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Innovation in the building sector - promoting energy efficiency in Sweden and Denmark

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Abstract

This thesis investigates the innovation of solutions promoting increased energy efficiency in the building sector in Sweden and Denmark using an innovation systems perspective. On the basis of a research matrix focused on key pre-requisites for innovation, namely, access to knowledge, access to resources, and the formation of markets, the dynamics of innovation in the building sector is examined. Through a literature review and empirical findings, interactions between actors and mechanisms underlying innovation are mapped and the role of national, sectoral and regional innovation systems is discussed in terms of factors constraining and enabling innovation. Potential opportunities and solutions are examined and the possible practical application of elements promoting innovation is illustrated in the case of the Danish and Swedish cross-border region of Øresund.

The research indicates that generic innovation models are insufficient in capturing the complexity of innovation processes in the sector, especially in light of the added complexity connected to the issue of environmental innovation. While the investigation shows that an innovation systems perspective is a valuable tool for understanding and analysing the case of energy efficiency in the built environment, it also indicates that other factors lying outside the typical innovation systems perspective scope are crucial. In conclusion, it is argued that there may be a considerable innovation potential in this area and that systematic efforts to address constraints and stimulate innovation could lead to the development of increased growth and competitive advantage.

Executive Summary

This paper investigates the issue of the development and integration of solutions promoting increased energy efficiency in the building sector in Denmark and Sweden by use of an innovation systems perspective. Environmental innovations are central in our efforts to decrease negative impacts and increase sustainability; furthermore, they may be a means of furthering competitiveness and growth. While more emphasis has been typically placed on solutions for energy supply, increased energy efficiency is an important tool for attaining increased security, promoting the use of renewable energy sources and sustainable development. Since a considerable part of our energy consumption stems from our built environment, the issue of energy efficiency is of particular relevance for the building sector.

The innovation systems perspective captures the many of the challenges connected to the process of change and provides a framework from which to examine the system and view interactions thus allowing for the identification of opportunities, but also barriers that need to be addressed.

On the basis of an initial theoretical investigation, a research matrix was developed focusing on key pre-requisites for innovation, namely, access to knowledge, access to resources, and the formation of markets, the dynamics of innovation in the building sector is examined. Through a literature review and empirical findings, interactions between actors and mechanisms underlying innovation is mapped and the role of national, sectoral and regional innovation systems is discussed in terms of factors constraining and enabling innovation. Potential opportunities and solutions are examined and the possible practical application of elements promoting innovation is illustrated in the case of the Danish and Swedish cross-border region of Øresund.

While environmental innovations can be incremental, significant reductions of the level of environmental degradation may necessitate more radical innovations. However, such innovations are characterised by high levels of risk and uncertainty, leading to potentially costly investments and uncertain returns. The complexity of environmental issues may also act as a deterrent to innovation. Environmental innovations may be solutions that, while providing benefits for society as a whole, do not necessarily initially provide direct benefits for individuals, therefore, regulation and state initiatives play an important role in promoting such innovations.

Similarly, while energy efficiency can potentially contribute to decreased environmental impact, improved economy for end-users and clients, as well as business opportunities for and increased competitiveness of companies, there are a number of organisational and conceptual barriers to the increased integration of energy efficiency promoting solutions in buildings. Increased energy efficiency requires that a number of actors agree on shared objectives and necessitates new types of building process with increased levels of cooperation. Demand for energy efficiency in buildings has fluctuated as a result of energy prices, building cycles and state policies leading to a situation where the returns for investments in development are unclear. However, the political focus on energy efficiency is increasing, as is awareness and interest within the sector.

The building sector is typically described as being conservative and as having low rates of innovation. Innovations in the sector are most often incremental rather than radical or system innovations. There are a number of constraints that affect propensity to innovate. Innovation in the building sector is a complex process that is hindered by a combination of sectoral and other features. In order to develop and integrate energy efficiency solutions, there is a need for

the access to knowledge and resources and a market demand for such solutions. However, due to the fragmentation and territoriality of the industry, the diffusion of cross-segmental knowledge is constrained, the project-based nature of the construction segment poses additional challenges for the collection of knowledge, and the long and complex value chain limits interaction between customers and producers. Due to a difference in perspectives, the interface between public research organisations and the sector is mismatched; leading to a situation where research needed for the development of future solutions may not be diffused or conducted. Access to resources is restricted by insecurities created by building cycles, short term policies, fluctuating demand and potentially by a lack of access to external financing. The formation of markets is in turn affected by split incentives, lacking incentives and short-term perspectives.

While national innovation systems play an important role and can constrain or enable innovations, initiatives on a sectoral and company level are also crucial. Regional systems can also provide opportunities that stimulate innovation.

Many different types of measures have been initiated to stimulate and reform the sector depending on what is perceived to be the problem at a given point in time. However, more long-term systematic approaches that are specifically developed for the sector may be needed to counteract the both sectoral constraints, as well as the insecurity caused by external factors such as economic cycles and fluctuating demand.

Substantial and systematic changes in the culture and structure of the building sector itself may be required to enable it to become effective, innovative and to provide the types of services and products needed in the future. While a single firm can drive forward an innovation, broader adoption necessitates the active involvement of many actors and stakeholders. For an innovation to spread and become accepted, it is necessary that it gains the support of a variety of actors. Consequently, coordinated efforts are needed to stimulate the creation of markets for innovative solutions.

The research shows that there may be a need to further develop innovation models in order to capture the intricacy of innovation in the building sector, as well as the complex issue of environmental innovations. While an innovation systems perspective is a valuable tool for understanding and analysing the case of energy efficiency in the built environment, there are other factors lying outside the typical innovation systems perspective scope that affect the development and integration of new solutions. There may be a considerable innovation potential in this area and systematic efforts to address constraints and stimulate innovation could lead to increased growth and competitive advantage. By building on existing strengths and utilising opportunities significant progress could be made.

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1 Introduction

Oil reserves are running out, population growth is increasing at an alarming rate, consumption is escalating, global climate is showing disturbing tendencies, and soil, air, and water is continually being polluted. These are all issues that need to be addressed. The achievement of a more viable use of resources necessitates the existence and availability of products and services that enable us to decrease our negative environmental impact and successful environmental innovation may be central in achieving this.

Environmental innovations are a possibility to maintain and increase economic growth while safeguarding the environment[1]. They have been identified as an important contributing force to the Lisbon process, which aims at making the EU the most competitive and dynamic knowledge driven economy by 2010 and to promote the decoupling of economic growth from environmental degradation[2].

Energy consumption constitutes a significant part of our negative environmental impact by contributing to the depletion of natural resources and by producing emissions that affect air quality, as well as potentially giving rise long-term effects on global climate. While studies tend to focus on the supply side of the energy issue, a transition towards renewable energy resources is dependent upon our ability to decrease our energy consumption. According to the Green Paper on Energy Efficiency, the most cost effective tool to address climate change and assure the security of energy supply is energy efficiency. Energy efficiency measures in Europe could cut present energy consumption by 20% leading to savings of EUR 60 billion annually and provide up to a million new jobs, as well as contribute to increased competitiveness and improved living conditions[3].

Since energy used in the built environment constitutes 40% of the total energy consumption in the European Union, changes in the built environment in the form of solutions and measures promoting energy efficiency provide the largest single potential for reducing the total energy consumption.[4] According to the *EC Directive on the energy performance of buildings* an estimated 40 Mtoe (Megatons of oil equivalent) could be saved by year 2020, corresponding to almost a fifth of the European Kyoto Protocol targets[5]. Other studies set the cost effective gains at even higher levels of up to 70 Mtoe, as well as indicate the possibility of the creation of 250 000 full time employment opportunities in Europe[6].

Buildings are complex products consisting of an outer envelope and an interior, building elements and systems including water, air and energy. They provide users with a multitude of functions including shelter, weather protection, comfort, seclusion and space for interaction with others. Buildings are part of the environment, the rural or urban setting. Furthermore, a variety of actors have a vested interest in the design and functionality of buildings. Energy use is dependent upon factors such as the materials used, systems installed, operation and maintenance of systems and user behaviour. Consequently, the issue of energy efficiency in the built environment can be viewed from a number of different perspectives. This paper uses an innovation system perspective to identify key interfaces and interactions that determine the successful development and dissemination of solutions that promote energy efficiency.

[1] NCM (2006)
[2] NCM (2006)
[3] EC Green Paper on Energy Efficiency (2005)
[4] EU (2006), EC Green Paper on Energy Efficiency (2005)
[5] Jansen (2004), EC Directive on the energy performance of buildings (2002)
[6] Ecofys (2004), EC Green Paper on Energy Efficiency (2005)

Currently, a variety of technologies and solutions that can be used to increase energy efficiency in buildings exist and further technological developments in this area are possible. Considerable energy savings can be achieved by integrating energy efficient solutions during the planning and construction phase. Similarly, significant savings can be attained by choosing energy efficient solutions when repairing existing buildings. Energy requirements can be decreased radically through relatively simple changes in building construction and materials. Technically this may be one of the easiest of the world's energy problems to solve, but from an institutional perspective it may be the most challenging[7].

There are technical estimations showing that energy consumption in buildings can be halved and while buildings that require very little energy have been built, considerable potentials still remain to a large degree unutilised and most of our existing buildings, as well as new buildings use more energy than actually necessary[8]. A reasonable question is - *Why*? *What is obstructing the use of common sense solutions that save money and resources*?

The answer to this question is unfortunately not simple or straight forward. To understand what can be done, it is necessary to examine the building sector and try to see what determines that a solution promoting energy efficiency is developed and what factors influence its integration in actual buildings.

This thesis focuses on the cases of Sweden and Denmark. Sweden has in a governmental proposition adopted in June 2006 set the aim of decreasing total energy use per built area by 20% to year 2020 and by 50% to year 2050 compared to use in 1995[9]. Similarly Denmark aims to reduce overall energy consumption in buildings by 25-30% and successively continue to increase savings[10]. To attain or surpass these targets there is a need for new products that enable increased savings and that these solutions are integrated into buildings. Consequently, the issue of innovation in the building sector is highly relevant for the attainment of a more sustainable built environment in these countries.

An initial review of literature indicates that there may be a gap in understanding of how change takes place in the sector in regard to environmental innovations. Thus research addressing how innovation creation and diffusion takes place may contribute to a higher level of understanding of how innovation occurs and how environmental innovation can be promoted and facilitated in the sector.

1.1 Purpose

The purpose of this study is to identify key factors and interactions influencing energy efficiency innovations in the building sector in Denmark and Sweden. In order to achieve this purpose, it is necessary to investigate the following two aspects:

- How innovation can take place in the building material producing segment and what factors and interactions enable and hinder the development of products and solutions promoting increased energy efficiency.

- What are the roles of actors in the building sector and what are the interactions influencing the integration of solutions promoting energy efficiency in buildings.

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[7] Flavin and Lensen (1995)
[8] Tommerup and Svendsen (2005), Nässén and Holmberg (2005)
[9] Swedish Ministry of Sustainable Development (2006)
[10] Danish State Building Research Institute (2006)

1.2 Research questions

To gain insight into the dynamics of change in regard to environmental innovation in the building sector, the research will focus on the following questions:

What are the key factors and interactions influencing the development of solutions promoting increased energy efficiency and the integration of these solutions in buildings?

- How have actors accessed, acquired and used knowledge?
- How have resources been accessed and used?
- How has the articulation of demand influenced actors?
- What factors and actors have influenced the formation of markets?

1.3 Scope and limitations

This thesis focuses on innovation in the building sector and on environmental innovations, specifically energy efficiency promoting solutions and the integration of these innovations. The geographical scope of this thesis includes Denmark and Sweden, and when pertinent, specific focus has been placed on Øresund region.

While several technologically interesting and energy efficiency promoting solutions for energy generation have been developed and are on the market, this thesis focuses on technologies limiting the consumption of energy. Thus technologies and solutions pertaining to energy generation and distribution are not covered. It should, however, be kept in mind that these are also of high relevancy for the improvement of energy efficiency in the built environment.

Contrary to what one might expect from a thesis dealing with innovation, this paper does not cover cutting-edge and newly developed technologies. The reasons for this are several. Firstly, one of the aims of the paper is to further an understanding of the innovation process, this necessitates information on market reactions to the innovation and possible changes and evolution in demand, thus focus needs to be placed on products that have already been established on the market.

Even though the use phase has considerable impacts on total energy consumption of buildings, focus is placed on inbuilt aspects rather than on changes in user behaviour.

In regard to various solutions for the built environment that promote energy efficiency, due to the geographical scope of the paper, greater emphasis is placed on heating rather than cooling, attention is mainly directed towards solutions relating to insulation, windows and ventilation.

This thesis is based on the presumption that more technological advances will not provide the full solution to the challenge of increasing energy efficiency in the built environment. Instead changes may be needed in the structure, organisation, cooperation, processes and priorities within the sector, as well as in the approach of policy makers.

1.4 Methodology

The innovation systems perspective is used to investigate how an increased development and integration of energy efficiency solutions can be achieved, as well as to advance understanding

of how dynamic sectoral systems work and how regional and national factors can influence innovation.

The first phase was aimed at **establishing the context** in which innovation can take place through the mapping of systems and identification of actors. This was done by literature studies, interviews with key actors and triangulation of information. To gain insight into flows of knowledge and competence in the sector and the interactions that lie behind these flows, focus was placed on certain key functions[11] such as the access to and creation of knowledge, the supply of resources, and on how demand is shaped and articulated. A research matrix was elaborated to be used in successive phases.

The second phase was aimed at **understanding the process of innovation** and design changes. This was carried out by the identification of a number of successful cases or important types of actors and interviews to find out:

- What are the main barriers they have faced?
- What characteristics do they possess that have allowed them to overcome barriers that have constrained others?
- Which of the provided support mechanisms have been crucial?
- What strategies have they used?

The third and final phase was an **analysis and synthesis** of collected input. The information elicited from the interviews was compared to identify possible patterns, commonalities and differences. The research matrix was converted into an analytical tool to facilitate the comparison and cross cutting of input, manage the complexity of the issue, as well as to serve as a base for proposals on problem solving. The objective of the synthesis was to provide a foundation for developing ideas on how innovation systems can be strengthened to increase the rate of successful market launches of energy efficiency promoting solutions and integration of these innovations in building projects.

Interview methodology

Personal semi-structured personal interviews were conducted with 34 actors; one interview was conducted by telephone. The selection of people to interview was based on a pre-study of companies and organisations of relevance to the topic at hand. In several cases, selection was based on the suggestions of other actors. While, unfortunately, it has not been possible to conduct interviews with all actors and organisations of relevance, the cumulative experience of the actors interviewed is considerable.

The intent of the interviews was to capture and map opinions, perceptions and experiences. The mode of interviewing was based on guiding questions and requests for further clarifications rather than direct questions and answers. The persons interviewed were to a large extent let to decide the direction of the discussion. The interview questions or topics were adapted to the specific person being interviewed and the discussion was allowed to develop freely. This mode was used so as not to miss topics or ideas that may be of significance and to avoid excessive steering, which could exclude possible topics of relevance. A diagram over the innovation process and the key areas of knowledge, resources and market was used during the interviews.

[11] as discussed in Jacobsson and Bergek (2004)

Triangulation of information elicited from written materials and from interviews was performed. In some cases, opinions on issues varied largely depending on the specific perspective of the people interviewed and on their experiences. When possible the differences were followed up and a joint effort was made to try to understand what could lie at the source of these variations.

The interviews were generally conducted at the production facilities or offices of the actors and had the duration of one to three hours. The interviews were conducted in the language of choice of the actor, typically Swedish or Danish, in some cases in English. The input from interviews was supplemented by participation in meetings, workshops and study visits. As requested by some actors, anonymity is provided through the use of codes in referencing, merely indicating country of origin (DK - Denmark, SE - Sweden) and type of products produced (INS - insulation, VENT - ventilation, WIN - windows).

1.5 Structure

In **chapter 2**, the issue of energy efficiency in the built environment is described with the aim of showing what technical options are available and introduce some of the factors that affect innovation and integration.

This is followed, in **chapter 3**, by an illustration of innovation in the building sector through a number of hypothetical cases in order to introduce key actors and interactions, as well as to provide insight into the process of innovation and integration so as to provide an understanding of innovation dynamics in the sector. The topic of change is introduced and several of successful cases where actors have been able to overcome constraints are presented.

Chapter 4 gives a presentation of theoretical models generally used to understand innovation, with a focus on the innovation systems perspective. These theoretical approaches are synthesised into a research matrix used to address the issue at hand.

In **chapters 5 -9** findings are presented and analysed. The first part of this chapter presents theoretical findings focusing on the building sector leading to an initial discussion on why innovation in the sector may be more complicated than in other sectors. In this section sectoral features that impact innovation are discussed, as well as environmental innovation in the sector. Subsequently, the cases of Sweden and Denmark are presented in light of the chosen research approach with focus on the building sector, innovation systems and energy efficiency. This is followed by a presentation and analysis of empirical findings. These findings are synthesised into a factor matrix based on the chosen research approach, issues relating to national, regional and sectoral innovation systems are identified. Selected key issues, organised in accordance with the research matrix, are then discussed to further explain innovation dynamics. After which, a selection of possible solutions are presented. The issue of coordination and timing is discussed and illustrated.

In **chapter 10** the findings are discussed in terms of opportunities for the sector as a whole, as well as for select groups. The conclusions from preceding chapters are then, in **chapter 11**, discussed in terms of regional opportunities taking the case of Øresund region. In **chapter 12** conclusions, recommendations, and topics for further research are presented.

2 Energy efficiency

The objective of energy conservation or increased energy efficiency is to achieve a higher useful output for the same energy consumption. The reasons for aiming towards higher energy efficiency are several, including increased national and personal security, increased comfort and the freeing of financial resources that could be used for more useful activities. Furthermore, increased energy efficiency provides a number of environmental benefits such as the conservation of resources, decreasing emissions and thus air pollution, and decreasing of contributions to global warming. Moreover, energy efficiency can be linked to an increased ability to cover energy supply with renewable resources.

2.1 Energy efficiency potential

There are various ways of looking at energy efficiency potentials.

- The *theoretical potential* is limited by the laws of thermodynamics and constitutes the minimum amount of energy that is needed to provide a given function or service.
- The *technical potential* is a measure of what can be achieved by using the best available technology or cutting-edge technology that has not yet been introduced on the market.
- The *techno-economic potential* - includes consideration of the need for cost effectiveness i.e. investment costs vs. operating costs and is a measurement of what is technically possible and economically feasible.[12]

It should be emphasised that while the theoretical potential remains static, the technical, techno-economic potential is subject to change due to development and the introduction of new technologies and changes in energy prices[13].

2.2 Technological options

The types of possible energy efficiency measures range from common sense solutions based on traditional knowledge to extensive high-tech computerised systems. In one sense, it is possible to speak of two disparate directions, one being passive houses, simple robust systems, the other being smart or intelligent houses with ICT based applications. Passive houses have extremely low heating requirements, in which a variety of energy efficiency promoting solutions are integrated. They are very well insulated, air leakage is kept at a minimum and mechanical ventilation systems ensure the recycling of heat.[14] At the other end of the spectrum, energy-efficient heating and cooling of buildings can also be promoted through the use of automated controls, ventilation and improved duct systems and technologies such as setback thermostats and intelligent building controls[15].

Technologies can be combined in a number of different ways and adapted to the location, environment and requirements of specific buildings and building projects. Thus it is not possible to identify one specific technology or approach that provides the solution to improved energy efficiency.

[12] Neij and Öfverholm (2001)
[13] Neij and Öfverholm (2001)
[14] Workshop (2006)
[15] US Department of Energy Efficiency and Renewable Energy (2006)

It should also be emphasised, that energy efficiency can be attained by various means and that it is possible to combine a set of materials or products with improved properties in a manner that leads to increased energy use, similarly it is possible to combine conventional materials in a way as to provide increased efficiency. Consequently, energy efficiency in the built environment is related both to products or building materials and also to the building process i.e. how products and building materials are combined.

Simply put, high levels of energy efficiency mean that energy is used to provide necessary services such as heating and lighting, but energy losses i.e. the waste of useful energy is decreased and less energy is needed to provide these functions.

Transmission losses occur through the building envelope. This includes everything that separates the interior of a building from the outdoor environment, including the windows, walls, foundation, basement slab, ceiling, roof, and insulation. These losses can be addressed by additional insulation and the choosing of building parts or elements with small heat transmission values (low U-values).[16]

Significant transmission losses are caused by poor glazing designs of windows. These losses can be significantly reduced by using windows with low emissive glazing and a warm edge construction.[17] Examples of such products are triple glazed windows, windows with gas between the panes and special low-emissive coatings[18]. As windows transmit more heat than surrounding walls, the size of windows is also a relevant aspect.

Another issue of importance is the avoidance of thermal bridges. Studs, sills, and other building components can potentially act as thermal bridges, conducting heat past a building's insulation.[19]

Highly insulated buildings can accumulate noxious gases if they are insufficiently ventilated, a problem known as *sick buildings*. An additional issue is moisture damage and mould, which can occur in tightly constructed buildings with insufficient ventilation systems. Air-exchange is thus a prerequisite for good air quality. However, ventilation, whether natural or mechanical, leads to heat losses, thus leading to an increased need for heating and higher energy consumption. Ventilation losses can also occur due to air leakage i.e. gaps in the building envelope. Potentially 80-90% of the energy lost through ventilation can be recovered by use of technologies such as heat exchangers[20]. In tightly constructed buildings, there are greater possibilities to control the air-flow[21]. In less tight constructions it may be difficult to control where the moisture-saturated indoor air flows, which can thus lead to condensation in walls or roofs.[22]

2.3 General factors affecting energy efficiency improvements

According to Neij and Öfverholm, market barriers often restrict the implementation of energy efficiency improvements. Barriers such as low energy prices, low priority of measures and investments, lack of information and knowledge, high initial cost of technologies, limited

[16] Eek (2002)
[17] Tommerup and Svendsen (2005)
[18] US Department of Energy Efficiency and Renewable Energy (2006)
[19] Eek (2002)
[20] Eek (2002)
[21] Tommerup and Svendsen (2005)
[22] Eek (2002)

access to capital, perception of high risks contribute to limiting the progress towards increased energy efficiency.[23]

Other factors include short-term perspectives and primary focus on initial costs as opposed to a life-cycle perspective, out-dated construction norms and rules of thumb for dimensioning technical equipment. Specific barriers can be posed by regulations, for instance taxes that are applied on energy saving equipment but not on energy use. Furthermore, it may be difficult achieve the economic potential for energy efficiency because market actors have differing approaches and priorities. [24]

According to the Swedish Energy Agency, possible explanations for the limited dissemination of solutions promoting energy efficiency can also be found in an unwillingness to change routines and behaviour i.e. social and organisational barriers have hindered the implementation of technically possible and economically feasible measures.[25]

An additional problem related to energy efficiency is that it is frequently difficult to appreciate the effects of increased efficiency. For example, additional insulation does not necessarily immediately lead to reduced heating bills, for instance in situations with rising energy prices or in cases where consumer behaviour is changed.[26]

2.4 Specific factors affecting improved energy efficiency

The U-values or insulation capacity of **windows** is successively being increased. Improvements can be made both in regard to the glass and the frame. There are also products for upgrading older 2-pane windows to more efficient 2-pane or 3-pane windows. However, the new windows may be hard to handle or heavy; they may be more difficult to clean and may not be aesthetically attractive. Other problems include the development of outside condensation or frost in certain weather conditions. Furthermore, the new windows have may have a relatively high cost and long-payback period especially for existing buildings. Other potential problems are unclear or unknown long-term properties and a lack of knowledge about their characteristics and system issues i.e. how they interact with installations and the rest of the envelope.[27]

Higher levels of insulation and air-tightness require improved **ventilation**. The energy efficiency of mechanical ventilation systems can be improved by the installation of heat recycling through heat exchange from out/in-going air or with out-going air heat pumps. Factors limiting integration, include an insufficient product range for existing buildings, insufficient testing of need-based ventilation systems and it is unclear whether future rules for re-circulation deters product development. Further problems include a lack of development in regard to in/out-going air systems, low effectiveness, high noise levels, drafts, dry air, high use of electricity and lack of maintenance-friendliness. Additional problems are posed by the insufficient adaptation of products on location and incorrect installations.[28]

Compared to the rest of Europe, Sweden and Denmark have traditionally used a high **insulation** standard and well-tested solutions exist for both new and existing buildings. However, increased use of insulation decreases available indoor space; this is especially

[23] Neij and Öfverholm (2001)
[24] Jansen (2004)
[25] Energimyndigheten (2000) in Svane (2002)
[26] Jansen (2004)
[27] Bygga, bo och förvalta för framtiden (2003)
[28] Bygga, bo och förvalta för framtiden (2003), interviews (2006)

relevant for facilities intended for rent or sale. While solutions exist, it is generally more difficult and expensive to improve insulation in existing buildings. [29]

[29] Bygga, bo och förvalta för framtiden (2003), interviews (2006)

3 Understanding the building sector in terms of innovation

In simple systems actors are connected in a linear fashion and thus by understanding the parts, it is possible to understand the system. Complex systems are characterised by the situation that the sum of the parts does not describe the whole. In complex systems, the interactions of actors or parts are more web-like and thus in order to understand such systems, it is necessary to pay as much attention on the links or interactions between the parts as on the parts themselves.[30] Thus to understand how innovation takes place in a complex system, namely, the building sector, it is necessary both to identify actors and to try to understand the interactions between these actors.

As stated in the introductory section, in order to address the issue at hand there is a need to understand how innovation can take place in the building material producing segment through the identification of factors and interactions enabling or constraining the development of products, as well as to understand the roles of actors in the building sector and what interactions influence the integration of energy efficiency promoting products.

The following sections, based on a synthesis of theoretical and empirical findings, provide an overview of actors involved in the process of product development and in the building process and show some of the interactions that are relevant to innovations pertaining to energy efficiency.

Innovation in the building sector is frequently described as a relay race, where actors pass on knowledge and responsibility to the next phase. One of the solutions proposed is to attain cooperation, which is more like that of a football team with continuous interaction towards the attainment of goals.[31] However, when investigating innovations related to energy efficiency in the built environment, the process often rather seems to be similar to that of a complex obstacle course, where the obstacles come in different sizes for various actors, some of them are very difficult to distinguish, some seem to be insurmountable, some obstacles seem to fill no apparent purpose and some are perhaps linked to the mind-sets of actors and for many cooperation is required to overcome them.

3.1 The path of the brick

Building materials are typically not products that we purchase as consumer goods; they are products that constitute the components or elements of buildings. Therefore, the value chain for building products is longer and more complex than for many other products.

To understand how the demand of building materials in the building sector is shaped it is necessary to understand how building materials enter the market and are purchased to be integrated into buildings. This brief illustration using a simple building material, namely, a brick, will also allow us to get an overview of which actors are involved in decision-making that underlies purchasing and integration.

Our brick is produced by a building material producing company. In order for the brick to be purchased, an actor or a combination of actors have to make a conscious decision or a set of

[30] Bertelsen (2003)
[31] Björklöf (1986), Skarendal (2006)

decisions that allow for the integration of the brick into the building and thus motivate the purchase of the brick.

The building developer is the actor that pays for the building to be constructed. Thus the building developer is typically the actor with the most influence; however, the decisions made by the building developer are shaped and influenced by a number other actors and institutions. Architects design buildings, thus determining the form and shape, but also to a large extent the types of materials that can be used. If the architect, in communication with the building developer, designs a house made up of wood or concrete elements then our brick is out of the picture for that given building. This means that our brick is not only competing with other bricks but is also competing against different materials. Engineers ensure that the designs of architects are viable and that the necessary utilities are integrated in a functioning manner. The engineer thus influences what building materials are used depending on decisions about stability, durability and calculations on energy and indoor air quality and on the types of solutions designed for various utilities. Thus the possibility for our brick to become integrated into the building and purchased is also limited or increased by the engineer. In the design phase, the building developer will be interested in the costs of materials. In the building sector, it is typical to place considerable focus on lowest price, thus the relative prices of building materials may also influence the design of the building.

After the design phase, a set of specifications are developed and typically a construction company is given the task of recruiting necessary subcontractors and purchasing materials. It should, however, be noted that frequently the construction company is also involved in the design phase. Subcontractors may in turn be responsible for purchasing the products that are necessary for the services they have been contracted for. The construction company and subcontractors may purchase products directly from the company producing them or they may purchase them from a retailer. A retailer is an outlet that offers a wide range of products. The retailer may influence the decision of the construction company and subcontractors by offering discounts, bonuses and by displaying certain products more prominently than others. The retailer will probably also offer similar bricks made by other producers and probably also imported bricks. The decision of whether our brick will be purchased may, therefore, depend on whether its price is competitive or on whether it offers additional values.

It is also possible that some of the actors have combined roles, for instance in smaller companies, an architect may be responsible both for design and construction, and in larger companies the construction company may also provide the services of architects and engineers.

While future owners or users may have limited influence over this decision making process, they can have an impact on decisions through both their stated demands and wishes or through the perception of their demands by other actors.

It should be noted that there are also alternative paths for our brick to become integrated in buildings, for instance through long-term contracts with larger construction companies. Another possible path for our brick is the export market, where it will be subject to a similar decision-making process but with national variations mainly related to the relative influence of the actors along the value chain.

Demand for certain types of building materials may also be influenced by trends, as well as by the demands of municipalities in their local planning.

In summary, the decision-making process behind the integration of a building material is complex, building materials are subject to dynamic competition, demand is difficult to predict and the ability of the producing company to influence decision-making may be limited due to a lack of a direct link with actors making decisions and a lack of information about which actors it would be most effective to influence through e.g. advertising or information.

Another way of looking at it is that our brick needs several actors to make the right (for the brick) decision at consequent stages of the process. Consequently, it may not be enough for only one actor to make the right decision because the possibility remains that this decision is negated at the next stage by a decision by another actor.

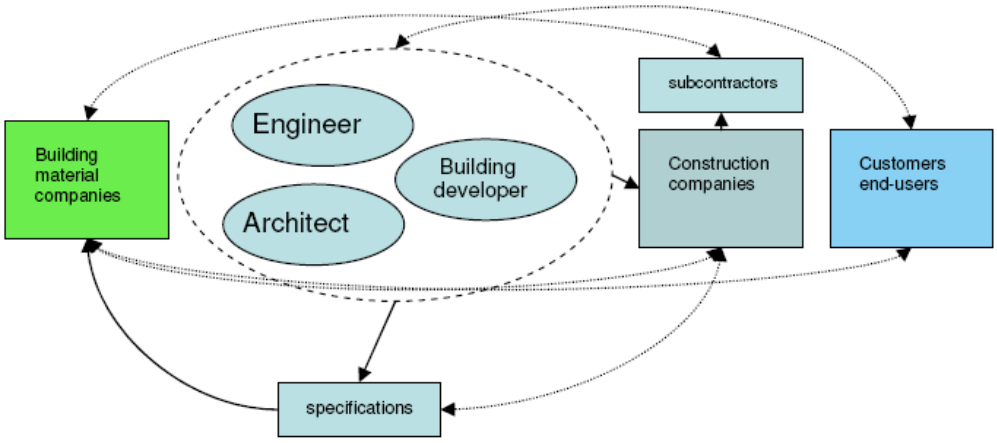

Figure 3-1: The formation of markets
Source: VR[32]

This illustration shows key actors involved in the decision-making process. The decisions made by a single actor are dependent upon interaction with other actors as well as on other factors.

3.2 The path of the innovative brick

Seeing the complexity of the path a regular brick follows towards incorporation in a building, it is only to be expected that the path of a new type of brick is even more precarious. There are different kinds of innovations. Our brick could include an incremental innovation i.e. it is slightly improved to provide additional benefits or enhanced performance. Or at the other end of the spectrum, our brick could provide significantly different functions from conventional bricks; it could be a systems innovation.

Since our fundamental question is about how companies develop new products promoting energy efficiency and how these are integrated into buildings, let us invent a brick that provides the additional functions of natural ventilation through special membranes, while providing a superior insulation performance. Since we are interested not only in how the innovation enters the market, but also in how it is developed, let us start at an earlier phase.

[32] Developed by the author

For the brick to be developed someone has to come up with the idea of the brick. In order to do so, knowledge and information are needed. Sources for such knowledge vary, and innovations are often the products of combinations of various types of knowledge. Knowledge may be formal or informal, come from inside the company or from outside.

Government decisions on of funding to research and what areas are prioritised may have a significant impact on the availability of certain types of knowledge. The ability of public research organisations to spread research results and to attain research results that are relevant to the sector and to product development will also influence the accessibility of knowledge.

In our case, let us have a project leader who has come up with the idea. Once an idea or concept is formed it needs to be developed into a product. For this resources are necessary. In order to get access to capital, our project leader has to convince someone who presides over capital and human resources to let her access these. For this she needs to show that it is a good business idea. Access to resources may also be dependent on other factors, for instance the building sector is subject to cyclical periods of growth and recession, which may have a considerable impact on the resources available to the company. The decision not to further develop an idea may be influenced by what phase of the cycle the sector is at that given moment in time. As we saw from the previous case, demand is difficult to predict for conventional products, so it is even more difficult to predict for completely new products.

Let us assume that our project leader is able to access capital and human resources to develop the product. A phase of product development involving a number of actors and additional inputs of knowledge follows. A phase where possible patents are sought may come during this phase or later. The product is designed and testing is conducted, and necessary certifications are carried out. Development projects can be stopped at any stage due to reasons such as lack of resources, a decision that the concept is not profitable, and changes in regulation. This process will most probably also be subject to a number of failures and re-designs. It is claimed that Honda, the car producer, has stated that success consists of 99% mistakes. However, Edison denied that he had made 1000 mistakes; and that instead, when inventing the light-bulb, he developed it in 1001 steps[33].

When the product is ready to be launched on the market, it is faced by the same problems as the conventional brick, with a complex decision making process underlying purchasing and dynamic competition, but since it is a new type of brick it faces some additional challenges.

Since our new brick is a systems innovation it requires changes in the building design and construction process, thus it affects the way actors typically design and build buildings. This entails that the brick is not only dependent on the typical set of decision-making; its success is also dependent upon the willingness of actors to change their behaviour or their way of doing things.

Since our brick is a systems innovation, it offers additional functions, but it could be more expensive than conventional bricks because we have invested in resource demanding development work. However, since our brick offers new functions, it also can improve the energy efficiency performance of the building and lead to savings of money over time. It thus may require an initially higher investment, but its total life cycle costs could be lower than for other bricks or materials.

[33] Öhlin (2006)

However, for decision-makers to take this into consideration, a different type of thinking is needed, and the decision-makers need to focus on total life cycle costs as opposed to the costs they are paying here and now. There are a number of reasons why this change may be difficult. Firstly, new ways of thinking and changes may take time. Secondly, the building developer has limited quantity money here and now that constrains his or her decisions, the savings on the other hand are in the future. Thirdly, while the developer may realise that he or she could use the savings to pay off the extra investments made now, he or she might be constrained by the structure of the organisation's budget and have one budget for investments and one for operation and maintenance. Additionally, savings and pay-back times may be difficult to calculate. Fourthly, the building developer may not be building for him or herself but may intend to sell the building. Thus the issue of operational costs are of no consequence and it does not make sense to make investments and depleting ones own profit margins for something that will benefit others.

The success of the new product also depends on the interest and ability of the architect to design a building into which such a solution would fit. This requires that the architect is knowledgeable about the product and can integrate it into the design concept.

The engineer also has to be on board and be willing to forgo conventional solutions and be prepared to integrate such a product with the rest of the design. New products with novel characteristics will affect other components of the system; this may require additional calculations and possible simulations or testing.

The construction company has to be able to work with the product i.e. it has to have specialists that can construct a building using the new type of brick. Since our new brick is a systems solution, it requires the cooperation of builders, engineers working with ventilation and insulation specialists, as well as other professionals. This may require a new type of building process, which then requires changes in the behaviour of involved actors. It may also necessitate some form of additional training or supervision, which would involve additional costs.

Using something new and changing processes may lead to higher risk. Risks are in turn related to potentially higher costs and potential failure is related to possible lawsuits, again involving further costs, or damage to reputation, affecting future income.

The retailer may also affect the success of the new product by not ordering it in, thus limiting availability. The retailer is interested in products that will be sold and may not be interested in using up valuable space for products with limited demand. The future owner or user may again have limited influence on the process, but again the perceptions of what they want will influence the decisions of others.

Trends, regulation and the demands of municipalities in their local planning may also affect the ability of the brick to succeed on the market. The demands set by government and municipalities may be important driving forces for some innovations, while they may limit the possible development of other solutions. Regulations can be used to set standards, thus forcing the use of technologies with improved performance. Policy instruments can be used to create incentives and stimulate decision making in a certain direction.

To promote innovation, incentives need to be created for each of these actors or at least the most influential actors to enable them to make decisions that promote the choice of energy efficient solutions.

3.3 Building a conventional building

In order to understand how energy efficient solutions can be integrated into buildings, it is necessary to have at least a superficial overview of the building process i.e. the process that combines building materials and services into the finished end-product - a building. Here we come across some of the same actors, as we did when trying to launch our brick on the market, but now we will focus on their interactions during the actual building process. This will be a highly simplified description, but will serve to briefly illustrate the process in order to highlight a few key issues.

The building developer is the actor with the money i.e. the one making the main economic decisions and consequently also the one making the main demands. The building developer can be a private individual or company, an industry, an investor intending to sell or rent out the building, a municipal or state agency, or a construction company intending to sell the building. The building developer may be an actor who only builds one single house or an actor who specialises in building.

Another important actor could be the investor; this could be a bank or a foundation that provides loans to the building developer. The investor can influence decision-making by placing demands on the type of project, pay-back periods, and interest rate levels.

Buildings are varied in regard to size, shape and use. Typically they are divided into residential, commercial, public and industrial buildings. Residential buildings can in turn be single dwelling buildings i.e. houses or multi-dwelling houses i.e. apartments. Ownership structures vary in different countries. In general, buildings, dwellings or office space can be privately owned or rented.

The building process is regulated by a framework that consists of rules and regulations. The main regulatory instruments are the building regulations or building codes, but environmental legislation and other legislation may also regulate the process. The municipality has influence over what types of buildings can be erected in various locations, as well as on what specific demands are placed on buildings in certain areas. The municipality has influence through its capacity to decide to which actor it will agree to sell plots of land.

The first thing the building developer needs is a plot of land; this can be either rented or purchased. To commence with the building process, building permits need to be acquired i.e. the building developer needs to show that the intended building will comply with regulatory standards, municipal demands and legislation. Applications for permits are submitted to the planning departments of the municipality where conformance with regulations and legislation is checked.

So, before starting the process, the building developer needs permits, an architectural design, an engineering design and specifications that are based in the two designs. The construction company can then on the basis of the specification start to contract subcontractors and procure materials.

It should be mentioned that the actors involved are typically chosen on the basis of competitions, in which price of services typically plays a decisive part. In regard to public buildings, regulation is in place to oversee public contracting and procurement competitions.

Contracting and procurement on lowest price has impacts on quality and on the building process. Focus on lowest price together with high levels of competition lead to actors working with relatively small margins of profit.

The building process has by some been described as a kind of chaos because the process is dependent upon a multitude of variables and so is to a large extent unpredictable[34]. This leads to difficulties with planning the process. It is estimated that in a typical building process, one third of the time is used for planning activities, one third is value creation and one third is waste[35].

For the distinct phases of the building process to move forward, a set of preconditions for each phase have to be met. For example, to paint a wall, the previous tasks need to be completed i.e. the wall has to be erected, the painters need to be there (human resources), they need to have place to carry out their job (space), they need to have their materials, they need information on what they are supposed to be doing, and the external conditions, e.g. weather, need to be acceptable for doing the task..[36] If any of these conditions is not met, then delays are inevitable. Delays in one phase of the process, typically affect the processes following it and bottlenecks may be created. Delays also give rise to extra costs and delays or rather dealing with the effects of delays may increase the risk of mistakes and accidents and thus lead to further costs. Since each task is dependent on different groups of actors or subcontractors process management is difficult.

Once the building is complete, it is handed over to the building developer who then keeps it or sells it or rents it out. Since buildings are large investments, typically the building developer will have taken a loan to finance the building, thus if the intent was to sell the building or rent it out, it is of utmost interest for the developer that the building is purchased or filled with tenants as soon as possible. Thus the building developer is also highly concerned with investing in features that are perceived as attractive for potential buyers or tenants.

3.4 Building an energy efficient building

To integrate solutions promoting energy efficiency in a building, it is necessary that a number of actors agree upon this already in the design phase. Furthermore, specific targets need to be set and all involved actors need to be aware of these targets and of how their work impacts the attainment of these targets. Another important precondition is that there are products available that can be used to attain increased energy efficiency. However, the higher the price of these solutions is, the longer the pay-back period, the lesser the motivation of building developers to use these solutions.

In the case of energy efficient housing, it was previously mentioned that a new type of building process may be needed with higher levels of cooperation between actors and clearer targets and objectives. Improving energy efficiency in buildings is not simply purchasing one energy efficient solution e.g. a window and then carrying on as usual. Improved energy efficiency is the sum of various solutions, it is a system. By, for instance, improving the air

[34] Bertelsen (2006)
[35] Bertelsen (2003)
[36] Bertelsen (2003)

tightness of the building, energy losses are decreased, but the flow of air is also decreased, which may require a new ventilation solution. A new ventilation solution may in turn affect other parts of the system. Consequently, energy efficient buildings are not buildings that have some products that promote energy efficiency, they are systems in which the interaction between various products or elements has been carefully investigated and assessed.

The building developer has to demand energy efficiency in designs and be willing to pay for such solutions. The architect has to design with energy efficiency considerations in mind and the engineer has to take into consideration energy efficiency when designing solutions and making calculations. This might necessitate new knowledge and new competences and may thus require additional training or the recruitment of external competences.

Architects have the possibility to develop energy efficiency concepts from the start and propose ideas about localisation, heating and cooling needs and can make a list of proposals, but then these are discussed with the building developer in terms of how much they cost. While architects can propose various solutions, engineers carry out calculations e.g. the effect of insulation thickness on the system. So for instance, while natural ventilation may be an interesting solution, engineers may prefer mechanical ventilation, since it is easier to calculate and control.

The construction company has to be able to provide professionals that can work with new products and new types of designs. Subcontractors have to be aware of the need to take energy efficiency into consideration and have to be able to work with this issue and the specified materials. If mistakes are made, these will have an impact on the whole system.

While the engineer and architect can guarantee that energy efficiency is taken into consideration in the blueprints, there is still a risk that the construction company or subcontractors may not build in accordance with these. The issue of responsibility is complex, since in such a dynamic system, it may be easy to transfer the responsibility or blame on the next phase of the process.

By integrating environmental issues to a greater extent in buildings, actors are faced with opportunities, as well as obligations. There is a need to keep to the playing rules when working these issues. Thus there is a need for increased knowledge and competence to know and understand what these rules are and how they can be integrated into the building process.

In summary, integrating energy efficiency solutions in buildings requires:

- Conscious decisions
- Clearly stated demand
- Agreement
- Specific targets
- A new type of building process
- Increased cooperation
- Clear responsibilities
- New competences
- Reliable and possibly new calculation tools and methods
- Available products for acceptable prices
- Long-term thinking (pay-back periods, return on investment)
- Greater attention to interaction between various building elements

Thus in addition to the complexity of the conventional building process, improved energy efficiency adds a whole new dimension of complexity and places high requirements on involved actors.

However, this can also be seen from a different perspective. Several of the above mentioned preconditions could actually contribute to an improved building process in general through improved management practices and improved communication between actors. This could in turn lead to a number of benefits in the form of decreased costs due to improved efficiency and improved work satisfaction.

3.5 The need for change

From a societal point of view, change towards more sustainable built environment is desirable. However, as we see from the sections about the innovative brick and the construction of the energy efficient building, change is difficult. As these overviews indicate, each actor acts rationally based on his or her standpoint. It is not reasonable to suddenly imagine that a developer will start constructing and selling buildings at a loss, that companies will invest in products for which there are no markets, and that architects and engineers will try to force energy efficient solutions on uninterested parties. We therefore need to ask - what are the incentives to change and how can these incentives be created.

While increased energy efficiency in the built environment brings a greater good to society, is it fair that actors in the building sector bear the brunt of the responsibility and the effort? It is not realistic to expect that actors will do this at their own expense, thus it is necessary to look at both ways of addressing barriers but also at finding and identifying opportunities that energy efficiency offers to actors.

3.5.1 Successful cases

While this brief overview contributes to illustrate the complexity of the value chain and indicates some of the barriers to innovation, it also paints a relatively depressing picture for the possibilities to innovate. However, companies are innovating and new products are being integrated into buildings. The interesting question is then - how are these actors doing it and what is helping them to overcome barriers? There are numerous successful cases, where actors have been able to access opportunities and overcome barriers, just to illustrate with a few examples:

- An insulation company in Denmark was able to offer a new product that complies with future energy efficiency standards and by developing a more efficient production process is able to provide cheaper solution with improved energy efficiency performance on the market[37].

- A Danish ventilation company has developed a successful concept for stimulating innovation in form of an in-house competition, which has led to the development of a number of marketable concepts and has through the provision of attractive training programmes for new employees ensured stable access to new talents[38].

- A building company based in Denmark decided that instead of trying to protect their knowledge and their products by patents, it would openly share its knowledge on

[37] DK INS-1 (2006)
[38] Nielsen (2006)

environmentally sustainable building with others. The motivation behind this is the understanding that, by sharing knowledge they will enable others to develop similar products or services thus creating an increased interest in these types of solutions and so creating a bigger market for their own products.[39]

- An architect firm in Denmark designed and developed a new system solution in cooperation with three producers coming from different sub-segments of the building material industry, as well as from different countries[40].

- Realising the need for a bridge between research and practical application, a group of Danish researchers, established a consulting company. Over the years, the company has been involved in a large number of projects aimed at increasing energy efficiency in the built environment and stimulating product development. For example, currently the company is working on a project involving Danish producers with the aim of improving their products to make them more adaptable to new regulations and standards. The company is also involved in demonstration and research projects, and is capable of accessing external funding for projects, as well as bringing together partners from various segments in the sector. [41]

- On the basis of findings from researching energy efficient elements of historical buildings, a Danish consulting company has together with a producer developed a new concept with improved performance[42].

- The Danish Radio, when building its new multimedia house in Ørestad, "DR BYEN", was not only able to develop a new partnering model and implement value based management, but also through accessing EU funding create a unique demonstration project, as well as to integrate environmental considerations throughout the planning process[43].

- The Danish municipality of Køge, in cooperation with the organisation Det Grønne Hus, launched a large scale project as a reaction to there being too few environment and energy considerations in the typical houses offered by building companies. As a result, 80 energy efficient houses are being built by different companies. These are model houses that can subsequently be built anywhere in the country.[44] This concept has is now being reproduced in other municipalities, and in the case of Stenløse municipality with even higher energy efficiency demands.

- A Swedish producer of windows made a strategic decision to establish windows with lower U-values on the market i.e. windows with higher insulation properties. The company was able to do so by offering windows with lower U-values at the same price as windows with higher values. When faced with the decision, the natural choice for the customer was to choose the window with improved performance. This led to a situation where other producers were forced to produce improved windows to comply with this new market standard. This strategy also was a tool for the company to get

[39] Abrahamson (2006)
[40] Hansen (2006)
[41] Mørk (2006)
[42] Kærgaard (2006)
[43] Erfa gruppen-2 (2006), Hirsbak (2006)
[44] Alm (2006)

increased public attention and to position itself as a market leader in regard to energy conserving windows.[45]

- A Swedish producer of ventilation systems was faced with the problem of the growing costs of providing ventilation and pressure from competitors that were able to provide solutions at a lower price. Instead of trying to compete on price, a new concept with ventilation modules was developed. This innovation enabled the company to prefabricate, thus improve production efficiency and decreasing cost, furthermore, time and resource consuming on-site design was limited and maintenance was made easier.[46]

- Upon entering a new market, a Swedish company was faced with the need to find a way of distinguishing itself from competitors and create interest in its products. This need, together with a wish to promote the increasing of knowledge on ventilation related issues, led to the establishment of a forum for a series of lectures by acclaimed researchers. Thus the company was not only able to contribute to an increased understanding of issues, including energy efficiency, but also able to link their name with a very popular and beneficial event.[47]

- A Swedish housing company was faced with the problem of needing to decrease building costs per square meter for a planned housing project. Together with a consultant, they developed a solution based on increased energy efficiency and thus were able to cut costs. The building also serves as a demonstration project showing that *passive house* principles i.e. extremely low heating requirements can be integrated in apartment buildings.[48]

- The Swedish municipality of Landskrona successfully accessed state project funding for subsidising energy efficiency renovations in the area. This will in turn stimulate the market for energy efficiency solutions for the renovation market.[49]

This overview indicates that a range of actors are able to make decisions that contribute to innovation, product development, the integration of energy efficiency solutions and spreading awareness about the issue despite barriers and challenges.

[45] Browall (2006)
[46] SE VENT-1 (2006)
[47] SE VENT-1 (2006)
[48] Eneborg (2006), Person (2006)
[49] Cronsioe (2006)

4 Conceptual framework

To understand the preconditions for innovation in the building sector, especially in regard to environmental innovations, the following theoretical overview is intended to supply a framework for understanding the process of innovation and the context in which innovation can take place. The literature review provides insight into research in this area and indicates possible research gaps, some of which this thesis strives to address. The innovation theories and models are synthesised into a research matrix, to serve as an organisational and analytical tool.

4.1 Innovation theories

In order to understand the topic at hand, a brief overview of the theoretical basis of innovation is warranted, due to the topic at hand, focus is placed on product and technological innovations. There is no definition of innovation that is generally agreed upon. Innovation is a term which is used to describe a novelty and thus relates to creativity and inventiveness and the ability to generate new ideas, new knowledge and to combine existing knowledge into new concepts. Innovation is also directly related to the ability to develop a marketable product i.e. to design, produce, and market the novelty in such a way as to make it appealing to customers. To further complicate matters, innovations can be products, services, processes and even new types of organisation. According to Charles Edquist, "Innovations are new creations of economic significance"[50]. Simply put, a product idea that is not developed and that does not have a market is an invention, while a product that is developed and has a market is an innovation.

Innovations could be said to stem from a common knowledge infrastructure (a system which creates and distributes knowledge) that is then utilised through the introduction into the economy in the form of innovations, which are then diffused and transformed into values such as international competitiveness and economic growth[51]. Successful innovation is based on the ability to identify, recognize and exploit business opportunities. Innovation is enabled or constrained by a number of factors such as the lack of access to knowledge, resources and perceived or actual lack of demand. Business opportunities are by nature changing and temporary and the decision not to exploit opportunities is frequently related to the costs of pursuing them being higher than expected returns.[52]

Innovations can be divided into types based on their nature i.e. whether they are small-scale or large-scale changes and on the extent to which they affect actors. **Incremental innovations** are technical changes that can be seen as a redefinition of previous technology and are based on experience and knowledge in the existing production and use system[53]. Such innovations do not significantly affect other components and systems[54]. At the other end of the spectrum, we find **system innovations** that lead to significant changes by the integration of multiple independent innovations created by different actor groups. Such innovations provide new

[50] Edquist (1997)
[51] Johnson and Gregersen (1997)
[52] Berchicci, Bodewes and Brezet (n.d.)
[53] Rogers (1995)
[54] Marquis (1988) in Slaughter (2000)

functions, attributes or improve the whole performance of the process and entail a significant advance in the state of knowledge or practices. [55]

Traditionally linear models have been used to describe the innovation process. Two typical models are the technology push and market pull models. Technology push is based on the use of new technology that opens up new applications that the market has not foreseen. Technology driven development is often more long-term since it may take a long time for new technology or applications to become established on the market. Market driven development or market pull is based on the demands of the market and competing products. The main focus is the effective utilisation and novel combination of existing technology to satisfy well-known customer needs. This type of innovation is often more short-term and includes more frequent modifications and adaptations.[56] Schematically these processes can be illustrated by the following linear flows:

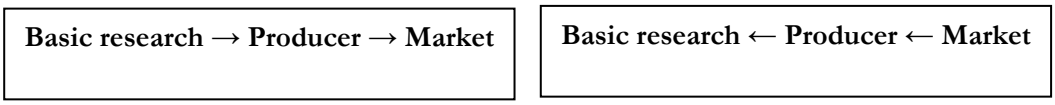

Figure 4-1: Technology push and market pull
Source: Widén (2002)

Systems of innovation is a relatively new approach that emerged during the 1980's in reaction to the inability of the linear theories to account for innovation processes in complex environments[57]. It is based on the concept that innovations emerge through an extremely complex process, which includes the diffusion of knowledge and the translation of this into new products and production processes. This translation process is not linear from basic research to advanced research to the development of products or processes, rather it is a process based on complicated feed-back mechanisms and interaction between the fields of science, technology, learning, production, policy and demand.[58]

Within the innovation systems perspective various types of systems have been identified. A distinction can be made between technological systems (industry sectors, specific technology) and territorial systems (geographical systems including local - regional - national - global). However, depending on the analytical context, they may be complements rather than substitutes. It should be emphasised that systems of innovation are open systems, which can overlap. A company can be part of a sectoral, local, and national innovation system. These systems exist at the same time and one may have to be viewed as a phenomenon of another.[59]

The concept of *national innovation systems* is based on the notion that the innovation performance of an economy is dependent on both how specific organisations perform and how they interact with each other and how they interact with the governmental sector[60]. Key aspects include governmental policies and regulation, the education and research systems and support systems.

A sector can be defined as a set of actors that are unified by related product groups or technologies for an existing or emerging demand and which share a basic knowledge base.

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[55] Henderson and Clark (1990), Goverse et al. (2001), Slaughter (1998)
[56] Johannesson et al. (2004)
[57] Edquist (1997)
[58] Edquist (1997)
[59] Johnson and Gregersen (1997)
[60] Johnson and Gregersen (1997)

Thus *sectoral systems of innovation* share a knowledge base, technologies, inputs, demand and are comprised of actors that carry our market and non-market interactions aimed at creating, developing and diffusing new sectoral products.[61]

The concept of *regional innovation systems* is based on the perspective that innovation results are determined by a specific institutional infrastructure and production system that exist in a certain territory. Consequently, the main idea is that innovative performance of a regional economy depends on the innovative capabilities of companies and research institutions, and on the ways they interact with each other and public institutions in that area. This approach emphasises the role of spatial proximity and its impacts on the innovation process.[62]

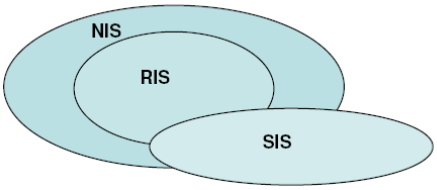

Figure 4-2: Systems of innovation, national (NIS), regional (RIS), sectoral (SIS)
Source: VR

The figure shows national innovation systems, regional innovation systems and sectoral innovation systems indicating that there is an overlap of systems, which could mean that an investigation of only one of the systems may fail to capture innovation dynamics. Furthermore, external factors may also have bearing on innovation processes.

While a national systems of innovation perspective provides insight into interactions, knowledge flows, innovation outputs, a sectoral approach is warranted since the building sector has distinct characteristics that affect its propensity to innovation; however, since building projects take place in a certain spatial context, which provides specific pre-conditions for innovation, and, furthermore, proximity may be a key factor in interaction, a regional approach is also relevant. These approaches are not mutually exclusive and the innovation process includes both sectoral and spatial dimensions.

4.1.1 Environmental innovation

Environmental innovation is the use of equipment, techniques, procedures, products and delivery methods that are sustainable i.e. that conserve energy, natural resources, and have decreased negative environmental impact[63]. Environmental innovations can be defined in two ways depending on the intent of the innovator. In the first case, an environmental innovation is created with the intent to reduce the environmental impact of processes or products. In the second case, the effect of the innovation may be to reduce environmental impact while the intent of the innovation may have been to e.g. improve quality or price.[64] In line with the used definition on innovations, they also should have economic significance, though this may be a debatable issue.

[61] Malerba (2005)
[62] Doloreux (2002)
[63] Derwick and Miozzo (2002)
[64] Markusson (2001)

While environmental innovations can be incremental, significant reductions of the level of environmental degradation may necessitate more radical innovations. However, such innovations are characterised by high levels of risk and uncertainty, leading to potentially costly investments and uncertain returns.[65] The complexity of environmental issues may also act as a deterrent to innovation. Environmental innovations may be solutions that, while providing benefits for society as a whole, do not necessarily initially provide direct benefits for individuals, therefore, regulation and state initiatives play an important role in promoting environmental innovations.

Environmental innovations differ from other types of innovations in that the incentive for companies to develop and adopt environmental innovations largely stems from regulatory pressure. Thus it is relevant to view the environmental innovation process in light of a society driven innovation or a "regulatory push-pull" effect that can affect both demand and supply. [66] In the case of environmental innovations, a different perspective that focuses on society driven development, which is based on legislation and regulations is needed. Intervention in the process by regulatory bodies addresses the problem that the market economy often entails a short-term profit orientated perspective based on competition that does not necessarily steer technology and product development towards solutions that are sustainable in the long-term.[67] Schematically, this type of process is more complex to depict since the intervention may be directed at basic research, the producer or the market.

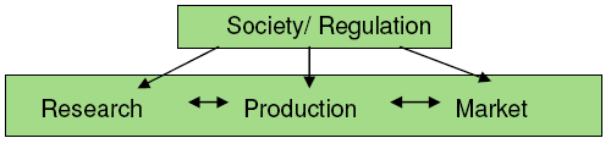

Figure 4-3: Society driven innovation
Source: VR on the basis of Johanesson et al. (2004)

Regulation may be needed to stimulate innovation and create a demand for alternatives that benefit society but have a higher price than conventional products. It plays an important role in the initial promotion of environmental technologies before they become more cost-effective[68]. Different public policy instruments may be better at promoting different kinds of innovations and situations occur where several public policy instruments can simultaneously influence the innovation process. This can affect overall effectiveness through reinforcing or conflicting with other instruments.[69] Policy instruments can be aimed to force (regulation), induce or motivate (economic instruments) or convince (informational instruments)[70]. Some argue that shift may be taking place where instead of just regulation, a combination of regulation and market forces become the most important drivers for innovation[71].

While environmental innovations are diverse, it may be possible to identify common features differentiating them from other types of innovation. For example, Malaman argues that the demand for cleaner production technologies is generally low and difficult to predict. He provides four reasons for this. Firstly, firms tend to prioritise profits over environmental considerations. Secondly, in the introductory stage, cleaner technologies tend to have higher

[65] Berchicci, Bodewes and Brezet (n.d.)
[66] Rennings (2000)
[67] Johannesson et al. (2004)
[68] Derwick and Miozzo (2002)
[69] Bang et al. (2001)
[70] Ödeen (2002)
[71] Markusson (2001)

costs and may have lower quality than conventional technologies. Thirdly, information problems may be significant due to the complexity of environmental aspects and a lack of knowledge, and finally, environmental innovations tend to require more organisational and institutional changes.[72] Other features specific to environmental innovations are that they involve social awareness and draw upon a wide range of fields. Furthermore, they tend to require complementary organisational innovations.[73] According to Markusson, the drivers or conditions that promote environmental innovations are complex and difficult to study since the incentive structure is complicated, inter-firm communication of environmental demands is interlinked with other demands and the field of knowledge that contributes to environmental innovation is diverse[74].

4.2 Other studies and research

4.2.1 Innovation in the building sector

Innovation in the building sector has received increasing interest since the 1990s[75]. While the results of various investigations differ, a general conclusion is that the level of innovation in the sector could be improved[76]. Different causes have been identified for the lack of innovation, including inappropriate innovation models and lack of supplier integration[77].

Often a division has been made between building material development and use of products in the construction process or a separation between innovation as idea or product development and innovation as implementation and use. In some cases, innovation focus is primarily placed on the adoption, purchasing and implementation of new technologies and limited consideration is paid to the invention process.[78] As explained by Clausen, a possible weakness in this approach may be that it gives the impression of a one-way dynamic in the cooperation between the product development part and the construction part of the building process.[79]

Despite acknowledgement that one of the main sources of innovation in the sector is the building material industry, according to Sundqvist, building material manufacturers are rarely included in theoretical models and research in the area of innovation and building materials has not been extensive. Sundqvist advocates the need for more research in the areas of mapping the current situation and finding ways of improving communication channels and information exchange.[80]

According to Clausen, few efforts have been made to theoretically conceptualise the building sector as a sectoral innovation system[81]. However, some research has been conducted in this area[82] and the International Council for Research and Innovation in the Building Sector (CIB) has developed a framework for analysis of the construction sector based on a sectoral system

[72] Malaman (1996)
[73] Markusson (2001)
[74] Markusson (2001)
[75] Widén (2002)
[76] Atkin (1999), Barlow (2000), Gann (2000), Winch (1998)
[77] Winch (1998), Atkin (1999)
[78] e.g. Slaughter (2000), Winch (1998)
[79] Clausen (2002)
[80] Sundqvist (2005)
[81] Clausen (2002)
[82] e.g. Winch (1998), Gann (1997)

approach[83]. Slaughter argues that current construction management theory and techniques may not be sufficient in anticipating and evaluating the effects caused by the introduction of changes in complex multi-system building products.[84]

Recently, an increasing number of researchers have chosen to look at innovation in the building sector from a project-based industry perspective. As explained by Gann and Salter, project-based industries represent a challenge for innovation research and traditional approaches may lack the methodological tools to explore the specific dynamics of innovation in such sectors due to a failure to connect project and business processes[85]. Moreover, according to Acha et al., there is relatively little research on how project-based firms innovate and develop their capabilities and how knowledge is captured across projects. Similarly, Slaughter argues that there is a need for further research on the means through which organisations in the construction sector can effectively re-use innovations in future projects[86].

While the results of various research efforts differ, there is a general agreement that generic innovation models cannot be used to understand innovation in the building sector, which is complex and differs significantly from other sectors. However, innovation and conceptual models that are specially adapted to the building sector are still under development. There is also agreement that the level or rate of innovation is comparably low due to a range of barriers arising from sectoral features.

4.2.2 Environmental innovation in the building sector

Environmental innovation in the building sector has mainly been focused on three key areas:

- Chemicals/toxins in building materials
- Building waste, less intense resource use, recycling
- Energy efficiency[87]

In regard to environmental innovations in the building sector, various approaches have been taken by researchers. Some have focused on specific products, for example, Goverse et al. have investigated the situation concerning innovations in regard to wood in the residential construction sector in the Netherlands[88]. Others have focused more on the role of regulation, for instance Bröchner et al. in their study on how performance based regulation can promote innovative environmental technology in the building sector[89]. Research with a wider scope has also been conducted, for example Odysseus et al. have investigated drivers to change in relation to sustainable construction in Greece[90]. Demaid and Quintas have, through investigating the management of knowledge for sustainability in regard to innovation in the building sector, come to the conclusion that due to the complexity of both the building sector and the concept of sustainability, further interdisciplinary research efforts are needed to understand the issue[91].

[83] CIB (2004)
[84] Slaughter (2000)
[85] Gann and Salter (2000)
[86] Slaughter (2000)
[87] Lilliehorn (2006)
[88] Goverse et al. (2001)
[89] Bröchner et al. (1999)
[90] Manoliadis et al. (2001)
[91] Demaid and Quintas (2006)

Lutzenhiser and Biggart have investigated innovation in regard to energy efficiency in commercial buildings in the USA. The researchers use a broad approach to understand actual context for the implementation of energy efficient solutions i.e. how the market structure impacts the diffusion of energy efficiency. Their research indicates that innovations in the building industry are largely incremental and that the structure of the industry inhibits innovation.[92]

Tommerup and Svendsen have explored the technical energy-saving potentials of the residential building stock in Denmark. While the authors show that investments in energy efficiency be economically profitable, they find that energy-efficiency measures are carried out only to a limited extent. Thus the authors have not found technical nor economic barriers for the realisation of a significant part of the energy savings potential in Denmark, rather it is thought that lack of building owners' interest and knowledge pose the greatest barrier.[93] According to Jansen, during the past ten years studies on energy efficiency have primarily focused on market barriers[94]. However, other types of barriers may be as important.

Ornetzeder and Roracher present some of the benefits of user participation in the innovation process and the possible potentials of such involvement in promoting the diffusion of sustainable energy technologies. Users can be involved in the development and dissemination of technology in various levels, especially experienced users such as self-builders may contribute to both improving design and dissemination rate. The authors explain that social learning processes between various actors are crucial for the successful dissemination of technologies, however, they note that such processes often occur in a non-systematic manner and user experiences and expectations are seldom used to their full potential in product improvement. They, therefore, emphasise the importance of stable organisational units and networks linking actors from various areas in long-term learning processes.[95]

It should also be noted that little is known about the demands of customers and the actual market for environmental innovations, similarly there is also a lack of knowledge about the effects of policies[96].

As shown, there are various approaches used to understand environmental innovation. Most studies seem to point at two general conclusions. Firstly, environmental technology is a field with great potentials for growth, and, secondly, environmental aspects or considerations in relation to innovation contribute an additional dimension of complexity.

4.2.3 Research gaps

This brief review of current research shows that while there is significant research on the topic of innovation in the building sector, further research efforts may contribute to understanding how environmental innovation can be promoted in the sector. The literature review suggests that there may be possible knowledge gaps in regard to the issue of innovation in the building materials segment, as well as in the understanding of the linkage or interaction between this segment and the construction segment in regard to the diffusion and integration of innovations, especially environmental innovations. Furthermore, additional exploration of the building industry from an innovations systems perspective with sectoral focus could perhaps

[92] Lutzenhiser and Biggart (2003)
[93] Tommerup and Svendsen (2005)
[94] Jansen (2004)
[95] Ornetzeder and Rohracher (2006)
[96] Markusson (2001)

further contribute to a better understanding of innovation processes. The issue of environmental innovation in a building sector context is a topic that has not been studied extensively.

Consequently, the use of a national comparison, a sectoral perspective and a focus on regional opportunities may provide a more nuanced understanding of the issue of the promotion of innovation and integration of innovations in the built environment.

4.3 Research matrix

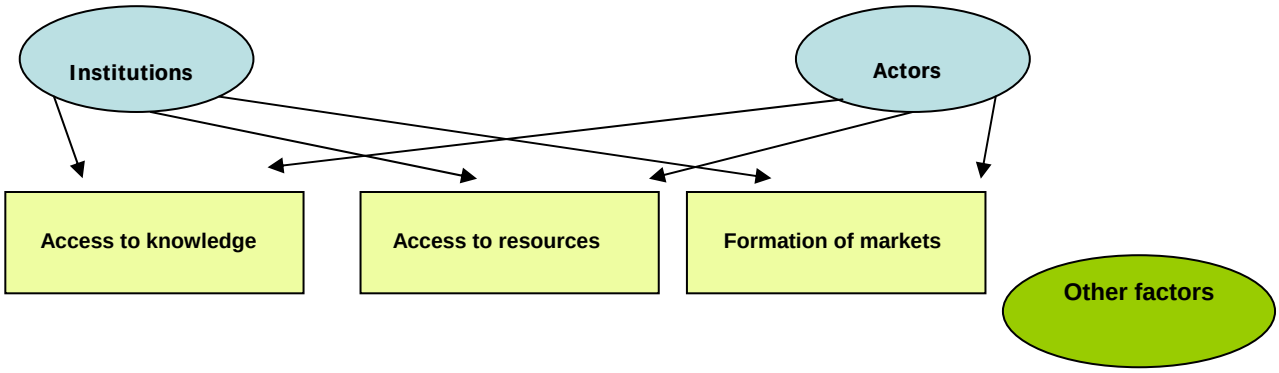

Figure 4-4: Research matrix
Source: VR/TE[97] partially based on Jacobsson and Bergek (2004)

The matrix illustrates key preconditions for innovation, the access to knowledge and resources and the formation of markets, which are affected by dynamic interactions with institutions and actors.

Access to knowledge is influenced by internal capabilities and organisation, external interactions, as well as by national innovation systems through the provision of education and research. The proximity of actors and their interactions in regional innovation systems may also be an important factor in this activity. It should be noted that this activity is also seen to include the creation of knowledge.

The *access to resources* determines whether the product is developed or not, it is thus dependent upon internal capabilities, access to external capabilities, access to capital and other resources. Access to resources is dependent upon perceived demand for the product. However, this access is also influenced by other factors such as economic cycles.

The *formation of markets* is determined by demand thus what interactions influence or create demand for a specific product. Demand can in turn be influenced by a number of factors including policies, regulation, prices and trends.

[97] Tareq Emtairah

In addition, it is thought that innovation is affected by *other factors* such as economic cycles, trends, and presiding technological systems.

This matrix is applied to understand innovation in the building sector. In order to understand the innovation process connected to solutions promoting increased energy efficiency, it is necessary to take into consideration the various segments in the value chain.

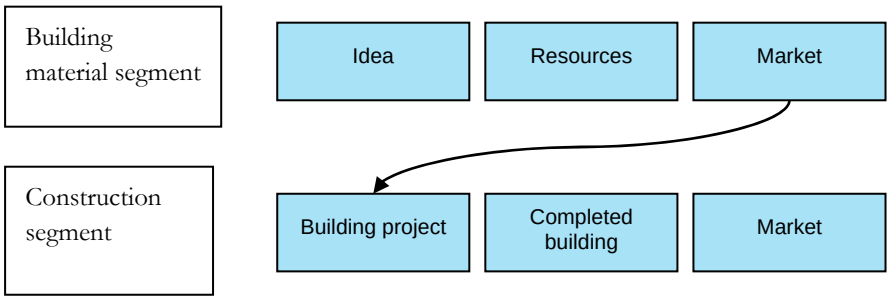

Figure 4-5: Building process
Source: VR/TE

This figure illustrates a flow starting with the creation of knowledge to the development of a product followed by the dissemination of the product i.e. its integration in buildings that are passed on to owners and users. However, it should be emphasised that this flow depicts the route of from building materials to completed buildings; it does not illustrate the innovation process, which is typically not a linear flow. It should be noted that while the building material producing segment is process oriented, the construction segment (i.e. the actors dealing with the design and construction of buildings) is project oriented.

5 Introducing findings and analysis

The following four chapters present the main findings and analysis of this paper. **Chapter 6** presents findings elicited from literature studies; this part serves to explain how sectoral features and factors affect innovation propensity and to further explain the context in which innovation can take place in the sector. In some instances, the theoretical findings have been supplemented with empirical findings in order to present an overview of current trends and developments. **Chapter 7** gives an overview of the cases of Sweden and Denmark with a focus on the building sector, innovation and energy efficiency. **Chapter 8** presents empirical findings acquired through interviews. Initially, factors that constrain or enable innovation are organised in relation to different types of innovation systems, this is followed by findings organised in accordance to the three key prerequisites for innovation used in the research matrix, namely, access to knowledge, access to resources and the formation of markets. **Chapter 9** is also based primarily on empirical findings and discusses possible solutions to some of the constraints identified in the preceding chapters. The aim of this chapter is not to provide a comprehensive solution to the problem, but rather to identify different types of possible measures in relation to the innovation systems. This is followed by a section where the need for coordination and timing of measures is discussed.

The research matrix that was used to collect and interpret findings focuses on three main areas, namely access to knowledge, access to resources and the formation of markets, in addition to these also certain external factors are thought to be influential. To understand how innovation can be promoted, the following hypotheses underlie further discussions:

In order for companies to be able to innovate they need access to knowledge. This necessitates functioning interaction with public research organisations, and that the types of knowledge that are useful for the production of marketable products is being generated and that the sector is able to convey its needs and that research institutions are able to convey their knowledge. In addition to this the companies also need to have own resources for research and resources to collect and handle incoming knowledge. In order to access tacit knowledge and experiences companies need to have functioning interactions with other actors in the sector and have mechanisms for collecting such knowledge.

As indicated, companies need access to resources that enable them to gather, create and process knowledge into marketable products. Resources in the form of capital, time and talent are needed. Thus companies need an inflow of talent, which requires an education system that produces specialists able to work with innovation issues. The companies also need to be able to recruit and maintain talent and competences. In order to use resources, companies need clear economic incentives. Furthermore, there may be a need for external capital supplied through a functioning venture capital system or national or international support schemes. Access to these resources is highly linked to the security of demand.

To develop new products, actual or anticipated markets for these products are needed. This is in turn connected to a need for functioning market mechanisms or state intervention aimed to stimulate the creation of markets for these products.

6 Theoretical findings

6.1 Innovation dynamics in the building sector

The building sector operates in a dynamic environment where rapid changes in the economy and the society create new demands[98]. The demand for the improved performance of the sector is continuously increasing due to increased knowledge in other sectors. Driving forces include demands for decreasing long-term and short-term costs, more efficient utilisation of resources, increased possibilities for clients and users to influence the quality and utilisation of resources and demands related to improved sustainability.[99] While it may be possible to address some of these issues by the utilisation of existing solutions, increased innovation and the creation of new solutions may be necessary[100].

As emphasised by Bang et al. the configuration of actors and the interaction between these actors is a significant determinant of innovation activity[101], thus it is of relevance to try to map these interactions to identify critical interfaces.

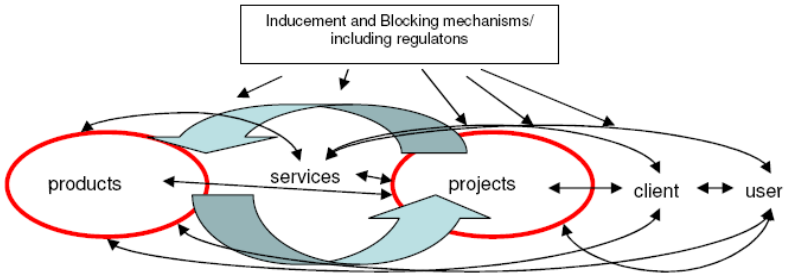

Figure 6-1 : Integration of models showing main areas of focus
Source: VR/TE

This diagram gives an initial overview of actors, here services are primarily meant to be architects and engineers, involved in the process of developing products and the integration of these solutions into buildings; it also indicates that instead of a linear flow, interactions are complex and varied and that it is necessary to take into consideration various types of interactions between multiple actors. Furthermore, it illustrates that inducement and blocking mechanisms affect all actors in the sector, which was previously indicated in chapter 3 through the exemplification of the case of the innovative brick.

Compared to other sectors, the building sector is typically classified as a traditional or low-technology sector with low levels of expenditure on activities connected to innovation[102]; furthermore, compared to other sectors, technical change is implemented relatively slowly[103]. Moreover, the sector is characterised by limited international competition, low quality, and fierce price based competition[104]. Compared to other sectors, the building sector also differs

[98] Gann and Salter (2000)
[99] Widén (2002)
[100] Widén (2002)
[101] Bang et al. (2001)
[102] OECD (2000), Seaden and Manseau (2001)
[103] Goverse et al. (2001)
[104] OECD (2000)

in regard to a division of the process into different phases, the number of actors involved in the process and in having a project perspective instead of a process perspective[105].

The sector consists of many groups of actors with different specialities working together to create a complete building. While building material producing companies develop products, construction firms are system integrators that adapt these new technologies and products in the building projects[106].

Factors affecting innovation include the strength of the knowledge base, the role of the government, the nature of strategic alliances, the attitude towards cost and quality ratios and the role of material manufacturers[107].

Nam and Tatum present five features that act as constraining forces on the development of building technology, namely, immobility, complexity, durability, costliness and a high degree of social responsibility. In combination, these create conditions resulting in a relatively locked system where innovation becomes difficult.[108]

Jacobs et al. present several characteristics that are specific to the building sector and affect its innovation potential. These include a cooperation based on temporary contracts between changing configurations of actors making the learning process more difficult and slowing down innovation and a strong distinction between building stages and poor communication between actors. A further feature is the presence of many sector organisations with fragmented coordination leading to limited attention being placed on sector wide-issues and environmental initiatives, which also complicates governmental intervention. Additional characteristics are a strong national orientation, a strong competition in regard to price, supplier dominated innovation and a strong tendency towards the standardisation of buildings and building products [109].

Others have also indicated similar and additional features affecting innovation negatively such as an adversal culture, changes in specifications, cyclic demands, fragmented industrial structure, inappropriate procurement forms, inappropriate allocation of risk, and inefficient methods of construction, and management problems[110].

6.2 Sectoral features

To further understand the preconditions for innovation in the building sector, it could be beneficial to examine some of the previously mentioned features and discuss how they can potentially affect the innovation process.

The building sector is characterised by interdependence and interaction of various actors[111]. The sector is complex and includes a wide range of actors such as material suppliers, producers of machinery, producers of components, specialists, developers, contractors,

[105] Widén (2004)
[106] Sundqvist (2005)
[107] Jacobs et al (1992) in Goverse et al. (2001)
[108] Nam and Tatum (1998)
[109] Jacobs et al (1992) in Goverse et al. (2001)
[110] Widén (2002)
[111] Widén (2004)

owners, consultants, transporters and the state. While some can be found within one firm, it is possible that one actor can be the customer of one firm and the supplier to another.[112]

The construction segment of the sector is project-based with intense cooperation during the duration of the project and a discontinuation of cooperation after the completion of the project.[113] These actors then enter into new constellations of cooperation on new projects. This leads to a situation where the process of development is abruptly stopped and progress attained may not be retained or transferred to new projects.[114] According to Koskela and Vrijhoef, there is a lack of retention and reapplication of experience from problem solving, which thus hinders the diffusion of solutions. Furthermore, there is a lack of incentives to share experiences.[115] An additional complication arises from a lack of communication between internal networks in the building process[116].

Traditionally, the main drivers of technological change in the building industry are new components or the improved performance of products introduced by suppliers[117]. However, while other industries have been able to involve suppliers in their innovative work through cooperation in the innovative process or through providing specifications that demand increased innovation, such integration has not taken place to the same extent in the building industry.[118]

According to Widén, one of the most significant differences between the building sector and other industries is that in the building sector, industry design and production are often separate processes, while higher levels of integration of these two functions have taken place in other industries[119]. In the building sector, a separation between the various parts of the product development and construction process exists[120]. To further complicate matters, as explained by Sundqvist, the building material manufacturers are largely a forgotten group in regard to research and are often not seen as a part of the construction process[121]. Dubois and Gadde explain that agreements between building material manufacturers and building producers focus mainly on standardised products and the "customer-supplier relationships in construction are generally of the arms-length type, rather than being partnerships".[122] The potential for the development of new products and diffusion of innovations may be affected by the types of relationships and interactions between these two groups.

Further specific features of the building industry include many relatively small firms with high levels of specialisation[123]. The number of actors involved in building projects is high, thus coordination, information and knowledge sharing mechanisms and leadership are especially important issues. The large number of specialised actors that are responsible for individual parts of the whole project may also be related to difficulties in attaining a holistic perspective and coordinated work towards a common end-state.

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[112] Widén (2004)
[113] Sundqvist (2005), Dubois and Gadde (2002)
[114] Sundqvist (2005), Dubois and Gadde (2002)
[115] Koskela and Vrijhoef (2001), Sundqvist (2005)
[116] Widén (2002)
[117] OECD (2000), Gann (2000)
[118] Atkin (1999)
[119] Widén (2002)
[120] Widén (2002)
[121] Sundqvist (2005)
[122] Dubois and Gadde (2000)
[123] Widén (2004)

Since each project is conducted in a new locality with new conditions, each project is unique[124]. While it is arguable that this provides ample opportunities for innovation since, in essence, a new prototype is constructed every time; this may lead to a situation where knowledge or innovative solutions are lost and not brought forward to new projects. This can in turn be connected to the issue of innovation in project-based industries or episodic innovation. Just as the site-based nature of projects ensures a uniqueness of the building products, similarly renovation and repair projects are also unique[125].

Another important characteristic of the sector is openness. Building construction is performed in a public setting and the mobility of specialists is high. This contributes to news spreading rapidly to competitors.[126] While this may be a factor promoting innovation, it may deter innovation if intellectual property rights are not sufficiently protected.

Another characteristic identified by Björklöf is a predisposition to transmit information orally, even in cases when it may be more beneficial to have written transmission. The mode of transmission may have both benefits such as increased openness and directness, as well as costs in the form of less careful consideration, calculations and planning. [127] Gann and Salter emphasise the difference in ways of dealing with codified and tacit knowledge and argue that tacit knowledge may be specifically important in the building sector[128]. The role of informal networks, which may both contribute to the sharing of information but also to restricting the market to new entrants, is seen as important in the sector[129].

Buildings are comparably large and expensive products. Thus, the issue of price is critical for both customers and companies. According to Dubois and Gadde, "subcontracting is procured to the lowest-priced supplier with little or no guarantee (or even incentive) to future work". This may place limitations on product development. Many companies in the sector work with low and unpredictable profit margins and companies may have limited resources to spend on development. Furthermore, the unbalanced distribution of technological risks and financial rewards may also impact on innovation propensity since financial reward of success travels upwards towards client and risk of failure downwards in the supply chain. Profit margins are affected by the long value chain, as well as by the contractual system based on fines in case of delays. The fixation on lowest price may lead to a strong reliance on standardised products and thus act as a barrier to alterations. Furthermore, by sending signals that price is the main priority; product innovation may not be stimulated.[130]

According to Luzenhiser and Biggart, the building industry strives to reduce risk and ensure reliable economic returns on investments by the use of standardised approaches and models that have previously been effective. This feature inhibits innovation and the use of new solutions.[131] Buildings have a relatively long life compared to other products. Their impact on the environment, upon society and the lives of people thus may span for more than 50 years. This places specific demands on the building product. Due to the visibility of buildings and the public nature of buildings, the sector draws media and public attention[132]; this is especially the case in the event of failures, problems or mistakes. This leads to a situation where the risk

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[124] Widén (2004)
[125] Manseau and Seaden (2001)
[126] Björklöf (1986)
[127] Lenard (1996) in Sundqvist (2005)
[128] Gann and Salter (2000)
[129] Lenard (1996) in Sundqvist (2005)
[130] Dubois and Gadde (2002)
[131] Lutzehiser and Biggart (2003)
[132] Gann and Salter (2000)

of the utilisation of new solutions may be deemed to be relatively high compared to less public industries.

Regulation and standards have typically been more rigorous in the building sector and have involved several levels of government - national, regional and local[133]. While environmental regulation is often seen as a tool to promote environmental considerations and innovation, some forms of regulation may actually pose hindrances to the innovation process. The building sector is typically subjected to a large quantity of different types of regulations, which may lead to synergistic or antagonistic effects on the innovation process. As the state owns and operates a significant share of the built environment it also has and impact on the sector as a building developer or client.

The building sector is typically a home market industry, which is characterised by national traditions, standards and practices. While some of the traditions and features of the industry may be national others are shared by most countries. However, increased internationalisation of the industry could contribute to decreasing national specificities.

6.3 Current trends in the sector

The building sector is currently in a state of change. This change is driven both by the sector itself, to enhance productivity and competitiveness, as well as by regulations and the market. Changing demands are driving a shift towards functional buildings with a greater weight placed on user satisfaction and productivity. Further trends include an increase of sophisticated equipment and increased environmental concern.[134] There is a shift towards industrialised construction including prefabrication, modularisation and standardisation. However, there is also an increasing demand for individualistic buildings and housing that cater to specific needs[135].

While previously focus has been placed to a larger extent on characteristics and material content of products and components, now greater attention is being placed on function. Functional thinking is also being integrated in the specification process. [136] This trend is also mirrored in the building material segment with the development of products with additional functions or integrated functions for example windows that also work as solar panels.

There is an increased trend towards a growing internationalisation of building activities; although, this is still to a large extent limited to large projects.[137] It should be noted that the building material producing segment of the sector is increasingly subjected to international competition, and is increasingly exporting products to new markets. Furthermore, there is a growing number of international building corporations and mergers and acquisitions of companies. An additional aspect in regard to internationalisation is a potentially growing number of foreign building companies and workers that may bring new types of building practices onto the national markets. Increased internationalisation is also facilitated by developments in regard to modularisation and transportability of building products.

Currently intense work is being done in the field of standardisation. Classification systems may promote innovation by providing a different way through which to view the building and

[133] Manseau and Seaden (2001)
[134] Manseau and Seaden (2001)
[135] Workshop (2006)
[136] Erfa gruppen-2 (2006)
[137] Manseau and Seaden (2001)

enable an overview of a multitude of different solutions that can be combined in various ways.[138] Standardisation is also an important precondition for expanding markets and exports, as well as for EU or other international tendering systems[139].

6.4 Challenges

Many of the demands placed on the building sector seem, at least at first glance, incompatible. For instance, how can demands for lower prices, which most probably necessitates increased industrialisation and prefabrication be bridged with user demands for increased individuality and uniqueness? Consequently, the building sector faces a challenging time and needs to find solutions for how to integrate the various demands in the built environment and to do this at competitive prices.

While the challenges faced by the building sector are imposing, the ability of the sector to find solutions may be hindered by the structure of the sector itself. Several studies have, on the basis of differing measures such as labour productivity, customer satisfaction, worker skill levels and R&D intensity, shown that the sector has lagged behind other sectors in the OECD countries. This has given rise to a series of proposals for the development and implementation of more efficient regulatory systems, as well as to improve actor relations, risk sharing, training and the promotion of R&D investments. While Manseau and Seaden note that changes have been taking place in regard to the building sector, no systematic change of the overall system has been implemented.[140]

6.5 Environmental innovation in the building sector

As we saw in the case of the brick in Chapter 3, while sustainable product innovations in the building industry may come from upstream product manufacturers and building material suppliers, all actors in the building chain are involved in the promotion and adoption of these technologies and products. Clients can influence the process through the specification of the use of technologies and by taking into consideration lifecycle costs, engineers and architects interpret the requirements set by clients and constructors include and integrate these technologies in projects. However, as Derwick and Miozzo note, rather than cooperating in the promotion of environmental technologies in building projects, actors tend to argue that the responsibility of taking such choices is the responsibility of other actors in the building chain[141].

Derwick and Miozzo explain that there are barriers that inhibit the uptake of new sustainable technologies in addition to an inherent conservatism in the construction industry. These barriers include capital costs, market failure to account for environmental and social costs, as well as a lack of system for the accountancy of environmental savings and long-term cost-effectiveness in a context of a duration or lifetime of 50 years. They also note that there are clear differences between countries in regard to the adaptation of sustainable technologies, which suggests that there may be specific factors or institutions that inhibit or facilitate adoption. Other deterrents to environmental innovation include increased risk and lack of information and public awareness. However, costs may constitute the single most important

[138] Erfa gruppen 2 (2006)
[139] Browall (2006)
[140] Manseau and Seaden (2001)
[141] Derwick and Miozzo (2002)

barrier, especially in situations where financiers of projects place more consideration on capital costs rather than on lifecycle or environmental costs.[142]

[142] Derwick and Miozzo (2002)

7 Sweden and Denmark

This paper looks at the issue of innovation in the building sector in Denmark and Sweden in regard to the development and integration of solutions promoting increased energy efficiency. The comparative approach is used as a tool to identify important issues and interactions, as well as to ascertain what can be attributed to a sectoral system or a national system of innovation. Furthermore, the comparison serves to provide suggestions of good practices. The following section is compiled from disparate literature sources as well as from interviews so as to ascertain the cause and effect of various aspects.

Sweden and Denmark are two countries with both considerable similarities and differences. Both countries are constitutional monarchies with high degrees of regional autonomy. The countries are located in Northern Europe and are subject to relatively cold climates. However, Sweden is geographically more northern, and has greater differences in average temperatures, while Denmark is geographically and perhaps also conceptually situated closer to continental Europe[143]. This impacts both energy requirements and connections to markets. Sweden has a territory of 410 934 km^2 and a population of 9 million, while Denmark has a territory of 42 394 km^2 and a population of 5.4 million inhabitants[144].

7.1 The building sector

There are considerable similarities between the building sector in Denmark and Sweden, which are increasing due to increased internationalisation of the building sector and harmonisation with EU legislation. The sector in Sweden and Denmark has experienced dramatic transformation during the past decades. Currently, they are both experiencing a phase of growth. Both governments have had a significant impact on the sector immediately after the Second World War.

In Sweden after the Second World War, following rapid growth in the Swedish economy, the building sector experienced a phase of growth and intense production, promoted by the "million programme". The programme was established by the government in the 1960s to address the need for housing due to increasing urbanisation. The goal of building one million new rental units in 10 years was set and achieved.[145]

During the same period in Denmark, there was also an increased need for building projects, however, the building sector was mainly characterised by craft-based firms unable to rapidly increase the quantity and quality of production. To address this, the government presented policy actions focusing on the industrialisation of production to enhance productivity. During this time, systems for financial support, standards for building components, tax legislation and unified rules and regulations were introduced. [146]

In Sweden, after the completion of the programme in the 1970s, construction slowed down dramatically, leading to lay-offs and unemployment. Production was partially stimulated through new subsidies, renovations and extensions of existing buildings[147]. Despite these

[143] in Sweden average winter temperatures in the north are -16 C and 0.2 C in the South, while average Danish winter temperature is 0.5 C, Official Gateway to Sweden (2006), Denmark's official web site (2006)

[144] Danish territory excluding Greenland and Faroe islands. Official Gateway to Sweden (2006), Denmark's official web site (2006)

[145] Swedish Institute (2004)

[146] Andersson (2003a)

[147] Swedish Institute (2004)

measures, the sector experienced a period that was termed "the construction crisis", characterised by a low number of projects[148].

The Swedish policy has traditionally had a strong focus on social and distribution policy. Through regulation and extensive subsidy system, the government has played an important role in the development of the sector. In reaction to the problematic economic situation in the beginning of the 1990s, the government reduced financial support to the sector at the same time as the system of regulations was eased. Changes in the residential building financing system led to a further decline of building activities. The previously detailed regulations on building design were replaced by more flexible regulations. The objective of these regulations was to promote the development and implementation of new technologies. This also led to a situation where contractors were given an increased responsibility and had to become more customer orientated.[149]

During the 1970s and 1980s in Denmark the number of building projects decreased significantly, leading to reductions in production and employment. The decline in productivity in the first part of the 1990s led to an increased export-orientation with a particular focus on the German market. During the past two decades, the approach of the government has shifted towards greater decentralisation and increased market orientation.[150] In the 1990s the main construction policy instruments were a series of development programmes dealing with various technical themes, as well as technical regulations for the building product and procurement regulations. At the end of the 1990s the sector underwent an increase in production and the domestic market has grown constantly since 1996.[151]

Both countries have to an extent experienced a decreased support from the state to the building sector and have developed own initiatives to address various issues. Sector initiatives in the form of networks and other organisations aiming to promoting environmental considerations in the building sector have been established. The building sector in Sweden has established the Eco Council for the Building Sector and a new organisation The Energy Alliance, which is a cooperative effort between the Building Developer Forum and the Eco Council[152]. In Sweden there is also a newly established state and sector initiative - the Building-Living Dialogue, which also works on energy efficiency related issue. The Danish Centre for Urban Ecology[153] was to be closed down but was transformed through a sector initiative into a network for sustainable building[154]. Several municipalities have organisations dealing with sustainability in the built environment, for example the Green House in Køge[155]. In addition to this, there are a large number of organisations and associations in both countries aimed at protecting and promoting the interests of members.

In Denmark the Ministry of Environment initiated a programme with the objective of finding ways to integrate environmental consideration into the products of various sectors including the building sector. As a result, an action plan was elaborated and it was decided that there was a need to establish a panel with decision-makers to continue to work with this issue and start

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148 Björklöf (1986)
149 Andersson (2003b)
150 Andersson (2003a)
151 Denmark's official web site (2006)
152 In Swedish - Byggsektorns krettsloppsråd, Energialliancen, Byggherre forum
153 In Danish - Foreningen for baeredytige byer
154 Pedersen (2006)
155 Alm (2006)

to implement the action plan; however, the project was discontinued due to a lack of interest from involved ministries.[156]

The recession in Sweden also significantly changed the composition of the sector. Middle size companies largely disappeared and a few large companies started to dominate the market. Still today, the sector is dominated by a few large companies that operate on a nation-wide and international level and numerous small locally based building firms, however there are some indications that middle size firms are starting to reappear on the market.[157] Large construction companies have shifted their roles from working mainly with contracting to placing an increased focus on project management and the outsourcing of work to subcontractors[158]. The sector has had a similar development in Denmark[159].

Companies producing materials for buildings, especially residential buildings, are especially vulnerable in times of recession, causing a situation where market fluctuations can lead to dominating firms strengthening their positions while smaller firms go out of business or become acquired by larger firms[160]. Both countries have a few large producers of building materials, which dominate certain parts of the market, as well as a greater number of small companies. In both countries, there is a trend towards both increased internationalisation and increased size of companies through mergers and acquisitions[161].

Both countries have several universities and institutes dealing with building sector related research. However, the level of centralisation seems to be greater in Denmark. While this may be the result of conscious coordination efforts, it could also be related to the relative size of the two countries.

The countries differ in regard to the relative influence of actors. Architects have a more prominent role in Denmark and are involved during the whole building process, while the role of architects in Sweden may end after developing and submitting the design[162]. However, the role and involvement of architects also varies among projects. In Sweden the construction company or general contractor often has a more prominent role and the construction company is frequently also involved in the design phase of the project. Sweden has some very strong construction companies that operate on a national and international level. However, there is a similar trend now in Denmark. In both countries, the consulting agencies providing engineering services often offer a range of other services. Both countries have international consulting companies, while Denmark may have larger and stronger consulting companies, as compared to Sweden. A typical feature of Sweden is the important role of private non-profit and municipal housing firms[163], while large retailers of building materials have a more influential role in Denmark than in Sweden[164].

An additional divergence can be found in the political orientation. Sweden has a social democratic political climate, while Denmark is more liberal market oriented. Thus on a very general level, it could be stated that Sweden may place more emphasis on state regulation and intervention, while Denmark might focus more on stimulating market mechanisms.

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156 Kærgaard (2006)
157 Swedish Institute (2004)
158 Swedish Institute (2004)
159 Interviews (2006)
160 Andersson (2003b)
161 Interviews (2006)
162 Andersson (2003b)
163 Andersson (2003b)
164 Interviews (2006)

For both countries trends within the sector include a striving for increased environmental considerations, which affects function, installation and production, as well as increased integration, improved planning and increased inclusion of a life cycle cost perspective in processes and activities.[165]

7.2 Innovation systems

Both countries are innovation leaders within the EU, Sweden being in first place and Denmark in third place in the European Trend Chart on Innovation[166].

In Sweden, innovation governance is organised along two lines, namely, growth policy and research policy. The Swedish innovation system is relatively decentralised. It is characterised by the use of ad hoc groups and temporary coalitions. While this provides flexibility, less emphasis is placed on coordination, which may lead to fragmentation, sub-optimisation and lack of synergy effects. Furthermore, according to the European Trend Chart on Innovation, there may be a need for a clearer innovation policy and efforts aimed at ensuring that the importance of innovation is recognised by all policy makers.[167] Other areas that could be improved is the share of university research and development financed by businesses and while there is an upward trend for public R&D, business R&D has declined during the past years[168].

The Swedish national innovation system is characterised by a considerable level of foreign dependence with large international corporations having an unusually dominant position in the R&D system. According to the European Trend Chart on Innovation, the key future objective of Swedish innovation policy is finding ways of translating strong knowledge creation into innovation output[169].

With the new government of 2001, innovation has been receiving increased political attention in Denmark. According to the European Trend Chart on Innovation, Denmark has a relatively strong and well-functioning system with several competitive strengths. Some weaknesses include regulations, modest investments, challenges within the education system and a weak collaboration between universities and firms.[170] A low share of companies report receiving direct public support for innovation and a low share of university research and development is funded by companies. Since Denmark is characterised by a large number of small and medium sized companies (SMEs) that lack internal resources for development and innovation, interaction with public research organisations is a key issue. However, Denmark has a high percentage of collaboration between SMEs on innovation[171].

Furthermore, as assessed by the European Trend Chart on Innovation, entrepreneurship is relatively weak in Denmark and behavioural attitudes and entrepreneurial culture does not foster the establishment and growth of new firms.[172] Currently, the innovation system in Denmark is in a period of change, new strategies and action plans are being developed and

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[165] Byggmaterialindustrierna (2005), interviews (2006)
[166] European Trend Chart on Innovation (2005)
[167] European Trend Chart on Innovation (2004-2005): Sweden
[168] Eurpean Trend Chart on Innovation (2005)
[169] European Trend Chart on Innovation (2004-2005): Sweden
[170] Eurpean Trend Chart on Innovation (2004-2005): Denmark
[171] European Trend Chart on Innovation (2005)
[172] Eurpean Trend Chart on Innovation (2004-2005): Denmark

reforms are being implemented and awareness of the importance of innovation is growing among policy makers. Several new organisation aimed to promote innovation have been established during recent years, including the Innovation Council founded in 2003 and several reforms aimed at addressing the low interaction between research organisations and companies have been implemented. [173]

It should, however, be noted that while a comparison of indicators such as conducted in the European Trend Chart on Innovation may be indicatory of relative strengths, weaknesses and trends, the indicators used do not necessarily capture all the important aspects of innovation and work on new types of innovation indicators e.g. for diffusion and spin-offs is ongoing[174]. It can also be noted that the European Trend Chart on Innovation does not cover the building sector in its overview of sectoral innovation systems in Europe and construction is excluded from total industry scores[175].

The Swedish innovation system underwent re-organisation in 2001, during which the council dealing with building sector research was disbanded and responsibility for this area was mainly directed to the new organisation Formas. However, this organisation places greater importance to scientific significance than to sectoral relevance, and is perceived as having a academic focus, and thus being of limited use for companies in the sector[176]. Meanwhile, the Swedish Innovation Agency Vinnova does not have any programmes specifically aimed at stimulating innovation in the building sector[177]. In Sweden, the responsibility for energy efficiency in the built environment, demonstration projects and support schemes for product development has been partially shifted to the Swedish Energy Agency[178].

To further promote innovation, the sector in Sweden initiated the development of the Building Sector Innovation Centre (BIC). However, discussions with actors in the national innovation system broke down due to the reform and the newly established actors were not interested in supporting this measure, which led to other actors not finding it possible to participate.[179] However, the sector decided to drive the issue as its own initiative and the centre was established, a positive development is that cooperation is now being established with other actors in the national innovation system[180].

According to Bang et al. the public policy shift which has taken place in Denmark, may affect the innovation potential of the building sector negatively since, according to various innovation programmes, inter-organisational structure and production processes need to be addressed to foster innovation, however, current public policy with its reliance on market forces does not push for such changes.[181] There are, however, initiatives aiming to address this, for example, the foundation Realdania was established in 2000 and is financed by the state and industry. The foundation supports numerous projects and organisations, including the establishment of an innovation centre for the building sector - Building Lab DK[182].

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[173] Eurpean Trend Chart on Innovation (2004-2005): Denmark
[174] Arundel, A. and Holanders, H. (2006)
[175] European Sector Innovation Scoreboards (2005)
[176] Interviews (2006)
[177] Klarin (2006), Grandinson (2006)
[178] Forsberg (2006)
[179] Grandinson (2006)
[180] Grandinson (2006)
[181] Bang et al. (2001)
[182] Realdania (2006)

In Denmark large parts of building related research is carried out by the State Building Research Institute (SBI) and the Danish University of Technology (DTU), while in Sweden there are a number of universities and institutes dealing with building sector research. In Denmark, the foundation Realdania provides a considerable part of the funding for demonstration projects, product development and other types of projects, in Sweden funding is accessed from various sources.

7.3 Energy efficiency

In Sweden and Denmark, interest in energy efficiency fluctuates due to energy prices and public policy, currently interest is increasing. Both countries have used various types of public policies aimed at increasing energy efficiency. Sweden has developed technology development and procurement systems for promoting new technologies. Both countries have had series of shorter subsidy programmes for certain technologies. Denmark previously had a system for energy certification and auditing of existing buildings.

As members of the EU, both countries comply with EU legislation. Both countries have developed action plans for improving energy efficiency in the built environment and both countries have this year issued new building regulations with increased energy efficiency demands and are implementing the EU Directive on energy performance of buildings.

The basic objective of the directive is to promote the improvement of the energy performance of buildings within the EU. The directive sets a framework intended to lead to increased co-ordination and harmonisation of legislation between member states in this area. However, the practical application of the framework is primarily the responsibility of the individual member states. The directive covers four main elements:

- Establishment of a general framework of a common methodology for calculating the integrated energy performance of buildings.
- Application of minimum standards on the energy performance to new buildings and to certain existing buildings when they are renovated.
- Certification schemes for new and existing buildings on the basis of the above standards and public display of energy performance certificates and recommended indoor temperatures and other relevant climatic factors in public buildings and buildings frequented by the public.
- Specific inspection and assessment of boilers and heating/cooling installations.[183]

In Denmark, a labelling and classification scheme is already in place, while in Sweden it is still being developed. Based on interviews with actors, it is perceived that the Danish scheme in combination with the building regulations focuses more on sending clear signals to the market, while the Swedish scheme may have a greater focus on awareness raising.

In Sweden, an energy efficiency action plan has been developed and objectives have been set, however, there may be a lack of clear and measurable targets and perhaps a lack of vision on how these objectives will be fulfilled[184]. Some of the initiatives proposed have already been implemented; some are yet to be put into practice. While Sweden does not have to decrease its emissions of green house gases to comply with the Kyoto Protocol, the parliament decided in 2002 that Sweden will work on reducing greenhouse gas emissions by 4% during 2008-2012.

[183] EC Declaration on energy performance of buildings (2002)
[184] Interviews (2006)

After a phase of decreased political attention, increased focus is being placed on environmental issues and energy efficiency in Denmark. Involvement in EU processes in this area is high and coordinated efforts are made to meet international obligations and comply with EU legislation[185]. Denmark has initiated coordinated measures consisting of an energy efficiency action plan with clearly stated strategy, focus areas and objectives, new building regulations with increased energy efficiency demands for new and even existing buildings, and the energy declaration scheme is in place, with a classification system of basic requirements and I and II type houses, which are more efficient than necessary level set in regulations. One reason for increased focus on energy efficiency is the need to meet Kyoto protocol targets; Denmark has committed itself to reduce CO_2 emissions by 21% to year 2012.

While these relatively recent measures have contributed to an increased interest in the building sector for energy efficiency promoting solutions, it is yet too soon to evaluate the effect on the market. While up to now, energy efficiency of new buildings has in general been increasing in both countries, the rate of this increase is not near to what could be seen as technically and economically feasible[186].

Denmark has traditionally had a focus on large scale projects in the building sector. Currently, in Sweden, there is a tendency towards larger multidisciplinary projects, i.e. fewer but larger research projects, involving more actors from various disciplines. The issue of energy efficiency is increasingly being seen as not merely in technical terms but pertaining to other areas as well.[187]

In Sweden, while research efforts are taking place, it could be debated as to whether focus is placed where it is most needed. For instance, during the past 20 years, the Swedish state has invested relatively large resources on energy research, while most of the funds have been directed towards research on supply side energy issues; only some of this has been related to energy use in buildings.[188] Similarly also Denmark as placed a greater focus on research on energy supply technologies.

A variety of networks, initiatives and programmes working to increase energy efficiency or sustainability in the built environment have been established in both countries. For instance, Sweden has an Investment programme for ecologically sustainable development (LIP) and a Climate Investment Programme (KLIMP) as well as the research programme Sustainable Building. There are plans for establishing a new programme focusing on energy efficiency (CERBOF).[189] The Swedish Energy Agency provides funding for demonstration projects, but there have also been municipality and company initiated demonstration projects.

As part of changes in the political agenda in Denmark funding was discontinued to several initiatives leading to a discontinuance of work on energy efficiency and sustainability issues. However, several of these initiatives have been continued due to sectoral support and involvement, for instance the Danish network for sustainable building[190]. Another positive initiative is the project initiated by the Technical University of Denmark "High technology networks regarding integrated low energy solutions in the building area" (LavEByg), which aims to ensure that the potential for energy savings (60-80% over the next 40 years) is met through the stimulation of research and development of the necessary technologies. The

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185 Interviews (2006)
186 Tommerup and Svensen (2005) Nässén and Holmberg (2005)
187 Skarendal (2006)
188 Bygga, bo och förvalta för framtiden (2003)
189 Forsberg (2006)
190 In Danish: Foreningen Baeredygtige Byer og Bygninger, Pedersen (2006)

project includes research organisations, companies, trade organisations, professional networks and public authorities.[191] Municipalities have during the past decade been an important driver for increased energy efficiency[192].

[191] Svensen (2006)
[192] Larsen (2006)

8 Empirical findings and analysis

The theoretical findings indicate that the criteria set in the three hypothesis in **chapter 5**, may not be entirely fulfilled and thus that innovation potentials could be constrained in the sector. In order to better understand the issue of innovation in regard to improved energy efficiency, selected key issues will be discussed using the insights and perceptions of actors in the sector.

It is difficult to isolate any specific set of factors that affect the innovation of and the integration of energy efficiency promoting solutions. Firstly, factors are highly interlinked. Thus a certain mindset could be seen as strengthening a lack of cooperation that stems from fragmentation and territorialism, however, it could also be argued that fragmentation and territorialism induce mindsets that hinder cooperation. Secondly, there are a number of different factors and interactions that influence the actions of actors in different ways depending on their situation at that time, thus it is difficult to clearly state that a certain set of factors are most important at any given time and for all actors. The following factors or rather groupings of factors have been selected for further explanation, since they were frequently mentioned during the interviews as having a relevance both on the propensity to innovate and well as on the propensity to work with increasing energy efficiency. However, it should be kept in mind that this is not a complete list, it is a selection aimed to illustrate some of the hindrances that exist and provide a basis for a discussion on what could be done to mitigate or cancel the effect of these.

8.1 Systems factors

Factors influencing innovation and diffusion of energy efficiency promoting solutions

System	Factor
National systems	Research and education policies
	Legislation, regulation
	Support systems
Sectoral systems	Cultural aspects - attitudes, types of cooperation, traditions
	Organisational aspects - building process
	Economic aspects
Regional	Priorities
	Building planning
	Decisions on energy supply
	Support systems
External	Economic cycles
	Division of budgets
	Organisation of market for buildings
	Energy prices

Table 8-1: Factors influencing innovation and diffusion of energy efficiency promoting solutions
Source: VR based on interviews

These factors have the potential to either constrain or enable innovation. Again, it should be noted that these are interrelated groups. For instance, what is classified as an external factor can be connected both to national systems and to regional systems i.e. public budget organisation is regulated both by national and regional directives. It should also be emphasised, that factors outside the typical innovation systems scope such as economic cycles are highly relevant.

8.2 Factors affecting innovation

In order to understand some of the interactions, mechanisms and factors that affect innovation and the integration of energy efficiency innovations, some select issues warrant further attention. These are organised in accordance to the initial research matrix covering access to knowledge, access to resources, and the formation of markets.

8.2.1 Access to knowledge

Capturing knowledge

Access to knowledge is an important feature in innovation and is also an important factor in decision making. In order to develop new products and integrate energy efficient solutions into buildings actors need access to various types of knowledge.

While the building material producing segment is process oriented i.e. based on product lines producing large quantities of the same types of products, the construction segment is project oriented i.e. various actors come together in projects and produce a unique product. While there are efforts to industrialise the building process, these are yet not widespread.

During projects, efforts are made to generate new knowledge, interactions give rise to new ideas and new solutions, and each unique project provides ample opportunities to develop new approaches. A typical problem with project oriented industries is that there are difficulties to capture and collect experiences from one project and use them in the next project. The reasons for this are several. Firstly, the actors participating in projects are not necessarily the same actors and each individual project can be based on a unique combination of actors. This provides a problem in regard to the responsibility for collecting experiences since there is no continuous project organisation that can benefit from this. Secondly, if projects are seen as unique, then experiences from other projects may not seem relevant. Thirdly, each actor has a specific role in the project, thus their specific set of experiences are related to their field of expertise. While information is to some degree spread since these actors take their experiences to new projects, each actor also has his specific role and spreads information in his limited area.[193] However, solutions may cross these territorial barriers, thus each actor may only have part of the solution, which makes it difficult to reproduce the solution in a new context.

A further problem is constituted by the fact that the project organisation is dissolved after the completion of the project; this means that experiences from the operation and use phase are accessed by a different set of actors. Consequently, potentially valuable knowledge, which could be used for product and system improvements and innovation, is not accessed by the actors that are developing and designing energy efficient systems. While this feature of the sector affects all types of innovation, it affects the innovation of energy efficient solutions considerably since the unique combination of materials and products that make up the system are typically only possible to evaluate after the system is completed and put into operation. This leads to a lack of knowledge about how types of solutions used could be improved or how materials and products could be combined in a better way in new projects. As explained by one actor, experiences are typically not collected from projects since there is no one who is responsible for collecting these. Consequently each new project is to a certain degree started from scratch.[194] Furthermore, an additional problem may be that many of the actors with valuable knowledge that could provide benefits in the planning stage enter the project only

[193] Hellström (2006)
[194] Abrahamson (2006)

after the plans have already been set. Instead they are left to work finding solutions to already set conditions and demands.

These are just some of the challenges faced by project based industries. An additional dimension related to the building material producing segment, is that that it typically supplies materials and products but is not involved in the building process. Thus it also lacks access to experiences from new combinations of products and materials that are developed during the project phase, this shuts of a useful source of inspiration and knowledge for the development of new products. Potentially many new product ideas are developed during the project phase, but these are not often collected and producers to continue to develop the concept are generally not found. The reasons for this weak link are probably several. One easily identifiable reason could be the lack of incentive for the construction company or sub-contractors to supply new product ideas to suppliers an additional reason supplied by one actor, is the tendency of the sector to divide design and production into separate processes[195].

The long and complex value chains in the building sector also make it difficult to access and capture knowledge. For instance, by not having direct contact with the customer, building material producers may lack knowledge about what determines demand, similarly by not having direct contact with the end user, the producer may lack knowledge about the performance of their product and possible ideas for improvement. Similarly, a building developer may lack sufficient insight into the needs of potential buyers and users. A related problem is the actual and perceived lack of customer influence on the various phases of the building process.

The long planning process in connection to building projects complicates customer relations. The end-customers may be ten years older than they were at the beginning of the project and have different needs and expectations that at the beginning of the project or they may have been replaced by completely different customers.[196] The long-life of buildings also means that the life cycle is split among generations, which makes the feed-back process complex and influences information flow, as well as decision-making[197].

Another development that could potentially have significant effects on the sector is that the building sector is under transformation in regard to a coming generation shift that may lead to loss of competence and knowledge. [198] Such a generation shift is underway both in Denmark and Sweden[199]. If this knowledge is not captured, then decades of built up experience and knowledge that could potentially form the basis for innovations, is let to go to waste.

Another aspect that could be related to a possible under-utilisation of experience is the presence of a negative attitude towards old knowledge and traditional-historical building technologies. Consequently, potentials of combining old and new technologies are perhaps not sufficiently investigated and utilised.[200]

Interface between sector and public research organisations

The interface between industry and research organisations is an important aspect of innovation. This interface seems to be somewhat unclear both in regard to energy efficiency and to the building sector.

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[195] Hellström (2006)
[196] Skarendal (2006)
[197] Svensen (2006)
[198] Lilliehorn (2006)
[199] Abrahamson (2006), Lilliehorn (2006)
[200] Abrahamson (2006)

As explained by the Swedish Association of Building Material Industries, considerable amount of research and development takes place within building material producing firms; however, state support is limited. Funding to basic research within material technology and other related areas has been drastically decreased despite increases in overall funding to research. The development within firms can be characterised as more dynamic.[201]

Among barriers mentioned during discussions, lack of funding for applied research was emphasised. It was noted that while applied research takes place in firms, the dissemination of research results is low due to ownership and competition issues.[202] A similar problem was noted in when researchers funded by companies also start working in the companies and their knowledge is then lost to the rest of the community[203].

While public - private research initiatives do occur, typically co-financing is demanded from the firms, which leads to high costs, making it cheaper to employ researchers in the firms themselves[204]. Similarly, a problem in regard to the funding of research is that some actors will finance research only if others or the state are also willing to go in with financing, leading to a situation when researchers are frequently left without funding.[205]

However, it should be noted that some firms are becoming increasingly aware of the added benefits of participating in research projects[206]. It was explained that research projects offer possibilities to develop prototypes and test them[207], furthermore, cooperation with research institutes is seen as especially important in long-term development projects i.e. the development of new technologies[208].

In order to enhance innovation, there is a need for both basic and applied research. According to actors from the research community, research is difficult to transfer to sector. One of the reasons for this is that there is a mismatch in regard to time. It takes at least ten years to develop new solutions from ideas to development of calculation tools to documentation to component level to improved solutions to full-scale experiments, furthermore there may often be a need to learn from mistakes and re-do experiments. However, the sector is only thinking one year ahead due to a need to focus on current problems. In order to find and develop solutions research needs to have a longer time perspective. However, since companies are focusing on current issues, they are not requesting research that could provide solutions in a longer time-frame.[209] If not addressed, this can lead to a situation where there is a lack of research-based knowledge in the future, due to a lack of necessary long-term perspective today.

In Sweden, for instance, there is a perception that currently basic research is starting to be diluted, and more focus is placed on applied research[210]. Furthermore, in regard to research, many basic research facilities have been shut down. This, since knowledge is to a large extent

[201] Byggmaterialindustrierna (2005)
[202] Gehlin (2006)
[203] Hellström (2006)
[204] Gehlin (2006)
[205] Browall (2006)
[206] SE VENT-1 (2006)
[207] SE VENT-1 (2006)
[208] Sandor (2006)
[209] Svensen (2006)
[210] Hellström (2006)

connected to people, has led to a situation where accumulated knowledge is lost due to reorganisations.[211]

While a lot of knowledge exists in the research community, it may be difficult to spread and disseminate this knowledge. Research is to a large extent centred on reports, while actors in the sector may have a limited time and interest in immersing themselves in long papers[212].

Education of professionals

There may also be a lack of long-term educational focus on sustainability in regard to education programmes for architects, civil engineers and other building sector specialists. As one actor experienced, when giving lectures and seminars in universities, there is an upswing of interest, however, this interest tends to recede after a while since the courses do not provide regular teaching on sustainability issues and students do not have the possibility to follow up on their interest.[213] While there are there are courses focused on sustainable building and energy efficiency accessible in the education systems of both countries, environmental considerations are not mainstreamed into programmes. An additional challenge is that the education system and especially higher education may not be sufficiently coordinated with business needs.

Also in the education system there may be insufficient overlap between fields. Divisions are very clear and there may be a lack of a link between theoretical and practical knowledge[214]. This may in turn constitute a future barrier to the creation of new knowledge and the re-combination of knowledge into new concepts.

Knowledge protection

The building sector invests less in R&D than other sectors[215]. One reason for this is that the building sector cannot protect developments and patents only work to a limited extent. Typically new ideas or innovations in the sector are in the form of re-used old ideas and low technology improvements using the same technology, these types of innovations are difficult to protect with patents[216]. Furthermore, patents are very difficult to get for process innovations and also to some extent for design innovations. This means that the companies are generally unable to generate a big profit from innovations, since they can easily be copied by others. Similarly, in the building sector it is typically the case that new ideas quickly get taken over by other companies. While this may facilitate the diffusion of new ideas, it may dissuade companies from investing in developing new products and concepts. Consequently, companies may be less inclined to invest in the development of new solutions. Furthermore, while energy efficiency solutions provide good economy for society, they are not necessarily profitable for individual companies that may actually earn more by not developing a new product[217].

Sectoral culture

There is a widespread perception that the sector as such is conservative and would rather optimise the systems of today than to develop new ones[218]. As one actor explained, many believe to already have the best solutions and that they are already using the solutions that

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[211] Gehlin (2006)
[212] Kærgaard (2006)
[213] Abrahamson (2006)
[214] Abrahamson (2006)
[215] Bygga, bo och förvalta för framtiden (2003)
[216] Hansen (2006)
[217] Svensen (2006)
[218] Hansen (2006)

work best. Conservative attitudes may block the development of new ideas as well as the integration of solutions. The reasons for conservatism can partially be accredited to the issues of insecurity and risk that are presented in the following section.

Several actors have described the interaction between groups to be characterised by conflict rather than supportive cooperation. This affects the ability to jointly identify and develop solutions. As noted by actors, there is a lot of potential in complete systems and elements that can be used in an industrialised or semi-industrialised building process. However, as one actor explained, there is a lack of cross-segment constellations and it may be difficult to find producers for concepts. One of the reasons for this is that companies generally look in a more narrow perspective and there is a strong division into segments.[219]

8.2.2 Access to resources

Insecurity

Buildings are comparably expensive products, they might constitute the single largest investment and individual makes in his or her life. Loans are typically necessary to cover the costs for building and purchasing. Each additional cost necessitates a larger loan; consequently more interest has to be paid. The longer the time between completion and the time when the building is purchased or tenant contracts are signed, the more the developer may stand to lose. While life times of buildings are long, guarantees are comparably short, thus leading to a situation where risk is distributed further along the value chain. This creates a state of insecurity and promotes a focus on lowest price and solutions with short pay-back periods or solutions for which prospective purchasers or tenants are willing to pay more for.

A focus on lowest price does not provide incentives for building material producers to invest in the development of solutions, which may have better long-term cost rations or which may provide additional benefits in the form of decreased environmental impact.

Building cycles

There are further elements that contribute to high levels of risk and instability. The building sector is, as any other industry, subject to economic cycles. However, the growth and recessions are more considerable to in the building sector. The building sector is subject to cycles of upswing and downswing that reoccur with regularity, each phase lasting approximately 5-6 years, but that are also subject to other influences and can in combination with other occurrences lead to building crisis or longer periods of recession[220]. This can be noted for instance in Sweden where public policies re-enforced the downturn and contributed to a delayed upswing[221].

The sector is subject to periods when there is a very high demand, which leads to lack of time, resources, employees and materials and periods with very low demand leading to low income, lay-offs, downsizing and for some even bankruptcy. This does not create a stable environment for long-term development strategies and the lack of resources in times of high growth and recession affect the ability of the sector to generate and integrate innovations. These cycles affect the work load, profitability and attractiveness of the sector and affect the availability of human resources necessary for innovation. During times of high-activity, employment increases, specialists are recruited, interest for the sector as a labour market increases, while during times of low-activity cutbacks may have to be made, important competences may be

[219] Hansen (2006)
[220] Björk Ausin (2006)
[221] Jagrén (2006)

lost. During recessions specialists may leave the sector or companies due to lack of work and downsizing. There may also be a lack of resources and an unwillingness to take risks due to a weakened financial situation and lack of security about how the building market will develop. During highs, the building activity is elevated, thus all actors involved in the sector are busy with current projects and with filling orders, thus there is a limited amount of time and resources to invest in development. Furthermore, during periods of intense activity, actors may be less willing to take on the additional complications that integrating new solutions into buildings involves.

Consequently, actors in the sector are faced with the challenge of how to maintain a momentum of development and high level of competences between peaks. Recessions also affect the sector's ability to recruit specialists since interest preparatory education for future work in the sector may be low. This can be illustrated by the case of one company where key competences were lost during the recession and thus the company was unable to develop and re-launch one of their innovations during the phase of growth[222].

Time is also an important resource that is affected by building cycles, as well as by the intense work the planning and construction process requires. As previously explained, the integration of energy efficiency solutions requires increased systems-thinking and new types of competences and even new types of building processes with greater involvement of actors, more communication, and clear shared goals and vision. However, actors may have a limited amount of time and capacity to invest in the acquisition of these new types of skills. This in turn may affect the demand for products.

Policies

An important element that can affect the sense of stability is regulation and policies. Clear and long-term policies can significantly contribute to stability - i.e. the playing rules for the actors are made clear. In the case of energy efficiency, long-term policies and programmes enable actors to adapt their behaviour and develop products in accordance with the set rules. In regard to regulation, if there is a clear strategy of clearly and continuously increasing demands, actors have incentives to develop products and build buildings that comply with future demands. However, if policies are short term and shifting, then insecurities are increased and incentives to develop products are not as clear. Shifting priorities in regard to certain technologies can also lead to situations where, for example if there is a subsidy promoting a certain technology, that actors develop products and services to accommodate for an increased demand, which then disappears when the subsidy programme is discontinued, thus decreasing the market for the developed products. A series of shifts can thus contribute to actors not reacting to the short-term incentives to develop products and services. While efforts have been made to address this issue, it does seem that there may have been a lack of coordination and long-term policies in regard to energy efficiency in the built environment. Further disruption may be caused by lack of coordination between energy supply policies and energy savings policies[223].

There are also examples of cases where regulation can block the development of some materials or technologies. As one company in Denmark explained, the formulation of some regulations, for example fire safety regulation, hinders innovations in certain areas, and that a number of interesting energy saving concepts could not be developed due to this barrier[224].

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[222] Hellström (2006)
[223] Svensen (2006)
[224] DK INS-1 (2006)

In regard to policies and regulation, historically building codes have placed focus on new houses, however due to the durability of buildings there is a need for a code for existing houses. This is especially important in regard to energy efficiency, since to attain results it is insufficient to only focus on new buildings since these constitute a small percentage of the entire building stock. This is gradually being implemented in EU and being transferred to member states.[225]

Risk

Another aspect that may limit the propensity of actors to try new solutions is the issue of risk. To get investments, actors need to show that the idea works i.e. they need reference objects and need to feel secure enough to guarantee that it works. General building guarantees are typically relative short and have the duration of approximately two years. This leads to the situation where the building developer has to take the risk upon him or herself, which may in turn limit their propensity to want to work with new solutions. This situation contributes to conservatism.[226]

Innovation may be connected to a higher risk of product failures or possibility of unexpected outcomes. Therefore, the possible need to fix problems, leading to additional costs may also act as a deterrent towards using new solutions. Aside from extra costs, mistakes or failures also affect reputation and for many actors in the industry reputation is one of their most important marketable assets i.e. it is what gets them the contracts.

Access to external capital

In regard to capital, most companies interviewed, used internal capital for development projects. While the reasons for not using external capital were not comprehensively discussed, in one case, a company had not really contemplated the opportunity provided by e.g. EU programmes[227]. One explanation for the reluctance to access external capital was put forth by one company, explaining that perhaps it was due to tradition and a mode of thinking that the company is itself responsible for its development[228]. An additional explanation could be found in a reluctance of traditional intermediaries such as banks of supporting energy efficiency products[229]. Furthermore, among the companies interviewed, the utilisation of state support programmes for product development was limited. This could indicate that either there is a lack of state programmes that cater to the needs of the sector in this area or that the attitudes of actors in the sector may hinder full utilisation of this opportunity.

Access to human resources

Rurally based companies may have difficulties in accessing and attracting key competences and high-level professionals[230]. As many building material producing industries are situated outside urban centres, this may constitute a problem for the influx of competences necessary for innovation. The reputation of the sector as being conservative may also contribute in deterring the recruitment of new specialists with skills needed for innovation.

8.2.3 Formation of markets

Short-term profits vs. long-term thinking

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[225] Svensen (2006)
[226] Hellström (2006)
[227] SE VENT-1(2006)
[228] SE VENT-1(2006)
[229] Noted in the EC Green Paper on Energy Efficiency
[230] SE VENT-1(2006)

While short-term thinking could be linked to mind-sets and culture, there are a number of organisational barriers to an increased long-term perspective. Several actors have mentioned that the market forces in regard to energy efficiency do not seem to be working and that there are different constraints that may not immediately be visible but that limit the dissemination of solutions.

Solutions promoting energy efficiency typically come at a higher initial cost than conventional solutions. However, over time, the total cost of the solution may be lower since savings are made. Thus, in a long term perspective energy efficiency promoting solutions may be cheaper than conventional solutions. However, maintenance and operation are frequently not considered in initial calculations despite, as mentioned, the life-time of products and the effects of daily maintenance being important factors in the total life cycle costs of buildings.[231] It should perhaps here also be noted that not all solutions promoting energy efficiency have higher initial costs; however, there seems to be a general perception that this is the case, and thus this perception affects the willingness to investigate options.

Another relevant issue is pay-back periods. While long pay-back periods are reasonable for investments that have a long life or a long technical duration, the situation is more problematic when the pay-back period and the user's expected duration of use do not correspond. In cases when the user's expected duration of use is short and the pay-back period is relatively long, investments typically do not happen. A lack of surety or guarantee that they will get their investment back when they sell then also acts as a deterrent to investments.[232] An additional problem may be that it is difficult to calculate pay-back periods, even though calculation methods and tools are continuously being improved, energy efficiency is a dynamic system composed of a number of interrelated elements, consequently, performance is dependent on a range of factors. Furthermore, there is some distrust in calculations, which also may act as a deterrent.

It was explained that energy savings of 30-60% normally convince the customer, as do pay-back periods of less than one year. It was explained that for industry, pay-back in 2-3 years is acceptable. Since some investments have payback periods of 10 or more years, it is difficult to persuade people to invest in these solutions also because the investors do not believe that they will get the money and tend instead to think that perhaps savings will be cancelled out by extra taxes or something else.[233]

Industries are dynamic and switch localities of operations and thus needed functions of the building and even dimensions are changed, thus limited interest in solutions with long pay-back periods. In regard to housing, there is a tendency to switch housing according to family size, employment, retirement, and housing market, and urban or rural development. Consequently, individuals and families may not live in the same house for a large number of years. These dynamics combined with insecurity in regard to the willingness of new owners to pay a premium for lower energy consumption affect attitudes towards energy efficiency investments

As mentioned, increased energy efficiency often entails initially higher costs. The problem thus arises, how these costs can be covered. Since different actors may be involved in developing, owning and using the building, investments made by one actor may bring benefits to other actors, but not necessarily to the actor making the investment. However, there is still a lack of

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[231] Hansen (2006)
[232] Larsen (2006)
[233] Nielsen (2006)

a system for how to integrate such costs into the price of the building or rents. In some cases, there may even be restrictions for the integration of such costs in prices or rents. For example, in social houses in Denmark, it is not possible to increase rents to cover such investment costs[234]. This may be the case even for regular housing, for example, in Sweden it is not permitted for public housing companies to increase rents for non-value adding renovations and investments. Leading to a situation where rents can be increased if tiles are changed in the bathrooms, but not if additional insulation is added to the roof[235].

In regard to public buildings, there is often still a division between investments and running costs, focus is placed on how many square meters can be built for the investment and operation costs may be a secondary issue. Similar divisions in budgets can also be found in private companies. Consequently, it is not possible to use the savings made from decreased energy consumption to cover investments.

In existing buildings, it typically only makes economic sense to improve energy efficiency when the buildings have to be renovated[236], however, if a short-term perspective is applied, it makes more sense to try to keep the costs of refurbishments initially low, rather than invest in decreasing maintenance and operation costs. Furthermore, many housing companies work with small margins, making it difficult to find funding for investing in energy efficiency[237].

When developers do not build for themselves but instead build with the intent of selling buildings, the incentives to take life-cycle and operation costs into consideration are low since they have to cover the initially higher costs and the purchasers will get the savings over time.

Lack of demand and incentives

Incentives are financial or non-financial factors providing motives for a particular course of action, thus providing reasons for choosing one alternative over another. In regard to the topic at hand, all actors along the value chain need to have incentives to act in a certain way, in this case to develop and integrate energy efficiency solutions.

A typical standpoint from actors in the sector is that, in regard to energy efficiency, the demand side is the biggest challenge. Demand is highly linked with the ability to make demands, several actors in the building sector have stated that if building developers were to demand energy efficient buildings, they would get such buildings and products to ensure improved energy efficiency would be developed. As previously explained, building developers are a highly diverse group consisting of individuals building their private homes to large-scale investors. So while there may be a need to improve the competence of developers in regard to sustainability issues, they are not a homogenous group and existing levels of knowledge and awareness vary. Furthermore, buildings are very complex as is the issue of sustainability and energy efficiency and thus developers require knowledge in a lot of areas.[238]

Users or buyers typically have a low influence on how the buildings function since they were not involved in the decision-making process. Furthermore, private consumers are not seen to be in a powerful consumer position due to a scarcity of housing. While the general public may be passively positive towards energy efficiency, they may not have the influence and the incentives to make effective demands and thus rely on the community to push for such changes.

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[234] Mørk (2006)
[235] Arnqvist (2006)
[236] Mørk (2006)
[237] Arnqvist (2006)
[238] Abrahamson (2006)

According to some estimations, 95% of all buildings are built according to regulations meaning that they are built in compliance to set standards, but do not go beyond these standards. This is explained by the incentives for going beyond compliance being weak. [239] Furthermore, the building sector is currently dealing mainly with mainstream requests, and standardised products. It is a large market, so companies do not have incentives to develop new products. [240] Moreover, since economic profits connected to innovations may be low since the market for these is limited, there is a tendency to try to sell standard conventional solutions.

An additional problem linked with demand is that it is more difficult to sell something that makes an impact rather than something that decreases an impact. As one actor explained, it is easier to sell something that does something active - makes noise, turns around, uses energy, than something that does not[241]. Other actors have also observed that energy efficiency is perhaps not something that is perceived as being very exiting, and saving energy is not seen to be particularly trendy. An additional issue is that the green housing or building concept may not appeal to the main market segment and that it may be perceived as more difficult to live in or use[242].

It was explained that environmental considerations are not an important part of demand and that customers are not driving green product development and, therefore, companies may not market their products as been green. Instead, performance, price and quality were identified as decisive selling points[243]. While there were some concerns about over-regulation, it was noted that regulation and legislation can influence demand in this direction and that regulation can be an important driving force for innovation. However, the sectors in both countries also actively work the issue of sector initiated regulation in the form of standards and targets, which can also be a driver for innovations and the development and integration of new solutions.

The demand for energy efficient solutions is frequently connected to energy prices, as energy costs become a larger part of household budgets, the interest for alternative methods and technologies such as energy conservation increases[244]. However, it is argued that energy prices need to be considerably higher to induce people to demand increased energy efficiency[245]. An issue that has been raised in regard to energy price is that the fixed costs are the biggest part of the energy bill. This leads to a situation, where savings have little impact on energy costs since fixed fees, which in Denmark may constitute 50% of the energy price, remain the same. Thus there is a low incentive to invest in solutions that provide savings.[246] The situation is similar in Sweden.

Another constraint is connected to the territoriality of the actors in the sector that constitutes a hindrance to products combining various functions[247]. On launching their product, one

[239] Mørk (2006)
[240] Mørk (2006)
[241] Abrahamson (2006)
[242] Cronsioe (2006)
[243] Nielsen (2006)
[244] Lilliehorn (2006)
[245] e.g. Kærgaard (2006), Lilliehorn (2006)
[246] Nielsen (2006), Abrahamson (2006)
[247] Hellström (2006)

company experienced resistance from consultants and experts since it was a system and some actors felt that it intruded on their business idea of selling know-how and expertise[248].

The rate of knowledge dissemination is also a factor that affects both innovation propensity and demand. Some energy efficient products are still new and not sufficiently tested, which leads to problems, they do not live up to promises and are difficult to handle[249]. Since negative information spreads quickly, while positive information seems to have a slower rate of dissemination, such cases can be detrimental for the success of future innovations or for similar products on the market. There also seems to be a tendency for the development and long-lived maintenance of preconceptions about certain solutions. The source of these preconceptions could be found in an aversion to change[250], but also to a lack of information about the products and their characteristics[251].

The long value chain also complicates the spreading of information to all actors and the lack of direct contact with end-users and customers complicates the marketing of products. Furthermore, due to the disparity of actors involved in decision-making different types of marketing approaches may be needed. This may in turn make the dissemination of new solutions more difficult.

8.2.4 Other factors

District heating is widespread both in Sweden and Denmark and is frequently mentioned as a possible deterrent to investing in energy efficiency in buildings that are connected to the network or buildings being built in areas where network connection is available. District heating is a solution that has led to increased efficiency in regard to the supply of energy, but it also constitutes a technological lock-in since it is a considerable investment that needs to be paid off[252]. For district heating, the more users are connected, the cheaper it is for the individual user and district heating prices are based on the assumption that everyone in the area will be connected[253]. Furthermore, municipalities typically have a vested interest in district heating solutions and thus may lack incentives to promote increased energy efficiency.

This leads us to the dilemma of shared financial applications where if users use more then prices are lower, if users use less, then prices are higher, which provides a negative incentive to conservation measures. Thus if municipalities stimulate inhabitants to decrease the use of heating, and inhabitants manage to use less, the district heating company may have to increase the price, so inhabitants end up paying the same amount. Furthermore, if people have invested in technologies and the expected savings are cancelled by higher prices, the people still have to pay of their investments. Similarly, if some people in a small area make dramatic savings, this can lead to an increase of price for other inhabitants.[254]

Other barriers to finding solutions for increasing energy efficiency can be linked the contracting system. In building projects it is typical that actors are paid in a percentage of the

[248] Hellström (2006)
[249] Eneborg (2006)
[250] Wall (2006)
[251] Browall (2006)
[252] Svensen (2006)
[253] Nielsen (2006)
[254] Nielsen (2006)

total project cost, thus the incentives to find solutions that already in the building process lead to savings are low.[255]

8.3 Fragmentation of solutions

As explained by one actor, it is a bit of a mystery why increased energy efficiency in the built environment, which provides environmental benefits, business opportunities for companies and lower costs for owners and users are not implemented to a greater extent[256]. As shown by the previous discussion, explanations or possible causes for this lack of implementation are many and the perception of their relative importance varies.

There are a lot of initiatives and measures that are taken and while these are in general successful and lead to positive results, there seems to be a lack of coordination, which entails that momentum does not build up to ensure that solutions become widely spread.

In one sense when developing measures to address the problem at hand i.e. the lack of a wider dissemination and use of solutions promoting increased energy efficiency, there is to a large extent a replication of the nature of the problem itself. While the fragmented nature of the sector, lack of long-term and holistic perspectives and project based work counteract innovation, many of the solutions and measures proposed an initiated are of an equally fragmented nature.

In some cases the issue has been addressed by variety of project based initiatives with a relatively short duration and thus also often a limited impact. Similarly, there have been initiatives that have focused on a very limited group of actors or products that may have led to improvements in regard to the promotion of a certain type of solution but have not addressed the whole issue. Policies may have not taken into sufficient consideration the need for a long-term perspective suited to the long durability of buildings and the culture of the sector. To some extent, it also seems as though the new initiatives that are taken are started from scratch rather than by using the developed experience and knowledge base from evaluating previous measures. It should here be noted that significant improvements are taking place in respect to this in both countries, with action plans, new building regulations and the development of certification schemes.

In regard to authorities responsible for the issue, the responsibility is split between a number of organisations. While there was an effort in Denmark to create a trans-ministerial working group to deal with environmental considerations in the building sector, this initiative died out due to lack of active interest from the involved ministries[257]. When it comes to research, there are also a number of organisations that provide funding and a number of institutions performing research.

In regard to sector initiated measures, there also seems to be a trend of fragmentation rather than of coordination. There are a large number of networks, associations and interest groups that address the issue in various ways. These may contribute to capturing specific knowledge but their limited scope may not necessarily contribute to increasing exchange between sub-segments. While there are attempts to collect these networks and initiatives and combine them, this has not always been successful[258] and there still seems to be a tendency for the

[255] Kærgaard (2006)
[256] Jagrén (2006)
[257] Kærgaard (2006)
[258] Björk-Ausin (2006)

establishment of new groups or networks. While all these initiatives fill important roles, there may be a need for increased coordination and synchronisation especially when dealing with external actors such as funding agencies and policy makers. According to the preliminary results of a project carried out by Swedish Council for Constructing Excellence (BQR), fragmentation may limit access to funding and may counteract the development of policies and programmes that benefit the whole sector[259]. However, it should be noted, that there are examples of cross-segmental networks that include a diverse collection of actors.

[259] Svedinger (2006)

9 Possible solutions

The previous overview shows us that there are a number of issues that need to be dealt with in order to promote innovation in the field of energy efficiency. There are multiple smaller and larger barriers that together constitute a significant obstruction in regard to the development and integration of new products, and the formation of markets. Many of these issues are already being and can be addressed by a top-down approach with different kinds of policy instruments, however, it should be noted that many initiatives can be sector or regionally initiated or even initiated by single companies and then spread to others.

When elaborating possible solutions, there are different approaches that can be used. One possibility is to look at other countries and investigate what types of policies they have used. The interviews indicate that countries such as the USA, Japan, Germany, Norway, Finland and UK have initiated especially successful programmes or activities that promote innovation in this area.

Another approach is to collect ideas for solutions from actors within the sector. Energy efficiency is a complex multidisciplinary issue and knowledge is not centralised in one place but dispersed between a large number of actor groups. This is not a structure that promotes change.[260] Furthermore, the issue of innovation is complex and there are no standard innovation processes, this necessitates a more sensitive approach to the development of measures so as to inadvertently not create mechanisms that can block innovation. While the investigation underlying this thesis is not by any means comprehensive, it could be seen as indicatory for the type of input that is possible to collect by involving actors in the elaboration of solutions. The following section presents some ideas for addressing some of the barriers and challenges previously identified.

9.1 Access to knowledge

Capturing knowledge

The specific features of the building sector make it difficult to collect experience and knowledge. As previously mentioned, many innovations take place during the building process, tools for the documentation of design and production innovations could promote product innovations. This necessitates not only the development of tools such as ICT platforms, but also of the assigning of clear information collection and evaluation responsibilities, as well as closer cooperation with producers. While ICT has been slower to spread in the building sector than other sectors, and some resistance may still exist, the use of ICT solutions and applications is spreading and leading to increasingly improved and more dynamic communication and interaction[261].

Workshops could be an additional way of addressing the problem of insufficient experience collection from projects[262]. Cross sub-segment cooperation can be promoted by the participation in networks. In Denmark the Danish Technology Institute hosts a number of such networks with the aim of promoting exchange of experience[263].

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[260] Skarendal (2006)
[261] Abrahamson (2006)
[262] Abrahamson (2006)
[263] DK INS-1 (2006), Thomsen (2006)

To counteract the loss of knowledge through generational shift, systems to capture existing knowledge and experience could be devised. For instance, by developing a system where retired trades-people can come in and teach young people. A system with incentives could be developed to induce the retired professionals to participate in such a programme[264]. Overseas work experience and internal rotation were also seen as possibilities for providing new insights and new perspectives and thus generate new knowledge[265].

Education

The education system provides the building sector with specialists. Through increased focus on innovation, creative problem solving and environmental considerations, innovation in this field could be promoted. While increasing specialisation is necessitated by the increasing complexity of building materials and solutions, there is also a need for broader expertise. Changes in the education system could address the need for increased cross-segmental cooperation and systems-centred competences. While changes could be made in the regular courses and training, additional workshops with specialists and future specialists from various fields could also be a way of addressing a lack of holistic approaches and cross-scientific education. By providing workshops as a supplement to the main field of study, understanding could be broadened and new perspectives enabled[266].

Another issue that was raised was a lack of connection between theoretical and practical knowledge, to address this, increased efforts could be made in involving future specialists in demonstration projects.

The education system also plays and important role in shaping future demand, as many mind-sets and attitudes are shaped during this time. By increasing focus on environmental issues emphasising the issue of life-cycle costing and external costs, future building developers may be better equipped to make sustainable long-term decisions. Additional efforts could also be made in the area of providing education for current specialists and actors.

Research

As previously explained, there is a mismatch in the time-frames of research organisations and companies. To address this researchers or research institutions have be become better at explaining the need for research and showing why it is necessary. Furthermore, this situation can be facilitated by the research community becoming more involved in the problems of today by asking companies what are their current problems and offer assistance, as well as using the opportunity to discuss future research. Thus by helping to fix current problems, long-term knowledge and research can be sold-in.[267]

There may also be a need for research institutions to adapt their results into forms that are more readily accessible by actors in the sector. The compilation of long reports may not be the best way to convey knowledge.

Demonstration, participation

Since the sector adopts innovations at a relatively slow pace, there is a need for reference projects or demonstration projects. As noted, there is the typical attitude or mind-set that doing things in new ways is not possible and, therefore, it is necessary to be able to show that things are possible. Consequently, demonstration projects play a very important role in

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[264] Abrahamson (2006)
[265] Nielsen (2006)
[266] Abrahamson (2006)
[267] Svensen (2006)

showing actors what is achievable and that it is feasible to do things differently.[268] Since companies may be unwilling to take risks and the benefits for individual companies to invest in demonstration projects may be unclear, there is a need for state funding of such projects. Demonstration projects also help stimulate the development of new products and new solutions[269].

There is also a strong need for working on evaluation and on information spreading. Mistakes and failures will occur and it is important to follow up and find out why things have not been working and improve systems, products and processes. It is also necessary to study what happens in the user phase and what impact behaviour has on the new systems.[270]

However, even in the case of demonstration or reference projects, many actors may remain unconvinced and argue that it worked for others but may not work for me, or it worked once but may fail the next time. To address this, there is a need for repeated demonstration, as well as the active involvement of successively more actors in the process as it has frequently been mentioned during interviews that initial scepticism often disappears after participation in projects[271].

Demonstration projects and evaluations are also necessary to see if stricter regulation is possible[272]. It is not possible to demand the untested technologies in codes and standards, regulatory demands need to be based on tested solutions and technologies. Demonstration projects are needed to test new technologies and to show that stricter demands attainable.

While the building sector is highly regulated and processes are clearly defined and set, a large part of the work is intuitive and creative[273]. This necessitates a special approach to the learning process.

Learning from un-typical sources

There is a wealth of knowledge pertaining to the development of energy efficient solutions, as one of the successful examples presented in Chapter 3 shows, also traditional building technologies may provide useful inspiration for new products. It may therefore be important to collect knowledge and experience and information about traditional building technologies and present these in an attractive way in order to show the potential of combining technologies. For instance technologies, that are to a large degree frowned upon now such as mud floors can potentially be successfully combined with floor heating and solar technology and straw roofing is a very versatile material with excellent insulation properties that can be shaped to fit a variety of forms. One possible facet of creative building is found in the attitudes and approaches of self-builders that are perhaps less restricted by conservative attitudes[274].

9.2 Access to resources

Development support

As explained, companies may lack incentives to develop new products. This means that there is a need from society or the national innovation system to stimulate this process by providing

[268] Abrahamson (2006)
[269] Mørk (2006)
[270] Forsberg (2006)
[271] e.g. Abrahamson (2006)
[272] Svensen (2006)
[273] Kærgaard (2006), Bertelsen (2006)
[274] Abrahamson (2006)

for more research and demonstration, as well as product development support. Programmes offering funding and expertise could be especially valuable for small companies.[275]

Support schemes specifically aimed at the development of products related to improved energy efficiency could provide valuable resources to actors in the sector, especially small companies that may not have sufficient internal resources. The interest of venture capital providers in investing in such innovations could be investigated, and possibly promoted. The capabilities of actors in the sector to access external sources of funding, for instance from EU programmes, could be promoted through workshops and networks. Networks and coalitions could also provide an opportunity for resource sharing, especially for small companies.

Recruitment of specialists

The building sector still has a somewhat tarnished reputation. While efforts have been made to address this issue, it still seems as though the sector is not typically associated with development, innovation and is perhaps not necessarily seen as a very exciting field for young professionals. As a study conducted by the Swedish Association for Building Material Industries shows, the public is relatively uninformed about the sector and a lot can potentially be achieved by highlighting what is positive and spreading information about interesting and exciting developments. There have been several positive initiatives in this area, for example by the same association that collected and published a series of good examples of innovative approaches. Efforts such as these could contribute to highlighting the innovative potential of the sector and contribute to the recruitment of creative and innovative professionals and the creation of new knowledge and innovation could be promoted by an influx of new approaches. The sector potentially offers a wide possibility of new types of work opportunities for project and system developers, IT specialists and product or concept designers. The importance of marketing the sector is shown by the case of a Swedish university that received increased interest from students by changing the name of the education course provided from to one that was more appealing.[276]

Internal incentives

Internal incentives for product development or idea generation are also an important aspect in the stimulation of innovation. During interviews different successful approaches were discussed such as the provision of bonus systems for employees that generate new product ideas and in-house innovation competitions for the stimulation of the generation and development of new concepts[277].

Focus on lowest price

The focus on lower price throughout the value chain is a difficult issue to address. In order to do so, efforts are needed in the area of life-cycle costing. Additionally, systems are needed for the inclusion of other costs such maintenance into calculations, as well as the cost in form of human resources and time for integrating the products into buildings. There is also a need for incorporating other values into the decision-making process. This can for instance be done through the value management phase of Lean Construction[278]. Similarly, Partnering may be a useful tool.

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[275] Svensen (2006)
[276] Björk Ausin (2006)
[277] Nielsen (2006), DK INS-1 (2006)
[278] Bertelsen (2006)

9.3 Formation of markets

Lack of incentives

As explained, the split-incentive division between the investor who invests capital and the owner or user who gets long term savings leads to a situation which counteracts investments in energy efficiency. There are examples where this problem has been addressed, for instance with systems enabling those who pay rent to pay off energy efficiency investments[279], however, currently there is a lack of a wide-spread system for how to address the issue of the division between the investor and the user. There is thus a need some form of calculation and financing system that promotes long-term thinking.[280] A number of various measuring and calculation systems exist, as do various types of solutions. However, there still seems to be some distrust towards calculation systems and energy services, thus efforts may be needed to market these concepts. In Sweden, for instance, in the case of energy performance contracting, this is being done by one of the regional energy offices[281]. In Denmark, the energy performance labelling of buildings that is now being implemented could, during sales, also influence customer decisions to pay extra for a more energy efficient building, thus potentially providing incentives to build such buildings.

Energy services

One option is energy performance contracting, which is a service that is successfully used in other countries. However, energy performance contracting is just in its initial stages in Denmark and Sweden, though Sweden has come further with developing such services. In Denmark it has been discussed for the past five years, but limited progress has been made in this area. Reasons for it not taking off could be connected to attitudes, of not really liking to give over the responsibility to a third party. Another explanation is that perhaps companies think that if a third party is willing to do it, then they could provide such service themselves, but then it turns out to be complicated. It also may take time to see it as a normal type of outsourcing and perhaps also actors do not realise the potential.[282]

The usability of energy performance contracting is directly related to trustworthy energy calculations. One problem is that buildings are complex systems and energy use is difficult to measure, another issue is that it takes time, up to two years, to verify measurements[283]. However, measurement systems are continuously being improved and since energy services of this sort have been successfully used in other countries e.g. the USA, it is possible to manage these problems. Since Sweden seems to have come further with the issue than Denmark, this could be a possible area for experience exchange and joint projects.

Other options to facilitate the financing of investments in energy efficiency could also be developed. One way of addressing the issue is, for example, by changing the accounting systems used by public housing companies[284]. Beneficial loans with reduced interest rate could be provided, as has been the case in e.g. Germany[285].

Demand

As explained by one actor, the quickest way to solve the issue may be to give money to housing companies to employ energy consultants and start making demands[286]. Similarly other

[279] Hansen (2006)
[280] Mørk (2006)
[281] Forsberg (2006)
[282] Mørk (2006)
[283] Nilsson (2006)
[284] Seminar (2006b)
[285] Workshop (2006)
[286] Svedinger (2006)

actors also suggested providing incentives in the form of subsidies, the possibility to use the subsidy programme developed for energy efficient white goods in Denmark as a successful model was suggested. This programme offered a subsidy to stimulate the purchase of products with improved performance, leading to a situation where the market for such products became firmly established[287]. However, the issue of short-term subsidy programmes that function as disruptive forces, or shift from technology to technology or that lead to high costs and limited impact was also raised indicating that there is a need to clearly link such programmes to overall strategies and coordinate them into cohesive long-term policies.

Furthermore, systematic efforts are needed to find a solution to organisational barriers in the form of divisions in budgets and a lack of system for integrating energy efficiency investments in building prices and rents.

Demand is also linked to the price of solutions; however, the price is also dependent upon demand since stable demand can enable the mass production of products. Schemes such as the technology procurement programme developed in Sweden may be an effective way of stimulating the demand for products that are being developed.

State/municipalities as role models

Public procurement can play an important role in the formation of markets. Firstly, the state and regional authorities own a significant number of public buildings and commission new public buildings. Thus by integration of stringent energy efficiency demands in the renovations of existing buildings and design of new buildings, not only are significant long-term savings of energy costs possible, such measures will also stimulate the production of new solutions. Such measures would also through increased sales increase the market for energy efficiency promoting solutions thus creating more significant market that allows for the offsetting of development and production costs. Furthermore, such projects could also act as demonstration projects leading to increased awareness about energy efficiency solutions.

Marketing energy efficiency

At first glance, energy efficiency is not particularly exciting. It may seem to be far more interesting to focus on new types of energy supply than to find ways of saving energy. As actors have explained, people invest in things that are interesting to them. Therefore, perhaps efforts need to be directed into making the issue of energy efficiency more interesting or trendier. This can be done through awareness raising measures, but could perhaps also be done by increased attention to the issue of design. As one actor noted, more appealing design leads to the perception of added value as well as promotes improved maintenance[288]. The development of systems products offers significant potentials to design visually attractive products that could lead to increased demand. In order to facilitate the formation of product design coalitions, workshops and other forums promoting the establishment of contacts could be beneficial. Other ways for promoting such efforts could be through the provision of programmes stimulating such cooperation and promoting an improved connectivity of the design and production phases.

Visually attractive design may not be a solution for some of the products that are components or that are integrated into the structure of the building and are not directly visible to customers or end-users. Instead other approaches can be used, as successfully done by one

[287] Svensen (2006)
[288] SE VENT 1 (2006)

company where branding was conducted by supporting various types of popular public activities and awareness raising initiatives[289].

In regard to demand, building developers are identified as a key group to focus on. However, due to their diversity, different kinds of approaches may be needed. However, it should again be noted that increased awareness needs to be combined with the creation of economic incentives. Differentiated measures may also be needed in regard to other actors for instance architects and engineers may have different priorities and thus successful marketing of the issue of energy efficiency should be adapted to the specific needs of the target group.

9.4 Other factors

District heating is most probably an integral part of a long-term sustainable energy system, it is rational to use low quality energy for heating and a centralised storage and distribution net is typically a more efficient solution than decentralised systems. Thus it is a challenge is to adapt district heating systems to changing energy consumption levels due to increasing energy efficiency. One possible option is to find a way of successively decreasing temperatures as more houses become more energy efficient.[290] Research is needed to find solutions to this problem, in Denmark, for instance, a project in this area has been initiated[291].

Fragmentation and territorialism are frequently mentioned as challenges that need to be addressed. Since energy efficiency is a complex issue that requires the cooperation and participation of most actors in the value chain, it necessitates new models of communication and new ways of working together and ensuring that feasible targets are set and met. Recent trends in Lean Construction, Partnering and industrialisation go against a territorial division as well as the division of the building process in separate phases. These management systems are furthermore based on the collection of knowledge and ensuring that knowledge is not let to dissipate.[292] Thus a further spread of these new approaches may be beneficial for increasing innovation and integration of energy efficiency promoting solutions. Since many important product innovations may take place in the design phase it may be necessary to strive for a greater connectivity of these phases. The previously mentioned management systems may contribute to doing this, as could support programmes aimed at stimulating the creation of innovation consortiums during projects. A further way to address the issue, is by workshops that could be a tool to make bridges between professionals in various spheres, as well as to link practical and theoretical knowledge. [293]

9.5 Policy options

The importance of regulation for the promotion of environmental innovations has been frequently emphasised. Regulation can contribute to increase demand and lead innovations as well as to help create a functioning incentive system. Many actors explained that in the case of energy efficiency, regulation is needed to get the process moving and it was emphasised that regulation is very important in initial phases, and then as more competence and knowledge is

[289] Nielsen (2006)
[290] Svensen (2006), Mørk (2006)
[291] Mørk (2006)
[292] Hellström (2006)
[293] Abrahamson (2006)

transferred, actors are more able to lead the issue themselves, similarly, once companies start making profits on energy efficiency, then consideration of it will spread[294].

There are a number of policy instruments that can be used to stimulate innovation and to promote the formation of markets for solutions promoting energy efficiency. This section provides a brief overview of possible instruments, the purpose of which is to illustrate some of the options and briefly discuss possible difficulties and impacts.

Taxes are price regulating instruments that can be used to generate income to the state budget or to force a change in behaviour. However, there does not seem to be a clear connection between taxation and increased development and diffusion of technology in regard to energy efficiency[295]. While the EC Green Paper on Energy Efficiency explains that there is a need for policies that ensure that tax is eased on products with low energy efficiency and raised on those with high demand[296], this may be difficult in regard to building materials. As previously explained, improved energy efficiency is dependent upon the system that is designed i.e. how various types of products and elements are combined and how they interact. Thus it is not entirely straightforward which products or building materials are actually more or less energy efficient, since their performance is interlinked with the actual system in which they are integrated. Thus it may be more suitable to levy taxes on actual buildings. However, here again we are faced with the complexity of the sector and the multitude of different kinds of buildings, which may complicate the development of such a system.

Building regulations are used to limit the available choices for actors. Norms can be used to effectively influence the spread of technology. However, for norms to function well-developed technology is needed, furthermore, norms may hinder innovative developments and competition on the market.[297] As explained, in both Sweden and Denmark, increasing demands for energy efficiency have been integrated into the building code. While most interviewed actors saw this as a positive trend, instances where some norms place limitations on innovation possibilities were noted. A further issue that was mentioned was that in some instances the norms may favour some technological solutions or materials more than others, which in turn may limit the possibilities for developing alternative solutions. However, despite these problems, building regulations are a powerful tool in pushing development in a certain direction.

Policies can also provide support to research and development to promote the development of develop new technologies and improve existing technology and to attain a greater rate of diffusion. Furthermore, research can contribute to increased knowledge about various energy systems, technologies, actors, institutions and the cooperation between these. Information and education can be used to influence the level of knowledge, attitudes, behaviour to promote market introduction and establishment of new technology. Information measures can be general or be focused on a specific technology. However, as previously noted, information may not be sufficient to promote change, and such measures may have to be combined with other instruments.

Technology procurement is used to stimulate the development and dissemination of products with better performance than those already on the market. The technology procurement process involves several actors such as purchasers and producers. Purchasers place demands

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[294] Nilsson (2006)
[295] Neij and Öfverholm (2002)
[296] EC Green Paper on Energy Efficiency (2005)
[297] Neij and Öfverholm (2002)

on the product and guarantee a certain initial market. This contributes to decreasing the insecurity for producers connected to the development and establishment of new products.[298]

Subsidies of certain products or for certain types of changes may contribute to improved dissemination and the formation of markets. However, as previously discussed and also explained in the EC Green Paper on Energy Efficiency; there has been a tendency to have disparate small subsidies with limited overall impact[299], thus in order to attain long-term effects on the markets such subsidies need to be coordinated with other policy measures or be part of a long-term strategy. Investment support and state guaranteed loans can be used to promote the establishment of new technologies on the market. Support contributes to investments in technology and experience, which may lead to further development, increased competence, market acceptance and eventually also market expansion.[300]

As previously explained, and as is being done in Denmark and Sweden to an increasing extent, in order to make a positive far-reaching impact, policy measures need to be coordinated and connected to a long-term strategy thus providing clear signals for actors in the sector and for the market.

9.5.1 Coordination and timing of policies

Currently, both in Sweden and in Denmark, state policies are developed and simultaneously regional and sector led measures are being initiated. While initiatives in all areas are crucial, if they are coordinated greater synergy can be achieved and the effect of combined measures will most probably be higher. Coordination of different types of legislation and policies may also be an important factor as innovation and the integration of solutions since the formation of market demand is dependent upon a number of different variables. As shown, the capacity to innovate is dependent upon access to knowledge and is consequently affected by education and research policies; furthermore, education policies are crucial for the generation of skilled employees. Environmental policies naturally also have an impact on the sector, as do labour policies. Housing policies and policies regulating rent-setting also affect the demand for energy efficiency promoting solutions and thus innovation. While energy prices are to a large degree set by international market interactions, the taxation of energy is highly relevant to the topic at hand, as is regulation enabling or constraining municipalities to push the issue of increased energy efficiency. As indicated, there are cases when regulation inadvertently may block successful innovation. Consequently, increased coordination may be needed to construct effective policies promoting energy efficiency.

Another aspect that needs to be taken into consideration when developing measures or solutions is the issue of time. Perfectly elaborated initiatives may have limited effect if they are implemented at the wrong time. As previously explained, the economic cycles have a considerable impact on actors within the sector and on the availability of resources. For instance, product development in the building sector during times of growth is constrained by lack of time and manpower and during times of recession by lack of funding, security and possibly lack of key competences. The impacts of economic cycles on innovation in the sector are illustrated in the following figure. It should also be taken into consideration that products can rarely developed in a short span of time, instead periods of ten years or more may be needed, indicating that long-term planning is needed.

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[298] Neij and Öfverholm (2002)

[299] EC Green Paper on Energy Efficiency (2005)

[300] Neij and Öfverholm (2002)

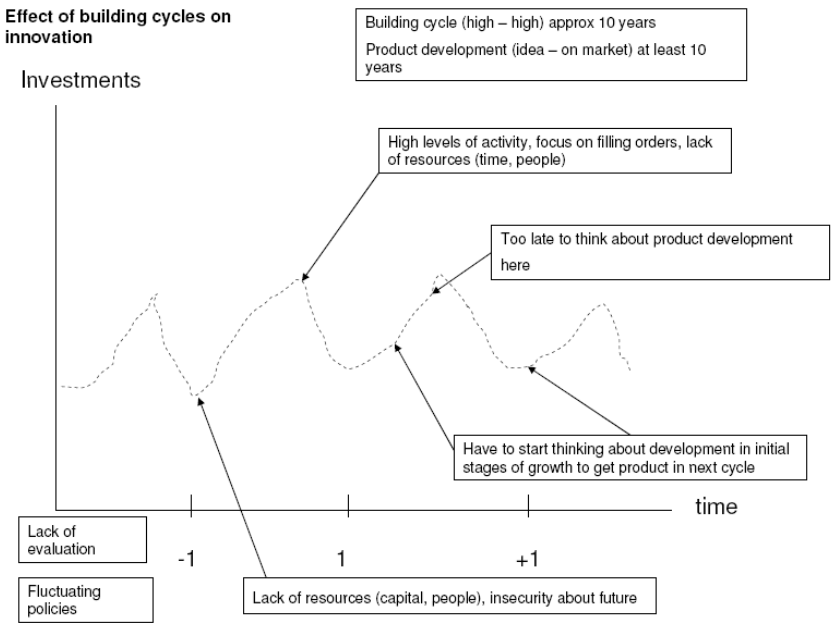

Figure 9-1: Impact of economic cycles on innovation
Source: VR on the basis of discussions with Jagrén (2006)[301]

This could mean that companies are unable to fully utilise opportunities provided by support programmes during both periods of intense growth and during recession. As shown in the following figure, one possibility would be to develop programmes that function during downturn and upturn phases, thus coinciding with the times when companies are more able to spend time and resources on development. Another possibility would be to try to find measures that partially counteract the negative effect economic cycles have on innovation and product development. For instance by earmarking some of the taxes paid during growth periods to be refundable to companies that are want to invest in research and development of energy efficiency promoting solutions during times of recession. The effects of building cycles could also be limited by providing companies with subsidised researchers or students during times of recession. Researchers could also be involved in conducting evaluation work, thus helping to capture experiences otherwise lost. It should again be emphasised, that long-term policies are needed to mitigate the effects of insecurity created by economic cycles and other factors.

[301] The graph is not plotted so as to represent any specific country or time instead random values are used to indicate trends.

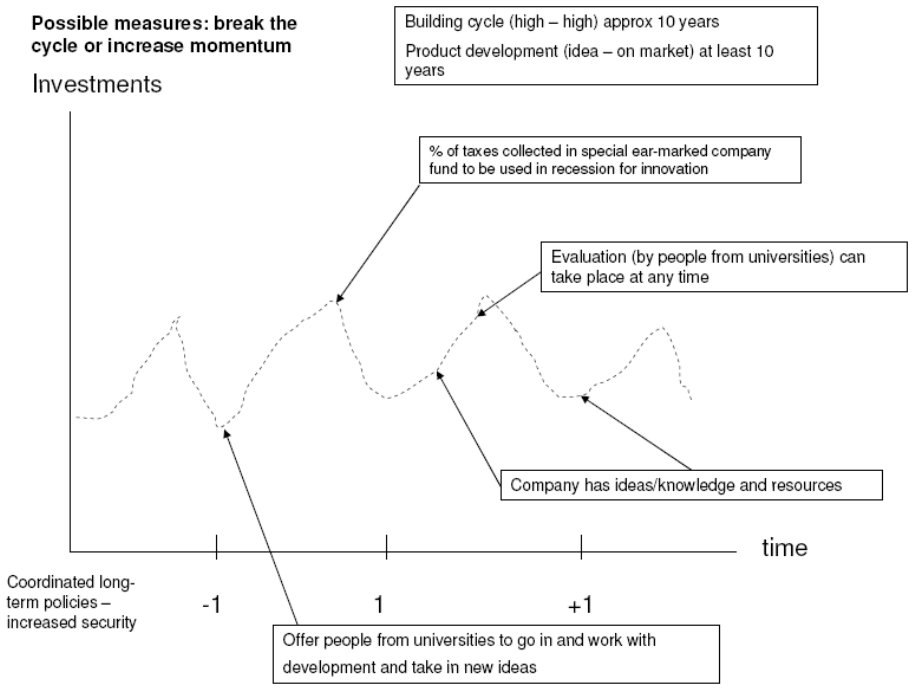

Figure 9-2: Impact of economic cycles on innovation
Source: VR on the basis of discussions with Jagrén (2006)[302]

[302] The graph is not plotted so as to represent any specific country or time, instead random values are used to indicate trends.

10 Opportunities - three scenarios

Perhaps rather than to let the conclusion that it is difficult to innovate in the building sector and that there are constraints to the attainment of increased energy efficiency in the built environment be the end of the story, it should instead be seen as the beginning. There is a huge and to a large extent yet untapped innovation potential both in regard to new products, systems, services and processes.

The depletion of fossil fuels is undeniable. Sources will successively become scarcer and prices will increase. Radical technological developments such as fusion may be possible but seem unlikely and would require considerable resources and time to be developed. While the share of renewable energy is growing and unutilised potentials exist, renewables may not be able to fill an increasing energy demand.

Focusing on energy savings and increased energy efficiency is a logical choice. It is based on the understanding that we do not need to waste energy and by limiting this waste we will be able to put freed resources to better use and promote growth. If we look at it from a logical and long-term perspective there cannot really be any arguments for using resources to sustain an inefficient system. Arguments such as the existence of numerous barriers, difficulties, lack of consumer interest, the need for investments, long pay back periods, should be seen as things that need to be fixed rather than reasons for not acting.

The building sector stands before a huge challenge and it will eventually have to become part of the solution towards more sustainable energy systems. However, there are perhaps two general lines that could be taken.

In the **first scenario**, the building sector is the passive recipient of orders from society, when society, through regulation tells it to increase energy efficiency in buildings it will be forced to develop technologies, methods and processes for doing this. Thus focus is placed on conformance and efforts to go beyond compliance with standards are limited.

In the **second scenario**, the building sector takes a proactive role and takes on part of the responsibility for developing and shaping the future system. Instead of being a passive recipient, it has the opportunity to become an active proponent of change. This scenario offers opportunities such as increased competitiveness and the development of new exportable products and services and greater influence on how the solutions are to be developed and implemented. While the second scenario does not preclude the need for regulation and societal involvement and support, it calls for greater coordination and cooperation between the sector and society.

In a Nordic perspective there is an additional opportunity that by increased cooperation and sharing of resources, the Nordic countries could strengthen their competitive position and become a provider of energy efficiency solutions to other European countries and to countries outside Europe. Compared to other regions in Europe, the Nordic countries have significant experience of working with energy efficiency and also have a long and successful experience of working together to create pan-Nordic solutions enabling the relatively small Nordic countries to become a powerful actor.

There are a number of barriers that may counteract the sector's ability to take on a proactive role. However, there are also a number of tools that could be used and there is also great potential for the development of new tools.

On the one hand it could be argued that the sector is in a grim position to be innovative due to various features that act as restraints to innovation. On the other hand it could be argued that especially due to this, the sector has a considerable untapped potential to innovate and that by systematically addressing the barriers to innovation, massive leaps forward could be made.

The dilemmas and complications faced by the building sector in Denmark and Sweden are not unique Scandinavian occurrences; they exist in sectors in other countries also. What is interesting is not merely noting the existence of these problems and how they affect innovation, but how we manage them and our opportunities for improving our management of them.

There are companies that have seen the value of engaging in public service activities to increase awareness about energy efficiency. Thus they are not only proactively participating in the formation of new markets, but also ensuring that they will have a leading role in them. There are also other actors such as municipalities that have seen the value of actively stimulating innovation and promoting energy efficiency in the built environment.

The energy efficiency issue perhaps is an opportunity for the sector to look beyond the typical boundaries. Companies in the sector are not merely providing products and services that will result in buildings, instead they are creating the infrastructure of the future.

Another window of opportunity is created by the processes of globalisation and internationalisation, which are leading to an expansion of the market and opening up new opportunities and a wider range of products and solutions, thus providing more alternatives[303].

A **third scenario** - a do nothing scenario - could also be identified. A shift towards energy efficiency will probably take place gradually even if no particular measures are taken. Increased energy prices will force the development of energy efficient solutions through increased demand and necessity. But by acting passively in this situation the competitive advantage will be lost. Services and products will be developed, but by companies in other countries and regions. Other actors will capitalise on this opportunity and will invest in research and development and will develop policies to promote innovation and thus will be able to offer solutions.

Not moving forcefully and in a coordinated manner now does not mean that there will not be an energy efficient built environment in the future - only that it will cost more and that it will be achieved with the competence and products of others.

10.1 Opportunities for actors

The building material manufacturers are seen as partly outside of the sector. To promote the development of products and the exchange of knowledge, the segment could benefit by becoming more involved in the building sector. However, to get into the process they have to have something extra to offer, something that would create an incentive for other actors to involve them. Therefore, the segment needs to develop solutions that contribute to the process. Instead of merely focusing on the supply of materials the segment could work on supplying systems or solutions. This can probably only be done effectively by working together in coalitions. This would lead to a situation where instead of supplying a number of components that can be combined in an almost unlimited number of ways, the coalitions or

[303] Skarendal (2006)

companies offer joint system solutions. These solutions would have the benefit of fitting together and working to achieve a certain level of energy efficiency. This is important in the case of energy efficiency because not only the individual characteristics of components are important but also how they interact with other components in the system. A further reason for actively working with the developments of products that provide added values is that the building sector is undergoing rapid internationalisation, which can lead to increasing imports of cheaper materials, products and prefabricated elements from other countries. Due to high labour costs in both countries competition on lowest price may not be possible, thus there may be a need to develop products that give companies a competitive advantage, for instance systems products, products with new integrated functions, products with particularly high quality, products that lead to decreased building costs and high design values or high-tech building materials.

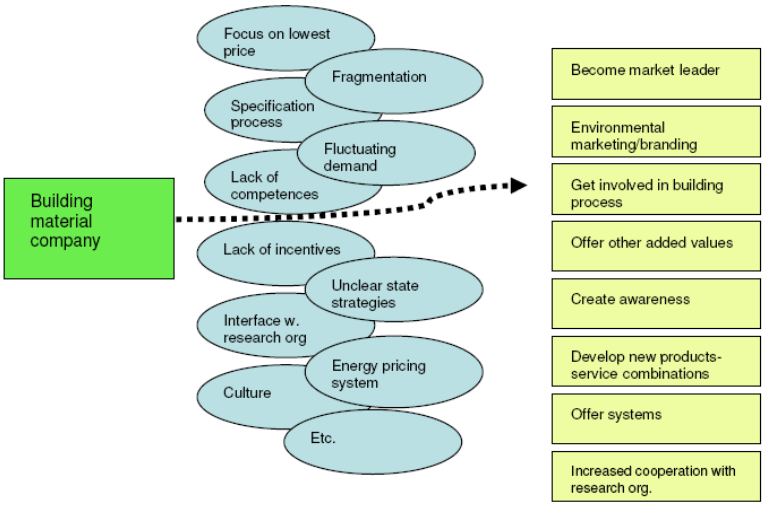

Figure 10-1: Opportunities - strategies for overcoming barriers
Source: VR

While regulation has an important role in stimulating environmental innovation, bottom-up approaches are also possible and necessary. As indicated by the successful cases presented in chapter 3, it is possible to overcome barriers and to attain a competitive advantage. There are different strategies that can be used, what could be interesting to note that while barriers are typically seen to block innovation, perhaps with a different perspective they can be seen to stimulate the development of new approaches.

Similarly, the issue of energy efficiency also provides opportunities for other actors. The development of existing and new types of energy services, management procedures, measuring and calculation systems, offers a wealth of business possibilities for consultants and other companies such as producers or construction companies. Sweden and especially Denmark has strong international consulting companies that could provide a gateway for exporting developed energy efficiency solutions.

Since the issue of energy efficiency innovation spans across the building sector and requires the involvement of many different actors, there may be an increased need for new types of coalitions. Possibly, current trends towards more vertical organisation may lead to the development of such coalitions or perhaps they can be established between autonomous actors. This may be an area where Denmark with its experience in SME collaboration and architect driven product design could become a leader and a model for Sweden. The role of

the architect as a product designer is an area with considerable potentials, since this combines the knowledge of what types of products and systems can be integrated into attractive buildings, with the specific knowledge on materials and processes that the production companies have. These coalitions could also be expanded to include engineers thus providing additional knowledge and expertise.

Sector initiatives are important in both countries; in Sweden the Eco Council has developed into a strong sectoral organisation working with sustainability issues. Strong organisations can in turn enter into policy discussions with decision-makers. Efforts to establish state-sectoral platforms have also been taken in both countries. In Sweden, the Building-Living Dialogue provides an opportunity for experience exchange and joint work on sustainability issues, however it can be noted that membership is relatively low[304]. Such organisations have a considerable potential in bringing together actors and creating a platform for discussions and cooperation necessary for problem solving and innovation.

As mentioned, both countries are leaders in innovation in a European context and while the building industry may lag behind other sectors, with systematic efforts to improve the generation of knowledge, access to resources and the formation of national and international markets, there is no reason why the building sectors should not be able to become innovation leaders.

10.2 Vision and strategy

Increasing energy efficiency in the built environment is a process or rather a transition. Each meeting between actors or situation in which choices are made can be seen as a step towards this transition. However, these steps necessitate new decisions, new resources and a new perspective. By connecting these meetings or decision making situations a process can be created. An overreaching strategy for the transition to a sustainable use of energy, may contribute helping each actor motivate decision making in the direction of improved energy efficiency.[305] While both countries have strategies, it could be questioned whether they are far-reaching enough. As explained by one actor, the risk of not having a final destination is that the journey might start going in a different direction[306]. The buildings we build today will be the houses, offices, facilities, schools, hospitals, shopping areas, research centres for the coming decades. Therefore, there is a need to plan the future built environment already today. In order to develop long-term strategies there may therefore be a need to envision how a sustainable built environment would look in 30, 50, or even 100 years from now.

[304] In Swedish: Bygga-bo dialogen, ByggaBoDialogen (2006)
[305] Svane (2006)
[306] Svensen (2006)

11 Øresund region - putting ideas into practice

Regional actors are important promoters in the area of environmental business development and environmental technology development and export. Furthermore, analysis shows that environmentally driven market and export can promote further growth in regions.[307]

The concept of *regional innovation systems* is based on the perspective that innovation results are determined by a specific institutional infrastructure and production system that exist in a certain territory. Thus the main idea is that the innovative performance of a regional economy depends on the innovative capabilities of firms and research institutions, and on the ways they interact with each other and public institutions in that area. This approach emphasises the role of spatial proximity and its impacts on the innovation process. [308] The OECD also emphasises the importance of the localisation effect, which entails that knowledge flows from the public sector to industry in a specific region[309].

In regard to the case of energy efficiency in the built environment, the investigation made shows that regional actors in Denmark and Sweden play a very crucial role in the promotion of innovation and the dissemination of new solutions. While sectoral innovation systems are important in determining the propensity to innovate, and national innovation systems, to a large extent, determine the framework in which innovation can take place i.e. the *space of possibilities*[310], regions have a potential to affect both of these aspects.

Regions can design programmes to counter-act barriers to innovation, as well as to provide a space of possibilities for promoting innovation and the integration of solutions. Municipalities and regional authorities play an important role in this and can act as drivers to stimulate other actors. Regional and local actors can also act as innovation promotion hubs or centrals by bringing together actors in joint projects or activities, as well as initiate activities that promote the exchange of knowledge and increase awareness. They can also be key actors in accessing resources for the region to enable innovation for instance through accessing state or international funding for projects and programmes. While regional and local governmental actors may have limited influence on national markets, they can through market stimulation measures, public procurement, and awareness raising contribute to the diffusion of innovations on a regional market, which can in turn contribute to influencing demand in other regions. Regional and local actors thus have a unique opportunity to provide an environment that fosters the development and dissemination of innovations, and to thus also act as a source of inspiration to other regions.

On the other hand, regional and local actors can also through their policies; attitudes, priorities and decision-making hinder the development of innovative regions and decrease the space of possibilities.

The Øresund Region is a dynamic Danish and Swedish cross-border region, which comprises Zealand, Loland-Falster, Møn and Bornholm in Denmark and Skåne in Sweden. It covers an area of 20 859 km², hosts 3.5 million inhabitants and generates a quarter of the combined GDP of the two countries. It is a major centre for research and teaching with 14 universities and colleges with more than 150 000 researchers and students.[311] The region has an especially

[307] SOU 2004:84
[308] Doloreux (2002)
[309] OECD (1997)
[310] term coined by Svane (2002)
[311] Øresund Portal (2006)

strong knowledge and resource base in the field of environmental science and related disciplines, as well as for the IT field[312]. Furthermore, the region actively promotes innovation and is known for its well-developed links between industry, establishments of higher education and authorities[313].

The region has initiated a number of significant projects in the field of promoting energy efficiency, and several municipalities in the region have initiated projects and programmes to stimulate increased energy efficiency and the development of innovative solutions.

Thus the Øresund region is in an excellent position, with access to a strong knowledge base, competences, resources and interested actors, to become a leader in the field of developing and promoting energy efficient solutions.

11.1 Opportunities for regions

There are a variety of possibilities to promote the issue of stimulating innovation in the built environment on a regional or local level. While there are a number of initiatives already taking place in the region, increased cooperation and coordination of measures could contribute to strengthening the positive impact of these and future initiatives. Furthermore, while energy efficiency is a case that can illustrate regional opportunities, a more sustainable built environment may be the envisioned end-state.

In order to capitalise on the opportunities provided by working with increased energy efficiency, it is necessary for relevant regional actors to agree that this is a prioritised issue. For this to happen, it is necessary to clarify what are the benefits of doing so.

While it is perhaps difficult to speak of a first mover advantage in regard to regions and municipalities, there is a general agreement that there is a huge economic potential connected to energy efficiency. If regions or municipalities are able to use this to their advantage, it could be possible to use energy efficiency measures as a tool for the development of new companies that offer new types of services; the competitiveness of existing companies could similarly be strengthened. This may in turn lead to the creation of new employment opportunities. Acquiring and maintaining a reputation of being a leader in this area could also contribute to elevated levels of interest from external parties. This could in turn stimulate the interest of individuals and companies to relocate in the area, thus increasing municipal income.

Increased energy efficiency leads to decreased long-term costs for building owners. This could also affect the competitiveness of rents, which could lead to increased interest of moving to the region and a freeing of income that could be used for other things. For disadvantaged members of society, lower rents could lead to a lessened dependence on social support.

11.2 Vision

While innovation is to a large extent a creative process, the development of marketable concepts needs long-term planning. All types of long-term planning need a visionary approach. This may be especially true for planning the built environment, since due to the long durability of buildings; we are today already building the housing, commercial and public buildings of the future.

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312 Øresund Environment Academy (2006)
313 Øresund Portal (2006)

Perhaps there is a need for new ways of looking at the issue and a need to break away from old and limiting patterns. There may be a need to work on a long-term vision, for instance entitled - *Envisioning and Innovating the Built Øresund Region of 2030*. The formulation of such a vision could be a launching platform for further initiatives. It could serve to involve the actors of the region in a discussion on what types of buildings will accommodate future needs and what sort of solutions are needed in a dynamic innovative region. While energy efficiency may be an important aspect, there are other issues that also may need to be included such as innovation and integration of solutions for increased mobility, upgradeability, improved comfort and quality of life, changing needs and special needs.

This could lead to a programme, for instance entitled - *Integrating environmental consideration in buildings through new forms of cooperation - a show-case in Øresund region*, coordinating efforts, building on existing strengths, utilising potentials and creating new joint measures. By increasing coordination, the Øresund region could be promoted as a testing ground for new innovative sustainable solutions for the built environment. This could be further linked to ambitious targets and goals such as becoming the most energy efficient region in Europe. As explained, increased energy efficiency can also be linked to increased competitiveness and thus could be part of a strategy aimed to build strong competitive regions.

11.2.1 Transforming vision into action

There are numerous barriers that contribute to hindering innovation in the building sector, thus working on the removal of hindrances is an important first step to unleashing the innovative potential of the sector. Therefore, a systematic effort to improve interfaces between actors, ensuring access to resources and solving structural issues should contribute to both stimulating innovation and the demand for innovative solutions.

When translating vision into practice, it is important to know the objectives or the desired end-state, to know the current situation, as well as to take into consideration previous activities and experiences.

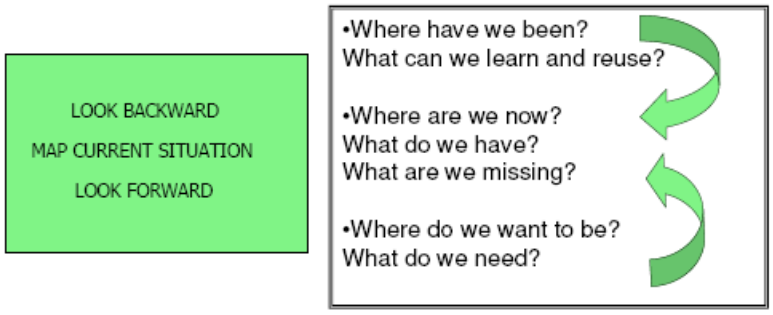

Figure 11-1: How to move forward
Source: VR

One way to systematically address the issue is to look at the three basic pre-conditions for innovation - access to knowledge, access to resources and markets and to ask what can be done to improve these. As well as to map existing resources to determine relative strengths and what could be further developed to gain a competitive advantage.

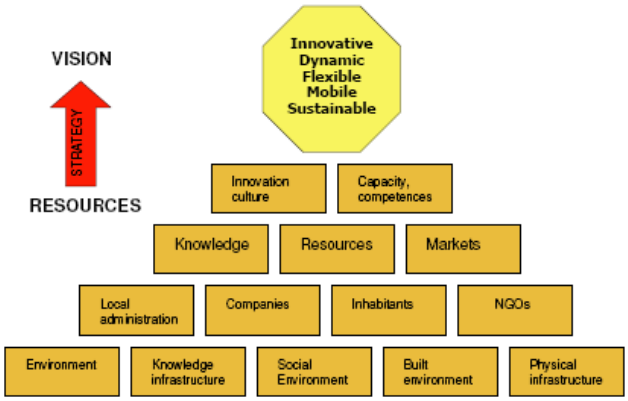

Figure 11-2: Using existing strengths to attain targets
Source: VR

An example of regional efforts in addressing barriers in the area of energy efficiency in the built environment is the leading position taken by the Energy Agency for South East Sweden in regard to the promotion of energy services[314]. Energy services are a set of tools that can be used to address the problem of lack of resources for initial investments in energy efficiency. The agency is currently working on an EU financed project aimed at the promotion of energy services, including Energy Performance Contracting, in the public sector[315]. Regional actors can also be very important in regard to demonstration, for instance Regionfastigheter Skåne is working on a large-scale energy efficiency promoting refurbishment project using Energy Performance Contracting[316].

An example of regional efforts promoting the formation of markets are the subsidies offered by Landskrona municipality, enabled by Landskrona receiving state funding from the Swedish Environmental Protection Agency in 2006, for measures aimed to decrease impact on climate change.[317]

Sweden and Denmark have very strong and internationally acclaimed design traditions. While energy efficiency may not initially seem to be an issue connected to design, the development of new systems products offers considerable design possibilities. Integrated and visually attractive solutions could contribute an opportunity to create added value and go beyond the limitations set by focus on lowest price. By finding ways of creating appealing designs that provide energy saving functions, energy efficiency need not remain something unappealing and un-trendy, but can instead become a desirable product. The involvement of architects in product design is a trend that has already begun in Denmark, and by increasing cooperation, possibly new Scandinavian design solutions could be created.

Demonstration projects, can be used not only to stimulate innovation and encourage the integration of new solutions, they can also provide an increased interest in the region, which could provide benefits for other industries in the region, for instance the tourism industry. There are a number of interesting demonstration projects on-going in the region, for instance in Køge and Stenløse municipalities, and a large-scale research and demonstration project is planned in Landskrona. Large-scale demonstration projects could also provide potential

[314] Forsberg (2006)
[315] Energy Acency for South East Sweden (2006)
[316] Energy Acency for South East Sweden (2006)
[317] Landskrona Municipality (2006)

export opportunities. As one actor explained, the Swedish building exhibition in Malmö Bo01 has attracted a lot of international interest and there have even been inquiries of the possibility to export the concept and build similar urban areas in other cities[318]. However, at the moment there is no such organisation that could transfer such concepts to other countries, and thus this business opportunity is not utilised.

New joint ventures and joint product development projects could continue to work with innovations stemming from the demonstration projects. Programmes could be developed to support such initiatives and stimulate innovation and the development of new products and services.

The region also has comprehensive experience from working with EU programmes, this experience could be utilised to access the numerous opportunities provided in the field energy efficiency and sustainability in the built environment.

A further opportunity could be the development of an *Øresund innovation model*, in which best practices from both sides of Øresund are collected and developed. There are numerous good cases and good examples, however, these need to be collected, evaluated, and replicable concepts need to be identified and disseminated to other actors. This model could provide a basis for the development of marketable services and concepts and the export of key competences in this area. Another opportunity could be the development of an *Øresund cooperation model* for the promotion of a sustainable built environment could be developed and exported to other international regions.

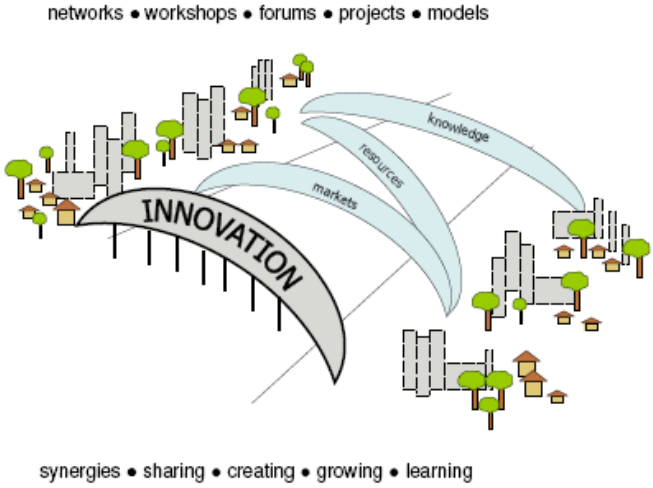

Figure 11-3: Øresund innovation model
Source: VR

Due to the proximity of actors, networks and joint education and workshops bridging Øresund could be developed. In Denmark there are cross-sectoral experience sharing networks hosted by the Danish Technological Institute, cross-sectoral cross-border networks could further contribute to the generation of new knowledge and new solutions. While the exchange of experience and knowledge takes place between the Danish and Swedish building sectors, information exchange is perhaps of a more random than systematic nature and focus is typically placed mainly especially noteworthy or successful cases. However, also minor

[318] Study tour (2006)

projects and even failures are an important source of knowledge, and joint competences could be used to find how lessons learned could contribute to improved solutions.
For these initiatives, building on the high ICT competence in the region, a virtual communication platform could be developed to further facilitate the exchange of experiences, as well as to provide the opportunity for actors on both sides of the Øresund to partake in the building process of demonstration projects.

There are numerous opportunities; it is largely an issue of getting the ball rolling and keeping up momentum.

12 Conclusions and recommendations

12.1 Conclusions

In order to move towards sustainable development, ensure energy security and counteract climate change, there is a need to decrease our consumption of energy. As the built environment constitutes a significant part of our energy consumption, efforts are needed to promote the continuous development of energy efficient technologies and the integration of these technologies into buildings.

Due to constraints stemming from sectoral and other features, innovation may be more challenging in the building sector than in other sectors. Environmental innovations can be linked to unsure returns for enterprises and additional complexity. Energy efficiency has, in turn, its own sets of barriers that hinder the functioning of market forces. This indicates that in order to reach the goal of increased energy efficiency in the built environment, serious efforts are needed to address these constraints and access opportunities.

In order to develop and integrate energy efficiency solutions, there is a need for the access to knowledge and resources, as well as a market demand. However, due to the fragmentation and territoriality of the industry, the diffusion of cross segmental knowledge is constrained, the project-based nature of the construction segment poses additional challenges for the collection of knowledge, and the long and complex value chain limits interaction between customers and producers. Due to a difference in perspectives, the interface between public research organisations and the sector may be mismatched; leading to a situation where research needed for the development of future solutions may not be conducted or diffused. Access to resources is restricted by insecurities created by building cycles, short term policies, fluctuating demand and potentially by a lack of access to external financing. The formation of markets is in turn affected by split or lack of incentives, short-term perspectives and focus on lowest initial price.

Considerable efforts are being made in both countries to encourage innovation in the built environment in regard to energy efficiency. While regulation is a key driver of environmental innovation, and can force through the development and integration of new solutions, it is also necessary to provide support and stimulate the propensity and ability to innovate in the sector.

While national innovation systems have a tendency to focus on rapidly developing knowledge intense sectors such as ICT, nanotechnology and biotechnology, not all nations can be leaders in these areas. By providing additional support for sectors that are traditionally not viewed as innovative, for instance the building sector, it is possible that a competitive advantage can be gained. This necessitates that the national innovation systems provide the same level of support to the building sector, as they do for other sectors, as well as provide programmes that are specifically designed for the sector taking into consideration sectoral features and dynamics.

The complexity of the sector requires a combination of state intervention, sectoral and regional initiatives to stimulate innovation. There is no simple formula for promoting innovation in regard to energy efficiency in the sector; instead progress can be attained through the coordination of long-term strategies and synergistic measures. By combining national innovation system efforts with sectoral and regional system initiatives significant momentum can be built up. Furthermore, the timing of measures is also of great importance

for attaining results and efforts could be made at counter-acting the detrimental effect of economic cycles on innovation in the sector.

As this thesis shows, many of the tools for success are already known, it is now more of an issue of how to utilise these tools. As explained by one actor, innovation involves stepping away from conventional beliefs and mindsets of "we cannot do things like that" or "doing something new will increase my risks" and seeing a problem and asking - "what can I do, how can I fix this?". There are considerable challenges for developing and integrating innovations promoting increased energy efficiency, however, there are also many actors with the ability to identify the problems and find innovative solutions to fix them.

12.2 Recommendations

As previously explained, the development of solutions promoting energy efficiency and the integration of these solutions into building projects is dependent upon a range of factors and interactions among actors. Therefore, it is not possible to identify one solution that would instantly lead to increased innovation and increased energy efficiency in the built environment, rather, a combination of various types of measures is needed. Specific measures to promote innovation could be made in the three innovation systems discussed, namely, sectoral, regional and national and since these systems are overlapping and interdependent, measures should be coordinated.

Innovation in the building sector could be promoted by strengthening actors' access to knowledge, access to resources as well as the formation of markets for solutions that promote increased energy efficiency. Further efforts could be aimed at strengthening key interactions and promoting increased levels of cooperation. The research shows that there are a number of areas in regard to access to knowledge and resources and the formation of markets that could be strengthened. It is of importance that state regulation and self-regulation pushes the sector forward, but also that a pull is created in the form of market demand and incentives, it is, therefore, also crucial that the basic prerequisites for innovation are present and accessible.

The innovation process and the improvement of energy performance of buildings involves a large range of actors, that have different priorities and needs. These actors may in turn need different types of incentives or regulation in order to make decisions that would promote increased energy efficiency. Since it may be an insurmountable task to identify all types actors and develop specific measures aimed at influencing their behaviour, the effectiveness of policies and initiatives is clearly linked to the identification of key actors that have the ability to influence the process and other actors. Ownership structure or tenure may be an important aspect in the formulation of effective regulation and support measures.

Policy design

In order to achieve effective policies, much could be gained by further involving the industry in the formulation and design of policies. As shown, industry initiatives are ongoing, and in regard to some aspects industry standards are higher than set state norms. These initiatives should be supported by state measures in order to promote achieve the attainment of goals and to stimulate further standard setting. By developing policy design groups with a broad range of representatives, the development of relevant and successful policies could be enhanced. Furthermore, increased coordination between policy makers in various spheres would be beneficial to ensure higher levels of effectiveness and avoid situations where some policies may hamper the effectiveness of other policies or act as a deterrent to innovation.

Regional actors
Regional actors also have an important role in stimulating innovation and promoting increased energy efficiency. Many good practices and examples of successful cases exist and further efforts could be made to diffuse information and replicate these successes. In addition to this, the capacity of regional actors to access funding for setting up programmes and initiatives could be stimulated. There are numerous opportunities in increased cross-segmental cross-border interaction, and while regional systems play a crucial role, there is perhaps an unexplored opportunity for the development of inter-regional systems of innovation. Public procurement could also be an important tool in the formation of markets for products promoting energy efficiency.

Innovation centres
The relatively newly established sectoral innovation centres will have a key role in establishing a stronger position for the building sector within the national innovation systems. Further efforts could be made to strengthen these centres, as well as at integrating the building sector into mainstream innovation support systems and the development of specific innovation programmes aimed at the sector. The innovation centres could play a central role in providing a bridge between the industry and the mainstream innovation support system. These centres could also hold a central part in publicising successful innovations and thus also promote the creation of a more positive image of the sector, which could in turn stimulate further investments in innovation related activities as well as stimulate the interest of venture capitalists and the development of state support measures.

Building material producing companies
Benefits could be gained from increased cooperation accross segmental borders and the development of joint or system products. Cross sectoral and segmental networks have a high value for knowledge exchange and the development of cooperation. From the research conducted, it seems as though there may still be some level of unwillingness or hesitancy to enter into joint ventures for product development. This could be addressed by the provision of support for the initial phases of such cooperation projects as well as clearly developed functioning cooperation models.

Building developers
Further efforts could be made in the development of programmes focusing on key actors, especially building developers, and to create incentives for increased energy efficiency in building projects, thus promoting the development of a market for solutions promoting energy efficiency. The issue of lack of incentives to invest in energy efficiency promoting solutions could be addressed by the creation of system where building companies or building developer are also involved in maintenance and renovation and thus has a vested interest in keeping operation costs low. This could be done through a system of extended guarantees or tools such as energy performance contracting.

Housing companies
Support should be provided to housing companies for ensuring improvements in energy performance during renovations. While larger housing companies may have a larger influence over a greater proportion of the building stock, small companies may lack necessary resources and thus may be in need of additional support. New methods for accounting and budget organisation may provide possibilities and incentives to invest in solutions for new and existing buildings.

Large construction companies
Due to the vertical integration of a wide range of services and the large number of building projects, as well as progress in the area of industrialisation, large construction companies could become leaders in the promotion of energy efficiency in the built environment. Not only do these companies have sufficient resources to invest in innovation, they also are owners of a large part of the value chain, furthermore, they can also place pressure on subcontractors and suppliers. A front runner position could, for instance, be stimulated through the involvement of these companies in demonstration projects and partnerships that receive high levels of public and media interest.

Retailers
Other important actors are large building material retailers that could, if incentives were created to promote energy efficient products, significantly contribute to awareness raising and the development of markets.

Credit institutions
Efforts could also be aimed at investigating the issue of external funding and venture capital to see whether there could be a possibility for promoting innovation in this field through the provision of accessible funding, or through strengthening the ability of actors to access such funding. Joint programmes between credit institutions and the state could be developed to provide beneficial loans for building projects that have an improved energy performance. This is also linked to the availability of credible and usable calculation methods and tools. Reliable tools are also needed to support efforts to promote life-cycle costing in decision making. Clear labelling systems may be a tool that could enable credit insititutions to provide incentives to invest in energy efficiency.

Education and awareness raising
The education system is crucial in the formation of attitudes and values of new consumers and professionals and could provide an effective forum for the diffusion of the understanding of the importance of energy efficiency. However, information campaigns and education may be insufficient if the issue of incentives is not simultaneously addressed. Furthermore, since the education system prepares new actors for building sector and through increased coordination with the industry's needs and by the provision of tools and skills enabling these future professionals to be innovative and creative, future innovations in this area could be stimulated.

In regard to knowledge and resources it is important that future specialists have the competence and ability to promote energy efficiency. This could be achieved by mainstreaming energy efficiency building principles in education programmes, i.e. not simply provide for the opportunity to access such courses as voluntary specialisation but as part of the main education programmes. While supplementary education for specialists is available further efforts could be made to make this education available and attractive to a broad range of actors.

The need for demonstration projects is undeniable and further efforts to use these as a source for sharing experiences and initiating new forms of cooperation and learning processes. Change requires awareness and knowledge and as indicated by this investigation many actors are involved in the innovation process and in the formation of markets. Consequently, awareness raising measures need to be directed at a broad audience, but also need to be adapted to specific target groups.

Research
The interface between research and industry could be improved through increased collaboration in projects, and further involvement of researchers in the evaluation of projects. Efforts could be made to make research results more accessible to a wider audience and emphasis could be placed on linking long-term research with more applied research. It is, furthermore, important that long-term research efforts continue and receive the support of the industry. In respect to innovation in the building sector, there is a tendency for research efforts to focus on constraints and barriers. While these are important to identify, discuss and address, it is equally if not more, necessary to focus on opportunities, spread positive information and share successful experiences.

Focus areas
Policies and initiatives should not only focus on key actors, there may also be a need to prioritise key types of innovations. While the energy performance of new buildings is of high relevance, these constitute a small percentage of the total building stock. Products, systems and methods for the integration of increased energy efficiency in the existing building stock are needed. Thus there is a need to create flexible solutions that can be adapted to already existing infrastructure and design solutions. Similarly, solutions that are adaptable to presiding technological systems such as district heating are needed. In light of export opportunities, developments in other countries are also relevant. While the ongoing standardisation process is crucial, adaptable and flexible systems or products that cater to the needs of export markets may also be a key area on which to focus.

Areas for further research
As frequently stated, the issue of environmental innovation in the building sector is complex and while this thesis has provided limited insight into the issue, further more in-depth research in this area is warranted especially in regard to opportunities and how to enable actors to access these. Another area of interest is the identification of new technologies and studies on how the building sector can cater to the future needs of society.

As previously mentioned, generic innovation models fail to capture the complexity and dynamics of innovation in the sector, consequently a further development of models or approaches for how to understand innovation in the building sector especially in regard to environmental innovations is needed. Research in the area could also be made using other approaches such as organisational management and problem solving theories.

While the comparative analysis used in this thesis served to identify both similarities and differences that could be used in understanding the issue at hand, comparative analysis between countries that are more different than Sweden and Denmark could highlight new issues that this paper has failed to capture. Comparative analysis involving a larger number of countries, could similarly promote a better understanding of the issue, as well as of possible opportunities.

Bibliography

Interviews

Abrahamson, F. (2006). Fornyet energi. 2006.07.27. Denmark

Arnqvist, P. (2006). SABO (Swedish Association of Municipal Housing Companies). 2006.06.27 Sweden

Bertelsen, S. (2006). Consultant. 2006.08.03, Denmark

Björk Ausin, M. (2006). Byggmaterialindustrierna. (Building Material Industry Association). 2006.06.28. Sweden

Browall, A. (2006). Elitfönster. 2006.06.26. Sweden

Cronsioe, A. (2006). Landskrona City Architect, 2006.06.20, Sweden

DK INS-1 (2006). 2006.08.02. Denmark

Dybro, H. (2006). Saint Gobain Isover AB. 2006.09.01. Sweden.

Eneborg, A. (2006). Landskronahem (public housing company) 2006.06.20. Sweden

Alm, O. (2006). Det Grønne Hus. 2006.07.06. Denmark

Forsberg, A. (2006) STEM (Swedish Energy Agency). 2006.06.30. Sweden.

Gehlin, S. (2006) VVS Tekniska Föreningen (Heat, Ventilation and Sanitation Association). 2006.04.10. Sweden.

Grandinsson, B. (2006). SBUF (Construction industry's organisation for research and development) 2006.06.28. Sweden.

Hansen, A. (2006). RH Arkitekt. 2006.08.02. Denmark.

Hellström, A. (2006). Strängbetong. 2006.06.27. Sweden.

Hirsbak, S. (2006). Consultant, 2006.07.10. Sweden.

Jagrén, L (2006). Sveriges Byggindustrier (the Swedish Construction Federation). 2006.06.28. Sweden.

Klarin, K. (2006). VINNOVA (Swedish Governmental Agency for Innovation Systems) 2006.04.10. Sweden.

Kaergaard, H. (2006). NIRAS. 2006.07.14. Denmark.

Larsen, A. (2006). AKF (Institute of local government studies). 2006.07.25. Denmark.

Lilliehorn, P. (2006). Byggsektorns krettsloppsråd (Eco Council of the Building Sector) 2006.04.10 and 2006.06.26. Sweden.

Nielsen, F.L. (2006) Danfoss. 2006.07.11. Denmark.

Mørk, O (2006). Cenergia. 2006.07.07. Denmark.

Nilsson, A. (2006). WSP Sweden AB. 2006.07.05. Sweden.

Partheen, K. (2006). Saint Gobain Isover AB. 2006.09.01. Sweden.

Person, M (2006). Landskronahem (public housing company) 2006.06.20. Sweden.

Pedersen, P.V. (2006). Cenergia. 2006.07.07. Denmark

Sandor, M (2006). Systemair. 2006.08.08. Telephone interview. Sweden

Skarendal, Å (2006). BIC (Building Sector Innovation Centre). 2006.04.10, Sweden

SE VENT-1 (2006). 2006.06.29. Sweden.

Svedinger, B. (2006) BQR (Swedish Council for Constructing Excellence) Incitament projektet, project manager 2006-06-26, Sweden

Sundqvist, J. (2006). PhD. Innovation Performance in Building Material Manufacturers. Chalmers University of Technology. 2006.06.30. Sweden.

Svensen, S. (2006). DTU (Technical University of Denmark). 2006.07.17. Denmark.

Thomsen, A (2006). Danish Technological Institute. 2006.08.04. Denmark.

Tigerfeldt, S. (2006). Saint Gobain Isover AB. 2006.09.01. Sweden.

Other sources

Erfa gruppen-2 (2006) meeting 06.06.01. Denmark

Study tour (2006). Arranged by the Danish Technological Insitute. 2006.06.21. Sweden.

Wall, M. (2006). Department for energy and building design, LTH. In the workshop of the seminar "Tools for Regional Innovation". 2006.06.01. Denmark.

Workshop (2006) on innovation for sustainable building in the seminar "Tools for Regional Innovation". 2006.06.01. Denmark.

Seminar (2006a). Drivers of Change. Building Lab DK. 2006.08.28. Denmark.

Seminar (2006b). Creative living and building. Tools for Regional Innovation, Building Sector. 2006.09.06

Literature

Acha, V., Gann, D.M. and Salter, A.J. (2005). Episodic Innovation: R&D strategies for project based environments. Industry and Innovation. 12 (2): 255-281.

Andersson, N. (2003a). The Danish construction sector at the end of the 1990s. In A mesoeconomic analysis of the construction sector. Division of Construction Management, Lund University.

Andersson, N. (2003b). The Swedish construction sector: its economic and social role. In A mesoeconomic analysis of the construction sector. Division of Construction Management, Lund University.

Arundel, A and Holanders, H. (2006). 2006 Trend Chart Methodology Report - Searching the forest for the trees: "Missing indicators of innovation".

Atkin, B. (1999). Innovation in the construction sector. European Council for Construction Research, Development and Innovation.

Bang, H. et al. (2001). Innovation in the Danish Construction Sector: The Role of Public Policy Instruments. In: Innovation in Construction. An International Review of Public Poilicies. Manseau, A and Seaden, G. (eds.). CIB. SPON Press, London and New York.

Barlow, J. (2000). Innovation and learning in complex offshore construction projects. Research Policy 29(7-8): 973-989.

Bertelsen (2003). Louise - en beretning om Trimmet Byggeri. [Louise - a story about Lean Construction]. Niras.

Björklöf, S. (1986). Byggbranschens innovationsbenägenhet (The building Sector´s Propensity for Innovation). Linköping Studies in Management and Economics, Dissertations No. 15. Linköping University, Institute of Technology.

Bröchner , J, Ang, G.K.I. and Fredriksson, G. (1999). Sustainability and the performance concept: encouraging innovative environmental technology in construction. Building Research and Information. 27(6): 367-372.

Bygga, bo och förvalta för framtiden (2003). Använd bästa möjliga teknik och utveckla ny. Working group report: Working Group Use of best available technology and need for R&D for good environmental and energy solutions.

Byggepolitisk Task Force (2000). Byggeriets Fremtid - Fra tradition til innovation. [The future of construction - from tradition to innovation]. By- och Boligministeriet and Erhvervsministeriet. Copenhagen.

Byggmaterialindustrierna (2005). Byggmaterialindustrierna som motor i utvecklingen av svenskt byggande. [The building material industries as a driver in the development of Swedish construction]. Partner Print Communication AB.

CIB (2004). The construction sector system approach: An international framework. Report by CIB W055 - W065, Construction Industry Comparative Analysis Project Group. CIB publication 293.

CIB (2005). Reevaluating construction. www.revaluingconstruction.scpm.salford.ac.uk

Clausen, L. (2002). Innovationsprocessen i byggeriet - Fra idé till implementering i praxis. [The innovation process in construction - from idea to actual implementation]. PhD thesis. Raport BYG DTU R-031.

Cooke, P., Uranga, M. G., Etxebarria, G. (1997). Regional innovation systems: Institutional and organisational dimensions. Research Policy: 475-491.

Danish State Building Research Institute (2006). Statens byggeforsknings institute (SBI). www.sbi.dk. [2006-09-07]

Demaid and Quintas (2006). Knowledge across cultures in the construction industry: sustainability, innovation and design. Technovation 26, 5-6:603-610.

Denmark's official web site (2006). www.denmark.dk. [2006-09-07]

Derwick, P. and Miozzo, M. (2002). Sustainable technologies and the innovation regulation paradox. Futures. 34: 823 - 840.

Doloreaux, D (2002). What we should know about regional systems of innovation. Technology in Society. 24: 243-263.

DuBois, A. and Gadde, L. (2002). The construction industry as a loosely coupled system: implications for productivity and innovation. Construction Management and Economics. 20 (October): 621-631.

Edquist, C. (1997): Systems of innovation approaches - Their emergence and characteristics. In Edquist, C. (ed). Systems of Innovation: Technologies, institutions and organisations. London and Washingtjon. Pinter. 1-35.

EC Green Paper on Energy Efficiency (2005).

EC Directive on the energy performance of buildings (2002).

EC Directive on energy end-use efficiency and energy services (2005).

Ecofys (2004). Mitigation of CO2 Emissions from the building stock. Beyond the EU Directive on the energy performance of buildings.

Eek, H. (2002). Hus utan värmesystem finns redan nu! (Houses without heating systems exist already!). Effektivare energi i bostäder. En antologi om framtidens styrmedel (Efficient energy in housing. An anthology on the regulatory instruments of the future). Boverket, Energimyndigheten, Naturvårdsverket

Energimyndigeten (2000). [Swedish Energy Agency]. Effektiv energianvänding. En analys av utvecklingen 1970-1998. [Efficient energy use. An analysis of developments 1970-1998]. ER 22:2000

Energy Agency for South East Sweden (2006). www.energikontor-so.com. [2006-09-07]

EU (2006). ec.europa.eu [2006-09-07]

European Trend Chart on Innovation (2005). trendchart.cordis.lu. [2006-09-07]

European Trend Chart on Innovation (2004-2005): Sweden. trendchart.cordis.lu. [2006-09-07]

European Trend Chart on Innovation (2004-2005): Denmark. trendchart.cordis.lu. [2006-09-07]

European Trend Chart on Innovation (2005). trendchart.cordis.lu. [2006-09-07]

European Sector Innovation Scoreboards (2005). trendchart.cordis.lu. [2006-09-07]

Flavin, C., Lenssen, N. (1995). Kraftmätningen - vägen till ett miljöanpassat energisystem. [Measurement of power - the road to an environmentally adapted energy system].Naturskyddsföreningens förlag.

Gann, D. (2001). Putting academic ideas into practice: technological progress and the absorptive capacity of construction organisations. Construction Management and Economics. 19 (3): 321-330.

Gann, D. (1997). Should government fund construction research? Building Research and Information. 25(5): 258-267

Gann, D. and Salter, A. (2000). Innovation in project-based, service-enhanced firms: The construction of complex products and systems. Research Policy. 29: 955-972.

Gann, D., Wang, Y. and Hawkins, R. (1998). Do regulations encourage innovation? - The case of energy efficient housing. Journal of Building Research and Information. 26 (4): 280-296

Green, A. (2006). Hållbar energianvändning i svensk stadsplanering. Från visioner till uppföljning av Hammarby Sjöstad och Västra hamnen. PhD thesis. Linköping Studies in Arts and Science. No. 336.

Goverse, T., Hekkert, M.P., Worrell, E., Smits, R. (2001). Wood innovation in the residential construction sector: opportunities and constraints. Resources, Conservation and Recycling. 34:53-74.

Henderson, R.M. and Clark, K.B. (1990). Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Administrative Science Quaterly. 35: 9-30.

Hobday, M. (1998). Product complexity, innovation and industrial organisation: CoPS working paper. CoPS Publication, No. 52.

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

Jansen, R. (2004). Towards energy efficient buildings in Europe. Final Report. The European Alliance of Companies for Energy Efficiency in Buildings.

Johnson, B. and Gregersen, B. (1997). Integration and National Innovation Systems of Innovation. Part of the Project Innovation Systems and European Integration ISE, 4th Framework Programme. IKE Group. Department of Business Studies. Aalborg Univeristy.

Johannesson, H., Persson, J.G, Pettersson, D. (2004). Produktutveckling - effektiva metoder för konstruktion och design. [Product development - effective mehods for construction and design]. Liber AB.

Lutzehiser and Biggart (2003). Market structure and energy efficiency: The case of new commercial buildings. California Institute of Energy Efficiency Report.

Koskela, L. and Vrijhoef, R. (2001). Is the current theory of construction a hindrance to innovation? Building Research and Information. 29 (3):197-207.

Malaman, R. (1996). Technological innovation for sustainable development and diffusion of cleaner technologies in Italian firms. Paper from a research project carried out by Instituto per la Richercha Sociale.

Malerba, F. (2005). Sectoral systems of innovation: A framework for the linking of innovation to the knowledge base, structure and dynamics of sectors. Econ. Innov. New Techn. 14(1-2):63-82.

Manoliadis, O., Tsolas, I. and Nakou, A. (2006). Sustainable construction and drivers of change in Greece: a Delphi study. Construction Management and Economics. 24:113-120.

Manseau, A. and Seaden, G. (2001). Introduction. In: Innovation in Construction. An International Review of Public Poilicies. Manseau, A and Seaden, G. (eds.). CIB. SPON Press, London and New York.

Markusson, N. (2001). Drivers of environmental innovation. Vinnova. VF 2001:1.

Nam, C.H. and Tatum, C.B. (1998). Towards understanding of product innovation process in construction. Journal of Construction Engineering and Management. 115(4): 517-534.

NCM. (2006). Nordic Environmental Technology. ANP 2006:701

Neij, L. and Öfverholm, E. (2001). In Silvera, S. (ed). Building Sustainable Energy Systems. Swedish Experiences. Swedish National Energy Administration.

Neij, L. and Öfverholm, E. (2002). Teknikens bidrag till effektivare energianvändning - och en studie av erfarenheter och behov av styrmedel. [The contribution of technology to more efficient energy use - and a study of experiences and needs in regard to regulatory instruments]. Effektivare energi i bostäder. En antologi om framtidens styrmedel [Efficient energy in housing. An anthology on the regulatory instruments of the future]. Boverket, Energimyndigheten, Naturvårdsverket.

Nässen, J. and Holmberg, J. (2005). Energy efficiency - a forgotten goal in the Swedish building sector. Energy Policy 33:1037 - 1051.

OECD (1997). Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data, 2nd Edition. OECD.

OECD (2000). Innovation and the Environment. OECD Proceedings. OECD.

Official gateway to Sweden (2006). www.sweden.se. [2006-09-07]

Økonomi-og Erhvervsministeriet (2004). [Danish ministry of Economic and Business Affair]. Handlingsplane for en fornyet energispareinsats. Energibesparelser og marked. [Actionplan for a renewed energy savings initiative. Energy savings and market]

Ornetzeder, M. and Rohracher, H. (2006). User-led innovations and participation processes: lessons from sustainable energy technologies. Energy Policy 34: 138-150.

Realdania (2006). www.realdania.dk. [2006-09-07]

Rennings, K. (2000). Redefining innovation - eco-innovation research and the contribution from ecological economics. Ecological Economics, 32: 319-332.

Rogers, E. (1995). Diffusion of Innovations. The Free Press: New York.

Sandström, U. and Ericsson, J. (1998). Under political scrutiny - Swedish building and construction research. Building Research and Information. 26(4): 246-252.

Sexton, M. and Barrett, M. (2003). A literature synthesis of innovation in small construction firms: insights, ambiguities and questions. Construction Management and Economics. 21:613-622.

Slaughter, S.E. (2000). Implementation of construction dynamics. Building Research and Information. 28 (11): 2-17.

Slaughter, S.E. (1993a). Innovation and learning during implementation: a comparison of user and manufacturer innovations. Research Policy. 22 (1): 81-95.

Slaughter, S.E. (1993b). Builders as sources of construction innovation. Journal of Construction Engineering and Management. 119 (3): 532-549.

SOU (2004): 84. Claes Roxbergh (2004). SwenTech AB –För en nationell kraftsamling på svensk miljöteknik. [Swentec AB - for a national focus of efforts in Swedish environmental technology].

Sundqvist, J. (2005). Innovation Performance in Building Material Manufacturers. Licentiate thesis. Department of Civil and Environmental Engineering Building Economics and Management. Chalmers University of Technoloy. Göteborg. Lic 2005:3

Svane, Ö. (2002). Från sparkrav till möjlighetsutrymme - bebyggelsen, miljömålen och energin. [From demanding saving to opportunities - buildings, environmental objectives and energy]. Effektivare energi i bostäder. En antologi om framtidens styrmedel. [Efficient energy in housing. An anthology on the regulatory instruments of the future]. Boverket, Energimyndigheten, Naturvårdsverket.

Swedish Institute (2004). Swedish Industry. Construction Industry and Infrastructure. www.si.se. [2006-09-07]
Swedish Ministry of Sustainable Development (2006). Miljö och samhällsbyggnadsdepartamentet. En effektiv energi användning gynnar ekonomin och miljön. En skrift om regeringens energipolitik. [An efficient energy use is good for the economy and the environment. A brochure about the governments energy politics].

Taylor, J.E. and Levitt, R.E. (2005). Inter-organizational knowledge flow and innovation diffusion in project-based industries. Proceedings of the 38th Hawaii International Conference on System Sciences.

Tidd, J., Bessant, J. and Pavitt, K. (2001). Managing innovation. Integrating technological, market and organizational change. 2nd ed. John Wiley, Chichester.

Tommerup, H. and Svendsen, S. (2005). Energy savings in Danish residential building stock. Energy and Buildings 38:618 - 626

Shrove, E. (1998). Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings. Energy Policy. 26 (15): 1105-1112.

US Department of Energy Efficiency and Renewable Energy. (2006). Building technologies programme. www.eere.energy.gov

Widén, K. (2002). Innovation in the construction process. A theoretical framework. Licentiate thesis. LTH, Division of Construction Management.

Widén, K. (2004). Nationella innovationsstrategier i byggsektorn - en internationell kartläggning. LTH Construction Management Publications.

Winch, G. (2000). Innovativeness in British and French construction: the evidence from Transmanche-Link. Construction Management and Economics. 18(7): 807-817.

Winch, G. (1998). Zephirs of creative destruction: Understanding the management of innovation in construction. Journal of Building Research and Information. 26 (5): 268-279

Ödeen, K. (2002) Teknisk kunskap som styrmedel för energianvändning i bostäder - vem behöver kunna vad? [Technical knowledge as a regulatory instrument for energy use in housing - who needs to know what?]. Effektivare energi i bostäder. En antologi om framtidens styrmedel [Efficient energy in housing. An anthology on the regulatory instruments of the future]. Boverket, Energimyndigheten, Naturvårdsverket.

Öhlin, P. (2006). F**k Logic - om konsten att tänka oklokt och få mera pang för pengarna. [F**k Logic - about the art of thinking unwisely and get more value for moneyC. Modernista.
Øresund Environment Academy (2006). www.oresund-environment.org. [2006-09-07]

Øresund Portal (2006). www.oresundsregionen.org. [2006-09-07]