



Innovation Systems and Environmental Technologies

Cross-sectoral analysis and policy implications

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Nordic co-operation

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Preface

Environmental Technologies and Innovations are at the heart of environmental policymaking in Europe and in the Nordic countries today. It is the combination of growing competitiveness and excellence on the one hand and environmental gains on the other that provides a successful concept to promote further.

The project Greener Markets and Cleaner Technologies has been a two year Nordic cooperation financed by the Nordic Council of Ministers Working Group for Integrated Product Policy, NMRIPP. The aim has been to provide analyses of actions to strengthen development and dissemination of environmental technologies through past experiences in the Nordic countries. This synthesis is supported by studies of three different sectors: pulp and paper, the building sector and electronics illustrated by mobile phones. The studies in these sectors show that the effects of policy- and other interventions vary considerably depending among others things on the structure of the sector and whether the innovation relates to core business or not. A common feature found was the difficulty in providing knowledge to the downstream user and enhance demand.

One of the key lessons learned is the continuous need for cross-disciplinary co-operation. Both environmental and innovation policies are needed to inspire and support the market for new environmental technologies and innovations. These Nordic experiences surely are an asset in implementing the EU Environmental Technology Action Plan, ETAP, whose priorities for the future include improving market conditions by building on promising member state practice

On behalf of the NMRIPP working group,

Karin Klingspor
chairperson

Summary

Promotion of environmental technologies and innovations is one way pursued both in European Union and Nordic countries to achieve the dual goals of maintaining competitiveness in a dynamic and knowledge-based economy while integrating environmental consideration in this process. This is manifested in the European Environmental Technologies Action Plan (ETAP). The ETAP, among others, points to the fact that despite the ample technological potential for environmental technologies, they are still underutilized, and strives to identify policy measures to enhance the commercialization and diffusion of environmental innovations.

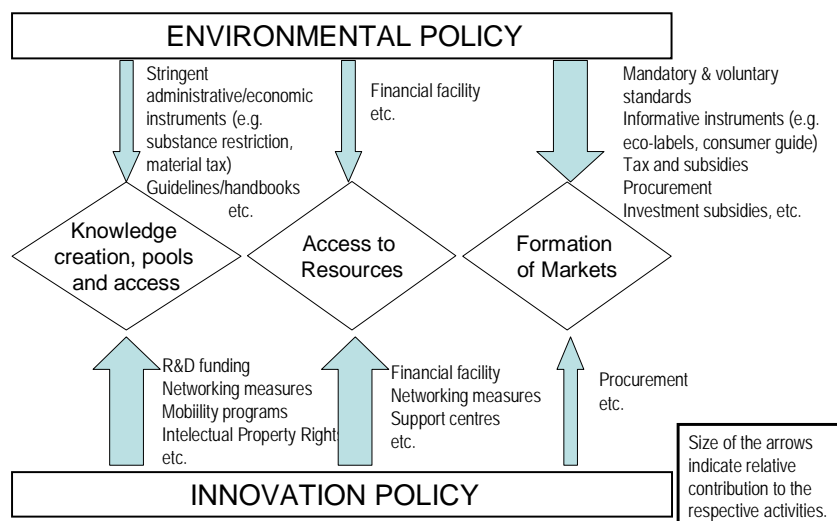
In this context, a 2-year research project (2006–07), Green Market and Clean Technologies – Leading Nordic Innovation and Technological Potential for Future Markets (GMCT) funded by the Integrated product Policy Group of the Nordic Council of Ministers, has been carried out. The overall aim of the GMCT project has been to provide analyses of the ways in which the development and diffusion of environmental technologies can be enhanced, by exploring existing works that have been ongoing in the Nordic countries and through in-depth analysis of specific empirical cases of environmental technologies. The purpose has been to identify policy interventions that could also be applied to sectors other than those analysed and, thus, provide material for the discussions on the feasibility of a Nordic-wide action plan on the promotion of environmental technologies. The project is a collaboration of four Nordic research institutions: International Institute for Industrial Environmental Economics (IIIEE) at Lund University (project coordinator), Finnish Environment Institute (SYKE), Department of Development and Planning at Aalborg University and Risø National Laboratory at the Technical University of Denmark.

The project consists of the following four main components: 1) literature review and development of a common analytical framework, 2) review of national innovation systems, 3) case studies of three industrial sectors: buildings, pulp and paper and mobile phones, and 4) synthesis of the case findings relevant to policy development (the content of this report). We took a “systems of innovation” approach as the basis for an overall analytical framework, and extracted three activities crucial for fostering innovation: the creation, transfer and pooling of knowledge, the access to resources and the formation of markets. The sectors are selected based on the relevance to the Nordic countries, availability of existing information, possibility of cross sector comparison and coverage of various types of environmental technologies and environmental innovations.

This final report synthesises the findings from the sector studies, with a view to contributing to the development of effective policy interventions for enabling environmental innovations. The report summarizes the overall findings of the three sector studies – the details of which are available in separate reports – and makes a cross-sectoral analysis of the issues relevant to policy development. The study focuses on two types of governmental interventions most relevant to environmental innovations – environmental policy and innovation policy – and explores environmental aspects in innovation policy and innovation aspects in environmental policy.

The role of existing environmental and innovation policy to the three key activity areas selected in this project can be graphically summarised in the figure in the next page.

Through the review of case studies of the three industry sectors in Nordic countries, various issues influencing the three key innovation activities are extracted. Regarding knowledge, these issues include the diversity of knowledge sources and of triggers for knowledge creation, roles of SMEs in generating knowledge, use of intellectual property rights, frame of reference among the actors involved and structure of the value chain. Concerning resources, the cross-sectoral analysis elucidates the commonalities and differences in which the respective industry sectors reach for human resources, public funding and other financial resources, as well as how their own resources are utilized. When analysing the activities related to the formation of market, the role and position of customers and suppliers in the supply chain, the relative importance of an innovation for the industry, discrepancy between the beneficiary and the cost-bearer of an innovation, demand from the end-users and cost are among the issues highlighted.



Some of these issues are common across all three sectors. For instance, environmental innovation examined in all three areas stemmed from various knowledge sources, both from industry and academia, and within and outside of the respective industry sectors. Public funding appears to be important in facilitating the creation of new knowledge, especially when it requires the collaboration of various actors. Education – and the link between industry and university – serves as an essential foundation for acquiring highly skilled human resources. A close link to education also helps establish the common frame of reference among actors engaged in the same innovation project, an important attribute that facilitates the access and transfer of knowledge. In all three sectors, there are cases where existence or anticipation of upcoming environmental legislation has played a role in knowledge creation as well as commercialization of new knowledge. Meanwhile, there are also cases where innovation activities took place without government intervention. The necessity of government intervention and other forms of external impetus would depend upon, among others, whether the environmental innovation in question improves the core business of the industry or not. A challenge facing all three industry sectors at the commercialization and diffusion of environmental technologies include information coordination at the user's end and corresponding incentives. Related to this issue is the necessity for industry to keep to the lowest cost.

Meanwhile, some specificity of phenomena and contributing factors found in the study find their roots in the unique characteristics of the sector. For instance, the mobile phone industry, whose growth is dependent on developing and commercializing new products, allocates a relatively large portion of their resources on R&D activities. Another example is the broken-learning loops experienced in the building industry, which are perceived to be caused by project-based nature of the operation and severe effect of economic cycle felt strongly by the sector. There are phenomena and factors that, although still stemming from the characteristics of the sectors, could be more generalisable. These include, among others, discrepancy between the beneficiary and the cost bearer of innovation, market steering power of large customers, installation/knowledge capital lock-in, customer or supplier-led innovation and vertical integration or fragmented structure of supply chain.

The necessity of tailor-made policy intervention tends to be higher in the former than the latter. However, in both cases, there is potential for replicability especially when other sectors have experiences in solving a similar challenge. Consideration on the structure of the industry, actors' ability to coordinate the innovation activities in the market, and nature, scope and user of the innovation in question, are among factors distilled from the case studies that may have important implications for policy choices. The essential starting point in all cases is the identification of causes and effective intervention points.

Concerning government intervention, the case studies reviewed have provided insights for several of the characteristics of green innovation policy – including both innovation policy facilitating environmental improvements and environmental policy that support innovation – suggested in literature. Environmental innovation in all sectors benefited from the public funding, which facilitated activities knowledge creation, pool and transfer. In some cases, it also facilitated commercialization. The cases have reinforced the notion that environmental policy can play an important role in forming market but have also demonstrated the ability of environmental policy to inspire knowledge generation activities by providing signals for future market directions. Stringency and ambition level of new regulations have driven forward innovation in the building sector, and reduction in market uncertainty has helped to spur innovations in the pulp and paper industry forward. The importance of the timing of introducing an instrument and providing support for the appropriate intervals has been demonstrated in the cases of both the pulp and paper and building industry. Positive synergies have been seen in the case of the pulp and paper industry in regards to innovation and environmental policy, supporting the value of supply and demand side measures in some instances. While economic drivers have assisted in facilitating market formation in some cases, the interventions which have directly encouraged an innovation have largely been of a mandatory administrative nature.

In furthering the Nordic contribution to the ETAP, in addition to the continuation of providing good educational basis for innovation, Nordic countries can direct government intervention to facilitate knowledge flow between sectors, disciplines, industry and non-industry actors and countries. They can facilitate the creation of knowledge which contributes to environmental improvement. The case study confirms the challenges facing the diffusion of environmental innovations despite the availability of knowledge. In addition to various measures to enhance the demand and awareness of the end users, focus should be put on facilitating knowledge flow among actors in the value chain – not least end users – with the intention to address the discrepancy between risk bearer and beneficiary of an innovation. Reflecting these learnings, concrete government intervention points that can be considered by the Nordic countries are highlighted in the end in accordance with the eight action areas of the ETAP.

1. Introduction

1.1 Background

1.1.1 Sustainable development and environmental technologies

The European Union has stressed that Europe needs to find ways to survive in the competitive, dynamic and knowledge-based economy (Lisbon Strategy)¹ while fully integrating environmental considerations in this process (Göteborg European Council).² One way to achieve these dual goals is through the promotion of environmental technologies and innovation, making them central in economic development and growth. This is the core of the European Environmental Technologies Action Plan (ETAP) which strives to identify various policy measures to enhance the commercialisation and diffusion of environmental innovations.

The Nordic Strategy for Sustainable Development recognises that the Nordic enterprises are in the forefront of environmental technology. The Strategy identifies the promotion of green technologies as an area where Nordic cooperation can influence international cooperation, for instance within the EU, the OECD, and the Commission on Sustainable Development (TemaNord 2004:568, 10, 16). The Strategy suggests that general policy pertaining to research and innovation must “support the development, application and spread of environmental technology to a greater extent than at present” (goal 2.5.4).

In line with these developments at Nordic and European level, the Nordic countries are furthering their efforts for environmental technology and innovation. Finland, Sweden and Denmark are as EU member states doing this explicitly through their contributions to the ETAP.

The ETAP, among others, points to the fact that there is ample knowledge potential for environmental technologies that is underutilized (COM(2004) 38 final, 7). Indeed, the mere existence of knowledge of environmental technologies does not contribute to the actualization of a sustainable society: the technologies have to be used and diffused.

1.1.2 Project Green Market and Clean Technologies

In the context mentioned in the previous section, a 2-year research project (2006–2007), Green Market and Clean Technologies – Leading Nordic Innovation and Technological Potential for Future Markets (GMCT),

¹ www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/00100-r1.en0.htm

² www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/00200-r1.en1.pdf

funded by the Integrated Product Policy Group of the Nordic Council of Ministers, has been carried out. The research is a collaboration of four Nordic research institutions: International Institute for Industrial Environmental Economics (IIIEE) at Lund University (project coordinator), Finnish Environment Institute (SYKE), Department of Development and Planning at Aalborg University and Risø National Laboratory at the Technical University of Denmark.

The overall aim of the GMCT project has been to provide analyses of the ways in which the development and diffusion of environmental technologies can be enhanced, by exploring existing works that have been ongoing in the Nordic countries and through in-depth analysis of specific empirical cases of environmental technologies. The purpose has been to identify policy interventions that could also be applied to sectors other than those analysed and, thus, provide material for the discussions on the feasibility of a Nordic-wide action plan on the promotion of environmental technologies.

The project consists of the following four main components: 1) literature review and development of a common analytical framework, 2) review of national innovation systems, 3) case studies of three industrial sectors: buildings, pulp and paper and mobile phones, and 4) synthesis of the case findings relevant to policy development. The preliminary findings from the sector studies and the subsequent policy analysis (Steps 3 and 4) were presented at the corresponding workshops, with a view to disseminating information regarding the on-going research work on one hand, while obtaining insights from stakeholders knowledgeable on the issues addressed in the respective workshops on the other.³ The preliminary work for the synthesis of case findings was carried out by Morrigan Hayes, a MSc student at the IIIEE between 2006–07 as her MSc thesis work under the supervision of Naoko Tojo and Tareq Emtairah, two of the project members.

1.2 Purpose of this report

The purpose of this report is to synthesise the findings from the sector studies, with a view to contributing to the development of effective policy interventions for enabling environmental innovations. The report summarizes the overall findings of the sector studies and makes a cross-sectorial analysis of the issues relevant to policy development. The findings of the sector studies can be found in three separate case reports.⁴

³ More information about the case workshops are found in the case reports (see footnote 4). Summary of the policy workshop is found in the Appendix of this report.

⁴ Kivimaa, Paula, Kautto, Petrus, Hildén, Mikael & Oksa, Juha. (2008). *Green Markets and Cleaner Technologies (GMCT) – What drives environmental innovations in the Nordic pulp and paper industry?* Copenhagen: Nordic Council of Ministers. TemaNord -series. Entairah, Tareq, Tojo, Naoko, Thidell, Åke, Rozide, Vida & Hayes, Morrigan. (2008). *Green Markets and Cleaner Tech-*

In accordance with the analytical framework developed for the project (see Section 2), the cross-sectoral analysis made in this report focuses on three activities which are crucial in fostering innovation: the creation, transfer and pooling of knowledge, the access to resources and the formation of markets.

1.3 Definitions, scope and limitations

Two concepts, environmental technologies and environmental innovations, are relevant for this project. The term environmental technologies has been used to refer to a broad spectrum of technologies, both in terms of approaches (e.g. preventative, end-of-pipe, life-cycle management) (Hemmelskamp, 1997) and of types of environmental issues (e.g. resource efficiency, energy, toxic substances). This project adopted the same definition of environmental technology as ETAP and considers environmental technologies as “all technologies whose use is less environmentally harmful than the relevant alternatives” (COM(2004) 38 final, p2).

While there is no unifying definition of innovation at present, there is a general agreement that (technological) innovation – as opposed to invention – requires the adaptation of the invented technologies to the market and production systems (Nordberg-Bohm, 1999). Environmental innovation in principle can, thus, be considered as the industrial adaptation of various types of new environmental technologies, regardless of the original intention of the innovation.⁵ Similarly to other types of innovation, environmental innovation can be classified in term of the scale of change – incremental, radical, technology systems, techno-economic paradigms (Freeman and Perez, 1991) – and of what is being changed – process, products or system. The project sought to consider these various typologies of environmental innovation, although it is more focused on individual innovations and local systems than changes in techno-economic paradigms.

Understanding the innovation dynamics of different types of innovations and of environmental technologies is deemed to facilitate extraction of factors influencing the innovation process. This, however, inevitably poses challenges in understanding the same type of environmental technologies and innovations in depth.

nologies (GMCT) – The challenges of energy efficiency innovations in the Nordic building sector. Copenhagen: Nordic Council of Ministers. TemaNord –series. Remmen, Arne. (2007). The Nordic mobile phone industry – Environmental innovations and policy instruments. Copenhagen: Nordic Council of Ministers, 2008. TemaNord –series.

⁵ Some consider environmental innovations as those directly aiming at reducing the negative environmental impacts (Hemmelskamp, 1997), while others regard that any innovations that as a result contribute to the improvement of the environment are environmental innovation (Klemmer, Lehr et al., 1999; Kemp, Smith et al., 2000).

Environmental innovation, compared to other types of innovation, arguably has its own particularities (Lehr and Löbbe, 2000; Beise and Rennings, 2005) and will be mentioned whenever relevant. However, the focus of the research is not to compare the general characteristics of environmental innovation with those of other innovations.

Environmental innovation can be affected by a number of factors and different types of government interventions. Among government innovations, the focus of our studies was environmental policy and innovation policy, as discussed further in Section 2.2 of the report. What is new in the current focus of the EU and the Nordic countries on environmental technology development, compared to earlier efforts, is the integration of innovation aspects such as economic growth, business development and competitiveness into environmental protection. This poses a challenge for both existing environmental policy and existing innovation policy. In both areas changes need to be made in order to enable the two sides to integrate and work in the same direction. Therefore, the study addresses the perspectives for governmental interventions in a double manner, discussing environmental aspects in both innovation policy and innovation aspects in environmental policy.

1.3.1 Selection of the case sectors

The empirical materials used in this synthesis report for analysis are primarily those obtained in the three sector studies, the details of which are found in the respective sector reports (See Footnote 4). These sectors are as mentioned the pulp & paper, mobile phones and buildings. The empirical material has been complemented with references to other relevant material in previous studies.

The sectors were selected based on purposeful sampling (Patton, 1987). That is, the principle underlying the selection of cases was that they were deemed to be rich in information and had high potential for learning opportunities (Patton, 1987; Stake 1995). Specific criteria considered when selecting the sectors include:

- **Relevance to the Nordic countries:** The selected industries have a significant contribution to the economic activities of the Nordic countries (see sector reports). The areas of interests identified by the Nordic environmental ministers as well as in the EU policy arena were also considered.
- **Availability of existing information:** Sectors that enabled capturing of developments over sufficient time horizons were selected, in order to understand the dynamic processes and system conditions that facilitate or hinder environmental innovations.⁶ Availability of

⁶ The choices do not capture all the potentials in all Nordic environmental innovation systems and particularly in emerging technologies. Instead of conducting ex-ante assessment, the aim of the

sufficient previous studies was also considered, which enabled in-depth comparative studies without initiating lengthy collections of primary data.

- Possibility of cross-sector comparison: The choices were made to enable, via cross-sectoral comparison, the extraction of relevant lessons regarding innovation dynamics, strengths and weaknesses, similarities and differences observed across the selected sectors.
- Coverage of various types of environmental technologies and environmental innovations.

In addition to these criteria above, the views of secretariats in Nordic Council of Ministers and experts in the relevant field were also taken into account.

1.4 Structure of this report

Following this introductory section, the analytical framework used for the project is introduced together with the literature that led to the development of the framework (Section 2). It is followed by the synthesis of findings from the cases of environmental innovations in three industrial sectors and within varying national contexts (Section 3). Based on the findings, Section 4 considers implication for effective policy intervention in inducing environmental innovation.

2. Research Framework

In order to facilitate cross-sectoral comparison of environmental innovations in the three sectors selected, the project team developed a common analytical framework. The framework was developed based on the review of two streams of literature: innovation systems (Section 2.1) and governmental policy interventions pertaining to environmental innovations (Section 2.2).

2.1 Innovation systems

The factors affecting innovations, their creation and diffusion has been described as an innovation system⁷ (Lundvall, 1992; Lundvall et al., 2002; Chaminade and Edquist, 2006). Dynamic models of innovations based on the systems perspective capture many of the challenges connected to the process of change, and provide a framework from which to examine the role of institutions, the behaviour of various agents and to view interactions (Edquist, 1997), thus allowing for the identification of opportunities and also barriers that need to be addressed. The innovation system perspective also adds to the understanding of the differences in the organization of innovation activities across industrial sectors (Malerba 2005, Jacobsson and Bergek, 2004) and nations (Freeman, 2002). It is from this general knowledge of innovation dynamics in national and sector systems that the framework of the project is formed.

2.1.1 Understanding innovation processes and systems

Understanding of innovation processes can be categorised mainly into the linear models and system models. Traditionally linear models, such as technology push and market pull, have been used to describe the innovation processes.

Technology push is the notion that it is the development of new technology that opens up new applications that the market has not foreseen. For an extended period of time, following the successes of technology-

⁷ “The concept ‘innovation system’ is different from the concepts ‘technological system’ or ‘socio-technical system’” introduced in Section 3.1. “They apply different logics. Socio-technical systems comprise technologies and institutions that have formed around an existing dominant technological design. In contrast, innovation systems consist of institutions and organisations deliberately created to support innovation – directly or indirectly. The aim of innovation systems is thus to induce change in the existing technological systems. Yet they may also include institutions (with no deliberate innovation effects) embedded in the wider, surrounding socio-technical systems” (Kivimaa, 2008).

based weaponry from science and engineering projects of WWII, this model of innovation became the reference standard that until now is deeply entrenched in various technology policy instruments of governments. It assumes that basic research followed by applied research leads to experimental development and then to new products or services. Thus the propensity of an industrial sector or a firm to innovate could be measured by its research intensity using indicators such as expenditure on R&D, citation analysis or education of research-qualified professionals.

Market driven development or market pull says that occurrence of innovation is based on the demands of the market and the customers and the quality of the competing products. This type of innovation is often more short-term than technology push based innovation and includes more frequent modifications and adaptations (Johannesson et al, 2004).

'Systems of innovation' approaches have emerged in reaction to the inability of the linear theories to account for innovation processes in complex environments (Freeman, 1996; Edquist, 1997). The concept of 'system of innovation' is based on the view that innovations emerge through an extremely complex process, which includes the diffusion of knowledge and the translation of this knowledge into new products and production processes. This translation process is not linear from basic and 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 (Edquist, 1997). This concept can be approached from the perspective of an industry (sector) or territory (regional, national). However, depending on the analytical context, different 'systems of innovation' may be complements rather than substitutes, as systems of innovation are open systems and can overlap. A company can be a part of a sectoral, a regional and a national innovation system. These systems exist at the same time and one may have to be viewed as a phenomenon of another (Johnson and Gregersen, 1997).

For certain industries, a 'national system' is a useful unit of analysis because of the common culture, legal framework, education, customer preferences, institutions and many other variables that impact innovation. Innovation systems have coevolved together with national political systems and have country-specific characteristics (Kuhlmann and Shapira, 2006). Thus, the concept of national innovation systems is based on the notion that the innovation performance of a national economy is dependent on both how specific organizations perform and how they interact with each other and how they interact with the governmental sector (Johnson and Gregersen, 1997). Key aspects include governmental policies and regulation, the education and research systems and support systems (e.g. Freeman, 2002; Kuhlmann and Shapira, 2006).

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. 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 (Malerba 2005).

2.1.2 Actors & networks

Actors may be firms, users, suppliers, or other organizations. The relative power of actors, their competences and interactions vary across sectors. Networks of actors constitute important channels for the transfer of both tacit and explicit knowledge, conducive to the identification of problems and development of solutions, or conducive for general diffusion of information or influencing the institutional set up. Different characteristics of actors and constellations of networks may result in differing responses to environmental innovation and to national policies stimulating environmental innovations. Thus it is important to capture the differences in the relevant actors and their networking structures when analysing the three sector cases.

2.1.3 Key activities in an system of innovation

A useful way to analyse the working of an innovation system is to focus on how a number of functions are served in the system (Jacobsson 2004). The innovation system literature suggests various levels of categorizations of these functions (e.g. Chaminade and Edquist, 2006). Crucial activities that can be elucidated from the literature are the creation, the pooling and the transfer of knowledge, the access to resources and the formation of markets. These can be detailed to more specific activities depending on the unit of analysis; technology system or territorial system.

Knowledge creation, pools and access

Knowledge is a necessary precondition for innovation, including environmental innovation. Activities enhanced in the group of “knowledge creation, pools and access” consists of the creation and diffusion of ‘new’ knowledge, the guidance of the direction of search among users and suppliers of knowledge, the application or modification of an existing idea to a new frame of reference, or the compilation of existing streams of knowledge to form a new solution.

The involved actor(s) must have access to the required knowledge, must be able to process this knowledge, and must be able to relate it to an application. The pooled knowledge must be utilised – via the presence of certain linkages – to facilitate cross-sectoral learning. As technological development proceeds, additional knowledge required to overcome barriers must be accessible. Further, the capacity to transfer the knowledge related to the innovation throughout the entire chain from conceptualisa-

tion to commercialisation must exist. With respect to environmental innovation, the integration of environmental considerations into the knowledge processes is important.

The access to different knowledge pools is influenced by the internal capabilities of the ‘innovator’ or of the organisation, the knowledge base of the sector concerned, external interactions, and national determinants of innovation systems including 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. For environmental innovation, the existence of specific types of knowledge pools such as inter-disciplinary ones may be essential.

Access to resources (capital and competencies)

In order for an innovation to be realised, the necessary resources must be available to the involved actors. These resources include those of both a financial and a human nature. Technology innovations are often coupled with high research and development costs and a need to demonstrate the new technology prior to attempting commercialisation. Furthermore, in order for innovation to be realised, qualified human resources must also be readily available. These human resources bring with them the necessary knowledge and capabilities to allow innovation to occur.

Access to these resources determines whether ideas have the necessary means to be developed into products, services or solutions. Access to capital and resources is dependent upon internal capabilities, external relations, and the availability of other resources in the sector and region. The perceived demand for the product or technology determines also the supply of resources and the willingness of capital providers to supply necessary investments. Many environmental technologies fail to raise capital at a late stage of development because of perceived risk associated with market stability and future policy developments.

Formation of markets

Innovation involves the first commercialisation of a new idea. As such, the existence of a market is a necessary precondition to allow innovation to occur. Furthermore, in the case of environmental innovations, a greater benefit will be realised with their diffusion throughout the marketplace, in lieu of less environmentally favourable alternatives.

The formation of markets is determined by demand and by the interactions that influence or create demand for a specific product. Markets can be created “naturally”, as a result of changes to the industry’s internal market situation (e.g. a need for new products) or by changes to external markets (e.g. changes in energy markets). Meanwhile, when innovation does not find ready-made markets, it requires stimulation, including coesive measures. This applies even more in the case of environmental innovation due to the appropriability problem. Regulations, standards, pro-

curement criteria, subsidies are some of the factors played out in enabling this function.

A schematic map that suggests these three activity areas can be found in Figure 1 and was used as an analytical framework when systematising the findings from the three sectoral cases.



Figure 1: Three key activity areas in a system of innovation

By arranging our empirical materials in terms of these activities, we can trace the way through which, for instance, a particular combination of actors or specific institutional set-up shapes the generation, diffusion and utilization of new environmental technology/process.

2.2. Government interventions pertaining to environmental innovations

2.2.1 The role of institutions on environmental innovation

The role of institutions in innovation systems varies; some influence ‘connectivity’ in the system whereas others influence the incentive structure or the structure of demand (Jacobsson, 2004).

Environmental innovations differ from other types of innovations in that the incentive for companies to develop and adopt environmental innovations may often arrive from public pressure in the form of, for instance, regulation or media attention. Therefore, for instance, environmental and innovation policies may have a specific role in the innovation process, sometimes named as the “regulatory push-pull” (Rennings, 2000). The intervention of public authorities in the innovation process addresses the problem that the market economy often entails a short-term profit perspective based on competition that does not necessarily steer technology and product development towards solutions that are sustainable in the long-term (Johannesson et al., 2004). In this case, the intervention may be directed at basic research (technology policy), the producer (environmental policy) or the market (environmental or innovation policy).

2.2.2 Environmental policy and Innovation policy

Environmental policy and innovation policy are among the policies most closely related to environmental innovations.

Environmental policy usually refers to the body of regulations and other policy mechanisms that the government creates and employs to deal with issues concerning the environment and sustainability (on different ways to separate environmental policies from other policies, see Lundqvist, 1996). The aim of environmental policy is ideally to address market failure resulting in environmentally damaging externalities and to correct the negative externalities through the use of various policy instruments (Grubb and Ulph, 2002). Externalities are costs or benefits arising from an economic transaction that are borne or received by parties who are not directly involved in the transaction. Pollution resulting from various production and consumption activities, for example, represents a type of negative externality.

Innovation policy originates from science and technology policies, but it adopts a much wider perspective, paying attention also to markets and commercialisation. Government intervention in scientific research largely took place in the post World War II era with the emergence of national science policies in many countries. These types of policies were largely concerned with the generation of scientific knowledge. These policies were followed in the 1970s by technology policies, which focused on the promotion of industrial application of knowledge. In the 1990s, a viewpoint began to emerge that existing technology policies were incapable of addressing the complex process of innovation (Russell and Williams, 2002). The result was a new focus on the creation of innovation policies, aimed at better responding to the complexities of the innovation process (Borrás, 2003).

2.2.3 Typologies of policy instruments

Government have been using a variety of policy instruments to achieve the goals of a policy – in this context, facilitate environmental innovation. These policy instruments can be categorised into various ways, such as administrative, economic and informative instruments (Vedung, 1998). The level of coerciveness of these instruments differs, varying all the way from mandatory to voluntary.

Administrative instruments cover various measures that concern the fulfillment of certain tasks, such as achievement of a certain recycling rate, elimination of the use of certain substances and prohibition of land-filling. The term “regulations” (Vedung, 1998), “judicial control model” (van der Doelen, 1998), and “regulatory instruments” or “mandatory instruments” essentially refer to these mandatory administrative instruments. Economic instruments generally provide monetary incentives – subsidies, refund and the like – when the addressees carry out tasks that

the instrument wishes to promote, or disincentives such as tax, when the addressees do not fulfil the required actions (Vedung, 1998; van der Doelen, 1998). Informative instruments, or information, concern the collection and provision of information, and are used with the assumption that people behave differently when they have better information and understanding.

2.2.4 Environment and innovation policy and innovation effects

A review of literature on the innovation effects of environmental and innovation policies, focusing on the three key activity areas of innovation described in Section 2.1.3, indicates somewhat different roles that the two policy areas have played so far.

By and large, the literature has demonstrated the usefulness of environmental policy towards innovation in specific cases in terms of its ability to contribute to the formation of markets through the provision of incentives (such as procurement) or imperatives (such as emission limits) for action (e.g. Porter and van der Linde, 1995; Kemp, 1997). Through the formation or modification of markets environmental policy instruments can create a demand pull in the innovation process, providing incentives for investment in knowledge and attracting new resources to the industry (Hayes, 2007). Furthermore, in cases of stringent regulation, such as the substance bans, administrative instruments have been shown to contribute to knowledge formation during the search for new and alternative solutions (Tojo, 2004). Yet, regulation has also been found to inhibit investment and slow down productivity growth (Palmer et al., 1995; Jaffe et al., 2003). Thus, its effects on innovation have found to be context specific (e.g. Hemmelskamp, 1997; Kivimaa, 2008).

Conversely to environmental policy technology policy has largely focused on the supply side of the innovation process (Georghiou, 2006; Fraunhofer Institute for Systems and Innovation Research, 2005). These policies have focused on R&D funding to provide resources for the creation of new knowledge and on measures to promote networking and actor interaction in the innovation system and to contribute to access to knowledge and resources (Hayes, 2007). Innovation policy, by contrast, may adopt both supply and demand-oriented measures. Increasingly, recent academic discussion has focused on innovation policy that is situated in a broader socio-economic context and overlaps different sectoral policies (Lundvall et al., 2002; Smits and Kuhlmann, 2004).

This can be graphically summarised in Figure 2 and is used as an analytical framework when studying linkage between the innovation dynamics in the three sectors and role of policies.

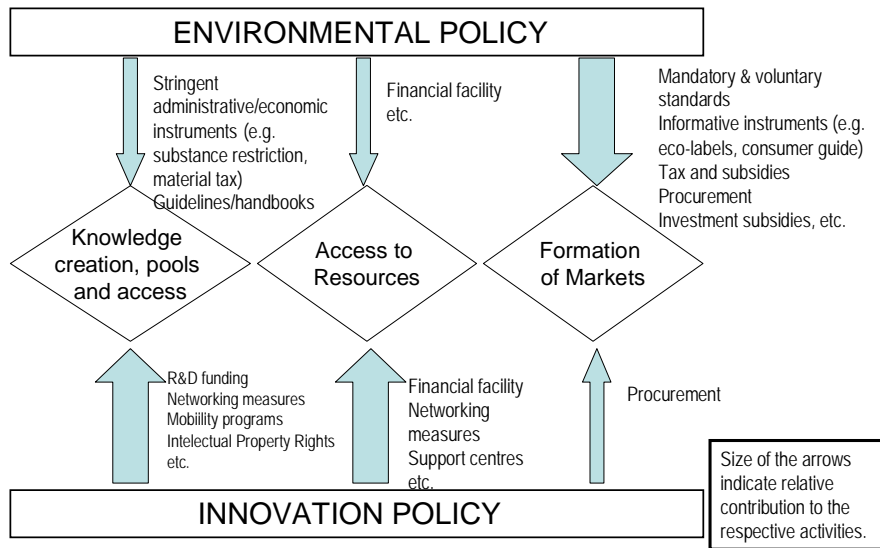


Figure 2: Linkages between environmental & innovation policy and the three key areas of innovation activities (source: based on Hayes 2006)

3. Findings from case studies

This section presents the cross-sectoral analysis based on the findings from the case studies of three sectors. It begins with a brief recap of characteristics identified in the three case sectors selected for this project (Section 3.1). This provides us with the background for cross-sectoral examination of the innovation dynamics observed in the case studies (Section 3.2). The information presented in this section is based on the sector reports (See Footnote 4) as well as materials gained through sectoral and policy workshops (See Section 1.1.2), unless otherwise mentioned.

3.1 Sector innovation characteristics

This section provides a concise overview of the characteristics pertaining to innovation systems of the three case sectors: buildings, pulp and paper and mobile phones.

3.1.1 The Building Sector

The building industry does not receive a classification according to the OECD system of manufacturing industries (which is based upon an analysis of R&D expenditures and output). However, it is generally considered to be a low technology sector, with relatively low levels of expenditures on innovation activities (Reichstein, Salter et al., 2005). This categorization however can be misleading. If we are looking at the building industry as a part of the retail and construction cluster (Uusikylä, Valovirta et al., 2003) we get a slightly more varied picture of the innovation activities within the sector. The building and construction cluster, as identified by the Finnish Funding Agency for Technology and Innovation (Tekes), consists of the real estate industry, the building industry, the building products industry and the building services industry (Uusikylä, Valovirta et al., 2003). While the building industry itself may have relatively low R&D investments, the building services sector which feeds the building industry has a relatively higher level of R&D inputs (for example, in Finland, in 2000, the total annual average R&D investment in the cluster was 0.8% of turnover whereas the building services industry's R&D investments represented 3.2%) (Uusikylä, Valovirta et al., 2003).

The building sector differs from other industry sectors with regard to innovation due to characteristics inherent to the construction work. These characteristics are found in the industry in general and they are not neces-

sarily specific to the Nordic markets. The most prominent feature of the industry with implications to innovation diffusion is its project-based orientation as opposed to a process orientation (Taylor and Levitt 2005). This means that different firms enter into temporary coalitions and collaborate on constructing specific projects every time. After the project is finished, the coalition is loosened. This unique feature has particular implications for our discussion on environmental innovation. Because innovation adoption takes place in projects, not firms, most innovations have to be negotiated with one or more of the actors in these temporary coalitions.

The project-based structure creates several constraints for effective learning and transfer of knowledge, necessary for innovation. The knowledge encompassed in a building project is both tacit and codified, with a large amount of knowledge gained during the actual building process. It has been suggested that tacit knowledge may be particularly important in the building sector (Gann and Salter 2000). However, the tacit-based knowledge combined with the project-based nature of the industry has been noted as a potential source of weakness for innovation process. New knowledge that is gained during a building project as a result of various interactions and learning processes may be difficult to capture and/or be transferred to future projects. A cooperation based on temporary contracts between changing configurations of actors makes the learning process more difficult and slows down innovation (Goverse et al. 2001). This is exemplified in the divisions between various actors in the building chain. Building materials suppliers are often not involved in the design or building process and the design phase is often separated from the construction phase. As such, lessons learned in one system area often do not get passed on to another.

In addition to the project-based structure, other features of building sector pertaining to innovation are the involvement of wide range of actors and the nature of building as the product. A building “project” requires engagement of a wide range of actors such as building material companies, engineers, architects, building developers and construction companies. Buildings are comparably expensive products with a long life-time. An issue often discussed in this regard is the inappropriate allocation of risks and benefits (Widén 2002). Due to the high price of the product, the building industry typically strives to reduce risk and ensure reliable economic returns on investments by the use of standardised approaches and models that have previously been effective, instead of striving to integrate innovative approaches. Furthermore, the distribution of technological risks and financial rewards is unbalanced, since financial reward of success travels upwards towards client (developer/end-users) and risk of failure downwards in the supply chain (investors on new technology). Another dimension of this problem is the cluster’s focus on lowest cost. Consequently, usage of internal resources for R&D by actors

such as building materials and equipment suppliers may not appear justified. This may make the building sector face a knowledge capital lock-in that dissuades it from undertaking significant change.

In addition, as the actors involved come from a variety of backgrounds, their experiences may be largely restrained to their particular sector of specialization. The networks between academia and the industry have traditionally been considered to be rather weak. These may further hinder the effective pool and transfer of knowledge.

Furthermore, the building industry has been noted to be subject to severe economic cycles of recessions and booms. These upswings and downswings can potentially have an effect on the industry's access to financial and human resources, acting as a barrier to investment in research activities.

3.1.2 Pulp and Paper

According to the OECD classification system of manufacturing industries, the pulp and paper sector is considered to be a low technology industry (OECD, 2005b). The R&D investments of pulp and paper producers tend to be less than one percent of turnover, and much of innovation has occurred in production processes, less on products. In process-based innovation pulp and paper companies have cooperated with medium and high technology sectors, including equipment manufacturing, chemicals and information technology. Therefore, similarly to the building sector, the Forest Cluster which the pulp and paper sector is a part of cannot be strictly characterized as low technology (Autio et al. 1997). The pulp and paper industry is a “consumer” of a number of high tech innovations (sometimes also a joint developer) originating within the cluster and has shown a capacity to work within the cluster and to absorb and integrate these innovations into its operations. While R&D expenditures of the pulp and paper companies have been considered to be variable and relatively low, the sector has also demonstrated its “internal” capacity to innovate when perceived necessary.

The Nordic pulp and paper industry has a long history of supplying goods to the national and international markets, however it is facing increasing pressure due to growing competition with other industries worldwide and with other materials. This competition may help contribute to the industry's integration into the forest cluster and to its interest in the innovation process.

Despite its position within the relatively innovative forest cluster setting, the pulp and paper sector remains a capital-intensive industry. Changes to existing equipment and processes require significant investment and may discourage industry to take risk in making radical changes (installation capital lock-in).

The Nordic pulp and paper industry can also be characterized by close links to public education and research. The R&D programmes funded on national and EU levels form a key part of the sectoral innovation system. Finnish Funding Agency for Technology and Innovation (Tekes) in Finland and the Swedish Governmental Agency for Innovation System (Vinnova) are significant actors in this field, although other funding agencies also exist. In Sweden, the Swedish Energy Agency, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) and the Foundation for Strategic Environmental Research (Mistra) are relevant funders of research related to environmental innovations of the pulp and paper industry. In Finland, other relevant public financiers include the Academy of Finland and the Ministry for Trade and Industry (MTI). A number of R&D programmes directly related to the pulp and paper sector have been coordinated by Tekes and Vinnova since the 1980s, while the pulp and paper sector has also participated in more general technology programmes (Kivimaa et al., 2008).

Partly due to the high organization of innovation activities through public and private funded programmes, much of the process-based innovation in the sector can be characterized as highly collaborative. In developing process innovations, equipment developers' joint R&D projects with universities, research institutes, pulp and paper producers and chemicals producers have improved the use of different types of knowledge and information flow (Kivimaa and Mickwitz, 2003; Kivimaa et al., 2008). By contrast, new products have often been created within companies (Kivimaa, 2008). In sum, 'innovation in the sector can be characterised by a larger focus on processes than products, heavy involvement of public sector actors (universities, R&D funders and environmental authorities), and networks of actors surrounding innovation commercialised by equipment manufacturers' (Kivimaa, 2008).

Following an intensive period of consolidation during the latter half of the 20th century, a few international corporations dominate the market. The Swedish-Finnish Stora Enso, Swedish SCA and Finnish UPM-Kymmene are among the largest producers of pulp and paper in the world. The Norwegian Norske Skog and the Finnish Metsäliitto belong to the largest paper producers in Europe. In Denmark, two paper companies, Dalum and Hartmann, export globally but are relatively small actors. Equipment manufacturers have also consolidated and internationalised, but in addition several smaller firms exist that focus on developing process innovations. Through globalisation of the industry, of its markets and the move of production facilities to places where the factors of production are inexpensive, the historically stable position of the Nordic pulp and paper industry has during the last decade been replaced with uncertainty for the future. This has influenced both the investment possibilities and interests of the companies operating in the sector (Kivimaa et al., 2008)

3.1.3 Mobile Phone Sector

According to the OECD classification system of manufacturing industries, the mobile phone sector is considered to be a high technology industry (OECD, 2005). Furthermore, the sector is characterized as product-based, referring to the fact that the focus of this industry is on the development of the final product and on its performance, rather than the process by which it arrives. The continual development of new products is an important activity within the industry and large brand holders spend approximately 10% of their turnover on research and development activities (Dirckinck-Holmfeld et al., 2007).

The mobile phone industry is characterised by a wide range of actors who play a role in the innovation dynamics of the sector. Globalisation of the industry has resulted in production, assembly and R&D activities being spread over a wide geographic area (Dirckinck-Holmfeld et al., 2007). Production of the most advanced components typically takes place in the U.S., South Korea and Taiwan. Production of basic components and assembly generally occurs in lower-labour cost countries. R&D activities typically occur in Western countries, though recently many knowledge-based activities are being off-shored to South-East Asia (Dirckinck-Holmfeld et al., 2007). All in all, the sector is characterized by complicated products and long supply chains. Typically, a brandholder has tens of thousands of active component items in its stock inventory. Thus, the supply chain and material data management is a demanding task (Kautto & Kärnä, 2006).

The intense competition in the handset market and the economic crisis experienced by many IT sectors at the turn of the century has resulted in a mobile phone market that is currently dominated by a few large global players. As of 2006, six major brand holders held approximately 85% of the share in the global market. Nokia alone has nearly 40% of the market and Motorola has more than 20%. Design of the mobile phones is typically done in conjunction with developers, marketing personnel and industrial designers, based on the technology road map created by the brand holders (Mousette, 2007, personal communication).

From the beginning of the 1990s onwards, mobile phone companies began to outsource phone manufacturing as a strategy to decrease production costs. The contract manufacturers, often referred to as Electronics Manufacturing Services (EMFS) in the electronics industry, face fierce competition. They often try to improve their position by providing production and assembly services to several brand holders at once (allowing them to further capitalise on their equipment investments and trying to avoid too great dependency on one brand holder/customer), and by providing additional value added services, such as the production of critical components. Recently, many large EMFS' have expanded their competences to include supply chain management, logistics planning, testing and customer contact, so that brand holders only need to deal with one

supplier. These EMFS' are referred to as turnkey suppliers. Other contract manufacturers provide the service of Original Design Manufacturing (ODM). The main difference between an EMFS and an ODM is that an ODM produces a product based on its own intellectual property rights, while the EMFS produces based on the property rights of its clients. ODM services include the technical and, sometimes, the visual design of its products. In many cases, EMFS' are large global providers whose turnovers and number of employees exceed those of the brand holders themselves (Dirckinck-Holmfeld et al., 2007).

Network operators play a major role in the mobile phone industry, representing the largest customers to both the brand holders and the network equipment providers (Mousette, 2007, personal communication; Lundberg, 2007, personal communication). The majority of phones are sold through operators and, through advertisements and subsidisation of phones (e.g. payment of phones through monthly instalments), they can have a significant influence over the types of phone produced. Operators are increasingly asking for customisation of phones around their services to support and drive the content and data applications that the operators are investing in (Singhal, 2005b) (Mousette, 2007, personal communication). Operators are largely interested in promoting phones that increase network usage (i.e. phones with features that encourage increased use of data transmission) in order to increase their revenues (Dirckinck-Holmfeld et al., 2007). The result is a corresponding increase in energy consumption of the phone and of the network system as such.

Despite high levels of competition between various actors, the mobile phone industry is characterised by a relatively high level of cooperation and interaction between major industry players (Singhal, 2007, personal communication). This can be partly attributed to the requirements for standardisation within the industry (Rice and Shadur, 2000). Additionally, the industry has a history of cooperative interactions with governmental authorities and strong ties to university research institutes within the Nordic countries.

Table 1 summarises the characteristics of three industry sectors in the Nordic countries pertaining to innovation systems and environmental innovations studied in this project.

Table 1: characteristics of three industry sectors in the Nordic countries pertaining to environmental innovation activities studied

	Buildings	Pulp and paper	Mobile phones
R&D expenditure and output	Considered low, but becomes higher when viewed as part of building and construction cluster.	Considered low, but becomes higher when viewed as part of forest cluster.	Considered high, dependent on continual innovation for market growth.
Type of innovation	Various (materials, systems).	Primarily process (or a combination of product and process).	Primary product .
Type of products	Complicated, expensive, long-life – risk of knowledge lock in.	Simple, relatively inexpensive product, but capital-intensive – risk of installation capital lock-in.	Complicated, many components, rapid change.
Industry actors and their roles/relations	Wide range of actors (e.g. building material companies, engineers, architects, building developers and construction companies). Collaboration is temporary and project-based. Unbalanced distribution of risk and reward for innovation.	Wide range of actors (e.g. equipment manufacturers, pulp and paper producers, consultancies and chemical companies). Collaboration in publicly funded R&D programs. Globalisation and manufacturers' consolidation into small number of large companies.	Geographically spread supply chain Relatively high level of collaboration despite high competition. Outsourcing manufacturing activities with varying level of specification. Network operators are the largest customer and have large influence.
Relation with non-industry actors	Relation with academia rather weak. Lack of direct link between end-users and actors with innovative technology. Inappropriate allocation of risks and benefits	Close relation with public education and research Supported by national and EU R&D fundings	Cooperative interaction with government. Close relations with universities and other R&D institutions

3.2 Cross-sectoral findings⁸

Now we turn to the question of how these sectoral differences shape and influence the propensity for environmental innovations and the response to policy stimuli. To explore this question, we take a comparative look at the case studies from each sector in relation to the three main functions of an innovation system as elaborated in our analytical model (knowledge, resource and markets).

3.2.1 Knowledge

Multiple knowledge sources and their triggers

The case studies from the three sectors have demonstrated the diversity of knowledge sources from which an innovation can originate, including individuals, companies and academia, as well as the differing motives for these innovations. In a number of cases in all three sectors, knowledge

⁸ The content of this section is primarily based on Hayes (2007).

that is required for the realisation of the innovation has stemmed from basic research and through research programmes, supporting the notion that funding and assistance in these areas are important elements in aiding the innovation process.

It is interesting to note that the more radical innovations in the pulp and paper and the building sector have originated from individuals outside of the main industrial sector in question, who were able to relate experiences from one sector to another frame of reference. A case in the building sector brought together two distinct pools of knowledge – materials and ventilation – to arrive at a unique energy efficiency innovation. A case in the pulp and paper sector combined knowledge from pulp and paper and automotive sectors. It has frequently been stated that innovations for sustainability require an interdisciplinary approach that makes use of knowledge and activities across a wide range of sectors. The experiences from the case studies reinforce this idea and illustrate some of the benefits that can arise from the combination of different perspectives and knowledge pools.

The case studies have further demonstrated that the full development of an idea often requires collaboration between a variety of organisations with the relevant knowledge. In almost all of the cases reviewed, realisation of the innovation was done through a combined effort of both academia and industry and required the input of a number of parties in order to be successfully developed. Even in a case where relationships with academic institutes were considered by the company to be distant, help from universities was sought out in order to legitimise products through certification and to develop an energy calculation programme for the company's product. In several cases in the respective sectors, the networking process between actors (both inter-industry and industry-academia) has been encouraged through public funding opportunities. Consequently, the importance of strong networks in the innovation process between and amongst industry and academia has been reinforced through the case studies.

In all sectors, there exists at least one case where the idea for the innovation was encouraged by the existence and/or anticipation of specific environmental regulation, indicating that in some cases environmental policy can inspire knowledge generation. In other cases, however, innovation efforts have emerged in the absence of direct policy "pull" and have been inspired by perceived need, desire for improved process efficiency and/or new products, reinforcing the idea that innovation is often the product of a complex series of interactions.

Role of SMEs in generating knowledge

The role of SMEs in a sector's actor network may also represent an interesting point of discussion with regards to knowledge generation activities in the innovation process. On one hand, innovation policy stresses the

importance of SMEs in the innovation system for reasons including: their use as an external resource of new technologies for large firms; their role in maintaining locally based innovative activities within a country; and their ability to develop and exploit high technologies more easily than large, established companies (OECD, 2005a). On the other hand, SMEs are often considered to be a weak actor from an environmental perspective, experiencing difficulties in complying with legislation due to limitations such as lack of time, personnel, experience and financial resources (Ecotec Research & Consulting, 2000). Particularly in more traditional, low technology industries, SMEs are said to have limited resources to invest in new technologies, R&D activities or higher risk endeavours and/or are often lacking capacities to absorb new innovations (Sexton, Barrett et al., 2006).

In the pulp and paper industry, innovation processes have involved SMEs through public R&D funding requirements posed for joint projects (Kivimaa et al., 2008). In the sector, often SMEs have been set up by larger companies or consortiums of companies to develop a particular innovation. SMEs in the equipment manufacturing sector have been found to have better potential to develop more radical technologies that might have faced difficulties in large companies due to competition with existing technologies produced by the same company (Kivimaa et al., 2008). Meanwhile, a lack of barrier to entry to new firms has previously been cited as an issue in the building industry.

Knowledge protection

Differences in the usage and applicability of intellectual property rights and patenting have come across in the three sectors under review. In the case of the mobile phone industry, patents play a significant role in the innovation process, serving as a means amongst actors to collect royalty payments. The decision regarding patent shares in a standard, such as in the case of the development of the 4G network, can play a role in influencing the direction of development of an idea depending on the interests of various parties. Conversely, in the building sector, the difficulty in patenting new ideas has frequently arisen as a disincentive towards innovation in the industry. In some cases, in lieu of attempting to obtain a patent, companies have chosen to rely on the complexity of technology and first mover advantage to capitalize on new innovations.

Access to knowledge and frame of reference

A sector's ability to gain access to and transfer knowledge can play a significant role in affecting its innovation capacity. The mobile phone sector is an industry focused on codified knowledge, whose business is substantially dependent on the ability to acquire information and to engage in the continuous development of new products in the sector. Accompanying this "knowledge-intensive" industry is a familiarity with the

research and development process and a strong network with universities and research institutes that facilitates knowledge transfer from the academic to the commercial arena. Key actors in the field often share a similar educational background, which can facilitate transfer of knowledge and ideas throughout the system.

The pulp and paper sector, while classified as a low technology sector in OECD classifications, finds itself in an interesting position due to its placement in the strategic forest cluster that exists within the Nordic countries. Sophisticated technology suppliers existing within the forest cluster have played a key role in innovation in the pulp and paper sector (Kivimaa et al., 2008) and past studies have put forward evidence that the industry has a high ability to use knowledge that is external to the firm (Autio, Dietrichs et al., 1997). The sector has close ties with research, universities and forestry-related communities that have historically facilitated knowledge transfer (Kivimaa et al., 2008). Actors within the pulp and paper industry often share a common frame of reference with respect to education, with a particular focus on engineering.

The common frame of reference can help to facilitate communication and knowledge transfer amongst actors. The case studies have reinforced the previous studies' finding on the ability of the industry to participate in and be privy to knowledge-related activities through links within the cluster. Environmentally relevant knowledge has been generated by several consecutive research programmes aimed at environmentally sounder technology. Moreover, despite the high focus on R&D oriented knowledge, the case studies also show that some innovation cases have rather involved market-generated knowledge or knowledge spurring from the interaction between different business sectors (Kivimaa et al., 2008).

Conversely, the building sector has been a point of interest for environmental researchers over the past years due to the apparent inability of energy efficiency innovations to diffuse throughout the industry. Arguments have been made that the knowledge to perform energy improvements in buildings exists (Fritzon, 2007, personal communication; Fabiano, 2007, personal communication; Workshop, 2007a) and the case studies have demonstrated that the capacity to innovate is, at least in some instances, present in the industry. However, numerous barriers affecting the capture and transfer of this knowledge have been identified within the sector. These include "broken learning loops" which exist as a result of the project-based nature of the industry and which mean that knowledge or experiences gained during one project are not transferred to the next, as well as segmentation and trust issues that exist between various actors. Furthermore, the actors in the building process are often from very different backgrounds, which may serve to aggravate this segmentation and act as a further barrier to communication, interaction and the formation of networks. This variation in frame of reference between ac-

tors may potentially contribute to the difficulties of actors within the building cluster to recognize and interact with one another.

Within the building industry, the networks between academia and the industry have traditionally been known as being rather weak, which can impede the transfer of knowledge and the commercialisation of new ideas. Past work, conducted regarding the Swedish construction industry, has shown that firms that lack employees with a university degree are unlikely to collaborate with universities and research institutes (Bröchner, 2006). Two of the case studies have involved limited interaction with the academic research community, as a result of the nature of the projects and, in one case, company attitude. However, some companies have successfully established close ties with research institutes that have facilitated the innovation process. In one such case, the product idea originated from work that was conducted by two individuals, one of whom was a university researcher, which could perhaps have facilitated the academia-industry interactions.

Structure of the value chain

The structure and the relation of actors in the supply chain can play a significant role in how knowledge flows within an industry. All three sectors have experienced increased internationalization, most notably in the pulp and paper and the mobile phone sectors, where globalization of markets and actor networks have been significant. The sectors are all now dominated by several large actors, who control a significant portion of the market and have the opportunity to take a lead in regards to environmental matters.

Still, the actor set-up and the network constellations creating the innovation opportunities are specific for the individual sector. While the pulp and paper sector typically maintains a more vertically integrated structure, the mobile phone and buildings sectors have a high degree of fragmentation throughout the industry. The pulp and paper industry has established tight, turn-key relationships with industry suppliers. This vertical integration may serve to facilitate the networking and the innovation process, allowing for easier collaboration between actors, in addition to providing different opportunities in a policy setting.

In the case of the mobile phone and building industries, a number of actors play a role in the value chain providing materials and/or services for the final product. These parts originate from a variety of sources and in order to achieve the complex finished products, the mobile phone and building industries rely on standards and specifications to communicate requirements across a broad range of actors. Companies in the value chain often buy the process or product for its function, not its composition. Furthermore, the products must operate within a framework that is established in conjunction with other actors. As such, clear, unambiguous

directions (e.g. for example through standards) may be better suited to facilitating changes across the industry in particular innovation cases.

Summary

Similarities and differences found among the three case sectors, based on the case studies conducted in the respective industries, are summarised in Table 2.

Table 2: Similarities and differences found among the three case sectors: knowledge creation, pooling and access

	Buildings	Pulp and paper	Mobile phones
Common across all sectors studied	Internationalised industry and globalised market (particularly for pulp and paper and mobile phone). Innovation and knowledge generation crosses sectoral boundaries and involves a variety of organizations (both industry and academia) which possess relevant knowledge. Sources of knowledge can vary: e.g. individuals, companies, academia. Innovation may be triggered with or without existence/anticipation of legislation. Public funding facilitates collaboration across actors when creating knowledge. A common frame of reference facilitates knowledge access and transfer.		
Knowledge creation	More radical innovations arrive from cross-sectoral or multidisciplinary collaboration. Barrier to entries for SMEs have been an issue. Difficult to obtain patents	More radical innovations arrive from cross-sectoral or multidisciplinary collaboration. Involvement of SMEs in R&D activities secured via public R&D funding requirements. Radical innovation may be easier in SMEs due to lack of competing technologies in the same firm	Knowledge intensive industry. Patent being an important issue to collect royalty
Access to/pooling of knowledge	Knowledge and capacity to innovate exists. Broken learning loop due to project-based nature and segmentation. Frame of reference varied among actors due to different educational background. Fragmented structure of supply chain may require clear, unambiguous specification may be needed to facilitate change across the industry	Sophisticated technology supplier exists within the forest cluster. Close ties with the research, universities and forestry-related communities. Vertically integrated supply chain, which may facilitate networking	Familiar with R&D process. Strong network with universities and research institutes. Share common frame of reference. Fragmented structure of supply chain may require clear, unambiguous specification may be needed to facilitate change across the industry

3.2.2 Resources

Industry financial resources

The resources within an industry and the attitude towards these resources and the value of R&D activities can shape the potential for innovation. As discussed in Section 3.1, the mobile phone industry is a high technology sector dependent on continual innovation for market growth. Meanwhile, the pulp and paper industry and the building industry are charac-

terised by relatively low levels of R&D, but is situated within a cluster where other actors undertake relatively higher R&D investments.

The pulp and paper sector is well integrated into the cluster and has benefited from the innovation activities initiated by/together with other actors in the cluster. In contrast, the building sector has not established the same relationships with its cluster members. The observed weak relationship can be attributed to project-based nature of the industry and unbalanced distribution of risks and rewards, and may potentially contribute to the difficulties in introducing new innovations (such as those experienced in the case studies) into the building process. Moreover, it has been noted that the severe economic cycles of recessions and booms affected the industry to invest in R&D activities.

Human resources

While a detailed study of education and human resources in the industries has not been completed and continuous efforts are important in all areas to provide a strong personnel base, in general, human resource issues have not arisen as a major innovation barrier in the materials reviewed for two sectors – mobile phones and pulp and paper. The mobile phone sector has attracted highly skilled human resources to the field, who are able to help drive the innovation process forward. A number of education and research programmes are directed towards the electronics and telecommunications industry, helping to attract new individuals into the field and, historically, significant efforts have been made to ensure the existence of a highly skilled staff-base in the Nordic countries through programmes designed to advance education levels in the sector (Blomström and Kokko, 2003).

Similarly, the pulp and paper sector in the Nordic countries has made efforts over the years to engage in educational programmes and to attract highly-skilled individuals into the field (Blomström and Kokko, 2002; Molkentin-Matilainen, 2007). Currently, a significant number of world's pulp and paper engineers are educated in the Nordic region and past efforts have been taken through employment programmes to ensure that the industry retains a competent personnel base (by supporting skilled staff and graduates during economic down cycles) (Blomström and Kokko, 2002; Molkentin-Matilainen, 2007). Thus, underlying the innovation cases is educational competence that can be perceived as a part of both national and sectoral innovation systems. In addition, the networks of actors within the forest cluster have enabled the employment of relevant human resources into R&D projects.

Conversely, the building sector has maintained a certain reputation over the years that may not lend itself to the attraction of skilled personnel (European Monitoring Centre on Change, 2005; Rozite, 2006b). While the case studies have identified a number of innovative and skilled individuals in the industry, the overall picture has indicated room for

improvement in this field, perhaps through increased efforts to attract individuals to pursue higher education and research in the sector. Past studies have shown that the presence of academics within the building industry can help to facilitate industry-academia interactions (Bröchner, 2006). Consequently, efforts to renew the industry's image and to strengthen the knowledge level of the human resources base may also serve to improve industry-academia networks. The human resource issue in the sector is further compounded by the cyclical losses of industry personnel during times of recessions (Rozite, 2006b). The loss of skilled industry personnel and researchers during down cycles can result in the discontinuation of research efforts (which must often be pursued on a long-time scale to achieve commercialisable results) and the loss of tacit knowledge embodied in these individuals. This is partly compensated by having governmental R&D institutions such as the Danish Statens Byggeforskningsinstitut, SBI, that takes part in specific developments projects and distributes knowledge among the different actors as well as in developing the building code and guidelines for constructions and buildings.

Public funding

Public funding is a frequently used tool in the innovation portfolio and has played a role in almost all of the studied innovation cases.

In the case studies reviewed for the mobile phone industry, public and university funding have played a role in the innovation developments. In one case, public funding has been received in collaboration with industry participation. In the other, university funding has constituted the primary source of project funding in the absence of industry partners.

Technological developments in the pulp and paper sector are often indirectly influenced by public R&D funding, as findings of the extensive technology programmes are used as basis for generating new knowledge (Kivimaa and Mickwitz, 2004). In some instances, environmental aims of public research programmes have especially facilitated the emergence of environmental benefits in an innovation (Kivimaa and Mickwitz, 2004). Among the case studies reviewed, public funding and research programmes have played an important role in the evolution of the technology from research infancy to commercialization in all the five process innovation cases, but less so in the two product innovations cases. In one of the cases, the innovation was developed and taken further towards commercialisation over the course of two consecutive research projects with the support of the public funding agencies Mistra and the Swedish Energy Agency. In another case, public funding has played a key role in keeping the technology alive as it changed ownership numerous times and experienced several difficulties (Kivimaa et al., 2008).

In the building sector, the development of one innovation was related to a series of unique research programmes initiated by Tekes (the Finnish Funding Agency for Technology and Innovation). The programmes rep-

resented an effort to integrate the building automation cluster in order to assist customers by bringing different building automation services to one place, to break the technology lock-in situation experienced within the building services industry due to propriety systems, and to improve the performance of the building services sector (Hyvättinen, 2006; Tekes, 2006). These programmes have attempted to orient the building services industry towards customer demand by calling for integration of these actors (building owners and contractors) in the development process. In an industry frequently described as being characterised by segmentation between actors, and where the contractor and/or developer can have a significant role in shaping the building process, this coordination effort could be considered as highly important. According to actors involved, the programmes have been credited with helping to facilitate technology development in the area of automation systems, helping to achieve system integration, and helping to initiate a break in the market lock-in experienced in the building services industry (Hyvättinen, 2006). There has, however, been some discussion regarding the success of the programmes in terms of assistance with product commercialisation. Comments from participants in the first programme have, in some cases, expressed the idea that following the end of the programme, the developed products were left without sufficient supporting markets (Hyvättinen, 2006).

In another case from the building sector, the innovating company chose not to seek out funding assistance during the development of the project, due to an internal policy that development falls within the responsibility of the company. While one case cannot be used to draw a sector-wide generalisation, this may potentially reflect on the traditional mentality of the sector, the weak links with research institutions and/or a lack of familiarity with the research and funding process.

Other funding

While public and industry funding can be important resources for technology development, the case studies reviewed have demonstrated the relevance and importance of other sources of funding for the innovation process. In particular, in the pulp and paper cases, resources to assist with the commercialisation of the product have been obtained through alternate means such as the pre-selling of technology licenses (in order to avoid giving up ownership of the technology) and venture capital funding (Kivimaa et al., 2008). Access to private funding can be highly important in facilitating the commercialisation of a new technology but the attraction of funding (both public and private) for an innovation project can be a complex and challenging task. In addition to providing financing through public funds, the assistance of public agencies in helping to seek out and negotiate funding (particularly for industries who are less familiar with the process or who may traditionally have a lower profile in investment terms) may potentially serve an important role in the innovation

process as shown in the pulp and paper sector case (Kivimaa et al., 2008). This may be particularly relevant in the case of SMEs, who have less familiarity with the funding process and may be particularly significant in industries such as buildings, where a large number of SMEs operate.

Summary

The findings from case studies of the three sectors pertaining to their access to resources are summarised in Table 3.

Table 3: Findings from case studies of the three sector cases pertaining to access to resources

	Buildings	Pulp and paper	Mobile phones
Common across the sectors	Public funding is important in facilitating the coordinated efforts among actors. Education is an important basis for acquiring highly skilled human resources		
Industry input on R&D	Low R&D, higher in cluster	Low R&D, higher in cluster, R&D benefits from cluster	High R&D, industry dependent on development of new products
Human resources	Can improve in attracting a larger number of skilled personnel	Attract highly skilled personnel	Attract highly skilled personnel
Others	Significant public funded applied research (DK)	Commercialisation has been facilitated by pre-selling of technology licenses and venture capital funding	
Sector specific influencing factors	Knowledge lock-in, unbalanced distribution of risk and rewards, economic fluctuation. Lack of strong connection with academia. Cyclic loss of skilled employees and their tacit knowledge during economic down cycle	Efforts to engage educational programs over the years. Support skilled staff during economic down cycle. installation capital lock-in	Existence of many educational and research program directed toward the industry

3.2.3 Markets

Customer vs. supplier-led innovations

The sector materials and case studies have shown that the customers and consumers⁹ in the innovation process have the potential to shape the way that a sector engages in innovation. In this section we first discuss the role of customers (purchaser of a good or service for further refinement or sale).

In the case of the mobile phone and the pulp and paper industries, the companies, in a sense, operate in a business to business environment, where their products are principally sold to another commercial actor. In

⁹ In this work, the term customer and consumer will be used as two distinct terms. Customer will be used to refer principally to the purchaser of a good or service for further refinement or sale. Consumer will be used to refer to the final, individual consumer of the product (e.g. the individual who purchases the mobile phone for final use).

the building industry, the picture is not always as clear, with contractors operating on behalf of a wide range of clients. However, in many cases, a similar business-to-business phenomenon (e.g. construction of buildings to property management and rental firms) is witnessed. In addition, depending on the type of innovation occurring, the role of customer can be fulfilled by differing parties.

In the case of the mobile phone industry, the customer role is often viewed to be filled by the network operators, who are by far the brandholders largest customer. Their demands have been noted to influence the direction of movement of the industry, exerting a significant pull on its progress (Dirckinck-Holmfeld, 2007, personal communication; Singhal, 2007, personal communication; Dirckinck-Holmfeld et al., 2007). While some of the brandholders' marketing strategies for the mobile phones centre on consumer preferences, they must also incorporate the demands of the operators into their decision-making processes. Currently, a trend towards increased data transmission exists within the industry, which is coupled with an increase in energy demand of the mobile phones and the network. In the cases examined as part of this work, the innovations did not pertain to the mobile phone itself, as a product, but rather to the accessories (e.g. chargers) and networks related to the product.

In the case of the charger, the mobile phone industry can serve to fulfil the role of customer, procuring the devices from industry suppliers (i.e. having a modular relationship with the charger manufacturers) and supplying them, in turn, to their customers. In this case, the mobile phone industry and operators have the potential to influence the direction of innovation being realised. In the other case concerning network development, the picture becomes more complicated, as the direction that the system will take is dependent on agreements and interactions between a number of actors. One of the actors playing a significant role is the operators, representing the customer base for the network providers and having the potential to shape industry developments through their demands (Lundberg, 2007, personal communication).

Within the pulp and paper industry, the product users represent a significant power group in regards to product innovations¹⁰ (and process innovations which alter products) within the sector. In some cases, the customers of the pulp and paper industry have been identified as a driving force for the adoption of environmental innovations (e.g. chlorine-free bleaching) (Harrison, 2002; Hildén et al., 2002). In some cases, the pulp and paper industry itself has been the effectuator of the innovation, where a desire to create a new product that responds to customer wishes has been a driving force. In other cases, however, it has been suggested that

¹⁰ While the scope of this work is to focus on energy efficiency innovations, product innovations are touched upon here due to their interrelationship with process innovations, whereby alterations to the industry processes have an ultimate effect on the end product that is produced.

conservative customers can also hinder the innovation process within the industry.

A new process in which a new product is produced may not be readily accepted by customers. Additionally, while changes to the pulp and paper process require significant capital investments for the industry, the production of new products can also require changes in capital infrastructure of the customer. For example, where a new type of paper-based packaging is offered to replace an existing plastic one to a food industry, changes to the packaging equipment may be required. In these cases, involvement of customers into the innovation process and customer targeted measures can potentially play a role in facilitating product innovation.

In the case of process innovations which are less drastically linked to product changes (such as those in the pulp and paper sector), a slightly different situation may be present. In this case, the industry may represent the effectuator and/or the consumer of the innovation (e.g. where the innovation originated from a supplier or consultant to the industry, rather than from the industry itself).

Within the building sector, the role of the customer and/or the consumer in the innovation process often appears less clear. The developer funding the project represents the actor with the final decision-making powers (Fabiano, 2007, personal communication). However, there are several factors influencing the developer/customer demands. In many cases, the developer is not the party who is intended as the final user or “consumer” of the building. The actual “consumer” chooses from what is available on the market (similarly to the mobile phone situation). As such, the developer designs a building as they see fit. In other cases, regardless of whether the building is developed for own use or not, the client (developer) may lack the capabilities to make environmental value judgments regarding the performance of the building, to know what is best available technology, or to evaluate life cycle savings. In this case, it is in the hands of the project management team to identify possible routes which the developer could take. As such, the client is limited to knowledge put forward by the supplier. The result is an innovation chain within the building industry that has been characterised as supplier-led. This may be an important factor as the case studies and reviewed data have shown that often the professionals, not the customers, are stepping back from potential building innovations (Rozite, 2006b).

The same market knowledge issue can also be seen with the renovation industry. Many building owners are not in the position to have the greatest level of awareness of energy efficiency options during the renovation process. Consequently, the power falls largely in the hands of the renovation companies, who tend to be small to medium sized enterprises. This may present an additional point of difficulty as SMEs in this and

other low-tech industries have been noted, as discussed above, to face some barriers in regards to the innovation process.

Characteristics of the innovations

In addition to demonstrating that the innovation process within sectors can be influenced to different degrees by different actors, the above discussion also highlights the fact that variations can occur within each sector depending on the type and nature of innovation in question. In some instances, the environmental innovation may represent a “core business” opportunity for the industry in question. For instance, in some cases in the pulp and paper sector the innovation allows the efficiency of mill to be improved resulting in a higher quality or more resource-efficient product in addition to representing an environmental benefit. In these cases, industries may have a certain degree of impetus to pursue or facilitate innovations in these areas. In other cases, the environmental innovation may not represent a core business concern as environmental improvements do not provide direct cost or market benefits. These cases, where the industry itself may not always benefit (at least in a core-business sense) from the innovations/ where the investments may appear less sure, are found in all the sectors studied. In these cases, external impetus may be required to help the innovation to succeed.

The case of network development of the mobile phone raises another interesting point in this area. While this innovation makes sense from both a product performance and core business perspective for the operators (energy costs are variable), the technology has not yet succeeded in attracting partners for the commercialization. Potential barriers cited include conservativeness on the part of the operators, the lack of an adequate payment structure for cooperative networks, and the need for compromise by all of the key players in the industry on how the 4G network will proceed.

Low-cost demand

In all three of the sectors, cost of the innovations has come up as a barrier to their adoption. While realisations are growing that a focus on high-quality and innovative products may be an important strategy, in both the pulp and paper and the building industry, focus on lowest price has continued to be the dominating market factor (Rozite, 2006b; Working Group of the Finnish Forest Industry, 2006). Similarly, in the case of the mobile phone charger, lowest cost has been identified as the principle factor in determining the success, or lack thereof, of innovation. This focus on lowest cost represents a barrier to the innovation process in general, including environmental innovations.

Discrepancies between beneficiary and cost bearer

In the case of energy efficiency innovations, the issue of discrepancy between the cost bearer and beneficiary has presented itself in both the mobile phone sector and the building sector. In terms of the mobile phone, there is an ongoing concern for energy efficiency from a core business perspective (Moussette, 2007, personal communication). However, in terms of peripheral devices, such as chargers, there is a discrepancy issue. The brandholder must invest in the better performing charger, while the user benefits from the lower energy costs. However, because the savings realised by the consumer are so low in relative terms, there is not necessarily an incentive for the consumer to want this charger or to pay extra. In the case of the building industry, the savings realised from energy efficiency investments are to the benefit of the end user, while the developer puts forward the initial investment. If the market interest in investing in more energy efficient homes is low, as suggested by the reviewed materials, the developer has limited interest in pursuing this strategy.

Market steering

Market distortions have been noted in both the mobile phone and building sectors, with regards to the ability of large actors in the industry to gain market control through subsidisation of the capital costs of a product or system. In the case of the building sector, in terms of building control systems, the large turn-key suppliers are often able to undercut the capital cost of their system by recuperating revenues through monopoly maintenance contracts over the life of the system (Linturo, 2007, personal communication). Similarly, in the mobile phone industry, the operators can subsidise the cost of the phones, allowing them to steer the market towards the purchase of specific products (Dirckinck-Holmfeld et al., 2007). This market-steering situation represents a potential impediment to the commercialisation of new technologies. This fact was recognized by Tekes in an attempt to break the market-domination situation present within the building services and automation industry.

Consumer demand, public perceptions and sensitisation

In all sectors, the low level of environmental awareness and/or demand of consumers have been cited as a barrier to the environmental innovation process. In the mobile phone sector, the awareness of environmental impacts and the demand for environmental products is limited (Jensen, Sørensen et al., 2003; Singhal, 2005a). In the pulp and paper sector, the general level of awareness of production and product impacts is has been mentioned to be low (Working Group of the Finnish Forest Industry, 2006). However, in many cases it has been the customer awareness and demand that has facilitated the development and diffusion of new process innovations, e.g. in non-chlorine pulping (Hildén et al., 2002). In the building sector, lack of customer demand for better buildings has been

cited as a market barrier and partly attributed to lack of knowledge regarding the options for and the impacts of the built environment (Fritzon, 2007, personal communication; Rozite, 2006b).

Consequently, there appears to be an ongoing need for efforts to stimulate the demand for green innovations. However, the ability to do this, and the role that the consumer will play, can vary between sectors and innovations. For example, the choice between a high-efficiency and low-efficiency mobile phone charger may appear to be a relatively straightforward decision for a consumer, assuming that they are aware and concerned. Conversely, however, system changes such as the decision of a mill to engage in biorefinery practices is less relevant in regards to the issue of consumer demand for the pulp and paper sector, while a general increase in the demand for biofuels could facilitate innovation in this area.

Different levels of public awareness, perceptions, and regulation have historically played a role within the various sectors. The pulp and paper industry has frequently found itself in the public eye with regards to environmental issues (due in part to the significant local impacts of its past production activities), and the industry production has been relatively heavily regulated in regards to environmental issues. Conversely, in the mobile phone industry, public awareness regarding environmental impacts has been measured to be relatively low. Many production and disposal actions are carried out in distant locations from the consumer (with regards to the Nordic and other developed countries). The increase of environmental regulations on the sector has been relatively recent, and some EU directives are still in the process of being implemented. Similarly, in the building industry, public perception of environmental issues (or at least though associated with energy consumption) has come across to be low. While energy performance stipulations concerning buildings are present, for example, in the building code, the sector has only as of late begun to be subject to explicit environmental regulation considerations on a larger scale.

There is no doubt that all the sectors will be influenced by the considerable increase in the most recent years in the public concern and the media and policy attention to the climate and environmental problems in general. However, it is too early to say how radical changes in demands and other market dynamics it will lead to.

Regulatory signals and market pull

In regards to the market precondition for environmental innovation, the case studies have demonstrated two things: 1) that markets for innovation are the result of a combination of factors; and 2) that an added element of regulatory pull in the traditional technology push, market pull model of innovation can be important in some cases of environmental innovation, supporting the previous findings of Rennings (2000) and Kivimaa (2007).

A direct driver for the innovation found in cases in the pulp and paper industry and the building industry has been new regulation that has provided a potential market for the technology. In the instance of the pulp and paper sector, for example EU regulation on the use of biofuels in transport has increased investor interest in the bio-refinery technology and renewable fuel tax signals have provided an additional economic driver. In another case, the innovation has been driven forward by its ability to increase the capacity of the pulp mill at a relatively low investment cost and has been further advanced by increasing oil prices and the biofuels directive (due to the biomass gasification potential). Moreover environmental policies on water discharges, air emissions and recycling have promoted innovation in the sector (Kivimaa, 2008; Kivimaa et al., 2008).

In one case in the mobile phone sector, new technology has been developed as a result of anticipation of new regulation. No regulation is yet in place however, and the new technology not yet succeeded in being commercialised.

In some cases in the pulp and paper and building sectors, commercialisation of the technologies has proceeded in the absence of direct environmental regulation intervention. In one case from the pulp and paper sector, market drivers have included needs to improve mill efficiency, energy savings, and the desire to produce a new product. An example from the building sector indicates that drivers have included perceived needs for efficiency improvements, rising oil prices, improved building performance, reduced capital costs for HVAC equipment, and extended product guarantees. In the other case from the building sector, drivers have included the desire for new products, improved integration of user needs, and sophisticated building performance. It is interesting to note that while these innovations in the building sector have been successfully commercialised, however, they have faced some difficulty in diffusion into the market.

Segmentation of actors

In the building industry, in addition to knowledge transfer, segmentation of actors has explicitly been cited as a barrier to commercialisation in at least one of the building cases.

Summary

Common and sector-specific phenomena pertaining to formation of market for environmental innovation studied, as well as underlining factors and actors influencing the occurrence of such phenomena, are summarised in Table 4.

Table 4: Sector specific and common phenomena pertaining to commercialisation of environmental innovation in studied sectors as well as factors/factors influencing their occurrences

	Buildings	Pulp & paper	Mobile phones
Common across the sectors	Demand on low cost pose challenges to adopt innovation. Nature of innovation influences the necessity of external impetus. Lack of information coordination at the users' end and corresponding incentives. Legislation may play an important role in some cases of environmental innovation		
Influential actors/factors specific to sectors	Suppliers who have the technological competence. Discrepancy between the beneficiary and cost bearer of the innovation. Market steering by large developers. Segmentation of actors	Customers (users of the products and production processes)	Customers(network operators) and consumers. Discrepancy between the beneficiary and cost bearer of the innovation. Market steering by network operators

3.3 Summary Points

As summarised in Table 2 to 4, the review of the case studies from the three sectors reveals that all three sectors have experienced the occurrence of similar phenomena and factors contributing to the occurrence of such phenomena. Meanwhile, there are phenomena and factors found only in specific sectors. Both of them are highlighted below with a view to extract policy lessons presented in Section 4.

Phenomena and contributing factors common to all three sectors

Environmental innovation examined in all three areas stemmed from various knowledge sources, both from industry and academia, and within and outside of the respective industry sectors. Public funding appears to be important in facilitating the creation of new knowledge, especially when it requires the collaboration of various actors. Education – and the link between industry and university – serves as an essential foundation for acquiring highly skilled human resources. A close link to education also helps establish the common frame of reference among actors engaged in the same innovation project, an important attribute that facilitate the access and transfer of knowledge.

In all three sectors, there are cases where existence or anticipation of upcoming environmental legislation has played a role in knowledge creation as well as commercialization of new knowledge. Meanwhile, there are also cases where innovation activities took place without government intervention. The necessity of government intervention and other forms of external impetus would depend upon, among others, whether the environmental innovation in question improves the core business of the industry or not. A challenge facing all three industry sectors at the commercialization and diffusion of environmental technologies include information coordination at the user's end and corresponding incentives. Related to this issue is the necessity for industry to keeping to the lowest cost.

Phenomena and contributing factors found in specific sectors

Some specificity of phenomena and contributing factors found in the study find their roots in the unique characteristics of the sector. For instance, the mobile phone industry, whose growth is dependent on developing and commercializing new products, allocate a relatively large portion of their resources on R&D activities. Another example is the broken-learning loops experienced in the building industry, which are perceived to be caused by project-based nature of the operation and severe effect of economic cycle felt strongly by the sector.

Meanwhile, there are phenomena and factors that, although still stemming from the characteristics of the sectors, could be more generalisable. These include, among others, discrepancy between the beneficiary and the cost bearer of innovation, market steering power of large customers, installation capital lock-in, customer or supplier-led innovation and vertical integration or fragmented structure of supply chain.

The necessity of tailor-made policy intervention tends to be higher in the former than the latter. However, in both cases, there is a level of replicability especially when a successful example of solution to the similar challenge exists in other sectors. The essential starting point in all cases is the identification of causes and effective intervention points.

4. Implication for policy activities

Building on the cross-sectoral analysis presented in the previous section, this final section extracts lessons and insights related to policy activities that better enable environmental innovations. The Section begins with a concise analysis of government interventions and their influences on environmental innovation activities (Section 4.1). We then discuss, through concrete illustration from cases, how selected factors influencing the sectoral innovation dynamics could potentially raise important implications on the appropriateness of different policy stimuli (Section 4.2). The section concludes with some suggestion as to the potential contribution Nordic countries can make in furthering the ETAP.

4.1 Government interventions and influences

Previous sections already indicated that government interventions have played roles in some innovation cases reviewed in this project. Specific interventions and the innovation activities influenced by the interventions in the three sectors are discussed below.

Mobile phones

In the case of the mobile phone charger, past improvements from linear to switch mode were the result of a combination of factors including various properties of switch mode chargers that provide market and technical advantages (e.g. shorter charge time smaller size, lower weight) and increasing political focus on energy efficiency. The development of energy efficient charger with low energy standby consumption has been encouraged, in one case, by market interest in another electronic products sector and the provision of funding from energy agency, and, in the other, as a preparatory work to develop best available technology to be considered in the EuP Directive.¹¹

Despite the technological advancements and existence of new knowledge, however, near zero standby load chargers have yet to be marketed due to economic considerations and stated lack of demand. The adoption of better performing chargers by the industry is currently being imple-

¹¹ Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council, OJ L 191, 22.7.2005, p. 29–58

mented, though on a much longer time scale than is technologically feasible. In the area of chargers, the mobile phone industry has performed relatively well in response to the voluntary European Code of Conduct regarding External Power Supplies, with a high percentage of its chargers available on the market today meeting the code (European Commission, 2005). However, there is criticism that little effort is needed to achieve this performance and that this voluntary standard has simply moved players to a “no pain” level of performance, whereas much more (i.e. at factor 20) is possible by today’s technological standards.

Pulp and paper

The innovations in the pulp and paper sector have all benefited from public funding opportunities. In many cases, the developments were made as part of ongoing research programmes in the pulp and paper industry. These programmes have facilitated network collaboration and procurement of funding throughout various stages of the innovation process. This has been noted to be particularly important during the demonstration phase of the technology due to the capital-intensive nature of the industry.

Commercialisation and the actual invention of technologies have often been encouraged by EU and national level policy signals¹² e.g. for biofuels.¹³ In one case, a national tax relief for renewable fuels helped reducing the production cost. In that case, the commercialisation process for one of the biofuel technology also received a major boost, receiving notable venture capital support from two interested parties, of Swedish and American origin due to a belief that more stringent regulations regarding heavy engine emissions will appear in the future.

In another case from the pulp and paper sector, while biofuel policy signals have acted as a driver on one hand, conflicting policy signals originating from the green certificates system have acted as a barrier to the technology’s development on the other. Despite this conflict, however, the technology is, to this point, very close to commercialisation.

In many cases from the pulp and paper industry, innovation and environmental policy have worked in conjunction to facilitate knowledge generation and transfer, access to resources, and market formation for the innovations. In other cases, however, no specific environmental policy interventions have been identified in driving forward the commercialisation process, but part of the selling point of the innovation has been the improved resource and energy efficiencies. While these changes represent economic benefits for the supplier and the customer, the growing attention which is being paid to environmental, energy and life-cycle related issues may also contribute to interest in the technology.

¹² More information on the policy drivers of specific innovations can be found in the pulp and paper sector report by Kivimaa et al., 2008.

¹³ Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport OJ L 123, 17.5.2003, p. 42–46.

On cases related to material efficiency, market for recyclable and biodegradable molded fiber packaging has been promoted by the implementation of EPR (Extended Producer Responsibility)-based system. In some countries, tax favouring fiber packaging over plastics also accelerated the introduction. This, together with the higher oil price, supported the market development of molded fiber packaging.

Buildings

In the building sector cases, innovations have been realised with the assistance of environmental and innovation policy. The automation system has been developed as part of a unique research programme designed to break market-lock and to better integrate the building services industry into the building cluster through collaborative development opportunities. The programme has been credited with helping to make a technological breakthrough in the building process, to create a market shift, and to change the attitudes of various actors (a task which may be particularly important in this more conservative, segmented field) (Uusikylä, Valovirta et al., 2003). In another case, development has been partially driven forward by more stringent requirement in the national building code. Part of the company's marketing strategy has been promoting the technology as being able to satisfy the new building regulation requirements and the technology has experienced successful commercialisation.

Summary

Table 5 summarises the government interventions that have positively influenced innovation processes in the cases studied in the three sectors. It indicates the domain of the intervention (environment or innovation), typology of policy instruments (See section 2.2.3) and the innovation activities (knowledge creation, pools and access, access to resources, formation of market) influenced by the intervention.

The case studies reviewed have provided insights for several of the characteristics of green innovation policy – including both innovation policy facilitating environmental improvements and environmental policy that support innovation – suggested in literature. Environmental innovation in all sectors benefited from the public funding, which facilitated activities knowledge creation, pool and transfer. In some cases, commercialisation was also supported.¹⁴ The cases have reinforced the notion that environmental policy can play an important role in forming market but have also demonstrated the ability of environmental policy to inspire knowledge generation activities by providing signals for future market directions. Stringency and ambition level of new regulations have driven forward innovation in the building sector, and reduction in market uncertainty has helped to spur innovations in the pulp and paper industry for-

¹⁴ In innovation policy related discussion in the Nordic countries, many business representatives have pointed out a need for more public funding support on commercialisation.

ward. The importance of instrument timing and providing support for the appropriate intervals has been demonstrated in the cases of both the pulp and paper and building industry. Positive synergies have been seen in the case of the pulp and paper industry in regards to innovation and environmental policy, supporting the value of supply and demand side measures in some instances (see also Kivimaa and Mickwitz, 2004). While economic drivers have assisted in facilitating market formation in some cases, the interventions which have directly encouraged innovation have largely been of a mandatory administrative nature.

Table 5: Government interventions positively influenced innovation activities in cases studied in the three sectors

Government interventions positively influenced innovation activities	Policy field (environment/innovation)	Typologies of policy instruments	Influenced activities identified in the case studies (M: mobile phone, B: building, P: pulp & paper)
Provision of funding directed to individual projects	Environment/innovation	Informative/economic	Knowledge creation (M,B,P), knowledge pool and transfer (B, P) , commercialization (P)
Public R&D programmes	Mostly innovation	Informative/Economic	Knowledge creation, pool and transfer (P, B)
EuP Directive	Environment	Administrative/informative	Knowledge creation (M)
EU Directive on the promotion of transport biofuels	Environment	Administrative	Knowledge creation and commercialisation (P)
Tax relief for renewable fuels	Environment	Economic	Commercialisation (P)
EPR-based system on packaging and packaging waste	Environment	Administrative & economic	Commercialisation, diffusion (P)
Tax on plastic packaging	Environment	Economic	Commercialisation, diffusion (P)
Anticipation of increased limits of heavy engine emissions	Environment	Administrative	Access to private resources, which supported knowledge creation and commercialisation (P)
More stringent standards in the building code	Environment	Administrative	Commercialisation (B)

4.2 Sectoral dynamics, innovation and policy Implications

The previous section has identified a series of similarities and differences between the examined sectors and has highlighted some of the policy interventions that have played a role in the innovation processes. A first conclusion from this project is that sectoral dynamics and innovation characteristics vary across sectors and that successful system changes require a combination of various interventions that are sensitive to these sectoral differences in line with earlier remarks in related literature (Guy,

2002; Malerba, 2005). To further be able to provide guidance on policy choices, it is relevant to explore the environment for innovation created by these differences. Therefore, our discussion here concentrates on exemplifying how selected factors could potentially raise important implications on the appropriateness of different policy stimuli. In the first section we consider examples from the case studies where the industry structure and market forces operating within an industry may potentially demand particular attention when designing policy intervention. In the next section we highlight examples where the nature, scope and user of innovation warrants particular attention for a meaningful discussion on enabling green markets.

4.2.1 Industry structure and market coordination

The three sectors examined in this project provide practical examples of the variety in industry dynamics shaped by among others the degree of ownership integration in an industry, the degree of coordination integration in an industry network and the ability of lead actors to influence market coordination with regard to information flows. It is expected that these differences would create different constraints and opportunities for development of green markets. The following distilled observations from the sector studies could potentially provide general guidance to understanding the constraining and enabling environment for the different innovation activities.

Horizontal and Vertical Integration

Vertical integration of a value chain, as found in the pulp and paper industry, tends to facilitate the networking and the innovation process, allowing for easier collaboration between actors. The industry manages to position itself in the forest cluster to benefit from technological advancement of its suppliers that feeds to its process innovation. In such a case, the role of government intervention can be fostering the integration of environmental consideration through, for instance, incorporating environmental criteria when providing R&D funding.

Meanwhile, in a sector such as the construction industry, where horizontal integration is often key to successful adoption of a particular innovation, the emphasis on supporting coordination integration may provide an entry point for a policy intervention. As we have noted earlier, segmentation between actors and the lack of recognition of clustering benefits represent a potential barrier to successful knowledge transfer and innovation generation in the building sector. Research programmes, such as SaMBA and CUBE, which incorporate a variety of actors in the value chain, including end users, could be promoted to help strengthen and foster relationships within the industry.

On the innovation adoption end, developers of an innovation must also attract the attention of a diverse set of actors and establish credibility. This process could be costly in a fragmented industry such as the construction industry. Tools which facilitate this process and which demonstrate product performance have been shown to be valuable in the commercialisation of material and system (ventilation case for example) innovations within the industry. In such contexts, institutional arrangement that could facilitate information flows and helping environmental innovators gain credibility will be valuable for environmental innovation. Related to this, various actors in the building industry have agreed that the building code is a valuable tool, perhaps partially due to its ability to provide a standard to which actors within an otherwise fragmented industry can relate. The building code could potentially be used as a means of improving energy efficiency throughout the sector by mandating better performances and therefore providing an important market opportunity for new innovations.. Public procurement of energy efficient buildings could be used to support this method. While individuals within the industry have questioned the potential of the energy labeling directive, labeling, benchmarking and publication of data may help to gradually raise the level of awareness of consumers, assisting in conjunction with supply side measures. One recommendation which has been put forward during discussions with a developer concerns the possibility of increased standardisation of the building code across the Nordic countries, in an effort to encourage competition and facilitate transfer of knowledge and ideas across borders.

Contrasting this, is the presence of dominant players that could assume greater responsibility for the coordination integration. As observed in the mobile phone industry, the operators of mobile phones have a significant demand power in terms of both mobile phones and networks, and there exists the opportunity for a strong demand side pull by these actors as has been shown in the past. Targeting these actors through policy measures, such as voluntary agreements to endorse and request environmental improvements in products, may represent one way to drive forward green innovations in this field. The short life-span of mobile phones is not due to technical reasons but is mainly caused by the subsidization of new phones by the operators, so this payment structure has to be changed in order for the consumers to recognize the real cost of the device (Dirckinck-Holmfeld et al., 2007).

Voluntary agreements may function well within an industry that is dominated by so few global players, however, the difficulty in pushing the industry above the “no pain” threshold without additional reward or threat has been witnessed with the Code of Conduct. While IPP has been criticised for shifting responsibility to the consumer, use of the supplier to undertake informational interventions may provide an opportunity. If, for example, messages regarding environmental impacts of the phone during

use and disposal were passed through the brand holder upon sale through labels or notices on the phones this could help increase awareness of the consumer (particularly since these brands have significant marketing power and skills).

Local steering in a global industry

The observation here is to what extent local steering matters in an industry that operates on a global scale? The mobile phone industry operates on a global scale and within the larger context of the electronics sector. Efforts to realise changes may be best made at an international (e.g. EU or at least Nordic level). In some cases, such as network evolution, decisions must be taken as a result of the compromises of interests of a variety of actors. Even when decisions appear to be potentially beneficial from an economic and environmental perspective, they may not be taken due to conflicting interests and factors. In these cases, while controlling the direction of the innovation through regulatory measures may be difficult, measures targeted at the knowledge and resources side of the innovation process using innovation policy could potentially be used to steer Nordic developments into a more environmentally favourable direction (for example, more research programmes for energy efficient options in the industry). This technique could further be extended towards other areas of product development within the industry. While the industry has demonstrated high innovation ability, additional emphasis on environmental considerations represent further opportunities for Nordic differentiation through specialization.

Exports represent a significant market for the Nordic pulp and paper industry. Therefore, similarly to the mobile phone industry, policy interventions to realise product change may be best directed at the EU level. As environmental product innovations have been much rarer than process innovations in the sector, policy development processes should consider how product oriented (e.g. IPP) policies best fit to support innovation in this sector. As the sector is experiencing significant changes in its operational environment reducing its stability and the more radical innovation cases show the importance of cross-sectoral cooperation, new policy instruments for innovation may not be so sector-specific but rather support environmentally sounder innovation that combines ideas and good practices from different business sectors.

Capital Intensity and Lock-in

The capital-intensive nature of the industry can serve as a barrier to the innovation process, dissuading the industry from investing in new capital-intensive technology. The pulp and paper industry in the Nordic countries has experienced significant regulation over the past decades and the industry has made extensive environmental improvements in its processes, partially as a result of these regulations (e.g. Kivimaa, 2008). Sector in-

terest in environmental improvements related to resource and energy efficiency appear to be relatively well established, due perhaps to a combination of factors including the long standing public pressure and regulatory concern regarding pollution, and desires for economically beneficial mill-level improvements. The sector has established a unique innovation network that allows it to benefit from the knowledge generation activities and networks of its cluster members. As such, research programmes which promote networking amongst actors and stress the inclusion of the technology users at an early stage are important in order to secure interest and to help facilitate the commercialisation process for these innovations. In light of the capital-intensive nature of the industry, consideration should be given to the appropriate duration of funding programmes that can help to provide the necessary support where it is often crucially needed at the demonstration phase (as shown, particularly, in cases such as the bio refinery developments, where risk appears relatively high). Venture capital and other private funding can play an important role in the innovation process, particularly in such a capital-intensive industry and can provide the necessary catalyst for commercialisation. The establishment of programmes that can assist companies in obtaining funding during critical phases such as development and demonstration could serve a valuable role in the innovation process.

On the other hand, actors may experience a knowledge capital lock-in situation, as found in the building industry, similar to that capital lock-in experienced by the pulp and paper industry. In this case, changes to the building processes require a significant amount of investment in terms of new procedures and new knowledge that must be acquired. Consequently, like their pulp and paper counterparts, the building industry actors may find themselves in a more reluctant position to demand and integrate new technologies. In these cases, where the developer/contractor and their consultants may often be in one of the most significant position to influence building decisions, the potential result is a sort of “supplier-dominated” innovation process. In this case, supplier targeted measures may represent one of the most appropriate courses of action. It is interesting to note, however, that in terms of energy efficiency, a large number of policy intervention measures have come in the form of economic instruments and demand side programmes (including the new building labelling programme). As suggested by a number of actors, advancing energy efficiency requirements in the building code itself and in the form of other “supply side” (contractor-oriented) measures may help to achieve the necessary markets for new technologies created within the material, equipment and service industries.

In the case of the building automation industry, as in the case of the mobile phone industry, subsidisation of conventional products has been identified as a potential issue affecting commercialisation opportunities.

Prevention of such product subsidisation measures may help with the alleviation of the market lock-in situation.

Industry Cycle

The cyclical nature of markets creates certain challenges for the knowledge base of an industry. In the sectors studies, this situation presented itself strongly in the building construction industry. Therefore efforts to help maintain and make use of this research base during the economic down cycles, which have traditionally been associated with loss of personnel and lack of development, could help to ensure continued progress within the industry. This technique has been used in the pulp and paper sector in the past, and the sector has involved into a unique innovation system. Typically, the construction market follows the general economic trend, measured in terms of GDP, but with a time lag of at least one year. The housing market reacts most quickly to the cycles, with other building construction being subject to a greater lag (NCC, 2006). Efforts to achieve stabilisation of the industry's human resource and research base require the provision of programmes prior to the down cycle that are capable of accommodating inflows of graduates, researchers and skilled individuals during down times, perhaps through a funding reservation system supported by industry and/or government.

4.2.2 *The nature, scope and user of an Innovation*

Together with the attention to industry structure, characteristics of innovation that affect developer-user interactions provide a second layer of analysis for the appropriateness of policy stimuli. One aspect we would like to highlight here is the range of users of an innovation. In some instances the innovation has a limited number of users and hence the need for communication is restricted to a number of narrow and easily definable groups as observed in the cases from pulp and paper and the electric charger case. The other case is when the developer is a small firm and the population of customers is large and diverse (for example the case of building automation systems). Such a case requires information coordination that is beyond the resources of the small firms. Coordination support like the one found in the building automation systems case can help to overcome the problem.

The number of users is among the factors that influence the information flow between the developer and the user of innovation and corresponding incentives for user to pay more for the improvement. The perceived lack of demand on environmental innovation, as found in the mobile phone sector and the building sector, can be attributed to, among others, the insufficient communication on the availability and benefit of an environmental innovation. The users' unwillingness to pay more for the added-value of an environmental innovation leads to the discrepancy

between the risk bearer and beneficiary of the innovation, thus may hamper the commercialization. There, informative instruments such as eco-labels and technology verification system can be useful.

Another aspect of the characteristics of innovation is the degree of systemic change it induces and with that the uncertainty created for users. A case is if the innovation necessitates corresponding changes in other parts of a system (for instance, the use of insulation foundation requires changes in the routines of construction workers) or if it is autonomous which means adoption is not affecting other parts of the system (mobile phones selling a more efficient charger). The uncertainty created by the changes induced by the innovation may in some cases necessitate particular institutional arrangements, as experienced in the development of bio fuels in the pulp and paper sector.

A third aspect which is not entirely unrelated to this discussion is the environmental dimension in the innovation itself. A relevant question to be raised here is: to what extent environmental feature can be close to core features (internal improvements) versus to what extent environmental features are solely based on the need to satisfy regulatory requirements? These differences could potentially create different incentives for both development and adoption. For instance and as in the case of mobile phones, energy efficiency represents a core business consideration due to operational requirements (e.g. sufficient battery life or usage time), which may provide additional incentive to brand holders for energy efficiency improvements in that domain. In the case of accessories, such as the chargers, however, the same incentive does not apply. In these cases, a clear, external signal may be required to induce innovation and diffusion, such as mandatory standard. Industry could, utilise the compliance with the legal mandate as its selling point, as experienced in the building sector.

4.3 Towards a Nordic Contribution to ETAP

4.3.1 Lessons from the case studies & the need for interaction of environmental and innovation policies

All of the cases reviewed here have served to emphasise the importance of multidisciplinary approaches to solving environmental problems. In order to realise more radical innovations, knowledge and experiences from a diversity of fields has been combined, bringing to light new solutions and new system possibilities. The experiences from one field can bring ideas into another area that may result in new innovations, as has been seen from cases in both the building and pulp and paper sectors. Additionally, sectors can learn from one another absorbing concepts and ideas that can improve efficiency and environment. As such, well di-

rected innovation policies, such as inter-industry research programmes, experience centres, and researcher and staff mobility programmes, may be beneficial to the development of environmental innovations. In the cases of both the pulp and paper sector and the building sector in particular, it has been observed that research activities and collaborations often occur within a national context. While this may partially be the result of the traditionally localised nature of the industry, increased cooperation at a Nordic level also represents a unique opportunity to strengthen the innovation potential of these sectors. For example, in one of the case studies within the building sector, innovation has resulted from the transfer of an idea from one country to another.

The cases from all the sectors confirm the importance of education as the essential knowledge base for providing highly skilled human resources. A significant number of engineers in the pulp and paper industry has received education in the Nordic countries, and the large market share of the mobile phone sector in the Nordic countries, together with the sector's characteristics as knowledge-intensive industry, indicate the strong knowledge base the Nordic countries possess in this sector. Maintenance and further nourishment of the knowledge base in the Nordic countries, accompanied by the interaction between the universities and the industry, would contribute to furthering innovation activities within and outside of the region.

The case studies have also reinforced the importance of the notion that the interaction of policy instruments can play a significant role in regards to innovation. Environmental policies or policies from other fields can interact in the innovation process, serving as a barrier or a driver for innovation, as has been noted in the case of the building industry (fire code) and the pulp and paper industry (green certificates). As such, a holistic view of the sector and policy setting is required in order to help avoid conflicts and manage the innovation process.

Lack of consumer demand/awareness has arisen as an issue in all of the sectors studied. Necessity of stipulating demand has been highlighted as priority issues in the report on the ETAP implementation between 2005–6 as well. (COM(2007) 162 final). Ecolabeling is one of the measures of supporting consumer awareness and demand for environmentally friendly products. The efficiency of eco-labeling systems is not pre-given but depends on many issues among other things the trustworthiness of the label, the administrative complexity and the capability of continuously being up to date and relevant concerning the environmental issues in the consumption areas covered. The Nordic Swan eco-label is among other things used in the areas of paper and housing and energy labels exists for instance refrigerators, washing machines and other white goods and for houses. Further development and extension of eco-labelling systems can be central for ensuring environmental innovation. The opportunities for extending the role of eco-labels in international supply chains and in

product marketing on foreign markets are among the important issues to pursue. Apart from ecolabelling systems, coordinated Nordic activities influencing international standards, target settings and certification systems can in many cases be fruitful, also apart from ecolabelling systems. It can lead to opportunities for establishing leading roles on the markets while at the same time driving environmental improvements. Export-promoting activities on environmental technologies and energy technologies have been established by Nordic countries in the latest years in a number of instances. As some of the challenges on the globalizing markets are common for the countries, there can be advantages in making Nordic joint activities on this in selected product areas and sectors. For example, it might be fruitful to carry out joint export-promoting activities of environmentally friendly buildings, building components and/or connected consultancy services. The Nordic countries could do this as active contribution to broader European export-promoting activities. The synergies might, however, appear primarily on the level of a few countries rather than on the level of Europe in general and it is important to maintain the relevance for the industry in each of the countries involved.

4.3.2 Contributions towards action points of the ETAP

Finally, lessons learned in relation to action points of the EU Environmental Technologies Action Plan (ETAP), as clustered into eight groups in the national roadmaps by the EU Member States (see Appendix 3), are summarised in Table 6.

Table 6: Summary of findings relevant to the EU ETAP action points

ETAP Action	Relevant findings from the GMCT project
Research and development	<p>Education is essential for provision of highly skilled human resources and has been the strength in the innovation systems in Nordic Countries. This, together with the further nourishment of interaction between the universities and the industry, is vital for further development of the innovation system.</p> <p>Public funding can effectively address, for instance in their criteria for provision of resources, the integration of various industrial and non-industrial actors, cross-sectoral collaboration and inclusion of SMEs in the innovation process.</p> <p>R & D funding can be a powerful tool to direct innovation activities towards those addressing environmental concerns. Public funding is especially useful/necessary when the environmental innovation is not connected to the core business concern of the industry, when the changes require large resources (e.g. in capital-/knowledge intensive industry) and/or require changes outside of the target areas.</p>
Verification of technologies	<p>Verification of new technologies by an independent third body has been useful in commercialising a new solution, especially in a sector such as the building industry which is relatively conservative and risk bearer and beneficiary of the innovation is fragmented.</p>
Performance targets	<p>Mandatory performance standards can be a useful way of disseminating and commercialising environmental innovation beyond the level that can be achieved in a non-pain scenario, especially when the actors in a value chain are fragmented and the innovation in question is not linked to the core business of the industry (examples found in the mobile phone and building industry).</p>
Mobilisation of financing	<p>Financial facility can play important roles not only in the creation of knowledge, but also in the facilitation of knowledge pool and transfer.</p> <p>Criteria for provision of financing can be used to orient the direction of the innovation to an environmentally beneficial one, and to facilitate the SMEs' access to financial resources.</p>
Market-based instruments and state aid	<p>Formation of market has been facilitated by tax/tax relief in some cases in the pulp and paper industry. The provision of subsidies to conventional technologies has hampered the development of new solutions, and continued efforts is needed to remove environmentally-harmful subsidies</p>
Procurement	<p>Green public procurement was not found in the cases examined in the three sectors. However, it can be a very strong driver for environmental innovation, especially when the standards are set in a level beyond what can be achieved in a business-as-usual scenario. The applicability of the instrument at the local level allows setting the target at an ambitious level, and different levels of governments in Nordic countries can lead the process</p>
Awareness raising and training	<p>Benefits of environmental innovation can be better communicated via improved connection between developer and user of the innovation. Informative instruments such as labelling schemes, which has been successful in Nordic countries, and technology verification system can be further promoted to facilitate the communication.</p>
Acting globally	<p>In the case of product innovation, the benefit is brought forward to the developing countries via exportation of the product, as experienced in all three sectors.</p>

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- K.R. Dirinck-Holmfeld, Project team member, Aalborg University, Denmark (1 Aug 2007)
- P. Singhal, Nokia Corporation, Singapore (formerly Finland) (10 July 2007)
- C. Moussette, Industrial Designer, Masters Project – Mobile Phones, Umeå University, Sweden (30 June 2007)
- S. Lundberg, Ericsson, Sweden (27 August 2007)
- P. Kivimaa, Project team member, Finnish Environment Institute, SYKE, Finland (19 July 2007)
- H. Toivanen, Ministry of Trade and Industry, Finland (15 Aug 2007)
- J. Laurila, Helsinki School of Economics, Finland (13 Aug 2007)
- M. Fritzon, Skanska, Sweden (8 Aug 2007)
- J. Fabiano, Prism Construction Ltd., Canada (2 Aug 2007)
- R. Linturo, Lonix, Finland (2 Aug 2007)

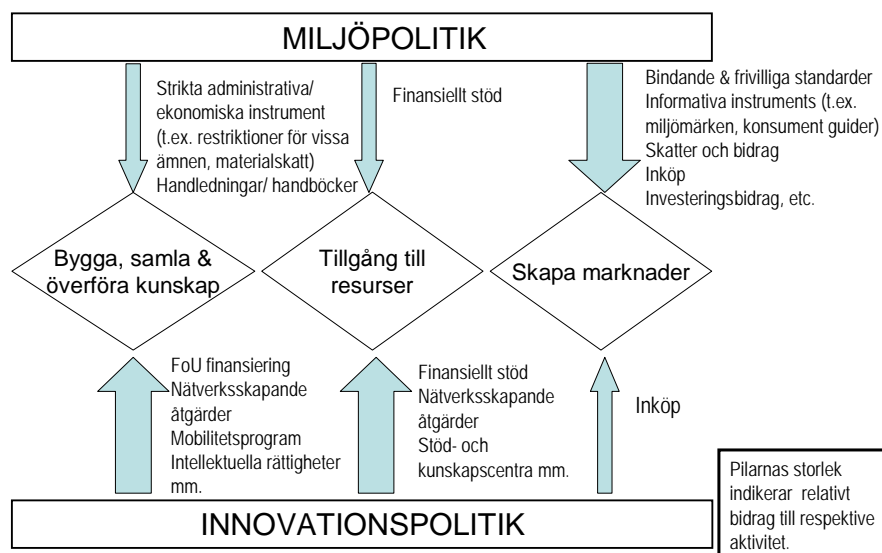
6. Sammanfattning

Både Europeiska unionen och de nordiska länderna ser stöd till miljöteknik och -innovation som en väg för att uppnå de båda målen att bibehålla konkurrenskraft i en dynamisk och kunskapsbaserad ekonomi och samtidigt integrera miljöhänsyn i denna process. Detta har även slagits fast i EU:s handlingsplan för miljöteknik – ETAP (European Environmental Technologies Action Plan). ETAP pekar bl.a. på det faktum att trots en mycket stor teknisk potential för miljöteknik är det ännu ett underutnyttat område och arbetar därför för att identifiera policyåtgärder som stödjer kommersialisering och spridning av miljöinnovationer.

I detta sammanhang har Nordiska Ministerrådets grupp för Integrerade ProduktPolitik finansierat ett tvåårigt forskningsprojekt “Grön marknad och rena teknologier – ledande nordisk innovation och tekniska möjligheter för framtida marknader” – GMCT (Green Market and Clean Technologies – Leading Nordic Innovation and Technological Potential for Future Markets). Projektet genomfördes under 2006–2007. Det övergripande målet för GMCT-projektet har varit att bidra med analyser av olika handlingsvägar för att stärka utveckling och spridning av miljöteknologi dels genom att undersöka de arbeten som redan genomförts i de nordiska länderna, dels genom djupare analyser av praktiska miljötekniska exempel. Syftet har varit att identifiera policyinterventioner som även kan tillämpas för andra branscher än de som analyserats i detta arbete och därigenom bidra med underlag till diskussionen om möjligheter för en nordisk handlingsplan för miljötekniksstöd. Projektet är ett samarbete mellan fyra nordiska forskningsinstitutioner: Internationella institutet för industriell miljöekonomi (IIIEE) vid Lunds universitet (projektkoordinator), Finlands miljöcentral (SYKE), Institutet för samhällsutveckling och planläggning vid Aalborg universitet och Risø Nationella laboratoriet för hållbar energi vid Danmarks Tekniska Universitet.

Projektet består av följande fyra huvudkomponenter: 1) litteraturgenomgång och utveckling av ett gemensamt analytiskt ramverk, 2) genomgång av nationella innovationssystem, 3) fallstudier i tre branscher: bygg, massa och papper samt mobiltelefoni, 4) syntes av resultat från fallstudierna relevanta för policyutveckling (innehållet i denna rapport). Vi valde att utgå från ”innovationssystem” som grund för det analytiska ramverket och kom fram till tre centrala aktiviteter som stimulerar innovation: skapa, överföra och sammanföra kunskap, tillgång till resurser samt skapande av marknader. Branscherna valdes baserat på relevansen för de nordiska länderna, tillgång till befintlig information, möjligheter för branschöverskridande jämförelser samt förekomst av olika typer av miljötekniker och miljöinnovationer.

Denna slutrapport kombinerar resultaten från branschstudierna för att bidra till utvecklingen av effektiva policyinterventioner som understöder miljöinnovationer. Rapporten sammanfattar de övergripande resultaten från de tre branschstudierna – detaljerna finns tillgängliga i separata rapporter – och gör en branschöverskridande analys av centrala frågeställningar för policyutveckling. Studien fokuserar på två slags offentliga interventioner centrala för miljöinnovationer – miljöpolitik och innovationspolitik – och undersöker miljöaspekter i innovationspolitik och innovationsaspekter i miljöpolitik. Rollen för befintlig miljö- och innovationspolitik i relation till de tre nyckelaktiviteter som valts ut för detta projekt summeras grafiskt på nästa sida.



Genom analyser av fallstudier i tre branscherna i de nordiska länder lyftes flera frågeställningar som påverkar de tre innovationsaktiviteterna fram. Beträffande kunskap omfattar dessa frågeställningar mångfalden av kunskapskällor och orsaker till kunskapsbyggande, de små och medelstora företagens roll för att generera kunskap, användande av intellektuella rättigheter, medverkande aktörers referensramar samt värdekedjans struktur. När det gäller resurser visade den branschöverskridande analysen likheter och skillnader för hur de olika branscherna finner personal med lämpliga kvalifikationer, offentligt finansiellt stöd och andra finansiella resurser så väl som hur företagens egna resurser används. När aktiviteter relaterade till skapande av marknader analyserades belystes speciellt kundernas och leverantörers roller och positioner i leverantörskedjorna, den relativa betydelsen för innovation inom branschen, avvikelser mellan avnämnare och kostnadsbärare för en enskild innovation samt kostnader och efterfrågan från slutkund.

Några av dessa frågeställningar är gemensamma för alla tre branscherna. Där finns t.ex. miljöinnovationer i alla tre branscherna med ursprung i

flera olika kunskapskällor i industrin och i akademisk forskning samt interna och externa för respektive bransch. Offentligt finansiellt stöd förefaller betydande för att stödja byggandet av ny kunskap, speciellt när det krävs samarbete mellan flera aktörer. Utbildning – och kopplingen mellan industri och universitet – utgör en väsentlig grund för rekrytering av välutbildad arbetskraft. En nära koppling till utbildning hjälper också till att etablera gemensamma referensramar för de aktörer som är engagerade i samma innovationsprojekt vilket är en viktig aspekt för att underlätta tillgång till och överföring av kunskap. Det finns exempel från samtliga tre branscher där befintlig eller förväntad kommande miljölagstiftning har spelat en roll för kunskapsbyggande och kommersialisering av ny kunskap. Det finns emellertid också exempel på att innovationer skedde utan offentlig påverkan. Behovet av offentlig intervention och andra former av extern påverkan beror bl.a. på huruvida miljöinnovationen i fråga bidrar till företagets kärnverksamhet eller inte. En utmaning vid kommersialisering och spridning av miljötekniska lösningar inom de tre branscherna är att samordna informationen till slutanvändare med motsvarande incitament för att använda den. En fråga som också relaterar till detta är industrins behov av att hålla kostnaderna nere.

Några speciella fenomen och bidragande faktorer som identifierat genom undersökningen har emellertid sina rötter i unika branschspecifika egenskaper. Inom exemplet mobiltelefonbranschen, som kännetecknas av tillväxt genom utveckling och kommersialisering av nya produkter, lägger en relativt stor andel av resurserna på aktiviteter inom forskning och utveckling. Ett annat exempel är den brutna erfarenhetsåterföringen inom byggindustrin vilken uppfattas beror på branschens projektbaserade arbetssätt men också att de ekonomiska konjunktursvängningarna ger en stark påverkan på sektorn. Det finns förekommer erfarenheter och faktorer som trots att de har sina ursprung i respektive bransch kan generaliseras. De omfattar bl.a. skillnader mellan avnämna och de aktörer som bär kostnaderna för innovationerna, stora kunders möjligheter att styra marknaden, bindning av kapital i befintlig utrustning/kunskap, kund eller leverantörsdriven innovation samt om leverantörskedjorna är vertikalt integrerade eller fragmenterade.

Behovet av skraddarsydd policyinterventioner tenderar att vara högre i de förra än i de senare. I båda fallen finns emellertid en potential för att överföra erfarenheter, speciellt när andra branscher har erfarenheter av lösningar för liknande utmaningar. Vid betraktande av industristruktur, aktörernas förmåga att koordinera innovationsaktiviteterna på marknaden samt själva innovationens natur, omfattning och användare finns bland de faktorer som utkristalliserats från fallstudierna som kan vara betydelse vid val av policy. Den fundamentala utgångspunkten i samtliga fall är att identifiera orsaker och verksamma påverkanspunkter.

Beträffande offentlig intervention har fallstudierna bidragit med insikter i vad litteraturen anger karakteriserar den gröna innovationspolitiken

omfattande både traditionell innovationspolitik som nedför miljöförbättringar och miljöpolitik som medför innovationer. Miljöinnovationer har i samtliga branscher gynnats av offentligt finansiellt stöd vilket har underlättat aktiviteter genom att bygga, samla och överföra av kunskap. I några fall bidrog stödet också till kommersialisering av innovationer. Fallstudierna har styrkt intrycket av att miljöpolitiken kan spela en viktig roll genom att skapa marknader för innovationer men har också visat på miljöpolitikens möjligheter att inspirera kunskapsbyggande aktiviteter genom att sända signaler för framtida marknadsinriktningar. Strikta krav och ambitionsnivåer i ny lagstiftning har drivit fram innovationer i byggsektorn och minskat marknadsosäkerheter som har stimulerat innovation inom massa- och pappersindustrin.

Betydelsen av rätta tillfället för att sätta in ett policyinstrument och att erbjuda stöd under lämpliga tidsperioder har visats av både fallstudierna i massa- och pappersindustrin och i byggsektorn. Några exempel på positiva synergieffekter har noterats mellan innovations- och miljöpolitik för att skapa värde för åtgärder både på utbuds- och efterfrågesidan. Medan ekonomiska drivkrafter i några fall har bidragit till att skapa efterfrågan för miljöinnovationer är den intervention som direkt har gynnat miljöinnovation varit av bindande administrativ natur.

I stödet för det nordiska bidraget till ETAP kan de nordiska länderna, utöver kontinuiteten i att erbjuda en god utbildningsbas för innovation, göra direkta interventioner för att underlätta kunskapsflödet mellan branscher och sektorer, olika discipliner, industriella och icke-industriella aktörer och mellan länder. De kan förenkla byggandet av kunskap som bidrar till miljömässiga förbättringar. Fallstudien bekräftar de utmaningar som ligger i spridning av miljöinnovationer trots tillgång på kunskap. Utöver de olika åtgärder som bidrar till slutanvändarnas medvetenhet och efterfrågan bör arbetet med att stödja kunskapsflödet mellan aktörerna i värdekedjan, och då inte minst slutanvändarna, ges en central plats. Syftet är att ge sig i kast med skillnaderna mellan de som tar riskerna och de som tjänar på en innovation. För att reflektera dessa lärdomar är de punkter som de nordiska länderna kan överväga för konkret offentlig intervention belysta i slutet av rapporten i enlighet med ETAP:s åtta områden för handling.

7. Appendices

7.1 Appendix 1: Final Program for policy workshop

The workshop, entitled “Linking Policy on Environment and Innovation – ETAP-relevant experiences for Nordic countries” is held as part of the project Green Market and Clean Technologies, whose overall findings is summarised in this report. Having the case findings as a starting point, the barriers and opportunities for furthering ETAP in Nordic countries will be discussed, with the intention to answer the following question: what changes should be made in a) the environmental policies and b) in the innovation policies in order to further ETAP and achieve Lisbon objectives?

The workshop was held on 4 October at Copenhagen, Denmark. It was generously hosted by Øresund Environment Academy.

09.00 **Coffee and registration**

09.30 **Session 1: State of ETAP in Nordic Countries**

Introduction of the project and participants: Åke Thidell, IIIIE

Welcome to and introduction of Øresund Environment Academy: Jacob Juul, ØEA

General Introduction to Environmental Technologies Action Plan: Jakob Weichert, European Commission

ETAP in Denmark: Rikke Traberg, Danish EPA

ETAP in Sweden: Berit Gullbransson, SWENTEC

ETAP in Finland: Merja Saarnilehto (MoE) and Mervi Salminen (Mol), Finland

ETAÅ in Norway: Per Sander Døvre, Norwegian Pollution Control Authority

11.05 **Session 2: Linking Policy on Innovation and Environment – introduction**

Links between policies and environmental innovations – general introduction to the theme: Paula Kivimaa, SYKE

Influences of environmental & innovation policy on environmental innovation – overall project findings: Morrigan Hayes / Naoko Tojo, IIIIE

Discussion & comments from participants (Moderator: Åke Thidell, IIIIE)

LUNCH

13.00 **Session 2 (cont.): Linking Policy on Innovation and Environment – findings and discussion**

Three Sector studies and insights to ETAP

Pulp and paper: Petrus Kautto, SYKE

Electrical and electronic equipment: Arne Remmen, Aalborg University

Building: Tareq Emtairah, IIIIE

+ Discussion & comments from participants (Moderator: Mads Borup, Risø National Laboratory)

Synthesis: Mads Borup, Risø National Laboratory

14.15 Session 3: Barriers and Opportunities for the ETAP in Nordic countries

Roundtable discussions of ETAP working groups in Nordic countries (Moderator: Naoko Tojo, IIIIEE)

- Merja Saarnilehto, MoE and Mervi Salminen, Mol in Finland
- Gert Hansen, Danish EPA
- Anna Hallgren, Vinnova, Sweden
- Per Sander Døvlø, Norwegian Pollution Control Authority

Discussion will be made in light of the on-going development of ETAP at the European Level. Examples of themes include: a) Technology platforms – opportunities and limitations. How can environmental benefits be ensured? b) How to make environmental R&D support and green market demands meet? c) Masters and servants – can industry lead public-private partnerships ensure environmental policy? d) Lack of binding targets

Coffee break

15.30–17.00 Session 4: Group Discussion and Synthesis of the Workshop

Introduction to group discussions: Mikael Hildén, SYKE

Group discussions are organized focusing on the following:
What changes should be made in a) the environmental policies and b) in the innovation policies in order to further ETAP and achieve Lisbon objectives?

Synthesis of group discussions and final words, Mikael Hildén, SYKE

7.2 Appendix 2: Participants of the policy workshop

	Name	Organisation
1	Jakub Wejchert	European Commission
2	Micael Hagman	Ministry of the Environment
3	Martin Flack	Swedish Institute for Growth Policy Studies
4	Berit Gullbransson	SWENTEC
5	Morten Brønnum Andersen	Danish Authority for Enterprise and Construction, Division for Research and Analysis
6	Stig Hirsbak	Consultant
7	Erik Hagelskjær Lauridsen	DTU
8	Mervi Salminen	Ministry of Trade and Industry
9	Merja Saarnilehto	Ministry of the Environment
10	Peter Malmström	Federation of Finnish Technology Industries
11	Per Sander Døvlø	Norwegian Pollution Control Authority
12	Michael Rantil	Energimyndigheten
13	Rikke Traberg	Miljøstyrelsen
14	Gert Hansen	NMRIPP
15	Lotte Kau Andersen	Miljøstyrelsen
16	Anna Hallberg	VINNOVA
17	Kasper R. Dirckinck-Holmfeld	Miljøministeriet, Miljøstyrelsen
	Jacob Juul	Öresund Environment Academy
18	Mikael Backman	Öresund Environment Academy / IIIIEE
19	Tareq Emtairah	IIIIEE
20	Naoko Tojo	IIIIEE
21	Åke Thidell	IIIIEE
22	Bernadett Kiss	IIIIEE /ÖEA
23	Morrigan Hayes	IIIIEE
24	Arne Remmen	University of Aalborg
25	Trine Pipi Kraemer	University of Aalborg
26	Mikael Hildén	SYKE, Finnish Environment Institute
27	Petrus Kautto	SYKE, Finnish Environment Institute
28	Paula Kivimaa	SYKE, Finnish Environment Institute
29	Mads Borup	Risø National Laboratory

7.3 Appendix 3: status of Environmental Technology Action Plan (ETAP) as of autumn 2007

The following summary, prepared by the GMCT project team at the International Institute for Industrial Environmental Economics at Lund University, was provided as a background document to the policy workshop – Linking Policy on Environment and Innovation held on 4 October 2007 (see Section 7.1)

Environmental Technologies Action Plan (ETAP) – where does it stand now? – A background document for the workshop on Linking Policy on Environment and Innovation

Environmental Technologies Action Plan (ETAP) was developed as a means for the EU to survive in a transition to the competitive, dynamic and knowledge-based economy (Lisbon Strategy) while integrating the environmental considerations in this process as agreed in the 2001 Göteborg European Council. Since the development of the ETAP Communication by the European Commission in 2004, the recognition on the importance of environmental technologies seems to have continually gained ground in the European policy arena. For instance, Commission's Communication on the Lisbon Programme recognises "significant economic, environmental and employment potential in environmental, energy efficient and renewable energy technologies." The European Council in spring 2006 mentioned of the importance of environmental policy in contributing to jobs and growth, and further endorses ETAP and some of the concrete actions discussed in ETAP.

Implementation of ETAP to date

Since its launch in 2004, the European Commission produced two reports on the implementation of ETAP. The first report highlighted some of the concrete actions implemented in 2004. Moreover, the report put together nine points as next steps for ETAP implementation, including, among others, the establishment of EU wide system for verification of environmental technologies, mobilization of additional risk funding for eco-innovation and environmental technologies, and development of national roadmaps by Member States by the end of 2005.

The ETAP national roadmaps should provide an overview of existing activities pertaining to ETAP in the respective Member States, where they are heading for and how they intend to reach the envisioned outcomes.

It was suggested that the national roadmaps include 1) overview of "state of the art" or "state of play, 2) existing strategies and action plans, 3) milestones and measures, 4) major achievements and best practices. The intention is to facilitate the exchange of knowledge and experiences between Member States as well as the obtainment of overall progress

across Europe. As of September 2007, the national roadmaps of 21 Member States plus Norway are available on the Commission’s homepage. In the national roadmaps, the 25 action items set forth in the Commission’s Communication in 2004 are grouped in 8, as found in the table in the next page. Member States were asked to describe activities most relevant to them in line with these 8 items.

An analysis of the national roadmaps in the 21 countries indicates that Member States have been active in prompting eco-innovation, and diversified measures have been taken. Among various measures taken, most of the Member States put emphasis on the research and development – supply side of the innovation activities. Meanwhile, the activities related to demand side – bringing the technologies developed to market and facilitate diffusion – is less consistent. According to the analysis, Denmark, Sweden and Finland are among the exceptions where the actions distributed evenly across all the ETAP-relevant activities. The report also suggested that most of the countries focus on the measures currently taken without talking much about the future outlook and vision.

Priority groups in national roadmaps	Action items specified in Commission’s Communication on ETAP
Research and development	Increase and focus research, demonstration and dissemination. Improve coordination of relevant programmes. Establishing technological platforms
Verification of technologies	Establishing European Networks of technology testing, performance verification and standardization. Develop an EU catalogue of existing directories and databases on environmental technologies. Ensure that new and revised standards are performance-related
Performance targets	Develop and agree on performance targets for key products, processes and services
Mobilisation of financing	Mobilising financial instruments to share the risks of investing in environmental technologies. Public/private partnerships. Promote new business niches. Financial instruments for renewables and energy efficiency technologies Measures in support of eco-industries. Promote socially and environmentally responsible investment. Dissemination of good practices among financial institutions. Identification of opportunities to integrate environmental technologies when capital stock is replaced. Review operational criteria of the Structural Funds
Market-based instruments and state aid	Review state aid guidelines. Encourage systematic internalization of costs through market-based instruments. Review environmentally-harmful subsidies
Procurement	Encourage procurement of environmental technologies. Life cycle costing promotion. Investigation of technology procurement
Awareness raising and training	Raise business and consumer awareness. Provision of targeted training
Acting globally	Promotion of environmental technologies in developing countries. Promoting responsible investments in and use of environmental technologies in developing countries and countries in economic transition

Priority issues

The report on the implementation between 2005 and 06 indicated that, despite various positive effects of implementing ETAP, environmental gains have not been sufficient. Lack of measures for stimulating demand and mainstreaming the environmental technologies is considered to be the main cause of this. The report indicated 1) Increase of demand on environmental technologies and 2) Enhancement of supporting measures as the two priorities and prioritised the following action items.

1. Increase of demand on environmental technologies
 - Acceleration of green public procurement and development of strategies for promoting green procurement in the private sectors
 - Mobilisation of greater financial investments on eco-innovation
 - Establishment of technology verification systems and enhancement of the use of performance targets, by finalising the on-going studies and upgrading the existing labeling schemes, such as eco-labels, energy labels and energy star schemes
 - Exchange of experiences on the promising policies and practices among Member States.
 - Focus on the sectors with high environmental gain (low hanging fruits), which are buildings, food and drink, private transport and recycling and waste water industries

2. Enhancement of supporting measures
 - Development of strategic knowledge resource on eco-innovation to enable European public organizations, business and financiers to further growth and investment
 - Further promotion of measures on active participation
 - Harness research by channeling future research themes (2007–13) based on ETAP priorities and future lead markets where eco-innovation plays roles.