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TRANSFORMING TECHNOLOGICAL INNOVATION SYSTEMS: A FUNCTIONAL ANALYSIS OF THE ESTONIAN RENEWABLE POWER GENERATION SYSTEM

Master Thesis

Supervisor: Kaija Valdmaa, MA

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I hereby declare that I am the sole author

of this master's thesis and it has not been

presented to any other university for examination.

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ABSTRACT

The current research takes a look at electricity generation from renewable energy sources in Estonia from a technological innovation system perspective. The system is analyzed based on how well a set of functions is fulfilled. Based on that the mechanisms that block or induce the transformation of the system from a formative to a growth phase and the policy measures necessary for that transformation to happen are identified. The research found that the main areas that need to be dealt with in this particular case are educational and institutional alignment between the incumbent and new systems; revision of the current institutional framework, including the allocation of subsidies and support measures as well as permit attainment processes; and fostering the creation of networks and feedback loops.

Keywords: technological innovation system, electricity generation, renewable energy sources, functional analysis, energy policy.

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INTRODUCTION

Creating energy policy is a very manifold issue nowadays. Policy makers must consider energy security, risks appertaining certain technologies (e.g. shale oil and nuclear), climate change, availability and longevity of resources, not to mention all the economic aspects of the policy, such as keeping the price as low as possible for consumers while, at the same time, fostering the creation of new market opportunities. Furthermore, for member states of the European Union (EU) energy policy must also coincide with quite strict regulations concerning climate change mitigation.

This research looks at the issue from the perspective of a small North-Eastern European nation – Estonia. This country has been chosen not only because of its connection to the author but also because of the rather interesting existing pretext. Estonia is the world's biggest producer of electricity from oil shale (Liik et al. 2005). Almost 90% of all electricity produced in the country comes from it. Oil shale is also accountable for about 70% of all non-hazardous and 82% of the hazardous waste, 80% of the entire water used, and roughly 70% of carbon dioxide emission in the country (National Audit Office 2012). Additionally, since 1998 the energy sector has been responsible for about 85% of the greenhouse gas emissions in the country (Tõnurist, Valdmaa 2013, 8). Nevertheless, the use of oil shale has been deliberately decreased by the government due to EU regulations and concerns for sustainability and the environment. That has fostered the emergence of electricity production from renewable energy source (RES).

This thesis takes a look at the current situation of electricity production from RES and how it could be transformed in order to move towards a wider use of RES. As an emerging technology renewable power generation (RPG) technology has to go through a formative phase before it can be subject to a market environment (Suurs 2009, 24). In a formative phase the technology is subject to policy measures, entrepreneurial and research activities, all of which determine whether the technology will 'take off'. In order to take all possible aspects that influence this take-off into consideration this thesis will adopt an innovation system approach to better understand the dynamics surrounding the technology and the steps necessary for the transformation of the technology from a formative to a growth phase. A framework for analyzing the possibility for this transition will be created by synthesizing different existing theories in the technological innovation system spectrum and beyond. This framework will then be tested on the specific Estonian context for electricity production from renewable sources. In doing so, this research will use mainly qualitative analysis to determine the current situation of this particular technological system and its future perspectives. The methods will include analyzing current policies on both national and EU levels and existing research on the subject matter, as well as, interviews with industry specialists, statistical data, etc. Much of the background information into the research is gained from the author's personal, work-related correspondence with government officials and industry experts who wish to remain unnamed. The purpose of this research is not to indefinitely draw out one solely plausible path for electricity production for Estonia, but rather to contribute to the research into one option – the option of renewable power generation.

The main research questions posed in this study are:

- What is the current situation of renewable power generation in Estonia?
- What is blocking the broader use of RES in electricity production?
- Which kind of policy measures can (should) be used to overcome these blockages?

In the first part of the thesis an analytical framework for examining a technological system will be created by synthesizing existing research in this field. The necessary focuses will be brought out and explained. In the second, case study part, firstly a brief introduction will be given into the situation of the Estonian electricity production and certain peculiarities brought out, as well as, the methodology explained. Secondly, the created framework will be tested on the specific case of Estonian RPG technology. Based on that the current situation of electricity generation out of renewable energy sources in Estonia will be examined, functioning of the system assessed, and relevant policies evaluated and suggestions for furthering the use thereof presented.

1. THEORETICAL FRAMEWORK

1.1 Innovation systems

The core function of this theoretical framework is to form a comprehensive overview of all the elements that influence the adoption of renewable sources in electricity production and indicate the necessary conditions that need to be fulfilled for the process of transformation. This matter can be addressed from various different angles, such as the angle of the entrepreneur, the policy makers or the consumer. To create a more comprehensive overview that also takes into account that the process of transformation of a sector is very time consuming and depends on all of the aforementioned stakeholders, the 'system innovation' (SI) approach is used (for advantages of a SI approach see: Edquist, Hommen 1999).

The SI approach has fairly many subsections, like regional (Cooke 1996), national (Lundvall 2010), global (Sagar, Holdren 2002), sectoral (Malerba 2004; 2002) and technological innovation systems (Carlsson, Stankiewicz 1991). The most well-known of those (roughly half of the publications in the last 20 years (Markard, Truffer 2008, 598)) is the national innovation system (NIS) (Jacobsson, Johnson 2000, 629). This term was coined by Bernt-Åke Lundvall in 1992 but, according to Christopher Freeman, can be traced back to as far as Friedrich List and his "National System of Political Economy" from 1841 (Freeman 1995). Lundvall defines the NIS as "the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge … either located within or rooted inside the borders of a nation state" (Lundvall 2010, 2). Metcalfe (1995, 462-463) goes a step further and describes the NIS as:

> *[T]hat set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation system. As such it is a system of interconnected*

institutions to create, store and transfer knowledge, skills and artefacts which define new technologies.

Since the research at hand deals with one concrete technological spectrum, that is renewable power generation technology, the latter definition helps to bring the technological aspect into the scope. For the purposes of this research even one more step further is taken and the slightly more narrow ‘technological systems’ approach is employed as the basis for creating the theoretical framework. This specific approach was first developed by Jacobsson and Johnson (Bergek) in 2000 to specifically cater the RPG technology. This approach shifts the focus from the national factor to the technological one while keeping the emphasis on the fact that the whole system matters. Furthermore, this approach, instead of sectoral SI approach, is applied because it takes into account that renewable technology is just one cluster of technologies in a wider energy technology sector (Berkhout 2002, 3).

1.2 Technological Innovation Systems

In their framework for analyzing the technological innovations system (TIS) for renewable electricity, Jacobsson and Johnson (2000) emphasize the need to identify the main elements of a TIS. Though it gives a very good overview of how the system looks like, it fails to provide an insight of the dynamics of the TIS or explain how the different elements influence the direction and speed of innovation (Edquist 2008, 4). Edquist argues that, thus, also the context of the system has to be taken into account (ibid.). Again Jacobsson and Bergek (2004) are the first ones who develop a theory for doing this with specific emphasis on energy technology. In this paper they explain what the functions of a TIS are and how these functions can be hindered or furthered. The legitimacy of these functions has been empirically tested by many authors on various occasions, such as Suurs (2009), Hekkert and Negro (2009), Huang and Wu (2007), Suurs and Hekkert (2009a; 2009b), Bergek et al. (2008a; 2008b), and Hekkert et al. (2007), Jacobsson and Bergek (2011).

In order to develop this framework even further, in 2008(a) Bergek et al. created a ‘six step analysis’ (illustrated in figure 1 below) that ties together the findings of the two abovementioned papers, and adds a policy dimension to them. The first step in the analysis is to define the TIS at hand, which in this particular case is the system built around the technology used for generating electricity from renewable energy sources. The main purpose of this step is to set the limits for the system. By defining the specific system under observation, the boundaries of the technological system will be set. This means that the unit of study should first be determined which then already indicates the depth and breadth of the study (Bergek et al. 2008a, 411; Bergek et al. 2005, 6). For example, examining the technological system around one very specific product will most probably go rather in depth but concentrating on a whole cluster of technologies will give a broader overview of the topic (ibid.). The research will come back to this step in more detail when talking about Estonia specifically.

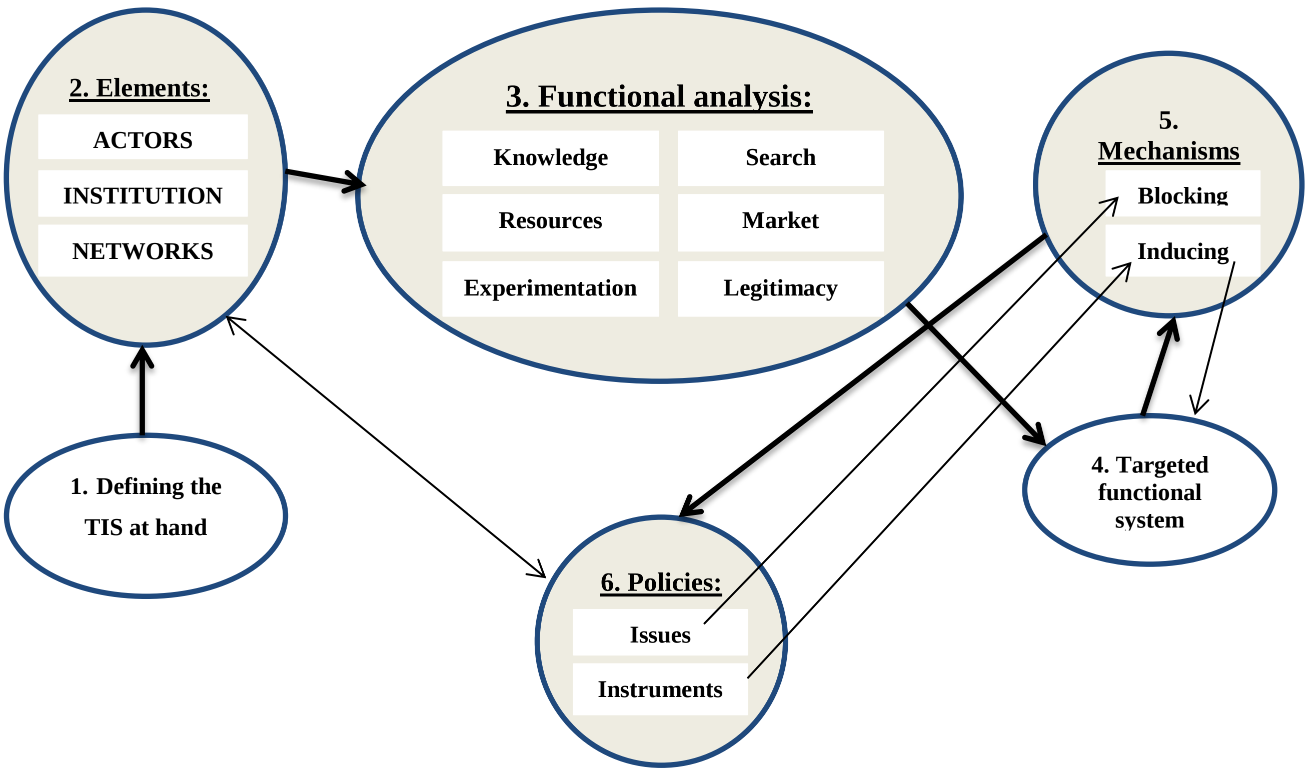

Figure 1. **The 'six step analysis' and dynamics of the functioning of an innovation system.**
Source: Author based on Bergek et al. (2008a) and Oltander, Perez Vico (2005).
Note: the bold lines refer to the direction of the 'six step analysis' while the narrow lines indicate other relationships between the components.

In the second and third steps the components (elements) and functions of the system will be identified. This will be done using the abovementioned frameworks established by Jacobsson and Bergek (2000; 2004) which will be further described in the sections 1.3 and 1.4 of the thesis. The fourth step is more normative than the previous ones, as it requires these same functions to be analyzed in terms of their performance and whether they coincide with the targeted (ideal) functional system that fosters the move from a formative to a growth phase. This is different for each specific system and depends on the elements and the functions. Thus, the research will come back to this step in the case study analysis.

In the fifth step the mechanisms that either induce or block the development towards the desired functional pattern must be identified and in the sixth and final step the policies behind these mechanisms will be analyzed. Latter is extremely important for the transformation of the system, since transition requires “changes in the structures in which earlier practices are embedded, and which have co-evolved with earlier practices” (Grin et al. 2011, 76). Politics serves as the context, obstacle, enabler, arbiter, arena, and manager of repercussions, all at the same time (Meadowcroft 2011, 71). Naturally what blocks and induces the system and the policies behind them relevant to the Estonian case can only be identified after the elements and functions of the specific TIS have been analyzed, since the components of the system greatly influence the functioning of the system. Nevertheless, a broader overview of these mechanisms and measures will be provided in section 1.5 of the thesis. Finally, by analyzing the existing and desired policy measures behind the blocking and inducing mechanisms it is possible to identify the necessary policy changes and steps that need to be taken for the transformation of the Estonian electricity production towards greater use of renewable energy sources.

1.3 Elements of a technological innovation system

The very first step to understanding a TIS is to define it. Jacobsson and Johnson (Bergek) (2000, 269) adopt Carlsson’s and Stankiewicz’s definition of a technological innovation system in their research. The latter two say that technological systems are “networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize technology” (Carlsson, Stankiewicz 1991, 94). Technological systems are “defined in terms of knowledge or competence flows rather than flows of ordinary goods and services" and "consist of dynamic knowledge and competence networks" (ibid.). Quite similarly to Metcalfe's (1995) definition they emphasize two important aspects: interaction and knowledge transmission between actors in the system and the importance of institutions.

Jacobsson and Johnson (2000), building upon those two aspects very broadly bring out three main relevant elements to a technological system and explain how they influence the generation, diffusion and utilization of renewable energy technology. They distinguish those elements as actors, networks and institutions. More simply put: a system consists of organizations (actors) that communicate and act (networks) according to the limits set by the rules in the system (institutions). These elements set the scene for the whole system. Any change in their structure influences the system and vice versa (Jacobsson, Johnson 2000).

1.3.1 Actors and their competences

Actors are the 'agents' mentioned in Carlsson's and Stankiewicz's definition (Bergek et al. 2008a, 81). They are "organizations or institutions that operate in a specific policy domain, such as the promotion of green electricity" (van Rooijen, van Wees 2006, 61). The array of actors is growingly large in the sphere of energy policy. They vary from producers to consumers, from financers to environmental activists, from academia to policy makers – all with their specific interests in the matter. Hence, it is important to understand their competences.

Besides the more obvious research and development (R&D) capacity of academia and the influence over the rules of the system of the policy makers, it is very important to understand the dynamics between the competences of incumbent actors and 'prime movers' or 'system builders' (Hughes 1983 in Jacobsson, Bergek 2004, 817) operating in the same sector (but not necesseraly in the same technology sphere) (ibid., 817). The term 'incumbent actor' refers to those organizations which have already established a strong presence in the sector. In this particular case this usually means those dealing with fossil fuel related activities but can also encompass more advanced and mature green technologies, such as hydropower. The latter – prime movers – stands for those actors (or a set of actors) in the sector who are "technically, financially and/or politically so powerful that they can initiate or strongly contribute to the development and diffusion of a new technology" (Jacobsson, Johnson 2000, 630).

Whereas the more competent the prime movers the better it is for the emerging technologies since they are one of the main motors for the legitimation of the new technology, the incumbent actors rather tend to inhibit transformation. Logically, this stems from their wish to (continue to) control the market. This is especially true when talking about companies who generate electricity from fossil fuels and have dominated the market for decades, since they wish to fight against disruptive forces (Geels 2005). Incumbents generally have large production capacities which are hard to remodel to fit the green paradigm which makes them reluctant to change (Teppo 2006).

1.3.2 Networks

The reason for the vast influence incumbents have on policy decisions is due to the established networks between them and policy makers. Van Rooijen and van Tees (2006) call these networks 'coalitions' whereas Carlsson et al. (2002, 233) refer to them as 'relationships'. These coalitions/relationships/networks indicate the interactions between the aforementioned actors. They constitute "important channels for the transfer of both tacit and explicit knowledge" (Jacobsson, Bergek 2004, 818) and the formation of power and influence through "relationships, particularly their [the actors'] mutual dependency and the distribution of resources" (van Rooijen, van Tees 2006, 61). Resources can be financial or take the form of knowledge and/or media access, etc. By distributing those resources among the actors, relative influence and power dynamics are formed which create the "perception of what is desirable and possible" (Al-Saleh 2010, 316). This means that since networks control knowledge they also influence the "images of the future, which guides specific investment decisions" (Jacobsson, Johnson 2000, 630). For example, the network dynamics decide whether future investment decisions are dominated by concern over climate change and carbon emission or economic considerations and keeping consumer prices low (Agnolucci 2008, 148).

Coalitions can also be built around the market rather than being political and aiming to influence the institutional set-up (Jacobsson, Bergek 2004, 818). Carlsson et al. (2002, 234) suggest that networks can be divided into three cathegories: user-supplier (input/output) relationships, problem-solving networks and informal networks. Whereas the latter aims at gaining influence over institutions, relatioships such as the user-supplier networks are important for “the indefication of new problems” (Jacobsson, Bergek 2004, 818) and the problem-solving networks for the “development of technical solutions” (ibid.). Such feedback (interaction) is crutial to any technology system because it is what makes them dynamic (Freeman 1996, 31). On the other hand, weak connectivity in these networks may lead to a number of issues. Jacobsson and Johnson (2000) call these ‘network failures’. To avoid and/or overcome network problems, strong and solid institutional frameworks must be in place.

1.3.3 Institutions

Institutions refer to the rules of the system that shape and regulate “the relations and interactions between individuals and groups” (Edquist, Johnson 1997, 46), as well as “the behavior and value base of various segments of society” (Jacobsson, Bergek 2004, 818) and “legitimacy of a new technology and its associated actors” (Jacobsson, Lauber 2006, 259). That is both formal rules, such as laws and obligations, and informal rules that reflect the dominant political culture (van Rooijen, van Tees 2006, 61).

These rules form the path the system takes. Because of path dependency – e.g. long term plans for the use of fossil fuels and laws, infrastructure and industry supporting those plans, embeddedness of the incumbents into the national economy – it is hard for a new technology to emerge which can lead to a lock-out of renewable technologies (Neuhoff 2005, 97). Hence, institutions “need to be adjusted or ‘aligned’, to a new technology” (Bergek et al., 2008a, 413) to pave way for the “growth of new industrial clusters” (Jacobsson, Bergek 2004, 818). One of the most well-known examples of the latter in the renewable energy sources (RES) technology is the role played by the European Union and its active and quite aggressive push for member states to cut carbon emissions and increase energy efficiency and the use of renewable energy sources (Midttun 2012).

1.4 Functions of the technological innovation system

Whereas identifying the different elements of an innovation system helps set the border for said system and get a general overview of it, identifying the functions helps to understand what is working in the system and what is not. They “constitute an intermediate level between the components of a technological system and its performance” (Jacobsson, Bergek 2004, 818). Charles Edquist (2008; Chaminade, Edquist 2005) calls these functions ’actions’. In his research he brings out ten actions incumbent to an innovations system. The current research follows Jacobsson’s and Bergek’s functions rather than Edquist’s activities as they are more relevant to the system under observation which is, by its nature, a technological system, and focuses more on the responsibilities of public actors and, hence, policy decisions of governments rather than private companies (Edquist 2008).

Jacobsson and Jacobsson (2004) bring out five main functions of a technological innovation system and Bergek et al. (2008a) add two more functions, as shown in table 1 below.

Table 1

Functions of a technological innovation system

Jacobsson and Bergek:	**Bergek et al.:**
• Knowledge development and diffusion • Influencing the direction of search • Resource mobilization • Market formation • Creation of positive externalities[1]	• Entrepreneurial experimentation • Legitimation

Source: Author based on Jacobsson and Bergek (2004) and Bergek et al. (2008a).

1.4.1 Knowledge development and diffusion

Knowledge development and diffusion is considered to be one of the most important functions of a TIS and is “normally placed at the heart of a TIS” (Bergek et al., 2008a, 414). In this sense the term

[1] The current framework leaves out the function of creating positive externalities because it can be argued that it is not a function as such but rather it enhances the other functions (Bergek et al. 2008a, 419). Though it is valuable for analysing the dynamics of the system, it is not relevant in the context of the current research, since it only gives insight into ’whether’ the system works rather than ’how’.

‘knowledge’ refers to technological innovations and not human capital. It explains how this knowledge is not only created but also transferred and exploited (Chaminade, Edquist 2005, 11). Not only is the creation of new knowledge – R&D activities – “crucial but so is its accessibility” (Edquist 1997, 16). The developed knowledge has to also be diffused through the aforementioned networks that are developed between and compise of actors.

Carlsson et al. (2002, 243) bring out some indicators that can be used to determine the ability of a system to generate knowledge. Firstly, they signify the patent indicator which reveals the “volume and direction of technological capabilities in the system” (ibid.). The second indicator is the number of engineers and scientists working in R&D which can be determined using bibliometrics. They also bring out the diversity of operations (number, size and orientation of R&D projects) as one possible indicator but add that it can only *presumably* reflect the “robustness of a system and its growth potential” (ibid.). Hekkert et al. (2007) add that R&D investments are an idicator for this function while Bergek et al. (2008a, 414) point out that there are different types of knowledge, such as scientific, market, technological, production, etc, and different sources of knowledge development, such as R&D, imitation, learning by doing, etc.

1.4.2 Influencing the direction of search

Al-Saleh (2010, 323) states that if the previous function is “concerned with the creation of technological ‘variety’, this function represents the process of ‘selection’”. It is used to make the TIS attractive to actors so that they choose to enter it by providing sufficient incentives and/or pressure for the organization to be induced to do so (Bergek et al., 2008a, 415). Al-Saleh brings renewable and emissions targets set by governments as an example of influencing the direction of search. Bergek et al. (2008a) also list this example as one of the qualitative factors that can help measure this function. They call it ‘regulatory pressure’. Other such factors include beliefs in growth potential, incentives from prices (for example taxes in the case of the energy sector) and articulation of interest by leading customers. Hekkert et al. (2007) also bring out the number of press articles that raise expectations as possible indicators for measuring performance concerning this function.

This function also covers the mechanisms that have an influence on the direction of search within the system. For example, the actors’ perceptions about which sources of knowledge are relevant and which are not. The most obvious example concerning green energy production is the extent to which actors choose to believe in the harmfulness of fossil-fuels. Bergek et al. (2008a) also bring out actors' assessments of the present and future technological opportunities, such as whether the technology will have short-term or long-term gains, or neither, or both; or whether governments employ long-term policies that create a stable environment for investing. Also, agents are influenced by what is happening with incumbent actors. For example, the demand for RES technology tends to rise when there is a crisis in the existing business, such as the oil crises in the early 1970s or the nuclear disasters.

1.4.3 Resource mobilization

Whereas knowledge development and diffusion deal with the technological side of the knowledge spectrum, resource mobilization analyzes the human capital part. The necessary training and education that is of importance to an innovation system is usually provided by public organizations, such as universities, but also by individual firms through learning-by-doing, learning-by-using and learning-by-interacting (Edquist 2005, 22). The first kind of competence building is quite easy to track trough investigating government's and universities' official plans. The latter tends to be tacit in its nature and is, thus, extremely difficult to quantify (Andersen, Lundvall 1988, 15).

This function also deals with resources such as financial capital and complementary assets, such as complementary products and services and/or network infrastructure (Al-Saleh 2010, 324). It indicates, for example, whether or not inner core actors perceive resource access as problematic (Hekkert el al. 2007). Bergek et al. (2008a, 417) define four ways by which to measure resource mobilization. Those are the rising volume of capital, increasing volume of seed and venture capital, changing volume and quality of human resources (e.g. number of university degrees), and changes in complementary assets.

1.4.4 Market formation

In the case of emerging TISs there is often a situation where the market does not yet exist or is underdeveloped and new technologies generally have to also compete with incumbents (Al-Saleh 2010, 324). Hence, a market needs to be created.

One way of doing so is to determine whether the technology under investigation is superior in some dimension, such as RES technology is when it comes to the lack of negative externalities and the abundance of the actual resources (sun, wind, water, etc). That enables the creation of niche markets (Jacobsson, Bergek 2004, 319). Such markets usually enjoy some sort of ’protection’ in the form of government subsidies or tax reductions (Chaminade, Edquist 2005, 24). These protected spaces may serve as ’nursing markets’ for new technologies (Jacobsson, Bergek 2004, 320) where a ’learning space’ is opened up, in which the TIS can “find a place to form” (Kemp et al. 1998 in Bergek et al. 2008a, 416). The desired stage – a ‘mass market’ – is one where the product – electricity produced from renewable sources – becomes a commodity (Jacobsson, Bergek 2004, 320). For this transition to occur there are numerous policy measures that can be employed, such as public innovation procurement (Borràs, Edquist 2013, 1519), creation of standards (Unruh 2000, 820) and the aforementioned government subsidies (Chaminade, Edquist 2005, 24).

In order to analyze the formation of markets it is important to identify the actors in the market, particularly the users, and how the purchasing pocess looks like, and whether demand has been clearly articulated and by whom. Thirdly, institutional stimuli must be evaluated or the lack thereof. Indicators to trace these developments also include such qualitative data as actors’ strategies, role of standards, etc (Bergek et al. 2008a, 416).

1.4.5 Entrepreneurial experimentation

Entrepreneurial experimentation is intended to fill the gap between the R&D stage and the product becoming a commodity. Without vibrant experimentation a system will become stagnant. The role of the entrepreneur is “to turn the potential new knowledge, development, networks and environments into concrete actions that generate, realize and take advantage of business opportunities” (Al-Saleh 2010, 322). These entrepreneurs might be new firms in new product areas, incumbents that diversify or foreign firms in the new product area (Chaminade, Edquist 2005, 26). They are crucial for solving the uncertainties inherent in an emerging TIS that result from the interactions between different actors in the system. These uncertainties go far beyond the “technical scope, e.g. within R&D laboratories, as they encompass the heterogeneous context where R&D activities may interface with government policies, competitors and markets” (Al-Saleh 2010, 323).

Bergek et al. (2008a, 415-416) bring out a mechanism to analyze this particular function of the TIS, which is to map the number and variety of experiments taking place in terms of new entrants, different types of applications and the breadth of technologies used (including complementary technologies). In the case of green electricity production technology it is important to monitor the building of, for example, wind turbines and installation of solar panels, companies operating in those fields, how the government funds R&D, etc (Hekkert et al. 2007).

1.4.6 Legitimation

Legitimacy refers to the social acceptance of the new technology and its proponents and to how it fits into the institutional set-up. It is not a given and must be formed through deliberate actions – legitimation.

One of the main obstacles to overcome is competing with incumbent TIS(s) which in this case is tied to fossil fuel based technologies. Since the new TIS must become part of the incumbent regime both conformance with the existing institutional framework and creating new frameworks is quite difficult (Al-Saleh 2010, 325). Hence, the institutional setting has to be somewhat 'manipulated' (Bergek et al. 2008a, 417). Arguably one of the best ways of doing so is by creating advocacy coalitions, i.e. groups of actors with similar beliefs created in order to influence the institutional setting in the lines of those beliefs (Jacobbson, Lauber 2006, 259). For a new technology to gain ground, technology-specific coalitions need to emerge for the purposes of lobbying, being involved in political debates and gaining support for the new technology.

In order to analyze this function of the system, both the legitimacy of the TIS in the eyes of relevant actors and the activities inside the system that influence the legitimacy must be mapped (Bergek et al. 2008a, 417). This signifies the need to understand the current situation of the TIS concerning legitimacy (whether there is an alignments with the existing legislation and the overall values of both the society and the industry), the ways in which demand, legislation and industry are, in turn, influenced by legitimacy, and what, who and how influences legitimacy.

All in all, as mentioned before no TIS is ever the same as another. Even though, this research does not look at the green electricity innovation system from a strictly NIS perspective, the national component is still very much relevant. That is because the elements of the system differ significantly from one country to another. Those specific elements, in turn, greatly influence the performance of the functions, as the 'six step analysis' very well illustrates. By analyzing the functions, the weaknesses and strengths of the system can be determined and the causes behind these weaknesses and strengths pointed out, as further explained in the next section.

1.5 Mechanisms and policies

It is important to understand that no one function can stand alone in the innovation system. Rather they are all intertwined and a single function's alteration from the eqalibrium necessary for the system to develop can cause either positive or negative changes in another and/or the system as a whole (Negro et al. 2007, 928). These alterations are, depending on the nature of their impact, called either inducement or blocking mechanisms. In essence these mechanisms represent what is negative and what is positive about the system (Jacobsson, Bergek 2001). These mechanisms differ greatly depending on the elements and functional structure of the system, as well as the spatio-temporal context, meaning that they are different for each country and each specific TIS at any given time. Nevertheless, the thesis will stop on the findings of Jacobsson and Bergek (2004, 825-827), who identified these mechanisms for the Swedish and German renewable technologies system (illustrated in figure 2 below), to give a brief overview of the nature of these mechanisms.

For example, activities of firms, especially entry of new firms into the system, help create and diffuse new knowledge, stimulate market formation and widen the resource pool (Negro et al. 2007, 927). Similarly, feedback loops contibute to the availability of resources, foster entrepreneurial expermentation and quite significally influence the direction of search (Hekkert et al. 2007, 426). High uncertainty and lack of legitimacy[2], on the other hand, affect the availability of resources, knowledge creation and setting the direction of search in a negative way (Jacobsson, Bergek 2004, 826). Contrary to feedback loops, weak connectivity – which refers to weak learning and political networks between proponents of the new technology – may lead to problems in the system being mishandled (Jacobsson, Johnson 2000, 633). Weak connectivity hinders the mobilization of resources, as well as knowledge diffusion, for example (Jacobsson, Bergek 2004). Also, as

[2] At this point Jacobsson and Bergek (2004) did not consider 'legitimacy' as a separate function yet. See Table 1.

mentioned before incumbent producers and capital goods suppliers usually have established wide-ranging networks, and, thus their opposing behavior can greatly influence the emerging system, as they have great influence over the direction of search, as well as the means to block the formation of new markets (Negro et al. 2007, 928).

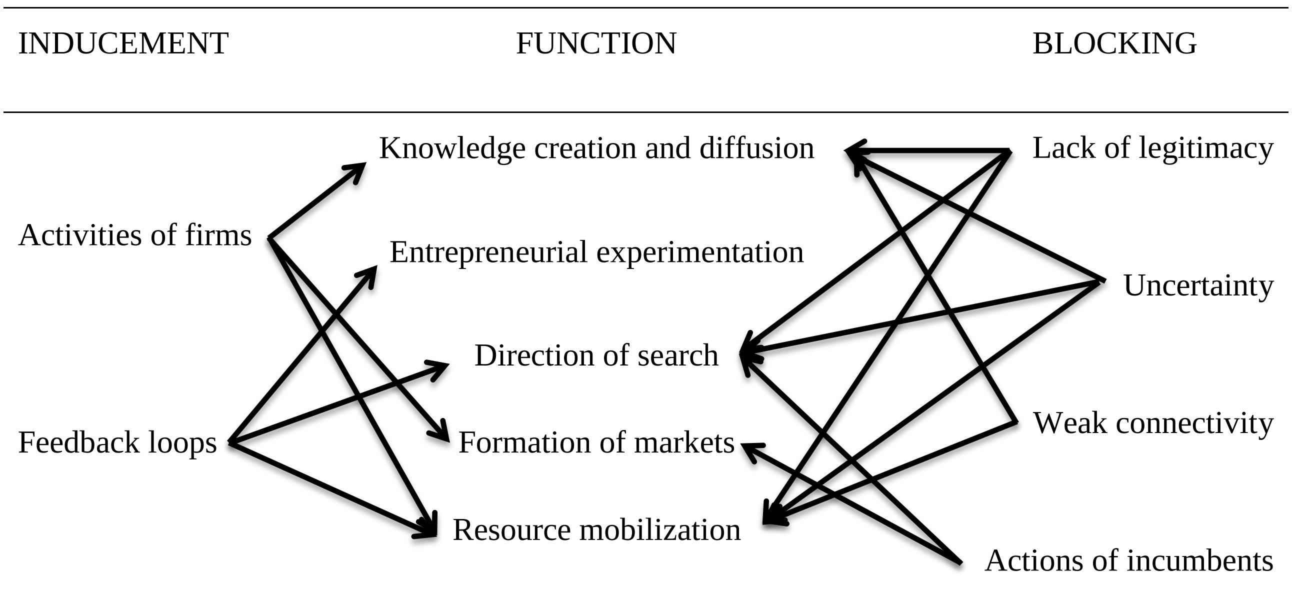

Figure 2. **Blocking and inducing mechanisms' influence on the functioning of a TIS.**
Source: Author based on Jacobsson and Bergek (2004).

Though some blocking mechanisms stem simply from the structure of the system, most of them are made possible by issues in the existing policies. As Suurs (2009, 50) puts it, the idea behind any TIS is to reach a goal (in this case transformation) by fulfilling "a set of system functions" or reaching the targeted functional system. To put it very simply: there are always certain policy issues (called 'policy problems' by Edquist (2008, 18) and 'policy failures' by Bergek et al. (2005, 25)) in place in the existing institutional framework that have created mechanisms that block the functioning of the system; and these issues need to be dealt with through policy instruments that induce mechanisms that drive the functioning of the system.

Government policies, such as, R&D funding, financial incentives, subsidies, tax policies and favorable legislation has been known to help induce all six functions: market formation, directing search, knowledge development, legitimation, supply of resources and entrepreneurial experimentation (Bergek et al. 2008a, 422). Thus, it is fair to say that government policies and the regulatory framework create the basis for the functioning of a technological innovation system (Jacobsson, Lauber 2006). Nevertheless, the lack of continuity when it comes to government policies is one of the main reasons behind uncertainty. Inconsistent and constantly changing policies drive away investors, thus, hindering the supply of resources and misguiding the direction of search (Jacobsson, Bergek 2004, 827).

One more aspect to pay attention to when it comes to policy measures, especially in fields that are relatively new, is the lack of them (Bergek et al., 2008a, 414). This means that there might not be sufficient laws and/or support mechanisms in place for the new technology to take ground yet. In the case of RES support measures, for example, there is an ongoing debate among scholars that started already a decade ago about which mechanisms – obligations, feed-in tariffs, quota systems, subsidies, portfolio standards, public procurement, tradable green certificates, premiums, tax incentives, fiscal stimuli, etc – are best suited for promoting renewables in energy generation (Jørgensen 2005; Madlener, Stagl 2005; Reiche, Bechberger 2004; Verbruggen, Lauber 2012; Mir-Artigues, del Rio 2014; etc).

All in all, this means that the institutional setting that sets the ‘rules for the game’ also determines what the functional errors and successes shall be (Jacobsson, Lauber 2006, 261). By examining the elements of the system and their functioning, a possible path to greening electricity production can be determined.

2. RENEWABLE POWER GENERATION IN ESTONIA

This thesis will take a look at a rather unique country in the electricity production context – Estonia. Estonia is unique, first and foremost, because the small EU country is highly dependent on its oil shale reserves. Whereas 25% share of renewable energy in the gross final energy consumption, which is the target for 2020 set by EU (European Commission 2013), was reached already in 2011, the dominance of oil shale is slightly more evident when looking at electricity production. There, according to the Estonian transmission system operator (TSO) Elering, only 12.6% (Elering 2014a) was produced from renewable energy sources (RES) and less than 7% from natural gas and other fossil fuels combined[3] . Even though this is quite an improvement from the level of the early 2000s (Liik et al. 2005) it still raises concerns about what will happen when Estonia runs out of oil shale?

Another issue with Estonia being overly dependent on oil shale in electricity production makes the country's primary energy intensity 50% higher than in Latvia and Lithuania and six times higher than in Denmark (Elering 2014b). Further concerns stem from the amounts of pollution from generation plants. This is vital because EU has not only set targets for increasing the usage of RES in energy production but also emphasizes greenhouse gas (GHG) emissions. According to Eurostat estimates the overall level of CO_2 emission, for example, has fallen 2.5% in EU in the year 2013, but has actually risen 4.4% in Estonia. The EU-wide (plus Lichtenstein, Iceland and Norway as members of the European Free Trade Association) Emissions Trading System (ETS) is the main tool for fighting emissions. At the moment the price for CO_2 quotas is much lower than the Commission would like it to be in order to accurately reflect the damage done to the environment and much of the quotas are actually allocated to power generators for free (Rosendahl, Strand 2012). Nevertheless, the Commission is lowering the carbon cap by 1.74% yearly and is planning to increase that to 2% after 2020 (European Commission 2014). If adopted the framework for 2030

[3] These figures are accesible through Statistics Estonia (*Statistikaamet*) and Eurostat

will serve as a legal basis to ensure that carbon emission will get more expensive and investment into low-carbon technologies is necessary.

What makes Estonia and its electricity production even more interesting is the country's close proximity to Russia. The small Baltic state is still connected to the Russian Federation's electricity grid and its only connection to the rest of EU (except the other Baltic States) are the two EstLink cables between Estonia and Finland with the total capacity of 1000 MW (350 MW via EstLink1 and 650 MW via EstLink2). Because of this the three Baltic States are often referred to as 'energy islands' in the EU context. In the framework of the Baltic Energy Market Interconnection Plan (BEMIP) electricity interconnections, both NordBalt (between Sweden and Lithuania) and the first stage of LitPol (between Lithuania and Poland), are scheduled to come online by the end of 2015/early 2016. For Estonian electricity generators this means that they will no longer have to compete only with even more expensive electricity produced from natural gas (in Latvia and Lithuania) but with, for example, cheaper Danish wind energy or Norwegian hydropower. Already the inauguration of EstLink2 in April this year has shown a decrease in electricity prices thanks to electricity flows from Finland (Source: Nord Pool Spot). With the further increase of cheaper alternatives, it seems rather likely that electricity produced from oil shale might not be competitive without extensive state aid (National Audit Office 2012).

Taking into account the abovementioned factors – oil shale being non-renewable, highly polluting and non-competitive on an EU-wide market (without government support) – it seems rather likely that in the long-term perspective generating electricity from oil shale is not a sustainable option for Estonia (ibid.). At this point there are not too many options for alternative energy sources. One option for Estonia is shale oil (European Commission 2014). Due to the controversies about the safety of fracking, though, this thesis will refrain from further discussion on this subject. Similarly, nuclear energy raises many questions. Apart from the safety issues, the technology is also very expensive and its advancement has reached a relative standstill in the recent decade or so (Schneider et al. 2013). Also, natural gas, at the moment, even with the advancements in transport through broader use of liquefied natural gas (LNG), is too expensive and too dependent on Russia. This leaves mostly renewable energy sources to be more broadly utilized in electricity generation.

2.1 Methodology

This research is by its nature a case study. This approach is used in order to effectively analyze this very multidimensional issue while catering for the wide range of sources that have to be used, the connection between the research and the context, and the constant flux the topic is in (Yin 2003). Taking this approach requires a very in-depth overview of the topic at hand. This has been done by historical event mapping (Suurs et al. 2010, 423). This means that the author has analyzed an extensive amount of relevant academic papers, both domestic and EU-level laws and regulations, news articles, reports, action plans, development strategies, conferences, policy papers, seminars, etc to map the situation of the Estonian renewable power generation technological innovation system (RPG-TIS). This also helps to create an overview of the key actors in the system, as well as an insight into the functioning of it, making this approach suitable for the implementation of the created analytical framework.

Much of the background information was gathered through personal correspondence with high officials from Elering, Eesti Energia, the Ministry of Communications and Economic Affairs, as well as other industry representatives and researchers (list of these interviews can be found in the appendix). This was done within a the period of more than half a year between fall 2013 and spring 2014 during which the author was working for the International Centre for Defence Studies in Tallinn as a researcher of energy security with a special focus on the electricity market. These interviews also greatly helped to validate the independent findings of the author and restructure them when necessary.

2.2 Step 1: Defining the system

The main purpose of the first step in this analytical scheme is to set the starting point for the rest of the case study. This thesis takes a rather broad starting point by choosing all renewable sources that are used for electricity production, rather than just focusing on, for example, wind turbines. This is done in order to get a broader overview of the condition of RES in Estonia. On the other hand, the thesis only considers electricity production and not energy generation in general or electricity storage. It will, though, consider cogeneration of heat and power (CHP), since the bulk of biomass used in electricity generation in Estonia is used in CHP plants. This specialization is done in order not to stretch the scope of the research too widely and risk being too broad and overly descriptive. Nevertheless, analyzing both aspects – specific technologies and the overall sector – can provide valuable information for both entrepreneurs and policy makers and, thus, should be subject to future research.

By looking at only electricity production from only renewable energy sources in only Estonia, the thesis already narrows the scope of this research to focus on biomass (wood) and wind energy, as the two most noteworthy RES players on the market at the moment, as shown in figure 3 below.

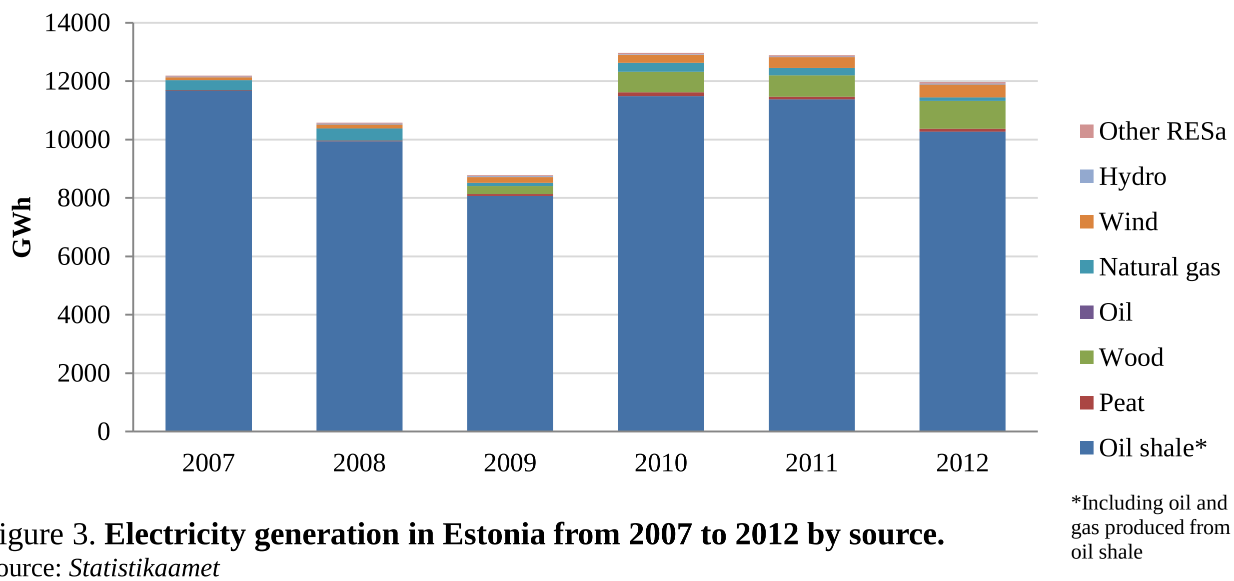

Figure 3. **Electricity generation in Estonia from 2007 to 2012 by source.**
Source: *Statistikaamet*

The figure also clearly indicates that the share of wind and biomass, as well as other RES, has been steadily growing in the last few years. This helps set a timeframe for the research. Since the use of RES in electricity generation took off in 2009, as indicated in figure 4 below. That year will be taken as the temporal starting point for the research.

One last important thing to decide when setting the limits for the research is whether to consider only domestic actors or also foreign actors within the nation-wide system (Suurs et al. 2009, 4691). Since Estonia is part of the European Union, meaning that the country's electricity market is (in principal) connected to the Common Electricity Market of the Union and considering only Estonian actors would presumably leave a rather small (probably too small) pool of actors, no discrimination will be made on the basis of origin.

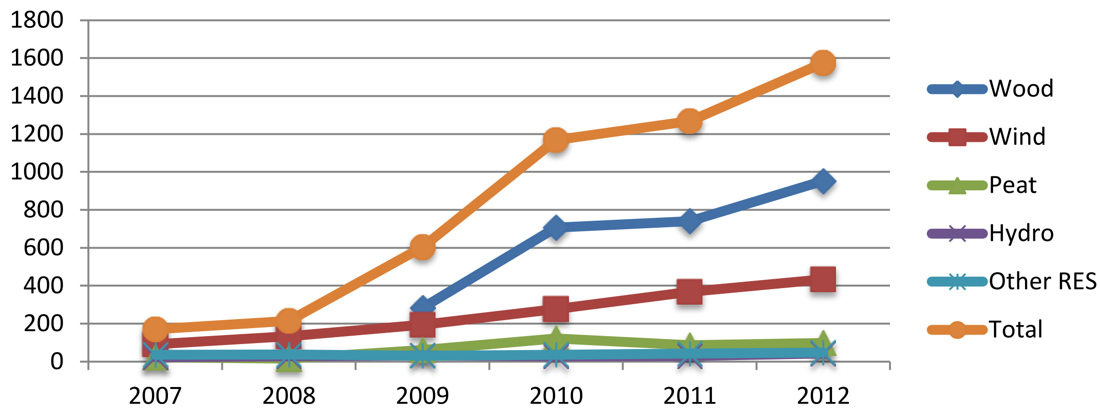

Figure 4. **Electricity generation from RES in Estonia[4] (GWh), 2007-2012**

Source: *Statistikaamet*

2.3 Step 2: Overview of the elements

The purpose of the second step of this analysis is to give a broad overview of the structure of the Estonian RPG-TIS by bringing out the most prominent elements. The elements of any given TIS comprise of actors, networks and institutions (Jacobsson, Johnson 2000, 629). Government agencies, firms, research institutions, consumers and other actors navigate within the established set of formal and informal rules. They form networks in order to influence these rules to better cater for their interests. Usually the system as a whole is analyzed rather than each individual component by itself (Edquist, Hommen 1999, 242) since single actors alone play a relatively small role in a TIS. Nevertheless, components of the system are vital to the functioning of the system and creation of an innovation policy, since analyzing them helps to identify how "a particular combination of actors or a specifical institutional set-up [has] shaped the generation, diffusion and utilization of a new technology" (Jacobsson, Bergek 2004, 819). No two systems are ever identical.

The basis for a set of institutions is laws, regulations and government policies (Unruh 2000, 824; Unruh 2002). Government related actors are also the easiest to identify, as they alternate the least and information about these actors is most easily available. In Estonia the main government actors

[4] The term 'Other RES' refers to biogas, waste, animal waste, black liqueur and up until 2008 also to wood

concerning electricity policy are the Ministries of Economic Affairs and Communication, the Environment, and Agriculture. Also, the Ministry of Finance plays quite a significant role as it is the shareholder of the biggest energy company in the country – Eesti Energia. The latter is also the most significant incumbent actor in the field of electricity production in Estonia.

Government agencies create the scene for all the other actors to operate in, they create the rules. The main laws and action plans guiding the sector (not including building permits, environmental impact analysis, etc) in Estonia are presented in table 3 below:

Table 3

Main regulations, plans concerning electricity production and the use of RES

Electricity Market Act	Sets the overall legislative framework for the functioning of the Estonian electricity market, as well RES support instruments and certification
Directive 2009/28/EC	EU Directive setting the '20-20-20' goals for the production and promotion of energy from renewable energy sources
RE action plan until 2020	Sets the short and long term targets for increasing the use of RES in energy generation
Electricity sector development plan	Sets the strategic objectives for the development of the Estonian electricity sector for the period of 2008-2018, including the target of 15% of RES in electricity gross consumption by 2015
Oil shale development plan	Sets the plan for reducing Estonian energy sector's dependence on oil shale. Currently under revision.

Source: Author based on *Riigiteataja,* Ministry of Economic Affairs and Communications, and EUR-Lex

Other than formal regulatory institutions, the system is also influenced by the established cultural norms and beliefs and, for example, public procurement policies (Bergek et al. 2008a, 414). From different action and development plans, it seems that the former is illustrated by the prevalence of concerns over electricity prices and immediate energy security rather than sustainability, i.e. using oil shale as efficiently as possible and fulfilling the RES obligations as cheaply as possible (Tõnurist 2014, 21). In public procurement more emphasis is put on energy efficiency (for example, in buildings) and electric cars, than power generation (see Lember et al. 2013, 15-16). Furthermore, the culture is influenced by the relative power of the incumbent actors (Jacobsson, Lauber 2000). In the case of Estonia this is Eesti Energia which for a very long time has had a monopoly position in power generation. It is very hard from both the energy security and economic perspective to radically move away from the established norm of producing electricity from oil shale (Liik et al. 2005).

Apart from Eesti Energia, Elering (TSO) and Elektrilevi (grid operator), all state-owned companies formerly under Eesti Energia, the system builders of the electricity production system are rather hard to identify. The current research’s focus on electricity produced from RES provides the advantage of being able to look at public records of companies which have received RES support for an indication. These companies are listed in table 4 below.

Table 4

Biggest receivers of RES support (in 10 000 €) from 2010 to first quarter of 2014

		2010	**2011**	**2012**	**2013**	**2014**	**TOTAL**	
Eesti Energia	**Narva power station**	1212	1654	2069	-	-	**4935**	**7642**
	Aulepa wind station	368	412	362	329	110	**1581**	
	Paldiski wind farm	-	-	-	156	74	**230**	
	Eesti Energia AS	50	55	73	496	222	**896**	
Fortum	**Anne Soojus OÜ**	720	697	748	799	205	**3169**	**6330**
	Fortum Estonia	76	712	775	861	241	**2665**	
4Energia	**Roheline Ring OÜ**	206	315	286	256	87	**1150**	**3895**
	Pakri wind farm	211	268	241	242	63	**1025**	
	Tooma wind farm	137	223	199	185	59	**803**	
	Vanaküla wind farm	-	121	76	70	24	**291**	
	Viru-Nigula wind farm	-	-	-	183	-	**183**	
	Aseriaru wind farm	-	-	68	267	63	**398**	
	Oisu biogas	-	-	-	26	9	**35**	
	Vinni biogas	-	-	-	2	8	**10**	
Tallinna Elektrijaam OÜ		799	811	852	859	216	**3537**	

Source: Author’s calculations based on Elering’s annual reports

Other than that Suurs et al. (2010, 423) suggest analyzing events in history to identify both the structure and dynamic of the system. Processing and mapping various projects implemented in Estonia (wind farm construction, research and cooperation, etc) gives a rather good overview of, for example, firms that manufacture the parts for the power plants and/or investment firms, such as ABB, General Electric, Eolus Vind AB, Bakeri, Environmental Investment Centre, etc, but even more importantly, it gives a rather clear indication of the networks of actors in the system.

The most important and openly visible networks formed to promote renewable energy in Estonia are different associations that comprise of firms operating in the sector. These include, for example, the Estonian Renewable Energy Association (EREA) – including the Renewable Energy Club intended for the wider public –, the Estonian Wind Power Association, Union of Electricity Industry of Estonia, the Estonian Biomass Association, the Estonian Green Movement, the Estonian Solar Energy Association and the Estonian Association of Electrical Enterprises. There are also networks between the industry and academia but they tend to be problem-based and not very stable (for a more in-depth overview of research activities see: Tõnurist, Valdmaa 2013) with just a few exceptions, such as the wind energy cluster, created by the Wind Energy Association, and the PAKRI Science and Industrial Park.

Naturally there are more actors, networks and institutions present in the Estonian RPG technological innovation system but the thesis will not stop on these for longer, since the purpose of this step is merely to provide an overview of the most important elements of the system and not provide a comprehensive list of all of them. The function of looking at the structure of the RPG-TIS is to get acquainted with the system, rather than to draw conclusions (Bergek et al. 2008a, 414).

2.4 Step 3: Overview of the functions

In this step of the analysis an overview of how the functions of the system are fulfilled in the Estonian RPG-TIS will be provided. The system functions serve as the tool for the structuring of empirical material (Negro et al. 2007, 928). The positive and negative aspects of the functioning will be analyzed in the next part of the thesis. In this part the performance of the system will be overviewed in the lines of the six functions. Those are knowledge development and diffusion, direction of search, resource mobilization, market formation, entrepreneurial experimentation and legitimation.

Suurs et al. (2009; 2010, 421) have brought out the main event types associated with the different functions of a system. For giving an overview of the current system at hand those events are synthesized with the indicators mentioned for each of the functions in the theoretical framework and then coupled with events that have been taking place in the Estonian RPG-TIS during the chosen period of 2009-2014. A more in depth overview of the results is illustrated in table 5 in the appendix. This overview, though providing an insight into the functioning of the Estonian RPG-TIS, does not by itself identify what is positive or negative in the system (Bergek et al. 2008a, 419). This means that merely looking at the functioning of the system illustrates *how* but not *how well* it works. That is, on the one hand, because all the functions are intertwined and a dysfunction in one may greatly inhibit the performance of another, seemingly strong function. On the other hand, the fact that some functions are performing well doesn't necessarily indicate that the system as a whole is working (ibid.). This is why the functions must be analyzed in the context of what is desired of the system.

2.5 Step 4: Analysis of the functions

Earlier in this thesis it was stated that the assumption of this research will be that the Estonian RPG-TIS is in a formative phase. The basis for this assumption was simply that there are overall very few examples of renewable energy technologies that have reached a market-expansion stage thus far (Suurs 2009, 41), and because RES has only been more widely used in electricity production in Estonia for about a decade (Bergek et al. 2008a, 420), makes it rather likely that the system has not had enough time to build up yet.

This phase of a TIS is characterized by a "range of competing designs, small markets, many entrants and high uncertainty in term of technologies, markets and regulations" (Huang, Wu 2007, 347). During this stage the actors are drawn in, networks are formed and institutions are designed and adjusted. This means that it is rather normal for a TIS in a formative stage to exhibit an uncertainty in the regulatory framework and for the new technology to lack legitimacy. In order to transform the TIS from a formative phase to a growth one, it is important to identify the dynamics between the functions brought out earlier. As Myrdal (1957, p. 18) put it: " the main scientific task is … to analyse the causal inter-relations within the system itself as it moves under the influence of outside pushes and pulls and the momentum of its own internal processes".

To exhilarate the rate of development and diffusion the system needs experimentation and market creation which, in turn, requires knowledge development and resource mobilization which are guided by the direction of search which is greatly influenced by the legitimacy of the technology, etc (Bergek et al. 2008a, 419). The latter is one of the most lacking functions in the Estonian RPG-TIS.

For example, a recent study conducted by the energy portal Energiaturg.ee, designed to provide information for the consumers in the framework of the opening of the electricity market, showed that end-users believe the difference between the prices of RES and conventional electricity to be five times bigger than they actually are[5]. Also, in a research conducted by the Swedish Environmental Institute, entrepreneurs point out the lack of knowledge and interest about environmental issues, lack of available investments, the high prices of environmentally friendly technology and the level of complication for maintaining building and other permits as the main obstacles for moving towards more environmentally friendly production (Lahtvee et al. 2013, 69).

In order to analyze the context of Estonia – which is one tilted significantly towards production from oil shale – the starting point of analyzing the influence of incumbent actors is taken. Their influence stems from the fact that they are tightly integrated into the economy and society. The latter is especially true when talking about Estonia as a small state with an ubiquitous government where different dimensions of society are closely interlinked and influence each other and "dangers of rent seeking and vested interests" make development difficult (Kattel et al., 2010, 2). Historically electricity generation has been mostly in the hands of national monopolies. Though this has changed in Europe due to market liberalization, Estonia remains in a situation where state-owned Eesti Energia is still the biggest player on the electricity market and, also, contributes rather considerably to the national budget (Tõnurist 2014, 24), hence, having the ability to influence policy decisions and block the emergence of new technologies.

They also provide much of the financing for applied research in energy technology (Tõnurist, Valdmaa 2013, 14) – giving them the ability to influence the direction of search quite substantially – and a great deal of jobs in the region of Ida-Virumaa (Pihor et al. 2013) – giving them even more influence over legitimacy. Surprisingly, Eesti Energia has also been the receiver of the biggest RES support (see table 4 in section 2.3), not to mention subsidies for CHP and oil shale (according to the Stockholm Environmental Institute the latter is approximately €814M/year[6]), and support in the form of CO_2 emission allowances credit (National Audit Office 2012). This trend is decreasing, though, with 4Energia receiving the most in RES support in the first quarter of 2014 due to the

[5] See: http://energiaturg.ee/2014/04/tarbijate-teadlikkus-roheenergia-hindadest-vaga-madal/ (in Estonian)
[6] Within the framework of the co-operational project with Praxis called "Government watch" which evaluates the government's fulfillment of its set goals, see : http://www.praxis.ee/index.php?id=991&L=1

increase of wind farms operated by the company over the last few years (such as Tooma, operational since 2010, Aseriaru, operational since 2011, Paldiski – in cooperation with Eesti Energia – operational since 2012). The company now holds the capacity of producing 222.7 MW of electricity from wind. 143.8 MW of that capacity is located in Estonia and the rest in Lithuania, with additional projects in all three Baltic States, amounting to 118 MW, on the way[7]. The entrepreneurial activities of 4Energia are fostering market creation and legitimation of wind energy. No such one prevalent system builder can be identified for biomass, though.

Nevertheless, in 2012 more than twice as much electricity (953 GWh) was produced from wood as from wind energy (434 GWh) (figure 3). One possible explanation for this might be that when producing both heat and power from biomass a company can apply for both the RES and CHP support. For example, according to Elering's annual report Fortum's Anne Soojus OÜ and Tallinna Elektrijaam OÜ received approximately €8M and €8.6M of RES support respectively, as well as €0.67M and €0.56M in efficient co-generation support. Other reasons might be that there has been much more research into the subject, as well as, the government being active in promoting the use of biomass, especially in state-owned Eesti Energia, since it is the cheapest and easiest way to reach the targets set by EU (National Audit Office 2012). Other than fulfilling the mandatory targets set by the EU, the government has not been very active in promoting RES. The lack of long-term planning from the government's side inhibits investments into the technologies, as does the lack of highly skilled labor (Tõnurist 2014, 20).

2.6 Step 5: Mechanisms

Drawing from these functions the inducement and blocking mechanisms of the system can be identified. This list is by no means final. The goal of it is simply to express the most pressing concerns and successes in the system. For example, the inducing mechanisms that immediately strike out include: the actions of firms (e.g. 4Energia), the influence of EU regulations and policies, but also the overall belief in the growth potential of the technology, as indicated by the extensive amount of projects under development. The first mechanism, actions of firms, influences the legitimacy of the system by increasing the amount of actors involved which, in turn, is likely to increase entrepreneurial experimentation, as well as the availability of resources and knowledge. EU

[7] For a detailed overview see: http://www.4energia.ee/en/projects/

regulations and policies guide the direction of search towards finding new solutions and help legitimize the new technologies by promoting them. The policies also foster market formation by promoting emissions trading. The belief in growth potential positively influences the direction of search, encourages entrepreneurial experimentation and the mobilization of resources, as well as contributing to the legitimacy.

On the blocking side such mechanisms can be identified as uncertainty (about the cost and profitability of the technology, lack of knowledge about the environmental issues among both consumers and industry), actions of incumbents, ambiguity of subsidies and support measures (tilted towards incumbents: low CO_2 tax, credit for incumbents, oil shale subsidies, etc), complexity of obtaining permits (e.g. construction permits and environmental assessments), but also weak connectivity between academia and industry, as well as industry and consumers. Uncertainty most obviously influences the legitimacy of the technology, but also knowledge development and diffusion, and resource mobilization, since it creates suspicions about the profitability of such actions. These in turn also greatly influence the direction of search away from the technology. Actions of incumbents, such as influencing government policies and directing the search away from new technologies, influences the legitimacy of RES electricity, as well as market formation and, of course, the direction of search.

The next two blocking mechanisms – ambiguous support measures and complexity of the process of attaining permits – both mostly inhibit entrepreneurial experimentation and market formation. The former also has a direct effect on resource mobilization (or rather the lack there of) because of the incumbents receiving the bulk of the available financial support. The weak connectivity factor mostly influences knowledge development and diffusion because without functioning networks between research institutions and the industry it is hard for the former to anticipate the needs of the latter. Weak connectivity also influences the legitimacy of the system through the lack of advocacy coalitions, as well as resource mobilization, especially when it comes to human capital.

2.7 Step 6: Policy measures

By bringing out the blocking and inducing mechanisms it is then possible to identify the policies they concern. Like with the mechanisms, the list of measures is not final. There might always be internal and external factors that influence the system in ways that cannot be understood by mere observation (Huang, Wu 2007, 354). Also, it is important to understand that policy intervention is not meant to be "neither one whereby national champions are selected and supported, nor a defensive industrial policy attempting to save dying industries" (Jacobsson, Bergek 2011, 44). These policy measures are rather such that incorporate a range of activities, including policies to shift risks, influence expectations, form standards, create early niche markets, form new networks, develop specialized human capital, etc (Suurs 2009). Hence, environmentally conscious electricity policy makers need to "understand and potentially manage a flora of technology-specific micro-level processes where their activities go much beyond subsidizing R&D and affecting relative prices" (Jacobsson, Bergek 2011, 44).

Bringing out the blocking mechanisms of the system helps identify the possible policies that can reduce the effect of those mechanisms. That can be done by asking the simple question: "What can be done to weaken/eliminate a certain mechanism?" (Bergek et al 2008a) For example:

- Weak connectivity and uncertainty can be overcome by fostering the creation of feedback loops and aligning the educational system with the needs of the industry (see e.g. Jacobsson, Johnson 2000, 633-634).
- Ambiguity of measures can be overcome by making the allocation of supports and subsidies more transparent and open, as well as more coherent. Increasing the transparency of the measures can also help reduce the uncertainties in the system. (Reiche, Bechberger 2004)
- Complexity of the permit process can be handled by simplifying the process. For example, a single objective government agency could be created that deals with all relevant permits. Also, creating feedback loops within the industry helps share the experience and, thus, helps new firms entering the market and existing ones to communicate the existing problems (Bergek et al. 2008b).
- The influence of the actions of incumbents is the hardest to tackle without deliberately hampering their economic standing. One way to do it is to lessen their embeddedness in the system and opening them up for free competition. This has to be done incrementally, though, not to jeopardize the security of supply (Neuhoff 2005). Overall, all such measures compiled can be characterized by the alignment of institutions to the new technology

(Jacobsson, Bergek 2004, 818; Huttunen et al. 2014). Furthermore, this helps to decrease the uncertainty and ideally also the weak connectivity in the system. Also, reducing the ambiguity of the support measures will set a more level playing field and, thus, reduce the power of the incumbents.

The measures are quite abstract because the goal of this thesis is not to create a concrete policy plan but rather to point out what seem to be the problems in the functioning of the system and set the possible direction for overcoming them. Naturally there are factors influencing the system that go beyond the scope of the current research.

2.7 Findings and recommendations

The current situation of the Estonian RPG-TIS is mostly characterized by its lack of legitimacy and the overpowering influence of oil shale based production. This is evident by the orientation of institutions, such as laws and regulations as well as the educational system. There were also signs of weak connectivity and resistance from incumbents – all very common for technologies in a formative phase. In order to move past those issues and further the transition from a formative to a growth phase a number or policy measures could be taken. These include institutional and educational alignment, reassessment of support measures and permit processes, and fostering the creation of feedback loops and networks that strengthen the legitimacy and connectivity of the system (figure 5).

Though, these findings give a much needed insight into the current and possible future developments in the system, it cannot alone serve as a basis for universal truths. As Midttun and Koefoed (2003, 677) have noted, the greening of the electricity industry in Europe is characterized by a multiplicity of challenges and contradictory patterns, such as a mixture of global, regional and local environmental problems, competition between national and EU-based regulation, balancing public regulatory and private commercial initiatives, and rivalry between specialized niche-oriented and broader price-based commercial approaches. Hess and Mai (2014, 11) also point out that there are ‘landscape’ factors, such as geography, demography, economy, that need to be taken into account in this context. Thus, further research into, for example, the whole energy industry,

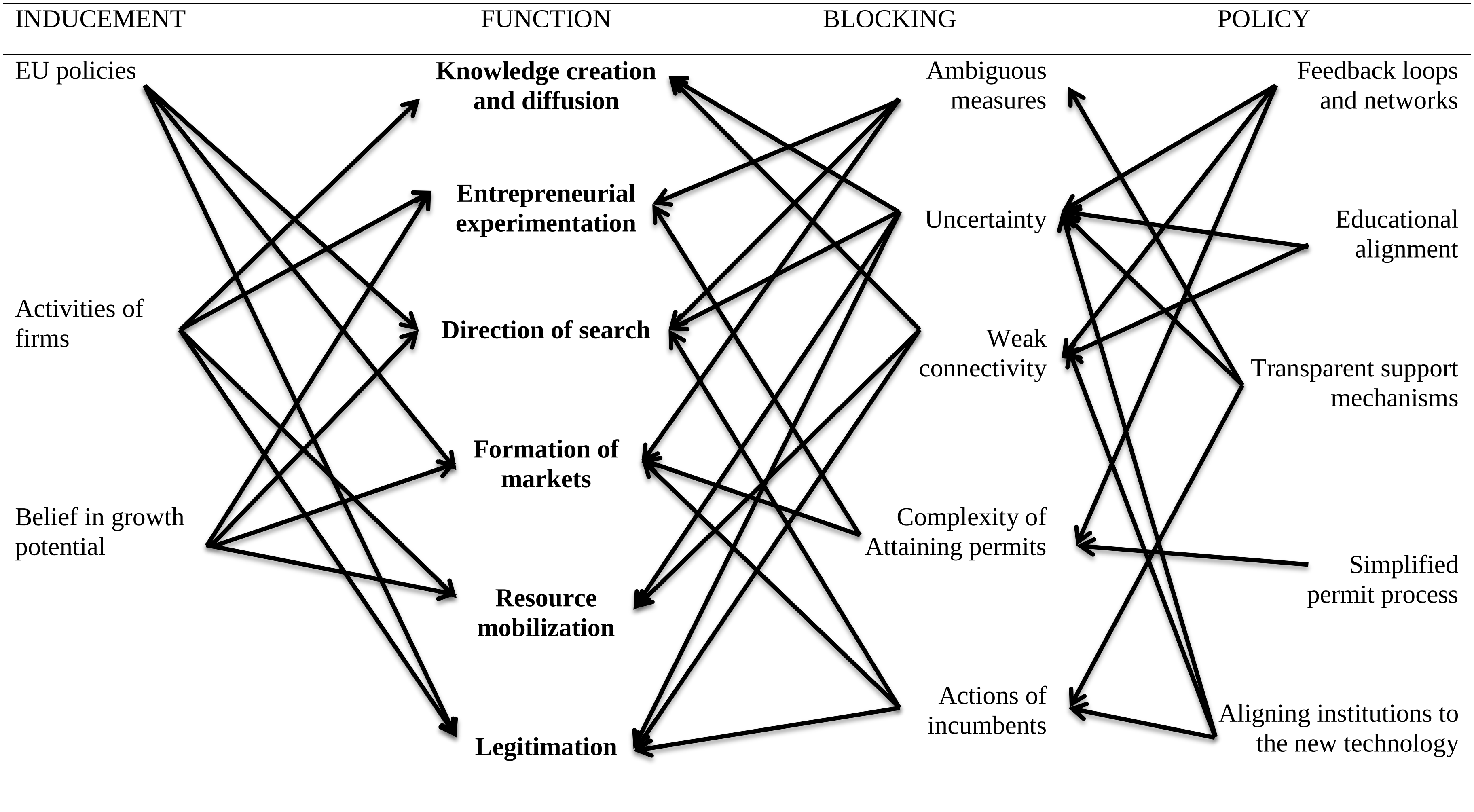

Figure 5. **Blocking and inducing mechanisms and the possible policy measures in the Estonian RPG-TIS.**

Source: Author based on Bergek et al. (2008a).

sociological factors influencing the transformation of electricity production, specific RES technologies and how this technological innovation system fits into the overall NIS, should be conducted in order to get a truly comprehensive overview.

CONCLUSION

The theoretical framework for this thesis suggests that by analyzing a technological innovation system by how the functions of said system are fulfilled the mechanisms that block and induce transformation from a formative to a growth period can be identified. For this the elements – actors, institutions and networks – were first identified, following which the functioning of the system could be analyzed. This was done by looking at six core functions of any TIS: knowledge development and diffusion, influencing the direction of search, entrepreneurial experimentation, market formation, legitimation and resource mobilization. This highlighted that in Estonia the RPG technologies' alignment with both the institutions and educational system is lacking. This mainly manifests, for example, in the lack of long-term planning in the first case, and low level of skilled labor and R&D action. The functioning of the system is also hindered by the lack of legitimacy of the technologies. For example, customers believe the prices of renewable electricity to be much higher than they actually are and industry members are uncertain about the profitability of investing into this technology. Nevertheless, there is an extensive amount of new projects on the way, especially in the wind energy sector, indicating an overall belief in the growth potential of the technology.

After analyzing the functioning of the system, the blocking and inducing mechanisms were identified. In the case of the Estonian RPG-TIS the mechanisms inducing the transformation are the policies set by the EU in terms of emissions reduction, wider use of RES and increasing energy efficiency; belief in the growth potential of the technology by the actors in the system, especially in the industry; and activities of firms, especially new firms entering the market. The mechanisms blocking development are weak connectivity among industry and research institutions and industry and customers; uncertainty about the necessity and benefits of the technology; actions of the incumbent firms; ambiguity concerning the allocation of subsidies and support measures; and the complexity of attaining different permits, such as building permits for wind farms. Based on those mechanisms the policy areas that need to be looked at and/or reevaluated were drawn out. The main policy issues that stand out in this framework are the need for institutional and educational alignment, making the allocation of subsidies, support measures but also permits more transparent and less ambiguous, and fostering the creation of new networks and feedback loops.

The findings of this study are not to be considered as the final truth about the Estonian RPG-TIS, rather it is a base for further research. For example, there should be more research done into each different technology in the electricity production sphere which would further indicate the peculiarities of those specific technologies and give a more in depth analysis into the issues. Also, looking at the issue from a wider energy production aspect can tie this specific issue to energy efficiency and broader production of heat, for example, to see how all of these technologies work together. Also, looking at this issue from a wider NIS perspective could potentially further develop the findings of this research.

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APPENDIX

Table 5

Main activities in the Estonian RPG-TIS from 2009-2014

FUNCTION	ACTIVITIES	OVERVIEW
Knowledge development & diffusion	Studies, laboratory trials, pilots, conferences, workshops, patents	• Research focuses mainly on oil shale, energy efficiency, but also CHP from biomass • Wide array of conferences and seminars • Little governments incentive for R&D in the field, dependent on private investments; much of the research is done and commissioned by the incumbents and increasingly abroad
Influencing the direction of search	Expectations, promises, policy targets, standards, research outcomes	• Low government RPG targets, short-term goals • Positive influence of EU policies, EU ETS • Unfavorable economic conditions, concern over electricity prices • Various, though short term, governmental action plans promoting the use of RES
Resource mobilization	Subsidies, investments, availability of human capital	• Feed-in premiums for RES electricity • Subsidies for effective CHP[8] • Lack of highly skilled labor • Plans to reduce the RES tax (paid by the consumers) and, thus, subsidies • Wind energy's capacity trigger reduction in support increased from 400 MW to 600 MW in 2010 • Allocation of free emission allowances credit for power generators to foster investment to decrease GHG emission
Market formation	Market regulations, tax exemptions	• Allocation of green certificates of origin by the TSO • Burning wood exempt from CO_2 emission fees • Environmental Investment Centre re-allocates money gained from selling CO_2 quotas (low prices: 6.5€/ton) • Lack of standards in attaining permits
Entrepreneurial experimentation	Projects with a commercial aim, portfolio expansions	• Growth of wind power capacity from 77.7 to 279.9 MW and nearly 3000 MW under development[9] • Incumbents diversifying their portfolios to include RES
Legitimation	Lobbies, opinions, news	• RES electricity believed to be expensive • Lack of belief in the short-term profitability of RPG technology • Mining oil shale responsible for a lot of jobs • Untapped potential of offshore wind due to public resistance • Subsidies are paid by the consumers (1.04 euro cents/kWh in 2014, including VAT

Source: Author based on Suurs et al. (2009; 2010).

[8] Effective in this sense means that the produced heat has to be utilized by the industry or transmitted into the long-distance district heating system

[9] According to the Estonian Wind Power Association. See: http://www.tuuleenergia.ee/about/statistika/arendamisel/

List of interviews

1. Interviews with Elering officials, conducted 22 November 2013 and 14 January 2014.
2. Interviews with Eesti Energia officials, conducted 4 February 2014 and 27 April 2014.
3. Interview with the Estonian Renewable Energy Association, conducted 7 December 2013.
4. Interviews with officials from the Estonian Ministry of Economic Affairs and Communication, conducted 10 December 2013 and 17 January 2014.
5. Interviews with energy policy experts from:
    a. the Estonian Foreign Policy Institute, conducted 4 February 2014;
    b. City Law School, London, conducted 28 April 2014;
    c. International Centre for Defence Studies, conducted 25 April 2014.
6. Interview with on official from the European Commission's Directorate General for Trade, conducted 28 April 2014.