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Driving Forces for Environmentally Sounder Innovations: The Case of Finnish Pulp and Paper Industry

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1. Introduction

Moving towards sustainability requires that new environmentally sounder technologies are developed and widely adopted. Policy instruments that advance technological development are necessary, while at the same time it is clear that public policy is far from the only factor affecting the emergence and diffusion of environmentally sounder technological innovations. Other factors influencing the innovation process arrive from company external influences such as market forces or within the company due to desires e.g. for cost cuts.

Even though there is wide spread agreement on the importance of technological innovations, there is still comparably little consensus on the relationship between different types of policies and technological development. Several contradicting claims have been expressed regarding the policy-innovation relationship, yet empirical thoroughly examined evidence is rare.

Some argue that environmental regulation is likely to stimulate innovation and technology adoption that will facilitate environmental compliance (e.g. Porter and van der Linde 1995, Jaffe et al. 2003), while others have found that emissions standards are often based on available technology with little incentive for innovation (e.g. Kemp 2000). Common to these studies has been the view that stringent regulations are more likely to produce innovations than lax regulations (Porter and van der Linde 1995, Kemp 2000). Another commonly held view is that economic instruments are more likely to prompt innovations than regulations (Milliman and Prince 1989, Jung et al. 1996, Hemmelskamp 1997). It has, however, also been found that, according to empirical studies, the dynamic effects of environmental policy instruments in practice differ from the ideal instruments in theoretical studies and that the relationship of policies and innovations may not be as simple as often stated (e.g. Hemmelskamp 1997). Regarding technology policy, it has been stated that public R&D may play an important role for environment-related science and technology (Jaffe et al. 2003), but that subsidies have had a limited impact on decisions regarding investments in environmentally beneficial technology (Kemp 2000).

Innovation has been defined by Freeman (1987) as "the introduction of a new product, process, method or system into the economy". If a broader view including also social innovations is taken, innovations can mean all new elements, practices and applications used in a social system. The term environmental innovation has had many different meanings. Some use it for all innovations with beneficial environmental effects (e.g. Kemp 1997), while others have used the term for those innovations intended to have positive environmental effects (e.g. Hemmelskamp 1997). In this article we focus solely on technological innovation and use the term environmentally sounder innovations to describe any new and innovative technology with less harmful environmental effects than the available alternatives. The term environmental innovations is, in turn, used only for those technologies that have specifically aimed at reduced environmental impacts.

Based on a previous examination of selected claims in the light of the pulp and paper and the marine engine sectors, we have chosen a number of specific innovations in the Finnish pulp and paper sector to further examine the driving forces for innovations and their diffusion. The sector provides an interesting focus because it has long been a target of traditional pollution control measures, while restructuring and globalisation have reformed the industry during the last decades. Three innovation cases, namely the development of black liquor recovery technology, a paper machine pump system, and an effluent concentrate combustion system, were selected to present innovations with reduced environmental impact but different innovation settings.

This article presents a study of how environmental policy and R&D support have affected the emergence and diffusion of these environmentally sounder innovations. It begins by providing a background for the study and introducing the Finnish pulp and paper industry. The impacts of environmental policy and R&D support measures on innovation are analysed empirically, followed by a discussion on their combined impact. The wider innovation setting is accounted for by discussing internationalisation and its influence on innovations. The article ends with a summary of the key conclusions.

2. The starting point and scope of the study

Previously we have examined selected claims on the effects of policy instruments on innovation and diffusion based on empirical experiences from the Finnish pulp and paper sector and a company producing marine engines (Mickwitz *et al.* 2003). The results for the pulp and paper sector are summarised in Table 1. Although the marine engine case is not discussed, it should be noted that the results differ for some of the claims.

Table 1: Summarising the experiences on the policy-innovation claims* (Mickwitz *et al* . 2003)

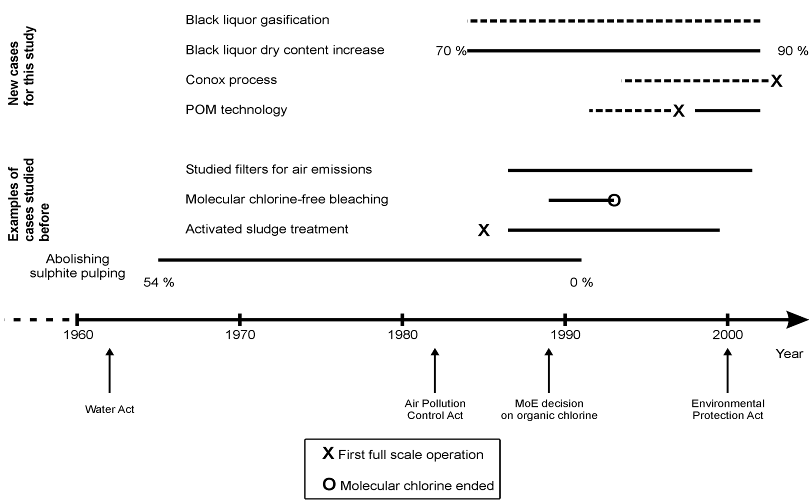
Claim	Supporting experiences	Contradicting experiences
• Environmental regulations (permits, standards, etc.) are often based on existing technology and provide no incentive to innovate but may stimulate diffusion.	• Activated sludge treatment - diffusion was stimulated • Chlorine-free bleaching of pulp • Filters for air emissions	• Activated sludge treatment - innovative application to this sector and these climatic conditions
• Non-binding permit conditions or standards do not provide any incentive to innovate.		• Waste water permits, especially for BOD and phosphorus
• Permit conditions or standards only confirm the development that has taken place otherwise.	• Reduced discharges of chlorine compounds from pulp bleaching • Change from sulphite to sulphate pulp production	• Activated sludge treatment was applied in novel conditions due to strict standards
• Environmental regulations can easily hamper innovations, by directly specifying the technology to use or indirectly making try-outs impossible.		• The flexibility of the Finnish water permits to support try-outs
• Environmental taxes are superior to other policy instruments with respect to innovations.		• The Finnish energy taxation had no effect on innovation in pulp and paper production
• R&D subsidies have limited impacts.	• The share of R&D subsidies is low in the total R&D expenditure of the forest cluster	• The existence of subsidies is important
• Innovations can be promoted by encouraging/forcing co-operation between organizations that would not otherwise work together.		• When networks are traditionally strong, as in the forest cluster, no change may be imposed.

**Some claims are widely supported and others are held by a few. They have all been challenged.*

Our analyses have shown clear effects of policies on the diffusion of environmentally sounder technologies but less on the very emergence of innovations. Furthermore, we have found that the effects of policy instruments on innovations are context specific, e.g. influenced by the cost-benefit distribution of the policy (Mickwitz *et al.* 2003). Various factors such as market demand for new technologies affect also the formation of different innovation settings.

Earlier studies by our research group (Hildén *et al.* 2002, Similä 2002, Mickwitz 2003 and Mickwitz *et al.* 2003) have examined the issues largely from the perspectives of the pulp and paper companies and public authorities. The innovations that were examined in detail were those technologies that have attributed to the drop in traditional water and air emissions, and our focus was largely on the period between the early 1970s to the mid 1990s (Figure 1). Since then the concentration and increased globalisation of the industry have affected for example the investment behaviour of the companies (e.g. Siitonen 2003).

Figure 1: Temporal distribution of some earlier cases and the new cases for this study



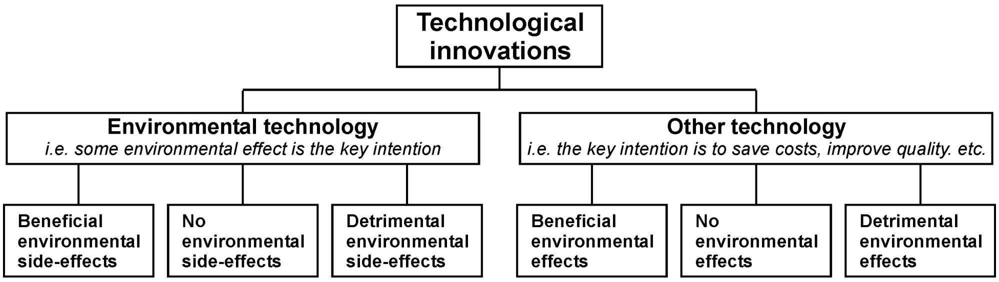
Three new cases were selected to expand our earlier picture of the innovation processes and to bring forth the perspectives of technology developers and researchers within the Finnish forest cluster (Box 1). Two of the cases were chosen to represent very recent innovations, whereas the third case covers innovations development on a wider scale and during a longer time period from the 1980s to the present. Also, the company format differs between the cases covering two small companies, POM Technology and Conox Ltd, and two major machinery developers, Tampella Power and Ahlström.

Box 1: Three additional cases

Technology	Description	Empirical sources
POM technology - air removing pump system for paper machine	**POM** is a compact wet end system for the paper making process, developed by *POM Technology,* and its main component is air-removing centrifugal pump. POM achieves faster and shorter water recirculations in the paper mill and reduces grade change times, resulting in improved energy efficiency and reduced water consumption, effluent discharge and waste compared to the conventional process. This has been regarded by some as one of the most important pulp and paper innovations of the 1990s (Oinonen 2000, HS 2004). The idea was generated in the early 1990s and the first full scale operation started in 1997.	www.pom.fi Interviews: *P. Meinander*, POM Technology Sept. 2003. E-mail quest. to 3 customers Newspaper & trade journal articles
Conox process - effluent concentrate combustion system	The **Conox** process, developed by *Conox Ltd,* is based on pressurised thermal oxidation of process water effluent concentrate. It was originally designed to eliminate organic compounds creating chemical oxygen demand (COD) present in bleaching plant effluents (Myréen *et al.* 2001). Later the concept was applied to black liquor from non-wood pulping. In addition to reduced water discharges, it's a development towards closed water cycles and it somewhat improves energy-efficiency. The idea was generated in the early 1990s and the first full scale operation for non-wood pulping started in 2003.	www.conox.com Interviews: *B. Myréen* & *L. Prepula*, Conox Ltd Nov. 2003. *M. Hupa*, Åbo Akademi University Nov. 2003. *B. Myréen* 2002. Trade journal articles & other documentation
Black liquor recovery technologies - increased dry solids content, gasification	The third case explores the development of various **black liquor recovery technologies** aimed towards increased dry solids content and gasification of black liquor. Efficient black liquor recovery reduces air emissions and increases the plant's energy supply. To a large extent, the significant sulphur emission reduction of the forest industry in the 1980s can be attributed to the increase of the black liquor dry solids content to over 70% (Interview II). These technologies have been developed by *Tampella Power* (now Aker Kvaerner) and *Ahlström* (now Andritz)	Interviews: *E. Vakkilainen*, Jaakko Pöyry Ltd Oct. 2003. *M. Hupa*, Åbo Akademi University Nov. 2003. Trade journal articles & other literature

Common to the selected cases has been reduced environmental impact, but in comparison, the innovations are of different types. Viewed from a purpose perspective, technological innovations can be divided into two categories: *environmental technologies,* where a specific environmental effect has been a key intention of the innovation, and *other technologies*, where the key intentions have not included environmental concerns but e.g. cost reduction (Figure 2). The paper machine pump system POM is a process innovation with beneficial environmental side-effects, whereas the effluent concentrate combustion system Conox was created as an environmental technology to reduce the organic pollutant load to water. Black liquor recovery technology positions itself somewhere between the two, being originally developed for improving the process and saving costs, but further innovative development has also had environmental intentions.

Figure 2: A typology of technological innovations viewed from the environmental perspective



3. The Finnish pulp and paper industry

The pulp and paper industry has had a highly significant role in the Finnish economy since the 19th century. Finland's first paper mill was established in 1873. The significant expansion of the industry began in the 1950s and by 1970s the production of paper had experienced a six-fold increase (VTT 1999, 39). In 2002 the annual pulp and paper production were nearly 12 million tonnes and 13 million tonnes respectively (FFIF 2003). The forest cluster, comprising forestry and the production of pulp, paper and wood products, contributes to about 20% of the industrial value added gross production (Statistics Finland 2002). The forest industry's share of total export value was 26% in 2001 and the largest share, 19% of total export value, can be attributed to the pulp and paper sector (Metla 2002, 284). Although exports have been growing, their share of the total export value has been shrinking with e.g. high-tech electronic companies gaining increased export volumes (Ali-Yrkkö and Hermans 2002).

Concentration of the Finnish pulp and paper industry has resulted in only six companies operating in the sector (Näsi 2001, 13) compared to over 20 independent companies in the beginning of the 1980s (Hagström-Näsi 1999, 88) and around 30 companies in the mid 20th century. The three largest corporations, Stora Enso, UPM-Kymmene Corporation and the Metsäliitto Group, constitute circa 98% of Finland's paper and pulp production capacity (FFIF 2000) as well as being internationally significant actors in the sector.

Also technology companies Metso Paper and Ahlström have developed globally significant market positions as manufacturers of paper and pulp machinery. Much of the technological development occurs in cooperation with pulp and paper producers, technology companies and consultancies, such as Jaakko Pöyry and some smaller actors. In addition universities, e.g. Helsinki University of Technology and Åbo Akademi University, have had important roles in basic and applied research.

The environmental impacts of the sector have been significant due to extensive use of energy and timber as well as emissions to air and water. Technological innovation and development have lead to increased production capacity simultaneously reducing the pollutant load significantly. A change from sulphite pulping to sulphate pulping is an example of a significant process change. In 1965, nineteen of total 35 pulp mills were sulphite mills but by 1985 only three sulphite mills were left and, since 1991, only the sulphate process has been used (Ministry of the Environment 1997, 39). This shift that has taken place mainly for economic reasons has contributed significantly to the decline in water discharges (Hildén *et al.* 2002). Several important developments in environmental technology can be identified in the past three decades, e.g.

chlorine-free bleaching and tertiary waste water treatment. Significant advances have been made to improve the resource efficiency and water consumption of the production processes, the latter developing towards closed water systems within the plant. For example, the per unit water consumption of pulp production has been reduced from 600 m^3 per ton, in the 1950s, to close to 10 m^3 per ton in the early 21st century (Kettunen 2002, 36).

4. The impact of environmental policies on innovations

4.1. Regulatory environmental policy instruments

In Finland permits, designed on a case-by-case basis, have been the main way of controlling point source pollution (Hildén *et al.* 2002, 37-44). Emissions to air and water were controlled separately through different kinds of procedures prior to the implementation of the EU Directive on Integrated Pollution Prevention and Control (IPPC) in 2000. For air emissions the limit values in individual permits were complemented with general norms and guidelines, e.g. regarding air quality, depositions or emissions. Contrarily, for water discharges the permit system has functioned without general standards to explicitly guide individual decisions. Our earlier empirical examinations have indicated that permit decisions have mostly been based on existing technology and have provided no incentive for innovation, and have affected diffusion mainly in relation to activated sludge technology for water treatment and filters for air emissions (Hildén *et al.* 2002, Mickwitz *et al.* 2003). The three cases examined here also reveal diffusion effects of the regulatory instruments.

The origin of innovations increasing the dry solids content of black liquor lies in basic scientific research and in attempts to achieve more economic thermo-technical solutions for black liquor combustion. For example, Ahlström's evaporation technology increasing the dry solids content of black liquor, achieved in the early 1980s, originated from the basic research of lignin not related to energy efficiency or emissions (Kettunen 2002, 88). As a result, it was noticed that sulphur emissions after the process were practically non-existent (Interviews II, III). During the 1980s and 1990s, the process was further developed through large national research programmes and development work by major technology companies. The air emissions received increased focus in the later development phases partly through tightening environmental regulation *"which probably brought forward these issues to the pulp and paper producers, who then knew both to require improvements from the technology developers and to enthuse about the developers' solutions"* (Interview III). Specific permit conditions have in some cases affected the diffusion of the technology, while in others adoption has preceded actual permit regulation. For example, one pulp mill postponed new investments for nearly ten years, and permit conditions effective from the beginning of 1999 finally forced investment in new technology including 80% dry solids content evaporation and recovery boiler with a new system to collect and combust odorous gases (Illi 1999).

For POM technology, environmental policy had no role in the innovation process (Interview I). Also, the diffusion of this technology to various countries, e.g. Germany and Japan, has occurred due to cost and competitiveness factors alone. As an exception out of 20 installations, environmental regulation was one of the reasons for acquiring this technology for a paper mill in Spain. POM enabled them to meet the short-term maximum limits in the water permit and reduce the emissions below the legal requirements set up by the Municipality (Clariana 2003). This together with increased flexibility was considered as an important characteristic when deciding on the investment. By 2003, POM had been installed in only one Finnish paper mill, for process improvement reasons not related to environmental issues.

In 2003, Conox had not reached the demonstration stage in Finland and the progress had halted for various reasons. Some view that the environmental regulations concerning e.g. discharges of heavy metals are not strict enough to awake the interest of pulp and paper producers for this technology, while others argue that competing solutions are more appealing (Interviews III, IV). However, during 2003, the Conox application to non-wood pulping was installed to small mills in Spain and China. These mills faced tight regulations, and non-complying would have closed the mills, resulting in serious conditions for the rural communities dependent on those mills (Interview IV).

4.2. Anticipation of new or tightening regulations

The impact of environmental policies on the innovation process is, in effect, not straightforward and the dynamic nature of both innovations development and environmental policy must be accounted for. The duration of an innovation process in the pulp and paper industry is often more than a decade, and therefore anticipation of future markets is essential. Anticipation of future environmental policies may, consequently, have a decisive role in the innovation process.

The development of the Conox system addressed the issue of water pollution caused by plant effluents. The original idea was spurred by anticipation of increased regulatory measures for closing the bleaching processes. The anticipation rose from the issue being high on the agenda for the Central European paper buyers and NGOs, such as Greenpeace, during the early 1990s (Interviews IV,V). Unexpectedly, in the late 1990s, the NGO and government interest in the chlorine issue diminished in Western and Northern Europe due to reduced organic loads, and the anticipated regulatory action did not happen. Simultaneously water discharges of non-wood pulping, e.g. in China, were discovered to be a significant environmental problem (e.g. WBCSD 1996) and the further development of Conox was redirected to those markets.

The anticipation of future regulation has also played a role in the development of black liquor innovations. Much of the R&D for increasing the black liquor dry solids content had already been carried out prior to the 1987 Council of State Decisions that for the first time set national guidelines for sulphur emissions. Yet the need to reduce forest industry's emissions was already discussed in the 1970s and e.g. Finland's signature for the Convention on Long-Range Transboundary Air Pollution in 1979 was an indication of possible future regulation regarding air emissions. Later, the need to reduce sulphur emissions affected the participation of pulp mills in the try-outs of emerging technologies. For example, this motivated the Äänekoski pulp mill to purchase Ahlström's LHT-system (Interview II), one of the first to achieve over 80% dry content and zero sulphur emissions, in 1990 (Pearson 1993).

In many instances technological R&D and environmental policy have progressed simultaneously, and it is difficult to identify when policy affects technological development and vice versa. For example, in the black liquor case, national air pollution regulations were implemented in permit decisions from 1987 onwards and national technology programmes, including black liquor research, were carried out from 1988.

5. The impact of public R&D support on innovations

5.1. R&D support

During the last decade the trend in Finland has moved from financing individual projects towards focused technology programmes. Also, the public expenditure on

R&D has increased both in monetary terms and as share of the GDP (Prihti *et al.* 2000). At the same time the financial contribution of external R&D support has reduced in the pulp and paper sector. In the 1970s, a large corporation may have received over 25% of its R&D finance from outside (Kettunen 2002, 102) whereas, in 2001, only 3,3% of R&D funding in the sector was received from external sources, less than received by industrial companies in general (4,7%) (Statistics Finland 2003). For example public finance received by KCL, a research company owned by the four largest pulp and paper companies in Finland, has reduced by half from 9,4% of turnover to only 4,6% between 1998 and 2002 (KCL 2002, 24). Although, the share of public finance seems rather low, a former head of research at Metsäliitto Group has stated that the National Technology Agency of Finland (Tekes), after its founding in 1983, has provided funding to every major research project of new technology that the company has undertaken (Kettunen 2002, 104).

Public funding is mainly given out in the form of grants and low-interest loans from Tekes and the Ministry of Trade and Industry (MTI). These constitute to 60% and 36% of external R&D funding respectively (Statistics Finland 2003). Tekes also supports pilot projects and commercialisation. Other sources of public funding include the Finnish National Fund for Research and Development (Sitra), the Start Fund of Kera, and the regional TE Employment and Economic Development Centres. Besides R&D funding for independent projects, there have been six major technology research programmes supporting the development of environmentally sounder technologies relevant to the pulp and paper sector.

With respect to black liquor innovations, it has been argued that technological change would have progressed more slowly without public subsidies that have lowered the barriers and risks to investors (Interview II). Black liquor related R&D has received financial aid motivated by several political goals, including environmental protection, enhancing the competitiveness of domestic industry and supporting the use of domestic fuels. The aid has been especially significant through the two LIEKKI research programmes (1988-1992, 1993-1998), financing projects related to combustion and gasification technology. These created a favourable climate resulting in "two waves": firstly, over 80% dry solids content evaporators focusing on other than sulphur emissions and, second, chemical research and information systems aiding e.g. gasification research (Interview II). The Jalo (1988-1992) and Code (1999-2002) programmes have also covered black liquor research. Code developed numerical modelling of combustion processes dramatically reducing the need for pilot experiments (Interview III). The technology programmes have been crucially important in creating and increasing the necessary knowledge base for black liquor research before specific innovations could be generated (Interviews II, III).

The Conox developer views that public R&D funding is important in the early stages for generating inventions, but for innovations to appear also risk capital and markets are required (Interview V). The general view appears to be that public funding is fairly well available for basic and applied research and technology development, but finding finance for prototypes is more difficult. Black liquor dry content technologies have reached the commercialisation phase because they have been fairly risk-free incremental innovations on the existing system, whereas black liquor gasification is a technology requiring more significant system changes. No demonstration system has yet been created in Finland due, likely, to the high risks and costs involved (Interview III).

POM Technology received public R&D funding in the technology development and the installation phase. Tekes provided product development support in the beginning and, with the help of development support from Tekes and risk capital from the Start Fund of Kera, the first four POM systems were installed in Germany and USA in the late 1990s (Lindén 2000, 1996; Oinonen 2000). Significant funding from

Tekes and other public sources reduced the risk for other investors and made reaching the commercialisation stage possible.

5.2. R&D networks

Co-operation of pulp and paper companies with technology developers, consultancies and research organizations has been characteristic to the industry throughout its history (Hildén *et al.* 2002). Information on end-of-pipe solutions has been quite freely exchanged between mills and often R&D has been undertaken jointly. For example Conox Ltd was jointly established by a consultancy, a chemical producer and an environmental technology company, and the technology was developed in cooperation with two large pulp and paper companies. The development of POM technology involved cooperation with a university and some paper mills, whereas the black liquor R&D has been jointly carried out by several public and private actors. The co-operation of the technology companies with public research institutes has been crucial to advance black liquor related R&D.

> "The Finnish situation, where two major technology developers have co-operated in the same projects and research programmes has been unique from the global perspective, and this has created a positive competition on the level of basic know-how… the know-how of both has clearly increased and they were clearly distinguished from their American or Japanese competitors." (Interview III)

Some public funding schemes require companies to have a university or public research institute as a partner in R&D projects. The critique suggests that the measures used to encourage or even force co-operation and networking between organizations can also have negative effects and that establishing a technology programme is not necessarily the best form of public R&D funding from the perspective of the established players in the field (Mickwitz *et al.* 2003). However, at least Ahlström saw the experiences from the LIEKKI programme positively:

> "The LIEKKI program has improved the availability of information resulting from public research, and it has enhanced the adjustment of the research needs of public organisations and those of industry for better mutual agreement. At the same time it has improved the cooperation between public projects…and the industrial projects aimed at product development" (Hupa 1994, 71).

Also, Tampella stated that the programme enabled international cooperation in black liquor related modelling, but viewed the programme benefiting cooperation only when entering new research areas (Hupa 1994, 73). This view is supported by the fact that POM Technology did not gain any new cooperation for joining the CACTUS programme (1996-1999) three years after patenting its first invention. In the POM case, there has not been a difference between participating in a technology programme and receiving outside-programme public funding since the CACTUS programme only resulted in one way information flow from the project to other participants:

> "…certain large companies invested in their own development projects and, regarding information access and participation, we did not gain participation to those seminars that covered these results and did not become sharers of others' results, but did present our own results." (Interview I)

In many occasions, the additional benefits of a technology programme in comparison to funding for independent projects seem insignificant from the technology developers' viewpoint. However, according to a consultant and former representative of a technology company, technology programmes are necessary to generate and share basic research knowledge, without which even private commercial projects would be difficult to carry out (Interview II). This point is further illustrated in the Conox case, where the developer received technical answers for many uncertainties from the 'combustion technology cluster' created by the LIEKKI-programmes (Interview III).

The impact of public R&D support on innovation may differ between smaller and larger companies. On one hand, smaller companies with fewer resources tend to be more dependent on outside financial support, but large companies benefit from wide access to various research programmes. For example, the role of Ahlström and Tampella has been significant in combustion technology programmes. Their projects, although not all black liquor related research, accounted for 29% of the total expenditure of the LIEKKI programme and received 17% of the total MTI funding (Hupa 1994).

6. Combined impact of environmental policies and R&D support

Although many policy issues of today are so broad and complex that they involve several traditional policy branches and institutions, there is still often a lack of co-ordination. This can result in at least two kinds of problems: aspects of an issue not being covered by any sector and aspects covered by several sectors but potentially in conflicting ways or inefficiently. It has been argued that these types of problems are present in the Finnish central administration (Bouckaert *et al.* 2000). Examining the combined impacts of environmental policies and R&D support can thus be seen as being relevant also in this wider context.

Environmental and technology policy measures are usually directed at very different aims, yet they both influence the emergence and diffusion of innovations affecting the environment. Table 2 lists the environmental policies and R&D support measures having affected the studied innovations. It appears that R&D support has affected all these innovations and environmental policy has acted as a driving force for all but one, namely the development of POM technology. However, the connection between policies and innovations is complex. For example, the CACTUS technology programme financing POM included environmental aims, such as reducing the use of water and the environmental impacts in water, in air and on land (Komppa and Neimo 2000). In turn, the development of the Conox system was partly influenced by the know-how created in the LIEKKI programme.

Table 2: The impact of environmental policies and R&D support on the studied cases

Environmental Policy	Innovation	R&D Support
▪ Generally no impact ▪ Water permit limits affected the adoption in a Spanish mill.	POM	▪ Start Fund of Kera capital & TE loan for company establishment ▪ Independent Tekes finance 1994-95,2000-02 ▪ CACTUS programme 1996-99 ▪ EU funding for first commercial installation
▪ Anticipation of regulatory measures for closing bleaching processes in W. Europe - did not happen ▪ Water discharge limits for non-wood pulping in Spain & China	Conox	▪ Research project partly funded by Tekes 1995-98 ▪ Independent Tekes finance 1999-2002 ▪ EU LIFE funding for a planned prototype in a Finnish mill - not realised ▪ Finnfund a shared owner of Conox Holdings Ltd to finance installations in China
▪ Anticipation of emission limits for sulphur & nitrogen in 1980s - Council of state decisions issued 1987 onwards ▪ Emission limits & technology specifying permit conditions affecting diffusion	Black liquor dry content increase	▪ LIEKKI programme 1988-92 ▪ LIEKKI 2 programme 1993-98 ▪ CODE programme 1999-02
▪ Anticipation of emission limits for sulphur & nitrogen in 1980s ▪ Discussion on the need to prevent the fifth nuclear power plant in the late 1980s and early 1990s by providing more electricity from gasification and biomass combustion. (Interview II)	Black liquor gasification	▪ JALO programme 1988-92 ▪ LIEKKI 2 programme 1993-98

The combined effects of environmental policies and R&D support can be studied more specifically by using the typology of technological innovations introduced in Section 2 (Figure 2). Potential goal-conflicts occur in areas where R&D support is directed at technologies with detrimental environmental effects (Table 3). These environmental effects may be anticipated or unanticipated. In occasions, there can be lack of knowledge transfer between the policy sectors. If an invention is dependent on a chemical that will be prohibited or the use of which will be circumscribed through environmental regulation, it might never be realised and the work done by the innovator and the allocated R&D support could be wasted.

Table 3: Policy intentions vis-à-vis different types of innovations

	Technological innovations					
	Environmental technology			Other technology		
	Beneficial environmental side-effects	No environmental side-effects	Detrimental environmental side-effects	Beneficial environmental effects	No environmental effects	Detrimental environmental effects
Environmental policy	Encourage	Encourage	Encourage / Obstruct	Encourage	Neutral	Obstruct
R&D support	Encourage	Encourage	Encourage	Encourage	Encourage	Encourage
Combination	Potential synergies	Potential synergies	Potential goal-conflict	Potential synergies	No interaction	Potential goal-conflict

While Table 3 only lists the overall intentions of the policies, actual policy practices might differ from these intentions. It is well known that good intentions do not guarantee good results. The adoption of environmentally sounder technologies may in fact be obstructed by environmental policies in force, even though there might be a joint interest to promote the diffusion of such technologies. Policies focusing solely on environmental technologies may delay environmental improvement, because often the non-environmental technologies bring many environmental benefits. This is in line with the results of several other studies, which have shown that a range of technological changes with major environmental performance impacts are not shaped by environmental factors (Berkhout 2003, Hildén *et al.* 2002). In Finland, due to the flexibility of the permitting system, conditions have often been temporarily relaxed during demonstration periods or pilot phases of new end-of-pipe technologies (Hildén *et al.* 2002). Innovations have, therefore, not been hindered in a way that for example emission limit values, in theory, could do.

The studied innovations are all examples of cases where there are potential synergies between the policies, i.e. they have resulted in beneficial environmental effects. For example, the further development of black liquor recovery was simultaneously supported by national emission limits and various research programmes. However, in some instances, the encouraging effect of environmental policies may not be strong enough to support the commercialisation or diffusion of environmentally sounder innovations, especially if the users cannot see the other benefits of the technology. The Conox process was not adopted in Finland because, despite a granted EU LIFE funding for a prototype in a Finnish mill, environmental regulations were not strict enough to keep up the interests of pulp producers to install this technology. In turn, the development and diffusion of some environmentally sounder technologies, such as POM, may occur without the direct impact of public environmental intervention. These are often so called 'win-win' solutions that are driven by other factors bringing also competitive advantage for the companies.

7. Internationalisation and its effects on innovations and policies

Market areas outside Finland have always been important for the Finnish forest industry. Until the 1970s the forest industry exports accounted for more than half of the total exports. Subsequently the forest industry's share of the total export value has decreased from 56% in 1970 to 27% in 2000, despite the real value of forest industry exports doubling during that period (Metla 2002, 295).

The pressures and opportunities caused by increased globalisation of the sector are an important factor behind the concentration of the industry, where a few major international companies control over 90% of the markers, in pulp and paper production as well as in technology development. The largest paper producer Stora Enso is a merger of two previously national companies, the Swedish Stora and the Finnish Enso-Gutzeit. A similar example from the technology side is Aker Kvaerner. There are about 20 companies in the forest cluster that are in foreign ownership, and especially the manufacturers of chemicals, suppliers of systems and equipment and industrial automation companies have attracted foreign capital during the 1990s (Lammi 1999).

One feature of the ongoing globalisation process is that it has become easier even for small and medium-sized companies to sell their products in other parts of the world than where they are designed or produced. This feature is especially important for firms in know-how intensive sectors where production does not require a lot of capital. For both POM and Conox technologies, the main markets have been abroad. Moreover, innovation spin-offs can emerge if the access to global information and markets is present, as the Conox case illustrates. This benefits both the domestic technology sector and the environment, through more rapid international transfer of new, environmentally sounder technologies. The Aracruz pulp mill is another example of the global deliveries of the machinery and plant manufacturing sector, installing equipment from several Finnish companies: Ahlström, Sunds and Rauma (Häggblom 1999, 300).

While globalisation has widened the market and created increased possibilities for companies, it is obvious that international markets mean an increased level of competition. It has also been argued (e.g. Foster *et al.* 2003) that, as a side-effect of globalisation, the company motivation for investing in new, innovative and unestablished technology has decreased. This is because new technology is simultaneously available for pulp and paper producers all over the world if proven successful, and the forerunner's benefit is thus reduced. However, even if technologies are usually available for purchase immediately after commercialisation, in practice technology transfer to other countries can be slower because, for example in Finland, the interaction between companies is more frequent and information transfer is faster than e.g. between Finnish and Brazilian companies (Interview II).

The internationalisation of companies can also have negative effects on the development of innovations. It sometimes becomes more difficult to receive public R&D support, because national organisations may not be willing to finance R&D by companies in foreign ownership (e.g. Interviews II, III). Conox Ltd has a contract for a cooperative project with a German research laboratory, but proceeding in it has been extremely slow perhaps partly due to local decision makers' reluctance to support foreign technology (Interview IV). However, it can also be argued that, generally, company ownership is not as an important criterion for public funding as the effects of the company operations for the country in question. Tampella still continued to be part of the LIEKKI research programmes after being sold to Kvaerner. Andritz and Foster Wheeler, that are not in Finnish ownership but continue to concentrate their research operations to Finland, have still been actively involved in Finnish research programmes after acquiring the Finnish companies (Interview III).

The internalisation of markets can also be observed in many other sectors, some of which may be linked to the pulp and paper industry. Several countries have deregulated the electricity market creating an opportunity for any company to participate, while previously selling electricity has been limited to a government-owned regulated monopoly. The next possible step to deregulation - common markets between countries - is gradually succeeding with plans for a common market for trading electricity within the EU borders and the already operating Nordic market covering four states.

The Finnish electricity market was deregulated in 1995 and Finland joined the Nordic electricity market system, Nordpool, at the start of 1998 (e.g. Pineau and Hämäläinen 2000). The new markets have increased the diffusion of new, more efficient black liquor recovery boilers by creating a incentive for the pulp and paper companies to produce electricity exceeding their own needs. Already three mills have been (re)designed for producing electricity for the markets: Metsä-Rauma in 1995, Joutseno Pulp during 1997-2001 and Wisaforest completed in 2004 (Interview II). For example, the Joutseno mill can annually export 15-30 MW of the electricity produced with the black liquor recovery boiler alone while, prior to the new recovery boiler, it had to purchase around 8 MW of electricity from outside producers (Illi 1999, Interview II). However, generally the short term effects of the electricity market liberalisation have been perceived as reducing the interest of companies for new investments (Interview III). In the future, electricity markets will guide the innovation development through the electricity price. If electricity prices increase, the development and diffusion of energy-efficient technologies will be promoted.

8. Conclusion

The cases studied have reinforced our position that it is equally important when analysing as well as promoting technological change to consider both technologies developed for environmental purposes and technologies with beneficial environmental effects primarily developed for some other reason.

Policy anticipation affects both the innovation and diffusion processes. When companies have reasons to believe that environmental requirements set by public policies will become tighter they often act in advance. By adopting environmentally sounder technologies before required to do so they gain leeway to respond to political and market situations. Our case studies have shown in practice that expectations about future environmental policies can have an important role for the innovation processes of environmentally sounder technologies. Developing innovations is a long-term task focused on future markets, where environmental policies are among the key shapers. However, uncertainties are always involved in future predictions and, in occasions, the anticipated conditions may not arise, as illustrated by the Conox case. If environmental policy does not develop as expected by the innovator, at the absence of alternative markets, the R&D efforts might have been wasted. Although the future will always be uncertain, this stresses the importance of transparent and predictable long term environmental policies.

For a successful environmental innovation to emerge and diffuse, often a combination of R&D support and environmental policy measures is required. While there are areas where the interests of the two policy fields are compatible, there are cases where these interests are conflicting, potentially resulting in both negative environmental impacts and wasted resources. When a technology, that is above all developed to increase competitiveness, has environmental benefits the challenge is to ensure that the intentions are also supported in practice. This stresses the significance of coordination in policymaking, but also emphasises the importance of accounting endogenous technological change when formulating environmental policies. Co-operative networks have been shown here to have a significant impact on innovation, and these could be expanded to include policymakers in order to facilitate information transfer. When environmental policies are well known by those providing R&D support there is a reduced risk of wasted R&D resources for technologies that will be impeded or even blocked by environmental policy measures. Also, when new technologies with negative environmental effects are emerging or when significant environmental improvements can be achieved with new technologies, it is important that the environmental authorities are aware of the development so that policies can be redirected accordingly.

The increased globalisation has at least two important effects on environmentally sounder innovations. Firstly, it increases the potential markets for these innovations. If the anticipation of one emerging market is wrong, there might be market potential for the new technology somewhere else as in the Conox case. Alternatively, if the conditions for the crucial first commercial application are not right in the domestic market it might be carried out elsewhere, as in the POM case. Secondly, when a Finnish innovation is developed because a potential market has been identified, it is likely that a foreign competitor has also seen the opportunity. Competition is thus clearly increased by globalisation.

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Interviews

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Interview II: Esa Vakkilainen, Jaakko Pöyry, 23 October 2003
Interview III: Mikko Hupa, Åbo Akademi University, 14 November 2003
Interview IV: Bertel Myréen & Lauri Prepula, Conox Ltd, 7 November 2003
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