research idea – creation of an innovative policy framework for renewable energy technologies based on strategic niche management approach.

1.1 RENEWABLE ENERGY: ADVANTAGES, BARRIERS AND PROMOTION STRATEGIES

An important subject of the research is renewable energy. This chapter depicts the main advantages of energy production using this type of sources instead of conventional resources. Although the advantages are undeniable and widely accepted and a number of commercially feasible renewable energy technologies are operating worldwide, the development of renewable energies (especially of advanced RE technologies) is generally vague and renewable resources are not considered to be the replacement for fossil fuels. The barriers for the shift to RE technologies in the energy sector are various and are presented in this section. Governmental renewable energy promotion strategies are important for two reasons – use of RE helps to implement national (e.g. environmental) goals, and there is a need to remove the barriers.

This section presents the arguments for importance of active introduction and development of renewable energy technologies, discusses the spectrum of policy instrument needed and serves as a guideline for the analysis of the renewable energy situation in Lithuania.

RENEWABLE ENERGY: ADVANTAGES AND BARRIERS

Fossil fuels constitute the dominant source of energy in the world and thus cause a number of environmental, security and other challenges. A way to meet the challenges is energy conservation and replacement of fossil fuel-based energy with renewable energy.

The basic reason for using renewable energy is the fact that it is renewable. Renewable energy sources derive from the existing energy flows trough the Earth, from on-going natural and continuous processes such as sunshine, wind, flowing water, waves or tides, biological processes, and geothermal heat flow. It can be said that these sources on a contrary to fossil resources are inexhaustible. Most forms of the renewable energy (except geothermal and tidal) come from the sun – rainfall and wind power are considered as short term solar-energy storage, while solar energy in biomass has been accumulating during several months or years. Usage of this type of energy does not permanently deplete the resource. Fossil fuels theoretically are renewable, however over a very long time-scale. The rapid consumption of fossil energy since the Industrial Revolution will result in depletion of these resources in the nearest future. (Wikipedia 2006)

The danger of ecological destruction caused by generation and consumption of energy is more immediate, though, than that of the irrecoverable exhaustion of resources (Scheer 2002). In the latter decades of the last century pollution, resulting from consumption of fossil fuels became a global concern, with the achievement of consensus about the fact that our planet's climate is changing as a result of a build up of greenhouse gases, such as carbon dioxide (DTI 2006). It is known that energy production from renewable resources, with exception of biomass, is emission-free. Thus, increased consumption of renewable energy resources instead of fossil fuel will help to reduce emissions of greenhouse gases, and other forms of environmental damage (such as local air pollution and acid rains), emerging from the use of fossil fuels.

With renewable energy resources it is possible to meet not only environmental goals, but also economic productivity targets in a more efficient way (Scheer 2002). Renewable energy production is economically advantageous because of shorter energy supply chains than those for energy produced in large scale fossil fuel-base plants (see Appendix A for comparison of supply chains by Scheer (2002). The economic advantage of shorter supply chains lies in reduced cost of energy generation and supply because of a smaller number of distinct steps (e.g. fuel supply, production, energy transmission and distribution) in the process. With exception of biomass, the chain of renewable electricity begins straight from electricity generation. In that way not only emissions from energy production are reduced, but also environmental impacts and costs from transportation are cut down.

Furthermore, one of the most prominent features of renewable forms of energy is the diversity of technologies and resources, which are available in many different locations. The technology choices for utilisation of renewable energy are numerous: photovoltaics (PV), wind power, hydropower, wave power, tide power and biomass combustion for generating electricity; solar water heating and hot water storage tanks, heat pumps and biomass-fired boilers for heating; motors that run on liquid, liquefied or gasified biomass; or hydrogen extracted using renewable energy for use as a fuel or to drive industrial processes. Whereas only relatively few locations in the world are rich with fossil fuel resources, while they are consumed everywhere. The location of energy resources is important, since it defines, who has economic control and who sets the prices. Disagreements about the access to energy resources can provoke dramatic conflicts. Wide distribution of renewable energy resources gives the possibility for local energy self-sufficiency and thus for economical and political independence. (Scheer 2002)

Moreover, in decentralized renewable energy sector industrial concentration and monopolisation are technically and politically avoidable; only one sector – the manufacture and construction of plant – is exposed to that. Whereas in conventional energy industry, large corporate pillars – the oil, coal, gas and uranium extraction and trading companies, the power station operators and the operators of the distribution grids, the power station construction industry and the backing of large investment banks – are already existing and, thus, inevitable. (Scheer 2002)

Additionally the effects of the development of renewable energy technologies can be significant for a country's economy because of the potential for high domestic added value, opportunities for the growth of capital goods and technical service industries i.e. new economic activities, which offer business opportunities and create new workplaces (Tsoutsos & Stamboulis 2005).

There are already a number of new enterprises producing renewable energy technologies and other related products, and governments around the world and various voluntary organisations are becoming active and the renewable energy commercial market is beginning to develop. However, "*the introduction of renewable energy cannot keep up with the growth in global demand*" and "*the proportionate growth in the use of renewable and fossil energy sources favours the latter*" (Scheer 2002, p.27).

Conventional energy sources are considered to have an (economic) advantage over renewable energies, which are considered to be a burden and can only be introduced in small doses. Further should be mentioned interests, vested in existing energy technologies and firms, and the international power structure and world order (Tsoutsos & Stamboulis 2005). In general it seems that the majority of barriers for introduction and diffusion of renewable energy technologies are originating from the dominating thought of conventional fossil fuel-based technologies.

Tsoutsos & Stamboulis (2005) summarize the possible barriers to the shift to renewable technologies in energy system, cf. Table 2.

Table 2 Factors that might create barriers for the shift to renewable energy technologies (based on Tsoutsos & Stamboulis (2005)

Technological factors	–Technological immaturity –RE technologies can not operate on their own, they have to be embedded within another system or to interact with other elements, unavailability or incompatibility of which can create barriers –The operation and management of new technology requires the "unlearning" of established wisdom on what is right and the establishment of new rationale
Government policy and regulatory framework	–Unclear messages about the need for the new technologies and their role in the energy system create uncertainty about the future of market development –Regulatory barriers to the deployment of new technologies –Risk aversion: governments do not risk change in the face of the political cost of vested interests –Ambiguous government's message to the society, concerning RE
Cultural and psychological factors	–Low social acceptance, because technology has not been established as reliable –The conventional energy technologies are associated with comfort and ease in everyday life, which people might be expecting and unwilling to lose with introduction of RET –The lack of information and therefore unfamiliarity with new technologies (and their advantages) and possible failures or bad examples lead to scepticism towards reliability of RET –The volatility of some renewable sources rises uncertainty when comparing with perceived safety of conventional energy supply
Demand factors	–Consumers and users do not have formed expectations of the use and value of renewable energy technologies –In many cases users will have to adjust their demands and preferences to patterns that fit the new technologies –The user willingness to pay and to trade perceived security and low costs for reduced environmental impact is low
Production factors	–Structure and organisation of energy production will have to change from large-scale centralised oil-, gas-, nuclear- or large hydro-based facilities to smaller-scale distributed production from renewable energy sources
Infrastructure and maintenance	–Introduction of new, renewable energy technologies requires certain changes in e.g. energy supply infrastructure –Maintenance needs change in conjunction with the geography of the new system and the new technologies involved –New actors and new relationships will be needed in connection to technology and fuel (in case of biomass) supply
Undesirable effects	–Concerns about aesthetic and environmental impacts of new renewable energy installations, such as wind turbines or toxic waste from solar cells
Economic factors	–Short-term incremental improvements in existing conventional energy technologies put off investments in new technologies, because of lower costs and possibility to continue operation of existing technologies –High initial investment costs and absence of corresponding financial mechanisms puts off potential adopters of modern renewable energy technologies –Slow take-off of new technologies reduces the impact of economies of scale and accelerated learning on the unit cost; as a result, high prices, even of relatively simple

	technologies, slow down diffusion –The economic rationale shifts from the growth of consumption to the minimisation of environmental impacts –Market distortions, or failure to internalise externalities, e.g. the appropriate prising that reflects the environmental damage, created by the use of conventional energy resources

Furthermore, the following factors should be added to the above table: the costs of switching to renewable energy technologies, associated with fixed assets and sunk costs of existing conventional energy technologies – a result of technological discontinuity of old technology, the existing infrastructure and competencies; and dynamic transaction costs – organisational and institutional arrangements, physical as well as human capital (Tsoutsos & Stamboulis 2005).

Additionally, the frequent articulation of the disadvantages or barriers for renewable energy technologies, by e.g. government and/or opponents of renewable energy, is forming a psychological barrier for introduction and diffusion of RETs, because it influences and forms society's opinion about these technologies. Besides, when it comes to a society, an important precondition for successful diffusion of renewable energy technologies is the existence of a strong civic society – absence of that reinforces the position of proponents of the existing situation, the existing fossil fuel technologies. This is because, that the existing energy technology systems provide the energy for (relatively) low prices and no changes, thus, no emerging unsure situations, which basically satisfies the society – final consumers.

Despite the existing barriers, renewable energy technologies should be promoted, because they, besides all the mentioned advantages, offer a considerable scope for development and large increases in efficiency and thus considerable reductions in costs of the technologies can be expected. While conventional fossil fuel technologies are largely mature technologies and no further large increases in efficiency are to be expected (Scheer 2002).

PROMOTION STRATEGIES

The described advantages of renewable energy use are closely related to national goals, such as energy goals (e.g. security of energy supply), environmental goals (e.g. carbon emission reduction), and economic and industrial development goals (e.g. rural development). Development and use of renewable energy resources and technologies is a way to implement these goals. However, because of a number of barriers, presented earlier, successful diffusion of renewable energy technologies is unlikely to occur on its own (Tsoutsos & Stamboulis 2005). Therefore renewable energy policies and long-term policy commitments are necessary as drivers and motivators of increased consumption of renewable resources. The ultimate goal of RE policy is greater use of RE technologies. The link between RE policy goals and the RE technologies are certain policy instruments, which are governmental efforts or measures. These policy instruments are mechanisms to implement institutional (financial, educational, political, administrative etc.) reforms needed to secure the development and greater use of RE technologies, i.e. to implement RE policy goals (Hvelplund 2001). The earlier described barriers to the shift towards renewables in the energy system show, that in general, existing institutional settings are not quite favourable for development and wider use of RE technologies. Hence, this explains the need for changes in institutional settings or development of alternative institutional scenarios.

There exist a number of different policy instruments (or programs) for promotion and support of renewable energy resource use and technologies. The policy programs range *"from low-cost, low-intervention education programs; to regulatory-based and high-intervention forced investments"* (Komor & Bazilian 2005, p.1876). There are also several ways to classify RE policy instruments and analyse and evaluate their effectiveness and efficiency.

Near-term RE policy goals, such as targets, set by EU-Directive on the promotion of electricity produced from renewable energy sources (Directive 2001/77/EC), can be met by economy wide instruments, which promote the use of renewable energy technologies that are already commercially available i.e. RE technologies that can be picked from the shelf, such as wind turbines. This type of policy instruments are for example tax relief, feed-in tariffs, guaranteed power purchase, quotas and tradable green certificates, bidding in tenders, environmental taxes (e.g. CO_2 tax), investment subsidies (Reiche (ed.) 2005 and Harmelink et al. 2006) . These policy measures are mainly directed to economical barriers for diffusion of already available RE technologies and for attracting potential investors. On the other hand, technology specific policy instruments are needed to bring new, technically and commercially immature RE technologies to the shelf. These instruments are the measures for increased research and development (search for new technical scenarios), support for emergence of new actors, for creation of networks between actors and new industries, setting of new standards and creation of new type of infrastructures (e.g. when it comes to energy storage). Consequently RE policy instruments can be divided into (1) economy wide incentives and (2) policies, related to the development of more advanced technologies. (Sanden & Azar 2005)

Meeting near-term RE policy goals is important for initial increase in renewable energy consumption. It shows how the energy system is responding to different policy instruments, and is a first step for developing new institutions, new actors, and new technologies, and for setting of further, more ambitious RE policy goals. Economy wide policy instruments usually involve larger economic transactions and thus cost-efficiency of the instruments is very important (Sanden & Azar 2005). Dinica (2006) takes an investor perspective in analysing the governmental support for the market introduction and diffusion of RET-E and raises the question of confidence of investors to invest in renewable energy projects. He suggests to analyse the relation between the RE support instruments and the investment decision process, and consequent diffusion of renewable energy technologies from the perspective of risk and profitability potential that the support instruments generate for project developers. Policy support instruments are often dynamic, due to changing goals, learning effects, budgetary considerations or changing governing parties. Consequently, support instruments create risks on project returns and, as a result, can discourage certain types of actors from investing in RE technologies. The profitability of renewable energy investments emerges from the financial backing offered by a support system. Dinica (2006) describes four profitability-investment contexts, that can be created by RE support policy instruments – (a) optimal with low/moderate risk and high very high profitability potential; (b) entrepreneurial with high/very high risk and the same profitability; (c) political where both risk and profitability potentials are low/moderate; and (d) minimal with high/very high risk and low/moderate potential. Optimal investment context is suitable for attracting as many potential investors as soon as possible. When there is entrepreneurial investment context, only most risk-taking actors, who expect profits correspondingly high to the risks faced, would be attracted. Political investment context is created by a support approach is to minimise public or consumer financial load for support of RE technologies, and it creates context "not very appealing to investors". Finally, minimal investment context is giving the least incentives to invest in RE technologies and this context is often a result of symbolic policy. (Dinica 2006)

Nevertheless, the economy wide policy instruments *"are not likely to spur technological development of more advanced technologies"* (Sanden & Azar 2005, p.1562). Technology specific governmental support is needed for development of new renewable energy technologies from invention to competitiveness and diffusion. The crucial type of governmental support of new technologies is funding of research and development. Not only is the funding of basic scientific research (i.e. the search for new technological possibilities) needed, but also the funding of the research that supports the link between invention and diffusion. The characteristic of these kinds of investments is that their payback time is quite long. Another type of support for immature technologies is demonstration projects, which serve as a test of technology performance. Demonstration projects generate knowledge and, as an advertisement, raise the level of awareness of a technology. Further a network of actors for dissemination of information, knowledge and visions about new technologies are necessary for the formation of a new technological system. Governments can support networks by e.g. arranging or supporting informational meetings, conferences and workshops. The existing regulations may need to be adjusted according to new technologies, or new regulations and standards need to be created in order to ease the adoption procedures of new technologies. The attention should also be paid to the educational system both in order to increase general awareness in society and to prepare experts of new technologies. (Sanden & Azar 2005) These and more governmental actions might be needed in order to foster development of not yet commercial RE technologies.

Political support instruments need to be coordinated, because neither R&D funding nor price incentives are effective on their own (Sanden & Azar 2005). For instance, without substantial R&D there will be no technologies to pick from a shelf by exploiting economic promotion instrument. While the introduction and diffusion of RE technologies will attract new actors in favour of renewable energy and new market entrants that can support (e.g. financially) R&D and influence the political process behind the development of policy goals and political instruments. The timing of introduction of support instruments is also important. For instance, it is wasteful to allocate investment subsidies or introduce economy wide price incentives, when performance of technologies is still too poor and more money should be spent on e.g. basic scientific research. Furthermore, the potential investors and other actors should be assured that the introduced policy support will not suddenly change in an unfavourable direction. Policy instruments need to be stable and predictable over a longer period of time. This might be a challenge for political systems with frequently changing governments. (Sanden & Azar 2005)

Reiche & Bechberger (2005) outline a number of factors that influence development of RE technologies and resource consumption and respectively the success of RE policies and instruments for promoting renewable energy. For example, the liberalization of the electricity market can be an opportunity for new green electricity producers to enter the market, especially if there is a group of consumers that would prefer electricity, coming from renewables. On the other hand, competitive conditions for immature technologies may be counterproductive and could encourage decisions, based on short-term benefits. Another favourable factor might be the existence of active Green Parties and their participation in governments, which would be an advantage for the promotion of renewable energy. The fact that administrative responsibility for renewable energy promotion and support lies within Ministry of Economic affairs can be unfavourable for development of renewable energy technologies, because *“there are often close connections between Ministries of Economic Affairs and the conventional energy companies”* (Reiche & Bechberger 2005, p.27). Additionally, often the top priority in these ministries is cost-efficiency. Besides, environmental pressures are a positive phenomenon for promotion of RE technologies, because they alter the performance criteria for energy plants and thus change the rules of the game in favour of renewable energy technologies (Tsoutsos & Stamboulis 2005). Moreover, another factor, important for success of promotion of RE technologies is public awareness about renewable energy and its advantages, and willingness to pay, in order to support renewable energy development.

The summary of important factor groups and illustration of factors that might have influence on the development of renewable energies in a country is presented below, in Table 3. The presented groups of factors will further be used for framing the evaluation of current renewable energy situation in Lithuania in section 1.3.

Table 3 Factors influencing renewable energy development (Reiche & Bechberger 2005)

Geography / starting position in energy system	Economic environment	Politics	Technology	Cognitive environment
–Amount of rainfall –Sunshine intensity –Wind speed –Availability of fossil resources –Availability of nuclear power –Age of existing power stations –Overcapacities –etc.	–level of oil and gas prices –subsidies for fossil- and uranium-based energies –internalization of external costs –etc.	–targets and definitions –administrative responsibility –green parties in power –permit procedures –international obligations and programs –etc.	–technological development of RES –grid capacity –etc.	–public awareness –compatibility with the dominant belief in the efficiency of large scale units –etc.

Thus, a number of conditions are influencing and should be in place for introduction and diffusion of both, already commercially available and not mature yet renewable energy technologies, and consequent shift to use of renewable energy sources instead of fossil fuel and uranium resources.

The conclusion here is that a country should seek to develop and adopt a variety of renewable energy technologies, e.g. according to different RE sources available locally, in order to gain energy independence and benefit the local economies. A country, which relies on technological advancement of others can not be considered progressive and independent. Consequently, corresponding RE goals and governmental strategies are needed, including R&D policy programs with prototype demonstrations, adequate (technology specific) price incentives for both, creating mini market conditions for adopting and maturing the advanced RE technologies, and for picking already commercial technologies from the shelf for implementing near-term energy and environmental goals. Clearly, network creation and encouragement of new actors as well as raising public awareness and increasing consumer willingness to pay are the important tactical element for renewable energy promotion strategies.

Further the Lithuanian energy sector will be analysed in order to display the importance and current situation of renewable energy in the national energy system, and to identify and evaluate the natural, technical, economic and social conditions as well as adequacy of energy policy goals and regulatory measures for development of technologies for renewable energy use.

1.2 BACKGROUND OF ENERGY SECTOR IN LITHUANIA

This section is presenting the comprehensive picture of the Lithuanian energy sector in order to be able to explain the resistance of the sector towards innovative renewable energy technologies and the relevance of RE innovative-niche policy framework. It is intended here to outline the geographical, technical, infrastructural and organisational characteristics of the energy system (focus is on the electricity sector). This will display the main problems in the sector, the importance of increased use of renewable energy resources and some of the difficulties, for introducing new RE technologies into the sector. I am also looking here for the potentials of renewable energy in Lithuania and the possibilities for development of advanced RE technologies.

Lithuania is a Former Soviet Republic, situated in North-eastern Europe. The main country data in the year 2004 are presented in Table 4. Lithuania is a country on the coast of the Baltic Sea, the length of the coastline is however only 99 km and is together with more than seven hundred rivers and streams and 2,8 thousand lakes mostly devoted to recreation and preservation of nature. The greater part of the county's territory is lowlands separated by low hills. Almost a third of the land is forested. The climate in the country is transitional between maritime and continental and the average annual temperature is around 6 °C.

Table 4 Main country data in 2004 (Statistics Lithuania 2006)

Population, thous.	3435,6
Area, thous. km²	65,3
GDP at current prices, mill EUR	18084
GDP per capita, EUR	5264
Inflation rate, %	2,9
Balance of trade, mill EUR	-2481
Average earnings of employees, EUR/month	332,9 (gross) 242,0 (net)
Unemployment rate, %	11,4 (8,3 in 2005)

Historically, Lithuania is an agricultural country and nowadays the agricultural sector performs very important economic, social, environmental and ethno-cultural functions in the country. (Streimikiene et al. 2005 and LEI 2004)

SOVIET LEGACY IN COUNTRY'S ENERGY SECTOR

Lithuania's Soviet past is an important factor in describing its energy system today. Planned economy has left significant fingerprints in the society, culture and different economy sectors. The main characteristics of the Lithuanian energy sector, as the inheritance from Soviet Union, are the high energy intensity, heavy reliance on nuclear energy for the electricity supply, high dependence on energy imports, such as gas, oil and nuclear fuel, and the high share of natural gas in the energy balance. (Urge-Vorsatz 2003)

There were several reasons for high energy intensity in the Soviet Union. The first and foremost reason is that efficiency was not rewarded or even encouraged. Energy prices were low, because of cross-subsidisation, e.g. prices for private consumers were lower than those for industries. There was no control of energy consumption, no metering of residential energy, energy charges were not equivalent to the actual consumption. Furthermore energy performance of buildings and industry was poor. (Urge-Vorsatz 2003 and LEI 2004)

Large industries in Lithuania were producing not only for the country but also for several other Soviet Republics, which resulted in high energy consumption in the country. However, after Lithuania re-established its independence in 1990 and Soviet Union fell apart the energy consumption declined radically in Lithuania cf. Figure 3. The Primary Energy consumption (PE) decreased from approximately 17 Mtoe in1990 to around 9 Mtoe in 2004 (LEI 2002, 2005). It was a result of the dramatic economic recession during the transition from centrally planned to market economy in Lithuania and neighbouring countries. Comparing the year 1990 and 2000 Lithuanian economy shrank by one third (Urge-Vorsatz 2003).

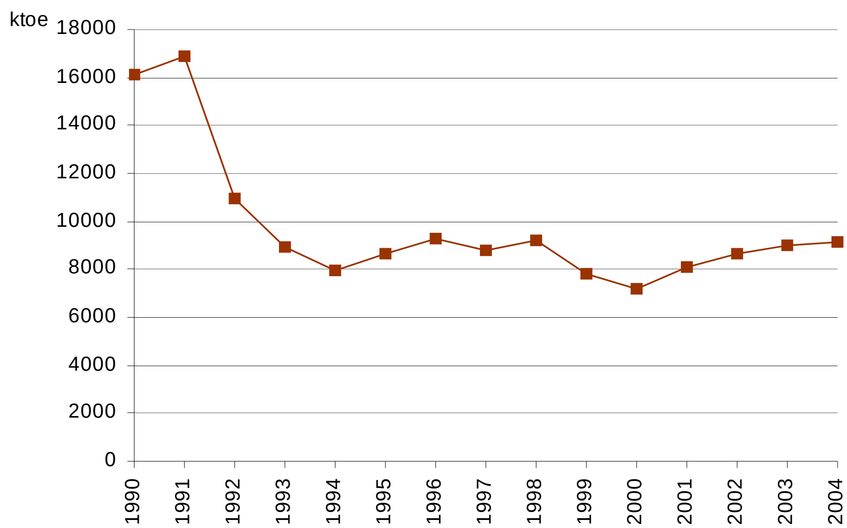

Figure 3 Primary energy consumption in Lithuania in 1990-2004 (Statistics Lithuania 2004 and LEI 2005)

Furthermore, Lithuanian energy sector was during the soviet era designed and built not only to meet the local needs, but also to cover energy demands in North-western region of Soviet Union. Consequently, Lithuania has inherited a strong energy sector with rather modern thermal power plants, the nuclear power plant, well developed district heating systems etc. Some aspects of this inheritance, especially the high share of district heating, give good possibilities for further development of the energy sector, such as implementation of small-scale cogeneration and decentralisation of electricity production. Besides, the city planning during Soviet era enabled utilisation of waste heat of power plants or industrial plants for district heating or other heat demands. It means that more advanced energy technologies, such as cogeneration are not new for Lithuanian energy system. However at present it is rather difficult to use the surplus of the existing capacity efficiently. (Urge-Vorsatz 2003)

PRIMARY ENERGY

The greater part of the primary energy resources consumed in Lithuania consists of crude oil, natural gas, coal and nuclear fuel, which are mostly imported form Russia. Before the fall of Soviet Union a high reliance on natural gas was a relatively positive fact, because of a fairly developed infrastructure for natural gas and lower environmental pollution from natural gas (comparing with e.g. coal). After the country's separation from the Soviets Union, the dependency on energy imports became a threat for the security of energy supply. Currently Lithuania imports approximately 90% of its primary energy resources. The composition of primary energy consumption in the country in the year 2004 was as follows: 36% nuclear and hydro, 28% oil products, 26% natural gas, 8% firewood and other renewables and 2% coal and peat (LEI 2005).

According to the Law on Energy of the Republic of Lithuania (2002) renewable energy resources are "*natural resources: potential hydro energy, solar energy, wind energy, biomass energy and energy which flows out from the centre to the surface of the earth (geothermal energy)*" and "*the origin and renewal of this type of energy is conditioned by processes created by nature or human activity*" (LR 2002, chapter one article 2).

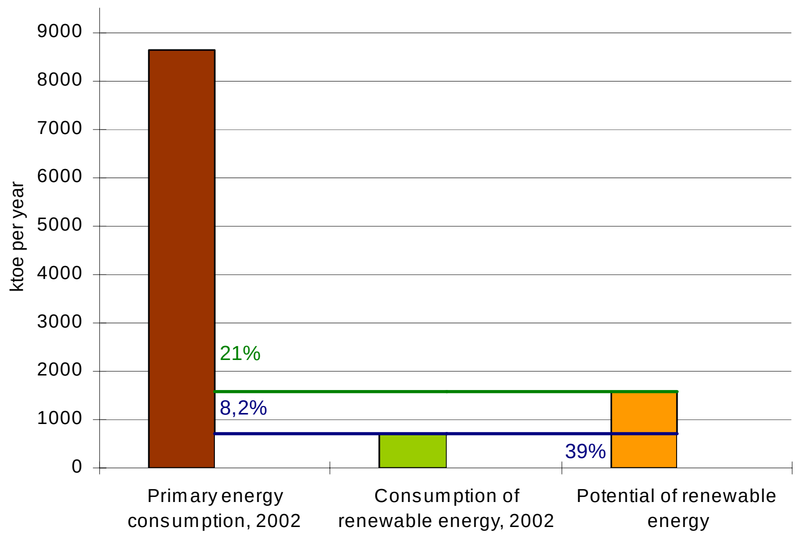

Figure 4 Comparison of primary energy consumption in the year 2002 and renewable energy potential (LEI 2004 and Statistics Lithuania 2004)

Currently the consumption of renewable energy is rather low in Lithuania. Today renewable energy sources (RES) cover approximately 8% of primary energy consumption in the country (LEI 2004). According to studies prepared by local and foreign specialists, such as Lithuanian Energy Institute, Danish Technological Institute etc., the technically feasible RES potential in Lithuanian is though more than double cf. Figure 4. However, the real potential of renewable energy sources is likely to be higher than the numbers, presented here.

Since forests cover approximately one third of Lithuania's area, it is reasonable that the renewable energy resource with the highest consumption potential is wood cf. Figure 5. Biomass is also so far the mostly consumed RE resource, comparing to other available renewable energy sources. As much as 78% of estimated technically feasible potential of wood was consumed in 2002. The main part of biomass energy projects are related to heating, mainly to district heating. According to the report on the use of local and renewable energy sources in Lithuania, prepared by the Danish Energy Management a/s (DEM) in 2003, the extension of usage of wood as a fuel should not face any serious obstacles. The important factor here is transportation and storage of the fuel (DEM 2003).

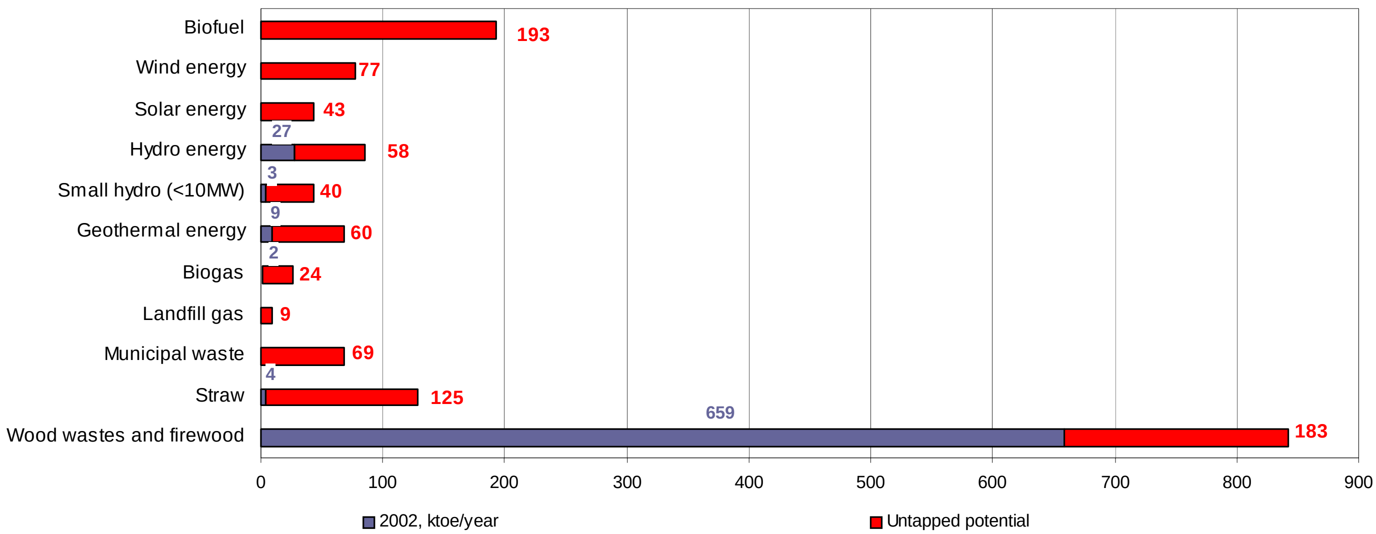

Figure 5 Consumption of RE resources by type in 2002 and feasible technical potential, ktoe (LEI 2004)

Again, it should be noted, that the real possible potential is likely to be higher, taking into account the potential for cultivating fast growing trees and under consumed forest waste. According to the Lithuanian Association for Biofuel Producers and Suppliers (LITBIOMA), currently there are 157 ktoe of unconsumed forest waste annually. Besides, 118 ktoe yearly could be produced from wood, collected when thinning out young forests. Moreover, the association predicts that in ten years around 165 ktoe of energy per year could be produced from 50 thousand hectares of energy plantations (LITBIOMA 2006). Straw as a fuel is mainly used in district heating boilers in Lithuania. It is not a widely used renewable energy source. Straw as energy resource started to be used ten years ago. Only a small share of the estimated potential was consumed in the year 2002.

In order to extend the use of different renewable energy possibilities a pilot geothermal plant was constructed in Klaipeda city. The district heating water is pre-heated using geothermal energy and further heated using natural gas. There is significant potential for expanding utilisation of geothermal energy, since geothermal areas cover 80% of countries territory (LEI 2004).

Furthermore, recently several towns have installed waste water treatment plants that include tanks for anaerobic digestion of organic substances in the wastewater. Biogas was not used in Lithuania until the very recent years. The largest part of biogas potential was found in agriculture, in waste water treatment plants and in food production. (LEI 2004)

According to Streimikiene (2005) solar energy is only expected to be used for hot water preparation and passive space heating in buildings. The potential of this type of energy is comparable with that in northern Germany and Denmark. The yearly solar potential in Lithuania is estimated to be 1000 kWh per square meter. (Streimikiene, 2005) Thus the area receives a total of 65400TWh (5624 Mtoe) of solar energy compared to estimated technically feasible potential of 43ktoe. It should be noted that solar energy in Lithuania is not considered as a possible electricity production source.

Green electricity in Lithuania is mainly produced by large hydro power plants. Nonetheless, small scale hydro power plants are also commercially available and feasible for implementation today. The second biggest part of RE projects after biomass heat boilers are hydro power plants. (LEI 2004)

Wind energy is considered to be a potential source for electricity production in the country. On the other hand, according to the literature, climatic conditions are not particularly favourable for this type of renewable energy due to rather low wind speeds (Streimikiene 2005). The average wind speed is 5-5,5 m/s at the 10 meters height in the coast zone. However, this is highly environmentally protected and one of the main recreational areas in the country. In the mid part of Lithuania the average wind speed is 3,5-4 m/s. (LEI 2004)

FINAL ENERGY

Final energy consumption (FE) by type and by sector is shown in Figure 6. The largest energy consumers in 2004 were industry (30%), transport (26%) and households (26%).

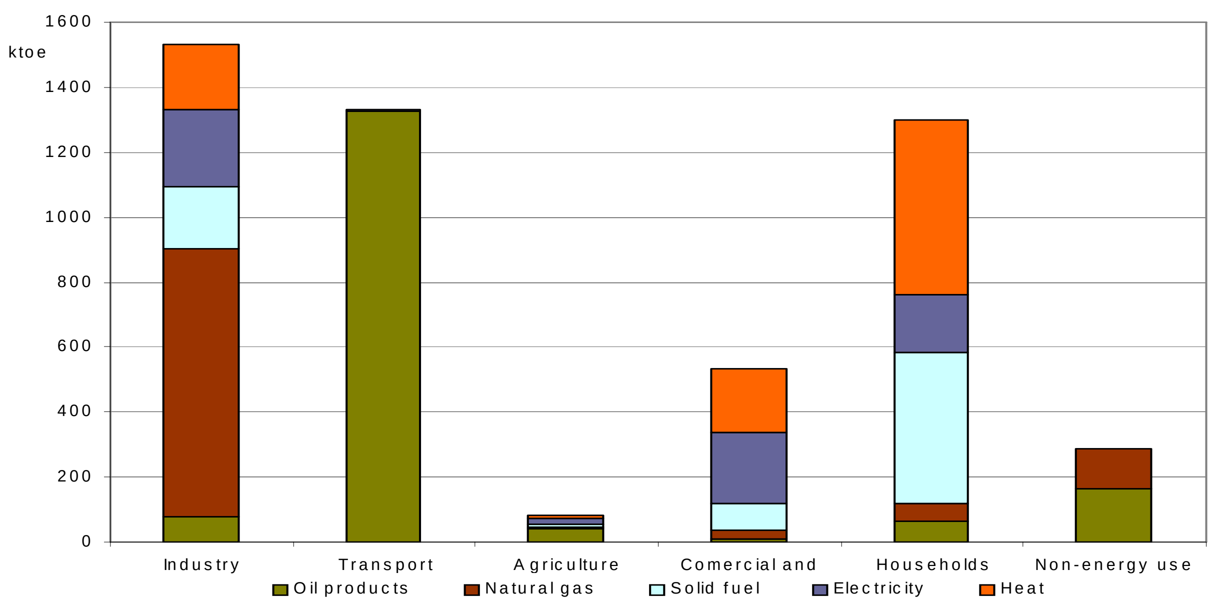

Figure 6 Final energy consumption by type and by sector in 2004 (LEI 2005)

The biggest part of electricity (35%) was consumed by industrial sector, and the largest heat consumer is household sector – 57% of heat was consumed by households. (LEI 2005)

According to the Energy balance 1990-2003, prepared by Lithuanian Department of Statistics (Statistics Lithuania 2004), final energy consumption in Lithuania has decreased approximately 2,5 times between 1990 and 2000 cf. Figure 7. Energy value added has significantly decreased in manufacturing and agriculture and increased in commercial sector (Streimikiene 2005). During the period from 1990 to 2000 electricity consumption has decreased two- and heat consumption three-times. However, according to Klevas & Minkstimas (2004) household and transport are the areas, where intensity of the final energy consumption has increased. In 2002 intensity of final energy in Lithuania was 0,15 toe/1000 (95') USD, it is slightly less than the World's average – 0,16, but higher than e.g. 0,11 in Denmark (IEA 2005a).

With decreased final energy consumption, the efficiency of primary energy consumption for production of final energy has also decreased. The ratio between final energy consumption (FE) and total primary energy supply (PE) expresses the efficiency of energy production, transformation and transportation. For Lithuania this number fluctuated between 0,55 and a little above 0,60 during the last decade, cf. Figure 7. It means that nearly a half of the energy is lost in production and transmission processes. The average ratio in 2002 for the World and OECD was 0,69, in Denmark this number was 0,77 (IEA 2005a). Therefore efficiency of energy systems in the world is by approximately 15% more efficient than in Lithuania.

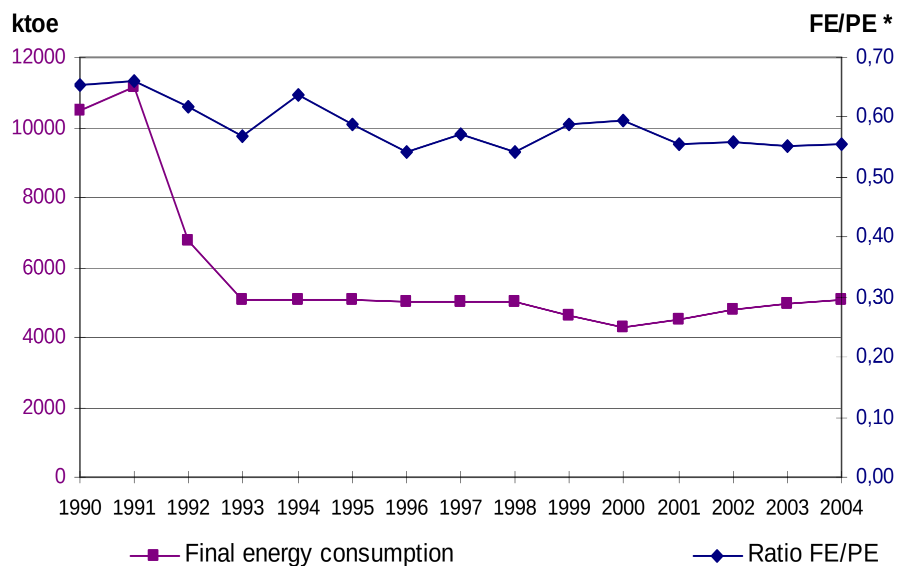

Figure 7 Final energy consumption and efficiency of primary energy consumption (Statistics Lithuania 2004 and LEI 2005)

Another disproportion of Lithuanian energy system is the correlation between the ratio of primary energy supply and GDP and the ratio of the net imports of energy resources and GDP cf. Figure 8.

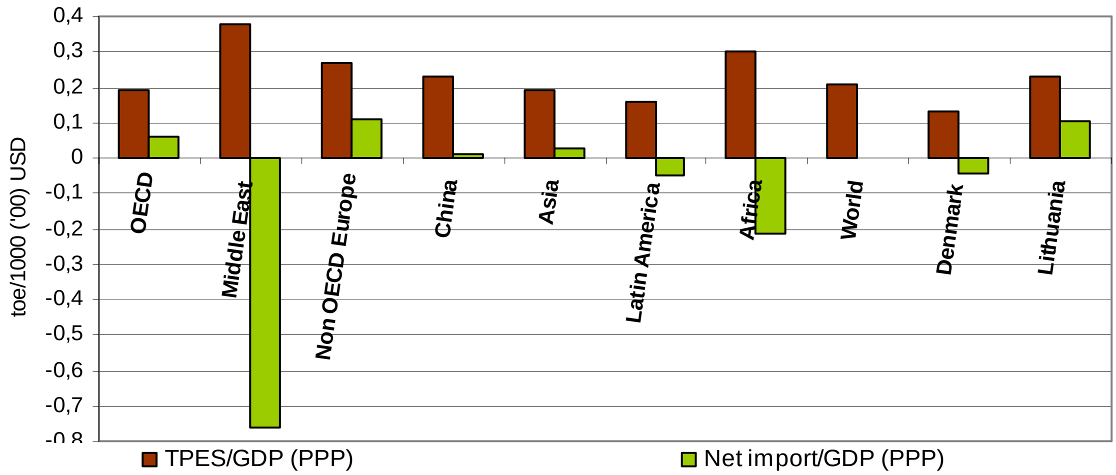

Figure 8 Primary energy supply and net import of energy resources in Lithuania and the World in 2003 (IEA 2005b)

It would be expected that the more energy resources a country has to import, the more efficient is the use of energy in a country. However, both, primary energy intensity and net import in Lithuania, as well as in other non-OECD countries in Europe, is rather high. The ratio between primary energy supply and GDP has a big impact to a country's economy. The Total Primary Energy Supply (TPES) intensity in Lithuania in 2002 was the fourth highest in European Union after Bulgaria, Romania and Estonia and ten times higher than in Denmark and around 6 times higher than EU average (Eurostat 2006). Furthermore, around 0,9 billion Euros (~36%) of Lithuania's foreign trade balance deficit is formed by net import of energy resources to the country (Klevas & Minkstimas 2004).

The main reason of inefficiency of the energy system in Lithuania is overcapacity of electricity and heat production plants and transmission networks. Several large CHP plants most of the time work only as boiler-houses, because most of the electricity demand in the country is covered by the production from Ignalina Nuclear Power Plant (INPP). Furthermore, nearly all companies in the energy sector are monopolistic suppliers (Klevas & Minkstimas 2004). The energy prices are regulated so that *"average cost equal to average revenue, which occurs at the intersection of demand schedule and long-run average cost curve"* (Klevas and Minkstimas 2004, p.311). Additionally, regulated companies have a tendency not to minimise operational costs.

Future energy consumption in Lithuania depends on a number of factors, such as GDP growth rate, structural changes in the country's economy and social factors, energy demand in various sectors, changes in energy efficiency in different sectors of economy etc. According to the medium growth scenario GDP will grow in average by 3,85% annually until the year 2020 (NES 2002). With growing economy energy demands will also increase, but this growth will not have the same rate, as there is a big potential for energy savings – about 27%. The greatest final energy saving potential is in the building sector, where about one third of the consumed thermal energy can be saved. (Klevas & Minkstimas 2004)

For a conclusion here, it should be summarised that the main problems in the Lithuanian energy sector currently are: the high dependency on fossil and uranium primary energy resources (90%), which are imported into the country mainly form Russia; the overcapacity in energy production and supply; the low efficiency in all sectors of energy production, supply and consumption due to overcapacity and neglected maintenance; the uncertainty in future energy consumption due to fast growing economy and large energy saving potential. Particularly, in order to solve these problems, all possibilities to increase energy efficiency, self sufficiency, both with respect to energy, its sources and energy technologies and to decrease environmental impacts from energy sector should be exploited. Thus it is important to find the ways and technologies to exploit all possibilities and utilise the highest possible share of renewable energy potential in the country in order to increase self sufficiency and also the efficiency of the Lithuanian energy sector. Unfortunately, the real physical potential of RE resources in the country has not been evaluated and therefore is not available for the report. Only currently technically feasible renewable energy potential is considered in the literature analysed. Such potential could replace approximately one fifth of the primary energy consumption. Overall it seems that there is a considerable potential of a mixture of different renewable energy resources and sources in the country to replace the fossil and uranium fuels together with energy savings. Additionally, it is reasonable to state that biomass has (one of) the largest RE potential, since agricultural and forest areas comprise over 80% of the country's territory.

ELECTRICITY SECTOR

The Lithuanian electricity sector is dominated by nuclear and thermal power production from Ignalina Nuclear Power Plant (INPP), Lithuanian Thermal Power Plant and a few large-scale combined heat and power plants in larger cities. An important component of

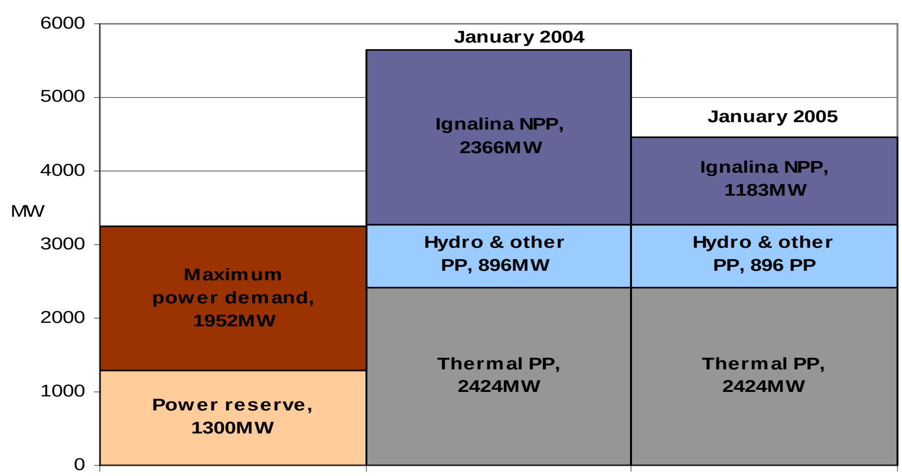

Figure 9 Electricity demand (2004) and disposable capacities (Ministry of Economy 2005)

the country's electricity system is Kruonis Hydro Pump Storage Plant, which helps to make nuclear power production more flexible. Electricity is also produced in large-scale Kaunas Hydro Power Plant and other hydro plants of smaller scale. Another characteristic of the country's energy system is its overcapacity. The installed electricity capacity in 2004 was more than 6000MW, disposable capacity was approximately 5700MW, but maximum power demand together with long term power reserve of 1300MW comprised only 3252MW, cf. Figure 9 (Ministry of Economy 2005). At the end of 2004 the operation of one of the two Nuclear Power Plant's blocks was stopped and the total disposable power capacity in the country remained around 4500MW. The final closure of INPP is expected by the end of 2009.

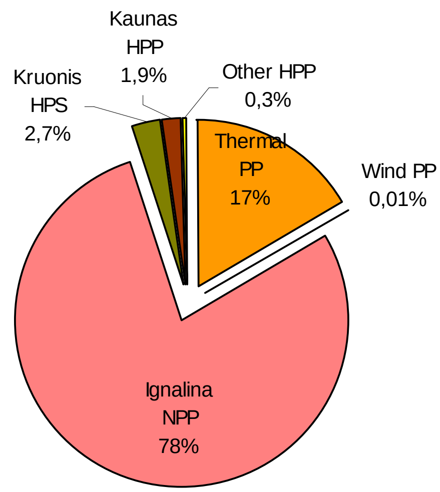

Figure 10 Electricity production structure in 2004 (LEI 2005)

Total electricity production in 2004 amounted to 19274GWh (1658ktoe) and almost 80% of this energy was produced in Ignalina nuclear power plant cf. Figure 10 (LEI 2005). While the capacity of thermal power plants (CHPs) was exploited only as much as local heat demand was – the average exploitation coefficient for CHPs in Vilnius and Kaunas was only around 0,6 (Ministry of Economy 2005).

Renewable electricity production in 2004 amounted to 2,3% of total power production. Around 430GWh (37ktoe) of electricity were produced using renewable sources, such as hydro energy, wind and biomass (Ministry of Economy 2006). Currently the most (~98%) of green electricity is produced using hydro energy – 420,5GWh. The largest hydro electricity producer (359GWh in 2004) is Kaunas HPP – a 100MW capacity hydro power plant. Biomass-based electricity production in 2004 amounted to 7,4GWh (0,64ktoe or 1,7% of renewable electricity). The first wind turbines in Lithuania were introduced in 2004 and produced 1,2GWh (0,10ktoe) of electricity during that year. (Ministry of Economy 2006)

The study, prepared by Danish and Lithuanian consultants and researchers (DEM 2003) was analysing the possible RES potential in Lithuania (see Figure 5) and proposing a scenario of medium utilisation of RES in Lithuania, taking into account technical feasibility of such utilisation. Indicative renewable electricity production targets, primarily for achieving the target of 7 % in electricity consumption in Lithuania, are for hydro-, wind power and biomass-based CHPs. The production of wind power in 2010 is foreseen to amount to 289GWh (850GWh in 2020) and installed capacity 170MW (500MW in 2020).

500MW is considered to be a maximum technically feasible potential which could be exploited without reconstruction of electricity network. The hydro power production is considered to increase to 465GWh in 2010 (577GWh in 2020), and capacities, respectively – 150 (186) MW. According to the study, in order to achieve the target the production of electricity in CHPs, using wood, straw, biogas and municipal waste in 2010 (2020) should account to 180 (282) GWh. Thus installed biomass power capacities should be 23 MW in 2010 and 39MW in 2020. Consequently, in order to achieve the targets, the production of electricity in 2010 should amount to 934GWh and in 2020 – 1709GWh. However, such estimation does not reflect the real possible electricity production from renewable energy resources in Lithuania, and does only include the currently commercially available technologies for power production from RES. Nonetheless, this is the only currently available study, dealing with renewable energy potential in Lithuania. Supposedly, the results of the study were used for preparation of quotas for supported green electricity production (see section 1.3).

The final electricity consumption in 2004 amounted to 40% of total electricity production cf. Figure 11 (LEI 2005). The consumption distributed almost evenly between three sectors – industry, public and commercial sector and the households. Electricity consumption after separation from Soviet Union until the year 2000 decreased by almost 50%. At present Lithuania is lagging behind developed European countries by the comparative indicator of electricity consumption per capita, which in 2003 was 3055kWh/capita – more than 2,5 times lower than OECD average and more than twice lower than in Denmark (IEA 2005a). According to the forecast presented in National Energy Strategy (2002) electricity demand in all sectors of country's economy would increase by 4,3% annually during the period before 2010. Consequently, electricity consumption in the year 2020 will be higher than in the 1990 and will amount to around 13TWh (1118 ktoe) compared to current 7,65 TWh (658ktoe).

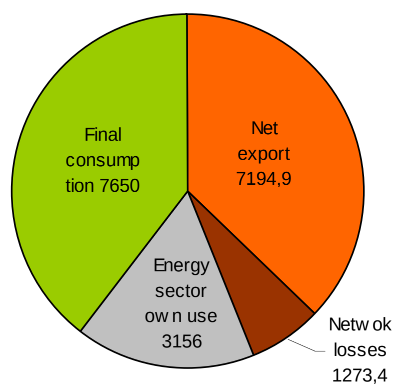

Figure 11 Electricity balance in 2004, GWh (LEI, 2005)

Approximately 37% of electricity produced in 2004 was exported to other countries. Lithuanian 330kV electricity transmission network is a part of the common electricity system, built during Soviet period, which connects Moscow, St. Petersburg, Baltic States, Minsk and Moscow again. Consequently, Lithuania has 1540MW capacity electricity line to Latvia, 1850MW to Belarus and 650MW to Russia Kaliningrad region. More than half of the electricity export was sold to Russia in 2004. (Ministry of Economy, 2005)

ELECTRICITY SECTOR ACTORS AND PRICES

The economic transition to market economy and social transition to a democratic society have resulted in a major restructuring of the economy in Lithuania, including the energy sector. In 1990 the Lithuanian energy sector was separated from the Soviet energy system. The country's energy system (except natural gas sector) was until 1997 recently managed by a single state enterprise. In 1997 this enterprise was reorganised by separating its district heating companies and CHPs in the two largest cities – Vilnius and Kaunas – and transferring the responsibility of them to municipalities. As a result "Lietuvos Energija" – a former state enterprise – became the monopolistic electricity supplier in the country. In the year 2000 Lithuanian Government, seeking to become a member of the EU and following other countries such as Great Britain and Scandinavian countries started the process of reorganisation of the electricity sector. Consequently, the vertically integrated company "Lietuvos Energija" was divided into five independent companies: two electricity production, one transmission and two distribution. After the reorganisation, the supply electricity in Lithuania currently consists of three separate activities – production, supply and transport (transmission and distribution). The actors in the electricity sector are therefore divided into three groups accordingly cf. Figure 12. "Lietuvos Energija" currently performs the role of the transmission system operator and is a monopolist in this sector. This company also exports electricity to other countries.

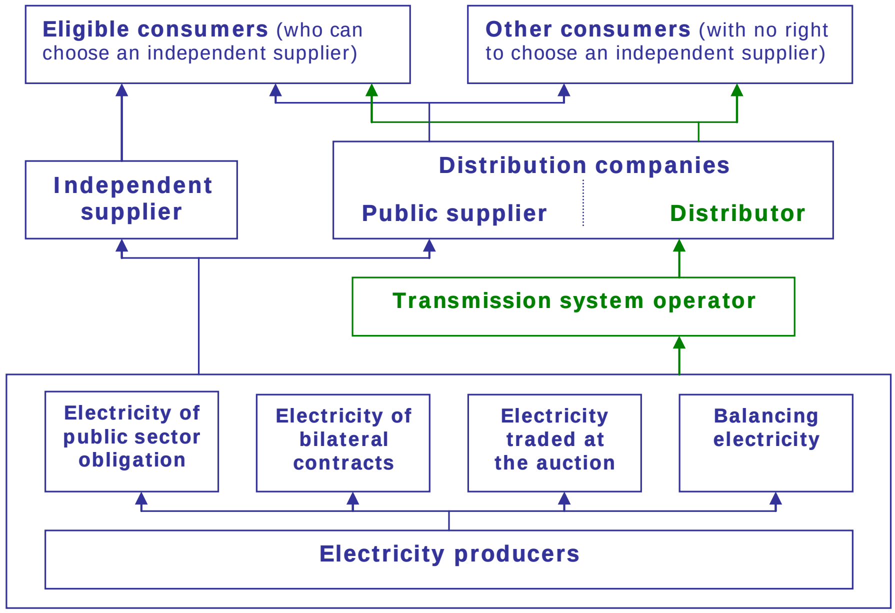

Figure 12 Actors in electricity supply system in Lithuania (based on Lietuvos Energija (2006)

There are two main electricity distribution companies, which are regional monopolists – in Eastern and in Western Lithuania. Distribution companies are also public suppliers and have an obligation to supply electricity to consumers, which can not or have not chosen an independent supplier. In 2004 there were 17 licensed independent suppliers (currently this number is 19), however only 5 were active and were selling electricity to eligible consumers for mutually agreed price. From the 1st of July 2004 the status of eligible consumer was given to all, except residential, consumers, that amounted to 45 000 eligible consumers, however, only 6 of them exploited the right to choose a supplier. Legally electricity market in Lithuania is currently opened by 74 percent. However, only actors that already had this right are active market players. Their electricity demand comprises only 15% from the amount of electricity, supplied to the final consumers. From 2007 all customers in Lithuania will become eligible. (NCC 2005)

Electricity production is the subject for competition in Lithuania. There were 8 electricity producers, competing in the electricity market in 2004. However, it is not a dynamic market, due to high concentration. In 2004 electricity market was dominated by Ignalina NPP. The plant keeps its strong position in the market even after its first block was stopped at the beginning of 2005. Electricity from thermal power plants is mainly sold to independent and public suppliers as Public Sector Obligation (PSO).

INPP generates cheaper electricity than thermal power plants, using fossil fuel. The price of electricity from the nuclear power plant in 2005 was 19,05 EUR/MWh, while average electricity production price in other power plants was expected to be 33,30 EUR /MWh. With Ignalina NPP dominating in spot market electricity prices were quite low and the price volatility was small. (NCC 2005)

The reorganisation of Lithuanian energy sector and the transition to market-based energy sector also included lifting of energy subsidies, and consequently increasing energy prices. Energy prices were subsidised (e.g. cross-subsidies between residential and industrial tariffs) during communist era, and therefore one of the big challenges, of reforms in the energy sector was lifting those subsidies, especially removing subsidies from residential energy prices.

Current organisation allows transparency in the price setting. Electricity price for consumers consists of power production price and delivery price cf. Table 5.

The separation of costs of different activities within electricity supply, allows seeing the separate prices of electricity production and transportation, depending on voltage. An important conclusion can here be made, that electricity, produced by small-scale distributed power plants, which is located close to consumers, can be directly supplied to low voltage distribution network. This means, that the cost for electricity transmission and voltage conversion is saved and small scale power plants can sell their electricity for a higher price without increasing the current overall electricity price for the final consumer.

Table 5 Composition of electricity price for final consumers (NCC 2005)

<table>
<tr><td>EUR/MWh, 2005 (2006)</td><td colspan="4"></td></tr>
<tr><td>Production (average price)</td><td>24,40</td><td rowspan="3">36,00
(35,85)</td><td rowspan="4">56,36
(55,93)</td><td rowspan="5">85,26
(84,05)</td></tr>
<tr><td>Transmission (>110kV)</td><td>10,95</td></tr>
<tr><td>Supply tariff</td><td>0,61</td></tr>
<tr><td>Distribution (35-110kV)</td><td>20,36</td></tr>
<tr><td>Distribution (0,4-35kV)</td><td>28,90</td><td></td><td></td></tr>
</table>

According to the Law on Electricity (LR 2004a) prices of electricity, sold by producers and suppliers shall not be regulated, with exception of the producers and independent suppliers that have more than 25% of the market share. As a result, together with a high market concentration, only a small share of the electricity is bought for the independently agreed price. Furthermore, the price caps for electricity transmission and distribution services are also determined by a public regulatory body. The electricity price setting principles, the prices themselves, the consumer right protection etc. are the functions of the National Control Commission for Prices and Energy (NCC), which is an independent institution, not subordinate to the Government.

Lithuanian electricity supply has the highest dependency on nuclear energy in the world. INPP commenced production in early eighties in order to meet not only national but also regional demands in the former Soviet Union. However, one block of this plant has already been shut down in January 2005, and the plant will be totally shut down in 2009. Consequently, after 2010 the composition of electricity production sources will change. The National Energy Strategy (NES 2002) states that after the closure of the nuclear power plant in order to ensure a reliable electricity supply with low cost, first of all, the capacity of existing (large-scale) thermal power plants based on natural gas will be exploited, and new CHPs of different scales will be built. The use of natural gas in electricity production in Lithuania will therefore increase. In case of significant increase of the prices of imported fossil fuel, the construction of two large-scale hydro power plants is planned. According to the National Energy Strategy the development of the Lithuanian energy sector is based on the continuity of nuclear energy production. Consequently, construction of a new nuclear power plant will be politically, legally and financially supported (NES 2002).

Summarising, the main characteristics of the Lithuanian energy sector they can be classified into problems and possibilities. The main problems in the energy sector currently are:

- the developed powerful nuclear and fossil fuel-based energy production plants (e.g. 80% of disposable electrical capacity in 2005) and related infrastructure, the use of which determines that country highly depends in imported fossil and uranium fuels;
- a large overcapacity of the energy system – the maximum consumer required power capacity comprises only 40% of currently disposable electrical capacity and the available district heating capacities are also only partially exploited;
- a result of partial load on the energy system and neglected maintenance for several years after the break of the Soviet Union is low efficiency in the energy production, supply and consumption This

results in a financially losing operation for some energy companies especially in the district heating sector;

- the low share of renewable energy in the country's energy balance – 8% in primary energy balance or just below 4% of total electricity, consumed in the country.

The positive aspects, or possibilities, of Lithuanian energy sector are:

- a considerable potential of renewable energy resources, which, employing currently available technologies, could cover around 20% of primary energy consumption;
- a well developed district heating infrastructure provides a possibility to develop e.g. combined heat and power plants using local biomass fuel;
- the shutting down of the Nuclear Power Plant might open a door for introduction of other electricity technologies, such as advanced RE technologies.

The problems in the Lithuanian energy sector show the necessity for introducing improvements and the importance of adoption of more efficient energy technologies, which enable the use of local energy resources, such as already commercially available and innovative RE technologies. On the other hand, the problems create a negative and uncertain environment, which is unfavourable for introduction of the advanced renewable energy technologies. Additionally, the economic rationality of least cost and the existing energy production, supply and consumption organisation practices, accustomed to the existing technologies, results in a prioritisation of improvement of the existing technologies, over the introduction of new ones. The possibilities clearly are the entry opportunities for new RE technologies.

1.3 RENEWABLE ENERGY POLICY AND REGULATIONS IN LITHUANIA

The purpose of the section is to describe the Lithuanian national energy strategies, identify policies and regulations concerning renewable energies and other relevant governmental actions in order to present the current regulatory conditions and support for introduction of innovative RE technologies. The focus here is on electricity from renewable energy sources.

Generally speaking, the goals of the energy policy and the governmental intervention instruments, used to reach these goals, create possibilities for introduction of renewable energy technologies into the existing energy sector by helping to overcome different barriers. The economy-wide price instruments are mainly encouraging use of already commercial RE technologies from the shelf, while R&D programs and research funding as well as demonstration project etc. are directed at putting new technologies on the shelf.

The national energy strategy, legal acts and related documents and EU energy regulation are the main sources of information for this section.

ENERGY GOALS

The regulation of energy activities in Lithuania, the basic principals of energy development and management, and energy and energy resource efficiency are defined by the Law on Energy, issued in 2002. Article 3 of the Law defines five objectives of energy sector regulation – one of them is the promotion of consumption of indigenous and renewable energy sources (LR 2002). Consequently, one of the tasks for state and municipal institutions, managing the energy sector, defined by this law, is promotion of renewable and indigenous energy resource consumption.

Another important document defining the development of Lithuanian energy sector is the National Energy Strategy (NES), already mentioned in the previous section. NES sets the overall objectives for the Lithuanian energy sector. The latest (2002) edition of the strategy sets the quantitative renewable energy target – 12% of primary energy in the country should come from renewable energy sources by the year 2010 (NES 2002).

In 2003 the agreement was reached, that, following the requirements of the European Union Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market, Lithuania is committing to the goal that 7% of electricity supply in the country would come from renewable energy sources by the year 2010.

The Governmental Resolution on the Directions of the Heat Sector Development (LR Government 2004a) sets the goal of ensuring that the heat generated from indigenous, renewable and waste energy resources would account for 17% of the total heat generation balance in 2010, and 23% – in 2020.

RENEWABLE ENERGY POLICY MEASURES

Measures for promotion and increase of consumption of renewable energy and therefore implementation of above objectives are provided by different laws, supplementary legal acts, governmental provisions etc. Here the measures will be described mainly for the electricity sector. The promotion measures of renewable resources for heat production will be outlined and promotion of biofuels in Lithuania will be briefly described.

The legal base of activities in the Lithuanian power sector is provided by the Law on Electricity (LR 2004a). One of the objectives of this law is to promote environmentally friendly technologies in generation, transmission and distribution of electricity. For the implementation of the Law on Electricity a number of supplementary legal acts have been issued. The main document on support and promotion of renewables in the electricity sector is the Procedure on Promotion of Generation and Purchase of Electricity Generated Using Renewable and Waste Energy Sources (further – the Procedure)

(LR Government 2001). The Procedure sets criteria, conditions, requirements and instruments for inducement of RES-E production and purchase. This procedure promotes production and purchase of electricity from wind, biomass and solar power as well as using hydro, geothermal and waste energy sources.

The feed-in tariffs for renewable electricity – 5,8ct/kWh for hydro power plants and power plants using biomass for electricity production, and 6,4ct/kWh for wind power plants – were set by the National Control Commission for Prices and Energy in the year 2002 (NCC 2002). The prices of electricity, produced using other renewable energy sources, are to be set by separate National Control Commission's decisions. According to the 2005 amendment of the Procedure these renewable electricity tariffs are valid until the introduction of the Tradable Green Certificate (TGC) system, which is planned in the year 2021, while according to the earlier edition of the Procedure TGC system was going to be introduced in 2010.

Furthermore, the Procedure sets the maximum annual production amounts (quotas) of "green" electricity (by source[1]) to be supported and promoted in the period 2004-2009 cf. Figure 13. Electricity coming from renewable energy sources, but consumed for plants' own needs and electricity produced in Kaunas Hydro Power Plant (large scale HPP) is not supported according to the provisions of the Procedure. The quotas ensure the 7% renewable electricity target for the year 2010, but they do not induce the faster growth rate of green electricity generation. According to the annual RES electricity quotas, the fastest growing production of renewable electricity will come from wind energy and the least amount will come from "other" renewable energy sources, such as solar, geothermal and waste energy.

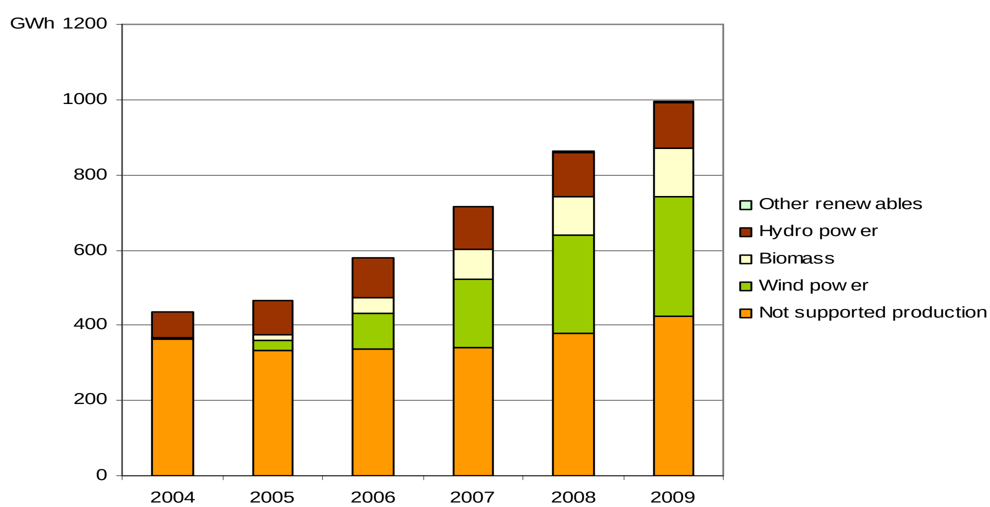

Figure 13 The annual quotas for supported renewable electricity and green electricity production that is not supported in 2004-2009 (Ministry of Economy 2006)

[1] The Procedure also sets certain eligibility criteria for renewable energy power plants to be supported.

It is planned that installed new capacity of wind turbines in 2010 will amount to approximately 200MW within the period; the same of biomass power plants will be ~ 30MW, small scale hydropower plants – 12MW and 4MW for other renewable energy sources (Ministry of Economy 2006). The Procedure also defines wind zones with available capacities and grid connection places in each zone. Maximum 30MW of collective wind turbine capacity is going to be connected to distribution network and the rest 170MW to 110kV and higher voltage electricity transmission lines. (Ministry of Economy 2006)

Furthermore, the Procedure provides renewable energy power plants with a possibility for a 40 % discount on the fee for connection to the electricity grid. Investors who intend to build RES power plants are participating in tenders in order to get a permit to build a plant and produce electricity. Criterion to win the competition is the largest bid for contribution to the plant's connection cost, which has to cover at least 60% of the total connection cost. The cost difference has to be paid by the grid operator. (Ministry of Economy 2006)

According to the Law on Electricity (LR 2004a) the State supports production of electricity from renewable energy sources by charging market, transmission and distributions system operators and electricity suppliers to fulfil public service obligations (PSO). By fulfilling PSO the public and independent electricity suppliers and eligible customers that import electricity are obliged to buy and sell electricity produced from renewable and waste energy resources (LR Government 2001). Additionally, in order to induce and support electricity production using biofuel, pollution from biofuel combustion for electricity generation is exempted from pollution taxes (Ministry of Economy 2006). Implementing the Directive on renewable electricity the Regulations on Provision of Origin Guarantees for Electricity Generated Using Renewable Energy Sources were approved in 2005. The Guarantees of Origin are to be used in order to determine the amount of electricity production from RES and to enable electricity producers to proof that their electricity is generated using renewable resources. (Ministry of Economy 2006)

One of the objectives of the Law on Heat (LR 2003) is to use local and renewable energy sources more extensively for heat production in the country. According to the Law, State and municipalities shall encourage the purchase of heat produced from waste and renewable energy sources into district heating supply systems – it is a Public Service Obligation. Furthermore, municipalities shall prepare heat supply development plans that would be in line with national priorities of the energy sector. For the implementation of national energy strategies in the heat sector, the Government has approved the Directions of the Heat Sector Development (the Directions) (LR Government 2004a). One of the directions in the area of heat generation is to diversify fuels and to accelerate the introduction of technological innovations. More specifically, the Directions provide the following guidelines, concerning RES in heat production: to give priority to indigenous and renewable energy sources, when constructing new or reconstructing existing boiler-houses; and by the year 2010 to construct 2 or 3 small-scale CHP plants, using wood, wood waste, straw and other RES. Finally, according to the Procedure for Purchase of Heat from Independent Producers to Heat Supply Systems (LR Government 2003), heat suppliers have an obligation to buy heat from independent producers if the offered price is lower than own production cost. The Priority shall be given to combined heat and power and heat only plants which use renewable fuel for heat production.

The promotion of the production and use of a specific type of RES is provided in the Law on Biofuel[1], Biofuels for Transport and Bio-oils (LR 2004b). According to the Law, tax (e.g. pollution tax, excise) exemptions shall apply to producers and users of biofuel, biofuels for transport and bio-oils. Furthermore, the production of biofuels shall be assimilated to development of new, environmental-friendly technologies and the status of a pilot project should be given to such activities. Additionally, the Programme for the Promotion of the Production and Use of Biofuel in 2004-2010 was approved by Government in August 2004 (LR Government 2004b). Among other, the tasks of this Programme are: to increase the electricity generation from biogas, wood and straw to 0,204 TWh/year, and the total energy – to 10,31TWh/year; to promote the cultivation and preparation of raw materials for biofuel and scientific research concerning production and use of biofuel and others.

In general there is no direct investment support from state budget for RES electricity plants and only investment project by state institutions, municipalities and other state bodies can be financed from the State's investment program (LEI 2004). Nonetheless, direct state support can be provided to demonstration and pilot projects in the field of renewable energy (Streimikiene et al. 2005). The National Energy Efficiency Program (NEEP 2001) also intends to finance demonstrational renewable energy projects, however, the financing possibilities seem to be not certain, as funds have to be attracted from the state budget, private funds and EU and other foreign assistance programs (LEI 2004). Furthermore, investors into power plants, which generate electricity, using renewable energy sources can apply for support from EU Structural Funds.

The Lithuanian Environmental Investment Fund (LAAIF), funded by 30% of collected pollution taxes, provides soft loans for the financing of projects that reduce the negative impact of economic activities on the environment and subsidies for the financing of renewable energy projects. Additionally, renewable energy projects can receive indirect support from the Small and Medium-size Business

[1] According to the Law, "biofuel" means flammable gaseous, liquid and solid products produced from biomass and used to produce energy.

Development Program, Special Rural Development Program, Rural Credit Guarantee Fund. (Ministry of Economy 2006)

Greenhouse gas emission trading, which has started in 2005, can make renewable energy investment projects more financially attractive. However, so far (from the year 2005 until 2007) only large-scale (>20MW) energy generation plants in Lithuania have been taking part in EU emission trading scheme[1]. Participation of small-scale energy production plants in emission trading is currently considered, when preparing National Greenhouse Gas Emission Allocation Plan for the period 2008-2012. (LAAIF 2006)

There is no prominent R&D program for renewable energy, other than National Energy Efficiency Program (NEEP 2001), which sets forth that Ministry of Economy and Ministry of Science and Education shall promote and support the science research and experimental activities related to energy efficiency and increased usage of renewable energy sources (LEI 2004).

Here conclusion can be made that renewable energy policy instruments in Lithuania are primarily aimed at meeting the near-term RE policy goals (12% of primary energy and 7% of electricity by 2010), given that they are mainly economy wide policy instruments (feed-in tariffs, tax relief etc.). As it was explained in the section 1.1, such policy instruments for meeting near-term renewable energy goals is an important first step in increasing the renewable energy consumption in the country. However, they do not encourage development of new renewable energy technologies. Technology specific policy programmes including support of R&D are needed for introduction of innovative RE technologies.

I will further talk about the drivers behind these goals and policies and the factors determining the existing energy governance when summarising and evaluating the renewable energy situation in Lithuania below.

1.4 Summary - the evaluation of the RE situation in Lithuania

This section will present generalisations and conclusions about renewable energy situation and factors influencing development of renewable energy technologies and increased use of RE sources for energy production in Lithuania. Again, the focus will be on renewable electricity. The assessment will be primarily based on the factors by Reiche and Bechberger (2005), outlined in Table 3 and the above description of Lithuanian energy situation and RE policies. Furthermore, I will analyse actors, and the institutional structures defining their relations to renewable energy development in Lithuania, mainly on the grounds of carried out interviews. The section forms generalisations, which lead to validation of the hypothesis, formulated at the beginning of the research, and to the elaboration of the ultimate research question.

[1] Directive of the European Parliament of the Council 2003/87/EC Establishing a Scheme for Greenhouse Gas Emission Allowance Trading within the Community.

As it was already presented in section 1.2 Table 3, main factors, which influence renewable energy development in a country are **geography and starting position in energy system**, **economic environment**, **politics**, **technology** and **cognitive environment**.

The Geographical position of Lithuania has determined that the country only has a very small amount of fossil resources and "rewarded" the country with highly forested areas and good agricultural conditions (agricultural and forestry covers ~80% of the country's area), a large number of rivers – thus rather big hydro energy potential, extensive geothermal energy resources and solar energy comparable to Germany or Denmark. There is also wind energy potential at the Lithuanian Baltic coast. Moreover, it seems that the real potential of renewable energy sources and resources is higher than described in earlier sections – the description was based on official studies, mainly stating the technically feasible renewable energy potential for the nearest future, and articles based on these studies). Unfortunately, the quantitative data, for the real potential is not available in this report.

The Energy system and in particularly the electricity sector has been mainly dominated by large-scale fossil-, uranium- and hydro-based power plants, since the second part of last century, when the construction of the large thermal power plants began in 1950s. The power overcapacity of around 2500MW until 2005 and current overcapacity of 1250MW until 2009 is one of the important factors discouraging introduction of additional (renewable) electricity capacities. The modernisation of existing large-scale thermal power plants, currently exploited inefficiently, is prioritised for covering the electricity demand after the closure of Ignalina Nuclear Power Plant. The construction of a new NPP is planned for the future. The already existing infrastructure of the "soviet" nuclear power plant, developed electricity transmission network and large electricity storage facility – Kruonis Hydro Pump Storage Plant and willingness to export electricity are the arguments for building a new NPP. The well developed district heating infrastructure throughout the country sets the favourable starting position for e.g. combined heat and power production using biomass. The existing infrastructure can be seen as a good starting position for distributed (renewable) electricity production. Additionally, the low efficiency in energy production, transportation and consumption causes high intensity and thus unreasonably high expenditures for energy consumption and also creates general uncertainty about future energy consumption levels.

It can be generalised that **the economic environment** seems to be unfavourable for renewable energy development, considering subsidies for uranium- and fossil-based energies in the country and the low natural gas price. The mentioned subsidies first of all consist of state covered investment costs when Ignalina NPP and large-scale thermal power plants were constructed during the soviet period – the era of planned economy. Secondly, the infrastructure – gas supply pipelines, electricity transmission and main distribution infrastructure, suitable to the mentioned power producers were also installed in the soviet times. Furthermore, electricity from thermal power plants is supplied as PSO (as electricity produced by power reserve suppliers or CHPs) and they receive the special prices, which are set by National Control Commission – and which are normally higher than average electricity production price. Additionally, the costs for ensuring safety of nuclear power plant work, storage and disposal of nuclear waste are covered as a PSO. Although the price of natural gas, imported from Russia, has increased after Lithuania's separation from the Soviet Union, the current (in 2005) import price is approximately 2,5 times lower than that for Germany and amounted to around 100 USD/1000m^3 (NCC 2005 and Ignotas 2006). Thus fossil fuel prices, so far, were not a driving force for increased use of local and renewable energy sources. However, recently, Russian natural gas supplier "Gazprom" has announced that natural gas price for Lithuania will reach "European" prices i.e. will be the same as for Germany, taking into account the lower transportation cost, in the year 2008. This increase in natural gas prices should encourage more active investments into renewable energy projects, especially in the district heating sector. The internalisation of external environmental costs of fossil-based energy production seems to be marginal. Until the introduction of the Greenhouse Gas Emission Trading system in 2005, CO_2 emissions were not considered to be a type of pollution and were not charged. Although environmental taxation in the energy production was not analysed in the report, the supposition is made, that emission charges so far have not been reflecting the real cost of environmental externalities of fossil-fuel use, while it does not appear as an important factor in the analysed literature. Commitment by the Kyoto Protocol to reduce greenhouse gas emissions by 8% from the level of emissions in 1990 is not an important driver for renewable energy development, as the development of CO_2 since the year 1990 shows that by 2010 Lithuania will not be able to reach the level of 1990 (taking into account the closure of Ignalina NPP, energy consumption increase and other factors) (Ministry of Economy 2006). Implementation of the Joint Implementation Mechanism of the Kyoto Protocol though can contribute to a number of renewable energy projects in the country.

The main **political** goals concerning development of renewable energy in Lithuania – 7% of electricity consumption and 12% in primary energy balance before 2010 – are directly related to the implementation of the EU renewable energy targets. The objective for renewable electricity is the result of negotiations with EU, seeking to ensure that the target will be achievable with existing and new for the country, but yet commercially feasible RE technologies (Jarmokas 2006). Thus it can be said that the main driver for these near-term RE policy goals are commitments to the EU by the Treaty of Accession, 2001/77/EC Directive on renewable electricity etc. It seems that the renewable electricity promotion procedure is designed to meet the 7% target in the cheapest way possible. Renewable electricity feed-in tariffs, set in the year 2002 seem only sufficient to spur investments into the most payable, but yet untapped RE potential such as investments into wind power production by buying used equipment form e.g. Scandinavia (Piesliakas 2006) and converting existing large-scale CHPs for using biomass fuel. In the case of wind power the provided connection cost coverage, by the grid operator, appears not to play its role as bids for covering this cost by producers (investors) often exceed 100% (Piesliakas 2006). According to Dinica's (2006) classification of policy support instruments for encouragement of investments into renewable energy projects, based on risk and profitability potential of the instruments c.f. section 1.1, RES-E support procedure and thus investment context in Lithuania (for more advanced RE technologies), without in-depth analysis, could be placed in between "Political" and "Minimal" investment contexts with low/moderate profitability and respectively low/moderate and high/very high risk. Usually such support instruments are created to minimise the public/consumer financial load and might be a result of symbolic policy (Dinica, 2006). Although renewable energy goals should be seen as measures to achieve important national goals, such as security of energy supply by reducing the dependence on imported fossil fuel and development of rural areas, the securing of low energy prices for consumers seems to have a higher priority in Lithuanian energy politics. The likely reason is the government's unwillingness to risk making unpopular decision, which could increase energy prices[1] and deter potential voters. On the other hand, meeting current and future commitments to the EU has also a high priority, not only when it comes to national energy policy, but also in other sectors. The energy policy directions, provided by EU energy regulations, are likely to reduce the regulatory risks for investors in RE projects created by the transition process from centrally planned to market economy, frequently changing governments and becoming a member of the EU.

As it was already mentioned, there is practically no support for R&D in renewable energy technologies in Lithuania. The reason for that might be the country's weak innovation system and innovation policy in general. The renewable energy promotion measures in Lithuania are mainly economy wide instruments for encouraging use of RE technologies from the shelf. Furthermore, the most of the renewable **technologies** are being picked not from the "national shelf", but imported from other countries (Balciunas 2006), although – and most importantly – there seems to be a scientific and productive potential as well as willingness to develop and produce also more advanced renewable energy technologies.

There are no green political parties in the Lithuanian Parliament currently. The neo-classical way of thinking economics and strong believe in market forces dominates the state administration as well as

[1] Especially when energy prices have significantly increased, since Lithuania reestablished its independence form Soviet Union, due to lifted cross-subsidies in energy sector.

the energy sector regulation and renewable energy governance, responsibility of which lies within Ministry of Economy. The current near-term RE goals and their implementation program, obviously have a positive effect on renewable energy situation in the country. During the past five years new actors, in favour of renewable energy have emerged in Lithuania. The Lithuanian Association for Biofuel Producers and Suppliers (LITBIOMA) and Lithuanian Wind Energy Association are actively lobbying trough their interests and, at the same time, creating awareness on the governmental level. The activities of economically independent actors, such as grassroots organisation Renewable Energy Information Consultation Centre (ATEIK) and the Centre of Renewable Energy Technologies at Kaunas University of Technology are important for raising the seemingly low public awareness of renewable energy and its advantages as well as changing the dominating thought and believe in advantages of large-scale fossil fuel and uranium energy supply. However, it should be said that the latter actors are marginal, and thus do not have a strong voice and need to attract more members and funding in order to be able to spread renewable energy discourse and influence the politics of renewable energy.

Further, I will attempt to present the institutional (regulative, normative, cognitive) structures behind the energy, namely, renewable energy situation in Lithuania, based on the collected and analyzed information, interviews with different actors and some assumptions about Lithuanian culture (mentality). It should be noted that this view was formed when searching for favourable factors for renewable energy development in Lithuania.

Table 6 Institutional elements behind renewable energy situation in Lithuania (based on Scott (2001)

Regulative Pillar	Normative Pillar	Cognitive Pillar
- Kyoto Protocol - Commitments to the EU according Treaty of accession - EU Renewable Energy policy goals and regulations - Nuclear energy safety requirements - Various international standards - National Energy Strategy goals - National energy legislation - National environmental legislation - Agricultural legislation - Free market laws	- The use of renewable energy should be increased in order to reduce fuel imports and environmental pollution - Lithuania has to meet international energy and environmental commitments - Lithuania has to comply/obey the EU policies and regulations - The free market should be ensured in the energy sector, including RE governance - Energy prices for consumers should not be raised - Cost-efficiency must be ensured when promoting renewable energies (least cost approach) - Taxes in the country should be reduced - Environment should be protected from possible adverse effects from e.g. hydro or wind turbines and extensive forest use	- RE can not replace fossil-fuel based energy and thus is not a competition for conventional power plants - Lithuania has poor renewable energy resources - There are not many technically feasible technologies - RE technologies are expensive - Increase of RE support and share in energy production will cause increase in energy prices - RE is not marketable – consumers would not be willing to pay more for green energy - Due to the high volatility of some of the RE sources they are unreliable and difficult to use - There is no scientific and productive potential for developing advanced RE technologies in Lithuania - Lithuania RE producers can benefit form advances made in R&D in other countries - Nuclear power is cheap - Lobbyism for renewable energy is simply an attempt to increase profits of RE producers - Nobody is lobbying for conventional energy - Aversion for high state intervention - As long as international commitments are met – it means there is done enough to promote renewable energy

This outline of rules, norms and cognitive believes concerning (renewable) energies in Lithuania shows and helps understanding the behaviour and rationality of different actors in the energy sector in Lithuania. Particularly cognitive elements impose the constraints on more active support of renewable energies and by some groups (e.g. politicians) might be used as empowerment, guidelines or justification, for only a marginal development of RE.

Additionally, *"institutions are transmitted by various types of carriers, including symbolic systems, relational systems, routines, and artifacts."* (Scott, 2001, p.48) The following carriers of the current approach on the (renewable) energy system development can be identified in Lithuania (based on Hvelplund (2005): at the **symbolic** level it is the way of thinking that the stable economic future can be achieved through "the invisible hand of the market" and aversion for socialist planned economy, with which public regulation in the energy system is often identified; on the **artifact** level the carriers are the existing energy system structure in the country with large-scale centralised electricity production in thermal power plants and nuclear plant with necessary infrastructure, specialists and employees that keeps the thought of conventional energy production; talking about **relation system** as carrier the possible close relations between public administration and conventional energy companies should be mentioned as well as the fact that long-time employees in fossil energy companies are currently leaders of state departments and divisions, responsible for renewable energy policies and support schemes; and finally, the **routine** carrier keeps the conventional energy generation by "you do as you are used to do", the "usual" way of generating electricity in Lithuania is firstly in thermal power plants, large-hydro and the nuclear power plant.

As a result of the description and analysis of (renewable) energy situation in Lithuania, the overall conclusions can be made on the existing difficulties as well as entry possibilities for introduction and development of innovative RE technologies in the existing technical, political, economic and social cognitive context of energy system in the country. The main difficulties are:

DIFFICULTY 1: The domination of the strong developed infrastructure for large-scale fossil fuel- uranium- and large hydro-based energy technologies, which currently offer a surplus of capacity and seek to keep their shares in the Lithuanian electricity supply system.

DIFFICULTY 2: The overcapacity and poor maintenance resulting in low efficiency of energy production, supply and consumption, together with growing energy consumption cause uncertainty about the future energy demands. The prioritisation of improvement of existing technological system set aside the consideration of introduction of new, renewable energy technologies.

DIFFICULTY 3: Ignorance and disregard of real potential of renewable energy resources and sources in the country and unavailability of alternative technological scenarios for introduction and development of innovative renewable energy technologies.

DIFFICULTY 4: The economic disadvantage of advanced RE technologies – low prices of energy coming from conventional technologies, low fossil fuel prices, regulatory failure to internalise e.g. environmental externalities (no CO_2 taxes), which could reflect the advantages of renewable energy technologies etc.

DIFFICULTY 5: Lithuanian RE policy, policy goals and regulatory instruments do not create favourable conditions for development of innovative RE technologies. The RE support scheme mainly encourages usage of technically and economically feasible in Lithuania "technologies from the shelf". The conditions for new technologies can be described by weak innovation policy in the country, political prioritisation of low energy prices for consumers and reactive position of compliance with EU policies and regulations as well as other international agreements.

DIFFICULTY 6: Unfavourable social cognitive environment: dominating thought of and confidence in advantages of large-scale fossil- and uranium-based energy supply; absence of influential actors, who would see the long-term benefits of e.g. R&D programs for the development of new renewable energy technologies, and who would understand the price dynamics of new technologies as they mature.

The favourable factors (possibilities), which might open some doors for introduction of new RE technologies, so to speak, are several:

POSSIBILITY 1: The existing good potential for renewable energy production – a variety of available renewable energy resources and sources: biomass, hydro, wind, solar etc.

POSSIBILITY 2: The shutting down of the nuclear power plant – a possibility to introduce new, renewable electricity capacities.

POSSIBILITY 3: The existing infrastructure, such as district heating systems, which could be used for development of certain RE technologies e.g. biomass for combined heat and power production.

POSSIBILITY 4: Positive developments in renewable energy resource consumption when implementing the near-term RE goals and the emergence of first actors (private and public voluntary organisations) in favour of renewable energy.

Having described the difficulties and possibilities for penetration of innovative RE technologies into Lithuanian energy sector, in the next section I will come back to the initial hypothesis and the research question in order to complete the first cycle of the study.

1.5 THE RESEARCH QUESTION

The research has started with an initial hypothesis, that it is difficult to introduce innovations in the form of advanced renewable energy technologies into the Lithuanian energy system and, consequently, the initiatives to carry out these innovations are poor. Also it was supposed that current RE policies and regulations in Lithuania do not foster development of advanced renewable energy technologies in the country. The conclusions of the analysis of the Lithuanian energy sector have confirmed the initial presumptions. Although increased introduction and use of RE technologies could significantly contribute to the solution of the energy sector problems and bring additional advantages, the current possibilities to adopt advanced renewable technologies are scarce (see the above summary of difficulties and possibilities).

Hence, it is important to create the possibilities and to help overcome the difficulties, for innovation of renewable energy technologies in Lithuania, in order to improve the energy system. Consequently this report suggests that development of immature and innovation of new renewable energy technologies should be more actively promoted and supported by different actors in Lithuania, first of all, by the government. In order to give recommendations for the governmental actions the following research question is formulated: ***how should renewable energy innovation policy in Lithuania be created in order to become an innovator of RE technologies?***

The search for the answer for the research question in carried out in the second part of the report. It is suggested that the special niches, existing or newly created should be used for initial application and development of new RE technologies, in order to eliminate the difficulties created by resistance of existing technological systems and to enable innovative technologies to penetrate the energy system gradually. Since technological scenario for (advanced) RE technologies is not available for the report (and was not within the scope of the report), an introduction and development of biomass gasification technology is described and analysed, as an example of a proposed strategy, in Part 2.

Part 2 RENEWABLE ENERGY TECHNOLOGY INNOVATION POLICY

The second part of the report is looking for ways to open the doors and create the niches for penetration of advanced renewable energy technologies into the Lithuanian energy system. For that reason a better understanding of the technology concept, innovation and change processes, and the fundamental reasons for resistance from the existing energy systems against the introduction of new technologies is needed. The analysis of the theoretical approach behind technology, innovation and change brings into attention the notions of radical technological change, which is usually brought by innovations, and the technological path dependency of existing systems. The conflict between them seems to cause the difficulties for introduction of innovative technologies. The question is how to overcome the conflict, to alleviate the difficulties and to exploit the potential of more advanced technologies? A possible perspective to expedite the introduction of new technologies – strategic niche creation and management approach – is therefore presented.

As it was described in the first part of the report, Lithuania has a considerable potential of biomass energy resources. There exist a number of different technological possibilities for utilisation of the potential and production of renewable final energy, which are presented in this part of the report. It is suggested to introduce an advanced biomass gasification technology for combined heat and power production in the district heating sector in Lithuania. However, as it is explained later in this part, the dominating technological regime in the Lithuanian energy sector is path dependent and resisting to introduce changes, such as advanced RE technologies. Therefore, for introduction and development of these technologies, the presented niche management strategy as the RE innovation policy approach is suggested and further described, based on the biomass gasification-CHP technology case.

2.1 TECHNOLOGY, INNOVATION AND CHANGE

This section sets a conceptual framework for analysis of (RE) technology, innovation process and technological change in the energy sector. An important notion of radical technological change and path dependency is explained in the section. The theoretical background of the technological innovation and change helps understanding the primary reasons behind the resistance and difficulties for introduction of innovations, and enables to find a way to overcome these difficulties. Finally, the strategy for creating and managing niches as protected breeding spaces for new technologies is proposed. The main principals and steps for creation and management of such niches are described and further serve as a methodology for a niche approach-based innovative RE policy strategy.

CONCEPTUALISING TECHNOLOGY

There are many different definitions of technology. Some of them are general and others depend on the context (e.g. energy technologies). Technology can be seen as *"the way society appropriates nature"* (Lorentzen 1988, p.12). In other words – technology *"is one of the basic solutions to the satisfaction of human needs"* (Muller 2003, p.27) and it *"is one of the means by which mankind reproduces and expands its living conditions"* (Muller 2003, p. 29). These definitions also show close relationship between technology and society – technology is embedded in society and society is the vital factor for existence of technology.

Another way of defining technology it as a combination of the following constituents: **Technique**, **Knowledge**, **Organisation** and **Product** (Muller 2003). These four components comprise the frame of any technology. Each constituent of technology is equally important and can be analysed separately from each other. Nonetheless, interaction between the four elements is very important when analysing technology. Indeed, the four interacting variables of technology should be in focus when the objective is to trigger technological change, or when the process of technological change is analysed (Muller 2003). Although technology is seen as a static combination of a number of elements, it is, in fact, dynamic. It means not only that technology goes through certain phases during its lifetime, but also that each component includes certain processes. Therefore, it can be said that technology also includes several simultaneous processes.

The **technique** part of technology is made up of all the hardware and the physical labour process, which is used for the transformation or consumption of raw materials, energy and other inputs. In other words, technique is the way in which labour, tools (in a wider sense) and materials (also in a wider sense) are brought together in the working process (Lorentzen 1988). The processes, that constitute a dynamic side of technique, are consumption, transformation and production. (Lorentzen 1988 and Muller 2003)

Knowledge is a soft component of technology (Lorentzen 1988). This constituent of technology includes theoretical kind of knowledge (applied science), the knowledge acquired empirically, trough experience (skills), and the tacit knowledge and intuition (spontaneous creativity). The most obvious knowledge is the knowledge related to a person e.g. qualifications of labour force (in a broad sense), whether it is scientific or professional expertise or practical skills. However, there is a large portion of human knowledge and abilities that is transferred to hardware – machinery and tools, e.g. the scientific knowledge and creativity of technology designers. Thus the knowledge component of technology reflects the scientific approach, the ideology behind the creation and development of a particular technology (Lorentzen 1988). Knowledge is a searching-learning, learning by doing process of a technology, which includes processing of all kinds of information. Additionally, knowledge can be considered as a key for controlling technology.

An important element of technology that brings together hardware, resources, labour force and knowledge into a certain production process – is **organisation**. Organisation is characterised by pattern of specialisation, division of labour and cooperation. It includes planning, management and coordination. Organisation involves all kinds of communication processes. (Muller 2003)

Product is an immediate result of the combination of the technique, knowledge, organisation and their concomitant processes. The product – an integral component of technology – is not the end of a technological process, but rather the purpose. Product (material or immaterial) is often chosen before the other constituents of technology and yet is formed by technique, knowledge and organisation that are employed for its production (Muller 2003). The product reflects features of the other components of technology. Therefore, even if a product of different combinations of techniques, knowledge and organisation seems to be the same it *"always reflects the conditions under which it has been produced"* (Lorentzen 1988, p.20). Further, the product constituent of technology has a use-value and therefore enters the consumption process. Besides use-value, product carries exchange-value (Muller 2003). An exchange-value attribute of a product is an important factor in the technology process – it influences all four of the elements of technology and also depends on the chosen technique, knowledge, organisation and product. An exchange-value supposedly brings profit, which also is a driving force for specific formation of most technologies.

An important concept, when talking about technology is infrastructure. It is not a part of technology, but rather something that technology relies on or is covered by. Infrastructure has physical (roads, electricity transmission lines, communication installations etc.) and institutional, organisational (educational organisations, health facilities, recreational installations etc.) elements (Muller 2003). Infrastructure facilitates connection of what is geographically and socially divided and provides reproduction of labour force, knowledge etc.

The above presented view of technology and its four elements describes technology from a micro-level i.e. at company perspective. Technology can though be analysed at various levels such as industrial branches, local or national levels. Further I will present other views on technology that are broader and focus more on the dynamic side of technology – development and change.

Another, way of describing and analysing technology is as a system which includes the following elements: natural resources, physical artefacts, organisational arrangements and legislative (regulatory) artefacts (Tsoutsos & Stamboulis 2005). All these elements form the system through their interaction, and therefore the features and behaviour of the whole technological system emerge from this interaction.

Each element of the system evolves simultaneously with the rest of the elements. Furthermore, over time a technological system manages to incorporate environment into the system, thus eliminating various uncertainties e.g. adaption to existing market conditions. Changes within the system take place through identification of critical problems (e.g. in one of the elements), which bring internal contradictions between interacting elements of the technological system. The contradictions occur, because substantial improvements of the system are prevented by inertia of the other elements. The development and change of the system builds on previous technical and organisational choices and arrangements, and therefore is path dependent[1] and creates a technological paradigm. (Tsoutsos & Stamboulis 2005)

Kemp et al. (1998) describe technological paradigm as consisting of *"an exemplar – an artefact that is to be developed and improved – and a set of (search) heuristics, or engineering approaches, based on technicians' ideas and believes about where to go, what problems to solve and what sort of knowledge to draw on"* (Kemp et al. 1998, p.181). However, this approach does not show the complete picture of technological dynamism – it only focuses on the cognitive aspect of technological change and does not include other (social) factors. Further Kemp et al. (1998) talk about a broader, socially embedded version of a technological paradigm – technological regime. A technological regime can be described as "technology specific context of technology", which includes *"the whole complex of scientific knowledges, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology"* (Kemp et al. 1998, p.182). A technological regime is a dynamic and ever-changing system – there are always tensions between the elements and a need for improvements. Technological changes are here seen as processes within a technological regime and according to the logic that is imposed by a combination of certain rules and beliefs, embedded in certain technological regime.

However, certain issues emerging within (or related to) certain technological system can not be resolved by building on an existing technological regime – radical technological changes have to be made. New technologies have to be invented and new techno-economic spaces have to be created. In the next section I will outline the stages of technological innovation and discuss peculiarities of this process.

PROCESS OF TECHNOLOGICAL INNOVATION AND SOCIAL ACTORS

[1] I will come back to the subject of technological path dependency later in this chapter.

Innovation in general can be described as a process that transforms ideas into commercial value. It is a development over time from invention over modification and adoption to diffusion. Inventions are the new ways of doing old or new activities, which are further modified in order to be suitable for adoption, and finally modified inventions are disseminated during the process of diffusion (Sanden & Azar 2005).
According to Muller (2003), in order to be realised, technological innovation must pass trough the following five phases: **basic research**, **development**, **formation**, **application** and finally **consumption**.
The initial phase of innovation process, **basic research**, is related to all four elements of technology, and is constituted by science in a broad sense. The focus of the **development** phase is on development of new technological concepts and production of knowledge element of technology from different fields of basic research. During the **formation** phase the theoretical knowledge is turned into concrete technical solutions – it is here the technique is formed. Further, in the **application** phase actual functioning and use of technique is organised into a particular mode of operation – a prototype. Finally a product of combination of knowledge, technique and organisation materialises in the **consumption** phase, either as a final product, or as an input to another production process. (Lorentzen 1988 and Muller 2003)
The process of technological innovation is the process of selection, where choices are being made at every phase, described above. These choices are based on social interests, economic considerations, social and cultural values etc. The choice of technology is more than the choice of a technological solution in the application phase or choice of a product in the consumption phase of the innovation process. *"If you want to influence the way the ready to use technology is going to be, there is no other way than to try to influence the direction of technological innovation at the higher levels as well."* (Lorentzen 1988, p.25) It should also be noted, that innovation process is not linear, but rather a dynamic and iterative process with feedbacks between different innovation phases.
An important precondition for the technological innovation process is the existence of so-called social actors of technology, which are involved in the process and are interested in forming and promoting technology. The functions of the actors differ and depend on the phase of the technological innovation process, they are involved in. According to Lorentzen (1988), actors, involved in the basic research, development and formation phases, are relatively independent from the actual production sector. Hence, in their choices they may follow other interests than e.g. socio-economic consideration, such as professional or scientific interests. However, the choices and efforts that these actors make do not have a direct impact in society until the technology in question is carried into the production area and put into function. Lorentzen (1988) calls actors that are involved in the process of application or introduction of a new-formed technique – social carriers of technology. Social carriers seek to pursue their interests and

by doing so they *"represent a "demand pull" to the early phases of technological innovation which stimulate a certain direction of the efforts and the funds dedicated to them"* (Lorentzen 1988, p.30). A social entity must fulfil six conditions – interest, power, organisation, information, access and knowledge – before it can act as a social carrier of a certain technology. Social actor must be interested in obtaining and operating the technology as well as have power (economic, social and political) to realize these interests. The social actor must also be organised to exercise the power and to formulate and establish the necessary conditions to apply the technology. Furthermore, the social entity must have sufficient information about existing technological options, access to the technology in question and knowledge about the technology and how to operate it, i.e. how to handle the four elements of it. (Lorentzen 1988 and Muller 2003)

It should be noted that the six conditions do not have the same significance – first three (interest, power and organisation) are more important than the last ones. Supposedly it should be possible to obtain information, access and knowledge once the conditions of interest, power and organisation are fulfilled. It can be said that possession of interest, power and organisation determines, who can become social carriers of a particular technology. Social actors that have interest in implementing a technology, but are not fulfilling some or all the rest of the conditions, and therefore can not realise their intentions, are called potential social carriers of technology. There are two possibilities for these actors to implement their interests – to cooperate with other potential carriers and complement each other, or to get public support (especially if their interests have a political priority).

Further, there can be distinguished social carriers of technology on micro- and macro-levels[1]. Social carriers on micro-level are e.g. a single engineer, a company, a cooperative or a trade union. They act to pursue their specific interests for example interest of a private company to maximise profit by increasing efficiency of resource use. At this level social carriers have to take the surrounding conditions as given (e.g. infrastructure, competition) and to choose and adopt technologies that can function in the given circumstances, unless a social actor is very powerful (e.g. a trade union). Furthermore, only actors with large resources can enter the early phases of innovation. The carriers at macro-level are state and other organisations representing national interests. The higher the level of social aggregation the more of resources, in terms of organisational strength and financial and human resources, social carriers possess. Usually social carriers at macro-level are able to enter and influence technological innovation process at its early stages and thus form a technology according to their

[1] At supra-level (international level) there can be found social carriers of technology as well, but I will limit myself here to the national (macro-) level.

interests. They are also able to adjust the surrounding conditions for new technologies e.g. through infrastructural innovations and changes. (Lorentzen 1988)

Furthermore, Lorentzen (1988) suggests that social carriers of technology represent the primary source of change. Technological changes are triggered by changes related to these social actors, such as changing interests, resources etc., and changing relations between existing social carriers or emergence of new ones. Innovations that have not entered the application phase but have passed through basic research, development and formation phases are only the potentials for technological change. And only when, by social carriers, an innovation is brought to the application phase, the innovation enters the process of (radical) technological change.

In the next section I will further analyse the process of technological change, triggered by technological innovations and will explain the notion of radical technological change. Most importantly, in the next section, the reasons behind the resistance of certain technological systems (regimes) towards and the difficulties for introduction of new technologies, which is an important question in the search for ways to bring in an innovative technology, will be explained.

RADICAL TECHNOLOGICAL CHANGE AND PATH DEPENDENCY

Technological changes of a non-radical type are aimed at optimisation of a technological regime rather than its transformation (Kemp et al 1998). Thus, technological changes, that are aimed at transformation of a technological regime i.e. changes, that are beyond the rules and beliefs of the regime, are radical technological changes.

Hvelplund (2005) compares radical technological change with a process of changing the technological path. As mentioned earlier, technological change is path-dependent when it builds on previous choices. According to Kemp et al. (1998) an important characteristic of a technological paradigm is the existence of a “core technological framework” which sets the starting point and directions for improvements. These types of developments of (and within) a technological regime follow the existing dominant mode of thought, which is build on accumulated experience and knowledge about the technology and thus are path-dependent. Consequently changes of (and within) a technological regime that do not follow that path are considered as radical changes. Radical changes are difficult to implement, because they require a new path.

However, technological path dependency is not based only on accumulated learning of a specific technology, but also on economic, social and political bindings. Sanden and Azar (2005) talk about mechanisms that reinforce technology lock-in by moulding the surrounding technical, institutional and behavioural environment, ones a technology has been adopted, cf. Table 7.

Table 7 Technology lock-in mechanisms (Sanden & Azar 2005)

Technological interrelatedness	Technology becomes interrelated to other technologies in the production chain. Upstream, technology becomes depended on industries, supplying inputs and the industries depend on the growth of the technology. Downstream, adopted technology defines the range of other technologies that consumers will use. New technologies need to be compatible with the old set otherwise the whole set needs to be changed.
Vested interests	Private sector has fixed costs related to the adopted technology that need to be recovered, and has invested in the knowledge base (sunk cost). Workers have invested in education and located their living in relation with work places, and academics have made the carrier, based on the specific knowledge, related to the adopted technology. Moreover, the users have also invested in learning and, furthermore, designed their lives according to the new technology.
Bounded rationality	The diffusion of the adopted technology influences, what different social groups (e.g. engineers) think the artefact (e.g. power plant) should look like. The narrowed understanding of what is the main purpose of the technology, how it should be designed, which kind of materials it should be made of and how it should be assessed etc. limit the imagination of engineers and consumers, and the vision of business managers.
Directed education and research	The public funds are spent on educating skilled labour and creating new academic disciplines that provide knowledge in order to enhance technological progress in an area.
Legal frameworks	The legal frameworks are designed to fit the use of the adopted technology. These technology specific legal frameworks may effectively lock out new technologies. If groups that advocate existing technology because of vested interests and bounded rationality have enough power, they can also bound rationality of other groups and in that way affect how legal framework are further designed and how public funds are used.

Technology lock-in mechanisms can be seen both – as the mechanisms behind path-dependency that creates difficulties for introduction of new technologies, and as the results of the successful introduction of a new technology.

However, at the beginning the introduction of new technology is an uncertain process, i.e. the production costs are high, the users and investors are uncertain about the technology and hesitate to invest. Tsoutsos & Stamboulis (2005) summarize eight types of barriers for the shift towards renewable technologies in energy system[1]: technological factors, government policy and regulatory framework, cultural and psychological factors, demand factors, production factors, infrastructure and maintenance, undesirable social and environmental effects of new technologies and economic factors. This slows down the technology adoption process, which receives positive feedbacks for further development of a technology. Sanden & Azar (2005) describe feedback mechanisms that can decrease production cost and make technology more attractive for users and investors. An increased production volume will decrease the fixed cost per production unit and also will enable an increased division of labour. Learning by doing and learning by using can give a positive feedback in terms of revised and refined production processes and organisation, increased skills of workers, increased performance-to-cost ratio and better suiting the needs of consumers. Furthermore, the technology growth may also result in use of by-products, value of which would decrease the production cost. The wider adoption of a technology will also gradually decrease uncertainty among users and investors, especially when users get

[1] These factors have already been presented in the section 1.1, when presenting possible barriers for renewable energy development.

experience with the technology, performance of the technology increases and technology service cost decreases. Finally, the more users using the technology, the higher availability and the lower the cost of complementary goods and maintenance services, the more attractive the technology seems for potential users. (Sanden & Azar 2005)

The stages of commercial maturity of a technology should also be mentioned. They are used by Foxon et al. (2005) for identification of, where e.g. a national innovation system fails moving technology along the innovation chain, and what prevents successful commercialisation of a technology. The considered stages of technology maturity are as follows: (1) basic and applied, university and industry R&D, (2) demonstration stage, where full working devices (early prototypes) are installed in single units, and which are financed mainly trough R&D funds, (3) at pre-commercial stage, a large number of technology units are installed for the first time (investment risks are high here) (4) supported commercial is the stage, where commercially oriented companies invest in a technology, given renewable support (fiscal incentives), and finally, (4) at commercial stage the technology can compete unsupported, given adequate regulatory framework. (Foxon et al. 2005)

However, a number of cognitive, technological, economic, and social cognitive factors that create barriers for new technologies along with resistance from existing technological systems should be overcome before adoption and diffusion can begin and positive feedback to adoption can be received. According to Tsoutsos & Stamboulis (2005) the most challenging route to take, when carrying out technological change, is to consider and treat the adoption and diffusion of new technology as a process of substitution of exiting technology. This is the way, along which resistance from old technologies would probably be the strongest and they (existing technologies) would be in highly advantageous position comparing to a new technology. Therefore the introduction of a new technology and the focus on its performance should be carried out on a new territory, where barriers and resistance would be minimal, and entrenched technologies would not have advantages (Tsoutsos & Stamboulis 2005). Moreover, an adoption process can not begin if a technological innovation is not carried by social actors, which are interested in adoption of the technology and fulfil the six conditions for becoming actual carriers of technology (see section describing process of technological innovation). In certain cases the potential carriers of technology are not able to fulfil all the conditions, needed for carrying a specific technology, and therefore have to cooperate and form coalitions. For that purpose a certain space or platform for communication is needed.

Kemp et al. (1998) outline the four most common aspects of technological regime shifts, caused by introduction of innovations: (1) new technologies give rise to managerial and user-supplier relationship changes; (2) the importance of a specialised application of a new technology in the early phases of development; (3) the importance of availability and cost of complementary techniques and changes in related technologies, and; (4) the constantly changing social beliefs, perception and views on a new technology. Furthermore, domains or niches for application are important for the initial take-off and further development of a new technology. They help demonstrating the viability of a new technology and provide financial means for further development; furthermore, they help to build a constituency behind a new technology and to set in motion interactive learning process and institutional adaptation. The process of a niche formation and success of a niche for the development of new technology depend on both, processes within a niche and outside it. (Kemp et al. 1998) Hence, the process of technological change is a complex process which is influenced by and influences the existing technological systems and social practices. *"The problem is to manage the change process (...) without creating transition problems."* (Kemp et al. 1998, p.184) This is primarily a task for policy-makers. Kemp et al. (1998) suggest the strategy for governments, which is aimed at creating room for experimentation and variation of a new technology, at learning about problems, needs and possibilities and keeping a technological change going in desirable directions – strategic niche management.

Next section will present a definition and the aims of strategic niche management – a technology specific policy strategy, the rationality behind this strategy and its advantages for introduction and development of new technologies in the path dependent technological environment. The main steps, processes and other important aspects of technological niche formation and management will be described.

NICHE CREATION AND MANAGEMENT

The purpose of this section is to form a framework for creating and managing a niche for introduction and development of new technologies in the existing path dependent technological environment. The description below should serve as a methodology for niche approach-based innovative RE policy scheme, which will be explored later in the report. The section is based on Kemp et al. (1998) article "Regime shifts to sustainability through process of niche formation: the approach of strategic niche management".

The definition of strategic niche management, proposed by Kemp et al. (1998, p.186) is as follows: *"Strategic niche management (SNM) is the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology."* The processes of strategic niche management strive to create conditions for a new technology development, which would not be constrained by existing path dependencies and different other barriers. The aims of strategic niche management more specifically are:

- to articulate changes in technology and in institutional and organisational settings that are necessary for economical viability and success of a new technology;
- to learn more about the technical and economical feasibility, environmental benefits and social desirability of the new technology in focus;
- to stimulate further development of a new technology, to achieve cost efficiency, and to promote the development of complementary technologies and skills by bringing together knowledge and expertise of both supply and demand side actors, and by economies of scale and other positive feedbacks to the adoption of the technology;
- to build a constituency behind a technology, to form a community of practice within and across institutions – private companies, research institutions, public authorities and other organisations, in other words, to bring together existing and potential social carriers of technology, whose actions are highly important for further diffusion of the technology.

Strategic niche management as a policy scheme consists of five steps – **choice of technology**, **selection of an experiment**, **set-up of the experiment**, **scaling up of the experiment** and **removing protection** from new techno-economic space. Through implementation of these five steps, strategic niche management must contribute to three key processes that are necessary for implementation of the primary aims of strategic niche management – **coupling of expectations**, **articulation** and **network formation**.

The process of **coupling of expectations** is important for attracting more actors on the side of a new technology. In order to create awareness of a technology and its advantages social actors (or social carriers) make promises about the technology. Promises should be supported by facts and tests, specific and coupled to certain societal problems, which are not expected to be solved by the existing technologies. In this way actors will translate their expectations to other actors and engage in cooperation. Clearly, the attention has to be paid to the implementation of the promises.

The **articulation process** is important for learning more about barriers for new technology and how they may be overcome. Articulation will contribute to a reduction of uncertainties and help alter the perceptions of a new technology. Articulation of the following is particularly important: technical aspects and design specifications, existing and necessary governmental policy, cultural and psychological meaning of a new technology, the market, productions network, infrastructure and the maintenance network and social and environmental effects of the new technology.

The formation of a niche for a new technology also requires the **formation** of a new actor **network**. A network of actors, interested in development of new technology can be a very powerful social carrier of technology, as described earlier. Public authorities could help to bring together actors into such networks and help to create and articulate the vision of a sector and the strategies of the different social actors – technology developers, investors, regulators and users.

I will further elaborate on the five steps and discuss the role of government and other actors in strategic niche management.

The choice of technology. Technological change is usually related to a (social) problem that can not be solved within the existing technological system (regime). Thus, clearly, technologies that are appropriate for support through strategic niche management are outside existing technological systems (regimes) but able to alleviate certain social problems, such as environmental degradation. Further, a new technology should fulfil the technological-scientific precondition – technology must have potential for overcoming initial limitations and for branching and extension, i.e. for further technological development. Another criterion for technology to be eligible for support trough strategic niche management is fulfilment of the economic precondition, which means that a new technology must *"exhibit temporal increasing returns or learning economies"* (Kemp et al. 1998, p.187). Technology must also be consistent with viable forms of management and organisation and compatible with important needs and values of users – the managerial and institutional precondition. The additional precondition, which makes it easier to create a niche for a new technology is the existence of certain applications of the technology, where advantages are highly valued and therefore disadvantages count less. The selection of a technology should however not be entirely (or blindly) based on mentioned criteria and therefore not only technologies that obviously fulfil the preconditions should be considered eligible for support. Strategic niche management has to allow and explore a variety of technological options rather than creating constraints and focusing only on certain specific technology.

The selection of an experiment is basically the selection of the area of application for a new technology. It can be e.g. a certain application, a geographical area or a jurisdictional unit. It is important for the area of experiment that the advantages of the technology are valued highly (e.g. because of specific problem like local pollution) and thus disadvantages (such as high cost or created discomfort) do not seem significant. Kemp et al. (1998, p.187) notes that *"there are almost always areas and types of application for which the new technology is attractive"*.

The set-up of the experiment. The most important in this step is to find and keep the balance between protection and selection pressure. It means that technology developers should be encouraged to improve new technology taking into account user requirement and to eliminate negative side-effects connected with increased application of the technology. However, the pressure (e.g. time pressures) should not be too strong, because that might push technology developers to make decisions, based on short term benefits instead of having a long-term perspective.

The policy of niche management should be based on and directed against the existing economic, technical and/or social and institutional barriers. The management of a certain niche may e.g. include the following elements: the formulation of long-term goals, the creation of an actor network and strengthening the positions of social carriers of a technology, creation of technical standards and establishment and use of regulatory instruments (e.g. economic instruments).

Scaling up the experiment is the expansion of adoption of a new technology by means of policy – a governmental support in the form of preferential treatment. The questions here are: how far governments should go supporting a specific technology and who should carry the cost of the support?

Finally, **the breakdown of protection** is carried out when support for a new technology is no longer necessary, or when the results of the experiment are disappointing and prospects are dim.

Different kind of actors – regulatory authorities, non-governmental organisations, private companies, industry organisations, special interest groups or an independent individual – might be the actual niche managers if they posses qualifications, needed to take on this task, which may differ from niche to niche. It should be noted that niche management policies have to be the result of a collective negotiations and interactions between different actors. The role of a government though is central, because a government as a social carrier of technology is supposed to be very powerful and resourceful, and it can therefore contribute to niche formation by taking on roles, which it can do better than other actors. Ultimately, *"governments have a special role as an enabler or facilitator to make sure that something happens, and that the project yields satisfactory results (which requires monitoring, evaluation of outcomes and policies and, in case of undesirable outcomes, the judicious exertion of pressure and the correction of adverse actions and policies)"* (Kemp et al. 1998, p.189). The role of a government on different levels is also different – local governments can be more directly engaged in niche management, while governments on national or regional levels should ensure a broad social learning process through e.g. social discourses and disseminating the knowledge that has been gathered throughout experiments. Furthermore governments on a higher level could help, either through direct sponsorship or different policies, to scale-up successful experiments.

Thus, strategic niche management is a package of policies and measures for learning about, articulating and dealing with possibilities, needs, problems and combinations of external barriers for new technology. The described strategic niche management approach is a recommended approach for the renewable energy innovation policy in Lithuania. The outlined above are the important aspect that should be taken into consideration, when forming such policy framework.

Further the more specific analysis of a technological innovation and change as well as strategic niche management approach for the Lithuanian case is carried out. It starts with describing the selected advanced renewable energy technology – biomass gasification technology – in the next section.

2.2 Technology description – Biomass Gasification

Biomass is one of the key opportunities on shorter and medium term to mitigate greenhouse gas emissions and substitute fossil fuel (Faaij 2006). Firstly because biomass is CO_2 emission free and a renewable energy resource, when adequate resource management practices are followed. Secondly, biomass is more widely available than fossil fuel. Additionally, use of biomass offers social benefits, such as enhanced rural development and employment. However, while in e.g. Asia the use of biomass appears to exceed sustainable consumption, in the rest of the world and namely in industrialised countries, the utilisation of this energy resource is much lower than the potential c.f. Figure 14 (Gross et al. 2003).

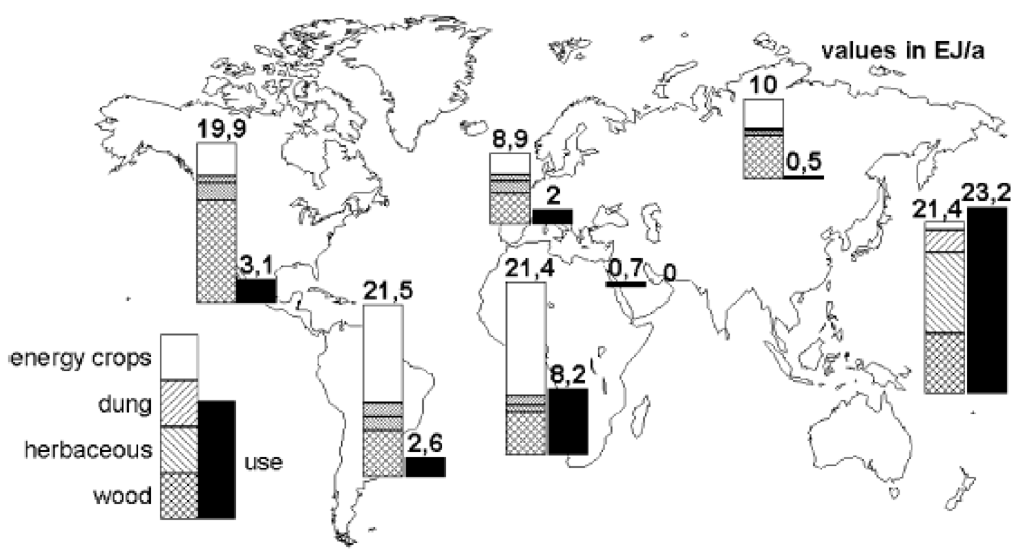

Figure 14 Biomass use and potential around the world (Gross et al. 2003)

The most utilised renewable energy potential in Lithuania is biomass energy resource (~660 ktoe in 2002) c.f. Figure 5. However, a considerable part of the biomass potential still remains untapped and, according to the rough estimations, the real physical potential of this resource could amount to approximately 1250 ktoe, which could contribute to approximately 14% of primary energy supply, or cover nearly 80% of the final electricity and heat consumption. Moreover, forests and agricultural areas cover a considerable part of Lithuania’s territory and have an important place in the country’s economy as well as traditions and culture. Consequently, biomass energy in Lithuania is considered to have good prospective, although currently available technologies do not allow an effective exploitation of the existing potential.

Energy from biomass resources presents a complex picture. First of all, there exists a broad array of biomass resources, such as fuel wood, various residues from forest, wood processing or other industries, agricultural residues etc. Furthermore, a wide variety of technologies are available for energy production from biomass for different applications, and some technologies are more developed than others.

Possible technological paths that can be followed for generation of heat, electricity and (transport) fuels are presented in Figure 15. The conversion of biomass into different forms of energy can be separated into two basic categories – thermochemical and biochemical/biological processes. Thermochemical processes include combustion, which produces heat and mechanical power/electricity; gasification is the conversion of solid biomass into a combustible gas, while pyrolysis produces bio-oil, charcoal and gas. The main biochemical conversion options are fermentation that is used to produce ethanol from biomass containing sugar, and digestion, which is the conversion of biomass into biogas. And finally, by mechanical extraction processes, energy in form of bio-diesel is produced. Various factors, such as type and quantity of available biomass resources, end-use applications of produced energy, environmental standards, economic conditions, development stage and availability of technology etc., influence the choice of conversion process. (Caputo et al. 2005)

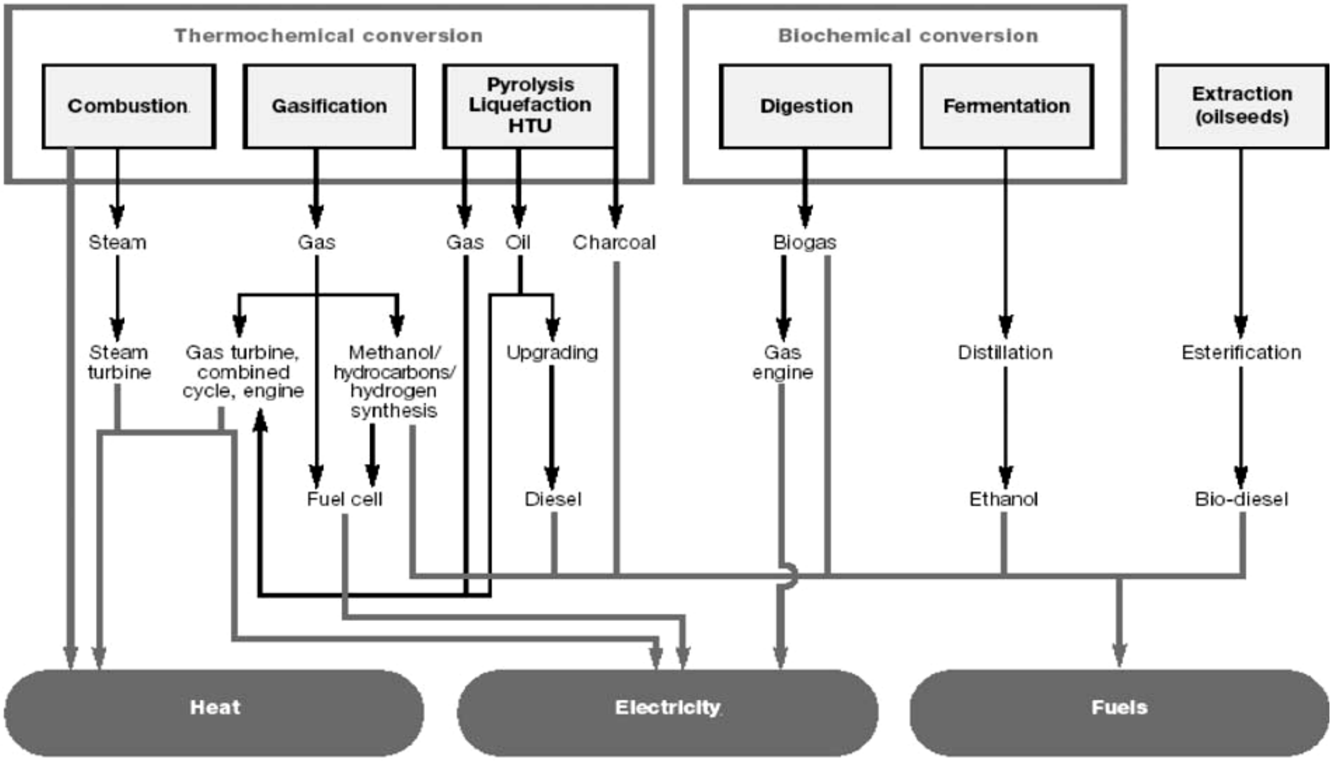

Figure 15 Main options for conversion of biomass to secondary energy carriers (Faaij 2006)

In the following sections I will focus on biomass gasification process as a more advanced alternative to combustion, enabling the use of more flexible, efficient and cleaner production of electricity and heat. The available technological combinations for energy production, based on biomass gasification and levels of commercialisation of different technological solutions will be described. Furthermore, I will describe the technological system for combined heat and power production based on biomass gasification which will be used as a case further in the report.

GENERAL PROCESS DESCRIPTION AND TECHNIQUES OF BIOMASS GASIFICATION TECHNOLOGY

The production of a combustible gas from materials, containing carbon is already an old technology. The main principle of gasification process was first commercially practiced in 1812 when London city's gas company started the production of so-called producer gas. The biomass conversion process and the gasification techniques were further developed and adapted for different solid fuels. Gasifiers were in use in specific industrial power and heat applications until 1920 when oil for energy production gradually took over the market. During World War II gasifier systems for automotive applications were used in Europe and other regions. After the War, the widespread availability of inexpensive liquid fuels again pushed out gasification technology. A renewed interest in gasification technology again emerged during the energy crisis of the 1970s. Until today the technology has been further developed and the emphasis currently is on heat and electricity production based on biomass gasification. However, biomass gasification is more popular in developing than developed countries. (Gasnet 2006)

Process and techniques

Biomass Gasification is a thermochemical process of solid biomass fuel conversion into a combustible mixture, called producer gas. Solid biomass such as firewood or agro-residues contains carbon, hydrogen, oxygen and a certain amount of moisture. The gasification process involves partial combustion of biomass under certain controlled conditions – high temperatures and low oxygen supply – which produces a combustible gas mixture of carbon monoxide (~20%), hydrogen (~20%), methane (~3%), carbon dioxide (~10%), nitrogen, some amounts of higher hydrocarbons, water and various contaminants such as small char particles, ash, tars and oils. Producer gas is characterised by low calorific value, usually 4,5-6 MJ/m^3 (Stassen & Knoef), compared to natural gas, which amounts to 33,5 MJ/m^3, and can substitute natural gas or liquid fuel in e.g. internal combustion engines or gas turbines, which makes gasification very appealing.

A gasification device itself is rather simple, compared to the gasification process, and consists of usually cylindrical container (made of fire bricks, steel or concrete) with space for fuel, air inlet, gas exit and grate. The whole gasification system includes more devices – for feedstock preparation, cleaning and cooling of producer gas and equipment, converting the gas into different energy forms cf. Figure 16.

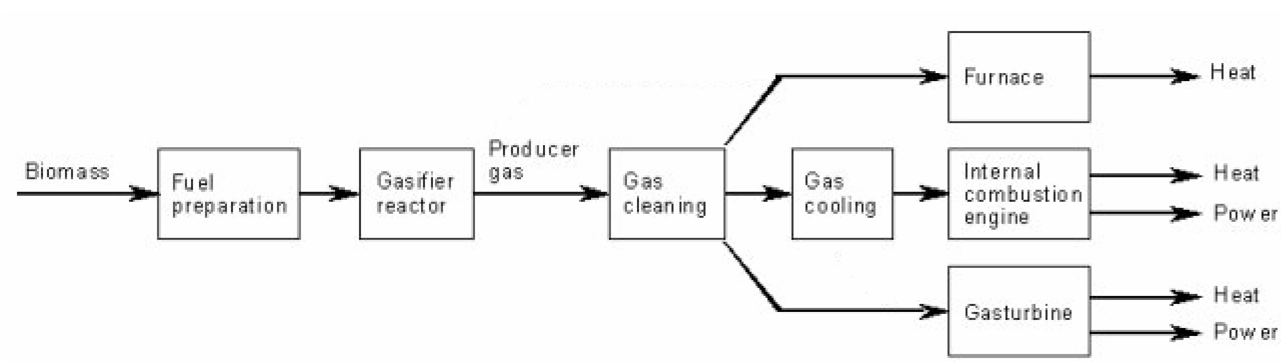

Figure 16 Biomass gasification system (Gasnet 2006)

A wide array of biomass resources can be used for gasification – wood, charcoal, sawdust, agricultural residues etc. The properties of fuel such as surface, size, shape, moisture content, volatile matter and carbon content are important for the gasification process. There are certain requirements for the feedstock properties, depending on the type of gasifier reactor, consequently supplied biomass has to be prepared – dried, sized, screened etc. There are several types of reactors, depending on fuel used, capacity etc. Small-scale gasifiers (up to couple of megawatts) are all of the “fixed bed” type, and depending on the direction of the gas flow in the reactor the gasifiers are up-draft, down-draft or cross (horizontal)-draft. For larger capacities (often more than 10 MW) “fluidised bed” gratifiers are used. Next, before the producer gas can be used for further conversion it has to be cleaned from tars, alkaline metals and dust. Gas turbines and engines require more or less tar- and dust-free gas, while boilers for heat production are not that sensitive to these types of impurities. (Gasnet 2006) At the current stage of technology development the efficient removal of contaminants, particularly tar, from gasifier gas still remains the main technical barrier for the successful commercialisation of biomass gasification technologies (EUBIA 2006).

Figure 15 presents a wide range of possibilities for use of the producer gas. The gaseous fuel can be used in boilers, for production of heat, and in gas engines or gas turbines for generation of electricity. Alternatively the producer gas can be used to produce methanol and hydrogen, which can further be used in fuel cells or micro-turbines. (Gross et al. 2003) All these technologies are at different development stages and therefore offer different energy production cost, which consequently influence the deployment rate of the technologies. The producer gas is mostly intended for immediate use on site and the gasification device is an integral part of the heat or power generating plant. Gasification technologies for heat and power production can be divided into three groups: heat gasifiers, smaller scale power (usually combustion engine) gasifiers and larger scale power (usually gas turbine) gasifiers. Heat gasifiers with capacities ranging from less than 100 kW to a few MW have proven as commercially established (Faaij 2006). The use of producer gas allows relatively higher efficiencies when compared to conventional (combustion) alternatives. Other advantage is lower NOx emissions, when using biomass gasification instead of combustion. (Gasnet 2006) The potential markets for heat gasifiers also include retrofits for oil fired boilers for heat production. According to Faaij (2006) although heat gasifiers are commercially available and deployed their total contribution to energy production is very limited. Further in the report I will focus on the biomass gasification-based technologies for power production.

In the small size units for power production producer gas is mostly used in combustion engines, and combined heat and power production (CHP) is possible using such technology. At the end of the eighties and in the beginning of the nineties down-draft or up-draft fixed bed gasifiers with capacities up to several megawatts received major support. They were undergoing a development and testing for small-scale power and heat production using combustion engines worldwide and in Europe (Faaij 2006). The removal of tars and other contaminants from the producer gas remains a problem for gasification technology producers, as engine manufacturers *“have not been able to design and construct more* *robust engines, which can tolerate some tar in the gas.“* (EUBIA 2006) Producer gas for combustion engine must be almost free of dust and tar, in order to minimise wear and maintenance expenditures of the engine. Tars can for instance condense and clog up the gas supply lines and accumulate on the engine valves. (Gasnet 2006) That is the major reason, why despite the continuing work, investments and demonstration projects the concept of small-scale gasification-based power production by combustion engine have had so far few if any breakthroughs. The small scale electricity production based on biomass gasification has a technological potential for further development. Moreover, the advanced gasification systems using fuel cells and micro-turbines could mean a breakthrough for small-scale power gasifiers. However, such systems require both, further development of fuel cell and micro-turbine technologies and major advances in producer gas cleaning. (Faaij 2006)

Another type of power gasifiers is of a larger scale (several 10s MW and more) and is associated with the fluidised bed gasification process and gas turbine technologies (Faaij 2006). The heat in flue gases, exiting gas turbine, can be used to produce steam, which further can be used in the same gas turbine or a steam turbine. Further, the waste heat can be used for heating purposes. Such concept is called Biomass Integrated Gasification/Combined Cycle (BIG/CC). BIG/CC technology combines the flexibility in terms of fuel used and relatively high electrical efficiencies(40-50%) when using solid biomass and on a larger scale electrical capacities (from ~ 30 MW). The technology is currently at demonstration stage. In Europe the interest in this technology and the subsequent research and demonstration projects started in mid-nineties. Capital cost of the first generation BIG/CC proved to be very high, which is a major barrier not only for entering the commercialisation stage, but also a discouraging factor to continue development of the technology through demonstration projects. Nevertheless, according to Faaij (2006), in a longer term BIG/CC is capable of producing power from biomass at a competitive price level. However, various demonstration projects have been terminated and, consequently, further development of BIG/CC technology has stalled. (Faaij 2006) The main technological issue that needs to be resolved is efficient producer gas pre-treatment and tar removal, which requires further improvement of both, gas turbine and gas purification technologies. However, the gas turbine manufacturers do not wish to develop more robust turbines that could withstand some impurities in the gas because the market for such power gasifiers is still very small. Hence, it is the gasification industry that has to solve the problem and improve gas cleaning technologies. (EUBIA 2006)

Another possibility for the application of biomass gasification technology is co-firing with coal or natural gas. This option could significantly enlarge the market for biomass gasification technology, since the overall costs are relatively low due to existence of the power cycle in both coal- and gas-fired power plants (EUBIA 2006). So far this application of gasification technology has not been demonstrated anywhere (Faaij 2006), nevertheless it could be an opportunity for introduction of biomass gasification technology into the existing energy systems.

Summarizing, the overall advantages of gasification technology for power generation – why this technology is worth further improvements for ultimate commercialisation – are as follows:

- first of all the conversion of solid biomass into gaseous fuel gives the advantages of using combustible gas, e.g. clean combustion (lower NOx emissions when using producer gas rather than combusting solid biomass), compact burning equipment;
- the use of gasification technology in CHP plant enables employment of gas engine or gas turbine that offer a higher electrical efficiencies than steam turbine, which is used when the fuel is solid biomass;
- technology has a significant potential for further development and branching;
- also biomass gasification enables use of local fuels for electricity generation and contributes to the creation of local small- and medium- size industries in rural areas;
- small-scale biomass gasification-based combined heat and power production can contribute to distributed supply of renewable electricity.

However, further research and development work, implementation of demonstration projects, and more experience with the technology are critical for successful commercialisation and diffusion of this technology.

Further in the report I will focus on the small-scale combined heat and power production, based on biomass gasification technology. Namely such technology is recommended to be introduced in Lithuanian energy sector (district heating sector) as an innovative renewable energy technology. This suggestion is further used as an example for describing the creation and management of a niche as a policy approach for development of new RE technologies in Lithuania.

TECHNOLOGY DESCRIPTION

For further discussions an example of a 2MWe combined heat and power production in a gas engine with biomass gasification technology will be used. The description of the technology in this section is based on the article “Small scale gasification systems” by Stassen & Knoef, where, as an example, 2MW electricity CHP with fixed bed gasification technique is analysed. Hereinafter the system will be described as a combination of earlier presented technique, knowledge, organisation and product cf. section, 2.1. Further, the innovation stage and technological maturity of biomass gasification-based small-scale CHP plant will be identified.

The technique of the CHP consists of the fuel preparation, gasification, electricity generation and heat recovery units. The feedstock preparation requires drying, sizing and densification equipment. Storage might also be needed if biomass fuel is supplied irregularly[1]. Further the prepared biomass is supplied to an updraft or downdraft gasifier with an ash container, where combustible gas is produced. Before the producer gas can be used in a gas engine it has to be treated (cleaned and cooled) in order to meet the quality requirements, which, as mentioned earlier, are very high. The gas treatment equipment includes a cyclone for dust removal, tar cracker (if updraft gasifier is used) and scrubber, which cools down the gas and removes the final impurities from the producer gas, such as tar, soot/dust particles, ammonia, H_2S, chlorides etc., by spraying water into the gas stream. Additionally treatment of the water from the scrubber is needed for removal of tar, before the water can be disposed. The treatments of producer gas as well as waste water are costly processes. Moreover, the tar cracking is still in a development stage. The next processes are electricity generation in the gas engine and generator unit and the heat production in heat recovery unit. The capacities and efficiencies of CHP gasification system are presented in Table 8.

Table 8 Performance efficiencies of CHP gasification system (Stassen & Knoef)

Unit	Downdraft	Updraft
Electrical capacity, MWe	2	2
Thermal capacity, MWth	3,7	5,5
Fuel capacity, MWf	8	10
Hot gas gasifier efficiency, %	90	95
Cold gas gasifier efficiency, %	75	60
Engine electric efficiency, %	35	
Engine thermal efficiency, %	45	
Generator efficiency, %	97	
Bruto electric efficiency, %	25	20
Efficiency of heat recovery from gas cooling, %	80	
Bruto thermal efficiency, %	46	55
Bruto total efficiency, %	71	75

Consequently, the processes which constitute the dynamic side of the power gasifier technique are consumption of feedstock (e.g. woodchips), its pre-treatment and transformation into combustible gas, and further transformation of gas, producing electricity and heat. Apart from the supply of fuel, other inputs to CHP gasifier are process water and electricity. Additionally, to the mentioned equipment, process control devices/automatics are also a part of the technique of the plant.

The knowledge element of the biomass gasification-based CHP can be divided into theoretical knowledge and practical knowledge, gained tough experience. Theoretical knowledge for the gasification part of the system is for instance thermal engineering, thermal chemistry, material science, and mechanical engineering; for designing and running the engine knowledge of electrical engineering is needed in addition to mechanical and thermal engineering. For control of the smooth and consistent

[1] Biomass fuel production and transportation is not included into CHP system here, though is an important part of the overall concept of distributed (decentralised) electricity production from biomass.

work of the system knowledge of electronics (control) is needed. Thus, for an overall theoretical knowledge behind biomass gasifier-CHP system a highly interdisciplinary cooperation and knowledge exchange is important. Although gasification of solid fuel is a century-old technology and internal combustion engine was first time applied in industry almost 200 years ago (Wikipedia 2006), the concept of small scale gasification linked to gas or diesel engines never took off (Faaij 2006). Consequently practical knowledge and skills, linked to the gasification-based CHP technology are scarce, as the most of implemented gasification-CHP projects have been of demonstration purpose and operation (hence learning by doing) of such power plants did not continue. It seems that most of the knowledge is accumulated in researchers and scientists and not the practitioners.

Next, for a power plant to be constructed and started an adequate organisation is needed. The theoretical knowledge should be organised into technique – the physical biomass gasification-based CHP plant. Further, the fuel supply and storage has to be organised and handled – manpower is needed. To run the plant continuously several operators and a maintenance staff are needed along with a manager and financial administrator. Since power gasifiers are still of a prototypical character and the performance of a power plant seems to be sensitive to rather small changes in various (e.g. fuel) parameters, technical and operational problems can be expected. For that reason the willingness and great dedication (motivation) of plant managers and operators to keep the plant working, and cooperation with- as well as commitment of- technique manufacturers to assist local operators in solving the problem is critical. Furthermore, communication between the manufacturers of different elements of technique and the CHP plant personnel as well as fuel producers and suppliers is important. Clearly, the personnel must be sufficiently trained; failure to do that might result in poor operation of the power gasifier plant and exposure to health and safety hazards (e.g. toxic emissions such as CO).

The ultimate products from a biomass based CHP plant are electricity and heat. Further, heat and electricity is supplied to consumers – large and small industries for further production or smaller scale consumers for e.g. space heating and functioning for household or office electronic devices. The final use value of the power gasifier products is practically the same as of electricity produced in large-scale fossil fuel or uranium-based power plants and heat produced in e.g. oil or coal using boilers. For this reason the products from different power plants seem to be the same and the general perception is that their exchange-value, i.e. the prise should also be the same. However, as it was explained earlier, in the section 2.1, a product reflects the production conditions i.e. the characteristics of used technology. Biomass CHP gasifier produces “green” heat and electricity, using advanced technology in a small-scale plant. While large-scale conventional energy plant produces e.g. fossil fuel-based electricity and/or heat. Consequently the products from these two types of plants are different; hence, the exchange values should also be different.

Additionally to power and heat, biomass gasification-based CHP produces ash residues, tar, and gaseous emissions. If not adequately controlled, these wastes could lead to negative environmental impacts. On the other hand, tar and ashes could also be used as an input in other production processes (e.g. ashes could be used in construction materials).

The above description shows a complex picture of the small-scale (2MWe) biomass gasification-based CHP technology with gas engine. In principal the technology has passed trough all five phases of innovation, outlined in section 2.1 – basic research, development, formation, application and consumption, since all four elements of the technology are formed and organised into a production of final energy. Moreover, the technology has been under development for a century and a number of commercial small-scale power gasifier systems had been carried out globally (mostly in developing countries). Nonetheless, innovation is a nonlinear process, where feedbacks from experience with technology are transferred to earlier innovation phases. The current experiences with fixed bed biomass gasifier-gas engine technology have showed the following status and need for further work:

- Major R&D work is needed in order to solve several issues, such as improving producer gas cleaning, especially efficient tar removal, developing more robust engines for use of producer gas, increasing stability of gasifier performance, advancement of automation of the process etc.;
- Technology is at demonstration stage and further implementation of (demonstration) projects is important for testing and demonstration of R&D improvements, receiving the feedbacks from users and further development;
- Development of practical skills and experience for operation and maintenance of the technology is central;
- The equipment manufacture lines and biomass fuel preparation lines, and other complementary techniques need to be developed;
- Technology seems to have future development potentials, e.g. for using biomass gasification technology with fuel cell or mictro-turbine technology.

The biomass gasification-gas engine technology has not been introduced into the Lithuanian energy system, with an exception of one experimental installation in a wood processing factory. Nonetheless the adoption and development of this technology considering a high potential for biomass production and well developed district heating sector is recommended as one of the prospective innovative RE technologies for the country. The introduction and development of such technology in Lithuania against the background of existing technological regime in the energy sector and using strategic niche management approach will be described and discussed in the following section.

2.3 TECHNOLOGY INNOVATION POLICY – DISCUSSION OF LITHUANIAN CASE

In this section the strategic niche management as a governmental strategy for support of innovation and development of advanced RE technologies in Lithuania will be discussed. The discussion will be based on an example – the description of strategic niche management process for development of above described biomass gasification-based small-scale combined heat and power plant.

First of all it will be shortly explained, why biomass gasification technology should be developed in Lithuania. As it was presented earlier biomass as renewable energy source seems to have a high potential in Lithuania taking into account both, the physical potential of biomass resources and the agricultural profile of the country’s economy, history, traditions and culture. Biomass use for energy production has become popular in the district heating sector in Lithuania. According to Lithuanian District Heating Association in 2005 11% of district heating came from boilers, burning biomass. However, it seems, that technology-wise energy production from biomass is “stuck” with commercially attractive biomass-based boilers for heat production and a few new or reconstructed CHPs using biomass, except for a small-scale experimental biomass gasification-based CHP, installed in a wood processing factory (Narbutas & Narbutas 2003).

Considering the advantages of renewable energies, the importance of developing a variety of new RE technologies and the earlier mentioned advantages of biomass gasification technology, including rural development, increased domestic value-added, and security of energy supply along with environmental benefits etc., it is suggested to stimulate innovation and commercial development of biomass gasification technology-based electricity production in Lithuania.

Further I will argue that the Lithuanian energy/electricity system is dominated by fossil fuel and uranium technological regime and that most of the changes, that occur, are within this technological regime and are therefore not of a radical nature. I will also continue to explain why a shift towards renewable energy, such as the introduction of biomass gasification-based CHP, is difficult and meets resistance. Finally, I will identify the social actors (carriers) of the technology in Lithuania for description and discussion of possible strategic management of niche market for gasification technology as an example of governmental support policy for innovation and development of RE technologies.

TECHNOLOGICAL PATH DEPENDENCY OF LITHUANIAN ENERY SYSTEM

Drawing on and continuing the discussion about the RE situation in Lithuania, it is claimed here, that development of the country's energy system, particularly development of the electricity sector, is path dependent. The dependency on previous technological choices in Lithuanian energy sector creates barriers for introduction and development of advanced renewable energy technologies. A number of cognitive, technological, economic and social/cultural obstacles should be overcome before commercial maturity of a technology can be achieved as a result of received positive feedbacks from adoption.

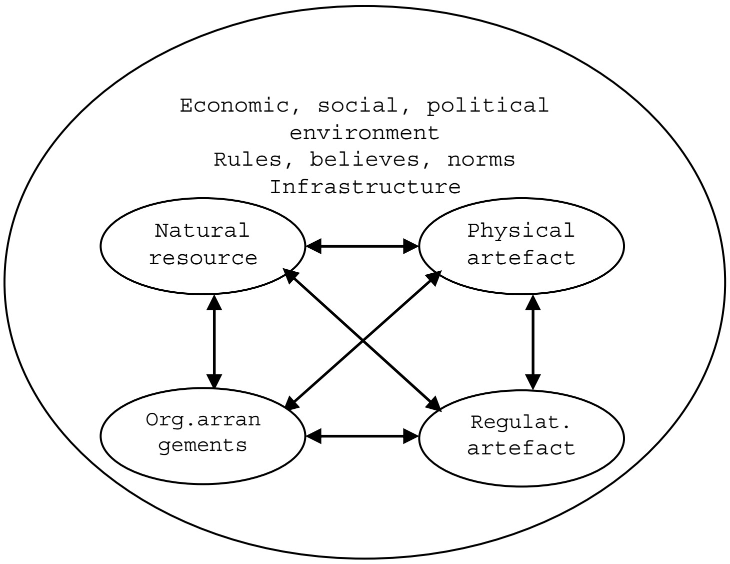

Figure 17 Technological regime – technological system and technology specific environment/context (adopted from Tsoutsos & Stamboulis (2005)

Figure 17 illustrates the structural view of the concept of a technological regime, described in earlier chapters. When drawing such a picture for the Lithuanian energy system (particularly the electricity system), it becomes evident, that the dominating technological regime is the regime of large-scale fossil fuel- and uranium-based energy technologies. Next, I will explain, why.

The most important natural resources in the country's electricity system are imported nuclear fuel (uranium) and fossil fuel (mainly oil and gas) covering around 95% of the electricity production in 2004 (cf. Figure 10). Moreover, natural gas and uranium are imported and has currently only one supplier – Russia. The main technologies for electricity production in the country are the nuclear power plant, the large-scale condensing thermal power plant and the large-scale combined heat and power plants in larger cities, the large-scale hydro power plant as well as the hydro pump plant, which is used for storage of electricity, produced by the nuclear plant. The electricity production is centralized in a few places – mainly the two largest cities – Vilnius and Kaunas, and Visaginas – the town of the nuclear power plant. Consequently, the supply of electricity in Lithuania is carried out trough long-distance high voltage transmission lines. As a result of the large-scale centralised power production the energy specialists are concentrated in these few areas in the country. Energy companies are large entities with a large number of personnel. For instance, Ignalina Nuclear Power Plant is located 6 km form Visaginas town, where nearly all the 4634 specialists, currently working in the plant live. The number of employees of the nuclear plant accounts for almost one fourth of Visaginas' population of employable age[1] (INPP 2006).

The electricity related infrastructure in the country is naturally built according to the current composition of electricity production technologies. The critical infrastructure, that fossil fuel- and uranium-based energy technological systems in Lithuania rely on, includes natural gas pipelines and oil storage tanks, roads, railways, high voltage electricity transmission lines and transformer stations, as well as institutional arrangements such as educational institutions, where specialists for operation of certain type of power plants, or maintenance of transmission lines are trained, study directions at universities e.g. the department of Thermal and Nuclear Energy at Kaunas University of Technology etc. For example, 142 km of roads, 50 km of railways, 390 km of telecommunication lines, 334 km of electricity network lines etc. was constructed for operation of Ignalina Nuclear Power Plant (INPP 2006).

The electricity production, transmission and distribution as well as relations between actors and other activities related to the electricity sector are, correspondingly to the composition and organization of the electricity system, regulated by the Law on Electricity (LR 2004) and other, supplementary, legal acts as well as technical standards.

The above described techno-institutional energy complex, developed during Soviet period of centrally planned economy together with later liberation from USSR and transition to market economy, has formed around itself a certain system of economic, political and social rules, norms and beliefs. The institutional structures of dominating technological regime are for example, the rule of low environmental taxation in energy sector, and short-term least cost approach along with the assertion that market forces should define the technologies introduced to the electricity system; the norms of not improving low energy efficiency, and growth of consumption along with low energy prices for consumers; the beliefs that nuclear power is cheap and clean, and that existing thermal power plants are more reliable electricity producers comparing to unpredictable renewable energy sources.

After the closure of Ignalina Nuclear Power Plant, the modernisation of existing and construction of new fossil fuel-based thermal power plants of a larger size, and the eventual construction of a new nuclear power plant are intended by the National Energy Strategy[2] (NES 2002). These changes in the Lithuanian electricity system appear to be path dependent in the sense that they will follow the fossil-

[1] The coming closure of the nuclear power plant is expected to cause job losses and thus social problems in the region.
[2] A possibility to construct two large-scale hydro power plants is also foreseen in the energy strategy.

fuel and uranium technological path, once chosen. The changes are directed to optimisation of the technological regime – modernisation of thermal power plants and replacement of the soon to be closed nuclear power plant with a new version of such a plant. At the same time the possibility for transformation of the electricity system by introducing and developing advanced renewable energy technologies, such as the analysed biomass gasification-CHP system, is disregarded.

The transition towards renewable energy seems to be opposed by a wide range of stakeholders that have vested interests in the prevailing electricity production technologies – private companies of conventional energy, institutions and the whole infrastructure adapted to existing power plants, like the infrastructure for Ignalina Nuclear Power Plant and Visaginas town. Furthermore resistance might be met from specialists and workers of the existing power plants as well as engineers and academics who have made a carrier on the specific knowledge of fossil fuel and nuclear energy. And finally consumers of electricity in Lithuania are also linked to conventional electricity by their beliefs and habits. The reasons for this resistance are the changes that renewable energy technologies require and bring to the electricity system. The change from centralised conventional to decentralised renewable electricity production means redistribution of the "centres" of concentration of plant maintenance personnel and the consequence that the existing techniques as well as related knowledge and expertise will become obsolete. Decentralisation also means the changes in electricity flows and supply scheme in Lithuania (from local producers to local consumers – mainly through distribution lines). To enable the growth of electricity production from biomass, a new infrastructure and legislation for fuel production and supply has to be developed along with new technical standards for new technologies. New actors and new relationships between actors will emerge together with new technologies and new fuels. The current structure and organisation of electricity production and supply will have to change with the introduction of new, renewable energy technologies and will also require changes in legislative framework. In addition to that, the current norms, beliefs and consumption habits (patterns) have to be changed. For example, the norm that electricity prices in Lithuania should remain as low as they are now should change into a norm and habit of more efficient use of electricity, and the belief that renewable energy is unreliable and too expensive should transform into consumers' pride to support the environmental friendly electricity.

These changes are difficult and unlikely to happen spontaneously, thus the transition should be initiated and managed by policy-makers. In this report I suggest to take a number of small steps in the form of development of different new RE technologies in the country. In the next section I will discuss strategic niche management as a governmental policy programme for support of small-scale biomass gasification-based combined heat and power technology. Such strategy should serve as an example of possible technology specific innovation programmes for development of new renewable energy technologies in Lithuania.

DISCUSSION ON STRATEGIC NICHE MANAGEMENT

The introduction of new renewable energy technologies is facing the on-going dynamics of socio-technical changes in the Lithuanian energy system with dominating technological regime including norms, such as aversion by politicians to impose higher energy taxes and beliefs that renewable energy technologies need large subsidies and are not feasible to implement. The further discussion will deal with the process of creation and management of niche for earlier described small-scale biomass gasification-based combined heat and power technology against the backdrop of existing large-scale fossil fuel and uranium technological regime. Key points here will be – selection of a niche for application of the technology in question, identification of actors, which are or have a potential to be social carriers of the technology, and policy instruments for effective management of niche dynamics as the technology grows mature and other important issues related to such policy strategy.

Niche for application

As it was mentioned earlier, Lithuania has a well developed district heating (DH) infrastructure – more than 50 DH companies (LSTA 2006). Many of the district heating companies are currently undergoing changes, such as conversion of existing oil boilers for combustion of biomass or other, cheaper and more environmental friendly fuel. Thus fossil fuel is gradually loosing its shares in district heating sector. However, in the areas with natural gas supply, heat is produced using this resource – which accounts to ~ 80% of fuel balance in the district heating production (LSTA 2006). The prices of heat supplied to consumers are higher in the districts without natural gas supply (which in fact became a social problem, as relatively many consumers can not afford to pay for heating). High prices, environmental disadvantages and the possibility to trade greenhouse gas emissions are the drivers for these DH companies to switch to renewable energy, i.e. biomass use. The decreasing economic advantages of fossil fuel based technologies in DH companies, especially those without natural gas supply, environmental disadvantages and acknowledgement of bioenergy advantages are the main reasons for suggesting such DH companies as niches for initial application of biomass gasifier-CHP technology. Apart from environmental and other advantages, the CHP with gasification technology in a long term seem to have a potential for increasing a DH company's revenues by electricity sales and possibility for reducing heat prices for consumers. Whereas small-scale district heating companies can offer already existing infrastructure for small-scale thermal power production. The areas without natural gas supply infrastructure are mainly remote, agricultural areas, without large cities, and biomass fuel supply would be local with short transportation distances. Additionally, as mentioned earlier, natural gas prices will raise, hence heat production along with cogeneration and biomass gasification will probably find a niche also in DH companies with natural gas supply.

A possible application niche for biomass gasification-based CHP technology is the district heating company in Taurage Municipality c.f. Figure 18. Around 35% of the municipality's area is covered by forests and around 53% by agricultural lands. The main economic activities in Taurage Municipality are traditionally agriculture, and peat extraction. The general socio-economic situation in the municipality can be described by low GDP (GDP per capita in Taurage County is the lowest among 10 counties in the country), high unemployment rate (12,6% in 2003) and low salaries, that result in low consumer purchasing power (Statistics Lithuania 2006 and Taurage Municipality 2004). The price of district heating in 2004 was almost by one fifth higher than the country's average. Moreover, Taurage DH Company had in 2003 the highest number of consumers in debt – 34% of all DH consumers. The boiler house in question is supplying heat to Taurage town, which maximum demand capacity is 39 MW, while installed capacity of oil boilers is 72,5 MW and a new (from the end of 2003) biomass boiler has 9,5 MW capacity. Consequently, boiler house has an overcapacity of 42MW (Zvingilaite 2004). Assuming that the earlier described 2 MWe (5,5 MWth) biomass updraft gasification-based CHP would be installed in the boiler house and that the annual operating hours (full load) of the engine would amount to 5000, heat production from the CHP would cover approximately one third of total heat production (27,5 GWh out of 94GWh) in the boiler house. Electricity production in such case would amount to 10 GWh per year and the sales of electricity could contribute to improving the economic state of Taurage DH Company and thus heat prices for consumers could decrease. However, the study on biomass gasification-based CHP installation in this particular boiler house (Zvingilaite 2004), has shown that current feed-in tariff for biomass-based electricity of 5,8 ct/kWh is too low for feasible installation of biomass gasification technology.

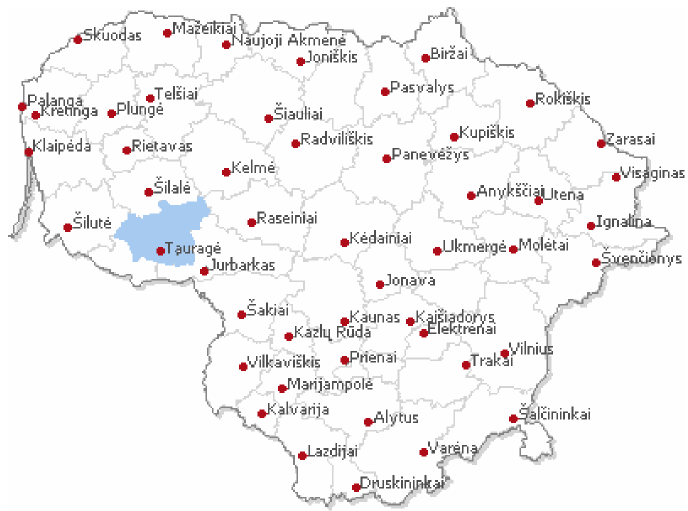

Figure 18 Location of Taurage Municipality (Zvingilaite 2004)

Actors

Besides the possible niche for application, actors interested in the application and development of the new technology are important for niche market creation and management, which is both a result of and a platform for interaction of these actors. According to Muller (2003), in order to carry a new technology an actor has to fulfil three main conditions – interest, power and organisation. The main prospective actors of biomass gasification-CHP technology, which have at least one of the conditions and thus the capacity to contribute to niche market formation and management, are the researchers, scientists and engineers, private actors (profit and non-profit) and the State actors.

- **Researchers, scientists and development engineers** from Lithuanian Energy Institute, Kaunas Technology University, Vilnius Gediminas Technical University, Agricultural University etc. These actors have organisational conditions for performing basic, scientific and applied research and forming theoretical knowledge behind the analysed technology. This is particularly important for several reasons. First, biomass gasification-based gas engine technology is not technologically mature yet and requires further basic as well as applied research. Secondly, such technology is new in the country and assistance by researchers might be critical, when installing and operating the first biomass gasification-based CHP plant. This consideration is based on the fact that, for instance, the first small-scale cogeneration plants were installed with assistance from universities, and it seems that it is research institutes and universities that still have the highest both basic and applied research capacity (together with an increasing capacity of consulting companies). Another important role of these actors in managing niche for biomass gasification technology or other new technology for that matter is assessing the technology and monitoring the process of development and maturity as the time goes, and advising for further support or withdrawal of support. Besides, researchers can identify a potential for further, more advanced techniques and concepts, on the basis of experience gained with biomass gasification CHP with gas engine, e.g. development of gasification-microturbine system after advancements in cleaning of producer gas. An important task for research institutions, when introducing a new technology, is to articulate changes in existing, or requirement for new, technical standards.

  The interest of researchers, scientists and development engineers in biomass gasification technology might be as a professional scientific interest, or formed by other actors or trough e.g. providing (governmental) funding or buying certain research/consulting services for private business needs. In Lithuania these actors seem not to have political power, and their economic power appears to be modest, and depends mostly on the governmental priorities as 63,1 % of research funding in 2004 came from the state budget (Statistics Lithuania 2006). Institutions of higher education are of particular importance for R&D in renewable energy field, because more than half of the R&D funding was spent for research in the sector of higher education in Lithuania in 2004 (Eurostat 2006). Among research institutions, that are potential carriers of RE technology, the Centre of Renewable Energy Technologies at Kaunas University of Technology, should be mentioned. This four-person centre has a high professional and civic interest in developing renewable energy technologies, uses the infrastructure, provided by KTU, and is organised to implement scientific research partially on a voluntary basis as well as in cooperation with other actors, and participates in various programmes e.g. Lithuanian State Science and Studies Foundation (LSSSF) and PHARE. Furthermore, the centre is creating the knowledge and disseminating information about renewable and alternative energy technologies (Balciunas 2006). Thus, this centre seems to be the most active among the research institutions in Lithuania, when it comes to renewable energy technologies. I see this organisation as the main research actor at the very beginning of niche market creation, which also has the capacity (in terms of organisation) for disseminating information and knowledge, while one of the primary goals of the centre is education in the field of RE technologies. Additionally, the centre has rather good networking skills – it can serve as a knowledge and network manager.

- Another group of actors are **private actors** – companies, trade associations and private voluntary organisations (PVOs). Here I will outline the private actors and their roles, for creating and operating a niche market in the described Taurage district heating sector. Clearly, the central private actor here is energy producer, who applies the technology. In this case it is Taurage DH Company, which is a municipality-owned[1] company (at least until it is privatised). Consequently, important actors here are potential investors into the DH Company – a few existing private energy companies (e.g. Dalkia, E-energija, Fortum) already administrating some of the DH companies; and prospective investors, such as investment funds, individual entrepreneurs, other firms, which activity is closely related to energy production and/or supply, foreign investors etc. The primary interest of DH administrators is energy production optimisation in order to reduce costs, and to keep and attract DH consumers[2]. Private investors are naturally also striving to increase their profit.

  Due to production and supply overcapacity and neglected maintenance of district heating infrastructure in the 90ies, the primary investment priorities are to improve the pipelines and optimise heat production mainly by fuel conversion. Although, theoretically investment projects, proposed by

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[1] In principal district heating companies in Lithuania are municipality-owned. Some of the companies are privatized, but according to the Law on Heat municipality still owns heat supply network equivalent to at least 5GWh of yearly energy supply and heat production capacity comprising not less than 30% of total consumer demand from each heat supply network (LR 2003).

[2] A big problem in district heating sector is consumer tendency to disconnect from DH network and produce heat individually along with high consumer debt.

municipalities, can be financed by various state investment programmes (e.g. infrastructure development projects, where RE development can also be incorporated) or from their own budget, practically this possibility seems to be not viable – especially for development of new RE technologies. In general, municipality owned district heating companies appear to be passive, especially when it comes to new technologies. Whereas the privatised DH companies seem to be more determined to bring positive changes (e.g. renovation of pipelines, improvement of energy production technique, switch to local fuels), however usually based on short-term benefits.

Another type of private actors that play a central role in developing a new RE technology in the country – biomass-based power gasifier – are the equipment producers along with producers and suppliers of energy resources – biomass. The manufacturing industry for (renewable) energy technologies is not particularly developed in Lithuania and firms producing the technique are only emerging. Hence, new actors would play an important role in development of biomass gasification technology and in general in changing the dominating fossil fuel technological regime. Most of the companies dealing with (renewable) energy technologies are importing them. Nonetheless there are also a few companies manufacturing energy production technologies (mainly for production of heat) such as heating boilers, steam turbines and supplementary equipment. The most prominent and active actor in the private sector, related to biomass energy both in fuel and energy conversion fields is the consortium Rubicon Group, which includes 30 companies, 5 of them are related to energy production, equipment design and manufacture, installation, automation and fuel production and supply, personnel training etc. Rubicon Group is mentioned here because it is a powerful private actor in the field of biomass energy production both economically and politically and seems to have openness for innovations. The company administrates the Lithuanian Association for Biofuel Producers and Suppliers (LITBIOMA), which is representing and lobbying through interests of actors in the biofuel sector. Since Rubicon Group seems to strive to be a front runner also in the field of energy, it has a potential for introduction of new technologies, consequently it can be considered as most probable manufacturer of biomass gasification equipment, if the niche for the technology will be created. On the other hand, the participation of existing small energy technology firms and emergence of new ones is important for creation of competitive market among equipment producers.

The biomass production and supply is a fast growing industry, mainly due to continuously increasing use of biomass for heat production in DH companies. The individual farmers, land and forest owners as well as the established biomass production and supply companies are the important actors, which can also benefit from the development of biomass-based energy technologies, installed locally.

Two main aspects are important for and influence the decision of the above described private actors to invest in new technologies and new production/manufacturing – sufficient profitability and not too high (market, regulatory etc.) risks. It appears that currently these conditions are not fulfilled for investments in biomass gasification technology in Lithuania.

In case of creating the niche for biomass power gasifier in a district heating company two interest associations might play a substantial role – the Lithuanian District Heating Association and the Lithuanian Association for Biofuel Producers and Suppliers. These actors have a capacity to influence political decisions in the area of district heating and biomass production and have an organisational capacity to support the strategic niche management process. They could be particularly important for building constituency behind the technology by informing specialists in energy field and potential investors, producers and manufacturers about the advantages of the technology and by forming a positive view of the future potentials of the technology. The associations could assist in involving the biomass gasification technology into the existing technological energy system, such as district heating system or biofuel technology system and also support the niche creation by providing the needed information and consultations, based on industry experience. Furthermore, industry associations can identify and articulate changes in governmental regulations and new regulatory provisions, necessary for the new technology. The two mentioned associations are important actors; however electricity production in small-scale renewable energy technologies is not within their preserve. There also exists the Lithuanian Electricity Association, which joins together actors within and related to electricity production, transmission and distribution activities. However, this association is closely related to the dominating fossil fuel- and uranium- based energy technological regime and might not be in favour of new RE-electricity technologies. Consequently, it is recommended that an association for renewable electricity producers would be established, including the already existing Wind Energy Association.

As regarding PVOs, only one organisation, directly dealing with promotion of renewable energy can be named – the Renewable Energy Information Consultation Centre (ATEIK). Additionally, the Centre of Renewable Energy Technologies at KTU can also be classified as a public voluntary organisation. In the case of niche management for development of the biomass power gasifier the main role of these organisations is to change the society’s view of the energy system as a large-scale fossil fuel system to as a small-scale decentralised renewable-based energy system; and to form cognizance of advantages of biomass power gasifier technology as well as RE electricity in general.

New, renewable energy technologies need financial support in order to be adopted and diffused. This means that electricity prices for consumers have to be raised in order to provide the financial support. The important mission of voluntary organisations is to enlighten and encourage the society to reduce energy consumption by saving and increasing energy efficiency, and to be proud of and willing to support (and contribute to) the development of RE technologies. Moreover, PVOs can carry out an objective independent monitoring of niche market management process, as well as development and maturing of the biomass gasification CHP technology. Unfortunately, the power and organisational resources of the PVOs are poor, when compared to their interest to implement changes in favour of RE technologies.

- The role of **the State actors** in strategic niche management is to initiate the process, as it is first of all a strategy for governments to manage a process of technological change. Here I will consider two types of State actors – the Government and local authorities (or Taurage Municipality in the particular district heating case). The role of the Government is first of all as a facilitator or enabler of innovative policy program, while the Municipality could engage in encouraging local actors by creating knowledge and business networks, and disseminating information about governmental programs as well as creating shared visions of local energy supply together with local business community and energy consumers. Three aspects of the State actors' role in strategic niche management are considered here – the start-up of the experiment, the creation of the further policy framework for the entire period as technology matures and financial support.

  Taking into account that biomass gasification-based CHP with a gas engine is practically still at demonstration stage and it is a new[1] technology for Lithuanian energy industry the strategy of introducing this technology should start from a demonstration project – as a mini-R&D program. The 2MWe biomass gasifier-CHP system could be installed in Taurage DH Company's heat plant, as described before. This should be done in order to get experience with the technology and to resolve the most critical installation and operation problems (such as producer gas cleaning or improved robustness of gas engine) together with researchers and engineers as well as to receive first feedbacks on technology adoption. Moreover, the demonstration would gather actors around the technology and raise awareness about biomass gasification and its advantages. This is primarily a task for the Taurage Municipality administration – to connect different actors and to ensure exchange of information, such as technology design specifications, technical and operational issues as well as requirements for infrastructure and maintenance. For example, a need for producers and suppliers of fuel with specific characteristics (moisture, fraction etc.), providers of suitable automation systems and specific operation and maintenance skills. The important role for public voluntary organisation at the demonstration stage, e.g. ATEIK, is to draw attention, interest and subsequent support from the

[1] Except of experimental micro-cogeneration plant (20kWe) using gasified biomass installed in wood processing factory (Narbutas & Narbutas 2003)

society by giving the technology a cultural or psychological (symbolic) meaning, for instance labelling it as “green-gas”, “tree-gas” or “tree-power” technology and by explaining in a popular way the working principles and the effects of the technology to the society and the environment, as well as how private energy consumers can contribute to the development of the technology. Furthermore, it is important, that the technology is manufactured locally – in this way also the manufacture and not only installation and operation of the plant will be experienced. After some experience has been gained (might need e.g. several thousand hours of operation) and the technology proved to have a future potential, a program for creating and managing the niche for investing in biomass power gasifiers e.g. in district heating companies, should be developed. The patience with technology at the demonstration stage is important in order to make sure that a number of possible (or known) technological options are tested and the experiment does not end after failure of first efforts. In case of described 2MWe biomass gasifier-gas engine system, gasification options include downdraft or updraft gasifier, a wide array of biomass resources (woodchips, sawdust, straw, agricultural residues etc.), different gas cooling and tar removal techniques etc. to explore.

As the technology moves from the demonstration to the pre-commercial stage, which means more substantial levels of deployment, a program for ensuring spaces for application (niche markets) and for enhancement of other skills than those involved in technology experimentation, is needed. I suggest here that the program would be based on ensuring a substantial price for electricity, coming from biomass gasification-based CHP technology installed in district heating plants. By implementing this measure the Government would act as broker – identify potential users (DH companies) and, by offering electricity price, through DH companies, organise competition between technology suppliers. The price should be high enough so that the revenues from sales of electricity could be used to reduce the heat price for consumers by e.g. a certain percentage, or to invest in other improvements, that would result in price reductions[1]. Clearly, a thorough estimation of the electricity price and how it can affect heat price, depending on the ratio of total installed heat and electricity capacity and evaluation of other social and environmental benefits, also taking into account the importance of project profitability for private investors, should be made. The price should be ensured for a number of years (close to a lifetime of technology). The annual amount of installed supported capacity could be defined in order to control the yearly volume of financial support. Additionally the offered price for electricity, coming from new installations of the technology, as the time goes and the technology matures should gradually decrease until biomass gasification-based electricity can be produced and

[1] My rough estimation, based on my previous work, dealing with biomass gasification in DH production (Zvingilaite 2004), is that price for the first installations should be at least 8-9 ct/kWh compared to current 5,8 ct/kWh.

sold unsupported given the appropriate electricity prices (reflecting externalities). Such a dynamic mini-market for development of biomass power gasifier should also be reinforced with capital grants, at least for a number of first installations.

Furthermore, the niche policy framework should address the risk issue of investing in pre-commercial technologies such as biomass gasification. In addition to favourable electricity prices (and investment subsidies), a long-term vision of the technology as well as stable and clear near-term policy framework is important. The long-term vision of the technology should be created in cooperation between the Government, the private sector and the research community. For example, the vision of what share of heat and electricity in the future is foreseen to come from gasified biomass and even in which regions of the country such technology should be pursued [1] as well as what future developments of biomass gasification technology are anticipated (e.g. use of technology for hydrogen production). The innovative support framework should be consistent and draw the clear conditions and requirements of support or withdrawal of support. It should be clearly stated, what is expected from the technology development, when the technology can be considered as failed e.g. on the basis of preliminary learning curves developed by researchers. For that reason, continuous system monitoring and technology assessment has to be implemented. For credibility of the niche operation a third-party monitoring might be carried out by a PVO, such as ATEIK.

It is central for the progress of the new technology towards commercialisation that the barriers for the technology penetration into the country's energy system are addressed by the innovative niche policy framework. The existing legislation and technical standards should be changed and/or complemented so they do not discriminate a new technology and/or in order to adjust to the changes, brought by adoption of a new renewable energy technology. For biomass gasification technology, technical standards of equipment (e.g. robustness of gas engines) and performance (e.g. gas production efficiency, the composition of producer gas) should be developed for reducing uncertainty and enable faster diffusion and learning process. To avoid negative environmental impacts the disposal of tar and ashes as well as removing tar from waste water should be regulated. Furthermore, legislation should be adjusted for regulating new relationships in the energy system, such as increased importance of reliable biofuel production and supply, and more distributed, local electricity supply. For example, current legislation concerning agriculture and forest development creates a number of barriers for cultivation of energy crops, such as long and complicated project approval procedures and various limitations.

[1] Applying the systemic approach, that a mixture of renewable energy technologies should be developed and installed in a country.

The lack of information and resulting low acceptance and perceived complexity of the technology, which might keep potential investors from investing, can be changed and reduced by sharing knowledge between researchers, technology manufacturers and energy producers. Another factor, contributing to low acceptance of advanced renewable energy technologies is economic rationale of growth of consumption in the society, which should be replaced by rationale of efficient energy consumption and minimisation of environmental impacts. This can be achieved by disseminating information and including the general public into the debate – here the role of public voluntary organisations is central. Also, the possibility to choose to pay more for renewable electricity should be provided for consumers – it means that electricity suppliers should, in bills for final consumers, specify the mix of fuels of their supplied electricity, and the resulting environmental impact of the fuels as well as, weather fuel is local or imported.

The initial financial support for new RE technology units might be rather high, on the other hand, the number of installations at the early stages of technology development is small, and thus, total costs would remain modest. Additionally, as the scale of the adoption of new technology grows, the cost of the technology decreases, due to scale and learning effects, and thus, requires less subsidisation. The demonstration stage can be currently financed through e.g. National Energy Efficiency Program (NEEP 2001), which intends to finance some demonstration projects, and other (foreign) assistance programs. As it was mentioned, in order to encourage investments in energy production using biomass power gasifiers, direct investment support or soft loans should also be provided in addition to favourable electricity prices (mini feed-in tariffs). First of all the existing possibilities for investment support should be made easier accessible as currently the existing support is underused (Streimikiene et al. 2005). One of the most important improvements to be made is the simplification of the procedures for receiving support from EU structural funds. Additionally, externalities of energy production from fossil fuel and uranium should be better internalised in a form of taxes and a part of the revenues from these taxes should be redirected into R&D, demonstration projects and financing of other innovative policy measures for development of advanced renewable energy technologies. For example, according to National Greenhouse Gas Emission Allocation Plan for the period 2005-2007, 4,9 tonnes of CO_2 emission allowances in average annually were allocated for electricity production sector (NAP 2004). Assuming that these emissions are charged by 1 EUR/tonne, 4,9 million Euros[1] per year could be collected and used for renewable electricity support. 1EUR/tonne of CO_2 would increase the electricity price for the final consumers only by 0,75% (~0,64EUR/MWh) comparing to

[1] The yearly budget of earlier mentioned Lithuanian Environmental Investment Fund, which provides capital grants to all environmental projects is ~3,5 million EUR.

the current electricity price of ~85EUR/MWh for private consumers. This is an important observation of, that a tax, with a minor impact on energy prices can contribute quite significantly to financing of RE technology development. For example, the tentative capital cost for the described 2MWe biomass gasification-based CHP with gas engine is 2 million Euros (based on Stassen & Knoef and Faaij 2006). Furthermore, a certain amount for innovations in energy sector could be covered by an obligatory payment (a type of PSO) by electricity suppliers, importers, exporters etc. The feed-in tariffs should naturally be covered by electricity consumers. The increase of finally consumed electricity price by 1 EUR per MWh (0,1 ct/kWh or ~1,2% from current price), when electricity consumption is equal to the consumption in 2004 – 7650GWh, would accumulate 7,65 million EUR per year. This amount would allow producing 85GWh/year, paying 9ct/kWh for generated electricity (comparing to current 5,8 ct/kWh for biomass-based electricity). Assuming 5000 annual operation hours of the biomass gasification-CHP in DH sector, it corresponds to 17MW of installed capacity of such technology. Obviously, development of a variety of advanced RE technologies should be started.

SUMMARY

The Lithuanian energy/electricity sector is dominated by fossil fuel and uranium-based technologies, which have formed a strong technological regime over the time. The fossil fuel and uranium technological regime keeps changes in the electricity sector follow the technological path, once chosen. The future technological scenarios for the electricity system are including mainly modernisation of existing large-scale fossil fuel power plants, construction of a new nuclear power plant, exploiting the existing infrastructure, and new large-scale hydro power capacities. It seems, that the technological "plans" for electricity generation disregard RE potential and technologies. The reason is believed to be the changes that RE introduction requires and brings, which are radical for the dominating technological regime.

Nonetheless, concluding on the above analysis of introduction of the biomass gasification technology for combined heat and power production in Lithuania using strategic niche management approach is manageable. Moreover, taking into account, that power production using biomass gasification technology never really took off (at least in industrialised countries), Lithuania could become a first comer with this advanced RE technology. Summarising, the main aspects of the described biomass gasification technology introduction based on niche approach are:

- The selected experiment (c.f. section 2.1 sub-section on niche creation and management), is the application of biomass gasification-based CHP in small-scale district heating plant in the Taurage Municipality DH Company. The main advantages of this application niche are the possibility to exploit the existing infrastructure and prospects to improve the technological efficiency and economic situation in the municipality's district heating sector;

- There exists a number of established and prospective actors: research institutions, investors into DH companies, manufacturers and importers of technique, fuel producers and suppliers business associations, public voluntary organisations However, they need to be given more incentives to innovate and adopt biomass gasification technology as well as other advanced RE technologies. Inclusion of a variety of actors into creation and management of a niche for a new RE technology is important for overcoming resistance, created by technological path dependency in the energy sector, by sharing knowledge and providing information and changing preconceptions about complexity and high costs of introduction of advanced renewable energy technologies;
- The role of the government is primarily of a catalyst for the innovation and adoption of advanced biomass gasification technology (and other new technologies), and participator in the process of development, rather than as a regulator performing command and control of renewable energy development. The main directions of governmental functions are: creating R&D strategies and ensuring that demonstration projects are carried out and continue to a stage of pre-commercialisation; next, adequate policy instruments should be employed for creating incentive for private actors to adopt the technology by offering sufficient profitability and minimising investment risks; creating non-discriminatory technical and legal conditions for the advanced technologies; and ensuring the broad learning process by supporting network creation for sharing of knowledge and experience as well as dissemination of information in the society, through e.g. public voluntary organisations;
- The cost of such advanced RE technology development approach does not have to be prohibitive. The initial adoption of 2 MWe biomass gasifier-CHP system, when covering investment cost (2 million Euros) and ensuring electricity price at 9ct/kWh (900 thousand Euros/year) would cost 2,9 million Euros for the first year, which can be collected by increasing the price for residential consumers only by 0,4% (0,037ct/kWh). It is important to note that development of new technologies is characterised by significant cost decrease as market penetration increases, thus, further support would require lower costs per installed capacity.

It is expected, that the successful implementation of the strategic niche management for development of the biomass gasification technology would have a self-reinforcing effect on renewable energy technology innovation process in Lithuania, and that it will give an impetus and confidence to new and existing actors to innovate a number of different RE technologies. Since niche management policy is a package of measures that deal with different barriers for adoption and diffusion of a new technology, the niche management strategy for different technologies would clearly be different.

There is no guarantee that all new RE technologies will successfully be commercialised. Nonetheless, it is important that the experience gained and the knowledge accumulated is not vanished once an experiment has failed to gain a momentum. Learning is an important aspect of strategic niche management approach.

Part 3 CONCLUSIONS

By this report I endeavour to achieve two main goals. First of all, to analyse and assess the current renewable energy situation, the difficulties and possibilities for introduction and development of advanced RE technologies and subsequent increase in share of RE in the Lithuanian energy balance. Second, I attempt to describe a preliminary outline for innovative renewable energy policy in Lithuania in order to answer the research question: ***how should renewable energy innovation policy in Lithuania be created in order to become an innovator of RE technologies?***

In this final part of the report I will conclude on the goals achieved during the research and answer to the research question. I will also present reflections on the performed investigation and suggest the directions for a follow-up research.

3.1 CONCLUSIONS AND POLICY RECOMMENDATIONS

Based on the analysis of the renewable energy situation in Lithuania it can be concluded that the initial hypothesis is valid – the development of advanced renewable energy technologies in Lithuania is scarce and the current RE policies and the policy measures are not fostering technological innovation in this area. The renewable energy situation in Lithuania, taking into account geographical, technical, economic, political, social etc. factors, can be characterised by the following:

a) rather low share of renewable energy resources in the Lithuanian energy balance – ~8% in primary energy consumption, ~11% in district heating supply and slightly more than 2% in electricity production (or 3,7% in total electricity consumption in the country);
b) a considerable potential for biomass energy resources (could cover ~80% of the final electricity and district heating consumption), as well as a potential for other e.g. hydro, geothermal, wind, solar energy sources for both, heat and electricity production;
c) the well developed district heating infrastructure – a good opportunity to develop small-scale combined heat and (decentralised)power production using biomass fuels (and/or waste);
d) currently low natural gas prices, electricity prices based on short-term marginal costs, failure to internalise externalities (no CO_2 tax) etc. – form the unfavourable economic environment for advanced RE technologies;
e) the installed power overcapacity of 1250MW – as a justification for not fostering developments of renewable energy technologies, on the other hand, the decision to shut down Ignalina Nuclear Power Plant in 2009 will eliminate this overcapacity;

f) path dependency of technological developments particularly in the country's electricity system – the lock-in large-scale fossil fuel and uranium technological regime, which resists and makes it difficult to shift to a renewable electricity production using innovative technologies;
g) regulatory support is directed primarily towards meeting near-term targets – 7% of renewables in electricity consumption and 12% in primary energy balance before 2010 – by picking RE technologies from the shelf;
h) absence of R&D programmes and sufficient funding for renewable energy technologies, resulting in scarcity of advanced RE technology development initiatives and demonstration programmes;
i) cognitive environment: a believe in, that market forces will define the type of (renewable) energy technologies, dominates among policy makers, consumers, accustomed to the combination of low energy efficiency and low energy prices, and scepticism toward renewable energy technologies.

The development of a variety of renewable energy technologies in Lithuania is important for a number of reasons. Lithuanian energy production depends by ~ 90% on fossil fuel and uranium, imported from Russia. This, not only, significantly contributes (by 36%) to the foreign trade balance deficit, but also raises a concern over the security of energy supply. If continuing business as usual and not advancing in the field of RE technologies, there is a possibility, that fuel import will be replaced by the import of RE technologies in the pursue for meeting the future's more ambitious environmental and renewable energy targets. Moreover, the earlier new RE technologies are developed, the lower future cost for shifting to renewable energy production will be. Clearly, exploitation of the existing renewable energy potential in the country will have environmental advantages. Decentralised character of renewable energy production will bring employment opportunities also to local regions with high unemployment rates. For the above mentioned reasons I assert, that Lithuania should strive to be an innovator and front runner in the introduction and development of advanced renewable energy technologies. To achieve this, an innovative renewable energy policy for the development of new RE technologies in the existing path dependent dynamics of the Lithuanian energy system should be created.

In order to answer the research question, in the report, I suggested and analysed the strategic niche management approach as a governmental policy framework for introduction and diffusion of advanced renewable energy technologies in Lithuania. Taking into consideration the considerable potential for biomass resources in the country and the well developed district heating infrastructure I recommend starting the programme of introduction and innovation of new RE technologies with development of biomass gasification technology for combined heat and power production. Biomass gasification technology is recommended as a technology, which corresponds to the agricultural traditions in the country, and it could therefore be easier for the local community to identify with, and hence also seem more plausible. Nonetheless, a variety of technologies should be developed in order to utilise the available variety of renewable energy sources. It is important to create options for meeting environmental, security of energy supply and other national goals.

I consider the niche management strategy as a suitable or even necessary governmental strategy for managing the shift in the Lithuanian energy sector from the dominant fossil fuel- and uranium- based energy technologies to renewable energy technologies. Firstly, niche management strategy is not intended for a large-scale revolutionary shift to new technologies, but rather oriented at creating physically small spaces for gradual development and dissemination of the new technologies. Consequently, the cost for implementation of such policy framework does not have to cause a considerable energy price raise for final consumers. Secondly, the strategic niche management is primarily a platform for learning, exchanging information and creating networks and promoting a new technology. This is important for building a constituency behind a new renewable energy technology, especially, when the acceptance of new RE technologies in Lithuania seems to be low, and actors in favour of them are basically marginalised. It is important to make sure that there is a broad social learning of a new technology and renewable energy in general, in order to alter the current thought structures among technology designers, users and energy consumers.

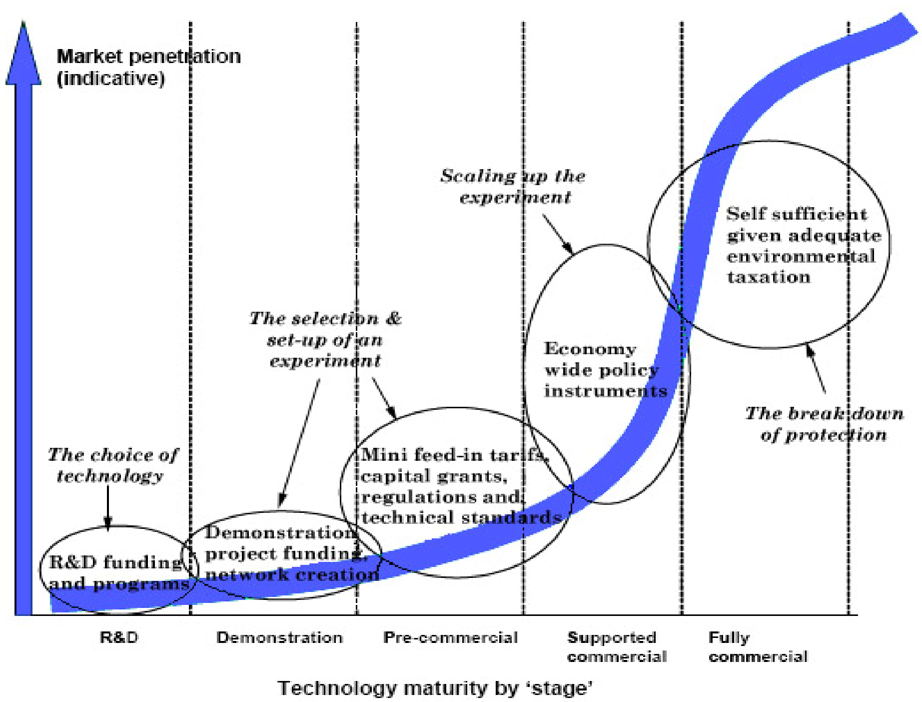

Figure 19 S – curve and innovative renewable energy policy – strategic niche management approach (based on Foxon et al. (2005)

The Figure 19 illustrates the recommended innovative renewable energy policy framework throughout technology development stages, based on Foxon et al. (2005). The described steps of strategic niche management for a technology development from the innovation to the commercialisation can be transferred into the innovative policy actions according to the stage of the technology maturity. Consequently, the main elements of innovative renewable energy policy, suggested here, are: funding of (basic and applied) research and development programmes; programmes for prototype demonstrations and creation of actor network around a technology; creation of mini innovative markets for maturing of a technology and developing skills, needed for further commercialisation along with getting user feedback and exercising learning economy; adjustment or creation of new legislations for indiscriminate installation of technology and technical standardisation; and finally, a gradual scale up of the "experiment", employing economy wide price instruments; and finally the withdrawal of support, establishing mechanisms for effective internalisation of externalities (environmental taxes, regulations etc.).

In order to answer the research question more concretely I will formulate a tentative proposal for renewable energy policy implementation in Lithuania.

First of all, it is important to establish a well functioning renewable energy R&D programme with reliable funding, rather than having a fragmental financing from different sources (state budget, private funds or foreign assistance) as it is provided by the National Energy Efficiency Program (NEEP 2001). For example, by charging energy suppliers 0,25 EUR/MWh of supplied electricity (except export and together with plants' own use) as a PSO for renewable energy R&D, around 3 million Euros could be collected, which comprises about 2% of current R&D funding in Lithuania. It is supposed that the largest expenditure for research and development in the field of RE technologies would be for the research equipment and construction of prototypes. The latter could be also covered by funding for demonstration projects. The main task for R&D activity is to perform a search and selection of innovative RE technologies[1]. A variety of technologies for biofuel utilisation (see Figure 15) could be researched and developed, e.g. the environmental impacts and efficiency issues of small-scale hydro power could be resolved; the utilisation of the existing considerable potential of geothermal energy could be researched; the solar energy use should be developed; the technological possibilities for exploiting wind energy potential in the country should be examined and implemented etc.

Further, a number of prototypes of the technologies, recommended by researchers as promising solutions for utilisation of the renewable energy potential, should be installed as demonstration projects around the country. The mentioned funds (4,9 million Euros) collected from charging CO_2 emissions by

[1] Clearly the role of researchers is broader, e.g. their expertise is central for demonstration stage, technology assessment etc.

1EUR/tonne or other type of taxes, or higher PSOs for RE research could be used to finance the first installation of prototypes. The capital cost for the described 2MWe biomass gasifier-CHP system is around 2 million Euros. Thus two such plants could be installed per year, but, clearly, different technologies should be "tested" – biomass, small-scale hydro, PV, geothermal, wind turbines for lower wind speeds etc. After the first prototypes have been installed and proved to have a potential for further development, a larger scale adoption should be ensured moving from basic and applied research and demonstration to the pre-commercial stage by finding and creating niches for application of new technologies.

For a larger scale installation of advanced technologies the capital grants, together with mini feed-in tariffs for produced renewable electricity should be provided, as a niche creation mechanisms. The green electricity quotas in order to control the yearly cost for support of innovative technologies could be established and tenders for investors (energy producers) and, as a result, for equipment producers, could be organized by government or assigned institution (e.g. Energy Agency), or local governments. For example, 7,65 million Euros, collected from increased (by 1EUR/MWh) electricity prices for final consumers, could be used for grants and feed-in tariffs. As it was mentioned, 85GWh of electricity could be bought for 90EUR/MWh for this sum. Clearly, tariffs, offered should vary, according to different technologies and their costs, e.g. the price for wind and hydro turbines might be lower than for geothermal or solar technologies. Furthermore, increasing the scale of production and learning effects tend to reduce the cost of new technologies. In order to encourage technology progress and continuous cost reduction the electricity tariffs for specific technology could be reduced annually by a certain percentage. Clearly, the tariff for electricity from a particular installation should be fixed for a number of years, depending on the lifetime and cost of the technology. I suggest that different technologies would go through such niche system at different times – to start with developing e.g. advanced biomass and improved small hydro technologies, and when these technologies would reach a higher level of commercial maturity, to start the development of technologies such as geothermal and PV. The rationale behind such recommendation is, that emerged RE technology industry is expected to supply more resources to R&D for further enhancement of the technology and for search for new technological possibilities. In that way more resources could be allocated for different technologies, than when developing a big variety at the same time. In this way a number of different technologies would move form demonstration stage to "the shelf" from which they could be picked up by employing currently used instruments in Lithuania, such as tax relief, purchase obligation, a reduced feed-in tariff or the planned tradable green certificate scheme. Guarantees of origin of green electricity (which currently are being introduced in Lithuania) could be used to inform final consumers, about the share of renewable electricity in the total mix of supplied electricity, by presenting such information in the electricity bills. Additionally, taking into account that from 2007 all electricity consumers in Lithuania will be able to choose electricity suppliers, the share of green electricity could be a criterion for consumer to choose a supplier. Or, electricity suppliers could provide possibility for consumers to choose the share of renewable energy in their electricity consumption and thus to pay more and support further RE development.

Finally, commercialised RE technologies should be able to compete with conventional technologies, given the internalisation of externalities – environmental taxes, higher transmission costs from large-scale power plants etc., which would change the "rules of the game" in favour of distributed renewable energy production.

It should be noted, that the presented is an idealised picture, assuming that technologies successfully progress trough the maturity stages to the fully commercial stage.

The described niche approach-based RE innovation policy should be consistent and stable, and at the same time targeted and flexible to address specific barriers and challenges that new technology faces during an innovation process. A balance between protection and support and pressure of technology development, should be found when implementing such policy. Too much pressure (e.g. too short time given) may result in choices, based on short term benefits and neglecting of different paths of development. Whereas too much of protection might result in costly failures. And, finally, a government should have an exit strategy, if a technology fails to meet expectations, and fails to prove long term benefits. Central here is to make sure that the lessons are learned and accumulated knowledge is not lost.

3.2 Reflections and future research

Finally, I will present reflections on the performed research and the observations from the investigation process, and suggest the directions for a follow-up research.

As it was mentioned at the beginning of the report, the main limitation of the research is the absence of alternative (innovative) technological scenarios for utilisation of renewable energy resources in Lithuania. The available renewable energy technology scenario(s) are mainly limited to the currently technically and economically feasible resource potential for meeting the target of 7% of renewable electricity by 2010. The real physical potential for renewable energy production is not available in the analysed information sources and, consequently, possibilities to develop alternative technological scenarios are limited. This disregard of renewable energy options can be explained by the lock-in of the

Lithuanian energy system in the existing fossil fuel- and uranium-based technological regime and consequent resistance towards introduction of changes. For that reason the result of the report is more methodological and tentative recommendations than a concrete proposal for the implementation of a technical renewable energy scenario. Therefore, an important recommended follow-up work is to assess the real renewable energy potential in the country and to develop a technological scenario for replacement of fossil and uranium capacities by development of innovative and use of currently available RE technologies.

Another limitation in the report might be that by proposing the renewable energy innovation policy I consider the niche approach, based on the position, that such policy should be technology specific. There might be considered other possible approaches, such as an overall support of development of different RE technologies, competing in between each other in the same niche market; or a more technology pull (user oriented) than push innovative strategy. Taking into consideration the lack of knowledge about and low acceptance of renewable energy among final energy consumers in Lithuania, the user oriented approach should foster a demand side, first of all by a broad learning process. Learning should first of all include the mechanisms for increased energy efficiency, which would consequently lead to reduced expenditures and increased possibilities to pay more for the green energy – with the aim to change the priorities of final energy consumers and to inform about the possibilities. Another user-oriented approach could be to support installation of advanced RE technologies “close to people”, such as PV installations on the roofs of family houses, public buildings (e.g. schools), collective ownership of wind turbines or small hydro etc. That would enable users to contribute to the environmental friendly energy production and hence evoke the pride and willingness to further support renewable energy development.

Further I will present reflections from the data and information collection process. The main collected data and information is concerning the Lithuanian energy sector – energy resources, consumption patterns, energy prices, technologies, policy and regulations etc., with exception of theoretical approach on renewable energies and technological innovation. First of all it should be noted, that the data on energy production and consumption are for the year 2004, when two blocks of Ignalina Nuclear Power Plant were still in operation, however, currently (from 2005) only one block is producing electricity. Thus the electricity production composition for the year 2005 is different, however this information was not available, when the data was collected. Second, although there is a number (although not big) of articles on renewable energy, there seems to be a lack of discussions on this theme in Lithuania – nearly all articles are presenting and based on the same data (technically feasible RE potential) and are not discussing but rather presenting the existing RE situation and policies in the country. The same observation can be made on the grounds of carried out interviews especially with policy-makers. Another observation, based mainly on the interviews, is that an important factor for successful renewable energy development is not only the existence of adequate organisations – agencies, departments, funds, programmes etc. – but, more importantly, the presence of the "right" persons in these organisations. The "right" people can be here described as people, treating the development of renewable energies as their personal goal, so to speak. If actors, in favour of conventional energy or actors, who do not understand and see the advantages of renewable energies and the dynamics of their cost etc., are in charge of promotion and support of renewable energy, only minimal efforts and symbolic actions can be expected. The examples of the "right" persons in Lithuania are the researchers at the Centre of Renewable Energy Technologies at Kaunas University of Technology and the founder of Renewable Energy Information Consultation Centre (ATEIK).

Considering the importance of actors, for further investigation of the possibilities to develop advanced RE technologies in Lithuania, I recommend a wider range of interviewees. The interviews, carried out for this report might not present an exhaustive picture, because e.g., only representatives form Ministry of Economy were interviewed as policy-makers; however, environmental regulators are also influencing the development of renewable energy. Additionally, the following actors should be interviewed in order to perform a more complete actor analysis: manufacturers of energy technologies, (renewable) energy producers, potential investors, energy suppliers, the researchers behind the implemented biomass power gasifier in a wood processing factory etc. Moreover, learning from the "lessons learned", of the countries that already have successfully developed a number of RE technologies, such as Germany and Denmark, should be initiated by interviewing the important RE actors in these countries.

Consequently, the recommended follow-up work is: the development of a technological scenario[1] for utilisation of the real physical potential of renewable energy in Lithuania and a consequent proposal of a more concrete policy framework (based on the described tentative framework) for development of advanced RE technologies and implementation of the scenario(s); the development of user oriented action scheme for education and promotion of energy efficiency and renewable energy; and a more extensive actor analysis.

[1] Identifying advanced technologies to be developed.

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Appendix A

Comparison of electricity generation from fossil fuels and renewables (Scheer 2002, p.79)