A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the

Degree of Master of Science

Environmental Innovation Dynamics:

Integrating policies, organization and innovation

in the wastewater treatment industry

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July, 2016

Budapest

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Thripti Puthran

CENTRAL EUROPEAN UNIVERSITY

ABSTRACT OF THESIS

submitted by: Thripti PUTHRAN

For the degree of Master of Science and entitled: Environmental Innovation Dynamics: Integrating policies, organization and innovation in the wastewater treatment industry.

Month and Year of submission: July, 2016

Continuous focus persists on reducing the environmental impacts of industrialization. This paper aims to evaluate the integration potential of environmental policies, organizational priority and innovation patterns related to the wastewater treatment industry, by referring to innovation trends in Hungary. I choose a combination of methods to understand the innovation trends by conducting a patent landscape study and surveying the organizational interests of SMEs to promote environmental innovation in wastewater treatment industry. My objective is to understand the role of environmental policies in the decision making process of environmental innovation. Then I investigate how the progress in environmental innovation is influencing development and superseding existing policies within the industry. My findings indicate that reference to environmental innovation and the benefits identified by successful investment in research have an opportunity to influence appropriate policy measures. I conclude that environmental policies focus on historical progress and adhere to the standards set by conventional organizations, creating a barrier for the more innovative small entities to showcase their success. I also formulate policy recommendations in order to procure the benefits from environmental innovation not just for the environment, also for the innovators and policy makers.

Keywords: innovation, organization structure, market strategy, environmental policy, wastewater treatment

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My ex-colleagues, who provided useful information throughout my research and took the time to be interviewed. The other participants who provided useful information during my research and took the time to answer my questions.

Last but not the least, my family, especially my mother and my husband, their constant support and encouragement, helped me to study further and submit all my assignments on time.

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1. Introduction

Climate change has been closely associated with the global economy from the beginning of the industrial revolution. Evidence from scientific research suggest that human activities have influenced and increased the release of carbon dioxide into the atmosphere for decades. It is one of the main reasons behind global warming, rise in sea level and recurrent extreme weather conditions on the planet (IPCC 2014).

Technology induced environmental damage is being addressed by innovators after thorough understanding of the negative impact. Ozone depletion and acid rain are examples where knowledge and implementation of alternate technologies have mitigated environmental degradation. As a result, innovation has been identified as a critical instrument in addressing environmental degradation (Elkins 2010; Jänicke 2012).

The Action Plan for Environmental Technology (ETAP) was established by the European Commission in 2004 for driving sustainable technological change, in order to promote economic development and sustainable growth (EU Commission 2004). Another policy instrument enrolled by the European Commission included the Communication on Integrated Product Policy (IPP) which identified that innovation used to create new products reduces the impact on the environment (EU Commission 2003). There are several such directives that have

been formed to control the impact of technology on the environment. However, the impact of these policies on innovation varied between benefitting and degrading the environment. The true potential of the impact that environmental policies have on innovation and the possibility of innovation surpassing the expectation required by these policies needs further study.

Numerous studies show conflicting results with respect to the positive and negative relationship between environmental policies and innovations (Ambec et al. 2013; Iraldo et al. 2010; Johnstone et al. 2009; Porter 1991). The varying results of these studies imply that a thorough understanding of the co-existence of environmental policies and innovation is required. Furthermore, it is required to narrow the scope of the study to a specific technology and link the additional factors, such as the role of the organizations involved in innovation and marketing strategy.

The thesis will study the innovation pattern in wastewater treatment industry using a patent landscape and identify the impact of environmental policies and organizational priorities in SMEs to innovate methods and products for the benefit of the environment.

Project Aims and Objectives

The core purpose of the thesis is to test and further develop the concept of integrating innovation with environmental policies and organizational priorities in SMEs using the wastewater treatment industry as an example. I consider the trends in innovation based on patent activities by conducting a patent landscape study and integrate the results with relevant environmental policies. This research suggests management of innovation within SMEs and its potential to play a role in proposing environmental policies. I am taking an exploratory approach and therefore am asking a set of broad questions to gather the information.

1. What are the environmental innovation trends observed in an industry?

2. How do environmental policies impact the progress of environmental innovations?

3. How do environmental policies limit SMEs from increasing development and marketing of environmental innovations?

4. How can environmental innovations developed in SMEs further influence environmental policies?

The thesis outlines innovation in the waste water treatment industry by identifying patent trends and the policies which have been regulating the industry thus far. In the process, this thesis studies the regional impact of innovation in the wastewater treatment industry and policies that have been implemented based on innovation in Hungary. The thesis will help answer the

question whether innovation through SMEs focused on delivering environmental benefit products is capable of propse new relevant environmental policies.

The objectives of the study are as follows:

1. Outline the innovation in the waste water industry, identifying the various innovation trends.
2. Compare the patent trends with policies and the changes in policies related to wastewater treatment. Identify if there has been any correlation over time.
3. Identify any potential integration links between innovation, policies and SMEs.

Research Statement

A patent landscape study will provide a deeper insight into the past and current innovation trends in wastewater treatment industry. The study will provide comprehensive empirical results to use while designing future policies for the wastewater treatment industry. It is possible to implement this method of studying patent trends and analysing the effects on environmental policy in all technological areas.

Research Approach

This research uses a varied method by gathering information from patent searches, industrial visit, interviews, surveys and policy documents. Qualitative and quantitative methods are used to enhance the authenticity of the results obtained from the research as well as to increase my knowledge and understanding of this subject. Quantitative analysis using patent database tools to identify relevant patents trends.

Thesis Structure

This master's thesis comprises of 6 sections.

Section 2: *Background* of the study is described: definition of key concepts, descriptions of relevant literature and the research approach. The key concepts, 'innovation' and 'environmental innovation' are defined, followed by a concise explanation of policy-related concepts: environmental policy integration.

The various literatures of the study constructs a relation between technology information, organisation and policy studies. It should be noted that several literatures are relevant to innovation research, however, this chapter focuses on those literatures most relevant for studying the links between environmental policies and technological innovations relevant to wastewater treatment industry.

Section 3: *Methodology* discusses the issues of authenticity, consistency and limitations. It also provides detailed information on the research approach and methodology, emphasising on the patent landscape study.

Section 4: *Results* summarizes the outcome of various data collection activities, interviews, surveys and the findings from the patent landscape analysis. Several figures are used to visually illustrate the relationship identified in the patent landscape study.

Section 5: *Discussion* examines the results further to determine the trends observed in innovation and policy implementation. It further compares different organisational perspectives while responding to policies.

Section 6: *Conclusions*. Theoretical and practical conclusions are presented in this chapter, aiming to answer the research questions identified previously. This section also includes recommendations for policymakers.

2. Background

Results from a study conducted by World Bank, World Health Organisation and UNICEF shows that availability to clean water affects 40% of the world population and more than 80% of the wastewater generated from industries and municipality is released untreated into the rivers or seas (SDG 2015). The study estimated that US$28.4 billion per year should be invested between 2015 and 2030 to address this scarcity in the identified regions.

Industrialization has caused an increase in the rate at which raw materials are consumed and generation of waste in terms of products and by-products. A large portion of this discharge has deteriorated the water quality and causing eutrophication. (Mekonnen and Hoekstra 2015).

Industries seek to maximise profit and reduce operational costs over energy efficiency and sustainable goods. A large time gap exists between inventions that are identified with scientific proof as having a harmful effect on the environment and imposing a mitigation action by the governments (Park 2014). Regardless of the emphasis by various institutions, environmental law has not been entirely successful in encouraging technological innovations with environmental benefits (Mandel 2005). Reduction of pollution, waste and sustainable growth should be promoted in an effort to control, and possibly reverse, the damages caused to the environment.

Scientific literature refers to innovation in a broad context to identify new products, services, technologies and all its applications. The concept of innovation was first introduced to define a new product for public use or an efficient method of producing the product as a lower cost (Schumpeter 1928). This definition of innovation was not limited to invention depending on its technical originality. Over the years, technological innovation has been defined as a novel use of an invention (Smith et al. 2012; Garcia and Calantone 2002). In general, innovation is defined as a method or product that is identified as novel. This study specifically identifies technological and product innovations that benefit the environment.

Specifically, this study focuses on environmental innovations, which is defined as technological innovation having the ability to directly or as a by-product of the inventive measure, promote environment sustainability. The term environmental innovation is used with caution as some inventive steps may have a negative impact on the environment depending on the time, location and surrounding of its use (Smith et al. 2010). Certain innovation that claim to reduce the environmental impact based on higher efficiency, will encourage higher usage, as a result, the environmental impact will be averaged to the previous methods employed.

Over the years, several unsuccessful environmental regulations have been introduced to promote environmental innovation. Though some regulations favoured the industries, by offering substantial incentives or imposing requirements to develop technologies that do not harm the environment, it appears, the efforts were not sufficient to constrict environmental damages (Martin and Trippl 2014). Since the ineffective environmental statutes have shown limited impact to increase environmental innovation, I focus my study on integrating and improvising a part of intellectual property law with environmental law to promote sustainable

innovation. Information relevant to my research regarding intellectual property law and environmental law is described to identify the concepts in brief, yet precisely.

Intellectual Property Law for Environmental Innovation

Intellectual property law protects technological and non-technological innovation. Copyright law and trademark law protect ownership of non-technological innovation. Patent and trade secret laws form the principal elements of Intellectual property law for technological innovation (Blackburn 2007). Trade secret law is used for legal protection against misuse of business information not commonly shared with the public. The business information includes, but not limited to, plans, processes, products related to businesses. The trade secret law does not encourage sharing of best practices and is not commonly used to promote environmental innovation.

I will provide further information related to patent law as it is more relevant to the study. The purpose of the patent law is to protect an invention by providing exclusive rights up to 20 years for the inventor to use his invention for manufacturing or licencing it. The terms innovation and invention are often used without any differentiation (EPO 2016). For this study, I use the term invention to define new usable technological advancement that has not been identified prior to the date of invention. An invention is the end product of cost, time and effort invested in research and development by the inventor. The inventor has the rights to protect his invention under the patent law. Whereas innovation is derived from the earlier definition, technological

and product inventions that benefit the environment along with representing the market realization of such an invention (Bertoni and Tykvová 2015).

The patent system is derived from the legal framework of the patent law. It provides a platform to support technological innovation to be protected as patent. For a patent to be valid, it must be novel (must include an inventive measure), must have a utility and non-obvious for an expert in the technology or skilled in the art (WIPO 2016). Patents offer useful information on the inventors, ownership, technical concepts and application details. Since the investments in owning and maintaining a patent is comparatively high, the patents ownership and its application provides further details of its market value. This market value is used to encourage and implement innovation. Hence, patents are considered the critical source of structured and precise innovation data that relates to technological and market information (WIPO 2016).

The patent is divided into three sections:

1. Title page with abstract and bibliographic data
2. Description of the patent along with drawings
3. Claims that is considered the scope of the patent, describes the elements that are protected by the inventor. (WIPO 2016).

The bibliographic information on the title page includes patent title, abstract containing short description of the invention and name of all the inventors. An inventor is a person who invented or contributed in part to the novel aspect of the patent. The additional information in the title pages are the applicant or assignee (represented by the inventor or an organization applying for

the patent at the selected patent office), the first date of filing of this invention is referred to as a priority date, the application number that is designated to the patent application during the filing. Other information on the title page include but not limited to technology class, citations identified as prior art by the patent examiners, principal invention drawing (WIPO 2016). The International Patent Classification (IPC) codes are commonly used to categorize a patent based on the core technology of the inventive method in the patent. IPC provides a hierarchical system of language independent symbols for the classification of patents according to the different areas of technology to which they relate (WIPO 2016). I use the core level classification and the secondary level of codes in IPC to identify patents according to the technology. However, other similar hierarchical code systems include the European Classification (ECLA), Cooperative Patent Classification (CPC) and US classification codes are widely referred and used depending on the jurisdiction of the patent filing. IPC codes are most frequently used, as it is associated with the most patents.

The description section begins with a summary of the background, disclosing all known prior art relevant to the invention, a description of the problem to be solved explaining at least one possibility of carrying out the invention, (the best mode of the invention should be disclosed), description of the drawings and details that enable all the claims of the patent (WIPO 2016).

The claims section is the most critical section of the patent. The claims define the scope of the invention, in other words, the boundary of the protection as per the patent law. The claims should describe clearly the precise novelty of an inventive step of the patent (WIPO 2016). The claims should be specific and state the limitation covered by the claims. The claims provides an outline for potential infringement cases to determine the outcome based on the validity,

strength and enablement of the claims. Enablement of the claim refers to the specific element of a patent, which is within the limitation of the scope of the patent boundaries, and that is described with its utility and applicability based on the inventive aspect (EPO 2016).

Analysing a set of specific technological patents provides information regarding its inventors, origin, trend of innovation within the technology domain and its impact on the global patent trends. Further analysis, such as a patent landscape study reveals critical information relating to the patents that are highly valued commercially and scientifically in a specific technology. Patent is a legal document and the information analysed is considered authentic and is widely used by professionals in public and private sector (OECD 2014).

Patent families

Patents are identified based on the jurisdiction that they are filed making them geographically specific. Therefore, an inventor applying for patent protection for one technology in more than one country will have multiple patents protecting the same technology or invention in multiple countries. This is referred to as a 'patent family'. It is possible for one patent family to have multiple patents in a single country, as long as each patent is protecting a different feature of the same invention (EPO 2016). Thus, patent families are described as an alternate for multiple inventions within a technology field. Furthermore, references drawn from the extent of the patent family, assists in identifying the patent filing strategies of the inventor or assignee.

Patent applications and granted patents

Patent research is conducted using a specific patent dataset relevant to a technology field. This patent dataset is formed by collecting patent applications, granted patents and at times by using patent families. Patent applications are published approximately 18 months after filing. The publication provides initial evidence of innovative activity by an organization or list of inventors (WIPO 2016). Differences in the number of publications and granted patents provide a method to assess the realistic innovation in the technology field. As some patent applications are withdrawn due to lack of interest in continuing innovation within the technology area or due to lack of funding.

A patent application is submitted at a National Patent Office, European Patent Office (EPO) or at the Patent Cooperation Treaty (PCT), based on the patent law that governs the country where the invention originated. The National patent office, EPO and PCT provide a different criteria of geographical protection. The national phase for individual countries only covers the countries selected to file the patent, usually the countries of strategic interest (WIPO 2016). The European Patent Organization is an intergovernmental organisation, set in 1977 on the basis of the European Patent Convention (EPC) signed in Munich in 1973. It consist of two bodies, the European Patent Office and the Administrative Council. The EPO offers inventors and assignees a single application procedure that permits them to seek patent protection in up to 40 European countries (EPO 2016). A PCT supports the patent applicants that seek patent protection internationally. The PCT assists National Patent Offices with patent granting decisions by providing prior art searches for the inventions, and enables public access to the technical information relating to those inventions. The inventor files one international patent application under the PCT and further claims to seek protection simultaneously by selecting

from up to 150 countries that are part of the treaty (WIPO 2016). The PCT does not grant a patent, hence the patent application from the PCT has to enter the national phase in the National Patent Offices selected by in the inventors and assignees.

In its essence, a granted patent from EPO or National Patent Office provides a protection to the owner of the invention for certain period (maximum 20 years) provided the patent assignee pays the required patent maintenance fees. The granted patent provides exclusive rights of the invention to the inventor to either manufacture, market, license or do nothing with its invention (WIPO 2016). After a patent expires (end of the protection period), withdrawn (lack of interest to pursue) or lapses (not paying the required maintenance fees), the invention methods described in the patent is freely usable by the public and competitors. The data in an expired or lapse patent also provides as unique source of information with free access to technical solutions available in the patent document (EPO 2016; EU Commission 2007).

Patent and Industrial Growth

Each country intends to achieve a higher target for industrial growth every year and it is certain this growth increases pollution. The best control of this industrial growth induced pollution is by technological intervention that enables upgradation of the existing technology. This technological intervention paves a path to use environmental innovations (EU Commission. 2015). A high number of technologies used in industries that have been identified as high economical interest are patented. It is important to support the selection of environmental innovation at the upgradation stage and implement the entire benefits an innovation offers than to implement changes based on environmental requirements after the upgradation is complete.

In this study, I use patents as indicators for analysing the trend in development of wastewater technologies. There is a pressing need to investigate and implement alternatives to current wastewater treatment that minimizes water pollution, production of greenhouse gases and power consumption. Wastewater is subject of concern of all environmentalists due to depletion of fresh water resources. The knowledge of reusing treated wastewater is well known and is currently driving interest amongst environmentalists, industries and general public. The purpose of this study is to understand the methods wastewater treatment and the extent of environmental innovation occurring, the trends of the research and development implemented by countries, industries and technologists.

Environmental Policies

Environmental policy is used to refer to policies implemented by both public and private organisations (Lascoumes and Le Galès 2007). In this study I refer to environmental policy as public policy focusing environmental protection. The public policies relating to the environmental impacts due to anthropogenic intervention is of importance to this study.

Technology and innovation policy

The technology policy of a country is designed to gain competitive advantage in the global market and promote growth (Smith and Stirling 2007). The focus of technology policy in developed countries is to increase capacity of production by using innovative products and

methods. The developing countries seek to understand and gain efficiency from innovative technologies that enter the market (Lundvall and Borrás 2005). The technology policy is related to several other sectors such as intellectual property rights, trade finance and research. The policies that promote research have resulted in partial success methods of environmental technological advancement. Hence, there is a shift to improvise innovation policy that support research and development along with marketing strategies (Seyfang and Smith 2007).

Several proposals have been made to adopt an innovation policy that covers the broader socio-economic context while including the important aspects of other sectoral policies (Seyfang and Smith 2007; Wolff and Schönherr 2011; Shipworth 2005). For this study, I refer to innovation policy as public actions that affect innovation processes in the form of development and diffusion for innovations that promote economic growth. Innovation policy might also promote non-economic growth in terms of cultural, social and environmental benefits (Fudge et al. 2013). In a rapid developing world, it is important, to implement innovation policies in order to encourage economic and non-economic benefits.

Policy integration

Economic growth and environmental sustainability are found to be opposing the benefits of each other based on public policies (Lanoie 2014). Studies show that integrating policies raises questions regarding the competence of the combined policies (Palmer et al. 1995; Pollitt and Boucaert 2002). Alternately, the "Porter Hypothesis" states that a well-planned and designed environmental policy is likely to improve competitiveness, hence increasing economic performance by generating significant innovation offsets (Porter 1991). A successful integration of policies is represented in the economic policy that states, important impacts of

the different policies that are identified and the impact of the policy is assessed according to the utility of all the policies in effect. Environmental policy integration aims at combining the responsibility of environmental and non-environmental governing bodies to achieve a common goal of reducing the impact on the environment (Lanoie 2014).

This study involves integration of advancing environmental policies and protection with respect to the wastewater treatment industry. Environmental innovation might be observed at different levels of innovation in an industry. For my study, I refer to environmental policy integration as a credible enabler of environmental innovations. Figure 1 illustrates an example of different levels of policy integration during innovation. I acknowledge that policy integrating with technology alone may not be sufficient to promote innovation.

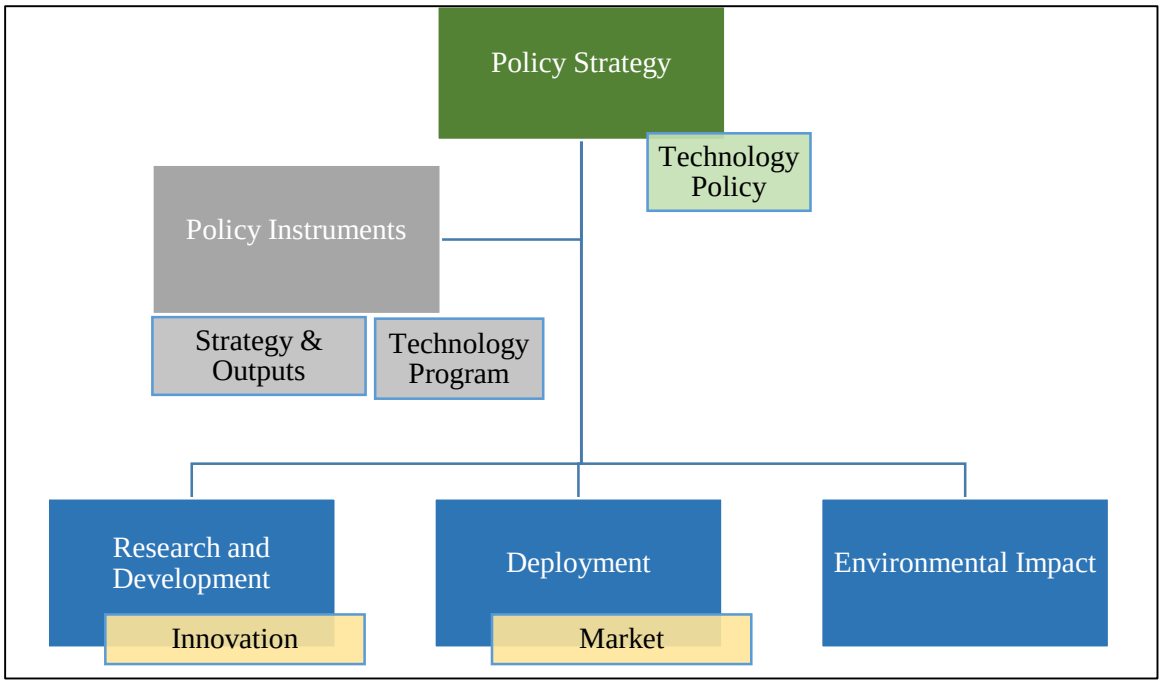

Figure 1. Levels of environmental policy integration

(Adapted from Mickwitz and Kivimaa 2006)

Environmental policy effects on innovation

As discussed earlier, integrating environmental policy has an impact from non-economic and economic standards. I focus my study on environmental policy effects on innovation within an industry.

Several authors have referred to the impacts of environmental policies on innovation and the reverse effect of innovation resulting from an environmental policy (Ambec et al. 2013; Iraldo et al. 2010; Johnstone et al. 2009). Interesting studies integrating policies and its impact on innovative "technology push and market pull" show a requirement for a "demand-pull policy" to be established and integrate in the innovation process (Horbach et al. 2012; Peters et al. 2012). Figure 2 shows a schematic representation of policy integration along the innovation chain.

Developing environmental technologies is assumed as a technology push factor due the emphasis on efficiency improvements, in contrast, developing environmental products are categorized under market pull factors based on willingness to utilize environmentally sustainable products (Ẅustenhagenn and Menichetti 2012). The strategies of market pull and technology push is one aspect of integrating environmental policies, however, an effective governing measure is needed for environmental innovation to succeed in the market. The energy sector, for example, has experienced essential modification and improvisations to succeed in

integrating renewable energy with innovation and government regulations (Markard and Truffer, 2006; Labelle and Goldthau 2013).

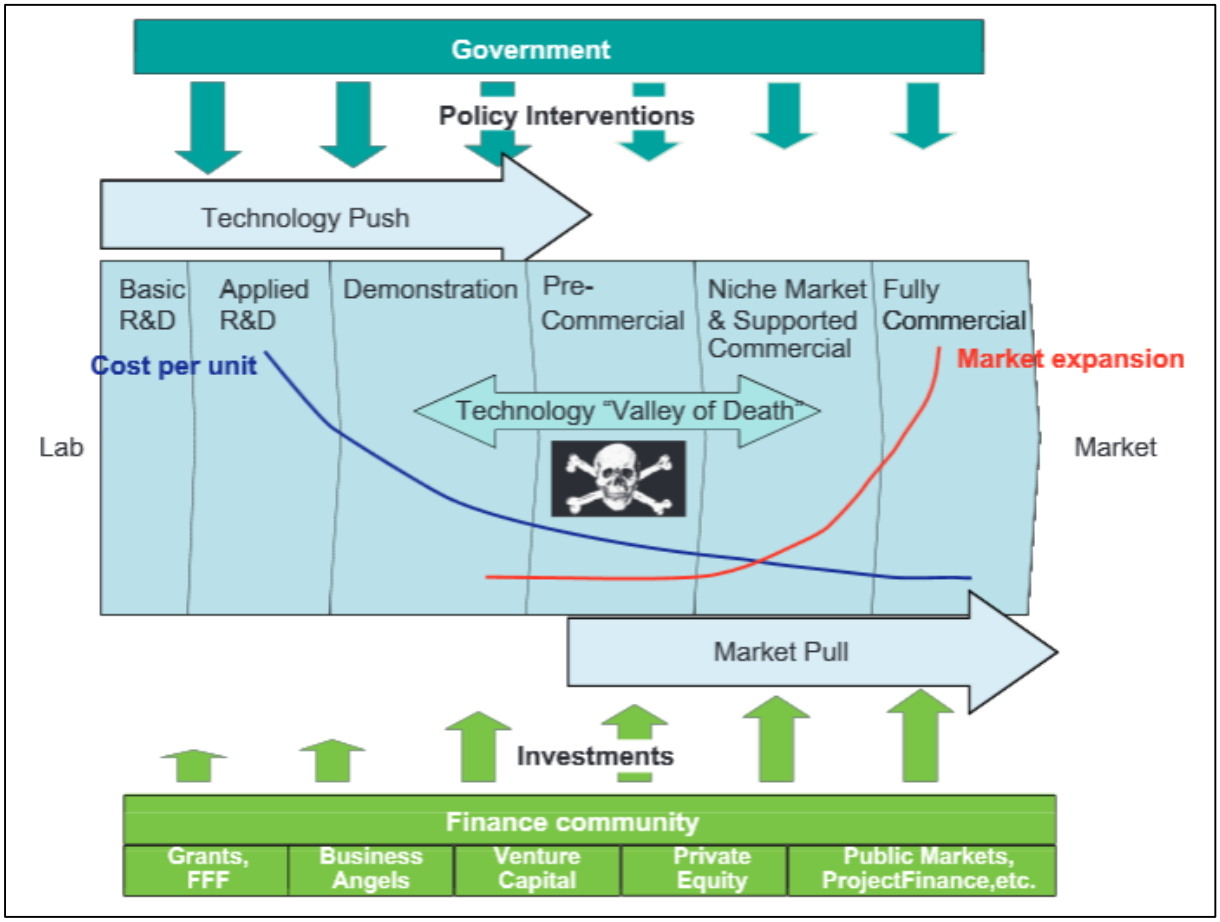

Figure 2. Policy integration along innovation chain

(Adapted from B̈urer and Ẅustenhagen 2008)

Environmental policy measures include instruments for directives, technology promoting platforms, investment tax subsidies, economic and non-economic instruments, sample illustration, financial support for research and development programs have been introduced to encourage successful integration and drive technology push into a market pull (Di Stefano 2012; Costantini 2015). These environmental policy measures have been referred to a support

system for environmental innovation and stimulating further growth. Other studies show tougher measures should be applied to the technologies based on the impact of the output than for an overall environmental innovation (Ruester et al. 2014; Frondel et al. 2007).

This varying interdependencies of policies and innovation apply differently in theory and in practice (Steward 2012; Costantini and Mazzanti 2012) since organizations have different priorities. These priorities and decisions to conduct research and produce environmental products will impact outcome of innovation. Depending on the outcome of the innovation, environmental policies will have the ability to provide useful information regarding resources, developing technologies, building awareness, reassurance of market stability and compliance measures.

For this study, I use the information based on organization's priority to innovate depending on environmental policies relevant to wastewater treatment in Hungary.

Wastewater Treatment - Hungary

Urban Waste Water Treatment Directive (UWWTD) under the Council Directive 91/271/EEC has an established prerequisite to collect and treat urban wastewater. It is considered as one of the critical key policy measures under the European Union water acquis. Hungary is fulfilling the UWWTD since it became a member of the EU in 2004 (EU Commission 2016). In most countries that were part of the EU prior to 2004 experience a positive effect of the directive

with a reduction in discharge of major contaminants that include organic load and nutrients, considered key contributors to eutrophication in water.

Countries, such as Hungary, and other central European countries that are a member of the EU since 2004 continue to face challenges in meeting the compliance requirements. Developing the infrastructure is one of the many challenges, due to financial restraints and executing construction of new wastewater treatment facilities. The EU provided substantial financial support, under EU Cohesion Policy funds (17.8 billion EUR in the 2007-2013 programming period, which is still liable to modifications). This funding was distributed to develop UWWTD in these countries (EU Commission 2016). The EU funding encouraged infrastructure development that had a positive impact on economic growth in terms of employment for these certain regions within the countries. My study focuses on the influence of these directives and environmental policies that effect the wastewater treatment industry in Hungary.

The compliance rates of each EU member state was assessed based on the collection systems and individual or other appropriate systems (Article 3), secondary or biological treatment (Article 4) and (Article 5) represents more stringent or tertiary treatment and sensitive areas (EU Commission 2106). The compliance rates for Article 3 was quite high in all states, however Article 4 and 5 shows scope for improvement in countries that are a member of the EU since 2004. The compliance rate per member state is represented in Figure 3.

Hungary has a high rate of compliance in Articles 3 and 4, however, the compliance rate is comparatively very low in Article 5. Hungary has obliged to apply more stringent treatment in

the future. The rate of compliance for Article 5 is low as a part of Hungary's territory is within the Danube catchment. This catchment was excluded from stringent treatment obligations under the Accession Treaties (EU Commission 2016).

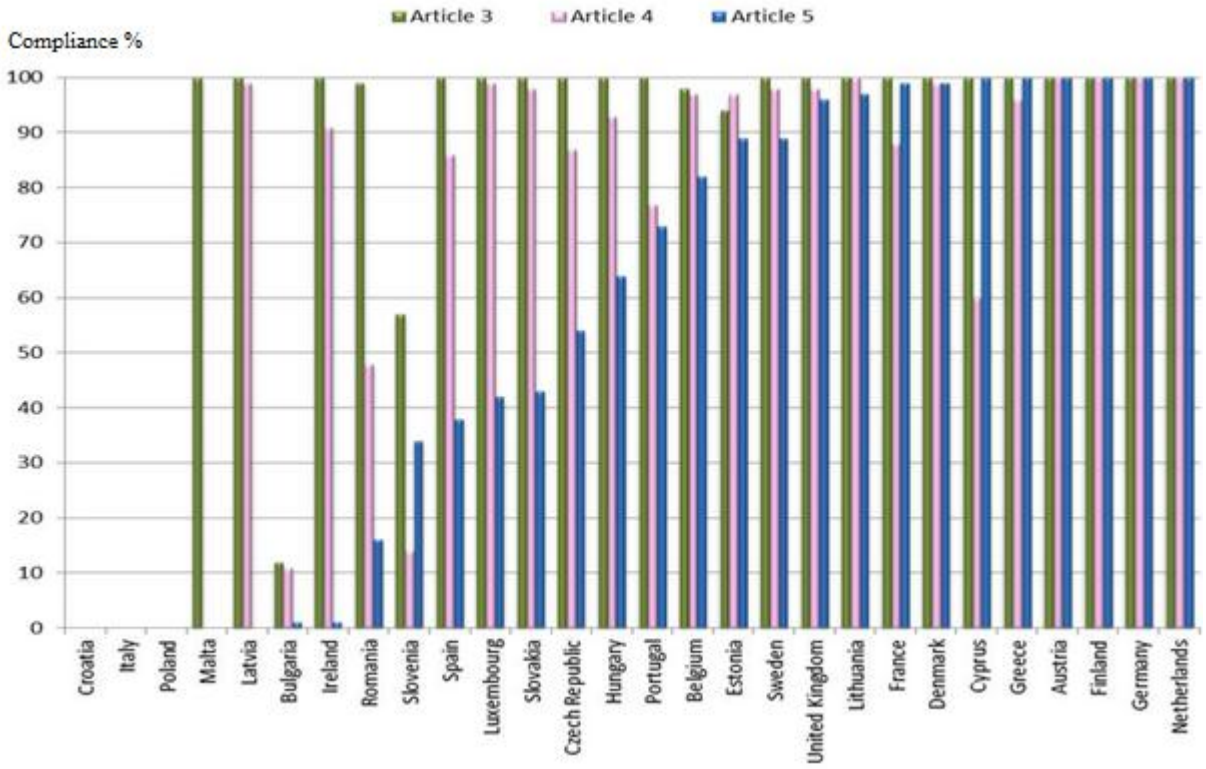

Figure 3 Compliance results per Member State

For Articles 3 of the UWWTD (collection), 4 (secondary treatment), and 5 (more stringent treatment). (Source: EU Commission 2106)

Hungary's current investment in new and wastewater treatment is identified as 47 Euros per inhabitant. The average investment is 50 Euros per inhabitant in EU (EU Commission 2016). Figure 4 shows the investment for all EU member states.

The EU Commission monitors compliance primarily through dialogues and promotion actions. It enters bilateral dialogue and commences infringement procedures against non-compliant

Member States as a last measure and when essential. The EU Commission has further identified investment in the expansion and large scale operation of innovative technologies to improve resource efficiency. The improvement in resource efficiency includes solutions for energy and nutrient recovery, treating to deliver saleable products and encourage water reuse (EU commission 2016). The priority to invest in research and innovation for wastewater treatment has been recognised in Horizon 2020, the 2014-2020 EU funding programme for research and innovation. Additionally, the European Innovation Partnership for Water (EIP) intends to facilitate innovative technologies and to create market opportunities, both within the EU and for a global market (EU Commission 2016).

MDGs, SDGs and COP21

The Millennium Development Goal (MDG) set a target in 2000 to enable provision of clean water to at least half of the population surviving without access to safe drinking water and essential sanitation. This was the first MDG goal achieved by the international society in 2012 (UN 2012). This set a precedent of the success for appropriate target of an integrated policy by using cost effective technologies in developing and underdeveloped countries. The Sustainable Development Goals (SDG) and 2015 Paris Climate Conference (COP 21) set similar goals for sustainable use of water setting targets for 2030 and 2050 respectively (SDG 2015; UNCCC 2016). The demand for fresh water will rise due to high urbanization and increase in global population. Thus, adequate investment, research and development is required in the water sector to ensure the demands are met.

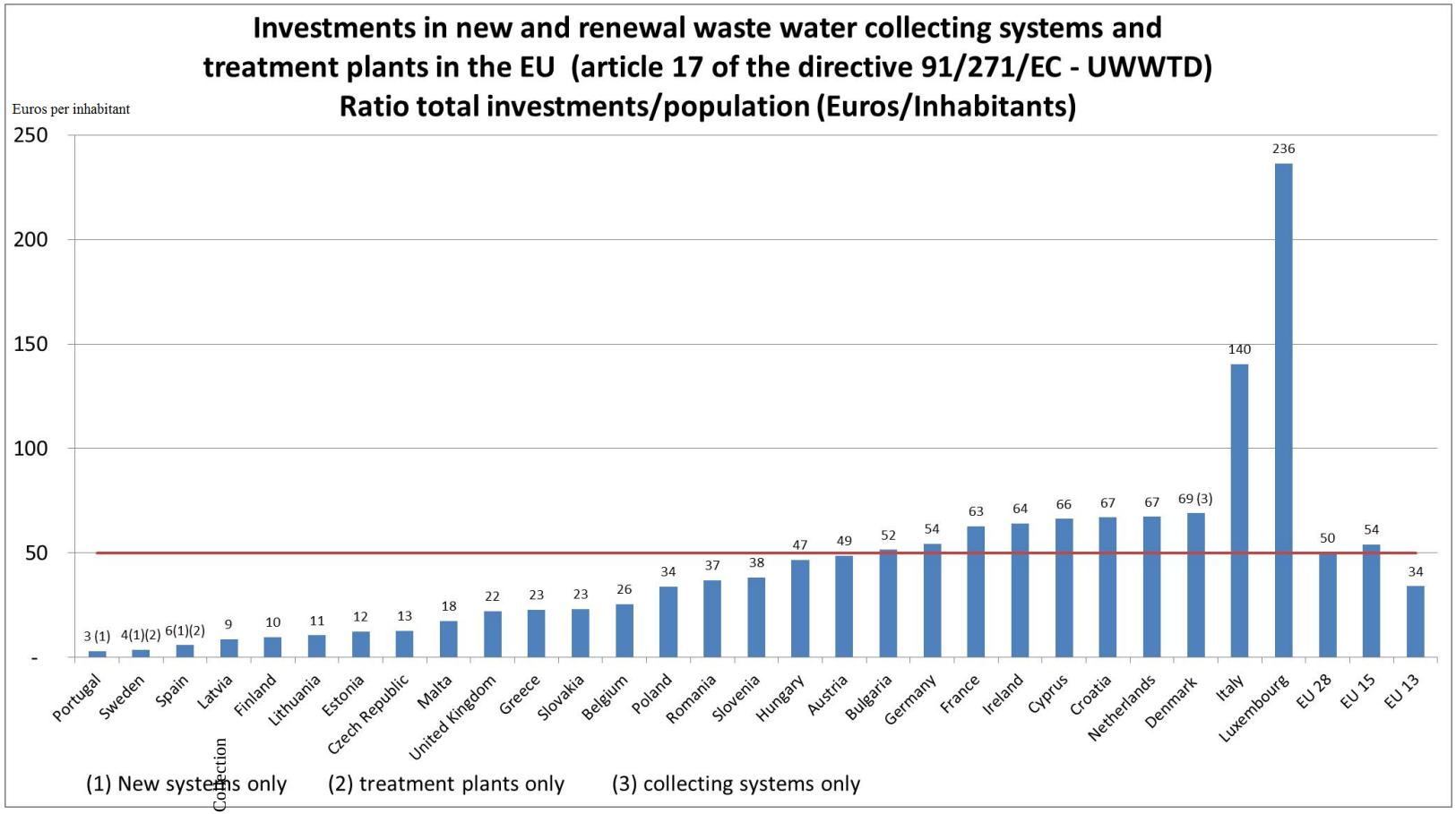

Figure 4. Investment per capita

in urban wastewater collecting systems and treatment plants (Source: EU Commission 2016)

Wastewater treatment

Availability of hygienic water as discussed in the previous section should be used as a measure of societal and economic development in a country. Public health and national security are often associated with availability and access to clean water. Many countries are currently facing severe water shortage and it is predicted that the number of countries having physical water scarcity by the year 2025 will increase as shown in Figure 5.

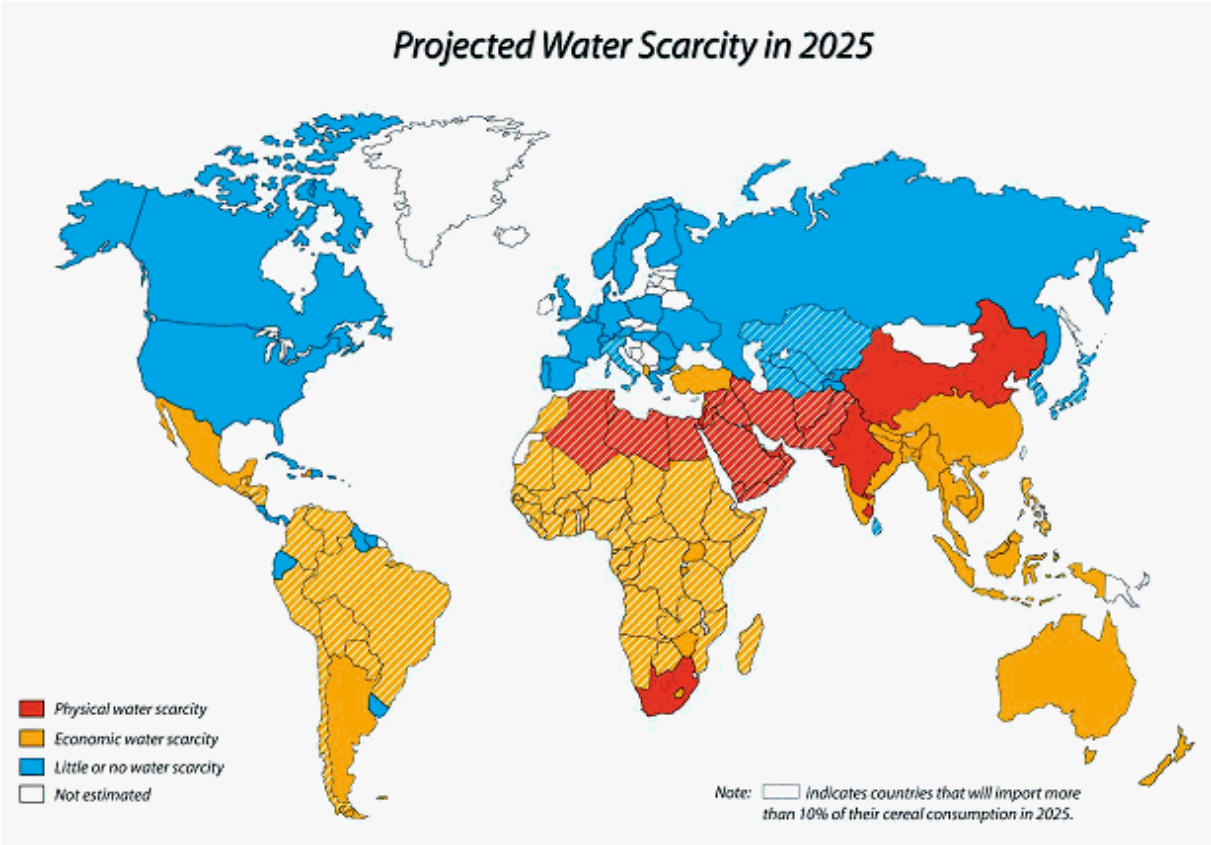

Figure 5. Global Fresh Water Availability

(Source: UN 2012)

Underdeveloped countries are attempting to meet a sustainable demand of clean water using portable water solutions, developing countries' demands for clean water has increased due to

higher consumption and growing industries. It is possible that countries that have a secure water source may confront water shortages in the future (SDG 2015).

It appears, the challenges faced due to water scarcity will directly increase investments in wastewater treatment. Market study expects approximately 3% rise in demand for fresh water will require investments between €400–500 billion in water infrastructure in the foreseeable future (EU Commission 2015).

Figure 6. Illustrates the global water industry showing the water infrastructure and use of the water resource. It appears, 70% of the total water resource is used in agriculture and 20% for industrial purposes. Investments to increase availability of treated water in agricultural and industrial use will reduce the demand of fresh water.

Technological developments in wastewater treatment have caused a reduction in operating a wastewater treatment facility (EU Commission 2016). A large number of inventions are patented globally to secure a competitive market. A patent landscape study of the wastewater treatment industry will identify the trends in this industry at global and regional level. Based on the patent trends, environmental innovations are identified to provide sufficient information for the policy makers to set adequate standards in order to have sustainable use of water.

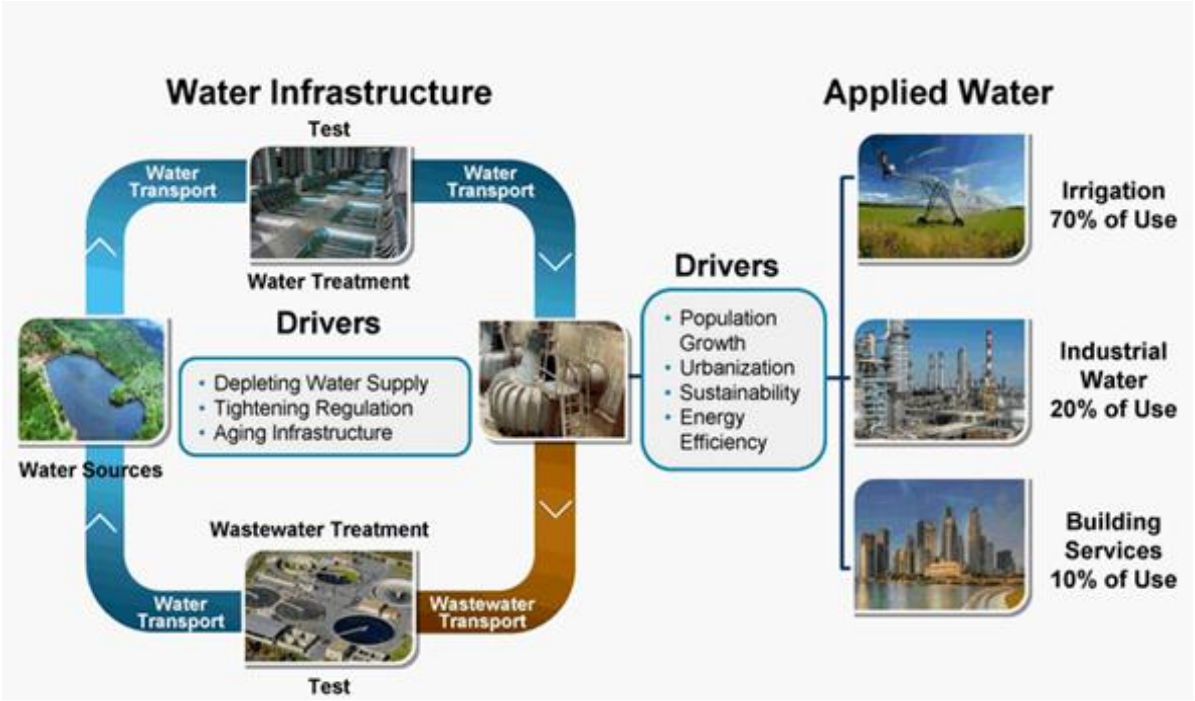

Figure 6. Global Water Industry

(Source: Xylem 2012)

Technology focus area

For this study, I have categorized the wastewater treatment technologies into four categories.

1. Biological method
2. Biological Membrane method
3. Chemo-Physical method
4. Advanced method

The categorisations used in the patent landscape listed with the relevant details of physical and chemical treatment of wastewater treatments is shown in Figure 7.

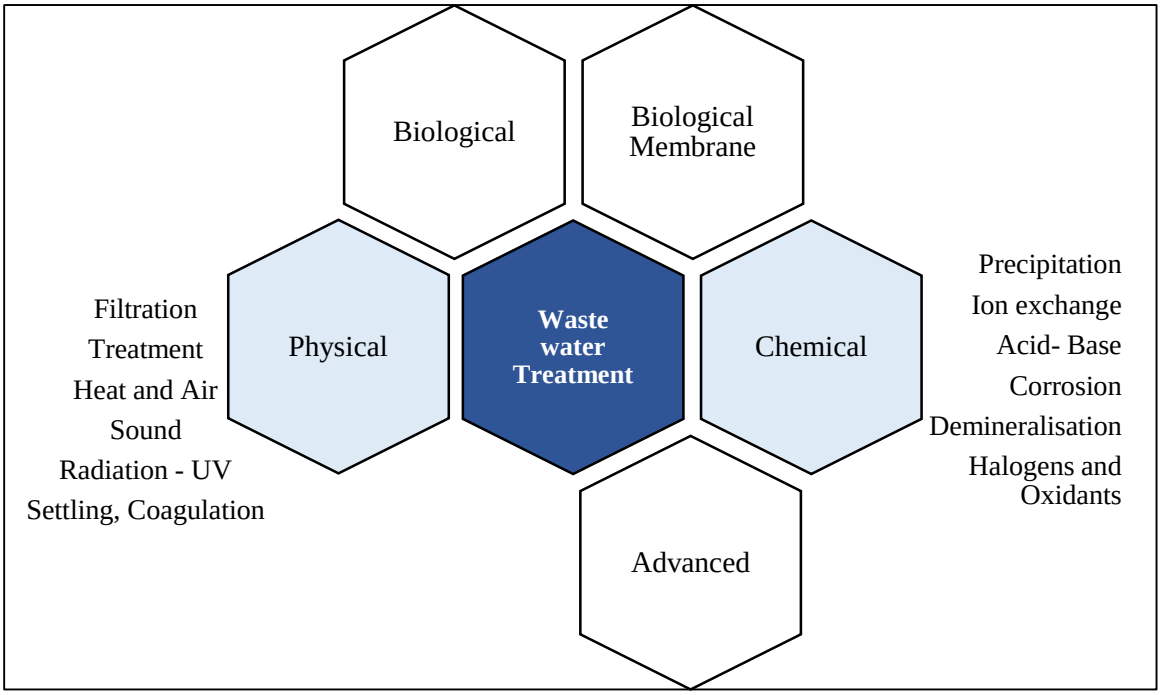

Figure 7. Keywords for the Patent Landscape.

A wide range of water treatment technologies exist. The patent landscape focuses on identifying environmental innovation in the four categories of wastewater treatment. The key reasons for selecting these categorisation are based on the application of technology.

3. Methodology

There is generally a lack of comprehensive data to assess innovation and its effect on the environment since a there is no direct correlation between the input and output of the invention. Patents have been widely used as an approximate measure of technological innovation, as the output of the patent is a result of an invention (OECD 2014). However, it should be noted that patents are not a complete representation of technological innovation since some inventions are not patented. Furthermore, rare examples of economically viable non-patented inventions have been identified in the past (OECD 2014). Patent data has several advantages in comparison to the alternative innovation measuring methods, as patents are based on an objective standard. The technology of the invention patented is specified clearly in the patent, and it must satisfy the three patentability criteria of the invention being new, non-obvious and useful (OECD 2014).

Patent Landscape

A patent landscape provides a list of critical patents identified in a specific technology and identifies trends associated with these patents. The patent data provides additional information related to the invention, such as the inventor(s), the applicants and the category of the invention listed under IPC. Various patent trends and analysis are extracted from all the information available in the patent. A patent landscape study is generally conducted to identify the key

players in a specific technology or an industry (Bergman and Graff 2007). Early stages of an investment in research and development is easily identified by tracking the patent activities, specifically categorised according to known competitors. The patent landscape study is an essential analysis method to build and shape a business plan that depends on innovative products (Bergman and Graff 2007).

Patent landscape dataset creation methodology

The method followed to generate a complete list of patents that form the patent landscape study is given below. The purpose of the patent dataset is to provide a thorough understanding of the inventions that were intended to be marketed (Bergman and Graff 2007).

a) Defining the focus of the patent search

The most vital step in a patent landscape analysis is to identify a specific technology area. Including very specific technical information in the search field for patents will result in a low number of patents, whereas not providing specific and clearly defined search criteria will result in a large patent dataset, possibly including a high level of noise in the result.

This patent landscape study highlights the innovation trend observed in wastewater treatment technologies. The technology areas focused for this study are biological, biological membrane, chemo-physical and advanced methods of wastewater treatment. The study focuses on identifying patented technologies and their utility that state a specific effect on the output of the patented invention. Patents that specify

environmental benefits as part of the output of the innovation are identified as patents related to environmental innovation, forming the patent dataset of the patent landscape study.

b) Patent search strategy

A technology matrix of the different technical fields was built. This information was used to build search strategies that are formed using keywords (specific technical terms used in patenting respective to the technology) and classification codes such as IPC and CPC. The patent search strategy used in this study is a combination of keyword and classification codes.

The search strategies included a combination of identifying keywords in title, abstract and claims of patents as well as classification codes specific to the technology areas. The searches were conducted on publicly available patent databases, such as Espacenet, Patbase (not publically available) and PatentInspiration (trial version). The patent searches were conducted in May and June 2016.

c) Keyword-based Searches

An exhaustive list of keywords were used to categorize the technology areas and capture the broad aspect of technology categories within wastewater treatment methods.

d) Classification Code-Based Searches

A patent examiner categorises each patent by list of classification codes during examination of the patent application. The various classification codes are: IPC, ECLA, USPC and CPC. A combination of IPC codes listed in Table 1 was used in the searches to capture a broad patent dataset relevant to the technology (WIPO 2016).

Table 1. IPC codes for search strategy

(WIPO 2016)

IPC	**Description**
C02F	Treatment of Water, Waste Water, Sewage, or Sludge
C02F 1/00	Treatment of Water, Waste Water, Sewage, or Sludge
C02F 3/00	Biological treatment of water, waste water, or sewage
C02F 9/00	Multistep treatment of water, waste water or sewage
C02F 11/00	Treatment of sludge; Devices therefor
C02F 103/00	Nature of the water, waste water, sewage or sludge to be treated
B01D	Physical or chemical processes | Separation
B01D 61/02	Processes of separation using semi-permeable membranes, e.g. dialysis, osmosis, ultrafiltration; Apparatus, accessories or auxiliary operations specially adapted therefore | Reverse osmosis; Hyper filtration;
B01J	Chemical or physical processes, e.g. catalysis; colloid chemistry; their relevant apparatus
A62D 3/00	Processes for making harmful chemical substances harmless, or less harmful, by effecting a chemical change in the substances

A combination of keywords and classification codes was used to generate a primary dataset, which resulted in an inclusive set of patents rather than an exclusive dataset (Bergman and Graff 2007). The extended keywords and combinations is represented in Appendix 1. These search strategies were further modified using specific keywords and classification codes to identify patents in specific technology areas from within the primary dataset. Patents not related to the four technology areas were removed from the patent dataset.

Patent categorization

As discussed in the earlier section, patent families are considered to be an alternative representation for patents filed in other countries for the same invention by an inventor. A study of the activity of each individual patent family provides market and manufacturing strategies of the inventor. It is possible for a single patent family to include multiple patents in a single country, such that the patents in that family protect a different features of a single invention.

One patent per family, which represents multiple patents with the same priority numbers, was used for the patent landscape study. Patents having extended families such that patents are related through one or more priority number were placed in their respective families, if the patent was found relevant to the scope of the study. The reason that one patent per family member was selected for the study is because the extended families include certain patents that are of low applicability to the technology area of interest. The final dataset was obtained after identifying one patent per family and listing patents relevant to the four technology areas.

Patent Study

The relevant patent dataset was analysed by studying the claims and the respective description section in the patent. Based on the inventive method, any environmental benefits mentioned in the patent description as part of an advantage were identified. This was critical to identify as the study is based on the impact of environmental innovation. Where patents do not specifically state any environmental impact in the description, the advantages of that particular product are mapped with information available through the website of the patent assignee or other publications.

Patent landscape analysis

After conducting the searches, the final patent dataset is used to conduct various trend analyses. The patent filing trends of the relevant patent families were further analysed for this patent landscape study. An overall patent filing trend of the relevant patents was analysed, and further analysis included identifying key players, technology trends and geographical distribution. Patent filing trends in Hungary and key players within the country were identified.

Overall patenting trend was conducted by identifying the annual number of new patent families in the wastewater treatment industry. The environmental innovation in the field of wastewater treatment industry was identified.

Technology trend conducted by categorising patent families between the four technologies to show the changes over time. The technology trend was also

conducted using IPC classification to show the distribution of patents within the respective core patent classification.

Geographic distribution was identified by categorising the patent publication trends in countries that were considered important players in patent activity in the field of wastewater treatment. The publication trends indicate the countries of interest in terms of innovation, manufacturing or marketing.

Trends in Hungary indicates the overall patent filing trend compared with countries in the same range of per capita nominal GDP. The environmental innovation trend was also identified for patents in Hungary. Also, an indication of the key players and the distribution of patent filings by SMEs and large enterprises was conducted.

Patent Landscape Limitations

Technology and definition - Varying terms and definitions are used to describe the same technology in patents. This is an attempt for the patent to be less obvious to competitor and not disclose entirely the specifications and benefits of the patent after the patent application is published.

Data source - This study was conducted using free patent databases. Lack of updated information regarding patents and limited availability of some of the features available on the database were some of the limitations for this study.

Search criteria - The keywords were formulated in English. It was worth nothing that a majority of the patent filings are captured either through one of the patent family members filed in English or based on a machine translation of the patent. National phases have the possibility of a number of patents being filed in a regional language instead of English. Patents in regional languages are not captured in the patent dataset.

Time-lag - Patent publications are typically first published having a time lag of up to eighteen months or more, depending on the patent office. There is a possibility that the most recent patent applications including recent developments in technologies is not captured.

Patent applicant name – Many publications are first listed under the inventor (s) name (s) and not under the organization. Additionally, changes in the patent ownership after mergers and acquisitions are not always updated in the patent database. Spelling errors in applicant's name or changes in the applicant's names are often delayed or not updated in the database.

Association with Study Participants

I had a pre-existing association with five of the interviewees, all of whom I have worked with as a patent professional. These interviewees also forwarded the survey questions to their colleagues and acquaintances working in the patent industry. Due to their perseverance I was able to receive sufficient responses from the survey.

I did not have any pre-existing association or acquaintance with any of the other participants of the study.

Research Methods

Research methods included interviews, site visit, discussions with wastewater treatment industry professionals, surveys and patent landscape analysis. Each research method provided better insight and served as a check on others.

Site Visit and Industry Professionals

A part of the study was to visit at least one SME based in Budapest that is actively involved in consulting and providing innovative solutions for wastewater treatment. The site visit provided a chance to understand the functioning and organizational structure in an innovation driven SME. The visit included discussion with the innovators, management and decision makers. A

tour of the facility including the lab provided better insight into the process used in research and development within the SME. The site visit was conducted in May 2016.

A second interview was conducted with a professional working in Budapest in the same sector. He is associated with a start-up. A telephonic interview provided insight into the functionalities and barriers faced by start-ups in this sector.

The site visit and the discussions with professionals in the wastewater treatment industry in Budapest provided adequate information for me to research the technological advancement in wastewater treatment industry. It also formed the basis for my patent landscape search. I was able to classify the technologies based on discussions with these professionals. Information gathered from these discussions was helpful in formulating questions to conduct interviews with patent professionals.

Interviews

Interviews were conducted with patent professionals with an average work experience of 6 years in multiple industries. I was able to contact and conduct telephonic interviews based on my professional experience. The interviews included questions about innovation activities, links to environmental policies, the environmental effect of the innovations and its possible reforms. Since the interviewees were my former colleagues, conducting the interviews over Skype made it possible to include several open-ended questions, and to acquire several valuable personal opinions at a fairly high response rate.

Survey

The questions used in the interview were sent as a survey through these interviewees to their current colleagues and other patent professionals in their networks. The questions used in the survey were derived from the interviews conducted with the patent professionals. I used twelve objective questions and three subjective questions in the survey. This distribution was used to ensure the survey had a higher rate of response taking into consideration a reduced time to answer the questions. I received thirteen replies from the survey and the ten complete survey answers were used to represent the outcome of the survey. The surveys were conducted between June and July 2016.

Limitations

The study focuses on the broad structure of wastewater treatment technology and does not focus on specific advancement of any product or method associated with water management, desalination or water reuse. A broad understanding of the wastewater treatment industry applicable in industrial and municipal facilities is used for this study.

4. Results

Patent Landscape

The results from the patent landscape in the wastewater industry and the associated patent activities and trends are listed in this section.

Each search string used keywords and/or appropriate IPC codes resulting in relevant individual technology patents. It is highly probable there are overlaps between technologies and unavoidable "noise" is present in the data. The results have been sorted to represent one member per family. Within the timeframe of the study and using prior knowledge of conducting patent landscapes, the effect of the noise on the patent dataset is minimized as much as possible by refining the patent dataset with CPC, ECLA and US classification codes. The patents were further analysed to identify trends in each technology area over time and geographic interests.

Technology search strings were formed for each of the four technology categories in wastewater treatment to create the patent dataset for the study. The categories are biological, biological membrane, chemo-physical and advanced method technologies. The technology categories should not be taken to imply that other technologies are less critical for the water treatment system, or that there is no scope for innovation in them.

The results of the patent landscape suggest a rising patenting activity in wastewater treatment industry. The global patent applications filed between 1991 and 2015 for wastewater treatment is shown in figure 8.

The timeline shows a steady progress in the patenting activities till 2006 and a drastic increase since 2008. The numbers in the figure represent the annual patent applications filed in the patent offices worldwide, one member per family. The actual number of granted patents is much lower due to various reasons ranging from and not restricted to withdrawal, rejection to grant patent and failure to respond to office action or pay maintenance fee.

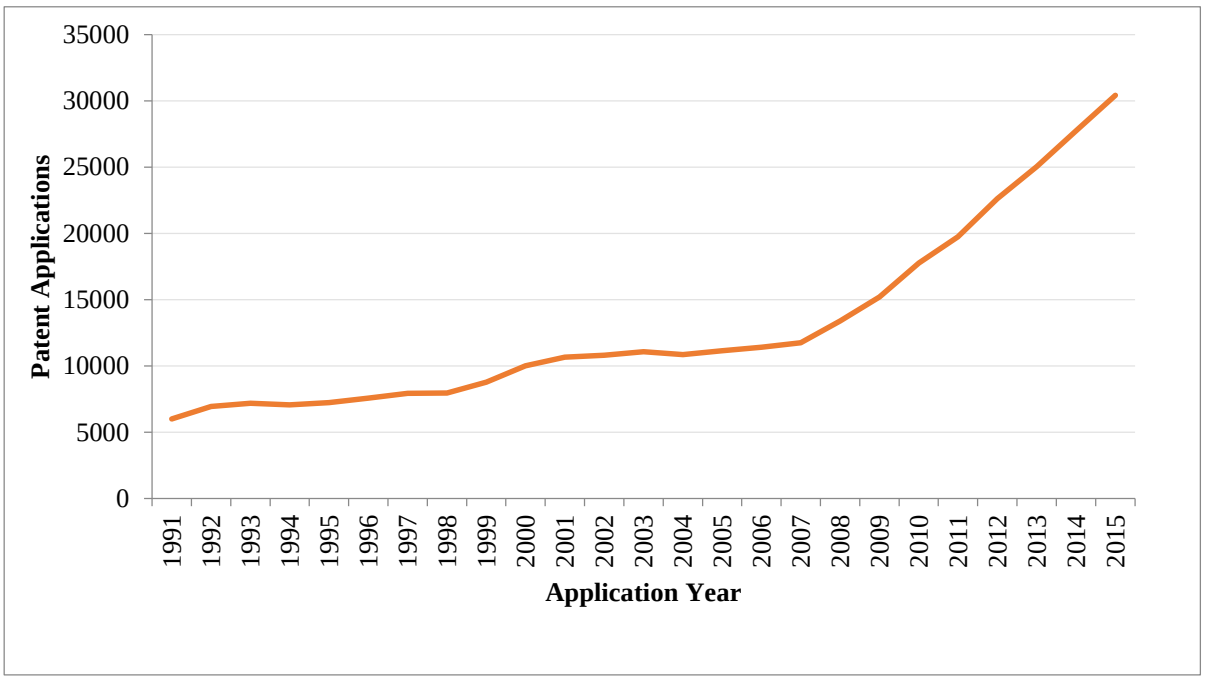

Figure 8. Timeline of patenting

(Wastewater treatment industry)

Technology distribution in wastewater industry

The next stage of the landscape study is to identify the technology trend in wastewater treatment since 1991. All the patents were further categorized into the following four technology areas:

1. Biological Wastewater Treatment
2. Biological Membrane Method for Wastewater Treatment
3. Chemo-physical Method for Wastewater Treatment
4. Advanced Methods for Wastewater Treatment

Technology Trend

The landscape results shown in Figure 9 suggest a steady growth in biological wastewater treatment since 1991, whereas biological membrane, chemo-physical and advanced methods of wastewater treatments have increased rapidly in patenting activities.

A large number of patents were identified as having a combination of different wastewater treatment technologies. This patent data is represented as an overlap area. The figure shows that an increasing number of patents since 2010 include a combination of two or more methods in wastewater treatment suggesting integration of wastewater treatment technologies.

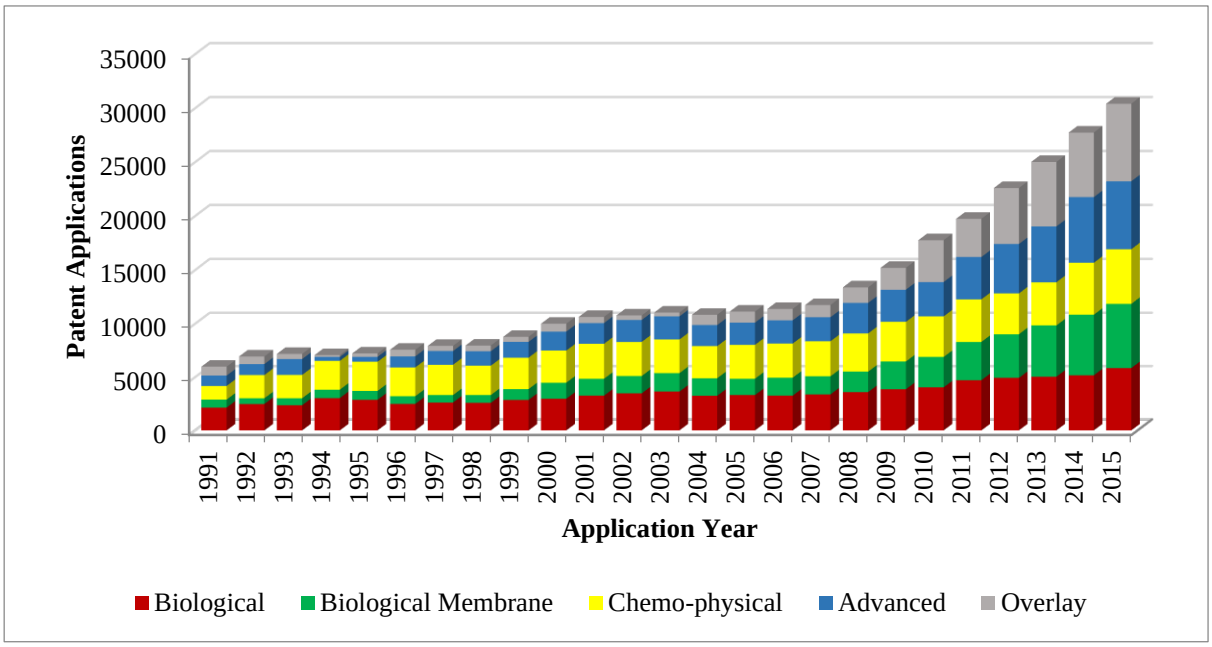

Figure 9. Technology trend

(Wastewater treatment since 1991)

The results of the patent landscape shows that the technologies invented in wastewater treatment are not mutually exclusive. A single patent family is clearly included in multiple technology areas.

Technology Overlay

A visualization indicating the relationship between the technologies categorized is shown in Table 2. Patents corresponding to the relevant technologies between 1991 and 2015 is represented along the rows and columns to highlight their overlap.

It appears from the table that advanced and biological methods have the highest overlap in the technologies, showing the development and innovation is built upon the known and successful technology within the sector. The next most relevant overlap is seen between biological and chemo-physical methods of wastewater treatment followed by the use of biological membrane with biological methods of wastewater treatment.

By identifying the overlap of the technologies, it is easy to identify the most researched and developed technology in the wastewater industry since 1991. The lower number of overlaps amongst other technologies either represent a lack of integration between the technologies or an early stage of research to integrate the two. Very few patents were found to overlap amongst three technology areas. It appears, advanced methods is highly researched and integrated with biological and biological membrane treatment methods.

Table 2. Patent family technology overlap

(Wastewater treatment (1991-2015)

	Biological	Biological Membrane	Chemo-physical	Advanced
Biological		4271	5017	6382
Biological Membrane			749	1653
Chemo-physical	291			1908
Advanced	642			

IPC – Technology Composition

IPC is generally used for patent examination and analysis by patent office examiners and analysts respectively. IPCs are often also used to identify interesting changes and trends within a specific industry. Table 3 lists the distribution of the most commonly used IPCs to classify patents in wastewater treatment since 2011. Patent families were identified based on the core invention associated with the IPC.

Table 3. Patent distribution according to IPC Code for wastewater treatment (2011-2015)

IPC	Description	Patents
C02F	Treatment of Water, Waste Water, Sewage, or Sludge	2510
C02F 1/00	Treatment of Water, Waste Water, Sewage, or Sludge	1687
C02F 3/00	Biological treatment of water, waste water, or sewage	605
C02F 9/00	Multistep treatment of water, waste water or sewage	1347
C02F 11/00	Treatment of sludge; Devices therefor	739
C02F 103/00	Nature of the water, waste water, sewage or sludge to be treated	164
B01D	Physical or chemical processes | Separation	1562
B01D 61/02	Processes of separation using semi-permeable membranes, e.g. dialysis, osmosis, ultrafiltration; Apparatus, accessories or auxiliary operations specially adapted therefore | Reverse osmosis; Hyper filtration;	948
B01J	Chemical or physical processes, e.g. catalysis; colloid chemistry; their relevant apparatus	1265

The IPC classification distribution search was conducted between 2010 and 2015 due to the large number of patent families in the patent dataset. Splitting the IPC into its core classifications provided too many categories and spread the patent distribution. Also, this data represents the most recent patent filings in the technology areas.

Figure 10 shows the categorization of IPC used in wastewater treatment patents since 1991. The distribution of the IPC classification C02F and B01D signify the majority of the patents in this field. During the analysis, it is observed that most of the applications have an overlapping IPCs in a single patent application. The broad classification of the IPC codes made it possible to gauge the patent trend since 1991.

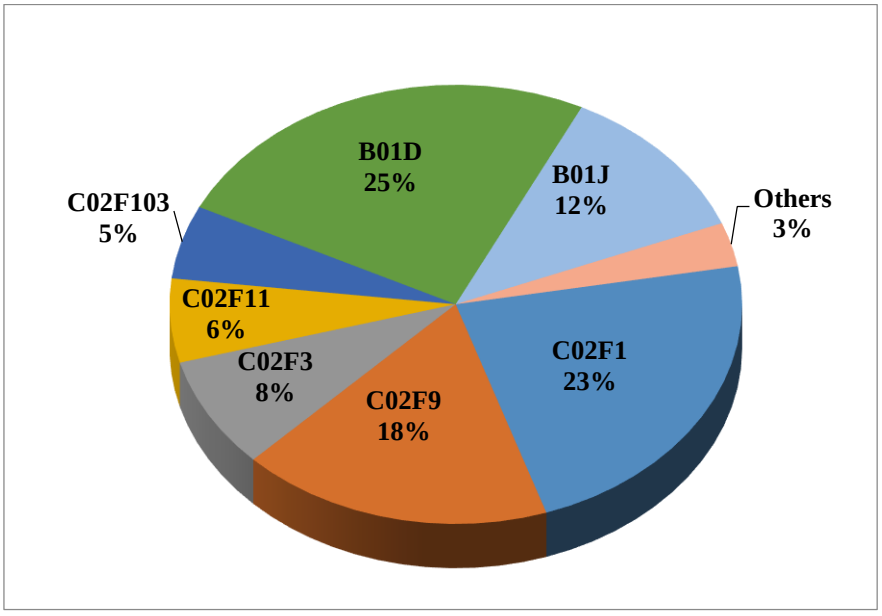

Figure 10. IPC distribution

Wastewater treatment patents (1991-2015)

To better understand the technology trends, a representation of the IPC codes of patent families is shown in Figure 11. The use of IPCs as a core classification for an invention in the patents

since 1991 can assist in identifying the change from the conventional biological treatment methods. An increase in the use of B01D after 1995 reflects the emergence of the separation process technologies and higher number of patents families filed under this IPC.

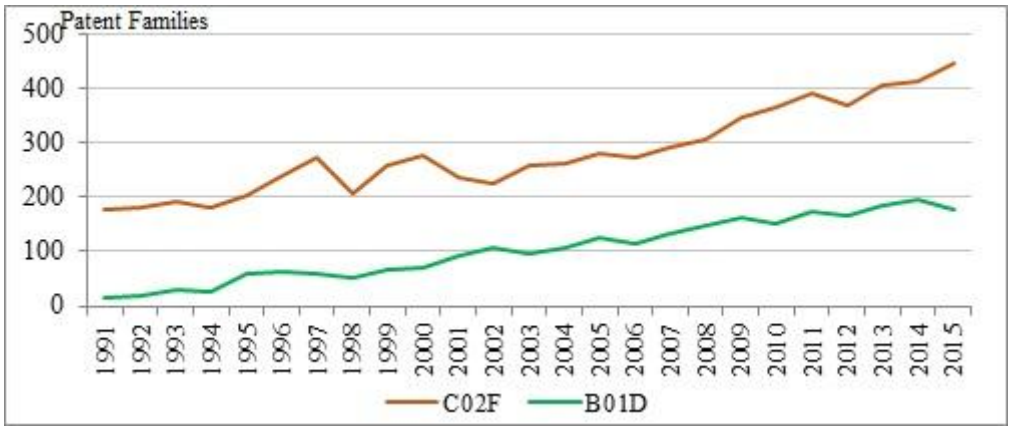

Figure 11. Core IPC classification of patent families

Wastewater treatment (1991-2015)

Geographic Distribution

The number of patent applications filed in each country represents either the patent interests from the location of innovation or a marketing and manufacturing strategy. The top ten countries filing patents in wastewater treatment were identified between 2011 and 2015. Due to the large number of patents in this industry, the number of years was reduced to the most recent five years of patent filings to better understand and analyse the trends in wastewater treatment. Figure 12 shows the total patents filed in countries most active in wastewater treatment innovations between 2011 and 2015.

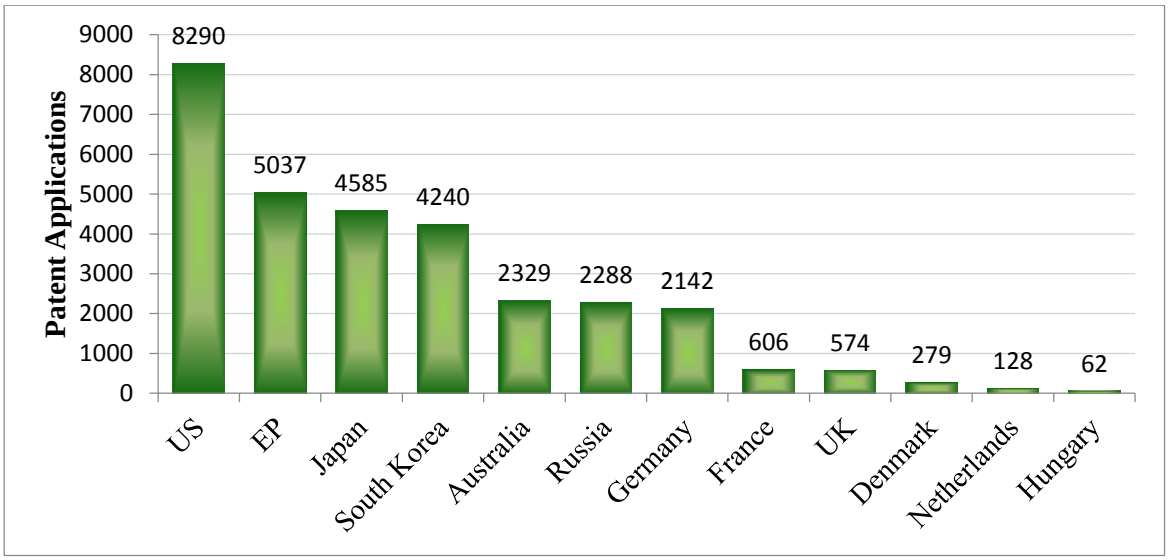

Figure 12. Geographical Distribution

Wastewater treatment (2011-2015)

The trends indicated in Figure 12 also include patents filed in EP and Hungary. Patents identified under EP represent the European patents granted by the European Patent Office. Patent identified in Hungary will be used for further analysis for patent trends in wastewater treatment industry. USA is leading in the overall patent activity in wastewater treatment industry followed by Japan and South Korea.

Australia known for dry conditions appears to have a high level of wastewater treatment technology activity. Russia's patent activity signifies a high level of expertise in the field, possibly associated with investment or upgradation in agriculture, irrigation or the oil and gas industries. It appears, the patent activities are representative of marketing interests in these countries as the priority countries of most of the patents do not represent Australia and Russia as the origin. They have been filed in in these jurisdiction in the National Phase filing. Countries

like The UK, Netherlands, Germany and Denmark are well known for their innovative interests and contribution in wastewater treatment industry and represent the innovation of technologies.

Figure 13 illustrates the technology trend within the top countries and EP. A technology distribution in these countries show the patent activities within the four technology areas that have been identified earlier. By identifying the patents in each country for a particular technology area, it is clearer to understand the global distribution and competition in different area of wastewater treatment.

It is evident from Figure 13 that the US is leading in innovation in three areas in wastewater treatment, however, Japan has a higher innovation trend in the biological membrane treatment. European patents show the next best participation in patent activity in the technology areas. European patent activity is subdued, as it is depicting either patents at the European Patent Office level or via individual national patent offices. South Korea is identified as the next best competitor in the field of chemo-physical treatment. It appears to represent a "research flow" from countries such as US and Europe into the East in developing countries in terms of technology commercialization. This process is likely to continue occurring into the future.

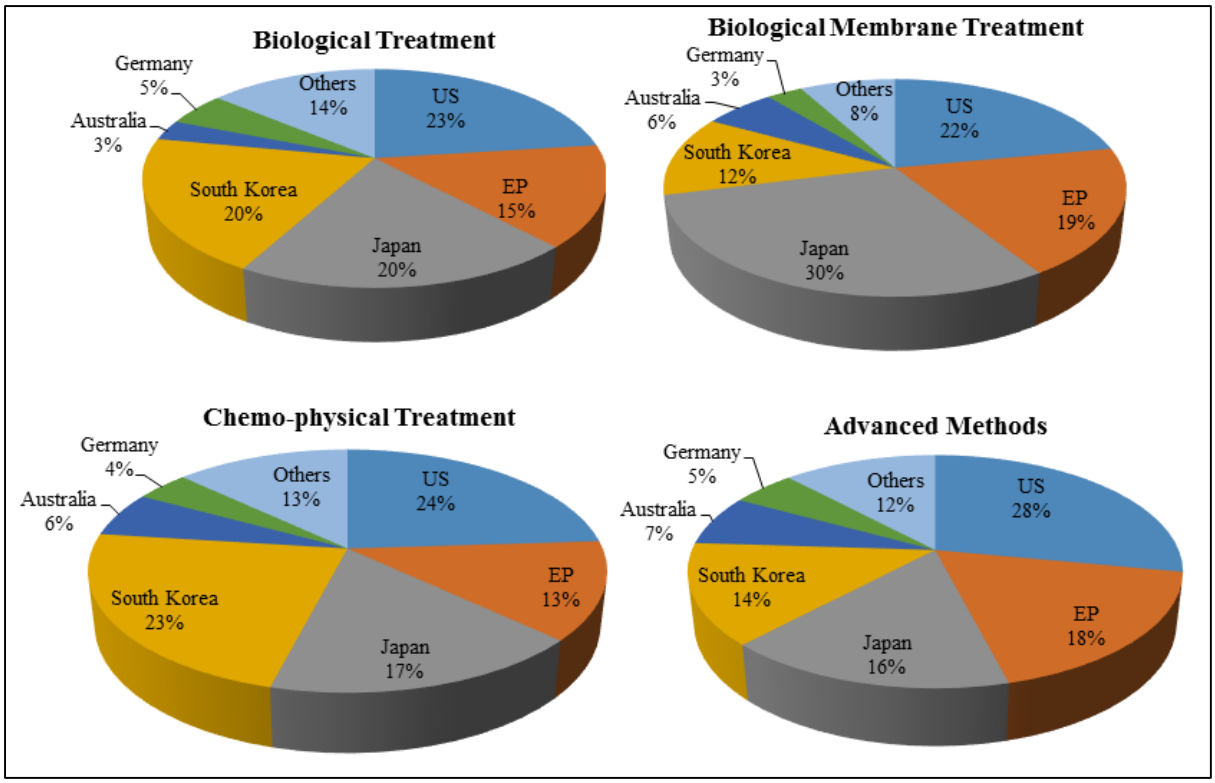

Figure 13. Patent Technology Areas

Wastewater treatment (2011-2015)

Patent Trend Analysis in Hungary

In 2015, the World Bank placed Hungary in the 53rd position according to the per capita nominal GDP. The other countries listed having similar GDP and the patent activities in wastewater treatment are shown in Table 4. The wastewater treatment patenting trends shows a progressive performance compared to the countries having approximately the same per capita nominal GDP.

Table 4. World Bank per capita nominal GDP, 2015

(Countries ranked 50 – 56th according to)

World Bank Ranking	Country	Per capita nominal GDP (US$)	Patents filed (2000-2015)
50	Panama	13265	24
51	Argentina	12622	547
52	Poland	12494	1418
53	Hungary	12252	877
54	Venezuela	11936	No data found
55	Croatia	11548	224
56	Equatorial Guinea	11056	No data found

The overall patenting trend in Hungary since 1991 is shown in Figure 14. A sharp rise in 1995 appears to show the interest to heavily invest in wastewater treatment in the country. A gradual decrease in the filing in the late 90s is possibly due to the global economic crisis experienced at that time. A gradual and steady rise of patenting in this sector since 2002 shows the interest to pursue technological advances. Additionally, various policies that have come into effect since joining the EU has also prompted for higher patents to be applicable in Hungary in order to ensure efficient treatment processes by introducing the technologies through patents.

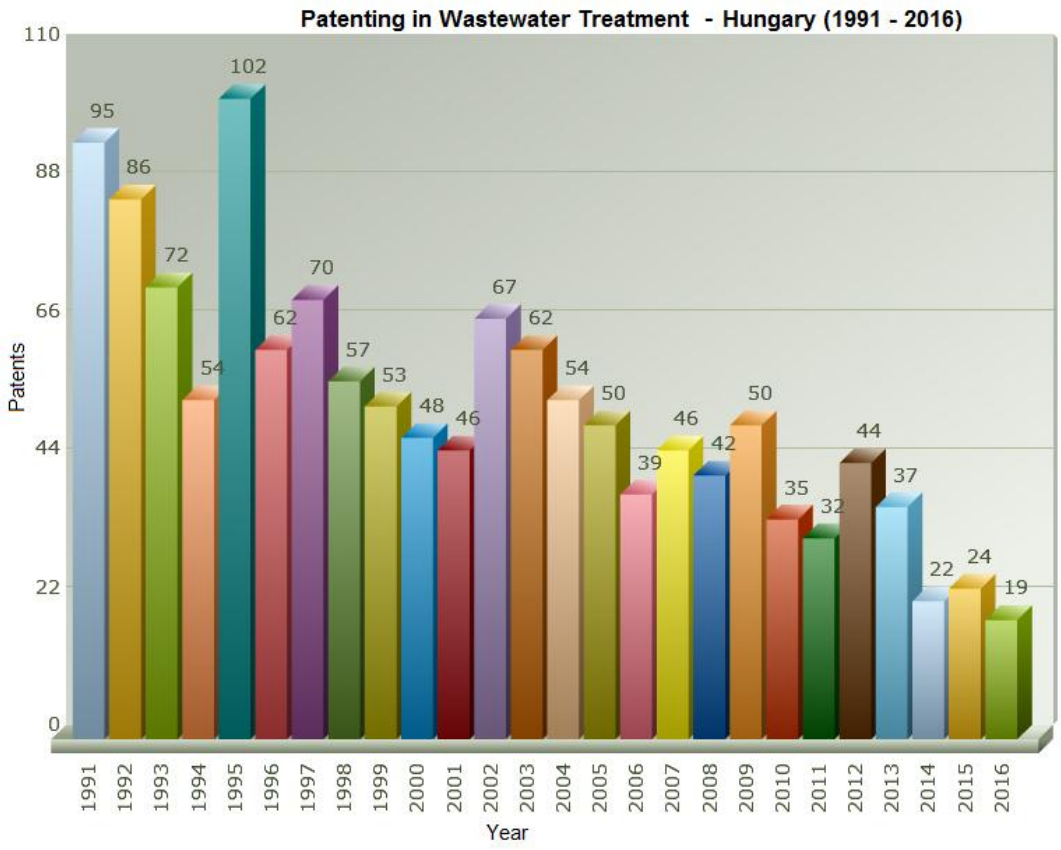

Figure 14. Patent Trend – Hungary

Wastewater treatment industry 1991-2016

To better understand the trends and interests of patenting in Hungary, environmental innovation in the patents were identified. Figure 15 shows the environmental innovation in the patent applications filed in Hungary. A brief study of the patents was conducted to identify specific environmental benefits through an inventive process or device. It is observed the patenting activity in environmental innovation is gradually increasing since 2000.

This analysis is not a complete indicator of the environmental innovation, as some patents do not always state any environmental impact of the patent. Additionally, this environmental innovation trend analysis is restricted to patents and is not a complete indicator of environmental innovation in Hungary.

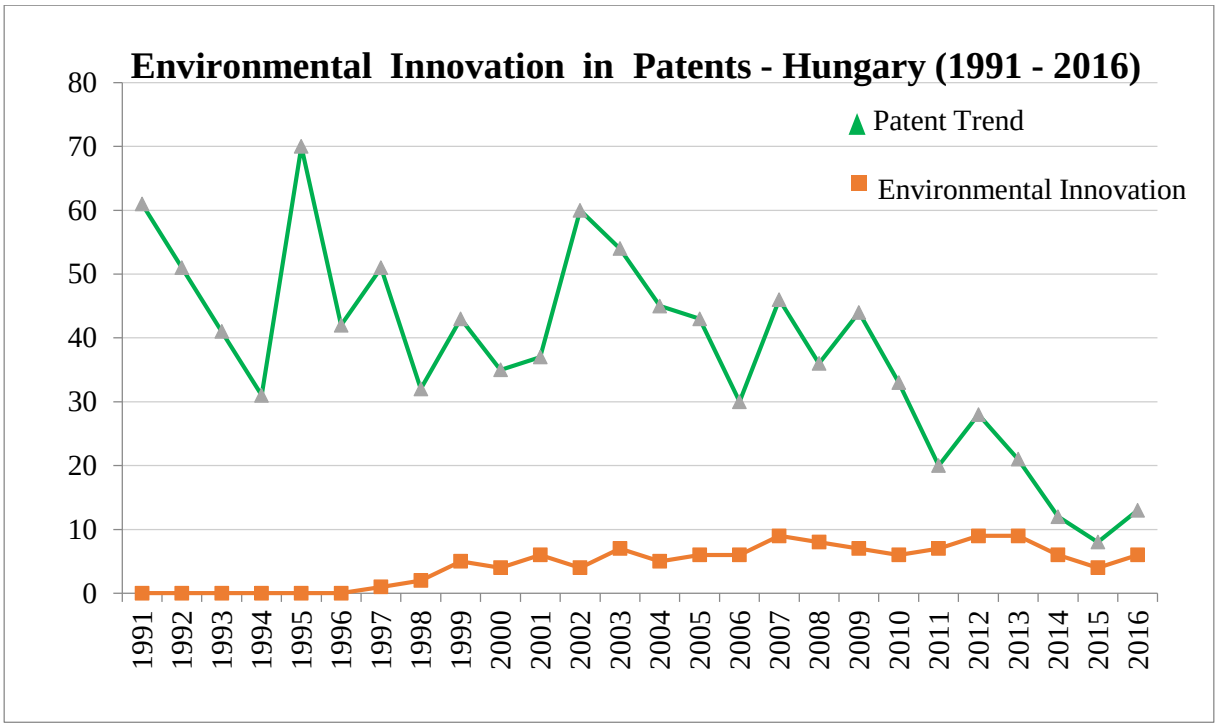

Figure 15. Environmental innovation

(Patents filed in Hungary 1991-2016)

In order to understand the influence of an organization's priorities in innovating, it is important to identify the distribution of patent activity by large and small entities. A list of the assignees including both SME's and large enterprises' patent filing trends in Hungary has identified in Figure 16. It appears that Rohm and Haas has the highest number of patent families listed under its name in Hungary, however, the last publication by this company was in 2000. It appears that a majority of the patents priority filings were in the US and Hungarian patents were filed to gain early entry into the market. The patents filed by Rohm and Haas are categorized in the chemo-physical treatment under the classification of this study. The more recent players since then have shown more interest in environmental innovation, as opposed to the patents that were filed only to secure the market space. Some of the most innovative patents have been filed by start-ups and SMEs in the advanced technology sector.

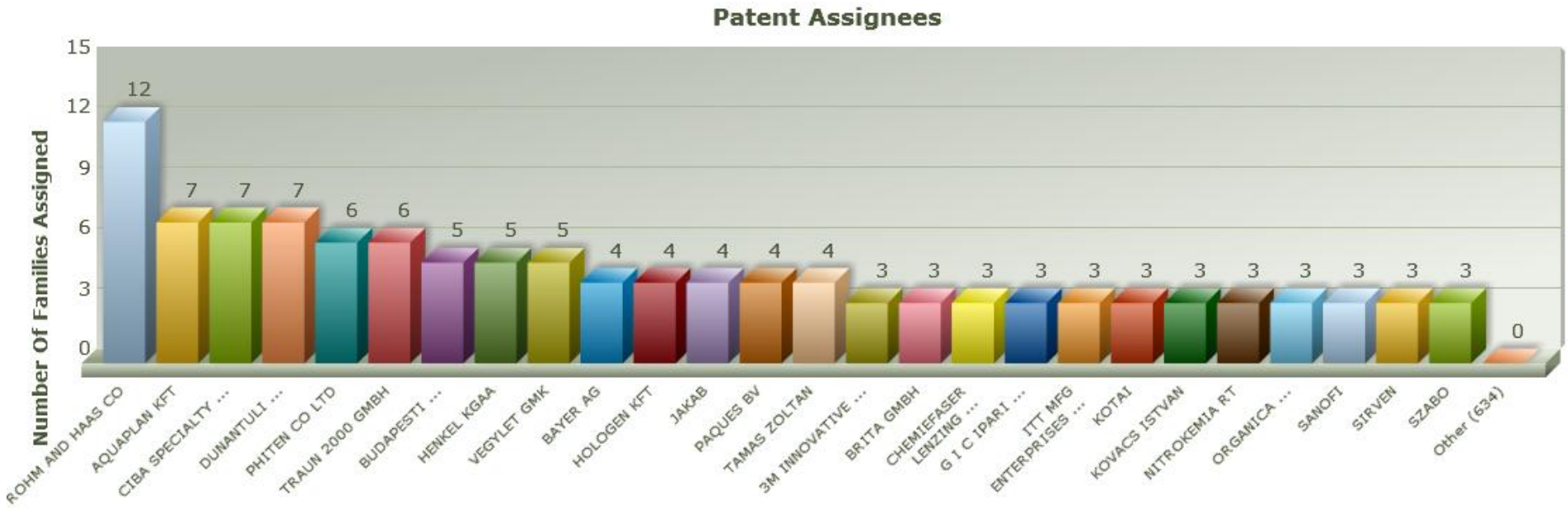

Figure 16. Hungarian Patent Assignee

Wastewater Treatment (1991-2016)

Further analysis of the distribution of the patent activities in Hungary was conducted, Figure 17 shows the pattern of environmental innovation in patent filings between the large enterprises and SMEs since 1997. The study identifies large enterprises dominate the patent activities. However, it is observed that since 2010, the patent filings trend show an increase in environmental innovations by SMEs. The data is represented from 1997 as environmental innovation in patents for wastewater treatment in Hungary have only been observed since 1997.

Patent data analysed form figure 17and 18 shows patent filings from Organica and Bioplus have a common inventor who also has patents filed under his name as an inventor. Upon further analysis, it appears, that Bioplus is comparatively a recent start-up and the inventor has vast experience in this technology. His name appears as an inventor in one of patents published in Hungary in 1991. The inventor is able continue to innovate and build products based on his previous experience and knowledge. This is the trend usually observed when inventors with knowledge are encouraged to experiment and research, and an innovative product is delivered as the end result.

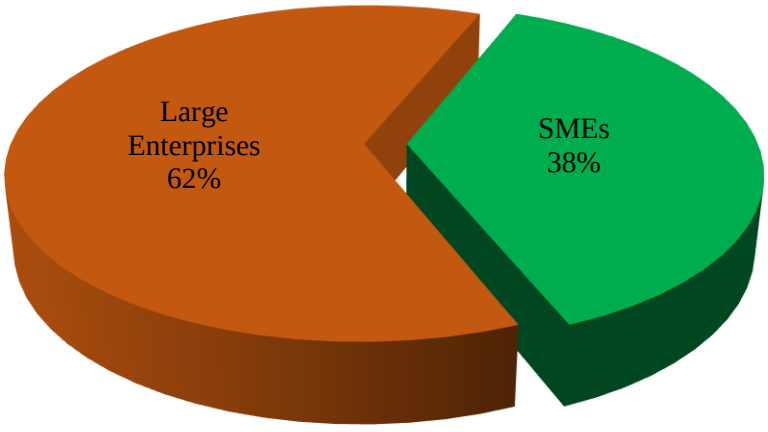

Figure 17. Organisation Segment

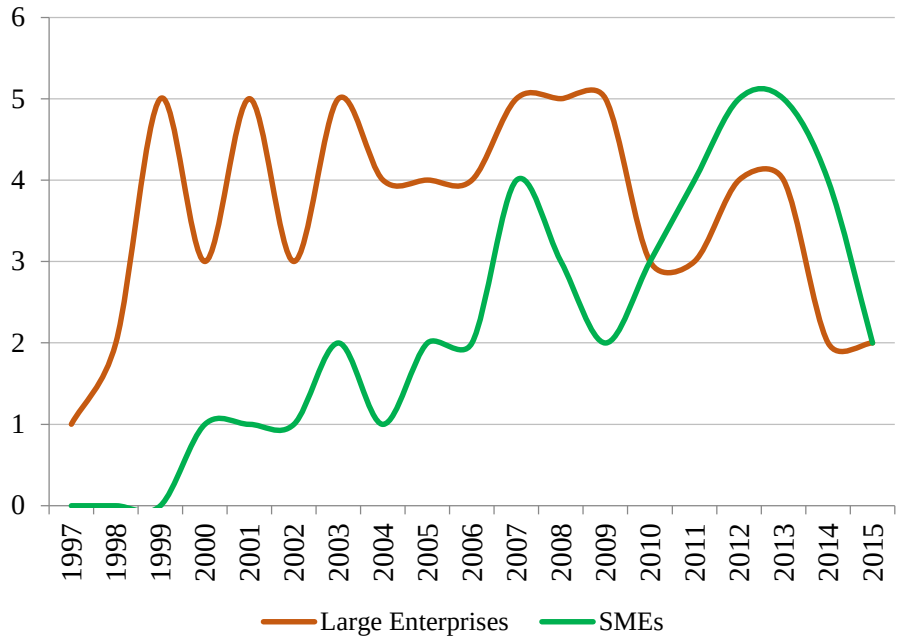

Figure 18. Environmental innovation (SME and Large Ent.)

Site Visit

As part of the study, I visited one of the SMEs based in Budapest providing innovative solutions for wastewater treatment. This company has also successfully patented and commercialized several processes to convert sewage sludge, organic solids and biomass to compost, nutrients and biogas.

Discussions with the team members of this company highlighted that innovation is a key driver of the company. While innovation is the focus of the organization, it is also a challenge to manage growth and successfully reach a global market with their products. This company

adapts the process of innovating within the company. The innovation is based on previous knowledge, experience and market understanding.

The team members also identified the importance of capturing and producing environmentally friendly by-products from domestic and industrial waste in order to align the company with the EU regulations and the Hungarian policies. Hungary became a part of the European Union in 2004, as a result it has implemented the EU Water Framework Directive (EU Commission 2015). The conditions of the Directive, decree 28/2004 (XII. 25) of the Hungarian Ministry for Environment and Water, categorised the receiving bodies and the suitable waste limits of wastewater treatment plants (WWTPs) into separate categories as shown in Table 5. Since 2004, existing treatment plants have been upgraded to optimize operations to match these standards. The new treatment plants operating within the country are comfortably meeting the prerequisites of the Directive.

Table 5. Emission Criteria

Category → Limit. parameter ↓	I. Lake Balaton and its catchment area	II. Other sensitive receiving bodies	III. Intermittent and ephemeral streams	IV. General receiving body
COD (mg l ^{1})	50	100	75	150
BOD_5 (mg l ^{1})	15	30	25	50
NH_4-N (mg l ^{1})	2	10	5	20
Tot. Inorg. N (mg l ^{1})	15	30	20	50
TN (mg l ^{1})	20	35	25	55
TP (mg l ^{1})	0.7	5	5	10
TSS (mg l ^{1})	35	50	50	200

During the visit, it was observed the research and development team members have been working on several innovative products and processes to recover useful nutrients from sludge. The lab visit provided an overview of the methods used to experiment new environment friendly recovery methods from sewage and sludge. Apart from studying new methods to

extract useful nutrients from the sludge, the general awareness related to health of the human and non-human population affected by the continuous use of environmentally damaging products and the loss of useful nutrients in wastewater was also discussed.

The company currently holds 4 published patents/applications and is one amongst the 189 SMEs selected in the most recent round of Horizon 2020 held by the European Commission in May 2016. Horizon 2020 is the largest EU Research and Innovation programme with approximately €80 billion of financing in 7 years (2014 to 2020). This funding will also provide an opportunity to attract private investment for successful projects (EU Commission 2016). Applicants from 26 countries applied for funding in various categories. A total of 53 companies had applied from Hungary and only 5 have been selected in the latest update. This company is the only applicant from Hungary selected in the "Societal Challenges" category under 'Climate Action, Environment and Raw Materials'. The company is innovating valuable product recovery from sewage and sludge. Programs such as the Horizon 2020 provide an excellent platform to gain visibility and interests of investments, especially for SMEs by driving innovations and discoveries from a lab to the global market.

The team members stated that recognition at a large forums, such as the Horizon 2020, is a crucial support for SMEs to enable growth and progress. Programs such as Horizon 2020 that focus on challenges such as climate change and environmental impact encourage SMEs and inventors in particular, to seek feasible solutions. It's a confirmation of the fact that, though the competition is tough with the large enterprises, support and reassurance through such forums can encourage and assist in development of feasible solutions from many more SMEs.

Interviews

Start-up

I had a second interview with a professional working in a start-up based in Budapest that converts wastewater and other organic material into products for sale. Open-ended questions were asked to the interviewee regarding the functioning of the start-up and the challenges faced to enter the market. It appears from the interview that innovation is driven by the founder of the company based on his experience and credibility, both in the Hungarian and global market. The Hungarian government also promotes this start-up and provides higher visibility to the company at a regional and global level. The founder has several patents filed under his name in Hungary as the primary inventor and as well as a secondary inventor.

The interview reinstated that the wastewater treatment industry is mature and appears difficult to innovate in a disruptive manner, largely due to the investment costs. Marketing in developed country is a challenge since the market is well established and customers are not keen to enter a contract with a new service provider. The high cost incurred in switching from a traditional to a new service provider is a deterrent. In contrast, developing countries are interested in low cost services to install and operate new systems. Both cases are a challenge for a start-up that relies on selling innovative products at a profit. The innovation trend has proved the useful products generated from the treatment has increase over the years. Recycled water from the WWTP is now proven safe to use for agriculture and industrial purpose.

Discussion related to the environmental policies that impact the progress of innovation in the start-up revealed a subsidy for research and development in countries is an incentive to explore and expand market. Additionally, Hungary's outreach to promote innovative organization in the country is a motivation to small enterprises and start-ups. The discussion also revolved around other awards, endorsements and funding programs, such as the Horizon 2020, which are an incentive to small scale companies. The interviewee also mentioned that mandating the use of recycled water in industries and agriculture will provide greater opportunities for start-ups and SMEs.

Patent Professionals

Interviews were conducted with patent professionals having an average work experience of 6 years in multiple industries. I was able to contact and conduct telephonic interviews based on my professional experience. The interviews included questions about innovation activities, links to environmental policies, the environmental effect of the innovations and its possible reforms (the questionnaire is provided in Appendix 2). Since the interviewees were my former colleagues, conducting the interviews over Skype made it possible to include several open-ended questions, acquire several valuable personal opinions at a fairly high response rate.

The questions were also sent out as a survey through these interviewees to their current colleagues and associated patent professionals. The ten best available survey answers are used to represent the outcome of the survey. The interviews and survey were conducted in June 2016.

The interviewees and survey shared similar opinions towards the concept of environmental innovation and the impact of patents on the environment. The coding of the interviews and the results of the survey is provided in Appendix 3. The five interviewees also provided better information on the reforms and the future path of tracking environmental impacts from patents. The answers from the surveys are not as explicit as the interviews (the results of the survey are represented in Appendix 4). The best available categorization of the answers from the interviews and survey is provided in Table 6.

Innovation:

Four respondents from the interview and eight from the survey mentioned that innovation that leads to patents are a result from further advancement from current job, or a research and development project or a result originating from an idea or concept. Twelve responses agreed to the fact that patents that build on previous inventions by the same organization and are patented based on a competitive market. The respondents agreed to the inventors having significant prior knowledge and information regarding the competitors provided by the inventors and the priority for patenting is to either market or licence the patent.

The interviews also revealed that patents are more widely referred in securing venture capital funding. Two respondents in the interview specified that investments are offered to inventors and organizations that have invested in patents to protect their inventions. The funding does not depend only on patents around 'ground-breaking' technology but the fact that the inventors have invested in the protecting the invention. Also, licensing agreements are generally used to coordinate the use of the patents with multiple suppliers.

Environmental Innovation:

All the respondents agreed that the inventors provide all the advantages and disadvantages of the invention during the patenting process. However, only two responded saying that environmental benefits are mentioned as part of the disclosure only if it's a significant impact.

Six of the respondents replied saying there are no specific methods to capture environmental impacts of an invention when analysing its patentability. The remaining nine respondents were not aware of any existing methods to determine an invention's environmental impact. All the respondents stated low or no usage of the IPC classifications to identify patents referring to mitigation or adaptation against climate change in their line of work.

When asked about the awareness of the inventions classified under the environmental impact and their level of experience with such inventions, all except one of the respondents stated their relevance as medium or low. Although, eleven of the respondents stated that it is important to appropriately categorize the patents under the correct classification in order to identify the environmental impact.

Environmental Policies

Though all the respondents are patent professionals, their level of interaction with environmental policies is rated as minimum to no interaction at all. However, all the respondents agreed to associate the environmental impact of the invention with the appropriate environmental policy. Majority of the respondents stated that the inventors of the patent should

take the ownership of the environmental benefits of the invention and whether it adheres or surpasses the requirements of the environmental policies.

The interviewees provided additional information such as the requirement by the inventors to provide examples, results of successful tests and report the benefits of marketing the patent. The survey results suggested that the knowledge and reference to the environmental policy governing the technology should be referred to in the patent, or an associated reference be provided to better understand the impacts of the invention.

Reforms

All the respondents agreed on the need for reforms in conveying the environmental impact of an invention. Nine of the respondents stated that the environmental impact of a patent should be conveyed using a tool that suggests its precise benefits or damages, while the remaining six responded that the possibility of making available more appropriate information with the patent and improved classification systems through the patent offices will help identify the environmental impact of the patent. During the interview, three respondents were more specific about the tools that should be introduced to measure the environmental impact of patents, comparing it to the success of using carbon reporting or measuring carbon footprint.

Table 6. Interview Result Categories

Categories	**Interviews**
Innovation	1. Internal driven motivation for research within organization 2. Marketing and licencing 3. Competitive knowledge and interest
Environmental Innovation	1. Build awareness 2. Increase use of appropriate classification 3. Specify environmental impact of the innovation
Environmental Policies	1. Link associated environmental policies 2. Increase ownership of inventors to align with environmental policies
Reforms	1. Develop tool to measure environmental impact of patent 2. Associate IPCs with relevant environmental impacts 3. Acknowledgement from patent offices and other governing authorities

The key findings from the patent landscape, site visit and interviews show the crucial role for intellectual property is the protection of an invention. The landscape study confirmed that patenting activities are much higher in developed countries. An additional advantage of patents is associated to the value placed on the invention. As identified in the interviews, the patent has a higher value which used as in successful marketing and licensing of the invention.

5. Discussion

Herein I will provide answers to each of my research questions in order. First I will describe the mechanisms through which environmental policies influence technological innovations. Then I will explain the reasons environmental policies fail at times to support environmental innovations. Finally, I will discuss how environmental policies, market, organizations and innovation can be successfully integrated.

1. What are the environmental innovation trends observed in an industry?

Patents are considered critical in the wastewater industry as they hold value and monopoly for highly priced products or services. The highly matured and structured industry indicates existence of limits in the use of patents by established innovating organizations and boundaries in the knowledge of the end customer implementing the technology. The focus of these organizations remains to operate within the stated limits set by the governing directive. Thus, success is limited to the successfully tested designs, generally restricted to organizations that have proved their technical efficiency over the years. Innovation in the industry is largely focused on improving efficiency of the existing and functional systems. It appears that limited opportunities for a novel and disruptive technology exist to provide an alternate solution, including systems that are environmentally beneficial.

The opportunity for implementing a novel system arises only during the upgradation of an existing treatment facility or the new installation of a wastewater treatment system at a certain location. These situations provide a platform for innovative technology to be showcased. Results from the patent landscape and interviews indicate that the trends in innovation in all technology areas are increasing. Hence, there are opportunities for innovative technologies to be implemented, provided there is sufficient market acceptance and government support.

The market for the wastewater treatment industry is highly segmented, allowing limited freedom to operate with innovative technologies. Countries that support the implementation of such innovative systems also have their limits to absorb these technologies, as the cost to replace or build new infrastructures to support functioning of these technologies is extremely high. This situation provides the opportunity for large enterprises to either licence an innovative technology from SMEs and start-ups or acquire the company in order to control the market. Hence, patents increase the value and protection of the smaller entities from competition amongst each other as well as against established organizations. SMEs prefer the use of licencing in order to control the ownership of innovative patents after they have been successfully tested. A licence maintains a continuous income flow rather than an acquisition which gives a one-time payment based on the value of the patents.

The inconsistency in the value of patents in the wastewater treatment industry varies depending on the countries using innovative technology and the impact of the technology on the entire system of the wastewater treatment facility. The patents that do not disrupt the system and require a replacement of essential sections are easier to implement, as opposed to an entire system replacement. The patents identified in Hungary represent increased activities from

SMEs and start-ups. As these activities indicate recent developments over the decade, innovation is considered in its nascent stage at the moment. Patents that are proven to have environmental benefits and increased efficiency are likely to be licenced or acquired in the near future.

According to the findings in the patent landscape study, developed countries such as US, Japan and western European countries are investing in patenting innovations. The rate at which large and small entities invest may vary for each country for a particular technology. The awareness and inclination to patent environmental innovation is increasing, however, the patent activities indicate that small entities are more interested in the benefits as compared to large organizations. Additionally, large entities are capable mobilizing financial resources to conduct research, licence or acquire. In recent years, several environmental innovations are acknowledged by governmental funding programs. This has increased the competition in providing sustainable products and services. It is likely that the trend in the future might represent large entities increasing investments in environmental innovation to remain competitive.

2. How do environmental policies impact the progress of environmental innovations?

It is observed that there is a varying interest to invest in environmental innovation, therefore, environmental policies have an opportunity to stimulate growth by:

- enabling significant and experimental innovation within traditional and established systems
- providing an opportunity for more discontinuous innovations to emerge outside the traditional limits and integrate the novel system into the existing solutions.

Promoting environmental innovation within the frame of the traditional system preserves predictability, a factor that promotes innovation in certain situations. Expectations for the policy to remain constant will encourage investments for innovation. Based on the policies implemented to control and maintain efficiency, environmental innovation is considered as a by-product and is not a solution that is actively addressed.

Environmental innovation largely depends on the use of an adequate environmental policy instrument relevant to the conditions during the time period. A mix of policy approach is best suited to achieve the optimum solution. This is observed from the EU Commissions' interest and activities to promote innovation. The funding programs along with targets for reducing environmental impact by controlling compliance act as a parameter for environmental innovation. This was emphasised in the stringent regulations and policies established for a set period of time with detailed targets as in the case of the EU commission, which enables a timeline for research and development to occur within the right frame. (Jänicke and Lindemann 2010; EU Commission 2016).

Based on various programs such as Horizon 2020, it possible for highly innovative solutions to take benefit and provide a standard to be followed. Hence, it appears that a mutual link exists between environmental policies and environmental innovation. Innovations with very high benefits are now providing insight into the modification of policies, ensuring the setting of stringent parameters.

Policies have an impact on the functioning of the market based on competition and market saturation. The cost of implementing innovative solutions depending on the policies that govern for a stated time set a matured market (Ruester et al. 2014). Based on the results of the interviews, it is not a feasible solution to encourage innovation at such a time.

Research and development in the environmental innovations sector largely depend on funding and support derived from the environmental policies. A considerable change in the technology development or market acceptance regulates and promotes policies that govern specific sectors. However, study show that current policies that were created to control the existing dominant technologies hinder the progress of unconventional methods (Lanoie 2014).

Successful development of alternate technologies transpire either when the performance of the dominant technology is challenged or the alternatives outperform each other and the previously dominant technology until the most efficient technology is selected (van Rijnsoever et al. 2015; Zhou and Wu 2010 ; Crossan and Apaydin 2010).

As observed in the patent landscape, the use of advanced and biological membrane treatment methods were dominated by the conventional biological treatment methods. However, the use of advances technologies was evident with an increase in patents in these technologies once the alternates gained stability. It also opened a window for successful overlapping of technologies to attain optimum solution to existing challenges. Statistics from the patent landscape show that large enterprises govern the market as compared to SMEs that have to work harder to be identified in the market.

Alternatively, large enterprises have the possibility of either procuring the smaller enterprises or licencing from SMEs providing a less challenging path to the market. It is noticed that the wastewater industry is considered to be a traditional and matured industry and some suggest it reflecting itself as a regulated monopoly (Howard-Grenville 2006). The traditional nature of this sector is governed by the decision makers and senior officials who hardly value the most innovative technology trends in the industry. In some cases, it is noted that ignorance and unfamiliarity of technological developments hinder the decision in favour of SMEs

It is comparatively easier for large enterprises to embark on research and development of alternative technologies or to build on existing solutions. However, the purpose the progress is largely conducted is to reduce operational cost or gain advantages of an early entrant into a long term solution within the industry.

The large enterprises either fund research through advanced SMEs or universities, or depend on funding from venture capitalists to enhance technological development through an

incubator. Large enterprises financing SMEs and universities to conduct research are considered ~~as~~ an obstacle to innovation, since the result of the research should match the expected solutions framed by the funding organization. Whereas, technological development through seed funded incubators allows large enterprises to project themselves as promoters of innovation (Kautto 2007). SMEs have the capacity to innovate much faster due to a leaner process than large enterprises. It is observed that in order to prevent SMEs from succeeding in innovative technologies, large enterprises delay the introduction of innovative technologies such that it matches their progress in research. The innovation is introduced when the large enterprise is capable of integrating it seamlessly with its current systems. A possibility of a competitor introducing a similar solution in the market exists during such intervals.

Alternatively, the current administrative process in the wastewater treatment sector is stated to permit and fund large enterprises having less efficient technologies as compared with the SMEs. This creates another obstacle for the SMEs to introduce efficient and innovative technologies as seen from the interviews.

3. How do environmental policies limit SMEs from increasing development and marketing of environmental innovations?

The research study showed the level of interest is low to change the entire functioning system in order to gain environmental benefits. The policies that govern the current functioning of the wastewater treatment are well established based on previous technologies. Although, the

capacity to improve regulation to match the new technologies exist, the interest to modify the regulations is low. It is likely, the value and acceptance of the environmental innovations will increase along the value chain, provided the regulations are stringent. A further study is required to understand the impact of introducing new technologies as a mandate in order to reduce the environmental impact.

It is difficult for alternative technologies to break the barriers over a prevailing technology that dominated the market and gathered sufficient public support. The outcome from the patent landscape study indicates that the wastewater treatment industry is forced to adapt essential changes in order to sustain global and political demands. The patent landscape showed the clear dominance of large enterprises in the wastewater treatment industry. The patent families owned by large enterprises create a platform for supremacy of such enterprises. Patents are only one of the tools utilised to govern the industry. As discussed earlier, large enterprises also dominate by using licences and acquisitions of innovating technologies.

A sample value chain of the wastewater process is shown in Figure 19 in order to understand the market structure of the industry. A well-defined strategy for each sector maintains the traditional integration of policy with technological innovation. Hence, the value chain indicates the wastewater treatment industry is well segmented. Observations made only in wastewater treatment indicate that regulatory measures are crucial in the intake, discharge and products of the wastewater treatment. This implies a larger investment in processing and functioning within the compliant limit. The value of the environmental innovation is likely to increase if the cost of operating the facility reduces after implementing the new technology.

The implementation of the novel technology depends on high investments, complex directives between governing bodies and a distributed market. These are the key reasons large enterprises are more successful in the wastewater treatment industry. A successful technology shift initiated by one government develops interests from large enterprises and other policy makers.

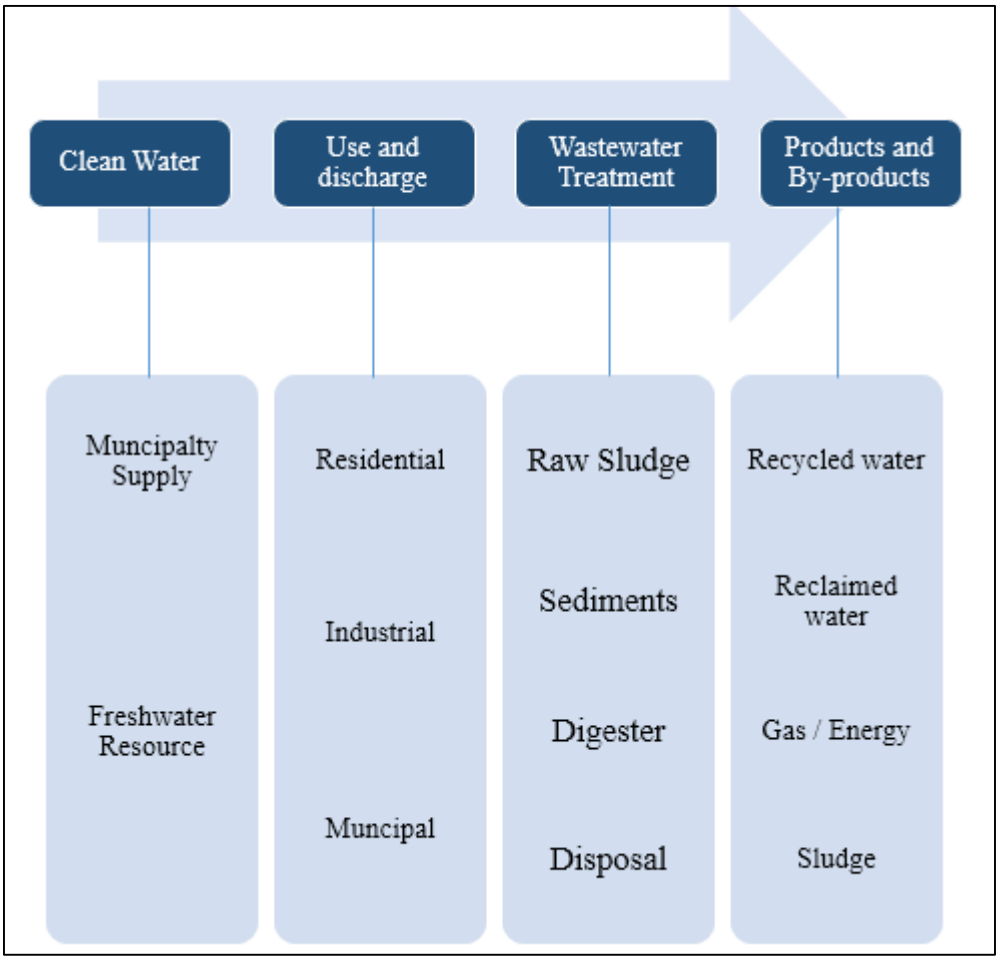

Figure 19. Value chain

(Water Industry based on patenting classification)

The patent landscape shows that the increase in patent activities in Japan in biological membrane treatment lead to an increase in patent activity by large enterprises in the US, EP and South Korea. However, this finding should not be an indication for general functioning of

the large enterprises in wastewater treatment industry. The possibility that the wastewater treatment is currently undergoing a structural shift is discussed by studying innovation combined with market strategy by SMEs, bi-lateral mitigation of innovative players and geographic distribution of patent activities.

SMEs and Innovation

The patent activity in Hungary identified as environmental innovation is occurring through SMEs in the recent years. Some of the smaller players in the market are strategically positioned to capture a niche market, as a result of their investments in research, patent ownerships and suitable market entry. This strategy has encouraged SMEs to compete in the regional and global market alongside large enterprises. SMEs that are not in the niche market and in direct competition with large enterprises depend solely on patent protection to gain entry into the market.

Bi-lateral migration of innovative players:

The patent landscape study disclosed that large enterprises identified as non-traditional players in the wastewater treatment industries are also contributing to the patent activity. Based on conventional technologies used within their industry, research and application of patents are diversified into wastewater treatment facilities. The interest in patenting innovative ultra-violet methods for wastewater treatment and introducing chemical or textiles that might be used in the treatment processes are developed by non-traditional players. The willingness to compete for a market space

generally is successful by providing the products at low costs. These results indicate further decentralisation of the wastewater treatment industry. This trend is obvious in the developing market having higher interest to invest in product at a competitive price. This is likely to cause further decentralisation of the wastewater treatment industry. A further detailed study is needed to identify the impact on centralised and decentralised systems in this sector.

Geographic distribution of patent activities

It is evident from the patent landscape that patent activities are high in countries like US, Japan and South Korea. Interests shown by Australia, Russia and countries in EP over the recent years and the last decades indicate the shifting trends that have attracted SMEs and large enterprises to invest in patents. This study focused largely on EP and other developed countries that had a substantial background of investments and patents in the wastewater treatment industry. Although, developing countries, such as China and India, have a large number of patents filed in the wastewater industry, they are considered as new players and have not been considered in this study. Additionally, information on the patent trend in these countries indicated innovation is largely occurring outside the country and the patents are an interest for viable marketing of the product. Trends displayed by the rapidly growing countries are not comparable to the countries selected for the study. Southern Asia and countries in Africa have not been identified as important sites for patent filings in this sector since their innovating interests are low, regardless of the preventive required to prevent a severe water crisis.

4. How can environmental innovations developed in SMEs further influence environmental policies?

There are various methods in which environmental innovation is capable of influencing the policies that govern wastewater treatment industry. Non-homogeneous strategies that integrate environmental impacts from the initial stages of research have been used in technological development in all industries. (Brandi and Hasse 2012; Howard-Grenville 2006). This strategy prevents the behaviour of the organizations to focus on the environmental impact while conducting research. Additionally, large entities have the capacity and tendency to cater and influence growth in public environmental policy (Kautto, 2007). It is likely that a non-transparent system hinders the communication to focus on environmental innovation to the respective teams involved in research. Likewise, a discontinuous association exists between organizations and policy makers as shown in Figure 20.

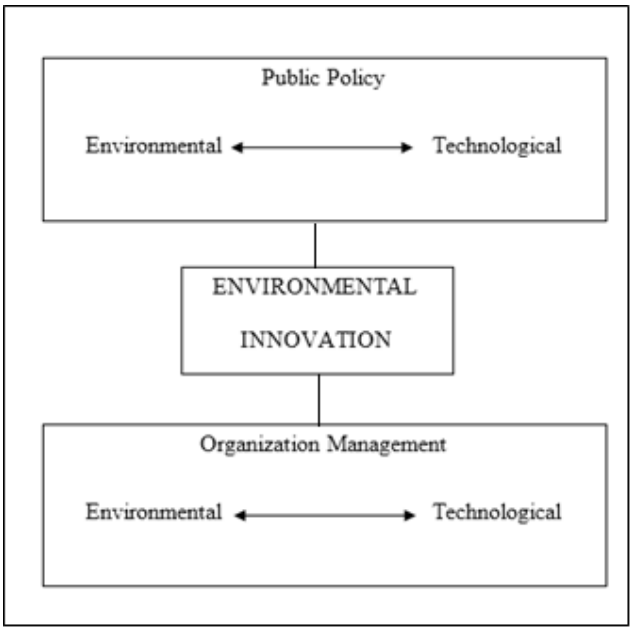

Figure 20. Integration

Alternatively, SMEs are capable of continuing research in a specific focus area, as the investment in research with respect to time and finance is critical for success. The discussions with the professionals in the industry also emphasised the inherent nature of innovation in a start-up and an SME. The progress in research within SMEs largely depends on the path to successfully innovate. Hence, it is comparatively simpler for SMEs to adapt to the environmental policies that govern the industry during research and development.

Additionally, the results from the study suggest that environmental innovations that are acknowledged and appreciated by government funded programs gain higher visibility. Based on the benefits from the environmental innovation, it is possible to implement guidelines that govern the functioning within the industry. This will encourage growth in SME and start-up sectors to research and grow further in environmental innovation.

The public research and development programs are increasing its influence on environmental innovators. Certain instruments introduced to identify the most effective innovator assist in promoting environmental innovations. The longstanding association between large entities and trading companies stimulate the design of policies and programs through such platforms. The flow of information between large entities, SMEs, policy makers and trade organizations is growing, and this appears to be increasing their influence on each other.

It is required for environmental policy makers to engage with both large and small entities to ensure a homogeneous growth in the industry. This should be maintained by distributing adequate funding based on their capacities to conduct research. The precise instruction

provided to conduct research will restrict the inventive aspect, at the same time ensuring that output standards are maintained within an acceptable limit. Organizations need feasible freedom to experiment and possibly evolve existing methods.

The wastewater treatment industry has a limited market to provide environmentally viable products and by-products. The lack of interest to increase environmental innovation at an increased cost does not appeal to the established customers. However, improved technologies should introduce a mandate in environmental policies to encourage sustainable products and by-products. This will increase the utility of environmental innovation and as a result, an opportunity to increase the market for useful products from wastewater treatment processes.

Finally, the social stigma associated with products and by-products of wastewater treatment should be improved. Innovations have shown that wastewater treatment products are proven safe for use in other industries such as agriculture. As identified in the earlier section, 70% of water is used for agriculture. Innovation in the wastewater treatment industry has led to treatment systems that save total land use. Additionally, the unpleasant odour normally associated with wastewater treatment facilities is also addressed in the patents filed for innovative methods recently. This is essential to capture markets interested in installing new wastewater treatment facilities in developing countries, as well as in regions experiencing urbanization in parts of the city allocated for wastewater treatment facilities.

6. Conclusion

From the study, it is evident that innovation, organizations and policies are linked and a suitable policies are required to project a successful sustainable system. It is reflected in the study that the market is largely governed by operational cost. Policies and government structures are also managed by the cost of operating wastewater treatment. Given the situation the SMEs have a substantial cost effective technology that is adaptable in the existing market, it will potentially attract the attention of the established enterprises and the governing bodies.

1. *Environmental innovation trend:*

The rising awareness of environmental impacts and various benefits that innovative technologies have to offer, has prompted improved acceptance into the market. The initial introduction of environmental policies on pollution control were introduced to solve the environmental problems due to discharge of harmful organic and heavy metals. Capturing of useful nutrients from waste was not in the interest of the governing bodies as that was considered as an additional cost to the system. As the large enterprises pursued feasible solutions to capture valuable nutrients and extract valuable products and energy from industrial and municipal discharge, the policies governing the percentage of influent and effluent parameters were modified.

It appears from the study that the innovation trend in the field of wastewater treatment has encouraged competitors to participate and improve the standard of their technology output or process. However, the dominant nature of large and established enterprises continues to be a deciding factor of the market value and policy changes. The rise in innovation activities by the SMEs has set a standard of high environmental benefits. The 'technology push' by the SMEs is gradually being transferred as a market pull. This is largely due the increased public awareness reduced operational cost.

The study also refers to broadening scope of innovation within the wastewater treatment industry. It is established from the study that a disruptive technology in this sector is unlikely to succeed. A planned and organized innovation strategy is required for SMEs to align its market and development strategies in competition with large entities.

The study also reflected the benefits and encouragement from funding programs and awards for innovative products. This supports the fact that change in technology will attract the attention of policy makers and competitors alike. Developing a tool to assess the innovative impact is another measure for analysing patent impacts and availing high visibility in the global market.

Emphasis from institutes, such as the EU Commission, encourages innovation in small and large entities.

2. *Integration and successful implementation of environmental policies and environmental innovation – policy recommendations*

Goals set by the COP21, SDGs and MDGs emphasize deployment of cost-effective and sustainable solutions using innovative technologies. The barriers associated with wastewater treatment have to be addressed as global accessibility to water resources is rapidly reducing. Investments and development in facilities and technologies should be improved to match the global requirements. Policies should be developed such that environmental innovation is encouraged and ensured an easier path for market acceptance.

The technologies employed in wastewater treatment follow a conventional method of operation. However, the growing concern and awareness of environmental impact have developed interests and focus on novel and innovative technologies from large and small enterprises in the industries. There is a possibility for government policies to encourage innovation in wastewater treatment. The policy recommendations based on the study conducted are as follows:

a) Policy regulators should coordinate regionally and globally to build awareness

Innovation by SMEs and independent inventors are successfully providing sustainable solutions at an attractive price. The availability of such solutions should be taken into consideration by policy makers to ensure that quick, easy and viable solutions are implemented to bridge the existing gaps in technology. It has been

identified that SMEs find it challenging to explore, coordinate and establish strong and successful relationships even at regional level. The policy makers and administrators should provide a system that enables participation of SMEs in providing innovative solutions at regionally and globally.

b) Convenient implementation of innovative technologies

Providing a suitable path for SMEs to implement their innovation in the market and offering an unbiased opportunity for the SMEs to participate competitively. The delays experienced in introducing new products should be reduced.

c) Upgrading testing and functioning criteria

The wastewater treatment industry is well established and treated as a mature industry. The criteria for testing and functioning is recognized and fixed by various authorities. The innovative methods developed by SMEs have the possibility to change the criteria based on the performance of dominant players. The policies should encourage for demonstration and testing of innovative technologies. Tax subsidies improve the opportunity for research and development.

d) Improved cooperation between universities and industries

Association with universities enables funding for research and enhances the knowledge of the students conducting research. The restriction of time and availability of resources hinders the progress and development of useful and

sustainable solutions. Micromanagement of research by the large enterprises has been indicated to restrict the true potential of research.

e) Transparent functioning of seed funded incubators

Seed funding and incubators are widely used to experiment while protecting the interests of the innovator and investors until the product is ready to be launched in the market. Providing an open space without any restriction and freedom to explore the inventiveness will encourage better solutions.

f) Recognition and adaptation of innovative methods by inventors or SMEs at larger forums organized by councils and assemblies

An interesting finding from the study was the recognition of inventors and SMEs in the field of mitigating climate change and enabling a societal change dominated by large enterprises in the traditional system. As the trend of appreciating and acknowledging environmental innovation is relatively new, it is possible there is a scope for further research in this area. It might be required to identify the impact on SMEs after receiving the benefits from a regional or global platform that enables funding and 'go-to-market' strategy.

3) Market acceptance of environmental innovations by SMEs

If a situation arises, that the market has entirely failed to support environmental innovation, due to lack of market pull, opportunities to test and experiment various beneficial technologies are lost. These should be addressed by enabling accurate policy instruments, such as:

- Changes in the organization's functioning such that viable products are promoted according to market pull
- Enabling organisation priorities to match the market requirements by having precise requirements from the environmental policy
- Conducting an analysis into the global and regional market trends associated with policy requirements to avoid such failures.

The findings of this study emphasise the importance of acknowledging organisational priorities, policy instruments and the combined impact of these factors on environmental innovation. This study provides an understanding of the functioning of policy instruments along with the variations in the market and organizational priority. There is a possibility for better comprehension of the management of organizations and the role an organization might have on policy making.

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8. Appendices

Appendix 1

Search Strategy

Keywords

Wastewater	Sludge, Sewage, Water, Waste
Treatment	Clean, recycle, purify
Biological	Organic, microbial, bacteria
Membrane	Filtration, osmosis, semi-permeable membrane, tubular membrane, flat membrane, hollow membrane
Chemical - Physical	Radiation, Heat, Settling, Coagulation, Precipitation, Ion Exchange, Acid-Base, Corrosion, Demineralization, Halogens, Oxidants

Appendix 2

Interview Questions

Please state your name, your designation and consent to be recorded.

1. Which of the following scenarios best describes the creative process that lead to an invention?

    a. Result or a by-product of a research or development project
    b. Unexpected by-product of a research or development project
    c. Further developed from current job or a research or development project
    d. Idea/inspiration/creativity
    e. Other

2. Do the inventions significantly build on previous inventions by the same organization?
    a. Yes
    b. No
    c. Do not know

3. Do the inventions have a competitive market?
    a. Yes
    b. No
    c. Do not know

4. How would you rate prior knowledge and information regarding the competitors provided by the inventors?
    a. High
    b. Medium
    c. Low

5. What is the main reason the invention will be patented? (You can select multiple answers)
    a. Marketing
    b. Licencing
    c. Individual/Inventor interest
    d. Do not know

6. Do the inventors provide all the advantages/disadvantages during the patenting process?
    a. Yes
    b. No
    c. Do not know

7. Do the advantages/disadvantages refer to environmental benefits/degradation?

a. Yes
b. No
c. Do not know

8. Is there a method to capture the environmental benefits/degradation of an invention when analysing its patentability? (Applicable only for inventions that are capable of having an impact on the environment)
   a. Yes
   b. No
   c. Do not know

9. The International Patent Classification (IPC) has introduced a classification 'Y02' to identify patent for mitigation or adaptation against climate change. How would you rate your use of this classification in your line of work?
   a. High
   b. Medium
   c. Low
   d. Never

10. When come across an invention classified under Y02, do you refer to the respective environmental policy?
    a. High
    b. Medium
    c. Low

11. Do you think it is important to rate the classification IPC Y02 on inventions that have an impact on the environment?
    a. Yes
    b. No
    c. Do not know

12. Do you think it is appropriate to have a tool to measure the possible environmental impact of an invention?
    a. Yes
    b. No
    c. Do not know

13. How would you like to understand the relevant environmental policies related to an invention?

14. What would be the best method to understand the environmental impact of an invention?

15. What method would you suggest to better track any environmental impact of an invention?

Appendix 3

Q	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5
1	C	C	C	C	D
2	A	A	A	A	A
3	A	A	A	A	C
4	A	A	A	A	B
5	A/B/C	A/B	A/B/C	A/B	A/C
6	A	A	A	A	A
7	C	C	C	C	C
8	C	C	C	C	B
9	C	C	D	C	D
10	B	C	B	B	A
11	A	A	A	C	A
12	A	A	A	A	A
13	Inventor should be aware and convey information in patent	A link to the information of policy in the description of patent	Should be associated with the invention	Regulations and limits should be stated clearly	Information should be readily available along with the invention

14	Need to know the exact details of the impact and authorized limits	Include details in the description of the patent, e.g with samples	Explicitly mention in the effects of the invention	Provide proof or results of the effect and state clearly the advantage /disadvantage	all positive/negative impacts should be stated along with the invention
15	Environmental Impact Tools for patents, IPC, link to carbon reporting	IPC not enough as not everyone will understand, need better representation	Relate to carbon footprint or similar tools	Environmental impact points for an invention	Scope for better tracking with a certificate or authorization

Appendix 4

S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
C	D	C	C	C	C	C	C	D	C
A	A	A	B	C	A	B	A	A	A
A	A	A	C	A	B	C	A	A	A
A	A	A	A	A	A	A	A	A	A
A/B/C	A/B/C	A/B	A/B/C	A/B	A/B/C	A/B	A/B/C	A/B	A/B/C
A	A	A	A	A	A	A	A	A	A
C	C	C	C	B	C	C	B	C	C
B	B	C	C	C	B	B	C	B	C
C	C	D	C	C	D	C	C	D	C
C	B	C	C	B	C	B	B	B	C
A	A	C	A	C	A	A	A	C	A
A	A	A	B	A	B	A	A	B	A

Read more or references in patents	Maybe a different department	Associate with invention	Link with benefits and damages	Should be mentioned in description of patent	Low requirement to understand	Should not matter as long as context is clear	Link with patent	Provide information on related policy	Track patents with policy
State the reference to policies and impact with patent	Use point system to refer to impact and refer to policies	Important to disclose in description	Should be mentioned as additional information along with patent	Can be introduced as an additional information along with patent	Ownership on policy makers to introduce system to inform changes on report	All advantages and disadvantages should be mentioned	Mandatory to disclose environmental damage or benefit	Introduce section for environmental impact	Points in patents for impact

Better use and classification with IPC	Point systems	Database with environmental impact patents	Patent offices can set up environment benefits for patents	Assignees should be able to report benefits and gather momentum for invention	Track with IPC and environmental benefits	Assignee should be able to advertise benefits through granted patents	Impact should be tracked only if the patent proceeds to manufacturing	Assignee should take ownership to propose environmental benefits	Link to policies that are adhered to and surpass expectations