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WIND ENERGY DEVELOPMENT IN RUSSIA

Technological innovation system analysis for policy improvements

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MSc Science and Innovation Management

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ABSTRACT

This research aims at exploring the system mechanisms causing inducements or barriers for the wind energy development in Russia as the process of catching-up with the advanced countries. The combination of the technological innovation system (TIS) analysis and the technology transfer concepts are used to address the notion of the developing countries striving to achieve a competitive advantage and a technological leadership. The theoretical framework is suggested in this research providing a structural approach for the analysis of a technological system under study in the developing countries involved in the process of catching-up. This approach contributes to the current literature by offering a practical tool for the policy makers to assess the performance of the TIS in the developing countries. The case of the wind energy system in Russia is taken to explore the current state of the system and provide recommendations for policy improvements. It was identified that the system is presently located in the first stage of the development, which is characterised by the involvement of foreign firms in the system formation. In addition, the "entrepreneurial motor" of innovation was identified by analysing the interactions between the system functions. This motor is characterised by the local entrepreneurs being a driving force for the system formation. The pattern of functions' interactions allowed to detect the system incentives and barriers. There is a number of incentives that induce the system development, however, the importance of them is not strong in comparison with the blocking mechanisms. In turn, the changes in the mechanisms identified that hamper the system are crucial for a system to transit to the next stage of the technological development. Even though the international system helps the formation of national system, the national system needs to create a favourable environment to exploit an emergent technological trajectory. As a result of this research the policy recommendations are designed for the system to proceed to the next stage of catching-up.

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1. INTRODUCTION

The importance of renewable energy sources as an alternative for traditional fossil fuels has been already recognized in Europe for a long time by introducing various political and economical measures. Russia has only recently started paying attention to energy saving, sustainable development and environmental safety. Historically, the Russian economy has been highly dependent on the oil and gas production. Being a country with industrial economy it became "locked into fossil fuel-based technological systems through a path-dependent process driven by technological and institutional increasing returns to scale" (Unruh, 2000, p. 817). In addition, a difficult situation in the post-Soviet period steered a destruction of economical and technological heritage obtained in the Soviet times, which has not been still restored (Klochikhin, 2012). A little attention has been always paid for the development of alternative energy sources in Russia. Moreover, low energy prices, less political incentives, low people's consciousness regarding energy savings and environmental problems did not encourage the diffusion of renewables. Given the fact that governmental initiatives play a significant role in developing any sector of the Russian economy, private sector was not very interested in providing investments to the renewable energy sector, which was not politically supported (Gati, 2008).

Russia possesses a large renewable energy potential (OECD/IEA, 2003). The technical potential of available renewable energy resources in Russia is at least 24 billion tons of specific fuel (Summary National Reports, 2011). At present the renewable energy sources in Russia are mostly presented by hydropower and nuclear energy, which are highly used and developed. Among the rest renewable energy sources, wind energy is considered as the most promising technology in almost all Russian regions (IFC, 2011). Its technical potential accounts for 6,500 billion kWh of power energy per year (Summary National Reports, 2011). It is seen as a good option for providing power to isolated areas with small populations in the Far East and Siberia, as well as on the coastlines of the Pacific and Arctic Oceans and mountains regions of the Caucasus, the Urals, the Altai and the Sayan Mountains (Summary National Reports, 2011; Gati, 2008).

The recent changes in political priorities on modernization and innovation of the Russian economy have marked a need for transferring the country into the one with less dependency on the energy sector (Henry & Sundstrom, 2012). The incentive of developing a low energy consuming economy and implementation of energy saving technologies was one of the key messages in the two latest political documents – "Concept for long-term social and economic development of the Russian Federation by 2020" and "Energy Strategy of Russia for the period up to 2030" approved in 2009. According to these documents it is expected to increase the power production from the renewable energy sources up to 4.5% by 2030 (Minenergo, 2009). This is a considerable growth meaning additional 22 GW of new power generated. The intermediate targets were set up in the Energy Strategy of Russia expecting the growth of 1.5% by 2010 and 2.5% by 2015. Despite a fact that the Russian government created a momentum for the industry to emerge, the intermediate target of 2010 has not been reached yet (Klochikhin, 2012). It is important thus to understand the reasons of a slow system formation, namely which factors deter the development of Russian wind energy industry in particular.

Many scholars have researched the development and diffusion of renewable energy sources in different countries (Jacobsson and Johnson, 2000; Jacobsson & Bergek, 2004; Tsoutson & Stamboulis, 2005; Negro et al, 2012). Much attention was also paid particularly to wind energy technology: the formation and maturity of wind energy industries in USA and Denmark (Garud & Karnoe, 2003), diffusion of wind energy in Europe (Söderholm & Klaassen, 2007). In addition to it, there is a lot of interest in investigating the success of Chinese and Indian firms in the global wind energy system. Lewis (2007) examines the fast technological paths of two leading wind turbine manufactures Suzlon (China) and Goldwind (India). In a short period of time (less than 10 years) they managed to obtain the technological know-how and become the competitive players on the international market. The research focused on which factors created a favourable environment for two developing countries to catch-up and what how the process of technology transfer between international and local systems took place. It was concluded that *"a combination of licensing intellectual property - creating strategic technology partnerships, accessing regional and global learning networks, and taking advantage of regional advantages (…) - were all important components"* (Lewis, 2007, p. 229).

These studies suggest thus that the technological development is not an isolated event. It is embedded in a system where social, economical, political and institutional factors influence the formation, diffusion and adoption of a technology. The systemic approach and specifically the technological innovation system (TIS) analysis provides a dynamic and structural tool for the analysis of technological change by examining important elements that shape the system structure and key activities taking place in the system, the so-called system functions (Hekkert et al, 2007). In addition, the TIS approach allows not to be restricted to the national boundaries of the system, but to be extended to a wider international scope (Coenen et al, 2012). This geographical aspect is important to be taken into account when examining an emergent technological system in the developing countries.

Lagging behind in terms of the technological progress the developing countries need to go through the same technological path as the advanced countries. Considering the fact that it took the advanced nations many years full of trials and errors to create a technological leadership, the catching-up countries are able to develop local capabilities by means of technology transfer. The availability of technological solutions on the global market allows the developing countries to skip some stages of technological development and adopt the latest solutions to the local contexts. Depending on the local capabilities and skills the developing are able not only to catch-up the advanced nations, but also to forge ahead. It is assumed that the process of the technology transfer unfolds in several stages (Watson & Sauter, 2008). Each stage requires some specific capabilities and skills to be obtained by a catching-up country related to the whole technological system including social, institutional, economical and technological competences. Consequently, combining the TIS approach with the technology transfer provides an opportunity to embed a technology within a global technological system, and hence to follow its transition path from the advanced to the developing countries.

The aim of this research is to describe the current state of the wind energy development in Russia and examine the process of technology transfer by analysing the factors stimulating or hampering the technological development, as a consequence of which the intermediate targets of the government are not met. The main research question that is addressed in this research is the following:

Which system mechanisms create barriers and incentives for the development and diffusion of wind energy technology in Russia in order to catch-up with the advanced countries?

The following sub-questions help to answer the main research question:

- *What are the system elements in the wind energy TIS in Russia?*
- *How are the functions of the wind energy TIS in Russia performed?*
- *Which stage of catching-up is the Russian wind energy technology currently located in?*
- *Which system mechanisms create barriers for development and diffusion of wind energy technology in Russia?*
- *Which system mechanisms create incentives for development and diffusion of wind energy technology in Russia?*

In this research the theoretical framework is proposed that combines two concepts (TIS approach and technology transfer concept) for addressing the problem stated above. In the innovation studies' literature the TIS approach is sometimes combined with different concepts focused on technology transition and development, such as the multi-level perspective (Markard & Truffer, 2008), or technological cycles (Jacobsson & Bergek, 2004). So far little attention has been paid to the applying the TIS concept to the analysis of the emerging technologies in the developing countries as the process of technology transfer. The geographical aspect of technology transfer from the advanced countries is thus addressed by identifying the stages of catching-up of the developing countries, which result in stage-specific policy recommendations. The research in this respect contributes to the current innovation studies literature by providing a theoretical framework for the analysis of systemic mechanisms focused on the technological catching-up in the developing countries. It is believed to be a practical analytical tool for assessing the current state of the technological system and for designing policy recommendations. In comparison with the present literature that provide a post-factum analysis of the catching-up process, the suggested analysis gives an opportunity to guide the technological development of the catching-up countries in order to archive a competitive advantage and a technological leadership.

The research identifies the current system performance and proposes the analysis based on which recommendations are given how to proceed with the catching-up process. So far little attention has been paid to the analysis of wind energy technology and its diffusion in Russia. Actually, no research has been found that examines the Russian wind energy sector from innovation studies perspective by providing a structural analysis of innovative developments in the sector and as a result, providing recommendations for improvements. The outcomes of the research can be thus used by the Russian policy makers to perceive the systematic mechanisms that hinder or stimulate the technological development of the wind energy system in Russia. The recommendations will be designed that are related to a current state of the catching-up process in order to proceed successfully to the following stages and catch-up the advanced countries.

2. THEORETICAL FRAMEWORK

Stimulation of innovation creates a favourable environment for the economic development of a country (Lundvall, 1992; Patel & Pavitt, 1994). The question of why some countries became the leading nations in terms of economical development and others are still lacking behind has troubled the minds of scientists for a long time. The notion of innovation system and the role of technological development have partly explained the process of becoming a developed country (Freeman, 1997). Differences between economies of different countries are explicated by the level of innovative activities and technological development together with other factors, such as social, economical and political backgrounds. However, such research has an approach of historical overview, without actually describing how countries can achieve technological leadership and catch-up the developed countries. This problem is a hot issue for developing countries that are currently striving for creating competitive economies.

According to the literature the catching-up process can be achieved by stimulating innovative processes on the national level (Lewis, 2007; Watson & Suater, 2008). Thus, it is important to understand which mechanisms should be activated by a catching-up country in order to create a favourable environment for the technological development. Unfortunately, developing countries having different and country-specific historical paths are not well prepared to transform their economies easily. The majority of advanced countries have a long history of technological development, so they accumulated a vast spectrum of knowledge that currently helps them to maintain leading positions. The knowledge gap between the countries creates a significant barrier; therefore it requires a great political will and readiness to changes.

In this research two theoretical approaches are used to address the research question. Firstly, the concept of technological innovation system (TIS) explains the dynamic process of technological development within the social, economical and political environments (Hekkert et al, 2007). It gives a structured perspective of technological embeddedness in the national as well as international contexts (Binz et al, 2012). Secondly, the theoretical concept of technology transfer provides insights on the process of technological adoption and diffusion from advanced countries. These theoretical concepts are combined into the theoretical and methodological frameworks that are useful for the analysis of the technological development in developing countries that are in the process of catching-up.

2.1. TECHNOLOGICAL INNOVATION SYSTEM

It is a well-known fact that a success of a technology is not only determined by firms dealing with it, but also by a broader environment such as social, economical and political surrounding a particular technology (Carlsson & Stankiewicz, 1991). The technology is embedded in a large system, which influence the process by stimulating its development or by creating barriers. This is a dynamic process, as the system evolves and changes over the time (Suurs, 2009). Thus, the system characteristics and growth should be taken into consideration when looking at technological development.

A systemic approach in analysing the technological change has been used by scholars for a long time. Depending on a system dimension different systemic approaches are used: geographical–national/ regional innovation system (Lundvall, 1992; Patel & Pavitt, 1994; Asheim & Isaksen, 2002); industry - sectoral innovation systems (Malerba, 2004); technology – technological innovation system (Carlsson and Stankiewicz, 1991; Hekkert et al, 2007). The benefits of applying the systemic analysis are that it allows exploring the whole process of emergence, development and diffusion of technologies and how this process is embedded in the economic, institutional and societal environments.

In this research the technological innovation system (TIS) theory is used for analysing the development and diffusion of wind energy technology in Russia. The choice of the TIS approach is based on the following issues. In contrast to the national innovation system approach, the TIS is not constrained to the national borders. In that respect it provides an opportunity to analyze the local system embedded in a wider context of the international TIS. This is in line with the goal of the research to explore the catching-up process of the developing countries. Moreover, the TIS approach provides a tool for the assessment of the system performance.

The approach has recently received much attention from scholars as a useful and structural tool to analyse a dynamic process of a development of a particular technology (Carlsson & Stankiewicz, 1991; Hekkert et al, 2007; Bergek et al, 2008; Wieczorek & Hekkert, 2012). The TIS is defined by Carlsson and Stankiewicz (1991) as *"network(s) of agents interacting in a specific technology area under particular institutional infrastructure for the purpose of generating and utilizing technology"* (p. 93). As it is seen from the definition, the major elements of the system are networks of agents that serve the goal of the system, which is to generate and utilize the technology (Carlsson et al, 2002). To pursue this goal the system actors are involved in a number of key activities. These key activities are called the "functions of innovation system" added to the TIS approach by Hekkert et al (2007) as a dynamic component for the system analysis. The function approach is a useful tool for analysing the current state of the innovation system, the performance of system actors and their interactions. The system performance can be assessed by determining the boundaries of the system, namely what factors stimulate or create barriers for technological transfer (Jacobsson & Bergek, 2004, Bergek et al, 2010).

The TIS analysis in this research consists of several steps. Firstly, the analysis of the structural elements of the system is performed. This includes the analysis of key elements that are involved in the development of technology. Secondly, the functional analysis is presented, that includes mapping of key activities in the system and the interactions between them. Further, the structural and functional analyses are discussed in detail.

STRUCTURAL ANALYSIS

By examining the structure of the technological innovation system the major elements of the system are identified. According to the definition these elements are building blocks of the system and play a core role in development, diffusion and adoption of a new technology (Carlsson et al, 2002). It is an essential requirement for a system performance that all elements are in place and function properly.

In various literature the elements of the technological innovation system are presented by actors, institutions, networks and infrastructure (Carlsson et al, 2002; Jacobsson & Bergek, 2004; Wieczorek & Hekkert, 2012). Actors are key elements of the system. Depending on the activities they perform actors can be companies, governmental bodies, non-governmental organizations, knowledge institutes, society, legal and financial institutions.

Institutions are a part of the system, as they generate rules, regulations, traditions and social norms. They regulate interactions between actors and vary when these interactions are concerned with economic, social, legislative or technological issues.

Networks are the interactions between actors. These interactions are used to transfer knowledge between different parts of the system. By interacting actors can fulfil joint tasks, such as solving technological challenges or creating institutional frameworks. Furthermore, actors have an opportunity to get access to resources, that they do not possess (Jacobsson & Bergek, 2004). Infrastructure comprises physical or technological artefacts, knowledge and financial programmes (Wieczorek & Hekkert, 2012).

These elements do not exist independently in the system, but interact actively with each other. If one of the elements is lacking behind or missing, then it influences the performance of the system.

FUNCTIONAL ANALYSIS

Focusing only on the structure analysis and interaction between the elements leads to the static description of the system. Such description ignores a dynamic component of the technological innovation system, which is the evolution of the system in time. To make the approach less static, several researchers added functions of innovation systems as dynamic components (Jacobsson & Johnson, 2000; Hekkert et al. 2007).

Functional analysis comprises the analysis of individual function performance and relationships between them. Activities performed in the innovation system are not isolated events, as they influence each other. If one element of the system performs poorly, this causes the performance of other system elements and system as a whole (Hekkert et al, 2007). Consequently, by focusing on system functions barriers can be identified that hamper technological innovation system development.

Initially the notion of functions was proposed by Jacobsson and Johnson (2000), where five basic functions of technological innovation system were presented. Different set of functions was also suggested by other scholars. In this research the seven functions proposed by Hekkert et al (2007) are used, as they combine collected theoretical and empirical knowledge in respect to functions and consequently present the aggregated set of functions.

F1: Entrepreneurial activities

Entrepreneurial activities play a crucial role in the economical and technological development of the system (Hekkert et al, 2007). The functioning of the innovation system is not possible without entrepreneurs. They are responsible for generation of innovation and early diffusion of innovative products and services (Van Praag & Versloot, 2007). Entrepreneurs are seen as drivers for technological development, as they translate ideas into successful business opportunities. Furthermore, by taking into account small and medium size of entrepreneurial firms, their activities are more flexible in comparison with large incumbent firms, which are often locked-in and less likely to be open for new, risky technological experiments.

F2: Knowledge development

Knowledge development is a key function of the technological innovation system. Generation of both tacit and explicit knowledge is an important activity of the innovation system. It implies that innovation and technological development requires knowledge and "learning by doing'', "learning by using", "learning by searching" (Lundvall, 1992). Accumulation of knowledge in the system is also seen as a key resource that can be exchanged, developed or traded in the best interest (Teece, 1986).

F3: Knowledge diffusion

The importance of knowledge diffusion consists in the process of information exchange and learning between various elements of the system (Carlsson & Stanckiewicz, 1991). This accumulates knowledge needed for a technological innovation system to evolve. Exchange of information occurs via formation of networks or alliances. It is believed that such communication channels facilitate agreements on standards, norms and a dominant design (Axelord et al, 1995).

F4: Guidance of search

Technological development implies variation and selection (Nelson & Winter, 1982). Out of a variety of knowledge generated within the innovation system frontier, the selection of the most promising ideas for further development is crucial. This creates the direction of the technological development, so it is seen not as an isolated event, but as a strategically visible choice (Hekkert et al, 2007). The selection process is influenced by various actors that are involved in generation of the new technological trajectory. Society, industry, governmental bodies have some expectations regarding a technological innovation system and thus create their own perceptions of the technological development. The expectations guide the awareness formation; therefore influence the technological change (Borup et al, 2006).

F5: Market formation

By entering the market an emerging technology faces rivalry from existing technologies (Porter, 1997). To compete with existing markets, a new technology forms protected environments where conditions are created to strengthen its position (Hekkert et al, 2007). Different variants exist for these protected environments. They can be niche markets (Kemp et al, 1998), where learning process takes place as well as networks formation. Alternatively, special favourable conditions can be organized by political initiatives, for example tax regimes or minimal consumption quotas (Hekkert et al, 2007).

F6: Resource mobilization

Resources mobilization is crucial for an emerging technology to create a competitive advantage (Mahoney & Pandian, 1992; Teece 1986). This includes assets (materials, capital, human resources, production facilities, patents) and capabilities (R&D, managerial, commercial). Resources that are sufficiently available in the technological innovation system facilitate the technological development. Various stages in the process of the innovation system development require mobilization of different resources. As a system matures and moves from niche markets the coordination of both physical and knowledge resources becomes an essential factor for gaining the competitive advantage over an existing technological regime (Teece 1986).

F7: Creation of legitimacy

This last function creates an opportunity for a new technology to disrupt the current technological regime and become a part of it. In combination with other functions creation of legitimacy forms favourable attitude and expectations regarding an emerging technology in society (Bergek et al, 2010). Conflicts between a new technology and incumbent technologies may arise, where the current technological regime is supported by powerful stakeholders that are reluctant to changes in their business routines (Poel, 2003). Thus, these interest groups may create obstacles for a new technology to develop and diffuse. In that respect, engaging society and different stakeholders in discussion of benefits of the new technological innovation system creates legitimacy for a new technological trajectory (Hekkert et al, 2007).

2.2. TECHNOLOGY TRANSFER

The reasons of uneven technological progress has been first investigated on the level of firms, where possible explanations of why some firms show the capabilities for the development and others do not, are discussed (Teece et al, 1997). The same idea of analysis was applied to understand an uneven level of progress of different nations (Freeman, 1997). It was observed that political will and initiatives are not always enough for a country to succeed. Instead a key factor of the catching-up process is a technological change supported by social, economical and political changes. There are examples of countries that succeeded in catching up and becoming highly technological countries. The key factor of that transformation is technology diffusion or technology transfer (Sauter & Watson, 2008). It is observed that developing countries do not follow the whole technological path of advanced countries, but adapt existing technologies and skip some stages (Lee & Lim, 2001).

New technologies typically emerge in advanced countries, and later are slowly picked up by developing countries. Adoption of technologies from advanced countries is a way to skip their technological paths, which were undoubtedly full of trials and errors. Latest technologies are already available for the catching-up countries, which gives them an opportunity not to be involved in the long and expensive technological process, but to adopt technologies with an established dominant design. *"The majority of inventions are already exploited globally, and this process is continuing at a rapid speed"* (Archibugi & Michie, 1995, p.138). The advantages of late adoptions are: (a) product innovation is no longer in place, but changes will be concerned the process innovation; (b) cheap technologies are available (Watson & Sauter, 2008).

A separate research strand in the study of technology transfer is devoted to sustainable or environmental technology diffusion that is focused on transition from using pollution intensive technologies to the energy saving ones (Watson & Sauter, 2008; Lewis, 2007). Especially this concerns the developing countries that usually rely heavily on fossil fuel energy systems. Thus, the notion of technology transfer is particularly useful for the analysis of energy transition from conventional energy sources as fossil fuels to sustainable ones such as renewable energy sources. Instead of following the path of advanced countries and becoming more dependent on carbon-intensive sources, catching-up countries can jump over several steps of technological development (Lewis, 2007). The ability of developing countries to skip carbon-oriented development and adopt the law-carbon and sustainable technologies is called leapfrogging (Binz et al, 2012). This concept is defined in the technology transition literature as:

"Far from developing factor proportions, appropriate industries and technologies both for the domestic and export world market, the opportunities offered by the international diffusion of technology to jump particular technological paradigms and import the more if not most, sophisticated technologies that will neither displace the capital invested nor the skilled labour of the previous technological paradigm, constitute one of the most crucial advantages of newly industrialized countries in their bid for rapid industrialization." (Soete, 1985, p. 416)

"A situation in which a NIC[1] learns from the mistakes of developed countries and directly implements more sustainable systems of production and consumption, based on innovative and ecologically more efficient technology." (Binz et al, 2012, p. 156)

As it is seen from two definitions leapfrogging means not only adoption of sustainable solutions, but also forging ahead and bidding for a technological leadership. This is difficult to achieve

[1] NIC= Newly industrializing countries

without accumulating nation-specific capabilities, such as organizational, political, financial, human and related to knowledge development (Archibugi & Michie, 1995; Watson & Sauter, 2008). It is therefore important to understand how the catching-up countries unfold the process of technological catching-up, whether they show capabilities for leapfrogging.

The concept of leapfrogging implies that a country has proceeded through several stages of catching-up and created the technological leadership (Sauter & Watson, 2008). The whole process is roughly divided into four stages: duplicative imitation I and II, creative imitation and real innovation (Lee, 2005). Depending on the stage of the development, various factors influence the successful transition to the next one. Few countries succeed in proceeding the whole catching-up cycle. Internal barriers and limitations hamper the technological process; therefore the catching-up countries are got stuck in one of the first stages. It is difficult for countries to reach the third stage of creative imitation.

Table 1: The stages of catching-up (adopted from Lee, 2005).

	Stage 1: Duplicative imitation I	**Stage 2: Duplicative imitation II**	**Stage 3: Creative imitation**	**Stage 4: Real innovation**
Patterns of catching-up	Path-following	Path-following/ stage-skipping	Stage skipping	Path-leading/ path creating
Learning object	Operational skills	Process technology	Design technology (for existing products)	New product development technology
Learning mechanism	Learning-by-doing (production following manuals and guidance)	Learning-by-doing (production following product designs)	How to learn? (crisis and switches to in-house R&D, R&D consortium, and overseas R&D outposts)	Co-development, strategic alliances

The first stage implies that catching-up countries accumulate knowledge about a new technological paradigm and attempt to apply it in the local context (Lee, 2005). The events are unfolded through the process of path-following from advanced countries (Lee & Lim, 2001). Foreign companies are allowed to enter a local market and organise learning on technology implementation. A favourable environment is created by local companies and the government for knowledge exchange. The local firms lack the operational capabilities and skills in this stage. Being highly interested in a new emerging market the advanced countries are willing to cooperate with catching-up countries in order to obtain enough skills for technology transfer. Sometimes the local assemble of technology is organised under supervision and guidance of foreign firms. The relations between local and foreign firms have different forms, such as license agreements, joint ventures.

The process of technology transfer involves also changes in other areas related to it, such as society, markets, routines, institutions, policies (Coenen et al, 2012). Hence, technology-specific initiatives and regulations are needed for a successful adoption and diffusion. The governmental support in the catching-up process is highly important for the technological development. This stage is thus characterised by knowledge formation and accumulation with an assistance form foreign firms; creation of networks and sharing platforms; state regulations easing the process of technology implementation.

In the second stage of catching-up local firms obtained enough knowledge for organising local production facilities (Lee, 2005). The process of learning continues, but foreign firms play a role of experts providing technical advice in organizing the production. Usually manufacturing of low-technological parts of technology is organised locally; the rest is still supplied from advanced countries. Foreign firms provide technical specialists and experts to assist with the local production and adjusting locally produced parts with supplied ones. This stage requires establishment of local standards for technology, and other required local regulations for organising local market. New firms enter the market, resulting in a slow market growth. Still a catching-up country proceeds through the path-following path, however depending on national capabilities and wiliness for technological progress the process can unfold at a faster pace, so some internal stages can be skipped (Lee & Lim, 2001).

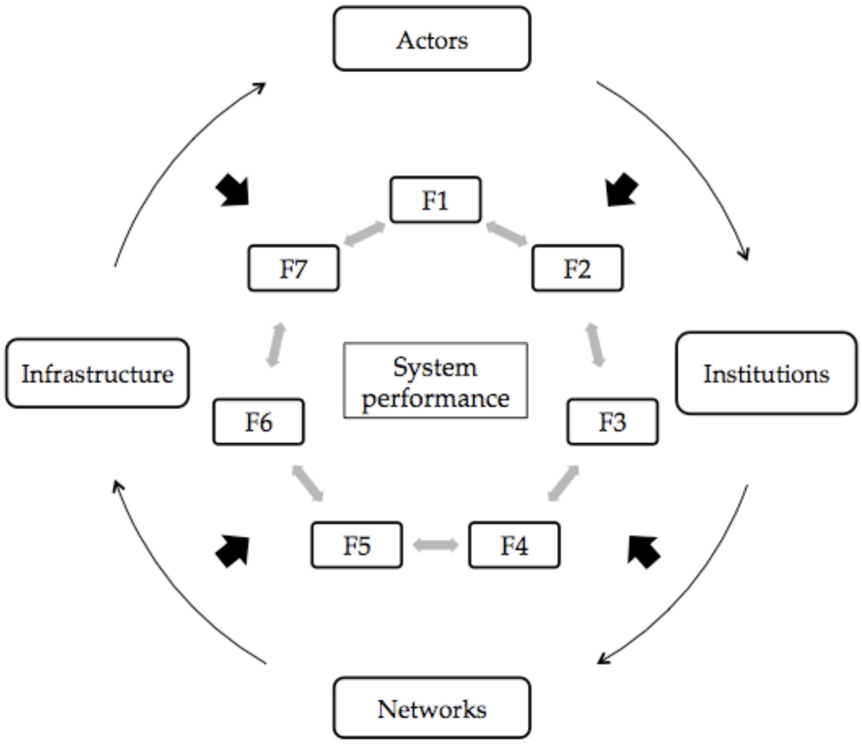
The third stage of creative imitation implies that local firms obtained operational and process technology skills by organising a local production of low-technological parts, hence local production of high-technological parts can be set up (Lee, 2005). It requires still cooperation with foreign firms in obtaining licencing for local production of technologies. However, the advanced countries are careful with sharing knowledge related to development and production of high-technological components and technologies. This makes their competitive advantage in the new market, so local competitors that are able to organise a cheaper local production can create a serious competition. Thus, this stage is believed to be the turning point for the catching-up countries, which might lead a catching-up country to be stuck in the first two stages, unless design and product development capabilities are obtained. A strong political support, significant financial flows into the system, directed in stimulating R&D in knowledge institutions and in local firms will help to overcome the barrier of being locked-in in the first two stages.

The last stage of catching-up involves the process of real innovation in the catching-up countries. The developing countries obtained capabilities and resources for organising research and development of new technology. Thus, a country creates a competitive advantage among the advanced countries and not follows already their technological path, but creates its own one by becoming an important player in a development of a particular technology (Lee & Lim, 2001).

2.3. SYSTEM PERFORMANCE

In this research the TIS approach that combines structural and functional analysis is not applied only to map the key activities in system, but also to identify and understand the related barriers and incentives. This is an implication of the use of the technological innovation system approach, which is designed to pinpoint specific aspects of a system that improve or hamper the growth of a certain technology (Hekkert et al., 2007, Wieczorek & Hekkert, 2012).

The geographical boundaries of the system are not strictly determined in the TIS approach. In fact, most literature on TIS does not focus on identification of level of research whether technological development is considered on the regional, national, global levels (Coenen et al, 2012). According to the definition presented above, the analysis should be conducted *"in a specific technology area"*, hence in all areas, where this specific technology is applied/relevant. In many cases the analysis is limited to some specific areas, for instance a country or European countries (Makkard et al, 2012). This creates a limitation for a TIS analysis, because some system elements might be coupled with elements within a broader global context (Coenen et al, 2012). The global context of the system is particularly interesting for the analysis of the developing countries, where foreign actors play an essential role for the local system development as the countries pursue the catching-up process.



Picture 1: The theoretical framework.

Sometimes the TIS analysis is combined with identification of the phase the TIS is currently located - formative or growth phases (Jacobsson & Bergek, 2004; Bergek et al, 2008). Knowing the development phase helps to understand the performance of functions and key elements of the system in accordance with a particular phase pattern. However, this type of research structure was conducted for analysing technologies in advanced countries. The same structure of the analysis can be also adopted for investigating the technological development in the catching-up countries. It is suggested therefore to use other phases of technological process. Instead of identifying the phases of technological development, it is useful to figure out the stages of catching-up the developing countries proceed.

The system performance can be assessed in terms of sustainable motors of innovation suggested by Suurs (2009). In this concept the formation of the TIS is described as a process of cumulative causation performed by interaction of system functions. As it was already mentioned above the TIS approach provides a dynamic tool for the analysis of the system development over time. However, in cases when the system is located in the initial stage of development the notion of innovation motors gives an opportunity to design strategies for the system to proceed to the following stages of development.

The functional analysis does not only include the analysis of separate functions, but also the interactions between the functions (Negro et al, 2007). By examining the interaction, the dynamic structure of the system is perceived. The functions tend to change over time, consequently this result in other functions' changes. This process can be seen as a cycle process with positive and negative feedback loops, the so-called virtuous or vicious cycles (Suurs, 2009). Various combinations of interactions are possible with seven system functions, however there are a limited number of patterns actually occurring and reflecting to the most of development paths. These patterns are called the motors of innovation as they present a sequence of interactions between system functions characterizing a specific incentive mechanism, which stimulated a system formation.

The typology of motors of innovations is suggested by Suurs (2009) and includes: the science and technology push motor; the entrepreneurial motor; the system building motor and the market motor. Each motor of innovation is characterised by a certain interaction pattern of functions as well as structural incentives and barriers. These motors are considered as incentive mechanisms for the system development, however as it was mentioned above the interactions between functions can have a negative connection, so there are motors of decline. Moreover, in a technological system a combination of motors of innovation can take place. For example, the system unfolds induced by the entrepreneurial motor at the beginning, but later it is guided by the science and technology push motor.

The system elements are important factors for the system development and they are closely related to the system functions (Suurs, 2009). The changes in the structure are considered to be slow in comparison with the changes in functions, which unfold faster. The performance and interrelation of functions is performed by system elements. Consequently, the structural analysis plays as important role as the functional analysis for identification of blocking and incentive system mechanisms and assessing the system performance. The system elements can be one of these mechanisms. This notion is also addressed in Wieczorek and Hekkert (2012), where the presence and quality of system elements is linked to the system functions.

The understanding of motors of innovation is a useful analytical tool for the identification of system mechanisms that stimulate or hamper the system development in a particular catching-up stage. It is possible thus to observe which structural elements or system functions cause strong or weak interactions in the patterns.

3. METHODOLOGY

The methodology of the research is presented in this part. The research design consists of several steps, depending on which different data collection methods are used.

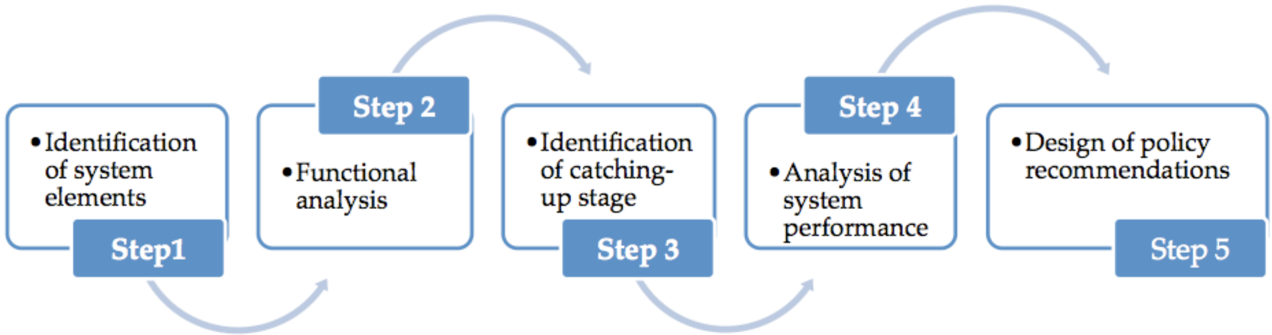
3.1. RESEARCH DESIGN

The research explores the mechanisms inducing or hampering a technological innovation system development in the developing countries, which show a potential for catching-up the advanced countries. The particular case of the Russian wind energy industry is taken for the analysis as an example of a developing country with a strong political inducement for transferring the carbon intensive economy to the one with sustainable and energy efficient solutions. One of these solutions that received an initial state support for the development is renewable energy sources. Wind energy is believed to have a huge potential in Russia, therefore the system is foreseen to grow intensively in the nearest future. Thus, the research identifies the current system performance and proposes the analysis based on which the recommendations are given how to proceed with the catching-up process.

Based on the theoretical framework suggested for this research, the research design consists of several steps. The order and content of steps are adopted and combined from Hekkert et al (2007), Wieczorek and Hekkert (2012), Suurs (2009), Bergek et al (2008). The first step of the analysis, suggested by Wieczorek and Hekkert (2012) and Bergek et al (2008) is the identification of system elements participating in the technological system formation. These are actors, institutions, networks and infrastructure. It is a crucial step of the analysis, as the boundaries of the system are identified. A technological system contains many technologies and practices, depending on which different boundaries can be chosen for the analysis. In addition to the technological boundary, the geographical boundary should be included, namely whether a regional, national or international TIS is under study. Strict boundaries help to identify all system elements (Carlsson et al, 2002). In the case of the Russian wind energy it is decided to focus on large-scale wind turbines that are placed either in isolated locations or combined in wind parks. Thus, the wind energy TIS implies all system elements that participate in the formation and development of large-scale wind power sector in Russia. As for the geographical boundary of the research, it is decided to focus on both the national level and to include foreign players engaging in the Russian wind energy system. This is done by exploring the role of international actors in the formation of the local TIS.

The analysis of the function of the innovation system is the second methodological step. The functions are coupled with specific indicators suggested by Hekkert et al (2007), Suurs (2009) and Bergek et al (2008).

The third step is the identification of the stage of technology transfer. In the work of Bergek et al (2008) this step implies the analysis of the stage of development (formative / growth). In this research it is proposed to use another stages of development, namely stages of catching-up. In case a technology is quite developed on the international level the developing countries proceed to other stages of development in order to catch-up the advanced countries. The catching-up stages have some specific characteristics, which are discussed in the theoretical part of this research. This is a contribution of this analysis to couple the TIS approach with the technology transfer concept, which provides an opportunity to explore the system performance based on a particular stage of development and the ways in which the process of catching-up unfolds in the system.



Picture 2: The methodological framework.

In the next step the analysis of system performance is conducted. In order to observe the system development in dynamics, the interrelations between functions are analysed. This gives a useful tool for identification of system mechanisms, not only related to a particular function, but which describe the development of system dynamics (Suurs, 2009). Thus, depending on relations between functions, the system barriers and incentive are found. Identified mechanisms are verified with the ones found in literature and mentioned in interviews with actors.

The last step is to design recommendations for Russian policy makers based on the outcomes of the analysis and identified system mechanisms. The incentives and barriers are carefully examined and conclusions are drawn which mechanisms are the most important and should be implemented at first place. In other words it is concluded how to change the current situation in a best way that the development and diffusion of wind energy technology in Russia was carried out according to the goals set up by the Russian government.

This is a qualitative research method, which proposes a step-by-step methodological tool to describe the current state of the technological innovation system in the developing countries by mapping structural elements and functions.

3.2. DATA COLLECTION

The data collection method depends on the step of the analysis. For the identification of system elements data are collected by the initial desk research, which includes search in the Internet and specialised literature review for references of system elements by taking the time period between 2008 and 2012. The five years time frame is chosen, since 2009 is the turning point for the renewable energy sector in Russia, when the Energy Strategy was introduced, following by governmental stimulation of energy and carbon saving technologies. The sources such as the Russian Wind

Energy Association[2], where the list of active actors of the industry is placed, were very useful for mapping the system elements.

For the functional analysis the data collection comprises of quantitative/qualitative indicators and qualitative semi- standardized interviews with the system actors, identified in the previous stage of the analysis (Table 2). The interviews lasted for approximately one hour and were recorded. The face-to-face semi-standardized interviews are useful when questions are related to the theoretical concepts, as well as when it is necessary to steer the discussion and not to be stick to particular questions. A list of questions was prepared using specific questions for each function suggested by Wieczorek and Hekkert (2012) (see Appendix I).

Table 2: Operationalization.

Functions	**Data collection method**
F1: Entrepreneurial activities	▪ Interview questions

F2: Knowledge formation	▪ Interview questions
	▪ Indicators:
	  ▪ Number of publications in specific journals
	  ▪ Number of citations
	  ▪ Number of patents

F3: Knowledge dissemination	▪ Interview questions
	▪ Indicators:
	  ▪ Number of workshops and conferences
	  ▪ Activities of industry associations
	  ▪ Number of joint projects
	  ▪ Participation in foreign conferences, workshops, etc
	  ▪ Foreign industry association activities

F4: Guidance of search	▪ Interview questions
	▪ Indicators:
	  ▪ Number of articles in professional journals that raise expectations (positive/negative)
	  ▪ Specific targets set by governments or industries
	  ▪ The extent of regulatory pressures

F5: Market formation	▪ Interview questions
F6: Resources mobilization	▪ Interview questions
F7: Creating legitimacy	▪ Interview questions ▪ Indicators: ▪ Number of statements in literature by interest groups

The literature on technological innovation system suggests some indicators for the analysis of functions (Hekkert et al, 2007; Bergek et al, 2008; Suurs, 2009). However, some indicators related to

[2] http://rawi.ru/en

the functions are difficult to analyse within the TIS, where the system formation is on its early stage of development and there is lack of data. In such cases some indicators are replaced by perceptions of the system experts regarding the functions (Wieczorek & Hekkert, 2012). If data availability allowed assessing the functions using the standard indicators, then they were used, but still together with the interview questions. Thus, the function of entrepreneurial activities was analysed by asking system actors regarding their perceptions of presence and quality of entrepreneurs in the innovation system. Another function of knowledge diffusion was examined by looking at both indicators such as number of patents and printed publications in specialized journals, and interviews asking regarding actors activities related to this function. The sources such as databases of European Patent Office and Russian Patent Office, database of specialized scientific journals eLibrary[3] were consulted. By looking at the number of conferences and other related events in the field of renewable energy and particularly wind energy the function of knowledge diffusion was mapped. However, an opinion of the experts was asked if there was enough knowledge dissemination between the actors. The guidance of the search function was analysed by examining both the national and regional targets for renewable energy development and diffusion. In addition to it, expectations regarding the technology were studied by looking at discussions in the specialised media. The experts were asked about their perception of the market formation. The last two functions of resources mobilization were examined by looking at the statements in the literature (newspapers, journals, specialised websites) regarding firstly the perceptions of actors concerning resources mobilization and secondly different opinions of various interest groups, as well as by consulting with the system actors.

After the actors (project developers, engineering companies, knowledge institutions and governmental bodies) were identified within the structural analysis, they were asked for being interviewed. As is was noticed while carrying out the research the wind energy industry in Russia is presently a small niche sector, where only a limited number of actors are active presently in the industry, as the rest are not directly linked to the wind energy, for example, being involved in renewable energy development in general. In the long list of experts contacted, there were fifteen companies, among which nine companies agreed for an interview. Several companies were difficult to track down and find a person responsible for the wind energy projects. One of the reasons some companies refused to participate in the research by saying that nothing happens in the industry, so there is nothing to talk about at this moment. This was a popular answer from the firms that are not actively involved in the wind energy projects. Their perceptions of the system development were guided by the common vision, as they link the system development directly to the present absence of the regulatory framework. In contrast to these perceptions the firms that are actively involved in the industry formation were glad to participate in the research and provide the insights. The experts that were interviewed represent different types of the system actors covering all system elements. Two experts were the project developers, two representing the engineering companies, two - the knowledge institutes and three - other organizations.

[3] http://elibrary.ru

Due to a small size of the system, a number of interviews were enough to get a critical mass of data for the analysis. Moreover, after several interviews information provided by interviewees started to repeat. It was observed that the majority of the experts share almost the same vision about the current state of the wind energy industry in Russia and the prospects for its development. However, in order to obtain more insights about the system and compare the results obtained from expert interviews, data were obtained from the desk research by analysing articles in printed and online media. This included journals specialized on wind energy articles, general national and local press published specific articles and news regarding the wind energy projects. The analysis of articles enlarged the understanding of the functions' performances and relations between them.

3.3. DATA ANALYSIS

Considering that the research aims at providing a review of the current state of the wind energy system in Russia, the data analysis present the description and explanation of the system elements and different events taking place in the system. The major activities that are relevant for understanding and assessment of the system performance are described. This method is adopted from the work of Suurs (2009) that suggests this method being a suitable one for the analysis of technological innovation system development.

However, it should be mentioned the bias of such method of analysis, when a scientist's perception and vision influence the interpretation of events and activities. This can lead to some important facts being missed or misjudged in the context of the whole system analysis. In order to escape the bias of interpretation, the method of triangulation is applied (Silverman, 2005). The outcomes of the structural analysis, which was primarily based on the desk research, were verified with information obtained from the interviews. The same applies for the functional analysis, where data from interviews were verified by conducting desk research.

The assessment of system performance was done based on the personal judgment after carrying out the structural and functional analyses. The identified system mechanisms were verified with problems mentioned by the interviewees as well as with the innovation studies literature that mentions the system barriers and incentives of renewable energy development.

3.4. QUALITY OF RESEARCH

In this part the quality of the research is assessed whether the procedures were carried our correctly and scientifically justified. According to Bryman (2008) the assessment of research quality is done by looking at the internal validity, external validity, construct validity and reliability.

Internal validity indicates whether a causal relationship between variables is established (Bryman, 2008). The system mechanisms identified in this research were verified with similar mechanisms mentioned in other research studying problems regarded renewable energy development in other countries. It is believed thus that the relationships between the theoretical concepts suggested here are reliable, so the internal validity is reached.

The external validity implies whether the results of the research can be generalized (Bryman, 2008). The outcomes of the research are believed to be helpful for the analysis of technological systems in the developing countries. Even though one case is presented in this research, it is assumed that the theoretical framework and the methodological tool can be applied for exploring other technological systems in Russia and in other developing countries. The external validity is achieved by generalizing the theoretical framework on the similar cases, in which a technological system develops as a result of the catching-up process.

Construct validity is concerned with whether the measurements performed accurately reflect the concepts they should measure (Bryman, 2008). It is covered in this report by translating accurately the theoretical concepts into the indicators. Owing to the fact that TIS literature provides a clear and straightforward guidance on how to perform the analysis, it was not difficult to apply it for this research. The works of Hekkert et al (2007), Wieczorek and Hekkert (2012), Suurs (2009), Bergek et al (2008) describe in detail the operationalization of the theoretical concepts, especially which indicators suit best for mapping the system functions.

Reliability accounts for the objectiveness and repeatability of the study (Bryman, 2008). In this research the reliability is achieved by a structural description of methodological steps that can be easily followed and repeated.

4. RESULTS

This chapter considers the outcomes of the research. In order to understand the structure and functions of the wind energy system in Russia, short background information is provided about the country and the Russian energy sector. It is important to know how wind energy system is integrated in the renewable energy system of Russia. Afterwards the results are described according to the theoretical framework proposed.

4.1. RUSSIA: BACKGROUND INFORMATION

Russia is the largest country in the world covering more than one eighth of the inhabited territories of the Earth. With population of more than 143,3 million people[4] it is the ninth most populated nation[5]. This makes Russia the fifth largest electricity consumer in the world[6]. 78% of the Russian population lives in the European part of the county, which covers less than 25% of the territory[7].

The Russian territory possesses one of the largest energy resources in the world, so its energy sector is dominated by energy produced from oil, gas and coal. The Russian energy sector has undertaken lot of changes and restructuring from being state-controlled to liberalization in the last 10-20 years.

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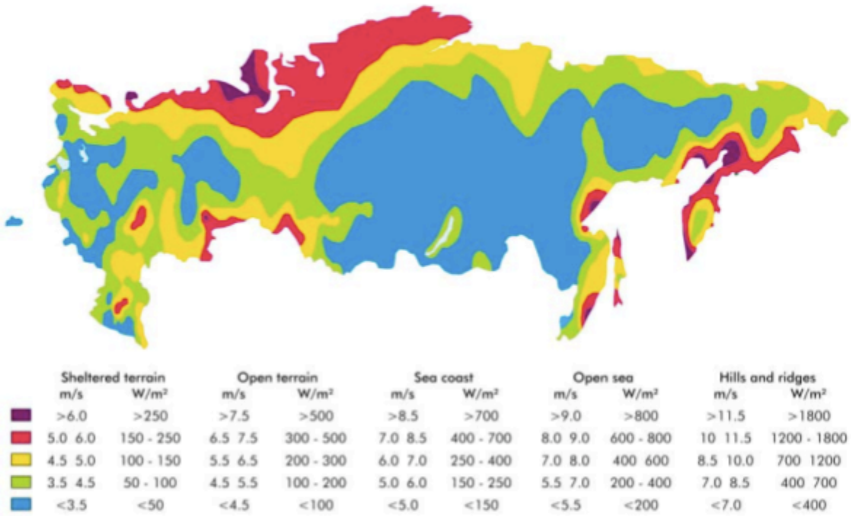
[4] on the 1st of January 2013 (Federal State Statistics Service of the Russian Federation, 2013)
[5] on July 2013 (CIA, 2013)
[6] 2012 est. (CIA, 2013)
[7] Federal State Statistics Service of the Russian Federation, 2013

However, the power sector is still highly characterised by state control, where grid operators, system operator, nuclear and hydropower plants are owned by the government (Market Council, 2013).



Picture 3: Wind potential in Russia (OECD/IEA, 2003).

Russia has a large renewable energy potential (OECD/IEA, 2003). The technical potential of available renewable energy resources in Russia is at least 24 billion tons of specific fuel (Summary National Reports, 2011). At present renewable energy sources are mostly presented by hydropower and nuclear energy, which are highly used and developed. Among the rest renewable energy sources, wind energy is considered as the most promising technology in almost all Russian regions (IFC, 2011). Its technical potential accounts for 6,500 billion kWh of power energy per year (Summary National Reports, 2011). According to many feasibility studies wind energy can be exploited in many Russian regions (Николаев, 2011; OECD/IEA, 2003). It is seen as a good option for providing power to isolated areas with small populations in the Far East and Siberia, as well as on the coastlines of the Pacific and Arctic Oceans and mountains regions of the Caucasus, the Urals, the Altai and the Sayan Mountains (Summary National Reports, 2011; Gati, 2008).

4.2. STRUCTURAL ANALYSIS

The major elements of the TIS are presented in the structural analysis, such as actors, institutions, interactions and infrastructure.

ACTORS

The Russian wind energy is a small niche sector, which only recently came into existence, namely in 2009, when the "Energy Strategy of Russia for the period up to 2030" was approved. It is considered as a starting point of the new history of wind energy in Russia. Currently the sector is presented by a number of companies that can be roughly divided by the type of activities they are involved in. These are equipment manufactures, engineering companies and project developers (RAWI, 2013).

Both local and international companies are present in each category, in some categories more than in others.

Project developers

Project developers initiate a project of wind park construction at a specific location. The project initiation involves many actions among which estimation of wind potential, legal procedures of land authorization, integration to the power grid (Expert, 2, Expert 3). Some experts used the terms project developers and engineering companies by naming the same companies. Usually the wind metering and monitoring are outsourced to engineering companies, but several project developers are capable of carrying out wind measurements themselves.

There are approximately 10 companies operating as project developers (Table 3). International companies are present in this category by Windlife Energy BV (The Netherlands), Falcon Capital (Czech Republic), SoWiTec Russia (Germany).

Table 3: List of project developers in the Russian wind energy industry.

Name	Short description	Sources
VentRus (ООО "ВентРус")	• 2 projects in Orenburg region and Altai region have started in 2009 • Wind turbines of Siemens will be probably used	Копылов & Гридасов (2012) [1]-[6]
Wind #5 (ООО "Ветер №5")	• 5 projects in Karachaevo-Cirkassian Republic started in 2009 • The brand of wind turbines to be used is unknown • The company performs wind metering	Копылов & Гридасов (2012) [7]
Wind Power Generation Company (ЗАО "Ветрогенерирующая компания")	• 2 projects in Krasnodar region and Astrakhan region started in 2012 • Wind turbines of Siemens will be used • Wind metering is carried out by a German company	Копылов & Гридасов (2012) [8], [9]
VetroOGK (ЗАО "ВетроОГК")	• It is an affiliate company of Atomenergomash Group of Companies, the machine-building division of the State Atomic Energy Corporation Rosatom, which was especially created for promotion of wind energy in Russia • More than 14 projects all over Russia started in 2012 • They consider organizing a local manufacture of wind turbines in cooperation with a still unknown foreign partner.	Копылов & Гридасов (2012) [10]-[13]
Wind Energy Systems (ООО "Ветроэнергетические системы")	• 9 projects in Krasnodar region started in 2010 • Wind metering is carried out in cooperation with companies CUBE and Garrad&Hassan • Engineering is carried out by companies: Infra (Austria), Ramboll (Belgium), Royal Haskoning (Netherlands) • Wind turbines of Vestas (Denmark) and Siemens (Germany) are used	Копылов & Гридасов (2012) [14]-[20]
Falcon Capital	• A Czech company, that created a joint venture with the government of Kalmykia in 2006	Копылов & Гридасов (2012)

	• A project in Kalmykia started in 2006 where 2 wind turbines were constructed • A new project started in Kalmykia in 2012	[21]-[26]
SoWiTec Russia	• A German company • Created a joint venture with Intertechelectro-New Generationt for the wind energy project in Kurgan region in 2012 • 6 projects in Russia • Wind turbines of Siemens or Vestas will be used	Копылов & Гридасов (2012) [27]-[33]
Windlife Energy BV	• A Dutch company • A project in Murmansk region started in 2010 • Wind turbines of Avantis Europe GmbH will be used	Копылов & Гридасов (2012) [34]-[38]

Engineering companies

Engineering companies perform wind metering and monitoring in different locations. The calculations provide estimation on how much power can be delivered from a wind turbine location. This type of companies are involved greatly in the current projects run in Russia. Since the projects are on their early stage of development, the most of work engages wind potential measurements, which can last up to one year depending on the location and difficulty of measurements.

There are around 5 engineering companies that are actively involved in wind assessment. It should be noted that Wind #5 provide also services for wind monitoring and metering, but it is also considered as a project developer. Among these companies half is international ones (Table 4).

Table 4: A list of engineering companies.

Name	Short description	Sources
Atmograph (НИЦ "Атмограф")	• One of the oldest and most experienced companies providing wind metering and monitoring • Involved in many projects	Expert 4, Expert 6
Aktiviti (ООО "Активити")	• The highly professional company involved in wind metering and monitoring for around 22 projects	[43]
Lahmeyer International	• German engineering and consultancy company active in developing renewable energy projects • Office in Russia	[44]
CUBE Engineering	• A German engineering company • 13 projects in Russia • Operate projects from the German office	[45]
Garrad Hassan	• A British engineering company	

Equipment manufacturers

The wind energy sector in Russia can be divided into two segments - small-scale power generation and large-scale power generation, which is based on wind turbine capacity. The capacity up to 30 KW is assumed to belong to small-scale power production and such kind of wind turbines are used for households or small locations (Experts 1-8). Russian equipment manufactures are active in this category, where around 10 companies develop wind turbines of small capacity (Expert 3, Expert 7).

The large-scale wind turbines are not manufactured in Russia. The turbines are delivered by major foreign manufactures, such as Siemens and Vestas. In the Eastern parts of Russia Chinese manufactures are more active considering a geographical proximity (Expert 2, Expert 5).

Taking into account the aim of this research to investigate the large-scale wind energy in Russia, the category of small-scale power generation is not elaborated further. It was mentioned in order to give an indication of developments that are taking place and perhaps will have some influence on the sector development in the future. The research on small-scale manufactures of wind turbines in Russia is conducted elsewhere (Николаев, 2011).

Knowledge institutes

Knowledge formation in the Russian wind energy takes place in higher educational institutions, research centres and other research organizations. Nowadays in Russia several universities prepare specialist for the energy sector and only a few of them have departments devoted to renewable energy (Table 5). Unfortunately, programmes specialized in wind energy were not found in any Russian university. The experts confirm this notion, that specialists in wind energy are not prepared in Russian universities (Expert 1-8). Even if research is carried out in the field of wind energy in Russian research institutions, it is fundamental in nature and is hardly linked to the real-life solutions.

Private sector is not involved actively in R&D projects in the field of wind energy. Only several companies, the so-called research and production organizations, are considering slowly opportunities for local production of some components of wind turbines (Expert 2, Expert 3, Expert 5, Expert 7). Taking into account that knowledge institutions are poorly funded by the Russian government and the private sector is not willing actively to invest in research and development, it is not expected knowledge valorisation to be developed in the nearest future.

Table 5: A list of knowledge institutions.

Research centres

- Russian Academy of Sciences
- G.M. Krzhizhanovsky Energy Institute
- Institute of Energy Strategy

Research and production organizations

- NPP "Wind"
- NPP "Raduga"

Governmental agencies

The Russian government is a key actor in any system formation in Russia (Table 6). Without a support from the government renewable energy sources would not take a niche place on the wholesale electricity market in Russia. Moreover, private investments can follow to the system only if it is politically supported (Gati, 2008).

Non-governmental organizations (NGOs)

NGOs have an advisory role in Russia by creating a space for experts and system actors to discuss changes to be undertaken for a better system functioning. Russian NGOs have some sort of influence on the Russian government, whereas foreign NGOs have a difficult life in Russia.

Table 6: A list of governmental and non-governmental organizations.

Governmental agencies

- The Ministry of Economic Development of the Russian Federation
- The Minister of Energy of the Russian Federation
- Russian Energy Agency
- Ministry of Regional Development of the Russian Federation
- Non-profit Partnership " Council for Organizing Efficient System of Trading at Wholesale and Retail Electricity and Capacity Market" (NP "Market Council")
- Regional governmental agencies

Non-governmental organizations (NGOs)

- The Russian Union of Industrialists and Entrepreneurs (RSPP)
- The Russian Wind Energy Association (RAWI)
- Bellona Foundation (Norway)

Other organizations

- International Finance Corporation (IFC): Russia Renewable Energy Program
- European Bank of Reconstruction and Development (EBRD)

Other organizations

International Finance Corporation (IFC) has a programme on renewable energy development in Russia, which provides advisory services and investments for the private sector on realization of projects.

European Bank of Reconstruction and Development (EBRD) is not currently involved in wind energy projects as they believe the market is still undeveloped and stronger political initiatives should be first implemented (Expert 9). However, a programme on energy efficiency and energy saving is run by EBRD in Russia.

INSTITUTIONS

This structural element incorporates soft (common habits, routines and shared concepts) and hard (rules, regulations and laws) institutions. The soft institutions are common for many systems in Russia. As it was mentioned by one of the experts interviewed the major barrier for renewable energy development in Russia is that Russian people “prefer things to stay as they are” (Expert 4).

Technological development causes changes for system actors and society that in turn support and adopt new ways of doing things. In Russia changes are associated with uncertainty and lack of understanding. Still some energy companies and a part of society do not realize the necessity to develop renewable energy sources when the country has a plenty of oil and gas reserves (Expert 1, Expert 2). Moreover, another shared concept is the influence of Western companies to adopt their practices. Russian people believe that Russia has its own way of development, so foreign strategies of development are not applied and should not be dictated by the developed countries. This concerns also renewable energy sources to a great extent (Expert 2, Expert 5, Expert 6, Expert 7).

Furthermore, it should be mentioned the importance of personal connections in Russia. Business in Russia depends highly on the level of personal relations with important partners and governmental agencies. In order to overcome time-consuming bureaucratic procedures, direct access to influential people may help to speed up the process. Lobbying power of those close to the policy makers increases the chance of the political decision to be in favour of a specific company or industry (Expert 7).

The hard institutions are presented by governmental laws and regulations related to the renewable energy development in Russia. Several important regulatory documents should be mentioned here. First of all, it is the Federal Law No. 35-FZ on "Power Sector" approved in 2007, in which the classification of renewable energy sources is presented as well as the necessity of the government to outline mechanisms for renewable energy support. Secondly, the "Concept for long-term social and economic development of the Russian Federation by 2020" was approved in 2009, which mentions determines the renewable energy development as a priority. Thirdly, in the "Energy Strategy of Russia for the period up to 2030" approved in 2009, the concrete targets were determined for the development up to 2030.

In 2013 it is expected the regulatory framework to be adopted that determines the mechanisms and market operations for power grid connection of generation facilities with an installed that operate on the basis of renewable energy sources. Several preliminary documents were already published in April and May 2013 (RAWI, 2013).

INTERACTIONS

The level of interactions in the existing state of the Russian wind energy is very active. The Russian Wind Energy Association (RAWI) creates a formal platform for sharing ideas, problems, solutions and finding partners.

It is observed that system actors have informal interactions between each other. In order the sector to take off, the actors need to consolidate joint efforts. Currently the system accumulates the knowledge and the actors share it gladly to promote the development of wind energy in Russia.

INFRASTRUCTURE

Infrastructure as proposed by the theoretical framework consists of physical, knowledge and financial category. Physical infrastructure is mainly adopted from foreign manufactures of wind turbines of large capacities. Local production of large-scale power generation wind turbines does not exist.

Knowledge infrastructure in the wind energy system comprises only expertise and knowledge in wind assessment, such as wind monitoring and metering. Knowledge related to developing new technological solutions and innovations is not currently created. It will take time for system actors to accumulate this type of expertise.

Financial infrastructure consists of private risks investments, foreign investments (e.g. IFS's Russia Renewable Energy Program has a budget of 5 million euro[8]) and governmental funds. Private investments were stated by the experts as being the main financial source (Experts 1-8). Then foreign investments are accounted for approximately 30% (Expert 7). Governmental funds have a tiny share in the total investment package to the wind energy system in Russia (Expert 1-8).

4.3. FUNCTIONAL ANALYSIS

As it was mentioned above the wind energy in Russia is currently a small niche sector, where a limited number of companies operate. These companies take a large risk investing in a sector, which is still not fully supported by the Russian government. The supportive mechanism is highly dissonant. On the one hand the governmental intention is to stimulate the development of renewable energy sources in Russia and to catch up the leading nations. On the other hand there is lack of actual movements from the government to trigger the sector. The experts with one voice state that the wind energy system is waiting for a clear signal from the Russian government to boost investment flows both from local and international companies (Experts 1-8). The system actors are currently in a waiting position.

However, there are more hidden system problems hampering the system development and diffusion. The absence of governmental trigger is an obvious system mechanism that everyone mentions and criticizes even not being involved in the wind energy industry. The functional analysis in that respect helps to identify all system mechanisms that do not only create barriers, but also create incentives for the system progress.

In addition, the functional analysis presents the description of every function of the technological innovation system from two perspectives. It is interesting to explore the role of international actors on the local system formation, namely how the systems are interrelated.

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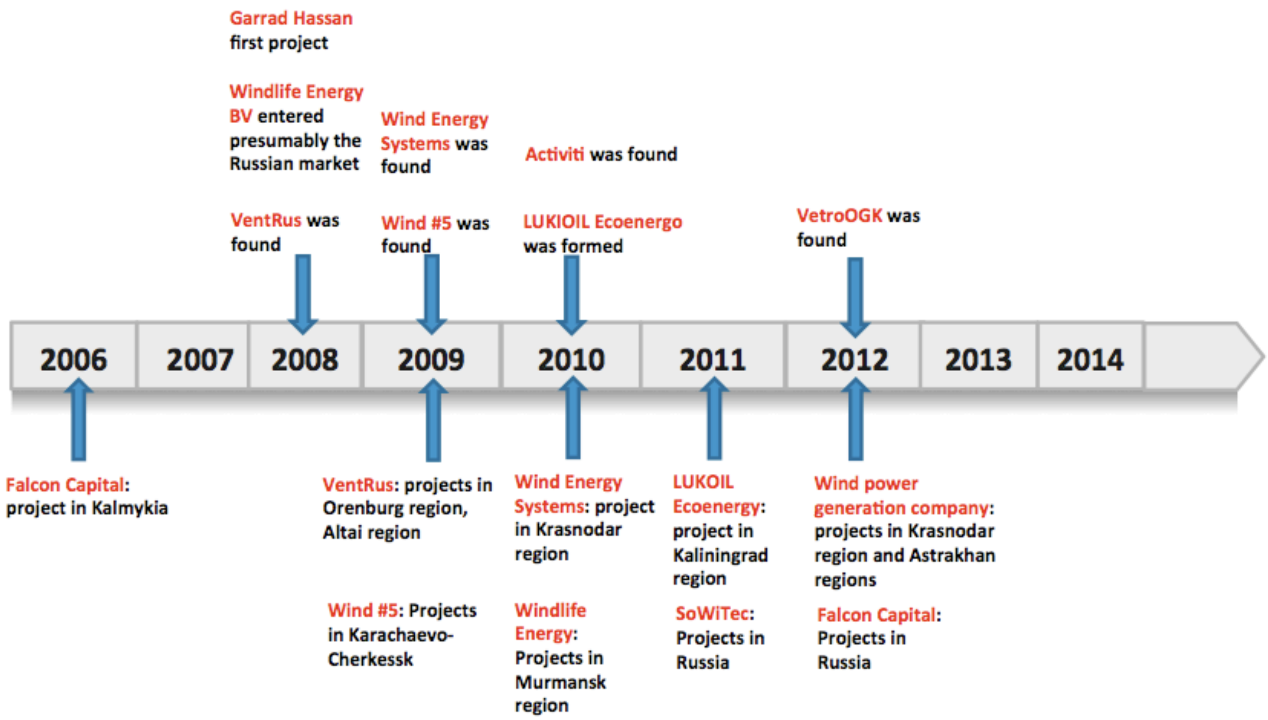
[8] Expert 7

F1: ENTREPRENEURIAL ACTIVITIES

Entrepreneurial activities are assumed to occur to some extent in the Russian wind energy. Most of Russian companies were found recently when the government initiative focusing on renewable energy was announced. Between 2008 and 2009 four companies (VentRus, Wind #5, Wind Energy Systems and probably Wind power generation company) started their business activities. Several companies were emerged as spin-offs of a large established company RusHydro, which was active in renewable energy projects and particularly wind energy ones. However, in 2009 it was decided to close wind energy projects when the dramatic accident took place on one of the RusHydro objects - Sayano–Shushenskaya hydroelectric plant in 2009 (Expert 7).

At the same time foreign actors started looking for business opportunities in a new emerging sector. This period is also associated with an increase in a number of projects that have been launched. The enthusiasm of companies to be the first and declare their capability of running projects was hampered with many difficulties arisen on the way. Hence, most of projects started in 2009 are delayed or frozen.



Picture 4: Graph of system actors entering the wind energy sector with projects.

After the first boom of entrepreneurial activities between 2008 and 2010, a fall of new companies entering the sector is observed. Many energy sector's actors believe that the formation of wind energy sector in Russia encounters many risks that are not worthwhile taking when ones are busy with projects in traditional energy systems where investment returns are permanent and secured. Therefore, the wind energy in Russia is a highly risky business adventure, where only "crazy and insane people" engage in the sector formation (Expert 1, Expert 2, Expert 3, Expert 5, Expert 7). This notion was mentioned by several experts interviewed, which were from different type of companies. It is increasingly interesting how they perceive themselves in the context of wind energy development in Russia as pioneers struggling with the traditional ways of energy development in Russia.

Large established firms in Russia behold the situation of the sector development and are ready to enter the new market as soon as the Russian government secures the investment returns by announcing clear structural mechanisms. For example, financial institutions such as banks and other investment organizations are not presently involved in financing the wind energy projects in Russia. However, they show an interest in the sector and consider different schemes of providing a financial aid by hiring specialists that are able to provide an investment analysis of such projects (Expert 5, Expert 6).

The experts predict a rapid increase in number of entrants in the upcoming years, as they expect the regulation framework to be approved this year (Experts 1-8). Thus, many companies both local and international reside currently in a waiting position of a market to boost. Existing companies has already made preparations for the momentum by establishing contacts with regional governments, finding partners (engineering companies, wind turbines manufacturers) and learning from current projects (Experts 1-8).

International wind energy system is an established sector that has already undertaken a range of different development stages. It is a mature sector where the technological progress focuses on improvements in a dominant design of horizontal wind turbine. The adoption of existing technologies takes place in the Russian wind system. Hence, international TIS participate in the Russian system by providing technologies, learning and maintenance. Several experts mentioned that large wind energy companies like Vestas, Suzlon, CUBE Engineering, Garrad & Hassan did not establish a local office, but operate successfully from abroad or via Russian partners (Expert 1, Expert 2, Expert 3,). In that respect these companies are actually involved in the local projects. Their current position is to monitor the sector, establish connection with local companies and authorities, learn about doing business in Russia, so that they are ready to open an office when the market is fully ready.

At this moment there is no production facilities for any component of wind turbine. The entrepreneurial experimentation occurs via learning on how to organize the project, namely how to identify a suitable location, to monitor wind direction and speed, to evaluate the investments costs and other activities. Pilot projects are launched in many Russian regions, where experiments are taking place on realization of projects. The major difficulty most of the companies encounter is power grid connection. There are still no regulation mechanisms on wind energy integration into the power grid. It is a time-consuming part of the project where personal agreements should be made with local authorities to get a permission to connect to the power grid. This is mainly the reason of some projects to be delayed at present.

Thus, for such a small technological system a number of companies is enough to cover the existing state of the art and demand (Expert 3, Expert 5). However, in order for a system to take off and implement the targets set by the government, more companies are needed in the system, namely investors who will provide capital for wind energy projects and therefore stimulate local and foreign companies to enter the sector (Expert 6, Expert 7, Expert 8).

F2: KNOWLEDGE DEVELOPMENT

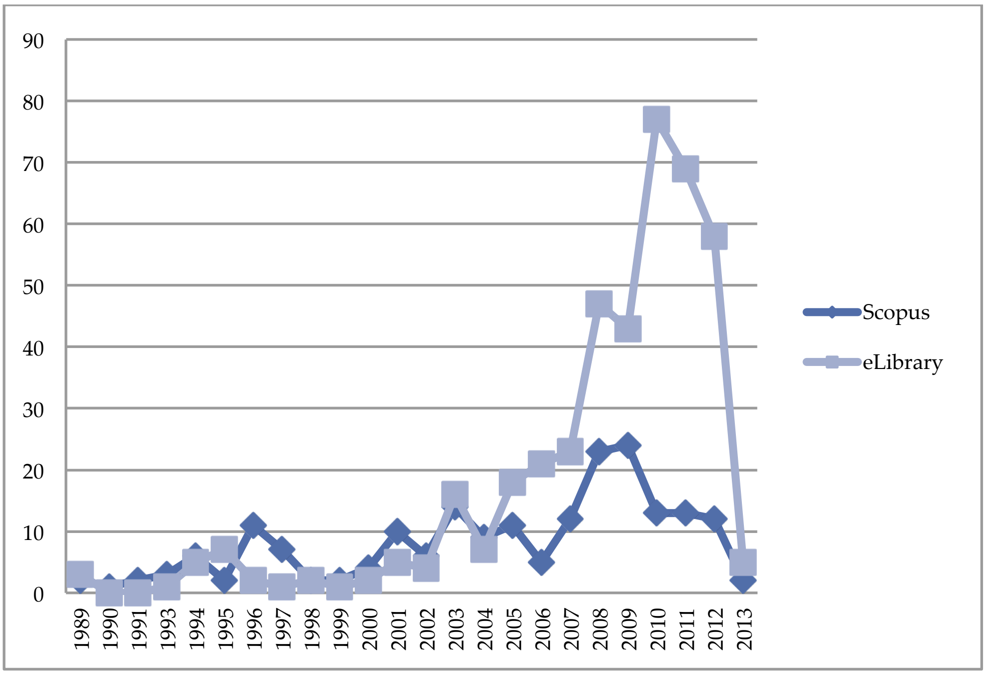
Knowledge development is a key activity for a system to accelerate and diffuse. In the wind energy system in Russia this function is performed in accordance with the current state of the system. In the Soviet time scientific and technological development of the country was on a very high level, where many organizations were involved in R&D projects. An intense competition between research organizations stimulated industries to grow fast and create innovative solutions. This affected wind energy as well, but already with a delay in decade from USA, Denmark and Germany. At the end of 1990 the development of the first wind turbine of 1MW was carried out by several research and production companies (Nikolaev et al, 2010). However, along with the collapse of the Soviet Union many research organizations ceased to exist or stopped elaborating many R&D projects including the project on a wind turbine. Russia explores still the consequences of a scientific and technological gap that formed due to almost twenty years of underfunding and lack of research in post-Soviet times. Not only the system of research institutes was damaged, but also the quality of education on the level of higher education institutions became very low. Thus, systemic changes require a lot of political initiatives, as well as public and private investments to reanimate the national science to the state already reached by the developed countries.

Understanding the general state of the Russian education and science helps to recognize the same difficulties in the development of wind energy in Russia. One of the concerns is the age of specialists engaged in academic research. Due to lack of financing, weak link between theory and practice in the Russian science, it is not attractive for young people to pursue a carrier of a researcher. One interviewee referred to this situation by stating:

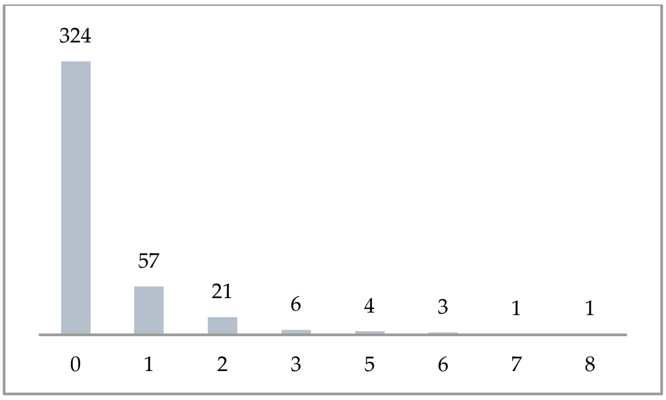
> *"In the Soviet Union there were research institutes, projects, programmes, technological base for innovative ideas, public funding. (…) And after that everything has died out, and I am one of those who possesses still expertise. In general, it is very difficult now with knowledge. Most of professors in higher educational institutes are above 70 years old." (Expert 5)*

The absence of young researches leads to the slow knowledge development. Moreover, the Russian education system is also characterized by its fundamental and theoretical learning techniques as well as lack of interactions with production and business companies. Furthermore, it was found that none of Russian universities have departments specialized in wind energy studies. This means that Russian universities do not prepare specialists in wind energy technology. The experts pointed out on this as being a cause of slow development of technological development (Expert 3, Expert 6).

However, some research is gradually carried out and it can be a good start for creating a scientific base (Expert 4). According to Scopus and the Russian equivalent eLibrary, a growth of scientific publication took place between 2008 and 2011 (Picture 5). The growth is believed to be caused by the government policy towards development of renewable energy in Russia, as before 2008 not many articles were published in the Russian scientific journals. Still, the quality of published articles seems to be low, because of law index of citations. According to eLibrary nearly 78% of articles are not cited, and only 14% - once (Picture 6).



Picture 5: Number of scientific publications according to Scopus and eLibrary.



Picture 6: Number of cited publications according to eLibrary.

A law quality of publications leads to another aspect of the knowledge development, namely an absence of practical application. Universities and research institutes conduct theoretical research that finds rarely application in concrete industries. The private sector is not involved in R&D projects concerning components of wind turbines, as it is believed an unnecessary activity to organize a research in the field, which is highly progressed in the developed countries (Expert 1). The actors predict that wind energy technologies will develop in Russia, when the market is established (Expert 1, Expert 3). Moreover, a regulatory framework is expected to be approved this year, which implies localization of production (Expert 1-8). Such a governmental initiative will probably create an impulse for R&D projects:

> *"Firstly, the assembly of low technological components will be organized, for example, wind turbine towers. Afterwards, something more difficult. Finally, when companies will learn to do simple technologies, then design and construction of new technological solutions will take place. If they start with innovations now, many mistakes will be made that were already made by developed countries." (Expert 3)*

Currently, the actors attempt to accumulate different kind of knowledge. Firstly, it is general knowledge about wind energy technologies. Still lack of awareness exists among companies in the Russian energy sector on advantages of renewable energy sources. Furthermore, decisions on renewable energy application on the regional level are made by local authorities based on lack of expertise and information on wind potential in particular locations. Regional authorities follow sometimes the policies of the federal government without providing analysis and expertise on their feasibility (Expert 7). Wind energy actors attempt thus to spread understanding and knowledge among governmental bodies and other institutions that renewable energy potential in Russia is very high and some local problems can be particularly solved by using modern technologies. In support for this the examples of other countries are used (Expert 1, Expert 2, Expert 5, Expert 6).

Secondly, the current state of the wind energy in Russia is characterized by creating knowledge regarding practical instruments to perform wind energy projects. It was mentioned during the interviews that the local project developers share a different level of expertise in running the projects (Expert 1-7). Presently most of them are involved in pilot projects in order to accumulate knowledge of practical project development. Another category of actors engineering companies executes wind metering and monitoring with a try and error method. This requires a lot of specific knowledge, which only a number of companies in the industry possess. Foreign companies are thus invited for knowledge exchange and verifying data received by the local experts (Expert 2, Expert 5, Expert 6, Expert 7).

Considering the early stage of industry development, research and development (R&D) projects are not actively developed. The current research is focused on investigation, which Russian regions suit better for wind turbines and on calculation of wind potential in these regions. Another strand of research deals with justifying the necessity to develop wind energy industry in Russia.

F3: KNOWLEDGE DISSEMINATION

When interviewing the experts of the Russian wind energy one gets an impression that everyone knows each other very well. The actors are aware of projects their rivals or partners are involved in and historical aspects of companies' development. This can be explained by a strong network connection between the major industry players.

Knowledge diffusion in the system is performed by formal assemblies and informal interactions. One of the important roles the Russian Wind Energy Association (RAWI) has taken, which strives to create a platform for sharing information and knowledge. As it was mentioned in the previous function it is basically the practical instruments on launching and executing the wind energy projects. The association has started a series of seminars on different topics in 2013. These topics cover the most essential issues, such as problems related to preparing and running a wind energy project; financing of wind energy projects; specifics of the Russian wholesale and retail power markets for renewable energy sources; difficulties related to integration to local power grids. Several seminars are to be held in Germany oriented on foreign investors and companies willing to enter an emerging niche market in Russia, as well as for Russian companies willing to learn successful practices from the developed countries.

Several conferences are organised each year to promote renewable energy development in Russia ("Future of Renewable Energy Sources in Russia"[9], "Energy efficiency and energy saving technologies in Russia"[10], "Current Status of Wind Power Industry in Russia"[11]). It can be noted again that the activities for knowledge diffusion has started in 2009 and later, when the development of renewable energy in Russia was announced as a top priority. The experts were consistent and mentioned conferences as a useful platform for networking and keeping the contacts between actors (Experts 1-8). As one of them said:

> *"Conferences is a very practical tool for knowledge exchange, where people meet each other at least once a year" (Expert 1).*

Another way of knowledge dissemination is interactions between the system actors with different forms of partnerships. Lack of knowledge and expertise in organising wind energy projects stimulate the companies to collaborate and exchange the knowledge one possesses. For this reason foreign specialists are invited to monitor the projects. There are a couple of examples, when large foreign companies provide different services, such as wind monitoring, engineering services, etc. This creates a good learning environment for the local companies. The Russian engineering companies use learning by doing when asking the foreign and local companies to provide a back up for their measurements in order to improve their techniques (Expert 3, Expert 7).

The foreign companies, in contrast, need another type of knowledge to accumulate. In order to learn more about specifics of the Russian energy system and to get access to the system, joint ventures with local authorities or companies are very crucial. It is very difficult for foreign companies to enter the Russian market without having a local partner, as they encounter many pitfalls that can be only overcome by knowing the local rules of the game. This form of knowledge exchange creates an added value for both parties.

The current level of knowledge is thus not enough for the system to develop and diffuse. The system needs investments for knowledge accumulation and sharing. Foreign specialists can be invited for trainings and learning while the technological system is located at the early stage of development. When the system starts to mature and specific technological knowledge is required to

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[9] It is organized by the Russian business daily newspaper Vedomosti (a project of Financial Times and The Wall Street Journal. The first conference was held in 2011. (http://www.vedomosti.ru/events/vie12/)

[10] It is organized by the Russian media company RBC. The first conference was held in 2012. (http://bc.rbc.ru/about.shtml)

[11] It is organized by RAWI. The first conference was held in 2009. (http://rawi.ru/ru/konferencii/5rawi.php)

launch manufacturing, foreign companies will be more careful in knowledge sharing (Expert 3, Expert 7).

F4: GUIDANCE OF SEARCH

The Russian wind energy system has received an impulse for development in 2009 by approving the Energy Strategy of Russia till 2030 (Minenergo, 2009). This inducement was supported by a number of companies by means of starting the corresponding activities. Unfortunately, it was not enough to form the system successfully. Soon it became clear that announcing the targets does not create an environment for the development and diffusion of the system. Additional regulations are needed to overcome the barriers that companies are currently encountering when running wind energy projects (Experts 1 - 8). The system actors anticipate these regulation mechanisms to be introduced. The upcoming regulation framework will stimulate the practical movements towards the sector development by proposing mechanisms for power grid integration of electricity coming from renewable energy sources (Minenergo, 2013).

While many experts rely heavily on the upcoming regulation framework as a trigger for the system development, some experts show examples of projects where successful grid integration was carried out (Expert 2, Expert 6). The success of these projects lies in a high interest of the regional governments in renewable energy development on the local level[12]. Autonomous wind turbines were installed in the isolated locations, where electricity costs from renewable energy sources are less than from traditional ones. This direction for development is believed to be a promising one in the wind energy system, while the regulation framework for wholesale electricity market is not approved by the government (Expert 5, Expert 6, Expert 7).

All experts have high expectations towards the development of the wind energy in Russia. The sector is expected to grow in the upcoming 5 years, if the policy regulations are approved (Experts 1-8). The mechanisms for power grid integration will be introduced, so there will be secured returns on investments. This will stimulate many projects to be finished and new companies will enter the market, particularly foreign companies interested in large projects.

> *"In my opinion, there will be a serious presence of foreign companies. Many engineering companies will enter the market and they will need a local support, so there will be knowledge exchange." (Expert 5)*

F5: MARKET FORMATION

The experts pointed out that the wind energy market does not exist yet (Expert 1-8). The majority of projects are pilot that are executed on private risky investments.

[12] Belgorod and Krasnodar Regions

> *"Insane people are working in the sector, that believe in market perspective and tank ahead as sheep". (Expert 1)*

However, several regional governments can be called as customers of wind energy turbines, because they took part in initiating projects [24]-[29]. The market is highly undeveloped at this moment, but some positive intentions for creating market regulations are observed.

F6: RESOURCES MOBILIZATION

Financial resources are one of the major concerns of the wind energy sector in Russia. Given the high investment risks, the investors are careful with providing a financial support for the wind energy projects. It is a chicken-egg problem. The investors are ready to provide a capital when the projects guarantee the returns on investments, so when the market functions. However, the market development depends highly on an investment flow to the system. The solution is currently found by the system actors by investing their personal capital. As several interviewees stated the majority of projects are financed by the project developers (Expert 2, Expert 5, Expert 6, Expert 7).

> *"There are not many sources of risk investments. (…) those who see the perspective of industry development and have spare money to invest, but they are crazy people"(Expert 1).*

The government on the federal level does not provide a financial support to the development of the wind energy system in Russia. There was one example of the federal investment programme to build a wind energy turbine on the Russky Island[13] where the Asia-Pacific Economic Cooperation summit was held in 2012. The project was announced in 2009 and the same year wind monitoring was started [41]. However, the project did not succeed, as it was frozen for an uncertain period of time [42].

The large Russian banks (Gazprombank, Vneshekonombank, Sberbank) consider presently entering the market as the strategic investors for the winds energy projects, yet the risks are still very high to guarantee the returns on investments. While waiting for the market, the banks monitor the situation, learn from projects abroad[14], hire specialized people who are able to conduct a project expertise and estimate the returns on investments[15] (Expert 5). Foreign investments in the wind energy are accounted for approximately 30-40% of the total investments (Expert 7). International Finance Corporation (IFC) and foreign project developers contribute for this statistics.

The wind energy industry lacks of qualified technical specialists. As it was mentioned above specialists in the renewable energy sources are prepared by a number of Russian universities. However specialists in the wind energy specifically are not taught at all. The quality of Russian graduates is very low, so they need to be re-educated in order to be able to work in the sector

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[13] The Russky Island is located in Vladivostok.

[14] Gazrpombank has acquired 21.74% of stakes in Energie du Porcien SAS, who is the owner and operator of two wind farms with a total capacity of 39 MW in France [46].

[15] Gazprombank

(Expert 3, Expert 5, Expert 6). This causes a lot of companies' investments and time to provide practical knowledge for employees. Thus, lack of specialists is felt already now by the industry actors, besides a growing demand for qualified specialist is expected in the coming years when the industry starts to take off (Expert 3, Expert 5, Expert 7, Expert 8).

Currently, the system actors do not worry about complementary assets, like logistics and maintenance services. Most of the companies have found a partner for supplying wind turbines and other components for the projects, as this is the stage in which project developers are mainly engaged. As it was mentioned before the majority of projects are at the pre-project stage, when wind assessment, investment justification and search for wind turbine suppliers take place. The challenges related to logistics and maintenance services will be thus later noticed (Expert 2, Expert 6). Logistics and infrastructure around locations of wind turbines can become a problem, considering the state of Russian road infrastructure and the large territory of Russia (Expert 2). Therefore the choice of wind turbine manufactures is influenced by the proximity of wind energy projects to the Western or Eastern part of the country (Expert 7).

F7: CREATION OF LEGITIMACY

The development of wind energy system in Russia encounters a misunderstanding and careful treatment from the oil and gas industry, which believes renewable energy sources as being an unnecessary source of power production in the case of Russia (Expert 6, Expert 8).

> *"There is no evident resistance from oil and gas industry. I would call it an inertness of thinking. Why to come up with something new, when oil, gas and coil are the usual schemes for energy projects." (Expert 1)*

It is also considered an influence from Western countries that attempt to impose their models of development (Expert 4). The same way of thinking is also observed in the society (Expert 3, Expert 6).

As it was mentioned before personal contacts play a very important role in the Russian business. People close to policy makers have a lobbying power to influence the system development. It was stated by the interviewees that the project developers and the engineering companies might influence the decision making processes when the government works on regulations related to wind energy (Expert 2, Expert 7). For example, the oil and gas companies and companies working in the solar energy sector have a higher lobbying power (Expert 8).

The governmental agencies[16] that are dealing with realization of the governmental plans are also resistant to changes. Their primary role is to make sure the regulation mechanisms are in place and the plans set up by the government are fulfilled. Thus, when the sector does not function property,

[16] Non-profit Partnership " Council for Organizing Efficient System of Trading at Wholesale and Retail Electricity and Capacity Market" (NP "Market Council") and Institute of Energy Strategy

this is their problem to introduce solutions (Expert 5). However, the work of these agencies is highly dependent on the general political climate. Until the impulse is sent by the government, the governmental agencies are not eager to be involved in creating the regulation mechanisms.

Still much work is needed to spread information about using renewable energy sources in the Russian regions. The regional authorities are responsible for making decisions regarding the local power markets. Therefore, knowledge and opinion about the wind energy on the regional level is highly important for the system development (Expert 6).

> *"Regional authorities were asked whether the regions needed wind turbines and how many by 2020. 10% answered positively. If there is wind potential in particular regions and how much electricity would cost nobody knows. And nobody in the regions can answer this." (Expert 7)*

However, several regions are good examples of promoting renewable energy sources and particularly the wind energy:

> *"The administration of Krasnoyarsk region works very actively. Another strong regional administrations are Belgorod (they created a center of renewable energy) (…) and Krasnodar Regions (in 2004-2006 a law was adopted regarding using renewable energy sources in the region). So they consider it as a strategic direction of development." (Expert 5)*

The system actors expend much effort to promote and create positive opinion among other industries and the society that the wind energy system can exist along with traditional fossil fuels and solve, for example, problems of isolated area, which are not covered by the power grid. The enthusiasm and personal examples of the system actors cause changes in peoples' opinion and stimulate the system slowly to progress (Expert 1, Expert 6, Expert 8). However, there is no one who consolidates the system actors to become a frontrunner for the sector development (Expert 4, Expert 5). The foreign organizations such as IFC and EBRD with their capacity to provide investments can help a great deal to consolidate the lobbying power (Expert 6).

5. ANALYSIS

In the previous chapter the results were presented that were obtained from the desk research and the interviews with the experts of the wind energy industry in Russia. Therefore, the structural elements were identified and the functions of innovation system were described. The next step is the analysis of the functions' performance in terms of which system mechanisms create incentives or barriers for the system development. The system performance and progress depends on the current stage of the technological development the system proceeds through. The stages of catching-up are characterised by different factors, hence they imply a certain pattern of the technology transfer.

5.1. STAGE OF CATCHING-UP

The research has shown a problematic structure of the Russian wind energy system. The technological development proceeds through a complex path that is still in the early stage of catching-up. The performance of the functions is characterised by the factors that are relevant for the early stage of technological development. The system possesses a weak technological base, on which only it is impossible to build the technological innovation system. Thus, most of the efforts are put on knowledge formation with the help of foreign expertise.

It is observed that the Russian wind energy industry is located in the first stage of catching-up, duplicative imitation. The technology transfer in this stage is characterised by a full imitation of foreign practices. In the wind energy system this imitation implies the projects running in the way foreign projects are carried out. The process includes project management and routines involved, as well as technology adoption for wind measurement and wind turbine installation. The advanced countries (mainly Germany and Denmark) provide knowledge sharing on organization and operation of the wind energy projects. The learning is taking place not only from outside, but also the local firms disseminate knowledge between each other, thereby striving for a faster development of the system. Mostly it concerns creating a general awareness of system opportunities among other actors. Being highly dependent on the conventional energy resources, the country is locked in the current routines of doing things. Hence, it takes much time and effort from the actors of the emerging technological system to change a mind-set of incumbent firms, local authorities and the society in general. Thus, in the early stage of technological development the focus lies also on creating legitimacy and stimulate the initial impulse for the system to grow.

Another factor that determines the stage of the catching-up is the number of firms operating in the system. Due to the undeveloped market regulation and high risks, local firms do not hasten entering the emerging market. Lack of technological knowledge and experience, as well as a weak governmental support create uncertainty for the technological development. The firms are not ready to take high risks and invest in technologies that are not proved to be successful in the current stage.

The system is partially financed by foreign investors that provide a support for the technology to overcome the early stage of development. The developing countries, particularly Russia, are huge markets for the advanced counties, where opportunities exist for them to create a competitive advantage over the ones that will be latecomers in emerging markets. Thus, foreign firms monitor actively the developments, so they are prepared to grasp the emerging opportunities very quickly.

As it was mentioned above, intense interaction between local and international technological innovation systems is a key aspect of the first stage of technology transfer. Local firms follow the path of the leading nations in the technological process. The latest technological solutions are adopted, but also best practices in the filed of legislation and other regulations are applied for the local context. It is stated in the literature that the catching-up process involves not only the technology transfer, but also a transfer of other related mechanisms, such as regulative, intuitional, social and economical (Archibugi & Michie, 1995). In this respect the first stage of the development is important for identification of procedures relevant for the local context. To proceed to the next stages of catching-up, the successful application of the mechanisms on the national level is required.

5.2. SYSTEM PERFORMANCE

Considering the fact that the wind energy system in Russia proceeds currently through the initial stage of development, the performance of functions is evaluated in accordance with the state of the system for this stage. The functions present an overview of the activities taking place in the system, but they also provide a perception of the path the system goes along. This path might lead the system to be locked in the first stage of catching-up and not to be able to progress to the next stages unless the changes are introduced.

The state of the Russian wind energy sector is believed to be a result of difficult interrelations between the system functions. The experts interviewed mentioned one major barrier they believed to hinder the development and diffusion of the wind energy system in Russia. This was the absence of the market regulation framework. Obviously, it is a strong barrier influencing the majority of system elements and activities. However, it is assumed to be a simplistic perception of the system mechanisms. It is important to analyse the relations between system functions, how they are related to each other and which relations are strong or weak. As it was mentioned in the theoretical part, the interactions of functions shape a pattern explaining a motor of the system formation and the development process. In other words, a particular motor of innovation is identified. Such approach helps to recognize deeply hidden mechanisms that create barriers for the system development (Suurs, 2009).

Based on the structural, functional analyses and knowing that the TIS is located in the duplicative imitation stage of the catching-up, a pattern of "entrepreneurial motor" is observed in the Russian wind energy system. The system is currently formed by the interactions of functions guided by this motor of innovation. However, some of linkages are still missing or performing weakly in the system.

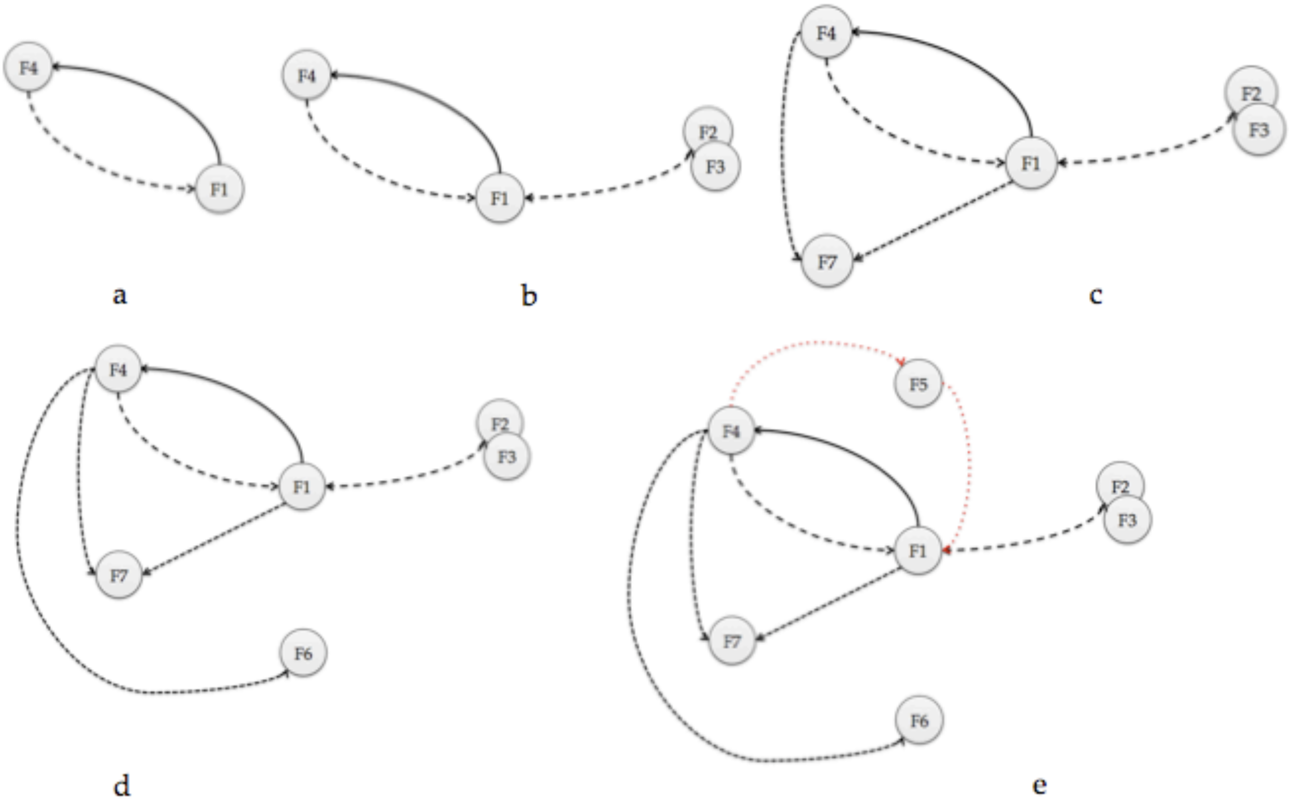
The system formation was encouraged by the governmental initiative related to the transit to the sustainable and energy efficient economy. Before that the wind energy was only presented by a small-scale power generation (Николаев, 2011). The incentive was supported by the local entrepreneurs (project developers and engineering companies) that later became the system frontrunners [F1]. Along with the local firms the actors of the international TIS showed an interest in the emerging sector. This was done by either establishing a local office in Russia, or by providing guidance and support via partnership agreements with the local firms. The entrepreneurial activities were focused on launching the wind energy projects, firstly in the isolated areas, which are not covered by a power grid, and secondly in other areas, where regional authorities showed a motivation and an interest. This was guided by the entrepreneurs' strong motivation and high expectations of the wind energy potential in Russia [F4]. The interaction between

F1 (entrepreneurial activities) and F4 (guidance of search) is strong enough for the current state of the Russian system (Picture 7a). High expectations and confidence in the market opportunities for the emerging technology stimulates new firms to enter the industry. In turn, the experimentation with the projects creates an environment for a technology to attract the attention of other actors. When the system starts growing, it will require new entrants to the system, especially project developers and engineering firms to run the wind energy projects. This interaction is seen as a driving mechanism for the system formation. However, due to the undeveloped regulations in the wind energy system the feedback interaction between F4 and F1 is weak. New firms do not enter the industry and foreign firms wait for a political signal, thus entrepreneurial activities do not actively take place [F1].

Considering a long history of wind energy in the world, the Russian TIS used the practices of the advanced countries in organizing the projects that included among others an initial stage of wind monitoring and measurements, as well as land preparation and formalities related to a land agreement. The entrepreneurs focused more on the experimentation with different methods of wind measurements (height of measuring mast), research on wind potential in various Russian regions and pilot projects for learning [F1, F2]. The relation between F1 and F2 (knowledge formation) is presented in terms of entrepreneurs accumulating knowledge on the procedures and routines related to the initiation and operation of the wind energy projects. The entrepreneurs are presented by the individualistic players of the market that went through different ways of becoming a part of the wind energy system. Most of them are spin-offs of incumbent firms working in the energy sector that realised a business opportunity for the emerging niche market. Just several of them are considered qualified enough to perform the projects in accordance with the international standards [F1]. Lack of knowledge and competences in the field of wind energy projects are the reasons of weak performance by the local firms [F2].

This is also closely related to the duplicative imitation stage of catching-up, when the entrepreneurs understand the necessity of technology transfer from the advanced countries (Lee, 2005). The participation of international actors in the system stimulates knowledge formation and diffusion [F2, F3]. Different forms of partnerships are formed in order to learn from foreign expertise. The foreign leading firms are invited to participate in the initial stage of the system formation by providing a guidance and knowledge of the wind energy projects' operation [F3]. Considering a significant scientific and technological gap between Russia and the advanced countries, the Russian wind energy system needs to obtain a lot of knowledge and capabilities [F2]. At this point foreign firms are interested to share basic knowledge, as in turn they get specific skills about the Russian market. This knowledge might help to get a competitive advantage in the following stages of the system development. The bilateral partnerships add value to both sides at this moment. Moreover, as soon as the system creates a critical mass of knowledge leading to the system actors being less uncertain about wind energy projects, new firms will enter the emerging system.

The research and development related to the technological components of wind energy are almost not carried out in Russia [F2]. The current state of the Russian science and technology base causes the technology and knowledge adoption from the advanced countries [F3]. Russia has lost its leadership in scientific research after the collapse of the Soviet Union. Unfortunately, poor attempts to recover the Russian research traditions are still taking place, but they are far from being successful. One of the important factors that hinder this transformation is a gap between theoretical research and its practical application. The entrepreneurs do not actively participate in the research and development projects [F1, F2]. This role is fully given to high educational and research institution, which do not know what happens in the real industry. There is a lack of cooperation between the research institutions and the entrepreneurs [F2, F3]. This can be explained by the fact that Russian firms have limited capabilities in bringing new technological solution into the market. The participation of firms in R&D expects these capabilities to be present. Moreover, in order to proceed to the next stage of technological development the role of national capabilities in terms of research and development will become more important. Even though the advanced countries provide knowledge, the Russian firms should be equipped to apply and adopt it to the local context. Thus, in the current state of the system there is a functioning interrelation between F1 and F2, F3 in terms of knowledge sharing between the entrepreneurs, but it is weakly performed in terms of the entrepreneurs' participation in organising R&D (Picture 7b).



Picture 7: The interaction patterns between the system functions (straight line - strong relation, dashed line - average relation, dotted line - weak relation, read dotted line - absent relation).

As it was slightly mentioned above, the entrepreneurs are the independent system players, which use their personal skills and perceptions of the system attempting to promote the wind energy in Russia [F7]. However, their lobbying power is too weak to foster the system development due to disunity of the system actors in a struggle for mapping the wind energy as an alternative perspective for the conventional energy sources. It is well known that the lobbying power is a strong mechanism to create a social and political awareness regarding an emerging technological trajectory. The Russian Wind Energy Association (RAWI) that was created especially with a purpose of making a platform for networking of the system actors, unfortunately, does not perform this function very well. It did not become a frontrunner for the system promotion and an intermediate between the government and the system actors. Indeed, an intermediate function is important for monitoring and proposing suggestions, adjustments and changes in the regulation frameworks related to wind energy [F4, F7]. Thus, the interrelation between F1 and F7 (creation of legitimacy) is not strong in the Russian case (Figure 7c). This is caused by a large distance between policy makers and the system actors. The entrepreneurs do not have a power to influence the decision making process and to lobby their interest on the level of the Federal government. This creates an obstacle for the system development, as important regulations and decisions are made without a discussion and agreement with the system frontrunners.

The government is responsible for creating an environment for the technology to develop and diffuse by introducing regulatory frameworks [F4], as well as by providing financial resources for the system formation [F6]. As long as the new technological system is supported on the national level, inflow of funds will follow. In the case of the wind energy system lack of financial resources is seen as a consequence of weak policy support, lack of subsidies and uncertainty of the system development. The relation between the functions F4 and F6 is weakly developed in the system (Picture 7d). Even though there is a shortage of investments in the system, there are a number of organizations (local and foreign project developers, IFC, governmental corporations[17]) financing the wind energy projects. It is also expected that the large Russian banks[18] with state-share participation consider providing loans.

Specialists in the wind energy are not prepared in the higher education institutions; financial institutions restrain funds from providing investments for the wind energy projects [F6]. A weak governmental support for the system development entails uncertainty in the society and high risks for firms to operate in the emerging technological system.

Meanwhile there is no market for the wind energy. The market demand side is completely absent in the system [F5]. This is explained by the lack of feasibility projects that are able to show the returns on investments as well as the market benefits for customers. The market will start functioning when the regulation mechanisms for power grid integration are adopted [F4]. In such a case the project developers or the regional authorities will be the customers for the wind energy projects. The current projects are considered as the pilot projects where the pre-project, feasibility studies are

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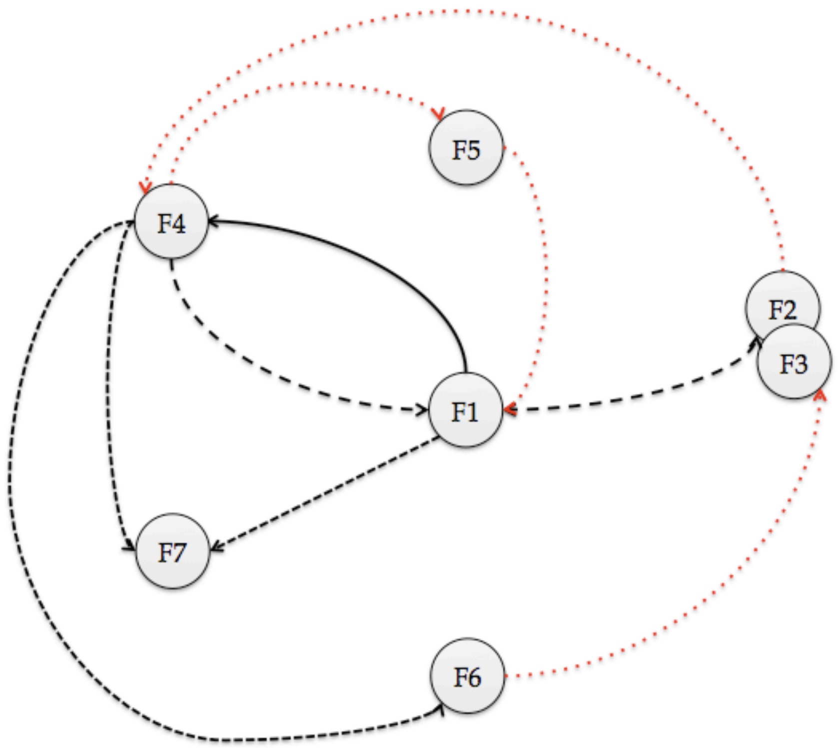
[17] Rusnano, Rosatom, RusHydro
[18] Gazprombank, Vneshekonombank, Sberbank

taking place, but still are not commercially attractive in terms of fostering the market formation. It is also a result of high uncertainty in the wind energy system. The system is currently placed in a waiting position, where the uncertainty relates to the Federal government adopting the regulation frameworks, how it will work for the wind energy projects and other anxieties. Usually the process of adapting the regulations to the practical actions takes some time in Russia and this leads to delays in initiating and operating the projects. Thus, the function F5 is not actively involved in the stimulation process for the system development. It will be induced by the function F4 when the market regulation mechanisms are approved in 2013 (Picture 7e). As soon as it happens, many local and foreign firms will immediately enter the promising market [F1].

Other interactions that are currently missing in the system are between the functions F6 and F2/F3; F2/F3 and F4 (Picture 8). Lack of financial resources and specialists does not stimulate the knowledge development and diffusion. The higher education institutions and research centres require substantial investments from both public and private funds. It is expected this mechanism to be put into action as soon as financial flows run into the system. The interaction between F2/F3 and F4 will also be in place when the system accumulates enough knowledge and increase the expectations of the system actors regarding the new technological possibilities.



Picture 8: The entrepreneurial motor of innovation in the Russian wind energy system (straight line - strong relation, dashed line - average relation, dotted line - weak relation, read dotted line - absent relation).

The traditional ways of doing things is reflected in the majority of system activities. The Majority of higher education institutions, governmental bodies and other organizations show a high level of dependency on conventional routines and traditions. The changes are adopted hence slowly. In addition, the Russian system is also characterised by a short-term vision. The wind energy system requires long-term investment programs from the Federal government, as well as from the authorities on the regional level. While the Russian government on the federal level provides still the targets and planning for the long-term technological development, the regional governments prefer to obtain a short-term return on investments. In the Russian regions the power of local authorities is very unstable and is subject to a huge uncertainty. Thus, it is preferred to run the short-term projects, which secure the return on investments before the projects are terminated. However, the wind energy projects imply a long-term planning and operation, which are currently unattractive for the regional authorities to be involved with. Moreover, the situation becomes complicated by the absence of the federal government's pressure upon the local governments to pursue the wind energy development on the regional level.

The government creates a visibility of actions from one side, but from another it shows a resistance for changes. The dependence on old routines and traditions hampers the changes and makes it difficult for the actors to promote the new technological trajectory. The political inertia implies a slow decision-making process, unwillingness to attract the system experts for the discussion of the regulatory frameworks or other important system developments, as well as high reliance on the lobbying power of specific interest groups (e.g. the oil and gas companies, the lobbyists for solar energy projects).

The entrepreneurial motor of innovation that guides the formation of the wind energy system in Russia was described above. It is observed that the majority of interactions between functions are still in the process of formation or undeveloped. If to compare the current analysis and the characteristics of this motor suggested by Suurs (2009) the following incentives and barriers can be outlined:

Incentives:

- The project developers and engineering firms play the role of the system frontrunners as they have high expectations regarding the system development, and consequently they initiate the adoption and implementation of the technology to the local context;
- An availability of wind energy technology, which is poorly aligned to the current institutional structures;
- The implementation of initial stages of the wind energy projects in various locations, which are seen as learning-by-doing, while waiting for a political signal;
- The national and regional governments observe the necessity for supporting the system by designing regulations and institutions, as well as by becoming launching customers;
- Foreign firms' readiness to provide expertise and knowledge in return for the market share in the local system.

Barriers:

- The resistance and misunderstanding from the conventional energy companies, the regional governments on the necessity to adopt the wind energy technology in Russia;

- The absence of the demand-side, which is characterised by the uncertainty of the wind energy projects;
- Shortage of financial sources in regard to the majority of system activities;
- Lack of qualified specialists to run the wind energy projects on the international level;
- Large gap between theoretical research and practical application;
- An Undeveloped regulatory framework directed on the market mechanisms for power grid integration;
- Lack of communication channels between the system frontrunners and the governmental bodies responsible for designing policy measures.

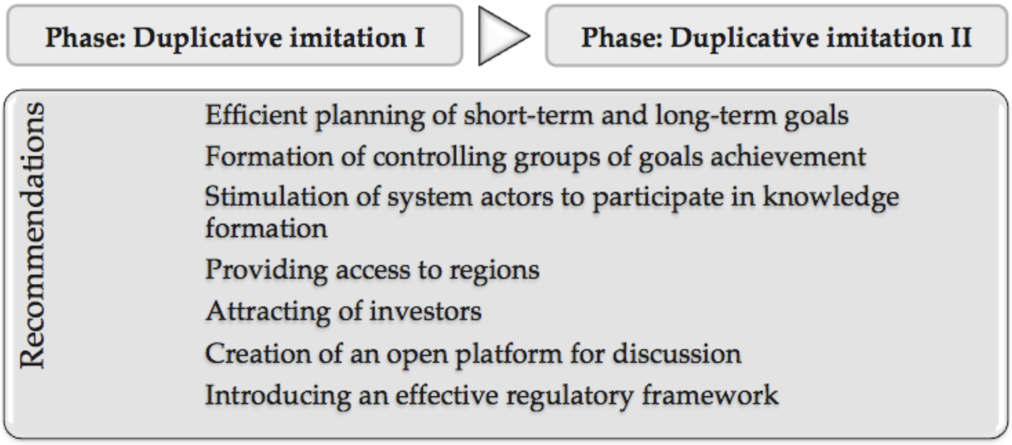
To sum up, there is a number of incentives that induce the system development, however, the importance of them is not strong in comparison with the blocking mechanisms. In turn, the changes in the mechanisms identified that hamper the system are crucial for a system to transit to the next stage of the technological development. This stage of catching-up involves the development of local production or assembly of some parts and independence of this process from foreign companies (Lee, 2005). The local firms need to learn how to create knowledge of low-technological processes and how to organise a process of local production. This stage is still characterized by a strong involvement of foreign firms that provide a guidance and support as external experts. However, the local production requires also encouragement from the national government to create a favourable environment. This leads also to a notion that the national capabilities to exploit a new technological trajectory are crucial. The international system helps the national technological system to develop only if it created a favourable environment for this process. This perception is also supported in the innovation studies literature (Archibugi & Michie, 1995).

5.3. RECOMMENDATIONS

Based on the analysis the recommendations are formulated for the system to transfer to the next stage of development. The recommendations are linked to the next stage, so that the Russian wind energy system would successfully proceed to the next stage of duplicative imitation.

It is recommended for the policy makers to settle the clear and realistic goals for the wind energy development both on the federal and regional levels. The planning is assumed to include both the short-term and long-term goals. This creates a long-term vision on the technological development process. Moreover, it will become evident, which system mechanisms and procedures are currently weakly performed or absent. These goals help also to escape uncertainty that the local and foreign companies encounter when a clear strategy is absent for the formation of the wind energy system in Russia. It also creates a good image in the international technological innovation system and stimulates foreign investors to take the Russian ambitions seriously.

The next recommendation is closely linked to the previous one and suggests creating a monitoring and controlling body. It will perform the responsibilities of controlling the goals realization. Such groups are believed to be formed both on the national and regional levels. Due to independent activities of the Russian regions it is useful for an every perspective region to form a monitoring group. The role of these groups will be to provide the national and regional governments with the overview of projects realization, therefore to organise a feedback mechanism if the goals are not fulfilled. The group should contain experts in the field of wind energy, preferably both local specialist and foreign experts.



Picture 9: The recommendations for the system transformation.

As a part of the previous advice, the creation of an open platform for discussion can be seen as its extension. This involves the process of sharing ideas and knowledge between the policy makers and the system actors. It is seen from the analysis that the system actors are not actively involved in the formation of policies and regulations. Consequently, the regulation frameworks are not adapted to the current needs of the system, which leads to slow implementation of the regulation mechanisms and even their changes. At the end the projects are run longer than they were planned. A well-functioning feedback mechanism will speed up the process of formulating and adapting the legislation and regulatory mechanisms. The policy makers of the advanced countries might be involved for sharing within this platform.

The next advice concerns the role of the system actors in knowledge formation. As it was mentioned in the previous chapters, knowledge formation is a weak spot of the Russian wind energy system. The gap between the research and its practical application is huge. Not mentioning the role of the government in transforming the Russian high education and research system in general, the system actors can stimulate the change of the situation to their own benefit. This can be done by participating in the higher education learning process, e.g. giving lectures, supporting practical research, providing internships and field work. Strong ties between the industry and the high education and research institutions will cause less investments and time when it is necessary to search for qualified specialists.

The Russian regional administrations can stimulate the development of the wind energy system locally. The successful examples of such regions were presented above. However, lack of information on the regional level and lack of initiative create a barrier for the system actors to get access to the regions. Without support of the regional authorities it is impossible to initiate a wind energy project in Russia. Thus, it is important for the policy makes to create procedures or mechanisms that will stimulate the regions to explore renewable energy opportunities relevant for a particular region and provide an access for the system actors. This can be done by inviting the regional authorities for specialized events (e.g. conferences, workshops) and create awareness of the wind energy opportunities in their regions.

The last two recommendations are important, because without their application the whole system will stagnate and stuck in the current level. The previous policy measurements will not work effectively if there is lack of investments and the regulatory framework is not introduced. The regulatory framework is a key aspect of the system; it creates the rules of the game. If these rules are not introduced, the system actors have to find different creative solutions for running the projects. It also creates uncertainty in the system, which hampers the technological development. The regulatory framework is expected to be approved in 2013, which will lead to a fast growth of the system.

Uncertainty regarding when the regulatory framework is to be approved hampers the national and foreign investors to provide a financial support to the system. Therefore, the next advice is to create a favourable environment for attracting investors. It is not necessary to wait for the regulatory framework to be approved, the system functions already, hence the best practices on the national level can be already provided.

The analysis of the Russian wind energy system shows that the current system performance is weak. The system development requires undergoing many changes in order to improve the system performance and to create an opportunity to transfer to the next stage of catching-up. Currently, the Russian system follows the path of the advanced countries, by adopting technologies and knowledge for operation of the wind energy projects. The international TIS participate actively in the national TIS formation, by either operating from outside and transferring expertise, or by providing direct investments and involving in the wind energy projects in Russia. The catching-up is still a long-run process, which is still far beyond reaching the leapfrogging. The system experts expect the system to move to the next stage in the upcoming five years.

DISCUSSION

This research aims at finding a useful tool for the analysis of the emerging technological system in the catching-up countries. The theoretical and methodological frameworks proposed here are believed to be helpful for assessing the current states of the system and provide policy recommendations. Two theoretical approaches are combined: the technological innovation system (TIS) and the technology transfer. The TIS analysis addresses the dynamic development of the system, whereas the technology transfer approach helps to determine a stage of the catching-up. In combination, this allows to identify system mechanisms that stimulate or hamper the technological progress of the catching-up country. The methodological framework comprises several analytical steps based on the theoretical concepts. By following this step-by-step analysis it is possible to design policy recommendations for the technological system to proceed to the following stage of catching-up.

This research has a couple of limitations. Firstly, one case was presented to test the theoretical framework. The Russian wind energy system was analysed. It was observed that the system is located in the first stage of the catching-up, so the incentive and blocking mechanisms were identified. Based on the system mechanisms the policy recommendations were designed in order to proceed successfully to the following stage of the catching-up. In the case of Russia the framework is believed to be working, however one case is not enough to justify the applicability of this approach. The theoretical framework needs to be tested on other technological systems both in Russia and other developing countries. In addition, it is interesting to find out whether the approach is suitable for the analysis of the systems located in different catching-up stages.

The second limitation of this research is the data availability. The detailed opearationalization of the system functions is provided in the TIS approach (Hekkert et al, 2007; Suurs, 2009). It allows applying the analysis straightforwardly. However, technological systems located in the early stage of the development have a problem of data availability. Due to the lack of reliable local data sources some indicators were not used for mapping system functions in the Russian case. Other data sources such as the literature review and the review of open sources were added to the analysis in order to solve a problem of data availability.

Several directions for further research are suggested. The analyses of other technological systems in the developing countries can be carried out to test and adjust the theoretical concept proposed in this research. The combination of TIS and the technology transfer concepts can be further elaborated by investigating more characteristics and factors that influence the system moving to the next stage of catching-up. While reviewing the literature related to the catching-up process, it was observed lack of research focused on identifying characteristics of different stages of catching-up. Hence, it is interesting to analyse the process of technology transfer between the advanced and developing nations in respect to different stages of catching-up.

Another research direction can be focused on identification the role of international TIS on the local TIS formation. The concept of the motors of innovation for the assessment of the system performance is currently applied for the technological system analysis in the developed countries. In this research an attempt was made to include this concept to the theoretical framework for the analysis of an emergent technological system in the developing country. Further research is needed to extend a geographical boundary of the motors of innovation by including the role of international TIS, namely whether there are any changes in the motors when the technology transfer is taking place from the advanced countries. In addition to it, Suurs (2009) states while the system unfolds the combination of motors of innovation is taking place. At the beginning of the system formation one motor can dominate, but later it is substituted by the rest. Thus, it is interesting to investigate the link between the stages of catching-up characterised by specific factors and a sequence of motors as the technological development progresses.

CONCLUSIONS

The reasons of uneven economical development of different nations have interested many scholars. Why some countries perform better than others? Which factors stimulate the nations to prosper? One thing is clear that technological development and innovations play a significant role in the economical growth of the countries (Lundvall, 1992; Patel & Pavitt, 1994). This notion guides the developing countries in a pursuit for the technological leadership. However, lack of national capabilities and skills bring the catching-up countries to follow the development paths of the developed countries. It is commonly seen in regard to energy technologies leading to being locked-in the carbon-intensive technologies (Sauter & Watson, 2008). The advanced countries went through difficult technological paths to become the leading nations. In order not to repeat the same paths full of trials and errors, the developing counties have a possibility to implement the latest practices and technologies of the advanced nations for their local contexts. The technology transfer adds value both the advanced nations by entering new perspective markets and the developing countries by providing an opportunity to adopt modern technological solutions.

Being a developing country, Russia possesses significant wind energy potential (OECD/IEA, 2003). It is estimated wind energy can be explored in many Russian regions, consequently it is considered as one of the promising renewable energy sources for development. In 2009 the Energy Strategy of Russia was approved by the Russian government stimulating the formation of the renewable energy sector in Russia. The ambitious goals were set up to increase power production from renewable energy sources by 2030. The development of renewable energy in Russia is a part of the recent political initiative directed towards the development of low energy consuming economy and the implementation of energy saving technologies (Henry & Sundstrom, 2012). Already now it is observed that the intermediate targets are not met due to some internal and external challenges hampering the system development.

This research presents thus the analysis of the Russian wind energy technology as a technological innovation system (TIS). The systemic approach and especially TIS provide a useful analytical tool to explore the system mechanisms, which stimulate or hamper the system development in order to catch-up with the advanced countries. Moreover, it allows to extend a boundary of the system by not only focusing on the national technological development, but by embedding a technology into a wider international context. The second theoretical concept of the technology transfer is used to address the catching-up process resulting in identifying a stage in which the system is currently located. The catching-up stage explains the current level of the technology transfer between the local and international TIS. It provides thus an opportunity to consider the system characteristics relevant for the particular level of technology transfer. The system performance is assessed by examining the interactions between functions. Depending on pattern of interactions, the system formation is guided by a particular motor of innovation. The identification of the motor of innovation helps to design policy mechanisms for improvements. Each motor is characterised by specific incentive and blocking mechanisms.

The proposed theoretical framework contributes to the current TIS approach and the technology transfer literature by presenting a combined analytical tool to address the problem of assessing the catching-up process by the developing countries. It is beneficial, as this approach is a practical tool for the analysis the current state of the technological system. Hence it allows giving policy recommendations for the further system development. The previous research related to the technology transfer between the advanced and the developing countries had a nature of a historical overview of the catching-up process, namely a post-factum analysis (Lewis, 2007). In turn, the analysis presented in this research gives an opportunity to guide the technological development of the catching-up countries in order to archive a competitive advantage and a technological leadership.

The methodology of the research comprises several steps, including the structural and functional analyses, identification of the catching-up stage and the assessment of the system performance. The last step is designing the policy recommendations for improvements. Data collection is desk research and semi-standardized interviews with system experts.

The research has shown a problematic structure of the Russian wind energy system. It is observed that the Russian wind energy industry is located in the first stage of catching-up, duplicative imitation. Technology transfer in this stage is characterised by a full imitation of foreign practices. In the wind energy system this imitation implies the projects running in the way foreign projects are carried out. The process includes project management and routines involved, as well as technology adoption for wind measurement and wind turbine installation. In the early stage of technological development the focus lies also on creating legitimacy and stimulate the initial impulse for the system to grow.

Based on the structural, functional analyses and knowing that the TIS is located in the duplicative imitation stage of the catching-up, a pattern of "entrepreneurial motor" is observed in the Russian wind energy system. The system is currently formed by the interactions of functions guided by this motor of innovation. However, some of linkages are still missing or performing weakly in the system. The analysis of the interactions helped to identify the system incentive and blocking mechanisms.

Based on the identified incentives and barriers it was suggested to strengthen the incentives and the barriers to overcome by implementing the recommendations elaborated in this research. It is believed that these recommendations will be helpful to transit to the next stage of the technological development. This stage of catching-up involves the development of local production or assembly of some parts and independence of this process from foreign companies (Lee, 2005). Local firms need to learn how to create knowledge of low-technological processes and how to organise a process of local production. This stage is still characterized by a strong involvement of foreign firms that provide a guidance and support as external experts. The recommendations are thus focused on setting up clear and realistic goals both on the regional and national levels; creating a monitoring and controlling body; creating an open platform for discussion and sharing ideas; stimulating the system actors to participate in knowledge formation; providing an access to the regions. These actions are directed on both local and international actors of the system, as the accumulation of national capabilities are possible in terms of a close cooperation with the foreign firms.

REFERENCES

Копылов, А.Е., Гридасов, М.В. (2012), Обзор проектов ВЭС России 2011. Издание Российской Ассоциации Ветроэнергетики. Москва

Николаев, В. Г., (2011), Ресурсное и технико-экономическое обоснование широкомасштабного развития ветроэнергетики в России. Атмограф. Москва

Archibugi, D., Michie, J., (1995), The globalization of technology: a new taxonomy. Cambridge Journal of Economics, 19, pp. 121-140

Asheim, B. T., Isaksen, A., (2002), Regional Innovation Systems: The Integration of Local 'Sticky' and Global 'Ubiquitous' Knowledge. Journal of Technology Transfer, 27, pp. 77-86

Axelrod, R.M., Mitchell, W., Thomas, R.E., Bennett D.S., Bruderer, E. (1995), Coalition formation in standard-setting alliances, Management Science, 41, pp. 1493-1508

Bergek, A., Jacobsson, S., Hekkert, M., Smith, K.H., (2010), Functionality of innovation systems as a rationale for and guide to innovation policy. In: The Theory and Practice of Innovation Policy. Prime Series on Research and Innovation Policy in Europe. Edward Elgar, Cheltenham, UK, pp. 115-144.

Bergek A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., (2008), Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy, 37, pp. 407 -429

Binz, C., Truffer, B., Li, L., Shi, Y., & Lu, Y. (2012), Conceptualizing leapfrogging with spatially coupled innovation systems: The case of onsite wastewater treatment in China. Technological Forecasting and Social Change, 79 (1), pp. 155-171

Borup, M., Brown, N., Konrad K., Van Lente, H., (2006), The sociology of expectations in science and technology, Technology Analysis & Strategic Management, 18, 3-4, pp. 285-298

Bryman, A., (2008), Social Research Methods - 3rd Edition. Oxford University Press, Oxford

Carlsson, B., Stankiewicz, R., (1991), On the Nature, Function, and Composition of Technological Systems. Journal of Evolutionary Economics, 1 (2), pp. 93-118

Carlsson, B., Jacobsson, S., Holmen, M., Rickne, A., (2002), Innovation systems: analytical and methodological issues. Research Policy, 31, pp. 233-245

CIA (2013), Central Intelligence Agency - The World Factbook. http://www.cia.gov. Used: May 26th 2013

Coenen, L., Benneworth, P., Truffer, B. (2012). Toward a spatial perspective on sustainability transitions. Research Policy, 41, pp. 968-979

Federal State Statistics Service of the Russian Federation, (2013). http://www.gks.ru. Used: May 26th 2013

Freeman, C., (1997), The Diversity of National Research Systems, in: Barre, R., Gibbons, M., Maddox, S. J., Martin, B., Papon, P. (Eds.), Science in Tomorrow's Europe. Economica International, Paris, pp. 5-31.

Garud, R., Karnoe, P., (2003), Bricolage versus breakthrough: Distributed and embedded agency in technology entrepreneurship. Research Policy, 32, pp. 277–300

Gati, T.T., (2008), Renewable energy in Russia's future. Journal on foreign affairs and international relations, 3

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., Smits, R. E. H. M. (2007), Functions of innovation systems: A new approach for analysing technological change, Technological Forecasting and Social Change, vol. 74, no. 4, pp. 413-432

Henry, L.A., Sundstrom, L.M. (2012), Russia's Climate Policy: International Bargaining and Domestic Modernisation. Europe-Asia Studies, vol. 64, No. 7, pp. 1297–1322

IFC (2011), Renewable Energy Policy in Russia: Waking the Green Giant. IFC Report

Jacobsson, S., Bergek, A., (2004), Transforming the energy sector: the evolution of technological systems in renewable energy technology. Industrial and Corporate Change, vol. 13, no. 5, pp. 815-849

Jacobsoon, S., Johnson, A., (2000), The diffusion of renewable energy technology: an analytical framework and key issues for research. Energy Policy, 28, pp. 625-640

Kemp, R., Schot, J., Hoogma, R., (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management, Technology Analysis & Strategic Management, 10 (2), pp. 175-198

Klochikhin, E.A., (2012), Russia's innovation policy: Stubborn path-dependencies and new approaches. Research policy, 41, pp. 1620-1630

Lee, K. (2005), Making a Technological Catch-up: Barriers and opportunities. Asian Journal of Technology Innovation, 13 (2), pp. 97-131

Lewis, J. I., (2007), Technology acquisition and innovation in the developing world: wind turbine development in China and India. Studies in comparative international development, 42, pp. 208-232

Lundvall, B-A. (ed.) (1992), National Systems of Innovation: Towards a Theory of Innovation and Interactive learning, London: Pinter.

Mahoney, J.T., Pandian, J.R. (1992), The resource-based view within the conversation of strategic management, Strategic Management Journal, 13, pp. 363-380

Markard, J., Raven, R., & Truffer, B. (2012), Sustainability transitions: An emerging field of research and its prospects. Research Policy, 41, pp. 955-967

Markard, J., Truffer, B. (2008), Technological innovation systems and the multi-level perspective: Towards an integrated framework. Research policy, 37(4), pp. 596-615

Malerba, F. (ed.) (2004), Sectoral Systems of Innovation: Concept, Issues and Analysis of Six Major Sectors in Europe. Cambridge: Cambridge University Press

Market Council (2013), Council for organizing efficient system of trading at wholesale and retail electricity and capacity market. http://www.np-sr.ru/norem/information/russianelectricity/#10. Used: May 26th 2013

Minenergo (2009), The Energy Strategy of Russia till 2030. The Ministry of Energy of the Russian Federation

Negro, S.O, Alkemade, F., Hekkert, M.P., (2012), Why does renewable energy diffuse so slowly? A review of innovation system problems. Renewable and Sustainable Energy Reviews, 16, pp. 3836-3846

Negro, S.O., Hekkert, M.P., Smits, R.E., (2007), Explaining the failure of the Dutch innovation system for biomass digestion - A functional analysis. Energy Policy, 35, pp. 925-938

Nelson, R., Winter, S., (1982), An evolutionary theory of economic change. Harvard University Press, Cambridge, Massachusetts

Nikolaev, V.G., Ganaga, S.V., Kudryashov, Y.I., Walter, R., Willems, P., Sankovsky, A., (2010), Prospects of development of Renewable Energy Sources (RES) in Russian Federation. The results of TACIS Project. Atmograph, Moscow

OECD/IEA (2003), Renewables in Russia: from opportunity to reality

Patel, P., Pavitt, K., (1994), The Nature and Economic Importance of National Innovation Systems. STI Review, 14, OECD, Paris

Poel, I. v. d., (2003), The Transformation of Technological Regimes. Research Policy 32, pp. 49- 68.

RAWI (2013), Russian Association of Wind Energy last visited on 25-05-2013 at http://rawi.ru/en/main.php?lang=EN

Söderholm, P., Klaassen, G., (2007), Wind power in Europe: A simultaneous innovation-diffusion model. Environmental and Resource Economics, 36 (2), pp. 163-190

Summary on reports, (2011). Summary on Reports from the national experts on development of renewable energy in the Russian Federation and CIS countries

Suurs, R. A. A. (2009). Motors of sustainable innovation: Towards a theory on the dynamics of technological innovation systems

Teece, D.J., (1986), Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. Research Policy 15, 285-305

Teece, D., Pisano, G. and Shuen, A. (1997), Dynamic capabilities and strategic management, Strategic Management Journal, 18, pp. 509-533.

Tsoutson, T.D., Stamboulis, Y.A., (2005), The sustainable diffusion of renewable energy technologies as an example of an innovation-focused policy. Technovation, 25, pp. 753-761

Van Praag, C.M., Versloot, P.H (2007), What is the value of entrepreneurship? A review of recent research, Small Business Economics, 29, pp.351-382

Unruh, G., (2000), Understanding carbon lock-in. Energy Policy, 28, pp. 817-830

Watson, J., Sauter, R. (2011), Sustainable innovation through leapfrogging: a review of the evidence. International Journal of Technology and Globalisation, 5 (3), pp. 170-189

Wieczorek, A.J., Hekkert, M., (2012), Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. Science and Public Policy, 39, pp. 74-87

LIST OF ARTICLES FROM OPEN SOURCES

[1] Проект ООО «ВентРус» по созданию ветряных электростанций (ВЭС) на территории Алтайского края. http://unionnis.ru/node/72. Used: May 25th 2013

[2] В Оренбургской области делают ставку на альтернативную энергетику. http://www.nanonewsnet.ru/news/2013/v-orenburgskoi-oblasti-delayut-stavku-na-alternativnuyu-energetiku. Used: May 25th 2013

[3] Оренбуржье становится лидером по строительству энергосберегающих объектов. http://www.orenburg-gov.ru/magnoliaPublic/regportal/News/EconomicNews/2012-11-20-18-38-16.html. Used: May 25th 2013

[4] Атомный ветер. http://www.vedomosti.ru/newspaper/article/269713/atomnyj_veter. Used: May 25th 2013

[5] Пономорев, В. (2011), Поймать ветер. http://expert.ru/2011/03/31/pojmat-veter/. Used: May 25th 2013

[6] В Оренбургской области планируется строительство трех ветропарков. http://www.kapital-rus.ru/index.php/news/news_v_orenburgskoj_oblasti_planiruetsya_stroitelstvo_treh_vetroparkov/. Used: May 25th 2013

[7] Ветер N5. Наши проекты. http://vetern5.ru/index.php?pid=4&PHPSESSID=832d606f34c4605977eb32be9a59fdd0. Used: May 25th 2013

[8] Коцубинская, М.,(2012). Энергия юга. http://www.kommersant.ru/doc-y/2024578. Used: May 25th 2013

[9] Крамер, А., (2012). Ветроэлектростанция появится на Кубани. http://www.dg-yug.ru/a/2012/11/09/Vetrojelektrostancija_pojavi. Used: May 25th 2013

[10] Атомэнергомаш создал "дочку" для управления активами в ветроэнергетике. http://ria.ru/atomtec_news/20120604/664723052.html. Used: May 25th 2013

[11] Локализация современных технологий является одним из ключевых элементов нашей стратегии. http://www.energy-experts.ru/comments6032.html. Used: May 25th 2013

[12] Суммарная мощность проектов в сфере ветроэнергетики в РФ превышает 10ГВт. http://www.energy-experts.ru/news6029.html. Used: May 25th 2013

[13] "Атомэнергомаш" не выбрал техпартнера по проектам в ветроэнергетике. http://ria.ru/atomtec_news/20121010/770939276.html. Used: May 25th 2013

[14] Wind Energy Systems. Projects. http://en.wes-south.ru/index.php?option=com_content&view=article&id=2&Itemid=3. Used: May 25th 2013

[15] Строительство ветроэлектростанции планируют в Каневском районе. http://www.yuga.ru/news/192987/. Used: May 25th 2013

[16] "ВЭС Юг" в 2012г может ввести первые ветряные электростанции в Краснодарском крае. http://www.interfax-russia.ru/South/news.asp?id=170661&sec=1679. Used: May 25th 2013

[17] Ейскую ветроэлектростанцию включили в план развития российской энергетики. http://www.yuga.ru/news/207173/. Used: May 25th 2013

[18] Романько, О., (2011). Две ветроэлектростанции построят в Ейском районе. http://www.dg-yug.ru/a/2011/12/20/Dve_vetrojelektrostancii_p. Used: May 25th 2013

[19] Строительство ветроэлектростанций в Ейском районе начнут в 2013 году. http://www.yuga.ru/news/248623/. Used: May 25th 2013

[20] "ВНИИР" перенимает опыт проектирования "ветропарков" у европейских специалистов. http://www.i-mash.ru/news/nov_predpr/19346-vniir-perenimaet-opyt-proektirovanija-vetroparkov. Used: May 25th 2013

[21] Falcon Capital инвестирует 600 млн евро на строительство ветроэлектростанции в Калмыкии. http://www.interfax-russia.ru/South/special.asp?id=346771&sec=1702. Used: May 25th 2013

[22] Энергия калмыцкого ветра. http://expert.ru/2006/11/28/calmvetrcheh/. Used: May 25th 2013

[23] Чешская компания поставит в Калмыкию 42 ветростанции. http://www.rosbalt.ru/main/2007/08/22/407823.html. Used: May 25th 2013

[24] Кисин, С., (2010), Ветряные замки. http://expert.ru/2010/03/24/vetr_zamki/. Used: May 25th 2013

[25] Falcon Capital инвестирует 600 млн евро на строительство ветроэлектростанции в Калмыкии. http://www.interfax-russia.ru/South/special.asp?id=346771&sec=1702. Used: May 25th 2013

[26] "Интертехэлектро" совместно с западным партнером дадут старт проекту строительства ветропарка. http://www.ruscable.ru/news/2012/01/10/Intertexelektro_sovmestno_s_zapadnym_partnerom_dad/. Used: May 25th 2013

[27] "Интертехэлектро" и немецкая Sowitec планирует построить в Курганской области ветропарк. http://www.interfax-russia.ru/Ural/news.asp?id=285392&sec=1679. Used: May 25th 2013
[28] Ветроэлектроэнергия. http://www.interfax-russia.ru/Ural/view.asp?id=286155. Used: May 25th 2013
[29] В Курганской области строят ветропарк. http://www.kommersant.ru/doc-y/1985844. Used: May 25th 2013
[30] В бывшей игорной зоне «АЗОВ-СИТИ» немцы построят ветропарк. http://ipa-don.ru/news/2012/9/266. Used: May 25th 2013
[31] Шестерина, Е., (2012), Иностранцы финансируют российский ветер. http://www.rbcdaily.ru/tek/562949985296133. Used: May 25th 2013
[32] Закон «Об инвестиционном товариществе» вступил в силу в начале этого года, однако в России появилось только одно подобное объединение. Оно создано на базе холдинга «Межрегионсоюзэнерго». Проекты товарищества в этом году были впервые представлены на комиссии ООН. http://www.bellona.ru/news/news_2012/1355206904.11. Used: May 25th 2013
[33] На выставке-ярмарке Hannover Messe 2013 компанией «Интертехэлектро» был представлен проект строительства ветропарка в Курганской области. http://www.bellona.ru/news/news_2013/1365598440.1. Used: May 25th 2013
[34] Windlife Energy. http://www.windlife-energy.com/. Used: May 25th 2013
[35] Голландцы помогут создать на Кольском полуострове ветроэнергопарк. http://ria.ru/zemlia/20080408/104056259.html. Used: May 25th 2013
[36] Нидерландская Windlife Energy вложит 300 млн евро в строительство первой очереди ветропарка на Кольском п-ове. http://top.rbc.ru/spb_freenews/09/10/2008/776819.shtml. Used: May 25th 2013
[37] Баумгертнер, О., (2009), Экономить с ветерком. http://www.ng.ru/energy/2009-04-14/15_wind.html. Used: May 25th 2013
[38] Наш ветер - в немецкие турбины. http://www.mvestnik.ru/shwpgn.asp?pid=20100311830. Used: May 25th 2013
[39] Власти Мурманской области прогнозируют в 2010 году рост инвестиций в экономику региона. http://www.regnum.ru/news/economy/1294754.html#ixzz2Vl0Z9JhZ. Used: May 25th 2013
[40] Деньги на ветер. http://expert.ru/2009/04/22/gidroveter/. Used: May 25th 2013
[41] Ветропарк на островах во Владивостоке не построили из-за Минэнерго РФ – эксперт. http://primamedia.ru/news/economics/16.10.2012/234053/vetropark-na-ostrovah-vo-vladivostoke-ne-postroili-iz-za-minenergo-rf-ekspert.html. Used: May 25th 2013
[42] Gazprombank has invested into alternative energy. http://www.gazprombank.ru/eng/press/news/178593/. Used: May 25th 2013
[43] Проекты ООО "Активити". http://www.vetromonitoring.ru/projects/. Used: May 25th 2013
[44] Пономорев, В., (2010). Ветряной Кувейт. http://expert.ru/2010/01/21/veter/. Used: May 25th 2013
[45] Cube engineering - Projects in Russsia. http://www.cube-engineering.com/references/references-filter.html?L=1&tx_cubereferenzen_pi1%5Botherregion%5D=RU. Used: May 25th 2013

APPENDIX I: INTERVIEW QUESTIONS

Functions	Interview questions
F1: Entrepreneurial activities	▪ Are there enough companies working in the wind energy sector in Russia? ▪ Are they locally established companies or international ones? ▪ What is their quality? ▪ Are they entrepreneurs or established companies? ▪ Do new entrepreneurs/ companies actively enter the sector? ▪ What types of companies are they? (producers of wind technologies, engineering companies) ▪ What range of wind energy technologies is currently present in the sector? ▪ Are they locally developed or adopted technologies? ▪ Do companies experiment?
F2: Knowledge formation	▪ What is your perception regarding R&D projects in the field of wind energy technologies? Do they exist? Are there enough of them? What is the quality? ▪ Can you mention the size, orientation and investments in R&D? ▪ Which actors are particularly active? ▪ Who finances the knowledge development? ▪ Does the technology receive attention in national research and technology programmes? ▪ Are there enough knowledge users? ▪ Are there joint R&D projects? ▪ What is more local R&D projects or joint ones? ▪ How much are foreign investments in R&D?
F3: Knowledge dissemination	▪ Are there strong partnerships in the wind energy sector? ▪ Who is involved in these partnerships? ▪ Is the knowledge development demand-driven? ▪ Is there space for knowledge dissemination? ▪ Is there strong competition? ▪ Does the knowledge correspond with the needs of the wind energy sector?
F4: Guidance of search	▪ What is your perception of the growth potential of the wind energy sector? ▪ Which level of government support (local/ national) creates incentive for wind energy sector development? ▪ Are their specific goals on the regional level? ▪ Who are system frontrunners? ▪ What is in your opinion currently missing in the regulatory framework / or in turn a good governmental initiative? ▪ What are the technological expectations (negative/positive)? ▪ Does the articulated vision fit in the existing legislation?

F5: Market formation	▪ What does the market look like? ▪ What is its size (niche/ developed)? ▪ Who are the users (current / potential)? ▪ Who takes the lead (public / private parties)? ▪ Are there institutional incentives / barriers to market formation?
F6: Resources mobilization	▪ Is there sufficient human capital in the wind energy sector? ▪ What is its quality? ▪ Are there sufficient financial resources in the wind energy sector? ▪ Where these finances are coming from? ▪ Do they correspond with system's needs? ▪ What are they mainly used for (research/ application/ pilot projects/ etc)? ▪ Can companies easily access the resources? ▪ Which resources are formed using foreign resources? ▪ Are there enough complementary services, technologies needed for wind energy sector?
F7: Creating legitimacy	▪ Is there much resistance to change? ▪ Where is resistance coming from? ▪ How does this resistance manifest itself? ▪ What is the lobbying power of the actors in the system? ▪ How legitimacy influences demand, legislation, firm behaviour? ▪ What (or who) influences legitimacy and how? ▪ Is coalition forming occurring? ▪ What is the lobbying power of foreign actors in the system? ▪ Do foreign actors participate in coalition forming?