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Technological Innovation System Analysis

A manual for analysts

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INTRODUCTION

The most important insight that has dominated the field of innovation studies in recent decades is the fact that innovation is a collective activity. It takes place within the context of a wider system. This wider system is coined 'the innovation system' or 'the innovation ecosystem'. The success of innovations is to a large extent determined by how the innovation system is build up and how it functions (Hekkert et al., 2007,Bergek et al., 2008).

The concept of the innovation system stresses that the flow of technology and information among people, enterprises and institutions is key to an innovative process. It stresses the interaction between actors who are needed in order to turn an idea into a successful process, product or service in the marketplace.

Many innovation systems are characterized by some flaws that greatly hamper the development and diffusion of innovations. These flaws are often labeled as system failures or system problems. Intelligent and evidence based innovation policy therefore evaluates how innovation systems are functioning, tries to create insight in the system problems and develops policies accordingly (Smits and Kuhlmann, 2004,Klein Woolthuis et al., 2005,Van Mierlo et al., 2010,Negro, S.O., Alkemade, F., Hekkert, M.P., 2011).

This manual contains instructions and explanations on the analysis of technological innovation systems for policy purposes. While literature about technology and innovation is abundant, the need for a single reference specific to the analysis of technological innovation systems for policy purposes prompted the development of this manual. This manual is not a definitive reference on the topics covered and is not meant to substitute for texts or journal articles. The manual is intended to serve as a convenient guide for any policymaker performing analysis of technological innovation.

The manual is based on the Technological Innovation System approach as developed by Utrecht University in cooperation with other European institutes like Chalmers University in Sweden and EAWAG in Switzerland. Technological Innovation System is a concept developed within the context of the Innovation System approach focusing on explaining the nature and rate of technological change. A Technological Innovation System can be defined as the set of actors and rules that influence the speed and direction of technological change in a specific technological area (Hekkert et al., 2007,Bergek et al., 2008,Markard and Truffer, 2008)

The purpose of analyzing a Technological Innovation System is to analyze and evaluate the development of a particular technological field in terms of the structures and processes that support or hamper it. The basic steps that are taken are the following:

First, we analyze the structure of the innovation system. These are the actors and rules that make up the system. Second, we analyze how the system is functioning. We will use seven system functions that stem from theory and are empirically validated as indicators. We analyze each function, but also the interaction between the functions. Finally, after we have established at what state of development a technological innovation system is, we can analyze the system problems that block the well functioning of the innovation system.

All innovation systems can be characterized by the same basic building blocks or components. These are actors, institutions, networks and technology. Examples of actors are organizations responsible for education, R&D, industrial activities, and consumers. Examples of institutions are supportive legislation and technology standards. Examples of networks are the linkages between organizations in research projects and advocacy coalitions. Technology is part of the innovation system as it enables and constrains the activities of actors in the innovation system. We will present a categorization of all components that are important in a Technological Innovation System and we will develop indicators to measure the size of these components. In this manual these will be applied to the case of the offshore wind innovation system as an example.

Even though different innovation systems may have similar components, they may function in a completely different way. Therefore, measuring how innovation systems are functioning is considered as the big breakthrough in innovation systems research. In a number of scientific articles lists of evaluation criteria are presented to evaluate how innovation systems are functioning. These assessment criteria are labeled in the literature 'functions of innovation systems'. In Hekkert et al. (2007)(2007) the following

functions of innovation systems are put central.

1. entrepreneurial activities,
2. knowledge development,
3. knowledge exchange,
4. guidance of the search,
5. formation of markets,
6. mobilization of resources,
7. counteracting resistance to change.

The important difference with the *structure* of the innovation system is that these system *functions* are much more evaluative in character. Focusing on functions allows us to address the performance of an innovation system. In other words: the structure presents insight in who is active in the system, the system functions present insight in what they are doing and whether this is sufficient to develop successful innovations.

In addition to quantitative indicators, the functioning of an innovation system needs to be assessed by experts or key stakeholders that are active in the innovation system.

The reason to evaluate the innovation system by means of expert opinions is that it is impossible at the moment to solely evaluate an innovation system based on quantitative criteria. The reason for this is that technologies and regions are different from each other and that it is impossible to define an optimal configuration of the innovation system. Consequently, benchmarking innovation systems is difficult; what works in one country may not work in another country. Furthermore, the development of an innovation system often depends strongly on the competition in other parts of the world and very often has very technology specific dynamics. For some technologies much more R&D funding is necessary than for others. Therefore, the best way to assess the functioning of the innovation system is by involving a sufficient amount of experts in the evaluation.

However, just asking how the innovation system scores on the different functions is not sufficient. The seven functions are quite broad in their description and a much more detailed set of indicators is necessary to make sure that the answers by the respondents are comparable. The function knowledge development can for example be measured by asking about the quantity, the quality and the direction research activities. Therefore, very specific diagnostic questions need to be developed to assess the functioning of innovation systems.

In summary, in order to monitor the development of emerging technologies, this manual offers 5 steps that will be described in detail to perform the innovation system analysis. The first steps describe the mapping of the structure and functioning of the innovation system. After establishing the stage of development, step 4 and 5 identify the main barriers and provide handholds for appropriate policy making.

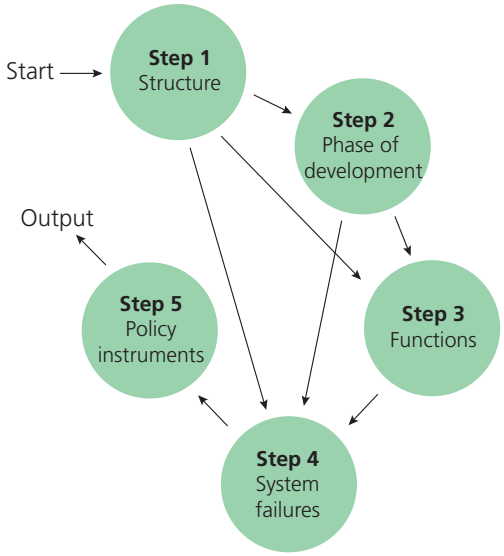

Figure 1 Schematic representation of the 5 steps in analyzing a technological innovation system for policy analysis.

STEP 1 STRUCTURAL ANALYSIS

The structure of the innovation system consists of innovation system components. We distinguish between four types of components:

1. Actors: Actors involve organizations contributing to a technology, as a developer or adopter, or indirectly as a regulator, financer, etc. It is the actors of a Technological Innovation System that, through choices and actions, actually generate, diffuse and utilize technologies. The potential variety of relevant actors is enormous, ranging from private actors to public actors, and from technology developers to technology adopters. The development of a Technological Innovation System will depend on the interrelations between all these actors.
   We distinguish between the following actors categories:
   a. Knowledge institutes
   b. Educational organizations
   c. Industry
   d. Market actors
   e. Government bodies and Supportive organizations
2. Institutions: Institutional structures are at the core of the innovation system concept. It is common to consider institutions as 'the rules of the game in a society, or, more formally as the humanly devised constraints that shape human interaction. A distinction can be made between formal institutions and informal institutions, with formal institutions being the rules that are codified and enforced by some authority, and informal institutions being more tacit and organically shaped by the collective interaction of actors. Even though informal institutions have a strong influence on the speed and direction of innovation, they are impossible to map systematically. Therefore, in the mapping of the innovation system structure, we focus on the formal policies that are in place that are likely to affect the development of the focal technology.
3. Networks: The central idea of the innovation system framework is that actors function in networks.
   In the case of networks it is interesting to map the geographical focus of the networks. Do the networks have a localized or globalized character?
4. Technological factors: Technological structures consist of artifacts and the technological infrastructures in which they are integrated.

In figure 2 the actors and institutions are represented that play a role in the development, diffusion and implementation of the technology. The different actors interact with each other in networks that develop or diffuse the technology. However these interactions are not represented in the figure. All together the four pillars (actors, networks, institutions and technology) form the structural components of the innovation system.

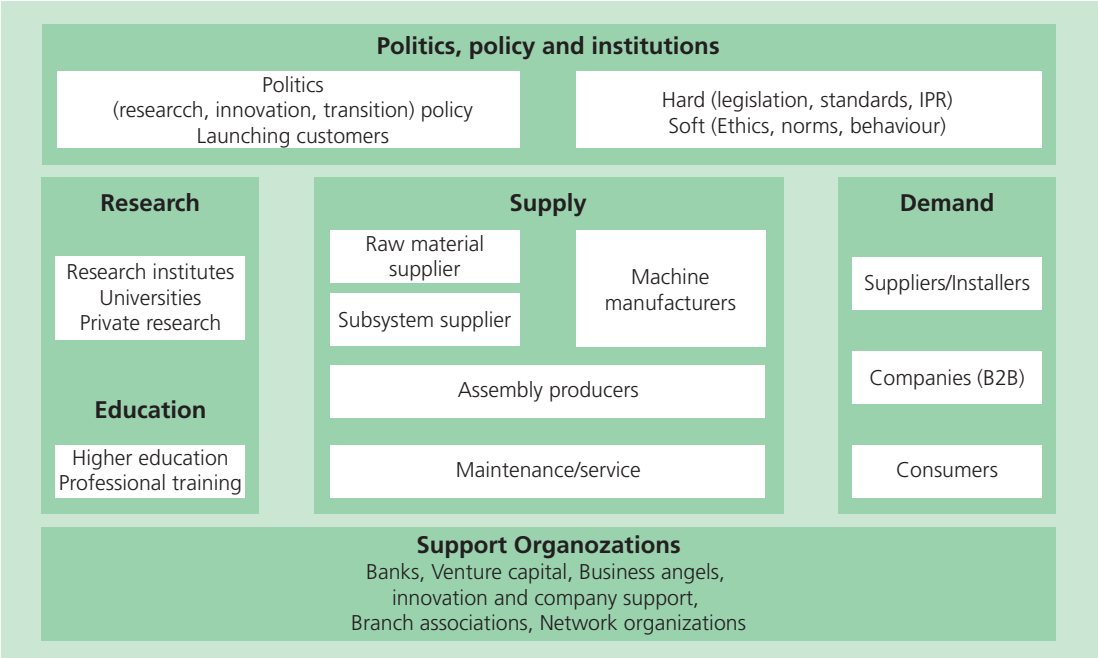

Figure 2 Structure of the innovation system (based on (Kuhlmann and Arnold, 2001)

DETERMINING THE SYSTEM STRUCTURE

To create insight in the structure of the innovation system the components (Technology, actors, networks and institutions) need to be mapped. The list below outlines the steps and questions that need to be answered, in addition to some key sources of information.

Technology – What are the technological trajectories?

Technological trajectory refers to a single branch in the evolution of a technological design of a product/service. As such, a technological trajectory is a set of technologies that consistently develop over time in certain direction. In this process an accumulation of knowledge takes place. Sometimes, different (and competing) technological trajectories exist.

Technologies also involve the techno-economic workings of such artifacts, including costs, safety, reliability. These features are crucial for understanding the feedback mechanisms between technological change and institutional change.

Patent classifications can provide an overview of the set of technologies (and their trajectories) that is relevant for the TIS under study. An overview of the International Patent Classifications (IPC) can be found at the WIPO.

The most convenient overview of patent data is provided by the WIPO database that can be found at *http://www.wipo.int*. Alternatively, the EPO database offers free access to more than 70 million patent documents worldwide, containing information about inventions and technical developments from 1836 to today. Always use the advanced options for bibliometric searching.

Also the US Patent and Trademark Office (PTO) offers World-Wide Web (Web) access to bibliographic and full-text patent databases. The USPTO patent database can also be accessed at *http://www.google.com/patents*.

Actors – Who are the actors?

Industry; Describe the value chain of the different technological trajectories

Value chain analysis describes the activities within and around a set of organizations, and relates them to an analysis of the competitive strength of these organizations. Therefore, it evaluates which value each particular activity adds to the products or services relevant to the TIS under study. This idea is built upon the insight that an organization is more than a random compilation of machinery, equipment, people and money. Only if these things are arranged into systems and systematic activates it will become possible to produce something for which customers are willing to pay a price. Porter argues that the ability to perform particular activities and to manage the linkages between these activities is a source of competitive advantage.

In most industries, it is rather unusual that a single company performs all activities from product design,

production of components, and final assembly to delivery to the final user by itself. Most often, organizations are elements of a value system or supply chain. Hence, value chain analysis should cover the whole value system in which the organization operates.

Please note that not every TIS contains a complete value chain!

Often consultancies, sector organizations and government organizations have information available on the different organization active in a sector. It is desirable to have an indication of size of the market in terms of total turn-over or number of employers.

Research – Describe the state of the knowledge system

Technological innovation systems differ greatly in terms of the knowledge base and learning processes related to innovation. First, knowledge may have different degrees of accessibility (Malerba-Orsenigo, 1997) i.e. opportunities of gaining knowledge that are external to firms. This knowledge may be internal to the sector (thus favoring imitation) or external to the sector (thus affecting the availability of technological opportunities to incumbents and new firms). In both cases greater accessibility of knowledge decreases industrial concentration.

The sources of technological opportunities markedly differ among technological innovation systems. In some cases opportunity conditions are related to major scientific breakthroughs in universities. Opportunities to innovate may often come from

advancements in external R&D, equipment and instrumentation. Possibly, external sources of knowledge in terms of suppliers or users may play a crucial role.

a. Which parties develop knowledge?
The codified knowledge base is well archived in the form of scientific publications. Several databases exist; the Science Citation Index, SCOPUS and Google Scholar. Of these, the Science Citation Index provides the most robust scientometric information.

CORDIS, the Community Research and Development Information Service for Science, Research and Development, is the official source of information on the European framework programs; it offers interactive web facilities that links together researchers, policymakers, managers and key players in the field of research. This search allows you to search quickly and easily all CORDIS content at once. This data permits a detailed assessment of the collaborations among institutions within the fields under study and its growth over time.

b. Where are the knowledge producers located?
Often, knowledge production is geographically concentrated in a relatively small number of locations. Especially when accessibility of knowledge is difficult, there is a tendency of increasing geographical concentration. If external knowledge is easily accessible, easily transformable into new artifacts and exposed to a lot of actors (such as customers or suppliers), then innovative entry may take place (Winter, 1984). On the contrary, when advanced integration capabilities are necessary (Cohen-Levinthal, 1989) the industry may be concentrated and formed by large established firms.

The uneven distribution becomes clear when measuring the clustering of knowledge production. All publications contain one or more author addresses that can be used to map the geographical distribution.

c. How much knowledge is developed?
The question of growth of knowledge is central in understanding patterns of innovation, and according to Bonaccorsi (2008) the direction of growth (converging or diverging) is a defining attribute of a sector. Opportunities for new developments are large when the knowledge base is fast growing and diverging.

d. What are the types of organizations involved in knowledge production?
Knowledge production involves different types of actors with different roles; universities, companies, and governments. This Triple Helix model assumes the traditional forms of institutional differentiation among universities, industries, and government as its starting point. The model thus takes account of the expanding role of knowledge in relation to the political and economic infrastructure of the larger society (Etzkowitz and Leydesdorff 2000).

Education - Are the education needs met?

In important aspect of the functioning of an innovation system relates to the match between the educational system and the entrepreneurial needs. In most cases, it will be difficult to obtain information about the extent to which the educational system provides to the needs/demands of entrepreneurs and researchers (partly due to privacy issues). Only in rare occasions sector organizations or universities have labor market statistics available of graduates from universities.

A general indication of the match between the educational system and the entrepreneurial needs is provided by the intensity if university-industry collaborations in knowledge production as indicated by co-authorships. Also the existence of special professorial chairs at universities funded by companies can provide insight in the educational organization providing relevant skilled labor.

Market - What does the market look like?

The most important question concerning the nature of the market is related to the demand side; which organizations provide demand for the technology under study? Furthermore, is demand technology specific or not?

From Schumpeter to Porter innovation-thinkers have recognized the importance of an advanced market, of well articulated critical demand as a driving force for innovation. An important distinction here is the extent to which private companies provide demand in relation to the public (governmental) demand. Often, very generic government initiatives exist such as educating the consumers or highly specific initiatives like procuring new technologies.

Politics and policy – What are the policy goals related to the TIS?

ERAWATCH provides information on European, national and regional research policies, actors, and programs in the EU and beyond. The policy goals and instruments with respect to the Technological Innovation System are an important aspect in understanding the functioning of the TIS. Relevant questions here are; How big is the variability of policy goals? What kind of policies, regulations, programs are there with respect to the new technology? How reliable is the policy? (Is it based on previous programs, regulations, instruments or is it completely different)

Intermediaries – Which parties try to engage collaboration between different parties?

In the interaction between Universities, Governments and Industry there are many intermediary organizations that facilitate the exchange of knowledge and resources. In addition to ERAWATCH, which provides information on European, national and regional research policies, actors, and programs there are consultancies, sector organizations and government organizations that have information available on the intermediary organization active in a sector.

Networks – What does the network look like?

Network analysis views relationships in terms of networks of nodes and ties. Nodes are the individual actors within the networks, and ties are the relationships between the actors. The resulting graph-based structures are often very complex. Networks play a critical role in determining the way problems are solved, organizations are run, and the degree to which organizations succeed in achieving their goals. Using data from CORDIS (project collaborations) and SCI (co-authored publications) we can establish what kind of formal relations occurred in the between organizations related to the technological trajectory. A central question here is; Who are the central players in the system?

STEP 2. DETERMINING THE PHASE OF DEVELOPMENT

Structures involve elements that are relatively stable over time. Nevertheless, for many technologies, especially newly emerging ones, these structures are not yet (fully) in place. For this reason, scholars have recently enriched the literature on Technological Innovation Systems with studies that focus on the build-up of structures over time. The central idea of this approach is to consider all processes that contribute to the development, diffusion, and use of innovations as system functions. These system functions are to be understood as types of processes that influence the build-up of a Technological Innovation System. Each system function may be 'fulfilled' in a variety of ways. The premise is that, in order to properly develop, the system should positively fulfill all system functions.

The way of how the structure and the functioning of an innovation systems should be build up is dependent on the phase of development of the technology. If the technology is still in an early phase of development than the innovation system has a different structure and certain functions are more relevant than those for a more mature technology. In order to monitor an innovation system it is first important to determine the phase of development. This is necessary to be able to evaluate whether the innovation system performs well with relation to the phase of development.
If the technology is diffused to a certain extent then the TIS should be of a certain maturity. On the other hand a certain size of a TIS determines the extent of diffusion of the technology. To determine the phase of development of the technology and the TIS, the international TIS is positioned on the diffusion curve (see Figure 4). The diffusion curve of a technology describes the extent of diffusion on international level of the technology and has the shape of an S-curve. The curve describes the process of development, application and further diffusion of the technology. The S-curve can be divided into different phases. The first is the *pre-development phase* where a prototype is produced, i.e. the first evidence that the new technology works. Then in the *development phase* the first commercial application occurs where the new technology or product is sold for the first time and enters the market without subsidy. In the next phase, the *take-off phase*, the technology or product will be diffused on a larger extent and the market will grow

further, i.e. *acceleration phase*, until saturation occurs and the degree of diffusion stabilizes, i.e. *stabilization phase*.

In order to determine in which phase of development the technology resides, diagnostic questions can be asked. If the answer is yes then the technology is in the next phase of development.
Pre-development phase: is there a working prototype?
Development phase: Is there commercial application?
Take-off phase: Is there a fast market growth?
Acceleration phase: Is there market saturation?

In each phase of development the structure and functioning of the innovation system is different. After determining the phase of development of the technology it can be determined whether the innovation system is build up in a correct way and whether it can make the move towards the next phase. The characteristics and criteria's that the structure and functioning of a system need to fulfill will be explained in the next steps.

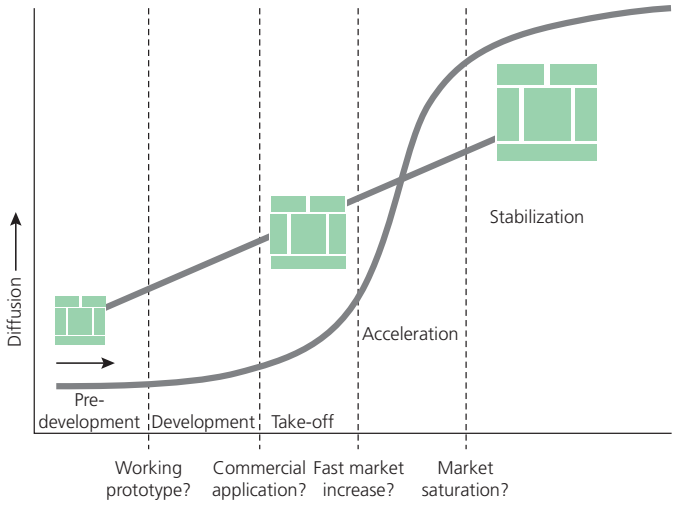

Figure 3 Phase of development

STEP 3. SYSTEM FUNCTIONS

Even though different innovation systems may have similar components, they may function in a completely different way. Therefore, measuring how innovation systems are functioning is considered as the big breakthrough in innovation systems research. In a number of scientific articles lists of evaluation criteria are presented to evaluate how innovation systems are functioning. These assessment criteria are labeled in the literature as 'key processes of innovation systems' (system functions). In Hekkert et al. (2007) the following system functions are put central:

1. entrepreneurial experimentation,
2. knowledge development,
3. knowledge exchange,
4. guidance of the search,
5. formation of markets,
6. mobilization of resources,
7. counteracting resistance to change.

The important difference with the structure of the innovation system is that these system functions are much more evaluative in character. They state *how* an innovation system is performing. The functioning of an innovation system needs to be assessed by *experts or key stakeholders* that are active in the innovation system.

The reason to evaluate the innovation system by means of expert opinions is that it is impossible at the moment to solely evaluate an innovation system based on quantitative criteria. The reason for this is that technologies and regions are different from each other and that it is impossible to define an optimal configuration of the innovation system. Consequently, benchmarking innovation systems is difficult; what works in one country may not work in another country. Furthermore, the development of an innovation system often depends strongly on the competition in other parts of the world and very often has very technology specific dynamics. For some technologies much more R&D funding is necessary than for others.

Therefore, the best way to assess the functioning of the innovation system is by involving a sufficient amount of experts in the evaluation by asking them very specific diagnostic questions, whether the amount of activities are sufficient and whether they form a barrier for the innovation system to further develop and move towards the following phase of development. Most of the data has already been

collected during the structural analysis, but with asking the experts an assessment can be done about the quality of the innovation system.

Table 1 Overview of System Functions, indicators and diagnostic questions for analyzing the functioning of the Innovation System Functions

Functions and indicators	Diagnostic questions
F1 - Entrepreneurial Experimentation and production - Actors present in industry (from structural analysis)	- Are these the most relevant actors? - are there sufficient industrial actors in the innovation system? - do the industrial actors innovate sufficiently? - do the industrial actors focus sufficiently on large sale production? - Does the experimentation and production by entrepreneurs form a barrier for the Innovation System to move to the next phase?
F2 - Knowledge Development - Amount of patents and publications (from structural analysis)	- Is the amount of knowledge development sufficient for the development of the innovation system? - Is the quality of knowledge development sufficient for the development of the innovation system? - Does the type of knowledge developed fit with the knowledge needs within the innovation system - Does the quality and/or quantity of knowledge development form a barrier for the TIS to move to the next
F3 - Knowledge exchange - Type and amount of networks	- Is there enough knowledge exchange between science and industry? - Is there enough knowledge exchange between users and industry? - Is there sufficient knowledge exchange across geographical borders? - Are there problematic parts of the innovation system in terms of knowledge exchange? - Is knowledge exchange forming a barrier for the IS to move to the next phase?
F4 - Guidance of the Search - Regulations, Visions, Expectations of Government and key actors	- Is there a clear vision on how the industry and market should develop? - In terms of growth - In terms of technological design - What are the expectations regarding the technological field? - Are there clear policy goals regarding this technological field? - Are these goals regarded as reliable? - Are the visions and expectations of actors involved sufficiently aligned to reduce uncertainties? - Does this (lack of) shared vision block the development of the TIS?
F5 - Market Formation - Projects installed (e.g. wind parks planned, site allocation and constructed)	- Is the current and expected future market size sufficient? - Does market size form a barrier for the development of the innovation system?
F6 - Resource Mobilization - Physical resources (infrastructure, material etc) - Human resources (skilled labor) - Financial resources (investments, venture capital, subsidies etc)	- Are there sufficient human resources? If not, does that form a barrier? - Are there sufficient financial resources? If not, does that form a barrier? - Are there expected physical resource constraints that may hamper technology diffusion? - Is the physical infrastructure developed well enough to support the diffusion of technology?
F7 - Counteract resistance to change/legitimacy creation - Length of projects from application to installation to production	- What is the average length of a project? Is there a lot of resistance towards the new technology, the set up of projects/permit procedure? - If yes, does it form a barrier?

ANALYSIS

In this step the system functions need to be scored on a 5 point likert scale (1 = very weak and 5 = very strong) in order to identify how well each system function is fulfilled and which system function forms the largest barrier that should be targeted by recommendations.

In the spider-diagram below (Figure 4) the extent to which each system function is fulfilled will be represented. The system function with the lowest scores can be seen as the most problematic ones.

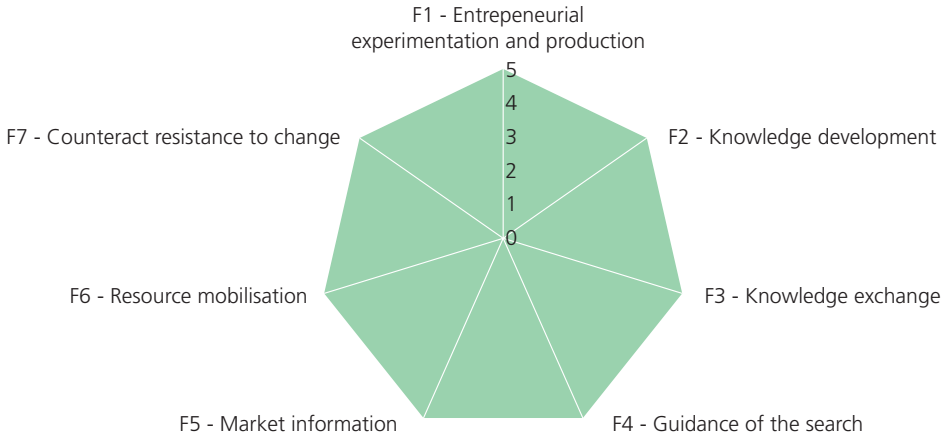

Figure 4 Overview of system function fulfillment

However in order to be sure which system function forms the biggest barrier we need to relate the presence and fulfillment of the system functions to the phase the IS is in. Not every system function is as important as other system functions in each phase.

The fulfillment of the system functions varies per phase of development of the technology. In each phase different system functions play an important role depending on the aim of the phase. The build up of the innovation system occurs over time throughout the phases which results that the fulfillment of the system functions is cumulative (i.e. more knowledge is build up). Therefore all system functions need to be fulfilled in order to support the build up of the TIS in question.

Figure 5 shows possible functional patterns per phase. The black arrows are the relations that occur in the current phase, whereas the grey arrows represent the relations that occurred in previous phases and are still occurring in order to further improve the development of the technology into 2nd or 3rd generations. In this way the system functions fulfillment differs over time but since the system functions influence and interact with each other they reinforce each other contributing to the build up of the innovation system.

For the pre-development phase we expect that knowledge development is the most critical system function. This system function may be negatively influenced by a poor performance of other system functions, such as knowledge exchange, guidance of the search and resource mobilization. Thus these four functions deserve most attention in the analysis when in this phase. The other system functions are expected to be less influential.

For the development phase we expect that entrepreneurial experimentation is the most important system function as the first experiments and pilot plants are set up that will show whether the innovation also works in practice. All other system functions may positive or negatively influence this system function. So all system functions may be critical in this phase and will need to be thoroughly analyzed.

For the take off phase, entrepreneurial experimentation and production is critical. In this phase entrepreneurs should really become system builders. Therefore counteract resistance to change and build legitimacy (F7) is also a critical system function. Guidance of the search, resource mobilization and market formation are important supportive functions. Knowledge development and exchange are most likely to be less critical in this phase.

For the acceleration phase market formation is the most important system function, as a growing

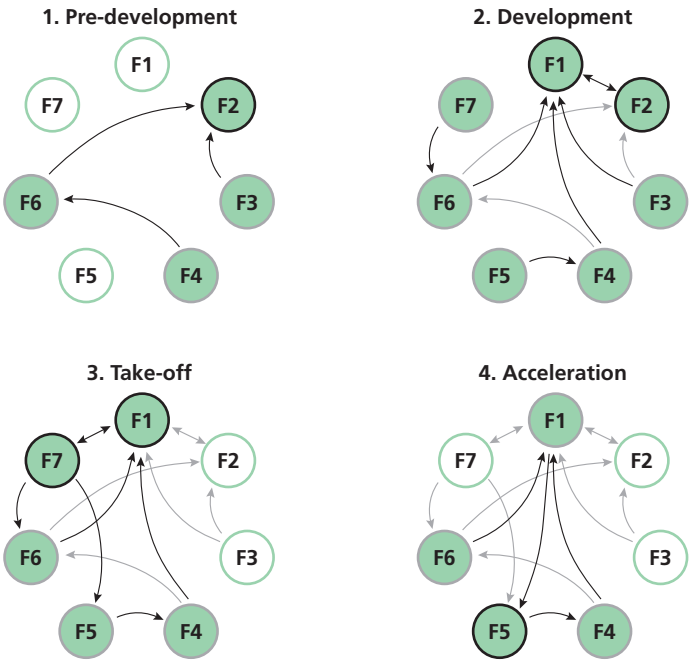

Figure 5 Functional patterns per phase

market fuels the innovation system to develop and diffuse further. Supportive functions are entrepreneurial production, resource mobilization and guidance of the search. The other functions are most likely to be less critical.

If the most important or supportive system functions of a particular phase are missing or are unfulfilled then they can block the build up of an innovation system. By identifying which system function blocks the further development of the Innovation System, appropriate policy recommendations can be formulated to remove this barrier.

STEP 4. STRUCTURAL CAUSE FOR FUNCTIONAL BARRIERS

The outcome of the previous analysis is the identification of a number of system functions that can form an obstacle for the progress of technological development. These obstacles can block the development and diffusion of the technology. In this step the causes for the hampering will be identified.

The causes can origin in the structure of the TIS. The system functions that are badly fulfilled are a manifestation of problems in the structure. By identifying where the problems are within the system the barriers can be removed. For example if function knowledge development is badly fulfilled than the cause could be related to the lack of knowledge institutes and universities that provide the appropriate courses to educate people that can work with the new technology. By identifying the problems in the structure these can then be removed or improved.

If the government develops policy to improve and facilitate the functioning of the TIS, then the new policy will be included in the structure which will influence the functioning of the system.
In order to find the causes in the structure of the system the following steps will be followed:

1. Determine which system functions are forming a barrier.
2. Determine for each system function which

structural component forms a barrier. Look at the following structural components:

a. Actors, different groups/parties
b. Networks, relations and cooperation between parties
c. Institutions (formal and informal regulations; these have not been elaborated on in step 4, so need to analyze them in depth here)
d. Technology, the knowledge related to technology
e. External factors/Context. For example competition between two TISs.

3. Describe the relation between cause and barriers. What are the functional consequences of the causes in the structure and what are the functional consequences of the competition between several TIS? Do the barriers have to do with a lack of structural components or with lack of quality? What are the effects of the structural components on the functioning of the system – which system functions improve or become worse due to structural problems?

STEP 5. OBSTACLES FOR POLICY GOALS

Innovation policy is about helping companies to perform better and contributing to wider social objectives such as growth, jobs and sustainability. There are many policy tools available to achieve this, ranging from establishing supportive framework conditions (e.g. human resources, an internal market, intellectual property) to facilitating access to finance, policy benchmarking and enabling collaboration or stimulating demand, for instance, through regulation, standards and public procurement.
However, the choice of policy instruments depends on the identified structural cause for functional barriers in the innovation system, as well as the precise goal of a policy and the geographical and technological scope of the TIS under study.

Therefore it is important to determine the *policy goal* of the respective innovation system because new emerging energy technologies provide different opportunities which can lead to different policy goals and changes of these goals over time. For the interpretation of the results it is important to determine what the goal is.

By policy goals we mean the vision of the government with respect to the societal contribution of renewable energy technologies. These can be short- or long-term goals for renewable technologies, i.e. PV or wind, or societal themes, i.e. sustainable mobility? The policy goals with respect to renewable energy technologies can be determined along 2 dimensions: 1) environmental/energy goal: contribution to CO_2 emission reductions, guaranteed energy supply and reduction of fossil fuel dependency; 2) economic goal: value and contribution of emerging sectors such as renewable energy technologies related to economic growth in and export of the home country. One goal does not exclude the other but they can be different and will have an effect on the evaluation of the functioning of the innovation system. The optimal configuration of an innovation system will then be dependant of the policy goals.

If the policy goal is to obtain economic profit then a lack of the system function market formation does not need to be a problem if the technology is exported but not implemented in the home nation. On the other hand if a large amount of the technology is important to achieve environmental/ energy goals a lack of

system function knowledge development does not need to form a problem as the goal is achieved. In this step the link needs to be made between the results of the analysis of the structure and the functioning of the ideal TIS. In this step the most important barriers need to be ranked in order to provide recommendations on how to achieve the policy goal.

Finally, an important insight from innovation studies is that there are different relevant spaces for public intervention, since some technological developments require international policies while others are the realm of regional policies. This means that the location of new policy programs and the geography of technological innovation more broadly, is subject to path-dependent dynamics where innovations may prosper in some locations and become marginalized in other locations (Arthur 1994).

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