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Weak policy implementation? A functional approach to the analysis of EU biofuels policy documents

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Abstract

Despite a general acknowledgement of the potential of biofuels and the presence of respective promoting policies at the European Union (EU) level, the utilization of biofuels is still lagging behind policy targets. This paper analyzes the content of some EU policy documents with respect to their capacity to facilitate the process of technological change in connection with a greater use of biofuels across Europe. The content analysis of the policy documents is based on the recently proposed theoretical framework on the "Functions of Technological Innovation Systems (TISs)". Proponents following this framework argue that technological change is the ultimate goal of an innovation system. To operationally achieve this goal, an innovation system has to undergo some important dynamic processes, i.e. the *functions*, which are responsible for the emergence, diffusion and widespread use of specific technology. Seven such functions were recently identified by scholars of the TIS, namely: (1) Knowledge Development and Diffusion (2) Influence on the Direction of Search, (3) Entrepreneurial Experimentation, (4) Market Formation, (5) Legitimation, (6) Resource Mobilization and (7) Development of Positive Externalities. Based on scholarly and policy literature, a set of 48 empirical indicators for these seven functions were identified and used to deductively code policy documents. The analysis showed a wide presence of the seven functions in the overall strategy for biofuels (the 1997 White Paper) and in the four policy implementation documents analyzed in this paper. Subsequently, it was concluded that the weak implementation of biofuels policy, associated with an inability to reach indicative EU targets on time, occurs despite the fact that the analyzed policy documents do in fact address the seven functions.

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List of Acronyms

BIS	Biofuels Innovation System
BtL	Biomass-to-Liquid
CO_2	Carbon Dioxide
ETBE	Ethyl Tertiary Butyl Ether
EU	European Union
GHG	Greenhouse Gas
IS	Innovation System
LCA	Life Cycle Assessment
MS	Member States
RD&D	Research, development and demonstration
RES	Renewable Energy Sources
RET	Renewable Energy Technology
TIS	Technological Innovation System
Toe	Tons of oil equivalent
WtW	Well-to-Wheel

~ To my parents, Alexander Batkov and Natalia Batkova.

1. Introduction

The introduction and consequent market expansion of renewable energy technology require substantial supports for that technology via specific governmental schemes. Biomass fuels used for road transportation (hereafter, biofuels), one type of renewable energy source (RES), are currently gaining increasing support within the scientific community (e.g. Gielen et al., 2000; Domac et al., 2005; Dufey, 2006; Charles et al., 2007; McCormick, 2007; Edwards et al., 2008) as well as from politicians in the European Union (EU) (e.g. COM (1997) 599; 2003/30/EC; COM (2005) 628; COM (2006) 34; COM (2006) 845; COM (2008) 19). This is due to their potential to contribute to the following socio-environmental and innovative technology objectives:

- Reduction of the dependency on increasingly high priced energy imports with positive implications for security of supply[1] by creating options in the form of heterogeneity of feedstock and diversification of energy suppliers;
- Reduction in the level of GHG emissions and pollution[2];
- Creation of jobs[3], predominantly among the small and medium sized enterprises that are central to the EU's economy;
- Development of rural areas with the aim of achieving greater social and economic cohesion as well as energy self-sufficiency; and
- Stimulation of innovative scientific and high-tech developments that may provide industrial growth and help to keep the competitive position of the EU in the global market.

To promote the production and use of biofuels in the EU, several policies and the indicative target of 5.75 percent by 2010 were adopted by the EU Commission. Analyses, however, indicate that this target is not likely to be reached on time. This leads to the conclusion that there is a gap between

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1 Hansson & Sterner (2006) argue that there are possible market failures related to the security of energy supply and that their impacts can be debated from an economic point of view. They explain that if biofuels are eventually substituted for fossil fuels, their price will start rising at some point which, in turn, will result in the transfer of a consumer surplus from exporters of fossil fuels to exporters of biofuels.

2 It is pivotal to highlight here that if biomass, for example, is not sustainably grown and then is converted into energy and distributed to the end users, it may create considerable environmental burdens such as indirect CO_2 emissions, soil erosion, increased water usage caused by the additional demands of new vegetation and ground and surface water pollution due to the increased utilization of fertilizers and pesticides. These issues require further research and policy considerations to ensure the sustainability of biomass systems.

3 There is still no scientific consensus with respect to the actual employment generation potential and some commentators doubt this claim. Thus, based on the modeling covering EU-15 and Central and Eastern European Countries (CEEC) for the period from 2000 to 2030, Berndes & Handsson (2007) concluded that the potential of employment creation for different bioenergy options varies depending on the scale of production and the types of biofuels, among other factors. Using an input-output model of the EU to trace the employment of the biofuels program, Edwards et al. (2008) added that employment in agriculture and biofuels results in a decrease in other industrial sectors that might in fact negatively influence urban economic development.

policy objectives and the translation of these objectives into practice: the reasons for this gap are, however, still unknown. Since evidence shows that biofuels policy goals are quite poorly followed by the MS, the question arises as to whether existing biofuels policies are able to sufficiently set such “fertilizing” conditions for biofuels technology to be used across the EU. To shed some light on the aforementioned question, this paper argues that an understanding of the reasons behind an inadequate technological change requires a qualitatively new analytical approach. Such an approach shall help us to understand which processes are actually important for a government to initiate, primarily in the form of legislation, in order to facilitate a transformation process associated with biofuels.

Recent scholarly literature on Technological Innovation Systems (TISs) argues that a transformation of the current energy system into an energy system with a greater renewable energy content will take place when the system can perform certain processes. In innovation systems literature, these processes are also called “the functions of TIS”. The proponents of this stream of scholarly work claim that these functions compose dynamic processes that are responsible for the overall goal of an innovation system, which is to initiate, diffuse and utilize specific technology.

Although, several versions of the functions of TIS are available in the literature, this paper follows one of the most recent studies of Bergek et al. (2008), outlining the following seven functions: (1) Knowledge Development and Diffusion (2) Influence on the Direction of Search, (3) Entrepreneurial Experimentation, (4) Market Formation, (5) Legitimation, (6) Resource Mobilization and (7) Development of Positive Externalities. Following these seven functions as the underlying theoretical framework, this paper aims to explore **whether the functions of TIS, i.e. the central processes that are vital for technological transformation, are actually present in the EU legislation and policy documents on biofuels and, if they are, which ones**.

This paper is comprised of six chapters, including the current one. The remainder are structured as follows: *Chapter 2* introduces some basic information on biofuels as well as their market expansion and political support in the EU. *Chapter 3* presents a theoretical framework based on the functions of TIS literature. *Chapter 4* outlines the research methodology for empirical data collection and analysis, as developed specifically to fulfil the objective of this study. *Chapter 5* provides an analysis of the research findings. Finally, *Chapter 6* discusses the findings obtained through the empirical study, draws conclusions about the “functionality” of the current EU biofuels legislation, outlines the limitations of the study and presents recommendations for future research.

2. Research context and objective

2.1 Defining biofuels

This paper focuses on biofuels - “liquid or gaseous fuel for transport produced from biomass[4]” (2003/30/EC). A distinction has to be made between first-generation biofuels (i.e. conventional biofuels) and second-generation biofuels (i.e. advanced biofuels). The first-generation biofuels are liquid fuels produced from a limited amount of dedicated feedstock. There are two major types of conventional biofuels that are widely used in the EU: *bioethanol,* from sugar plants and cereal crops (e.g. sugarcane, corn, beet, cassava, wheat), and *biodiesel,* from oil crops (such as rapeseed and sunflower), waste, cooking oils or animal fats. The second-generation biofuels are transportation fuels produced from a broader variety of feedstock[5], in particular cellulosic feedstock and by-products, which can be cultivated on marginal, lower productivity lands. *Lignocellulosic ethanol* and *synthetic diesel from biomass (BtL)* are considered to be two major types of the second-generation biofuels (Wiesenthal et al., 2007).

It is beyond the scope of this paper and the technical knowledge of the author to discuss the trustworthiness of both the advantages and disadvantages of the first and second-generation biofuels. For that purpose, several publications could be consulted (see e.g. Wiesenthal et al., 2007; Bomb et al., 2007). However, what is evident from the technical discourse on this subject is that the second-generation biofuels seem to be socially and environmentally friendlier than their first-generation counterparts[6]. Other than that, the latter appear to have had a more favourable position to date mainly due to their compatibility with the existing diesel and petrol-fuelled car engines[7] and distributional infrastructure[8]. This paper will only focus on the first-generation biofuels, i.e. biodiesel and bioethanol. This is due to the following reasons: (i) their production involves more mature technological processes[9] and (ii) they

[4] The definition of biomass used by international and multinational organizations and in national regulations varies widely (Vesterinen et al., 2009). To avoid any misinterpretation, ***biomass*** shall be defined in this paper according to the German Federal Government definition adapted from the Ordinance on Generation of Electricity from Biomass (BiomasseV, 2005): the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste, excluding paper, peat, municipal solid waste (MSW), landfill and sewage gas as well as sewage and harbor sludge.

[5] Feedstock is a wide range of biomass sources that can be utilized to produce biofuels.

[6] The majority of scholars argue that apart from indirect emissions of the first-generation biofuels, which are difficult to consider in a Life Cycle Analysis (LCA), they also raise concerns about negative environmental impacts from planting and harvesting energy crops. Another important issue the EU is confronted with is the limited land available for planting the necessary feedstock (see e.g. Smeets, 2008; Hoogwijk et al., 2005; Ericsson & Nilsson, 2006; de Wit & Faaij, 2008; EEA, 2007; Fischer et al., 2007 for details).

[7] Bomb et al. (2007) argues that both biodiesel and bioethanol can be used in its pure form with only minor changes performed on the existing petrol and diesel engines in specially adapted vehicles - Flexi-fuel Vehicles (FfVs). Alternatively, both types of first-generation biofuels can be blended with petrol or diesel at a concentration of 5-10%.

[8] This includes transportation, storage and retail systems.

[9] Basic production processes for these types of biofuels are quite mature and include fermentation and esterification, respectively (Doornbosch & Steenblick, 2007; Dufey et al., 2007; SRU, 2007; Wiesenthal et al., 2007).

were able to take on a more advanced stage of market formation in comparison to the second-generation biofuels.

2.2 Market formation and policy development of biofuels in the EU

Throughout last couple of decades, first-generation biofuels have indeed developed their niche in the market for transportation fuels in the EU. This market is currently considered to be one of the largest in the world, apart from Brazil and the USA. What is striking about the EU biofuels market is that it contains several national markets with different trends regarding the type of biofuels used and/or produced (bioethanol vs. biodiesel and pure vs. blends). Two countries, namely Germany and France, exhibit the leading position in both the production and consumption of biodiesel and bioethanol, as illustrated in Table 1. Another distinct feature of the EU biofuels market is the domination of biodiesel over bioethanol, with the former enjoying 75% of the total biofuels production in the EU (shown in Figure 1). The lower performance of the latter as compared to biodiesel can be explained by the larger share of diesel-fuelled vehicles in the EU (Wiesenthal et al., 2007) as well as by the increasing price of cereals (Bomb et al., 2007). This distinguishes it from Brazil and the USA, where bioethanol plays a more dominant role (Wiesenthal et al., 2007).

Table 1: Top five EU-27 countries in biofuel consumption in 2007 (in Toe) (EurObserv'ER, 2008)

Bioethanol			Biodiesel		
Country	**Consumption**	**Production**	**Country**	**Consumption**	**Production**
Germany	293 078	399	Germany	2 957 463	2 890
France	272 937	550	France	1 161 277	872
Sweden	181 649	70	Austria	367 140	267
Spain	112 640	383	Spain	260 580	168
Poland	85 200	120	UK	270 660	150
Total EU-27	**1 166 243**	**1 708**	**Total EU-27**	**5 774 207**	**5 713**

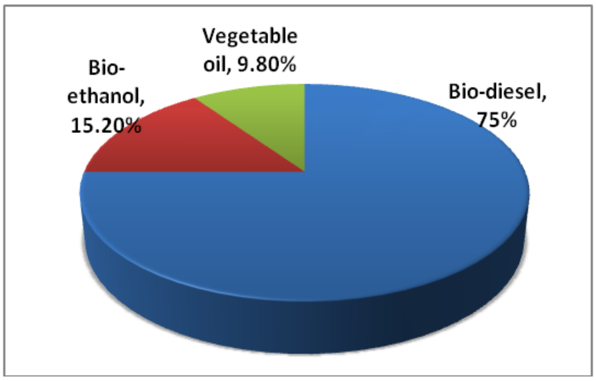

Figure 1: Types of biofuels in the total biofuel consumption in the EU-27 in 2007 (EurObserv'ER, 2008)

Perhaps one of the most important factors orchestrating the dynamic market formation of biofuels was the development of the policy mix at the EU level. It encompassed various policy areas, such as agricultural, energy, transport, environmental, trade and R&D, as summarized in Table 2. It is difficult to say which EU policy directive was in fact the major trigger of the emergence of the biofuels market. The majority of scholars, however, seem to agree that the *Biofuels Directive* (2003/30/EC) adopted by the European Commission in 2003 was an important and direct step towards the development of biofuels. According to this regulation, biofuels had to replace conventional transportation fuels in accordance with the overall Community targets of 2% by 2005 and 5.75% by 2010. Stemming from this EU directive, each MS had to define its country-specific biofuels targets and the policy instruments to be applied to achieve these targets. Table 3 illustrates some examples of the biofuels policy instruments that were announced by the MS and further classified as proposed by Kuhndt et al. (2006).

Table 2: Legislation, shaping development and diffusion of biofuels in the EU (adapted from Thuijl et al., 2003; Wiesenthal et al., 2007; FAO/GBEP, 2008; Wiesenthal et al., 2008)

Policy areas	EU legislation/policy activity
Agricultural policy	- CAP Reform (Reg. (CE) 1782/2003) - “Health Check” of the CAP (COM (2008) 306)
Energy & transport policy	- Green Paper on energy (COM (96) 576) - White Paper on RES (COM (97) 599) - Green Paper Towards a European strategy for the security of energy supply (COM (2000) 769) - Fuels Quality Directive (2003/17/EC) - Biofuels Directive (2003/30/EC)* - Energy Taxation Directive (2003/96/EC) - Biomass Action Plan (COM (2005) 628) - Proposal of the Support of Clean Vehicles by Public Procurement (COM (2005) 634) - EU Strategy for Biofuels (COM (2006) 34) - Energy Green Paper on the European Strategy for sustainable, competitive and secure energy (COM (2006) 105) - Renewable Energy Road Map (COM (2006) 848) - Proposal of the Directive on Promotion of the RES (COM (2008) 19)
Environmental policy	- Kyoto Protocol (2002/358/EC) - EU Emission Trading Scheme (2003/87/EC)
R&D policy	- VII Framework Program (1982/2006/EC)
Trade policy	- EU Sugar Reform (20/02/2006)

* It is important to mention that this paper had initially been written at the end of 2008, before the new directive on RES (2009/28/EC) was adopted by the EU. Therefore, this directive was not included in Table 2 and later in the empirical analysis. To provide a general note, the new RES directive puts forth a 10% policy target for biofuels by 2020, outlines their sustainability criteria and subsequently amends the Biofuels Directive (2003/30/EC).

In order to review the implementation process of the Biofuels Directive, the EU Commission published the “Biofuels Progress Report” (COM (2006) 845)[10]. This document showed that while some of the European countries were successful in setting up national targets, designing sufficient institutional infrastructure and stimulating market growth, others were not. Moreover, many MS signalled various obstacles to achieving the 2% (2005) and 5.75% (2010) Community-wide policy targets[11]. These obstacles included, but were not

[10] This Report is based on the April-June 2006 public consultation exercise where 144 total respondents presented their opinion with respect to the implementation of the Directive. In October 2006, the Energy Research Center of the Netherlands (ECN) published a summary of the results gathered over the public consultation (Londo et al., 2006).

[11] It was stated in the “Biofuels Progress Report” that only 52% of the community-wide target of 2% was reached in 2005 by all MS. Moreover, this document claimed that if the development

limited to, the following: insufficient policy support, technical and information barriers and public acceptance (Londo et al., 2006). Consequently, the Report concluded that "the Biofuels Directive's target for 2010 is not likely to be achieved" and additional measures will have to be deployed for the stimulation of proactive biofuels consumption in the MS (COM (2006) 845). In other words, the Report indicated a weak implementation of biofuels policies.

Table 3: Biofuels policy measures, as announced by the Member States of the European Union (adapted from Wiesenthal et al., 2007 using the classification proposed by Kuhndt et al (2006))

Type of Measures	Biofuels measures, as announced by the Member States of the European Union
Regulatory, command & control	- Quota systems for producers/distributors of biofuels - Mandates to use biofuels by distributors - Fuel quality standards, assurance & control system
Economic /fiscal	- Direct subsidies (e.g. premium for energy crops; investment in biofuels production facilities; for construction or modernization of distributional infrastructure such as filling stations) - Funding & (cheap) loans (e.g. for biofuels production facilities & infrastructure) - Tax incentives/ excise relief (e.g. for producers of biofuels)
Procure-ment	- Public and private green procurement (e.g. use of vehicles powered by pure biofuels in public fleets) - Common procurement (e.g. potential customers group together to reach sufficient amount of vehicle orders)
Collabora-tive	- Networking (e.g. between farmers→biofuels sector→petroleum sector) - Partnership and contracts (e.g. between farmers→biofuels producers→fuel distributors→car manufacturers) - Voluntary agreements
Communi-cation & diffusion	- Information and awareness campaigns - Labelling (e.g. sustainability of energy crops growth; labelling of fuels with minimum level of biofuels) - Education & training (e.g. of vehicle-sales personnel, mechanics, fleet operators, emerging services) - RD&D

Most of the scholars, policy makers and other societal groups interested in biofuels field are, therefore, still confronted with two major questions: First, why does the transformation process of the current (fossil-fuels-based) energy system into a system with a greater biofuels content not take place the way policy actors wish? And secondly, how can the implementation of biofuels policies be improved? In order to shed some light on these questions, an extensive body of (mainly empirical) literature was consulted and reviewed.

A preliminary literature review showed that some authors (e.g. Fischer & Schrattenholzer, 2001; Berndes et al., 2003; Hoogwijk et al., 2003; Hoogwijk et al., 2005; EEA, 2006; Ericsson & Nilsson, 2006; EEA, 2007; Fischer et al., 2007; de Wit & Faaij, 2008) focused largely on the question of whether there is in fact enough biomass potential for meeting the EU policy targets. Other authors (e.g. Hansson et al., n.d.; Pelkmans et al., n/a; Hillring, 2000; Kautto, 2005; Ragwitz, 2005; Hansson & Sterner, 2006; Harmelink et al., 2006; Mitchel et al., 2006; Berndes and Hansson, 2007; Charles et al., 2007; Cooper & Thorney, 2007; Junginger, 2007; Harmelink et al., 2008; Edwards et al., 2008; Wiesenthal et al., 2008) questioned the efficiency and/or effectiveness

were to progress with the same speed, the collective share of biofuels would only be reached at the rate of 5.45% (compared to the planned 5.75%) by 2010 (COM (2006) 845).

of biofuels policies[12]. Additional scholars (e.g. Roos et al., 1999; Roesch & Kaltschmitt, 1999; EEA, 2001; Painuly, 2001; Kautto, 2005; Thuijil & Deurwaarder, 2006; McCormick & Kaberger, 2007) tried to provide a more general understanding of (mainly non-technical) barriers causing the weak implementation of biofuels policies (see Annex I for a list of barriers derived from the consulted studies).

Two important aspects became apparent from the reviewed literature. First, no article was found dealing primarily with the question as to whether the current biofuels legislation addresses the important aspects that are vital for the initiation of technological change in the first place. Second, biofuels (if mentioned separately from bioenergy) were merely understood as technology and sometimes as feedstock. However, biofuels technology is not the policy objective, but rather a means to reach the ultimate policy goal. In fact, the ultimate policy goal is to transform the current energy system by establishing certain conditions in such a way to enable biomass transportation fuels to be utilized throughout the EU. It is therefore argued here that in order to understand the implementation process associated with biofuels policies, one should not be limited to the issues of: available biomass resources, quality of innovative technologies and efficiency and effectiveness of the policies (although all of these factors have to be considered additionally). Alternatively, in trying to understand the causes behind weak policy implementation, analysts should instead focus on questions about *what processes* have to be initiated in order to establish new technological knowledge, implement this knowledge into specific technology and research and demonstration projects, form new markets and expand these markets. Even more importantly a better understanding is needed of *how legislation is able to assist* those pursuing the above mentioned processes.

Recent scholarly literature on Technological Innovation Systems (TISs) argues that it is important to evaluate the performance of the entire innovation system when analyzing the implementation of certain policies. To undertake such an analysis, the scholars propose to focus on the evaluation of seven dynamic processes called "the functions of TIS". The proponents of this stream of scholarly work claim that these seven functions are in fact responsible for the ultimate goal of an Innovation System: to generate, diffuse and widely utilize specific technology.

Following the framework on the functions of TIS, this study puts forth the proposition that the European MS experience a poor implementation of biofuels policy targets because the existing legislation at the EU level does not address the key processes necessary for technological change to take place. Therefore, the research objective of this study is to investigate **whether the functions of TIS, i.e. the central processes that are vital for technological transformation, are actually present in the EU legislation and policy documents on biofuels and, if they are, which ones**. Knowing this can help us understand whether the opinions of scholars working in the field of technological change coincide with the opinions of politicians in the EU who

[12] Following Rycroft (1978: 16, 97), *efficiency* is the ratio of a resource's expenditures to a policy, while *effectiveness* refers to the degree of correspondence between the impact of biofuels policies and principal objectives of the EU associated with GHG reductions, security of supply and employment creation in rural areas.

designed biofuels-related legislation. The following chapter presents detailed information on the overall concept, central elements and functions of TIS. This will serve as the theoretical underpinning for a further analysis of the EU biofuels policy documents.

3. Theoretical Framework

3.1 "Conventional" and "Novel" Technological Innovation Systems approaches

Although not yet considered to be a theory, the Innovation Systems (IS) approach is a widely used framework within the field of innovation studies. According to Edquist (1997), the development of this knowledge stream started a little more than two decades ago. Since its first introduction, the IS approach has been taken forward and widely used not only by numerous scholars, but also by public organizations both nationally (e.g. Fraunhofer Institute of Germany, Centre of Excellence for Science and Innovation Studies of Sweden) and internationally (e.g. OECD, World Bank). This scholarly approach is based on the assumption that it is not enough just to look at the consequences of an innovation (e.g. economic growth, growth of labour division, growth of the number of technology), but that the important dynamics driving an innovation system to further progress must also be determined.

There are several streams within the literature on IS, varying in terms of the unit of analysis used. It is widely accepted among scholars (Edquist, 1997; Jacobsson & Johnson, 2000; Edquist, 2001; Foxon et al., 2005; Bergek et al., 2008) that the IS approach initially started with the work of Freeman (1987), Lundvall (1992) and Nelson (1993). These scholars focused on the differences in "National Innovation Systems" by exploring how national institutions and the structure of production influenced technological choices made by individual firms. Furthermore, a focus on the regional and sectoral levels emerged. Finally, some scholars used the "Technological Innovation System" (TIS) approach which was introduced by Carlsson & Stankiewicz (1991) and is of prime importance to this paper. The main difference of the final approach as compared to the others is that it is technology-specific beyond sectoral and geographic boundaries[13]. In describing the TIS approach, Bergek et al. (2008) pointed out that a technology in this context is not limited to material (e.g. products, tools, machines) and immaterial (e.g. procedure/processes, digital protocols) objects, but also comprises technical *knowledge*, both of a generic character and embodied into physical artifacts. The concept of the TIS was defined for the first time by Carlsson & Stankiewicz (1991:111) as follows:

[13] Several scholars (Edquist, 1997; Carlsson et al., 2002; Bergek et al., 2008) claim that in times of globalization and internationalization, national borders do not necessarily coincide with the boundaries of a TIS. Although it may sometimes be reasonable to limit research to a specific spatial level for capturing a particular set of actors in a national or regional context, the global context should also not be neglected (Bergek et al., 2008).

"… a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure (…) and involved in the generation, diffusion, and utilization of technology"

The basic idea of this approach lies in the assumption that emerging technologies are developed and applied within the context of specific TIS and that there are many technological systems in any given country or region (Jacobsson & Johnson, 2000). The TIS is unique in character, evolves over time and varies (Carlsson et al., 2002) in terms of its capacity to develop, diffuse and use particular technology. The growth of the TIS, however, is a function of complex and dynamic processes associated with the system's elements, i.e. actors, networks and institutions. These system elements were later labelled as "social structure" or "orgware" by Hekkert et al. (2007: 414) and as "structural components" by Bergek et al. (2008: 409). Edquist (1997) and his colleagues (Bergek et al., 2007) criticized IS scholars for mainly concentrating their work on analysing the structural components of TIS (i.e. actors, networks and institutions) or their dynamics (e.g. analysis in terms of how actors enter into TIS, networks are formed and institutions are changed or remain the same). However, little attention was paid to the issue of "what is being achieved in the system" in terms of the processes that have "direct and immediate impact on the goal of the system (…) to generate, diffuse and utilize new technology" (Bergek et al., 2007: 8-9).

The focus on the *functions of Technological Innovation System*, i.e. central processes driving a system towards the attainment of its ultimate goal, emerged as a response to this critique (Jacobsson & Johnson, 2000; Jacobsson & Bergek, 2004; Bergek et al., 2007; Hekkert et al., 2007; Bergek et al., 2008; Hekkert & Negro, 2008). It cannot be called a completely new theoretical approach because the fundamentals remain the same: instead, it is "a novel addition" (Hekkert & Negro, 2008: 2) to the "conventional" TIS approach, as Bergek et al. (2008: 410) labelled it, with a strong focus on the activities responsible for the performance of the TIS and the complex process of technological change.

It is not clear from the reviewed literature who exactly is responsible for starting the "novel addition" (Hekkert & Negro, 2008: 2). Hekkert & Negro (2008) argues that Galli & Teubal (1997) started thinking in this direction and were later followed by Johnson (1998), Jacobsson & Johnson (2000), Liu & White (2001) and Rickne (2001). However, what is striking about this approach is that it has been widely used by a number of scholars who have applied it to different levels of aggregation and a range of applications and spatial foci. In many studies, the focus was on emerging renewable energy technologies (RET) in general (see e.g. Jacobsson & Johnson, 2000; Jacobsson & Bergek, 2004; Hekkert et al., 2007; Kamp et al., 2004) as well as bioenergy (Jacobsson & Johnson, 2000; Negro et al., 2007; Hekkert & Negro, 2008; Negro et al., 2008) and biofuels (Suurs & Hekkert, 2007; Bomb et al., 2007; Hillman et al., 2008) in particular. These scholars analyzed and compared various TIS in functional terms.

While some of the functions of TIS were considered in empirical studies pursued by scholars working in the field of innovation systems, others were omitted (Bergek et al., 2007). One of the most recent pieces of work in this direction was carried out by Bergek et al. (2008): they derived the seven functions presented in Figure 2 largely from the literature on IS, evolutionary economics, political science, sociology, organizational theory and other related fields (Bergek et al., 2008).

The authors claim that although there is a general agreement on the functions of TIS in the scholarly literature, all seven functions have not been studied together to date. Based on the identified seven functions, Bergek et al. (2008) developed an analytical framework for the analysis of the TIS in functional terms. The authors believe that the implementation and performance of the TIS depends on how successfully the entire innovation system, comprised of complex arrangements and interactions between actors, networks and institutions, performs these seven functions. In the following section, the conceptual basics of the structural elements are introduced and followed by a more detailed overview of the seven functions.

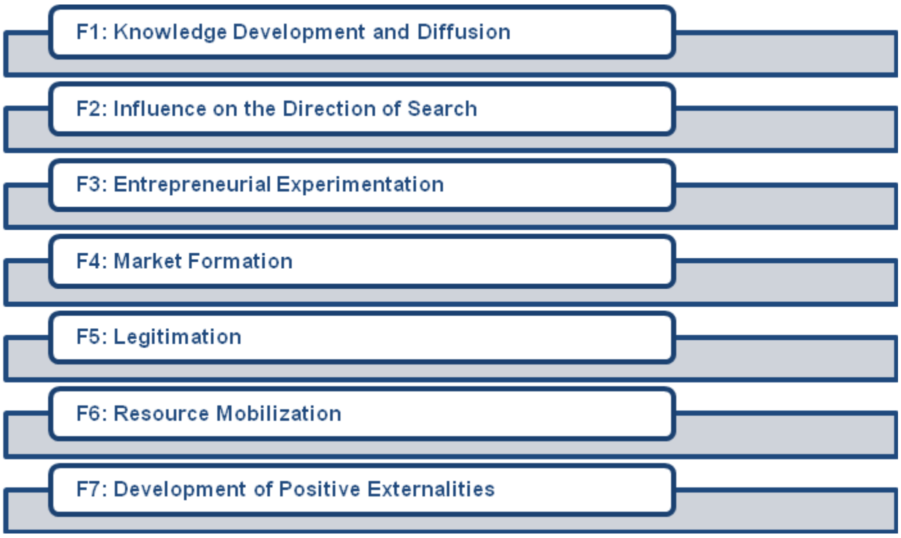

Figure 2: The seven functions of the Technological Innovation System (TIS) (Bergek et al., 2008)

3.2 Structural components of the TIS

The TIS is normally defined in institutional terms, placing institutions at the heart of innovation processes (Edquist & Johnson, 1997). Edquist & Johnson (1997) argue that both organizations (e.g. firms, universities, state agencies) and networks are often considered as institutions in economics and IS literature. The same could also be applicable for actors if one considers behaviour, beliefs, norms, rules, etc. as the elements comprising an actor. Following this statement, the term “institution” then becomes too broad to be called a concept and covers a large part of economic behaviour as well as many types of economic activities and processes (Edquist & Johnson, 1997). For understanding each structural component of the TIS, i.e. actors, networks and institutions, Bergek and her colleagues argue that it is more helpful to make a distinction between these three by making their definitions clearer (Bergek et al., 2008). It is important to mention that the majority of the reviewed literature on the TIS lacks precise definitions of each structural component. In this paper, however, the definition of each structural component will be made based on the author's general understanding and the consultation of some literature on the TIS. Therefore, *actors* shall be defined in this paper as firms and other organizations engaged in the generation, diffusion and utilization of technological innovation. *Networks* shall be considered as relations and interactions among actors. Finally, *institutions* shall be defined as norms and rules shaping the activities of both actors and networks. The following three sections will unfold each of the structural components in more detail.

3.2.1 Actors

Numerous actors are involved in the formation and evolution of the TIS. Bergek et al. (2008: 413) defined actors not only as firms along the whole value chain (including those up and downstream), but also as organizations working towards the generation, diffusion and utilization of technological knowledge and experience. Organizations, as defined by Edquist & Johnson (1997: 47), are "formal structures with an explicit purpose and they are consciously created. They are players or actors". Through their interactions, actors facilitate the learning process, building of trust and reduction of uncertainty associated with technological innovation. Jacobsson & Bergek (2004) pointed out that two groups of actors are important for the transformation process of the TIS. One group consists of non-commercial organizations acting as proponents of specific technologies (Jacobsson & Bergek, 2004). Another group contains the "prime movers" or the system-builders with distinctive competencies and capacities. They are technically, financially and/or politically so powerful that they can influence pre-existing institutional infrastructure and contribute to the development and diffusion of new technology (Jacobsson & Johnson, 2000; Jacobsson & Bergek, 2004). According to Bomb et al. (2007), some important actors in the biofuels industry are inter alia biomass and biofuels producers and suppliers, trade associations, oil companies, automobile manufacturers and state agencies.

3.2.2 Networks

The second structural component of the TIS is networks, both formal and informal (Jacobsson & Johnson, 2000). According to Saviotti (1997: 194), a network is a set of stable and reasonable relations and interactions connecting some actors and representing the structure of socio-economic systems. Networks not only influence the establishment of the TIS, but they also serve as arenas for discussion and the constant improvement of technological knowledge. Moreover, networks facilitate the dissemination of knowledge and expertise among actors via certain channels of communication, resulting in an interactive process of learning within the TIS.

Jacobsson & Bergek (2004: 211) identified two major types of networks within the context of TIS development: (1) market-oriented networks that are built around markets and may therefore be conducive to the identification of problems and development of new technical solutions (e.g. standardization networks, technology platform consortia, public–private partnerships or supplier groups having a common customer; buyer–seller networks) and (2) non-market networks that are related and conducive to a more general diffusion of information or to an ability to influence the establishment and alteration of institutions (e.g. university-industry networks, professional networks and associations or customer interest groups).

Jacobsson & Johnson (2000) argue that when individual actors engage in networks, they gain access to the resource bases of other actors (in terms of information, knowledge and technology). At the same time, networks may constrain individual firms by limiting their technological choices while guiding specific investment decisions (Jacobsson & Johnson, 2000; Jacobsson & Bergek, 2004).

3.3.3 Institutions

The concept of institutions is the third important structural system component. The definition of institutions used in this paper is from Jacobsson & Bergek (2004: 211), stating that institutions are "… norms and rules regulating interactions between actors and the value base of various segments in society". Edquist & Johnson (1997) suggest differentiating between informal institutions, i.e. those generally observed through the behaviour of people, e.g. work norms, norms of co-operation, practices, and formal institutions, i.e. those that are generally more "visible" as compared to informal institutions, e.g. different types of laws. Moreover, each type can be either hard, i.e. perceived as being binding or as commands to be obeyed, or soft, i.e. perceived more as rules of thumb and suggestions. Edquist & Johnson (1997: 51-54) identify three additional basic roles that institutions play, both in general and within the context of the TIS in particular:

(1) *Institutions reduce the amount of uncertainty about the behaviour of actors by providing or limiting the information needed*. An innovation is inherently highly uncertain mainly due to the fact that the demands of customers are not yet formed, markets are not yet set and the relationship and trust among actors is unstable. As a result, it is difficult to predict how others will behave. Here, institutions play a fundamental role in predicting the behaviour of others in accordance with the established norms and rules.

(2) *Institutions manage conflicts and cooperation*. The formation of the TIS may be characterized by the path-dependency of actors and networks that may be resistant to changes. Therefore, the diffusion of new technology often results in numerous conflicts *between* pre-existing and new actors and networks (Jacobsson & Johnson, 2000; Bergek et al., 2008). The reason for this is that a transformation process is often associated with the restructuring of firms' power, prestige and/or income. Moreover, conflicts may also appear *within* established networks and actors (e.g. a conflict between the R&D and production departments within an organization). The development of institutions therefore helps to control and regulate conflicts and build a sufficient amount of trust.

(3) *Institutions can provide both incentives and disincentives*. If a new technology has to be developed and diffused, sufficient incentives should be put in place for guiding the creation of knowledge and facilitating actor learning processes and connectivity. Furthermore, once the technology is developed, institutions can facilitate the consumption of an innovative technology and, by

doing so, influence the demand structure. On the other hand, disincentives are also of great importance to constrain the actors and set limits to the choice of technology. Thus, institutions can serve as both a stick and a carrot.

To summarise, institutions are important not only for the specific path a technology takes, but also for the emergence and evolution of new actors and networks. Some examples of biofuel institutions are legislation, fuel quality standards, patent laws as well as norms influencing the relations between, for example, universities and firms (Edquist, 1997). This paper focuses on the EU biofuels legislation, i.e. a formal, hard type of institution. The following seven sections will introduce the reader to the seven functions, i.e. the seven processes, which are supposed to take place if an innovation system is to be developed and a technological change is to be made, according to Bergek et al. (2008).

3.3 The Seven Functions of the TIS

3.3.1 Function 1 (F1): Knowledge development and diffusion

During the early development of the IS approach, many scholars considered knowledge and learning to be the two central elements of an innovation (Edquist, 1997). Bergek et al. (2008) suggests distinguishing between types and sources of knowledge. The type refers to a specific knowledge base that is required for developing a new product or process (e.g. scientific, technological, production, market, logistics and design knowledge). The sources of knowledge, in contrast, refer to the means to be applied for the creation and diffusion of that knowledge within the TIS (Bergek et al., 2008). Johnson (2001:12), in her review of different approaches with respect to the functions of innovation systems, concluded that most of the scholars have agreed on the following possible sources of new knowledge:

- R&D within, between and outside of organizations;
- “Search and experimentation” (e.g. learning-by-searching, learning-by-experimenting and learning-by-interacting);
- “Learning in connection to daily activities” (e.g. learning-by-doing and learning-by-using); and
- “Imitation” of a product or a process.

Thus, the evolution and implementation of the TIS depends not only on the variety of knowledge to be developed, but also on the learning process through which new knowledge is diffused and utilized within the system. According to Hekkert et al. (2007) and Bergek et al. (2008), this function can be measured by a number of indicators, such as by the number, size and orientation of R&D projects, workshops and conferences devoted to a specific technological area, the size and thickness of networks, patents and learning curves.

3.3.2 Function 2 (F2): Influence on the direction of the search

Technological change is not an autonomous process (Hekkert et al., 2007) because firms do not innovate in isolation (Edquist, 1997). Actors choose to innovate when certain pressures and/or incentives are given to them. These impulses can be either endogenous or exogenous in character, for example (Bergek et al., 2008: 415):

- Visions, expectations and beliefs in growth potential (e.g. incentives from changing factors and product prices; growth in the TIS in other countries; changes in global trends and debates such as climate change);

- Actor's perceptions of the relevance of different types and sources of knowledge;

- Actor's assessments of the present and future technological opportunities and the appropriateness of conditions;

- Regulations and policies (e.g. regulations on a minimum level of adoption ("green" electricity certificates, etc.) as well as tax regimes);

- Articulation of demand from leading customers;

- Technical bottlenecks or "reverse salients"; and

- A crisis in the current business.

Based on these factors, actors decide (i) whether or not to enter TIS and (ii) the direction of their investment behaviour in order to innovate. Thus, this function not only supplies incentives for companies to engage in innovative work (Johnson, 2001), but also influences the direction of that work, i.e. in what way actors deploy their resources. According to Johnson (2001), most of the scholars consider primary guidance in a technical sense when referring to this function, but the guidance towards new technological areas or different markets should also not be neglected. This function, for example, can be measured by the existence of the targets and policy measures announced by either governments or industries regarding the use of specific technology (Hekkert & Negro, 2008).

3.3.3 Function 3 (F3): Entrepreneurial experimentation

Entrepreneurs[14] who are engaged in an experimentation process are central to a well functioning innovation system. The central role of entrepreneurs is to turn the potential of new knowledge and markets into concrete actions for generating and taking advantage of new business opportunities. Even an entrepreneur with substantial advantages (e.g. skilled labour, unique expertise

[14] Here, entrepreneurs are considered in a broad sense, including not only firms, but also other actors involved in the TIS, e.g. policy makers who experiment with new ways to promote new technology (Bergek et al., 2007).

and competence, beneficial geographic position, abundant natural resources) may fail if they do not experiment with innovation (Bergek et al., 2007). Experimentation requires two interdependent aspects. First, an entrepreneur has to be open to the learning process, which can in turn decrease the uncertainty and risk associated with future returns. Second, the long-standing and well-recognized role of the government in reducing, shifting or diversifying risks and entrepreneurs' uncertainty is imperative (Bergek et al., 2007). To measure this function, the variety of experiments can be evaluated in accordance with the (i) number of new entrants, (ii) number of different types of applications, (iii) breadth of technologies used and (iv) character of the complementary technologies employed (Bergek et al., 2008).

3.3.4 Function 4 (F4): Market formation

The diffusion of new technology cannot take place if a market for it has not yet been established. The formation of a market often undergoes a three-stage process. First, "nursing markets" for new technology have to be created. This can be done by setting up (temporal) competitive advantage structures, such as introducing favourable tax regimes or minimum consumption quotas (Hekkert et al., 2007). Such measures may enable the formation of "niche markets" or so-called "protected spaces" for new technology. By entering "nursing markets", actors (i) learn about new technology and (ii) formulate their risk expectations. Second, "bridging markets" have to be created. These types of markets help to increase the production volumes of new technology and the number of actors operating on the market. The greater the volume of production and number of firms on the market, the faster the new technology will become a commodity and its production will reach the "mass market" stage. The formation of new market is thus a long and challenging process requiring the process of learning to take place, the price/performance ratio of new technology to be improved and the demands of new customers to be formed. Possible indicators of this function can be found in facts on the market size and customer groups, actor strategies, the role of standards and purchasing processes.

3.3.5 Function 5 (F5): Legitimation

For a new technology to become part of an existing innovation system, it has to go through the process of legitimation, i.e. the process of becoming socially acceptable and normative (Bergek et al., 2008). Various individual actors struggle to increase acceptance for their product and/or organization by competing with adversaries who, as a rule, defend the institutional architecture of existing TIS (Bergek et al., 2007; Bergek et al., 2008). To gain more resources and a favourable lobbying position, new actors form advocacy coalitions, i.e. a group of like-minded actors, who participate in a nontrivial degree of coordination. By doing so, they engage themselves in the dynamic process of legitimation, often taking considerable amounts of time, and thereby influence the expectations of managers and their strategies (Bergek et al., 2007; Bergek et al., 2008). Three legitimation strategies can be recognized in the literature: (i) *manipulation* of the rules of the game, (ii) *conformance* to the existing institutional framework and (iii) *creation* of new institutions. Evaluation of this function requires an analysis of the strength of the TIS legitimacy, how legitimacy influences demand, legislation and firm behaviors and what or who influences legitimacy and in which way (Bergek et al., 2008).

3.3.6 Function 6 (F6): Resource mobilization

Resources are basic inputs to all activities within any IS (Hekkert et al., 2007). According to Bergek et al. (2008: 417), three types of resources have to be mobilized for the development of the TIS:

- *Human capital and their competence* in specific scientific, technological, entrepreneurial, managerial and finance fields;

- *Financial capital* to enable the flow of investments and liquidity; and

- *Complementary assets* to create efficient production systems (e.g. complementary products and services, network infrastructure).

Development of the TIS can only be considered efficient when all of the aforementioned types of resources are mobilized to a high degree (Bergek et al., 2008). An evaluation of resource mobilization requires an understanding of (i) changes in the volume and quality of human resources, (ii) rises in the volume of capital, (iii) increases in the volume of seed and venture capital and (iv) changes in complementary assets (Bergek et al., 2008).

3.3.7 Function 7 (F7): Development of positive externalities

Development of positive externalities is the last function, as proposed by Bergek et al. (2008). An externality exists whenever an (economic) activity of an agent, either a firm or a household, results in certain consequences for the welfare of another agent (Tietenberg, 1992). These consequences can impose either benefits or costs onto the agent who themselves do not cause the externality. These are called positive and negative externalities, respectively. An example of a negative externality is the consequences of air and water pollution borne on ‘Community A’ because of the economic activities of ‘Community B’. An example of a positive externality is the development of a new technology for pollution reduction.

According to Bergek et al. (2008), many positive externalities can arise in the context of innovation and the role of new actors entering the market is of prime importance. Entrances into new markets can reduce at least some of the uncertainty associated with the new technology and market. Moreover, by entering a new market, actors strengthen the political power of advocacy coalitions and, in doing so, can eventually legitimate a new TIS. Once the TIS is accepted by society, it can lead to the enlargement and creation of a variety of subsequent actors serving existing TISs (e.g. providers of intermediate goods and services). The enlargement of the actor base of the TIS can attract new skilled labour and eventually result in the flow of information and knowledge spillovers. Finally, the subsequent entrants can access the knowledge of early entrants by recruiting their staff (Bergek et al., 2008).

This function enables the development of positive loops, as illustrated in Figure 3. These positive loops can be formed in the sequence described above or vice versa. Thus, this function serves as an indicator of the overall dynamics of the TIS and its functionality in terms of the remaining six functions (Bergek et al., 2008). According to Bergek et al. (2008), this function can be analyzed by searching for external economies in the form of resolving uncertainties, political power, legitimacy, combinatorial opportunities, pooled labour markets, specialized intermediates as well as information and knowledge flows.

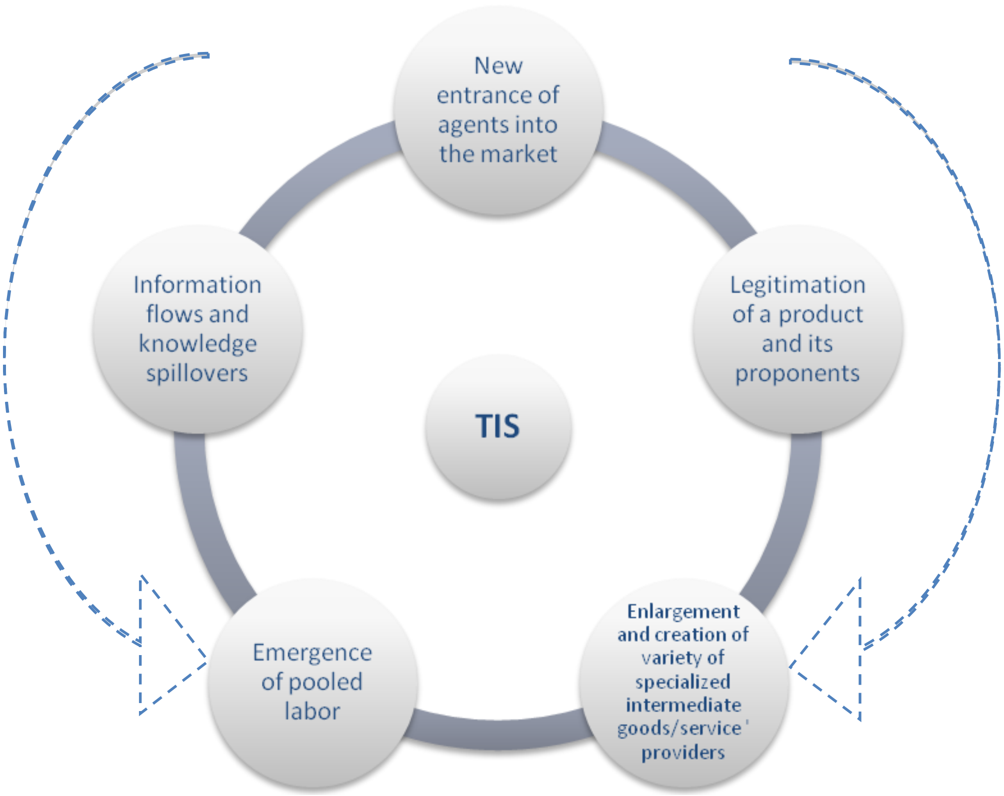

Figure 3: Loops resulting in positive external economies (adapted from Bergek et al., 2007: 418)

3.4 Conceptual framework

Following the functions of the TIS framework described above, potential reasons for the weak implementation process of biofuels policies will now be explored, focusing on the Biofuels Innovation Systems (BIS) in the EU. Thus, the BIS shall hereafter be understood as *networks of actors interacting in biofuels-specific industrial area under an institutional infrastructure to generate, diffuse and utilize biofuels technology*. The industrial area under consideration is biofuels industry in the EU, including both biodiesel and bioethanol. Biofuels producers and suppliers, trade associations, oil companies and automobile manufacturers shall be considered as the key actors and their interactions and relations shall be viewed as networks. Institutional infrastructure shall be regarded as policy documents (legislation) influencing development of biofuels in the EU.

Scholars of TIS state that in order for an innovation system to emerge and to develop, it has to perform the seven functions, as illustrated in Figure 4. Following this assumption, this study will determine whether EU biofuels policy documents contain and address these seven functions on their own. It is important to mention that the author of this study is fully aware of the complexity and ambiguity of all social processes involved in transformation processes: it is beyond the scope of this paper to study these processes. What is more important for the author is to create an in-depth understanding of whether or not the views of EU policy makers coincide with the views of scholars regarding the driving processes central to the establishment and development of the BIS which are, at least hypothetically, supposed to be reflected in EU legislation. The methodological strategy developed to meet the research objective of this paper is presented in the following chapter.

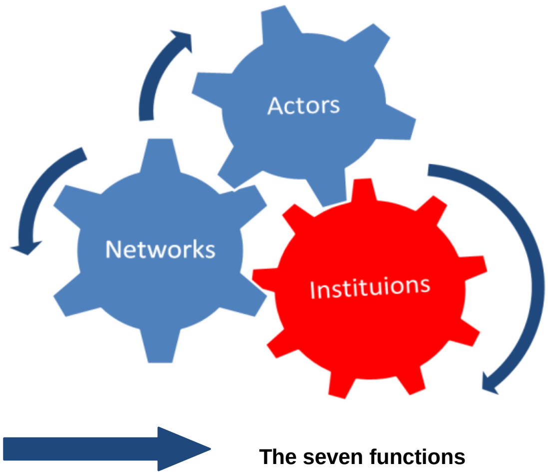

Figure 4: Performance of the seven functions by structural components in the Technological Innovation System (adapted from Bergek et al., 2008)

4. Methodology

This chapter presents the research methodology that has been developed specifically to fulfil the research objective of this study and is presented in Figure 5. The overall research design is a qualitative case study of a number of purposefully selected EU biofuels policy documents, namely one policy action document and four policy implementation documents. They were systematically analyzed with the help of a deductive coding strategy. Prior to the analysis of empirical data, a list of indicators that were (hypothetically) important for the fulfilment of one function or another was developed. The indicators were derived from the theoretical and empirical literature, which was consulted prior to the analysis.

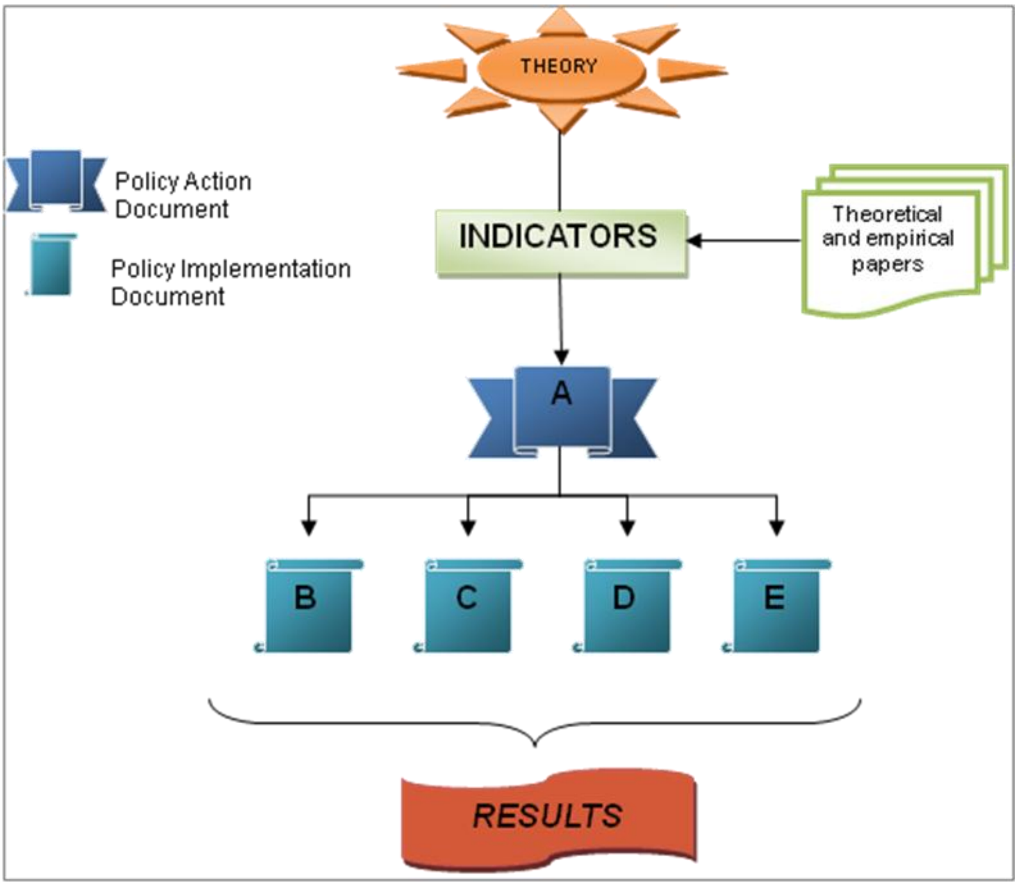

Figure 5: Research methodology of the study

4.1 Research design

A variety of possible research designs is available in the social sciences. Creswell (2007) identified five major types, namely narrative research, phenomenology, grounded theory, ethnography and case study. Case study can be defined as a "bounded system" within a holistic context in which special attention is given to the question of what in particular can be learned from a single case. Thus, the choice of a case study design helps to optimize an in-depth understanding of the case, scrutinize its context and add specific details in terms of the ordinary activities associated with the case (Norman & Lincoln, 2005).

According to Yin (2003), there are two basic types of case study designs: single-case and multiple-case. Within this differentiation, there can also be holistic, i.e. single-unit of analysis, or embedded, i.e. multiple-units of analysis (Yin, 2003). In this paper, the single-case study design of the biofuels' EU legislation shaping development of the Biofuels Innovation System (BIS) was used. Within this case study, two embedded units of analysis were studied, namely policy action documents and policy implementation documents, as illustrated in Figure 6. Details on the collection of policy documents and the reasoning behind the separation of policy documents into two groups are further elaborated in the next section.

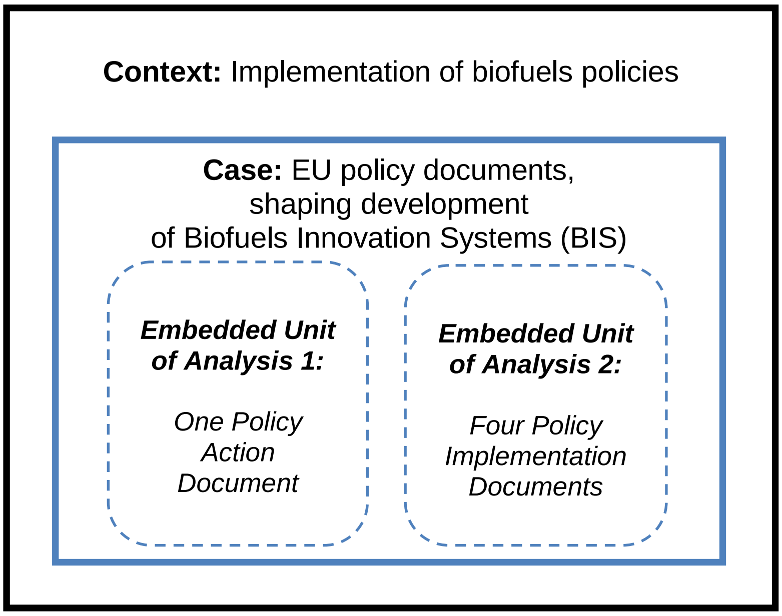

Figure 6: Case study design of the current study (multiple units of analysis) (adapted from Yin, 2003)

A case study can either be analyzed in a quantitative or a qualitative way. Although widely debated among scholars (Trochim, 2006), the choice between the two is a fundamental question that any researcher has to ask before conducting a study as it shapes the procedures used in the subsequent research steps (Creswell, 2005). According to Norman & Lincoln (2005: 12), quantitative scholars abstract from this world and represent "a nomothetic (…) science of large number of randomly selected cases" without considering the significant units functioning within the context of a system. These scholars heavily rely on inferential empirical methods, namely measuring and analysing causal relationships between variables often with the help of statistics and modelling (Norman & Lincoln, 2005: 12).

In contrast, qualitative researchers stress the socially constructed nature of reality in which the researcher is in an intimate relationship with what is being studied and the situational constraints that shape the inquiry. By exploring the case in depth, qualitative researchers embed their findings, presented either in numerical or written format, in a particular context of everyday social life (Norman & Lincoln, 2005). This study will follow a qualitative research design, taking the worldviews and perspectives of the author of this paper into consideration as well as the complexity of the phenomena to be studied. Thus, the EU biofuels legislation will not be considered in isolation, but will instead be viewed within the overall context of the policy implementation mechanism associated with the BIS.

4.2 Data collection

When using the functions of the TIS framework, policy analysts (usually) follow historical event analysis to evaluate the performance of the TIS by mapping the seven functions (e.g. Jacobsson & Lauber, 2006; Jacobsson & Bergek, 2004; Hekkert et al., 2007; Negro et al., 2007; Hekkert & Negro, 2008). In this study, the framework will be used for the first time to analyze the micro-level of implementation, namely legislation.

Legislation present at the EU level and related to the development of the BIS served as the purposeful sampling for this study. To choose the sampling, a number of scholarly and policy papers were reviewed beforehand (Thuijl et al., 2003; Faber et al., 2006; Thuijl & Deurwaarder, 2006; Wiesenthal et al., 2007; FAO/GBEP, 2008; Wiesenthal et al., 2008). Consequently, five EU policy documents were selected for the analysis and were coded (see Table 4). Additionally, all five documents were divided into two units of analysis: policy action documents and policy implementation documents, depending on whether the document was just a policy strategy/plan or actual legislation. This was done in order to see whether the functions of the TIS framework present in the policy action document are also addressed in the policy implementation documents.

Table 4: Purposeful sampling for the analysis

Policy action document			Policy implementation documents		
Year of adoption	**Code**	**Name of the document**	**Year of adoption**	**Code**	**Name of the document**
1997	Document A	White paper for a Community strategy and action plan - energy for the future: renewable sources of energy (COM (97) 599)	2003	Document B	Latest amendment of the Directive 98/70/EC related to the quality of petrol and diesel fuels (2003/17/EC)
			2003	Document C	Directive on the promotion of the use of biofuels or other renewable fuels for transport (2003/30/EC)
			2003	Document D	Restructuring the Community framework for the taxation of energy products and electricity (2003/96/EC)
			2006	Document E	Decision concerning the seventh framework program of the European Community for research, technological development and demonstration activities (2007-2013) (1982/2006/EC)

4.3 Data analysis

The analysis was pursued based on a generated list of indicators with which both types of policy documents were manually coded in a deductive manner. The aim of coding was to either confirm or deny the presence of the seven functions in the policy documents. The indicators were developed in the first place based on the consulted theoretical and empirical literature: together, this literature can be divided into three major groups:

- Literature focusing on the functions of TIS, including Bergek et al. (2008) and their colleagues (Negro et al., 2007; Foxon et al., 2005):

- Literature focusing on the barriers and drivers to implementing policies related to renewables in general and biofuels in particular (Roesch & Kaltschmitt, 1999; Painuly, 2001; Kautto, 2005; Harmelink et al., 2006; Wiesenthal et al., 2007); and

- Literature focusing on environmental policy instruments and regulations (Agrawal & Ostrom, 2001; Meidinger, 2003; Kuhndt et al., 2006).

It is important to mention that while the majority of indicators mentioned in the TIS literature are stock or quantity-based (Hekkert et al., 2007; Negro et al., 2007; Bergek et al.,2008; Foxon et al., 2005; Hekkert & Negro, 2008), the indicators developed for this study are mainly flow or quality-based[15] in nature.

To facilitate the analysis of the policy documents, a total of forty-eight (48) indicators were developed, with each indicator being distributed among the seven functions. Out of these forty-eight indicators, thirty-six (36) were derived from the literature sources outlined above. The remaining twelve (12) indicators, although missing in the consulted theoretical and empirical literature, were present in the analyzed policy documents and were added to the list via the process of coding because they signalled certain activities that were potentially important for the fulfilment of some functions. The distribution of indicators among the seven functions was based on the consulted theoretical and empirical literature as well as on the opinion of the author. Each indicator was also numerically coded in order to facilitate its identification in the policy documents. In Annex I, an indicator’s code, name, source and proposed belongingness to the functions are illustrated: the twelve indicators that were later added to the list during the coding process have “Author” as their source in the table.

After each indicator was distributed according to its hypothetically appropriate function(s), all of the indicators were found to serve multi-functional purposes. Thus, 42% of the total number of indicators served the purpose of three functions, as can be seen in Table 5. It should also be noted that 33% of all of the indicators were present in all seven functions. These are mainly indicators associated with education, training, RD&D as well as a reporting mechanism of the MS and the EU Commission. Following the claim of Bergek et al. (2008) about the need to fulfil all of the seven functions in order to achieve the overall functionality of the TIS, it can already be assumed that the presence of these indicators in the policy documents might be important. The following chapter presents detailed insights into the results gained through the analysis of the EU biofuels policy documents.

[15] Here, the word *quality-based* implies an emphasis on processes rather than experimentally measurable meanings in terms of quantity or amount, such as bibliometrics – citations, volume and orientation of publications.

Table 5: Overlapping indicators per functional composition

Functional composition	Number of indicators per functional composition	Code of an indicator	% of total number of indicators
Seven-function indicators			
F1,F2,F3,F4,F5,F6,F7	16	01,02,03,04,05,06,21,36,37,38,39,40,41,42,45,46	
Total	16		33
Six-function indicators			
F1,F2,F3,F5,F6,F7	1	07	
Total	1		2
Five-function indicators			
F2,F3,F4,F6,F7	1	18	
F2,F3,F4,F5,F7	1	20	
Total	2		4
Four-function indicators			
F2,F3,F4,F7	1	16	
F2,F3,F4,F5	4	24,25,47,50	
F3,F4,F5,F7	1	33	
Total	6		13
Three-function indicators			
F1,F3,F6	1	08	
F2,F3,F4	12	09,10,11,12,13,14,15,17,19,22,48,49	
F3,F4,F7	2	28,51	
F4,F5,F7	5	29,30,31,32,35	
Total	20		42
Two-function indicators			
F5,F7	2	34,44	
F3,F4	1	27	
Total	3		6
Total	***48***	***48***	***100***

5. Case study findings

5.1 Analysis of policy action document: Document A – "White Paper" (COM (97) 599)

The overarching policy document related to the development of Renewable Energy Sources (RES) in the EU is "*White Paper for a Community Strategy and Action Plan - Energy for the Future: Renewable Sources of Energy*" (COM (97) 599), hereafter referred to as the "White Paper" (Document A). Although this policy action document deals with all the RES, only content applicable to biofuels was subject to the analysis.

At the centre of the "White Paper" lie the EU policy goals, namely: security of supply and competitiveness as well as the improvement and reinforcement of environmental protection and sustainable development. RES were acknowledged in the document as being one of the solutions to attain these policy goals. In order to promote RES in the EU, two fundamental measures were outlined: (i) a non-binding "ambitious but realistic target" to double the contribution of RES in gross inland energy consumption to 12% by 2010 (indicator 16) and (ii) a Community-wide Action Plan with the proposed policy measures important for achieving the set target.

The proposed preliminary Action Plan for the development of RES in general and biofuels in particular identified the following issues as being important areas for further consideration by the Community:

- Development of internal market measures, including application of fiscal and financial policy instruments (indicators 11, 13, 18, 28 and 29);
- Reinforcement of community policies, including RD&D, state aid schemes, Common Agricultural Policy (CAP) reform, regional policies and external relations (indicators 01, 02, 03, 04, 06, 43, 06, 09, 10, 18, 19, 21, 22, 48, 49, and 50);
- Strengthening co-operation between MS (indicator 07);
- Supporting measures for the achievement of biofuels targets, market acceptability and consumer protection of biofuels as well as the provision of public, private and/or third-party financing (indicators 05, 08, 13, 14, 18, 20, 30, 35, 43, 45 and 51);
- Campaign for taking-off (indicators 06, 27, 31 and 34); and
- Implementation and monitoring, including internal coordination of EU policies, programs and targets as well as their implementation by MS and their co-operation at the EU level (indicators 30, 32, 36, 37, 38, 39, 40 and 42).

The results of the functional analysis of Document A showed that while 24% (12) of the total number of proposed indicators were not addressed, 76% (37) were present and covered all of the seven functions in the document. These results signify that the 1997 White Paper incorporates most of the indicators claimed by scholarly analysts as being important for the overall functioning of the BIS. This in turn shows a (large) congruence between scholarly persuasions and the proposed policy measures across political, administrative, legislative, economic and marketing aspects.

5.2 Analysis of policy implementation documents

Four policy implementation documents related to the BIS development were analyzed on the subject of the function’s presence. Each document was coded in chronological order, according to the date of adoption by the EU Parliament and the Council. The documents under consideration were the following:

- Document B – “*Latest amendment of the Directive 98/70/EC related to the quality of petrol and diesel fuels” (2003/17/EC);*
- Document C – “*Directive on the promotion of the use of bio-fuels or other renewable fuels for transport” (2003/30/EC);*
- Document D – “*Restructuring the Community framework for the taxation of energy products and electricity” (2003/96/EC);* and
- Document E – “*Decision concerning the seventh framework program of the European Community for research, technological development and demonstration activities (2007-2013)” (1982/2006/EC).*

The following four sections manifest the results of the analysis for each policy implementation document. Each section will only present the indicators addressed in the documents: the functional composition of indicators for each of the documents are presented in the Annexes III – VI of this paper, respectively.

5.2.1 Document B – "Fuels Quality Directive" (2003/14/EC)

The first policy implementation document analyzed was the "*Latest amendment of the Directive 98/70/EC related to the quality of petrol and diesel fuels" (2003/17/EC)*, hereafter referred to as the "Fuels Quality Directive" (Document B).

This document laid down fiscal measures by guaranteeing the introduction and availability of diesel and unleaded petrol with a maximum of 10 mg/kg of sulphur content (indicator 22). Fuel producers and distributors were required to comply with the environmental standards outlined in Fuels Quality Directive (indicator 14). To ensure compliance with the proposed policy measures, the document contained a number of implementation tools, namely: monitoring of compliance (indicator 30), setting up fuels quality monitoring system in accordance with the requirements of the relevant European standards (indicator 32), reporting on fuels quality data and geographical coverage of fuels with a maximum sulphur content of 10 mg/kg by the MS (indicators 37 and 40) and by the EU Commission (indicator 36). Additionally, the Fuels Quality Directive required the MS to ensure the transposition of the EU indicative targets and proposed measures into domestic legislation (indicator 42). Moreover, this is the only policy implementation document analyzed, that obliged MS to determine penalties applicable to breaches of the current legislation (indicator 46).

5.2.2 Document C – "Biofuels Directive" (2003/30/EC)

The second policy implementation document was the "*Directive on the promotion of the use of biofuels or other renewable fuels for transport" (2003/30/EC),* hereafter referred to as the "Biofuels Directive" (Document C).

In order to reduce the environmental impact of transport and to increase the security of energy supply, the EU imposed community-wide indicative targets for biofuels (either in pure or blended form as well as liquids derived from biofuels) sold on the domestic market of 2% by 31 December 2005 and 5.75% by December 2010. Additionally, the MS were strongly encouraged to introduce national indicative targets (indicator 16) that considered the overall climate and environmental balance of the various types of biofuels sold on the market (indicator 14). Setting the targets lower than the ones suggested had to be justified based on objective criteria (indicator 41). Moreover, car manufacturers had to provide a warranty of vehicle compatibility to its customers (indicator 13). Consequently, MS had to give the information on the availability of biofuels and other renewables to the public (indicator 43) and to ensure the labelling of biofuels at the sales points (indicator 35).

Before July 1st each year, the MS had to address a report to the EU Commission on the measures taken to promote the use of biofuels (indicator 37), the national resources available for the production of biomass for energy purposes other than transport (indicator 38) and the total quantities of fuels sold on the market (indicator 40). Finally, the EU Commission had to present the report to the European Parliament and to the Council before the 31st of December 2006 on the progress achieved in terms of biofuel use by the MS (indicator 36) and also had to subsequently decide whether any additional legislative proposals were necessary.

5.2.3 Document D – "Energy Taxation Directive" (2003/96/EC)

The third policy implementation document analyzed was "*Restructuring the Community framework for the taxation of energy products and electricity" (2003/96/EC)*, hereafter referred to as the "Energy Taxation Directive" (Document D).

This document set up the minimum rates of taxation applicable to energy products when used as a motor or for heating fuels as well as electricity (indicator 11), while granting total/partial exemptions or reductions in the level of taxation to biofuels (indicator 9). Each MS was strongly advised to introduce a national taxation scheme following the proposed Community taxation framework. Moreover, the MS could apply total/partial exemptions or reductions in the level of taxation for demonstration projects related to technological developments of more environmentally friendly products (indicator 19). The MS had to monitor exemptions and/or reductions of energy taxation (indicator 30) and report on the measures taken and their performance effects (indicator 36 and 37), the national taxation rates introduced (indicator 39), the effects of the imposed taxation scheme (indicator 40) and the adoption of the respectful national legislation (indicator 42). Moreover, the EU Commission was also obliged to report on the overall Community performance and the effects of the outlined fiscal measures (indicator 36).

5.2.4 Document E – "Seventh Framework Program" (1982/2006/EC)

The final document analyzed was the "*Decision concerning the seventh framework program of the European Community for research, technological development and demonstration activities (2007-2013)*" (1982/2006/EC), hereafter referred to as the "Seventh Framework Program" (Document E).

At the heart of the Seventh Framework Program lie the provision of financial means for the optimisation and development of information and research infrastructure (indicator 08), R&DD (indicators 04, 06 and 21), education and training (indicators 02 and 03) in the Community and beyond its political boundaries (indicator 07) in nine specific fields[16] (indicator 01). The document

[16] According to the Seventh Framework Program, these specific fields are: health; food, agriculture and biotechnology; information and communication technologies; nano-sciences, nanotechnologies, materials and new production technologies; energy; environment

repeatedly stressed the importance of stimulating transnational cooperation and improving the links between industries and research organizations (indicator 05). Moreover, the Seventh Framework Program emphasised the importance of safeguarding intellectual property rights (indicator 33). To support research projects and to communicate and disseminate research results, Document E set up a special organization – the European Research Council (indicator 45). Moreover, the EU Commission had to continually and systematically monitor the implementation of the Seventh Framework Program (indicator 30) and regularly report and disseminate the results of this monitoring (indicator 36).

5.3 Indicators absent from the analysis of policy documents

In comparing the initially proposed indicators with the indicators addressed in the analyzed documents, it became evident that eight indicators were absent from the policy documents. These indicators are presented in Table 6. Absent indicators fulfilled a total of five functions, except functions F1 ("Knowledge Development and Diffusion") and F6 ("Resource Mobilization"). It can be seen in Table 6 that three indicators (12, 15 and 17) were shared between functions F2, F3 and F4. The other three indicators (24, 25 and 47) were associated with the same functions as the previous ones plus function F5. Finally, two indicators (29 and 44) fulfilled functions F4, F5 and F7.

Table 6: Indicators not mentioned in the analyzed EU policy documents

Code	Name of indicator	Source	Functions						
			F1	F2	F3	F4	F5	F6	F7
12	Imposing environmental pollution taxes	Painuly, 2001; Harmelink et al., 2006; Kautto, 2005; Wiesenthal et al., 2007		x	x	x			
15	Imposing regulations concerning import of bio-fuels (including import duty exemption/reduction)	Kautto, 2005; Wiesenthal et al., 2007		x	x	x			
17	Granting guaranteed prices (including for energy crops and bio-fuels)	Roesch & Kaltschmitt, 1999; Wiesenthal et al., 2007; Painuly, 2001		x	x	x			
24	Green procurement of vehicle fleets (voluntary/mandatory)	Roesch & Kaltschmitt, 1999; Wiesenthal et al.; 2007		x	x	x	x		
25	Common procurement	Roesch & Kaltschmitt, 1999; Wiesenthal et al.; 2007		x	x	x	x		
29	Permitting by authority	Kautto, 2005; Kuhndt et al., 2006				x	x		x
44	Development of the conflict-resolution mechanism/agency	Ostrom, 1997				x	x		x
47	Imposing mandates (e.g. for bio-fuel blending, procurement of clean vehicles, refuelling stations to offer bio-fuels)	Roesch & Kaltschmitt, 1999; Kautto, 2005; Wiesenthal et al., 2007		x	x	x	x		

However, the fact that these indicators were not found in any analyzed policy document does not imply that they are unimportant or absent in other EU policy documents that were outside the scope of this study. For example,

(including climate change); transport (including aeronautics); socio-economic sciences and the humanities; and security and space (1982/2006/EC).

indicator 15 (“Imposing regulations concerning import of biofuels“) might hypothetically be present in the EU’s Sugar Reform (1260/2007/EC). The same could be assumed for indicators 17 (“Granting guaranteed prices”) and 47 (“Imposing mandates”) since both are most likely addressed in the Single Legal Framework for Financing the Common Agricultural Policy (EC/1437/2007).

Another reason why the analysis did not show the presence of some indicators relates to their potential misinterpretation and concurrence with the indicators present in the analyzed policy documents. Thus, indicator 12 (“Imposing environmental pollution taxes”) might correspond to indicator 11 (“Imposing tax on non-renewable energy sources”), addressed in documents A and D. A similar factor might cause the absence of indicators 44 (“Development of the conflict-resolution mechanism/agency”) and 29 (“Permitting by authority”) that may both be compatible with indicator 30 (“Monitoring and inspection”), actually covered by all of the analyzed policy documents.

Finally, two indicators, namely 24 (“Green procurement of vehicle fleets”) and 25 (“Common procurement”), might be too detailed of policy instruments to be addressed in both action and implementation documents. However, both could potentially be considered in future legislation in order to encourage entrepreneurial engagement in experiments and the establishment of “niche markets”.

6. Discussion and conclusion

For a long time, policy makers have been confronted with the problem of weak biofuels policy implementation. This paper undertook the task of determining whether existing policy documents at the EU level incorporate the functions of TIS (Bergek et al., 2008), i.e. dynamic processes, which are responsible for technological change. In other words, the intention of this study was to make a better understanding about the “functionality” of the current biofuels policy at the EU level. This chapter presents the reader with the complex “functional” roles of legislation in the transformation process, discusses the findings of the study and proposes areas for future research.

6.1 Functional roles of legislation in relation to the transformation process

Institutions were defined in this paper as being “*norms and rules regulating interactions between actors and the value base of various segments in society*” (Jacobsson & Bergek, 2004: 211). Following this definition, a number of EU biofuels policy documents were considered in this study as one form of institutions and were analyzed in “functional” terms for the first time.

According to Edquist & Johnson (1997), institutions are important in affecting the amount of resources devoted to innovation and for (re)channelling them from one specific area to another. Thus, institutions enable the creation of variety in the knowledge base, often by providing government support to education, training and RD&D projects as well as grants and scholarships to students and researchers. Moreover, institutions can improve the linkages and interactions among actors within the TIS in order to enable the flow and exchange of knowledge. Through institutions, for example, the supporting mechanism for funding organization of conferences, study and research exchange programs, scientific and technical congresses and other measures can be set. Subsequently, the development of a knowledge base and dissemination of this knowledge within the system enables the mobilization of resources and capacities of both actors (i.e. firms and other organizations) and networks.

Once the variety of technical and scientific knowledge and expertise is created and actors have had an opportunity to obtain and exchange this information, institutions can reduce uncertainties and the risks of entrepreneurs by affecting their expectations in terms of the attractiveness of new technologies and markets. Such expectations can be influenced by the establishment of long-term user-supplier links for beneficial effects through, for example, fixed contracts and partnerships. When users and suppliers have common interests and agreements, the development of trust as well as the creation and expansion of markets can be facilitated.

According to Jacobsson & Lauber (2006), setting up markets often involves the formation of different types of standards as well as the establishment of niche markets, i.e. markets where new technology is superior in some dimension as compared to the others. Here, institutions can also play an imperative role by, for example, providing government subsidies to biofuels while introducing a tax on non-renewable energy products. Another important aspect of market formation and expansion is setting up "protected spaces" for new technologies to emerge into. This can facilitate the process of learning and an improvement of the price/performance through the demonstration effect. Some examples of "protected spaces" are green public procurement and leadership by example: this is when government, public or private transport companies include environmentally friendly vehicles in their fleet to serve as an example for other potential users. In so doing, the demands and preferences of potential customers can be influenced. Finally, this may attract new firms to enter the market, to provide opportunities for user-supplier relations and other types of networks, as well as to generate the "space" for new industry to evolve within the TIS (Jacobsson & Lauber, 2006).

Moreover, institutions are important for the reduction or avoidance of conflicts between and within both actors and networks resulting from the effects of path-dependency. First, institutions can establish the conditions for the legitimation of new products and their proponents by, for example, setting up certification programs or labelling biofuels. Second, institutions are important for ensuring compliance with already existing rules, norms and standards: the role of government inspection and monitoring could help to open up this function.

When all of the processes outlined above are performed by institutions, a "take off" (Jacobsson & Lauber, 2006) into the rapid and self-sustained growth of a Technological Innovation System may occur. As this happens, a powerful positive feedback loop, characterized by an autonomous, dynamic, and constant process of learning within the system, will materialize as a result (Jacobsson & Lauber, 2006). This process of cumulative causation may be revealed by the entry of new firms and other organizations into the arena, by strengthening their political power, by enlarging the variety in intermediate sectors, by experimenting with new combinations and by the formation of new knowledge and skilled labour. Subsequently, an effect of positive economies emerges as a result, an imperative factor for the overall goal of the TIS (Bergek et al., 2008).

As has been shown above, legislation can potentially fulfil all of the seven functions in one way or another. The next section will introduce the reader to the conclusions derived from the analysis of policy documents and will give a comprehensive answer to the research question of the current study, as to whether the current legislation shaping the development of biofuels at the EU level addresses the seven functions of the TIS.

6.2 Are the seven functions addressed in the EU biofuels policy documents?

Issued by the European Commission to lay down a set of proposed strategies and the action plan to promote biofuels (along with other RES), the 1997 White Paper (Document A) is the first policy action document to recognize the importance of biofuels in reaching the EU's policy objectives. The analysis showed that EU politicians took good care to incorporate all of the seven functions in this document in the form of various policy measures (76% of the total number of indicators) that are supposed to be addressed in more detail in the actual upcoming legislation. In so doing, they have initially established "fertilizing" conditions for the facilitation of a technological shift towards a greater use of biofuels in the Community.

To enable the implementation of proposed policy measures that were formerly outlined in the 1997 White Paper, a set of statutes were adopted by the EU Parliament and the Council. Due to time constrains, only four policy implementation documents were analyzed, namely the Fuels Quality Directive (Document B), Biofuels Directive (Document C), Energy Taxation Directive (Document D) and Seventh Framework Program (Document E).

It was observed that documents B, C and D have similar conceptual patterns in functional terms. First, it is important to mention that these three documents address all of the seven functions that were proposed to be central for driving technological change by Bergek et al. (2008). Second, the documents contain a relatively small number of indicators (from 9 to 10 indicators per document). This statement, however, should not be interpreted as being a weak representation of the proposed indicators and, as a result, a weak representation of the functions. Instead, it proves that these implementation documents have a more pointed policy object as compared to the 1997 White Paper. Third, the analysis of documents B, C, and D suggests that these statutes seem to primarily target three functions, namely F2 ("Influence on the direction of search"), F3 ("Entrepreneurial experimentation") and F4 ("Market formation"). This is because the central measures addressed in these documents aim to either induce the pressure on existing actors and networks for sharing biofuels market space, or to introduce incentives for new actors to experiment with innovative technologies and to enter the market by guaranteeing subsidies and tax reductions. Finally, these three implementation documents contain similar policy instruments to monitor, control and report on the results of the measures outlined above, thus opening up the “Legitimation” function (F5).

As for the Seventh Framework Program (Document E), 27% of the total number of indicators were detected. Similar to previously analyzed policy documents, this statute addresses all of the seven functions. The analysis suggests that this document primarily influences “Knowledge development and diffusion (F1), “Resource mobilization” (F6) of actors, and “Development of positive externalities” (F7). It can be explained by the fact that the majority of indicators in this document comprise measures associated with setting up objectives and providing financial means in order to promote education, training and RD&D within and across the Community’s boundaries.

Although it was interesting to see whether the results of a scholarly analysis, i.e. the seven function of TIS (Bergek et al., 2008), were mirrored in the policy documents, it is not possible to explain and/or predict the success or failure of biofuels policy implementation based on the obtained empirical findings. It is important to remember that this was by no means the goal of this study. However, what is significant from the findings is that the overall strategy for biofuels (the 1997 White Paper) and the four policy implementation documents do de-jure possess promises for a successful establishment and development of the BIS in the EU. Secondly, weak implementation associated with an inability to reach indicative EU targets occurs despite the fact that the analyzed policy action document and four statutes incorporate the seven functions.

6.3 Methodological limitations and future research

In analyzing policy documents based on the seven functions of TIS, the role of indicators proved to be imperative. Although a set of indicators were suggested and applied, the current study did not allow the author to reliably validate the indicators. The development of indicators was based on the theoretical and empirical literature analyzed, with the exception of some of the indicators that were identified during the process of coding. Based on the literature and on the author’s conclusions about what could hypothetically be appropriate for the fulfilment of one function or another, each indicator was further distributed among the seven functions. Some might call it subjective and the author of this study does not deny it, but as Donella Meadows (Meadows, 1998: 10-11) states “(a)ll indicators are at least partly subjective (…) and based upon some value, some inner human purpose that tells us what is important to measure”. It is also important to mention that such subjectivity can be explained by the fact that very few attempts have been made to date to define and justify indicators to study the functions of TIS.

If the timeframe had allowed, it would have been significant to determine whether the indicators and functional distribution proposed in this study coincide with the views of stakeholders engaged in the BIS. Moreover, the investigation would gain more value if one could inquire whether the indicators for the national/regional/local levels would be different from the EU level and, if they were, it would be interesting to develop and compare them. Additionally, it was outside the scope of this paper to analyze in *how far* indicators influence the fulfilment of one function or another. This remains both an imperative and challenging task for future research.

The second limitation is related to the bounded number of policy implementation documents considered within the scope of the paper. Although the analyzed statutes are important for the development, diffusion and utilization of biofuels, some legislation documents were left out due to time constrains. Had more time been available to the author, a number of other statutes would have also been analyzed, such as the Single Farm Payment (EC/1782/2003), EU Sugar Reform (1260/2007/EC) and Single Legal Framework for Financing the Common Agricultural Policy (EC/1437/2007), among others. Moreover, it is worth mentioning that between the time when this paper was initially written and subsequently published, the so-called "New RES Directive" (2009/28/EC), amending the Biofuels Directive in 2009, was adopted by the EU Parliament and the Council.

Another important area for further research is related to the identification of the TIS functions. It was outside the scope of this study to test whether the seven functions were appropriately identified by Bergek and her colleagues and whether there are only seven important functions and not more/less. If one wants to understand the causes of weak policy implementation, it might also be helpful to look at other theoretical concepts that could supplement or prove the validity of the functions of the TIS framework. Moreover, it is vital to understand in *how far* each function (or a composition of functions) influences other functions and the overall performance of the TIS by looking at a set of empirical studies.

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Annex I: Results of preliminary literature review on factors influencing development of bioenergy

Author	Factors	Comments
Roos et al., 1999	- Integration - Scale effects - Competition on bio-energy market - Competition with other sectors - National policy - Support of local policy and population	The authors presented a framework for the understanding of "critical factors", i.e. barriers and drivers, behind implementation and commercialization of bioenergy technology from both productive structure and market structure perspectives.
Roesch & Kaltschmitt, 1999	- Financial - Administrative - Organizational and Infrastructure - Perceptual	The authors identified, analyzed and systematized different non-technical challenges that have to be met for the successful implementation of an energy plant to provide energy from solid biofuels and to present measures to reduce the risk of non-technical delays or failures.
EEA, 2001	- Legislative - Financial - Fiscal (taxation) - Administration - Technological development - Information, education and training	The report sheds some light upon the factors leading to a successful implementation of projects dealing with renewable energy technologies in a number of EU's Member States.
Painuly, 2001	- Market failure/imperfection - Market distortions - Economic & financial - Institutional - Technical - Social, cultural and behavioural	The author presented a framework for the analysis of barriers to the penetration of renewable energy technology. Moreover, the author presented detailed suggestions of how to make such analysis, starting with the selection of renewable energy technology to be studied and different methodological approaches to possibly analyze the barriers.
Kautto, 2005	- Political - Legislative - Structural - Financial & fiscal - Administrative - Technical/technological - Cognitive - Biomass issues	The author analyzed the performance of different supporting measures to deliver green electricity from biomass and biogas in the EU-25 over the period 1990 – 2002. The country by country analysis revealed a number of success and risk factors for bioelectricity development and, in many cases, more generally for bioenergy development.
Thuijl & Deurwaarder, 2006	- Political commitment to biofuels - Active market actors and/or lobbying groups initiating biofuels activities - Financial compensation to bridge the financial gap between biofuels and fossil fuels - End-user market for pure or blended use of biofuels	The authors gave a historical retrospective of biofuels policies for a selection of EU countries with the purpose of identifying conclusions and crucial factors for biofuels market introductions from the European experience that may be valuable for Indian and South-East Asian policy-makers and other parties involved in the biofuels sector.
McCormick & Kaberger, 2007	- Economic conditions - Know-how & institutional capacity - Supply chain co-ordination	This paper contributes to the identification, analysis, and discussion of barriers for bioenergy in the EU, derived from industry interactions, research workshops, and case studies in Sweden, Finland, Austria, Poland, Italy and the UK.

Annex II: Code, source and functional composition of indicators used for the empirical analysis

Code	Name of an indicator	Source	Functions						
			F1	F2	F3	F4	F5	F6	F7
01	Setting up targets and objectives for education, training and RD&D activities for development of the TIS-specific knowledge	Kautto, 2005; Kuhndt et al., 2006	x	x	x	x	x	x	x
02	Provision of financial means for formal education in the TIS-specific fields (incl. Grants to TIS-specific graduates such as M.Scs. and PhDs)	Kautto, 2005; Wiesenthal et al., 2007; Foxon et al., 2005	x	x	x	x	x	x	x
03	Provision of financial means for training in the TIS-specific fields	Kautto, 2005; Kuhndt et al., 2006; Negro et al., 2007; Wiesenthal et al., 2007; Foxon et al., 2005	x	x	x	x	x	x	x
04	Provision of financial means for R&D in the TIS-specific fields	Roos et al., 1999; Roesch & Kaltschmitt, 1999; Kautto, 2005; Kuhndt et al., 2006; Negro et al. 2007; Wiesenthal et al., 2007; Foxon et al., 2005	x	x	x	x	x	x	x
05	Provision of financial means for the dissemination of knowledge and expertise over the entire value chain via conferences, workshops, congresses, scientific & professional networks and other communication channels.	Kautto, 2005; Kuhndt et al., 2006; Negro et al., 2007; Wiesenthal et al., 2007; Foxon et al., 2005	x	x	x	x	x	x	x
06	Provision of financial means for demonstration projects (both within the EU-27 and internationally) in the TIS-specific fields	Roesch & Kaltschmitt, 1999; Kautto, 2005; Kuhndt et al., 2006; Negro et al. 2007; Wiesenthal et al., 2007	x	x	x	x	x	x	x
07	International collaboration (within and beyond the EU-27) with respect to education, training and RD&D	Author	x	x	x		x	x	x
08	Provision of financial means for optimizing development and utilization of information & research infrastructure (including establishment of consumer centres)	Kuhndt et al., 2006; Wiesenthal et al., 2007	x		x			x	
09	Imposing tax reduction/exemption for biofuels	Kautto, 2005; Painuly, 2001; Wiesenthal et al., 2007		x	x	x			
10	Removing subsidies for fossil fuels and nuclear energy	Kautto, 2005; Harmelink et al., 2006		x	x	x			
11	Imposing tax on non-renewable energy sources	Kautto, 2005; Harmelink et al., 2006		x	x	x			
12	Imposing environmental pollution taxes	Painuly, 2001; Harmelink et al., 2006; Kautto, 2005; Wiesenthal et al., 2007		x	x	x			
13	Requiring technological standards (including fuel quality, vehicle compatibility and others)	Roos et al., 1999; Kautto, 2005; Negro et al., 2007; Wiesenthal et al., 2007		x	x	x			
14	Requiring environmental standards (including air quality)	Roos et al., 1999; Kautto, 2005; Wiesenthal et al., 2007		x	x	x			
15	Imposing regulations concerning import of biofuels (including import duty exemption/reduction)	Kautto, 2005; Wiesenthal et al., 2007		x	x	x			

16	Setting up targets (general political and/or binding) and objectives to promote biofuels by EU/MS/industry/NGOs	Painuly, 2001; Kautto, 2005		x	x	x			x
17	Granting guaranteed prices (including for energy crops and biofuels)	Roesch & Kaltschmitt, 1999; Wiesenthal et al., 2007; Painuly, 2001		x	x	x			
18	Provision of public investment's subsidies & third party finance incentives for producers & distributors (e.g. subsidies for biofuels' production and distribution facilities)	Roesch & Kaltschmitt, 1999; Painuly, 2001; Kautto, 2005; Negro et al., 2007; Foxon et al., 2005		x	x	x		x	x
19	Setting up tax reduction/exemption for demonstration projects	Author		x	x	x			
20	Certification programs	Kautto, 2005; Wiesenthal et al., 2007		x	x	x	x		x
21	Provision of financial means for education, training and RD&D in complementary industries	Bergek et al., 2008; Wiesenthal et al., 2007; Foxon et al., 2005	x	x	x	x	x	x	x
22	Banning marketing of leaded petrol and reducing sulphur content	Author		x	x	x			
24	Green procurement of vehicle fleets (voluntary/mandatory)	Roesch & Kaltschmitt, 1999; Wiesenthal et al.; 2007		x	x	x	x		
25	Common procurement	Roesch & Kaltschmitt, 1999; Wiesenthal et al.; 2007		x	x	x	x		
27	Voluntary agreements & contracts throughout the value chain	Roesch & Kaltschmitt, 1999; Roos et al., 1999; Painuly, 2001; Meidinger, 2003; Kautto, 2005; Kuhndt et al., 2006; Harmelink et al., 2006; Wiesenthal et al., 2007			x	x			
28	Provision of public investment's subsidies & third party finance incentives for end-users	Wiesenthal et al., 2007			x	x			x
29	Permitting by authority	Kautto, 2005; Kuhndt et al., 2006				x	x		x
30	Monitoring and inspection (including compliance with laws, standards, and permits)	Kuhndt et al., 2006; Wiesenthal et al., 2007				x	x		x
31	Flexible permitting programs	Meidinger, 2003				x	x		x
32	Setting up monitoring, controlling and regulatory agency/system	Author				x	x		x
33	Protection of property rights (patents)	Kuhndt et al., 2006; Foxon et al., 2005			x	x	x		x
34	Regulatory negotiations	Meidinger, 2003					x		x
35	Requiring labelling (including labelling of fuels with minimum level of biofuels; of biofuels-compatible vehicles)	Kautto, 2005; Wiesenthal et al., 2007				x	x		x
36	Reporting by the Commission to the EU Parliament and Council	Author	x	x	x	x	x	x	x
37	Reporting by the Member States on measures taken as a response to the EU legislation	Author	x	x	x	x	x	x	x
38	Reporting by Member States on availability of the resources	Author	x	x	x	x	x	x	x
39	Reporting by Member States on the targets	Author	x	x	x	x	x	x	x
40	Reporting by Member States on the progress	Author	x	x	x	x	x	x	x
41	Reporting by Member States on inability to comply with the EU legislation	Author	x	x	x	x	x	x	x
42	Reporting by Member States in terms of incorporating the EU's legislation into domestic legislation	Author	x	x	x	x	x	x	x
44	Development of the conflict-resolution mechanism/agency	Ostrom, 1997					x		x

45	Creation of coordinating/supporting organization facilitating participation of various actors in the TIS-specific fields & improving information flow, fostering learning and technology diffusion	Kuhndt et al., 2006	x	x	x	x	x	x	x
46	Imposing penalties for violation of the EU's legislation	Author	x	x	x	x	x	x	x
47	Imposing mandates (e.g. for biofuels' blending, procurement of clean vehicles, refuelling stations)	Roesch & Kaltschmitt, 1999; Kautto, 2005; Wiesenthal et al., 2007		x	x	x	x		
48	Allowing growing energy crops on set-aside land up to a certain limit	Wiesenthal et al., 2007		x	x	x			
49	Provision of direct payments for energy crops	Wiesenthal et al., 2007		x	x	x			
50	Requiring sustainability reporting by firms	Wiesenthal et al., 2007		x	x	x	x		
51	Best practice experience & "leadership by example"	Wiesenthal et al., 2007			x	x			x

Annex III. Functional composition of the "Fuels Quality Directive" (2003/17/EC)

Code of indicator	Functions						
	F1	F2	F3	F4	F5	F6	F7
14		x	x	x			
22		x	x	x			
30				x	x		x
32				x	x		x
36	x	x	x	x	x	x	x
37	x	x	x	x	x	x	x
40	x	x	x	x	x	x	x
42	x	x	x	x	x	x	x
46	x	x	x	x	x	x	x

Annex IV: Functional composition of the "Biofuels Directive" (2003/30/EC)

Code of indicator	Functions						
	F1	F2	F3	F4	F5	F6	F7
13		x	x	x			
14		x	x	x			
16		x	x	x			
30				x	x		x
35				x	x		x
36	x	x	x	x	x	x	x
37	x	x	x	x	x	x	x
38	x	x	x	x	x	x	x
40	x	x	x	x	x	x	x
41	x	x	x	x	x	x	x

Annex V: Functional composition of the "Fuels Taxation Directive" (2003/96/EC)

Code of indicator	Functions						
	F1	F2	F3	F4	F5	F6	F7
9		x	x	x			
11		x	x	x			
19		x	x	x			
30				x	x		x
36	x	x	x	x	x	x	x
37	x	x	x	x	x	x	x
39	x	x	x	x	x	x	x
40	x	x	x	x	x	x	x
42	x	x	x	x	x	x	x

Annex VI: Functional composition of the "Seventh Framework Program" (1982/2006/EC)

Code of indicator	Functions						
	F1	F2	F3	F4	F5	F6	F7
01	x	x	x	x	x	x	x
02	x	x	x	x	x	x	x
03	x	x	x	x	x	x	x
04	x	x	x	x	x	x	x
05	x	x	x	x	x	x	x
06	x	x	x	x	x	x	x
07	x	x	x	x	x	x	x
08	x		x			x	
21	x	x	x	x	x	x	x
30				x	x		x
33			x	x	x		x
36	x	x	x	x	x	x	x
45	x	x	x	x	x	x	x