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Policy driven innovation - the role of energy saving obligations for energy distributors in Denmark

Tobias Møller Ruby
Technical University of Denmark
Management Engineering
trby@man.dtu.dk

Abstract

Through the case of the energy saving obligations for energy companies in Denmark and the theory of technological innovation systems this paper aims at providing an increased understanding of indirect policy-driven innovation within energy efficient technology.

The preliminary findings show that energy saving obligations has influence on both the structural components and the functions of the innovation system. Specifically the functions of Market formation, Resource mobilization and Development of external economies appear to have increased activity because of the obligations and they are generally increasing the commercialization of new energy efficient technology.

Keywords; energy policy, innovation, energy technology, utilisation of technology.

Jelcodes:O33,O38

POLICY DRIVEN INNOVATION – THE ROLE OF ENERGY SAVING OBLIGATIONS FOR ENERGY DISTRIBUTORS IN DENMARK

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Tobias Møller Ruby, Ph.D. student, cand. polyt.
Technical University of Denmark – Management Engineering
Section for Innovation Systems and Foresight
Mail: trby@man.dtu.dk
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Introduction

There is to some extent global consensus on the importance of energy savings as a part of solving the current issues concerning energy, environment and the economy. The International Energy Agency estimates the global potential of energy efficiency policy to approximately 17% of current annual worldwide energy consumption in 2030, making it a crucial part of energy policy and environmental goals (IEA, 2011a).
Denmark has a long tradition of saving energy going back to the oil crisis in the 1970's and the country's dependency on importing energy. Earlier studies have also shown that the area of energy efficient technologies in Denmark is a highly innovative field. As new product introductions and new business activities appear more frequently than in many other areas (Borup et al., 2009). However, what the innovation dynamics specifically consist in and how competitiveness is actually created in the field is a largely unanalysed question on many points. The objective of this paper is to analyse the innovation dynamics in the field, departing empirically from the recently renewed policy efforts within energy saving obligations for energy distributors and net-companies in Denmark (electricity, heat, gas and oil companies – hereafter energy companies).

This paper will investigate the link between energy policy and the innovation within energy efficient technology by applying the theoretical framework of technological innovation systems (Bergek et al., 2008) to the case of energy saving obligations for energy companies in Denmark and.
The institutional background for the energy saving obligations was founded in the basic understanding that there are cheap and available energy savings everywhere but no one is initiating the process of implementing new technology to achieve these energy savings (Sorrell, 2004; Palm and Thollander, 2010). This was the reasoning behind the actions of the Danish Government and the Danish Energy Agency when they in late 2005 negotiated with the organisations representing Danish energy industry. In 2006 an agreement was made and formulated as: *The energy companies must afford concrete efforts, which assist the completion of energy savings at end-users. Only energy savings, which had not occurred without the company's effort, are valid. The efforts can for instance be through consulting, professional assistance, financial support or a combination of these.*

The financing of these savings is made through a tax on each saved kWh that is put towards the consumers[2] and which for the electricity and gas companies is set to a fixed price. For the other companies the tax is regulated through market benchmarks ensuring that no company is creating overly expensive savings. This creates a market for energy savings where the most cost-effective savings, in any area and using any technology, is preferred.

[1] Please do not cite without the authors permission!
[2] The savings required for each energy company is determined based on their recent yearly energy supply

Since the agreement was made it has once been revised and today the energy companies are responsible for creating energy savings of 6.1 PJ/year, which is a very substantial part of the total 10.3 PJ/year savings goal in Denmark (Danish Energy Agency, 2011). The current Danish government plans to further extend the energy saving obligations and increase the yearly goals as a part of the forthcoming energy agreement (Danish Government, 2011).

These conditions create an interesting case in which energy and environmental policy has a distinct influence on the innovation, commercialization and market formation within energy efficient technology. This will be the research focus of this paper.

An outline of coinciding literature

The brief overview of existing research will consist of three parts that all relate to the subject matter approached in this paper. It will not function as a thorough review of the literature but more as an overview that enables the identification of a possible research contribution. The first part deals with the link between energy efficiency policy and the development and use of energy efficient products, mainly bound in national and international energy and climate policy. The second part deals with policy and innovation in a broader sense specifically linked with national innovation policy and policy efforts in where innovation is the main objective.
The third part concerns those which investigate the greater link between energy efficiency policy and innovation, making it the one closest to the investigation attempted in this paper. The main difference from the first two to the third is that it merges the way it investigates innovation influenced not by innovation policy but by energy and climate policy.
Within the three parts there will be given a brief overview of the common understandings in the present literature and there will be made distinctions between. It will however not function as a complete or systematic overview of the literature.

Part I – Energy efficiency policy, acceptance and use

An extensive amount of literature investigates and researches into why energy efficient technology is not utilised and accepted to a higher extent as well as describing how policy can and should influence the process. Most would agree that both the environmental and economical benefits are there, but the products have not seen the success anticipated (Vermeulen and Hovens, 2006). This inadvertently relates to the commercialisation, market dynamics and innovation within energy efficient technology (Balachandra et al., 2010).
Much research has gone into identifying the barriers and the drivers for this increased lack of commercialisation for energy efficient products. There is made a clear distinction between home users or consumers (Shove, 1999) and the adaption of energy efficient solutions in industry (Rohdin and Thollander, 2006; Palm and Thollander, 2010).
This part of the literature focuses on the descriptive elements of explaining why products are not used as well as provide some prescriptive policy elements to try and increase the use of these products.

Much related to this part of the literature, but with a different approach, focus and outcome, is the American economic research on energy efficiency policy. A few American researchers have done extensive work within the area of energy efficiency gaps, diffusion of technology and the concept of rebound effects (Jaffe et al., 1993; Jaffe and Stavins, 1994; Newell et al., 1999; Popp et al., 2010). These researchers put forward similar questions as others (Kounetas and Tsekouras, 2010) as to whether more efficient products just make users consume more energy. These classic economic assumptions of users will not be used in this paper as it is not seen to be explanatory for present practices.

Part II – Innovation policy

The second part is the area in literature concerning research and innovation policy. The occurrence of innovation policy as a part of national policy is increasing as well as its attention within research. Much literature in the area originates from Joseph Schumpeter's evolutionary

economic thought later used in the innovation systems theory from the late 1980s and the early 1990s (Freeman, 1987; Lundvall, 1992; Nelson, 1993) while its application in policymaking came through the OECD in the 1990s (OECD, 1997). In present time, research and innovation policy (Smits et al., 2010) is closely linked to science, technology and innovation policy in both policy making and research.
The innovation policy research consists primarily of quantitative economic studies which aim show the affects of policy and typically used in theoretical work and normative papers aimed at both researchers and policymakers.

Part III – Energy efficiency policy, technological development and innovation

The third and last part of literature relevant in this paper is attempting to cover the area of environmental policy or energy efficiency policy and its influence on technological development and innovation, which is closely related to the aim of this paper. Here the aim is to investigate the influence of energy and climate policy on innovation, thus it not being specific policies that are aimed to induce innovation. As described by Rennings and Rammer is the influence on firm competiveness rather ambiguous because it in one way limits and burdens them but in another way provides induced support for compliable products (Rennings and Rammer, 2011). This summarises much of the present literature as most indentify a positive relation between competitive inducing regulation, such as building regulations (Noailly, 2011), and technological development and innovation. These do however not describe the dynamics of these relations or account for specific conditions as for example with the energy saving obligations in Denmark. Others have however put necessary attention towards the area of learning in relation to technological development and policy (Kiss and Neij, 2011). The example of the Swedish window industry is used to highlight how different types of learning must be supported through policy to facilitate technical change and knowledge creation over time.

Targeting the area of energy efficiency

With regards to the research scope, what can be seen in the present literature is one of two things. Either there is a specific focus on a single energy saving technology (e.g. Noally 2011, Building components and regulations) or it is a matter of investigating the effects of energy saving in general (e.g. Jaffe et al. 1993, Rebound effects). The direct link to national and international energy efficiency and energy saving policy is not really present in these two directions and furthermore is there no mention of the range of technologies and products included or how it might influence the development of such differently.
When addressing the area of energy efficiency or more specifically efficient energy use, whether in relation to policy, research funding or new product introductions, the understanding differs a great deal. The considerations as to what energy efficiency is, is therefore crucial to determine what is included and what is excluded in the scope of the research. Energy efficiency as a concept in itself refers to the basic understanding of - *the amount of energy to provide a given service (heating, lighting etc.)*. However, when dealing with energy efficiency in a policy and research perspective the correct understanding is really more about *efficient use of energy* as there is an inherent assumption of reducing energy consumption through better energy efficiency.
If we only look at the product-level, there are two major workable definitions relating efficient energy use and individual products (Jaffe et al., 2004; World Energy Council, 2011).

a) *An energy efficient product is an energy using product (electricity, heat etc.) which uses less energy in its use-phase than a comparable product with the same functional output – e.g. a household circulation pump which utilises new control mechanisms to lower the overall energy use in its life-cycle*
b) *Products which enable energy reductions for other products while not using energy itself (e.g. insulation and windows)*

These two definitions are valuable when describing product-level details but they are not sufficient when assuming a system perspective or a policy-oriented understanding. Therefore the following understanding is proposed to capture a broader definition;

> *The concept of energy efficiency refers to a classification of products and services in where increased energy efficiency (referring to either a or b) is desired - with the main goal of achieving energy savings*

The proposed definition ties energy efficiency together with the more action and goal oriented energy saving-policy as the main way of achieving such. The one does not go without the other and what connects them is the political desire to reduce energy consumption. The composition of products and technologies within energy saving-policy is therefore very diverse – generally related to the obtainable energy savings seen from a technological and economical perspective as well as desirable political focus areas and national interests.

The term energy efficient technology or energy efficient products can be widely interpreted as described above. Below is an overview of the different classifications of energy efficiency areas, technologies and products from four different sources (Table 1). The sources are the International Energy Agency (IEA, 2011b), research funding from ElForsk and EUDP, Go'Energi (Go'Energi, 2011) information campaigns and the energy companies self defined consulting areas.
These classifications are therefore indicators of the technology and product-areas where the notion of energy efficiency is applied and where the respective institutions and actors are working to promote energy efficiency and energy savings. The different areas are shaped on differences in political interests and objectives, technological capability and overall potential savings.

Table 1 – Energy efficiency classifications

	Authors	*Classification*
A	IEA (XXX)	• Cross-sectoral (Investments and national strategies) • Buildings (Building codes, MEPS[3], Zero-energy housing, Promote renovations, Windows) • Appliances and equipment (MEPS for appliances and equipment, labelling, standby power requirements) • Lighting (Phase-out incandescent lamps, Non-residential building lighting) • Transport (Fuel-efficient tires, Fuel economy, Eco-driving) • Industry (Industry indicators, MEPS for electric motors, Energy management, Energy efficiency in SMEs) • Energy utilities (Utility end-use energy efficiency schemes)
B	Research funding; ElForsk (2011)	• Buildings • Ventilation • Lighting • Cooling and Heat pumps • Effect- and control electronics • Processes • Behaviour, barriers and agents
	EUDP (Energy efficiency area, 2011)[4]	• Buildings • Ventilation • Heating and cooling • Lighting • Industrial processes • Energy efficient products
C	Go'Energi – Campaigns areas 2011	• Households (buildings) • Public institutions • Private trade and service • Industry production
D	Energy companies, areas of consulting (overview from elsparesiden.dk 2011[5])	*Private* • Insulation • Windows • Heat • Heat pumps • Renewable • Financing • Energy consulting *Business* • Energy optimisation (cooling, ventilation) • Energy optimisation (heating systems) • New installations and rebuilding • Financing

Across the different classifications there are some clear similarities despite whether a policy or research funding focus, indicating a common-understanding on the areas within the concept of energy efficiency. This is, as described, very much dependent on the political attention, the technological advances and the potential savings.

[3] Minimum energy performance requirements
[4] Interpreted and rewritten to fit table format
[5] The energy companies generally express that they do all types of energy savings, but in reality are their choices mainly based on their expertise, the prices and the possibilities available. E.g. is the district heating company more likely to do heating reductions instead of electricity reductions.

Transport is generally not included as the area of transport is typically dealt with through its own policy area. It is also not covered by the energy saving obligations and will not be considered further in this paper.
There seems to be a focus in the classifications on energy efficiency and energy savings related to electricity and heat. These two energy products will be the focus of the paper excluding oil and gas as it is generally undesired in the Danish energy system as in others.
The research will therefore be concentrated on the main areas of *Buildings, Heat and cooling, Lighting* and *Industrial processes*.

Outlining the contribution

With the outset in existing literature, the present classifications in the area of energy efficiency and the chosen case, the contribution of the paper is outlined. Using a qualitative approach and a comprehensive theoretical framework to investigate the dynamics between the multiple actors, institutions and networks in the energy innovation system will provide further understanding of the links between energy policy, innovation and commercialisation of energy efficient technology.

This paper aims to answer a series of research questions, exemplified through the case of energy saving obligations for energy companies in Denmark. The main question to be answered is: *To what extent is energy saving obligations for energy utility companies influencing the "structural components" and "functions" of the innovation system.*
Elaborating on the knowledge-development in the system is it relevant to ask: *what is the influence of these specific policy-measures on the creation, diffusion and utilisation of knowledge in the innovation system.* Lastly with regards to the classification Table 1: *how might the policy have different impacts within different sectors – all covered by the classifications.*

The contribution will not be a complete overview of the technological innovation system related to energy efficiency, but rather how the case of energy saving obligations influence the innovation system, with regard specifically to the structural elements and the functions of the system.

Methodology and research approach

The methodology adapted in this paper is that of innovation systems theory. The innovation systems theory originally comes from evolutionary economics and co-evolved as a theory in academia as well as a applied methodology in policy institutions (e.g. OECD) (Sharif, 2006). The theory began mainly in the form of the national innovation systems theory (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997) which in the true Schumpeterian thought placed innovation in the centre of nations growth and competiveness.
As described in the 1997 OECD publication titled "National Innovation Systems";
The concept of national innovation systems rests on the premise that understanding the linkages among the actors involved in innovation is key to improving technology performance. Innovation and technical progress are the result of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge. The innovative performance of a country depends to a large extent on how these actors relate to each other as elements of a collective system of knowledge creation and use as well as the technologies they use.
(OECD, 1997)

The theory have afterwards developed in four main directions; National, Regional (Cooke et al., 1997), Sectoral (Malerba, 2002) and Technological (Carlsson and Stankiewicz, 1991; Hekkert et al., 2007; Markard and Truffer, 2008). The main distinctions between these theories are to some extent the different theoretical assumptions about where the systemic notion of innovation is most relevant and how such understanding of the system of innovation can be framed.
In this paper will the focus be on applying the theory of technological innovation systems (TIS). The reasons behind choosing this framework are firstly its inherent focus on technology and technology development and secondly its applicability through presently available analytical frameworks. The TIS scheme of analysis as presented by Bergek et al. (2008) will be the focus and main analytical framework of this paper.

The TIS scheme of analysis argues the necessity to analyse technological innovation systems with regards to their functional dynamics more specifically consisting of *structural components* and *functions* (Bergek et al., 2008). The actors, networks and institutions within the innovation system make up the structural components while the functions consist of seven activities or conditions that the structural components interact with. The functions are *Knowledge development*, *Resource mobilization*, *Market formation*, *Influence on the direction of the search*, *Legitimation*, *Entrepreneurial experimentation* and *Development of external economies*.

These structural elements and functions are incorporated into a six-step approach, beginning with defining the TIS and ending up with key policy issues that should optimize inadequate innovation system performance.
The starting point of the analysis is defining the TIS which is according to Bergek et al. is about identifying a key technology or knowledge-domain that characterises it. The next two steps are mainly descriptive as they concern with mapping the TIS according to its structural components and its functions. The gained understanding of the TIS is then used in the last four steps to create prescriptive efforts to elevate the performance of the TIS. See Figure 1 below for the visual representation of the scheme of analysis.

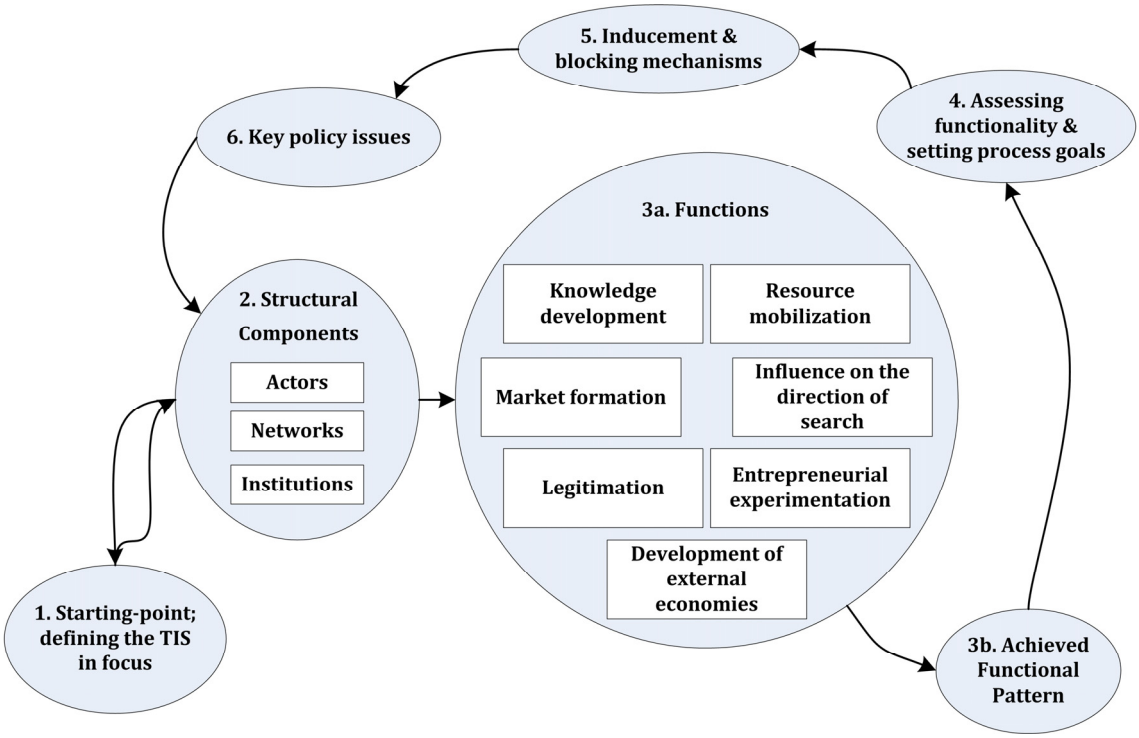

Figure 1 - The scheme of analysis (Bergek et al., 2008) (Adapted from Oltander and Perez, 2005)

The scheme of analysis as presented by Bergek et al. enables a systematic approach to the analysis of technological innovation systems while able to provide an overview of the innovation system seen through its structural components and functions. In this paper will the focus of the analysis be on the descriptive parts of the framework and exclude the policy measures as the aim of the paper is to investigate the influence of policy and the subsequent dynamics in the innovation system.

The analysis of an innovation system is very much about defining the system and determining what is in and what is out. This is especially difficult in the case of energy efficient technology as it is not a specific technology or knowledge-domain as intended with the TIS scheme of analysis. Special attention will be given to this in the discussion of the paper.

Research approach

Somewhat separately from the methodology described above is the research approach. In the scheme of analysis presented by Bergek et al. (2008) is the focus on quantitative research methods to discover the structural components and functions of the innovation system (e.g. bibliometrics). In the research presented in this paper, is the data gathered using qualitative methods and constructed as a case study (Yin, 2009) in where the involved actors are interviewed to construct the empirical data. The interviews are semi-structured allowing for the conversation to evolve into unplanned but relevant subjects. The "roll a snowball" method (Social Construction of Technology – e.g. Bijker, 1997) has been loosely applied to indentify the networks and relations between actors and institutions by starting with one actor and then evolving the data collection from that.
The selection and use of these methods should enable a more descriptive understanding of the innovation system, capable of discovering the subtle dynamics at play in the case.

Analysis

The analysis is constructed on preliminary research data, where only a few of the involved actors and institutions have been investigated. Little company-level data has been gathered and the analysis will therefore focus on the systemic level and not describe exactly how the influence is on individual companies. Nonetheless, the preliminary data is able to show some of the overall influences of the energy saving obligations on the innovation system under investigation.
The analysis will not be a complete descriptive overview of the technological innovation system related to energy efficiency, but rather how the case of energy saving obligations influences the structural elements and functions of the innovation system. Based on the scheme of analysis from Bergek et al. will the focus of the analysis be on the descriptive parts 1-3a and exclude the prescriptive parts 3b-6 (Figure 1).

From the preliminary data there are three aspects of interest identified which assist the structure of the analysis. These will be analysed separately using the TIS scheme of analysis to investigate their individual influence on the structural elements and the functions of the overall innovation system. The first aspect described will to some extent provide a general view of the system, while the two subsequent ones describe narrower focus points.

Increased system activity and involvement of new actors

The utilisation of energy saving technology can happen in numerous ways and for numerous reasons. For instance can a homeowner get a carpenter to install energy efficient windows for aesthetic, economic or practical reasons while a large production company can use a consulting company to increase energy efficiency in its production and subsequently save money. The common factors in these examples are that the end-user is solely responsible for initiating the projects.
This new setup in the network is mainly changed because new actors now are responsible for the initiation, financing and completion of energy saving projects - the new actors being the energy companies. This changes the activities, the value-chain and the system setup by including the energy companies as the driving force for achieving energy savings with regards to offering financial support and knowledge of energy savings and energy efficient technology.

The influence of this is apparent on the structural elements of the innovation system as it adds new actors, changes the network between actors and to a higher degree interrelate them with institutions. The energy companies are large and powerful actors, which not only to some extent sets the agenda of energy savings but also defines the relations between actors. For instance is the relation between district heating companies and plumbers must more established than between electricity companies and plumbers because of the heating companies and the plumbers similar professional-background and shared knowledge-domain. These relations somewhat define the energy efficient technology applied as for instance heating companies are more likely to do savings within heat than electricity – even though they themselves are paid for distributing heat.
The interaction with institutions of different kinds is also increased as the energy saving obligations is defined by the Danish policy institutions. This legislative process also involves the industry organisations for energy as well as other interest organisations making the overall involvement of institutions more present.

A clear exemplification of how the structural elements are influenced by the new configuration is the “2100.nu” project in Østerbro, Copenhagen. The project is a formalised energy saving activity project where the energy company is working together with local interest organisations, professional installers and workmen, product suppliers and the technological institute to facilitate energy savings at the local housing association level. From the energy company’s point of view this is a way of targeting energy savings at the household-level

without the resources necessary to provide energy consulting for every individual household and overall attempt to make it easier for end-users to find the contacts for purchasing and installing new energy efficient products. These kinds of network activities are according to the energy company involved not something they would have gone into without the energy saving obligations. The actual outcome of such projects is unknown, but it will undoubtedly increase interaction between actors and establish new networks in the innovation system.

Looking into the functions of the innovation system with the outset in the aspect of increased network activity and involvement of new actors it is clear that more or less all the functions of the innovation system are influenced;

Knowledge development
The increased interaction in the system and the introduction of new actors should influence the knowledge development in a positive way. The complexity of the relations between actors does however seem to limit these interactions. For instance are the energy companies somewhat afraid of openly and actively working together with suppliers and producers as they believe it might look as if they favour some products over others. This is also related to the professionalism of the workmen which install the solutions, as the energy companies wouldn't want to overrule their judgement. This general reluctance to interact limits the development and diffusion of knowledge.

Resource mobilization
The energy companies are the main driver with regards to resources in the system, much related to their obligations of providing consulting and financial support to facilitate energy savings. The resources provided by the energy companies are therefore both knowledge of energy efficient products and their application as well as a supported business models for the financing of solutions. These are crucial elements for obtaining end-user approval.

Market formation
The system facilitates the co-evolvement of several markets. The energy company is interested in creating a market for inexpensive energy savings which in turn influence the general energy consulting market. These two then draw on the overall market for energy efficient technology and products. The interrelations between these markets are quite crucial to the innovation system as it influences the general energy consulting practice and how product demand occurs on the market.

Influence on the direction of search
The energy companies are obligated to show initiative on behalf of the end-users. This shapes different energy saving practices based on the knowledge-domains of the experts in the energy companies. The practices might also be founded in company strategy, technological possibilities or practicality and results in more directions being included in the system. This makes it difficult to have a coherent and sharable path for all included as the path will be different from actor to actor.

Legitimation
The area of energy efficiency is quite accepted in society, industry and public institutions because of its crucial role in mitigating climate change. The energy companies do however provide some added legitimacy to the system as a result of their size, history and institutional-like form. This influences the end-users reaction to their advice compared to external energy consulting.

Development of external economies
Much related to the co-evolving markets is the development of external economies also occurring in relation between the energy saving obligations, the energy consulting market and the market for energy efficient products. This creates links between existing economies and new ones created as a result of the energy saving obligations.

The function of *Entrepreneurial experimentation* has not been mentioned as the described aspect has little influence on it. It will however be the focus of the next aspect.

Indications of an entrepreneurial gateway

The aspect of the entrepreneurial gateway refers to how new companies producing energy efficient products can use the energy companies as an entrance into the market. Normally, the process of gaining market attention and overall roll-out is quite difficult, but by convincing an energy company to use your products you immediately gain access to larger potential market with easier accessibility.
This aspect is not so influential on the structural level of the innovation system but more the consequence of small and new companies having a market entrance through the energy companies and their projects making the inclusion of smaller actors more probable.

The functions of the innovation system are however influenced by this aspect in the following ways;

Resource mobilization
The resource-based actions of the energy companies are vital for the small new companies especially in their early stage. In this relation it is very connected with both the function of *Market formation* and the *Development of external economies* as the energy companies are their entrance into the market.

Legitimation
The solutions and products chosen by workmen are typically well established and tested solutions while the energy companies might chose differently according to their decision-making. The energy companies are able to create legitimacy surround the use of new products by choosing more experimental solutions which then in turn assists the new companies in establishing themselves.

Entrepreneurial experimentation
The use of new products in projects provides valuable application knowledge although there is not a direct link to how new products are developed as a result of it. The energy companies are not especially risk willing as they are most interested in the price per saved kWh, which somewhat simplifies the additional functionality of new products on the market. Nonetheless are the energy companies increasingly able to utilise new products as ways for them of staying competitive in supplying energy savings.

Affect on the adaption and utilisation of technology

Related to the two aspects previously described is the aspect of adaption and utilisation of technology, which describes how the agenda and knowledge-domain of the energy companies define their energy saving practice and the utilisation of technology connected to it. Where the energy companies facilitate and create energy savings is to a greater extent up to them, as they are only expected to do it in a cost-effective way. This cost-effectiveness is the main competitive parameter in the system as it defines which solutions are desirable and which are not. Table 1 on page 6 shows the diversity of the energy consulting areas supplied by the energy companies, which highlights their broad approach to energy savings where the focus is on achieving inexpensive energy savings, regardless of the area (e.g. windows, ventilation, industrial processes etc.).
This broad and pragmatic approach towards energy savings provide the energy companies the ability to incorporate a broad combination of energy efficient technology in different areas, both encouraging the market to find new areas while also ensuring the adaption of technology on areas where the initiation and market formation is needed. An example of them finding new areas is for instance within office servers and server parks, which offers great potential savings while not being specifically mentioned as a part of the focus areas shown in Table 1.

The influences of the described aspect on the structural elements of the innovation system might not be great. The main difference is as described the introduction of the energy companies as an actor, which initiates energy savings through the implementation and adaption of energy efficient technology that would otherwise not have materialised. This is of cause very much interlinked to the public institutions as the obligations are continuously negotiated with them.
The influence on the functions is however highly relevant;

Knowledge development
Development of application knowledge in the relation between companies, suppliers and the energy companies occurs. The energy companies ensure the use of the existing and new products in a broader way than through traditional market dynamics, enabling but not necessarily ensuring valuable knowledge development between actors. The reluctance is mainly due to historical and institutional factors, which traditionally force the energy companies to withdraw from cooperating with other actors on the basis of them being "public utility companies".

Market formation
Resource mobilization, Development of external economies and *Market formation* all interrelate in the aspect of adaption and utilisation of technology. To some extent is Danish industry already able to supply the energy efficient technology and products necessary, but the energy companies help force initiation and ensure that competitive products are utilised in the market.

Influence on the direction of search
Because of the cost-effective market dynamics created by the energy saving obligations the direction of the development is not very coherent (as for instance with public research funding). The energy companies mostly adapt readily available solutions and do not explicitly encourage for further development within specific focus areas. This it to some extent the case although energy companies are increasingly aware of their actions and issues related to energy supply and energy use, which is why some chose to explicitly state their company visions and interests.

The adaption and utilisation of technology is much about utilising existing knowledge, which for instance was developed earlier by Danish industry and universities, supported by public funded research and influenced by policies such as building regulations. This is the case with many products like the energy efficient circulation pump and low-energy windows, which have had great market success although there are still households and industry buildings where these products are not incorporated. The energy saving obligations for energy companies help ensure greater exploitation of these present products while also discovering new areas and new approaches to ensure further energy savings through the use of new energy efficient technology – dynamics which are crucial to the energy technology innovation system in Denmark.

Discussion

The discussion will be of a theoretical character mainly looking whether the application of technological innovation systems theory is appropriate in an analysis of energy efficient technology and products.
Applying the TIS scheme of analysis by Bergek et al. (2008) on the papers particular case leads to the methodical question of; *What limitations are there when applying a technological innovation systems approach to an incoherent set of knowledge-domains and technology-domains.*
The reasoning behind applying the theoretical framework to the case presented in the paper is that of the interconnectedness of the systems and the policies which are targeting energy efficiency. From this point of view the analysis would be difficult without having the broad perspective of energy efficiency as it is in between those that the dynamics are at play.
The limitations are, I would argue, mainly to do with dissemination and presentation of analysis and research results as it adds complexity and possibly inconsistency to the line of argument in the qualitative approach. If applying a quantitative approach this might be different.

Specific theoretical frameworks better capable of analysing heterogeneous technology areas could be needed. Other research has for instance put more emphasis to the TIS functions of *Market formation* and *Development of external economies*. Dewald and Truffer focus on a market segments within the photovoltaic industry in Germany (Dewald and Truffer, 2011) and present a framework for analysing the creation and maturing of market segments in a TIS. Their paper presents an understanding of TIS market dynamics, which extends on the conventional understanding of a coherent and uniform market.
The classifications of different energy efficient products cannot necessarily be regarded as market segments, but more as application segments within the broad area of energy efficiency. Then again, it is very much defined by the approach taken by the actors and the perspective of the researcher. Case in point, the energy companies will definitely see it as equal energy savings market where they are able to use a variety of different products to create energy savings where as the suppliers, producers and others might see it differently.

Conclusion

The area of energy efficient technology is a much overlooked topic within innovation systems research. This does however not diminish the importance of it, as it is a crucial part of future green development. The main reason for not approaching the area of energy efficiency is its heterogeneous nature, mixing different technology, knowledge domains, products and actors. On one hand, this is making it a difficult area to exemplify for use in conceptual research, but on the other hand is it great for challenging current theoretical frameworks, in this case technological innovation systems.

As the research in this paper is still undergoing no final conclusions can be made. The empirical evidence of the current analysis and research findings is rather limited and so are the presented results merely preliminary indications for further investigation and validation.
Further empirical data will therefore be collected with special attention on interactions between energy companies and suppliers of products. This should provide a better understanding of the transformation of energy saving obligation to conventional market demand and how the relations are between them.

There will however be some initial conclusions which will work as guidelines for further research.
It is clear that the innovation system for energy efficient technology is highly influenced by the energy saving obligations for energy companies. The obligations influence all of the structural elements and functions in the innovation system, as the energy companies are introduced into the system as an actor with new resources, knowledge and interests. The overall activity in the system is increased as more projects and work is initiated as well as more actors being actively included. This increased activity in the system facilitates an increased flow of knowledge between both existing and new actors. The flow of knowledge is however not as well diffused as could be expected because of individual actors and their reservation with cooperating with others.
The major influence of the energy saving obligations are on the system functions of *Market formation*, *Resource mobilization* and *Development of external economies* as the policy measures target specifically the problem of energy efficient technology not being implemented. The obligations are therefore especially important for the commercialization of new products and the engagement of larger markets as it makes sure that new knowledge is commercialized and put into use (Lundvall, 1992). It also has a distinct influence on the success of new and small companies as they are able to use the large energy companies as a gateway to market deployment.
These circumstances will affect the technological development and market introduction of new products in a positive way, however to an unknown extent. Within the system there is however reluctance towards a clear and continuous articulation of needs as well as cooperative activities between actors, which definitely limit the creation and diffusion of new knowledge.

The policymakers attempt to prioritise focus areas in the saving obligations, with mixed results. The idea is to reward savings done through green long-term investments such as upgrading housing insulation. These prioritisations have not yet shown extensive success as the energy companies are finding larger and cheaper savings elsewhere. This underlines the abilities of the energy companies as they are able to discover savings in areas that are unconventional, enabling both large energy savings as well as creating the need for new technology to enable the savings. Further research will uncover how the obligations as well as the prioritisation of the energy companies' influence the different technology areas and the direction of search in the innovation systems.

Evaluating the energy saving obligations with regards to its effectiveness in inducing innovation is difficult. It is not a direct instrument for encouraging technological development and innovation as for instance can be argued with building regulations (Noailly, 2011), but it will at least influence the innovation system through the aspects highlighted in this paper. The

policy increases system activity, knowledge sharing and enhances commercialization, use and adaption of products which is crucial within an area known for its reluctance and its difficulties with getting new technology successfully applied.

The energy innovation system described in this paper is however dependent on two variables, namely the political agenda (Danish Government, 2011) and the obtainable energy savings. These two elements will continue to change, to some extent without possible influence from the actors in the system, but forcing the actors to react and create new ways of adaption.

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