Strategies for Energy Transition.
The Swedish Pulp and Paper Industry 1973-1990.

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1. INTRODUCTION

This paper explores strategies to accomplish energy transition in the Swedish pulp and paper industry during the 1970s and the 1980s. For decades economic historians have paid interest to the interplay between energy supply, energy consumption and economic development, where the transition from a bio (organic)- economy to a mineral based (fossil fuel)- economy has been viewed as essential to the industrialization process and modern economic growth.[1] Although most business activities include the use of energy, and while, over time, innovators, entrepreneurs and firms have played a major part in changing the energy system and energy consumption patterns in society, energy as such has not attained much interest from business historians.

Needless to say though, there exists a voluminous literature investigating entrepreneurship and growth of major companies within the oil industry and electricity production.[2] Recently, also novel works on emergent industries and the central entrepreneurs within sustainable energy production has been tasked.[3] Clearly the Arabic oil embargo and the run-up in energy prices during the 1970s had major impact on the global oil industry, countries energy systems

[1] e.g. Antony Wrigley, *Continuity, chance and change: the character of the industrial revolution in England*. (Cambridge University Press, 1988); Kenneth Pommeranz, *The Great Divergence. China, Europe and the Making of the Modern World Economy* (Princeton University Press, 2000) Astrid Kander, Paolo Malamina, Paul Warde. *Power to the People. Energy in Europe over the Last Five Centuries* (Princeton University Press, 2013); Nathan Rosenberg *Exploring the Black box. Technology, economics, and history.* (Cambridge University Press, 1994), see essentially chapter 9 on Energy-efficient technologies: past and future perspectives.

[2] See e.g. the work on Royal Dutch Shell, by Stephen Howarth, Joost Jonker, Keetie Sluyterman and Jan Luiten van Zanden, *The History of Royal Dutch Shell* (Oxford University Press, 2007); Alfred D. Chandler, Jr. *Scale and Scope. The Dynamic of Industrial Capitalism* (Harvard University Press, 1990); Geoffrey Jones. The State and the Emergence of the British Oil Industry. (London: Macmillan Press, 1981).

[3] Jones, Geoffrey & Bouamane, Loubna (2011) "Historical trajectories and Corporate Competence in wind energy". Working Paper 11-112, Harvard Business School. Jones, Geoffrey & Bouamane, Loubna (2012) "Power from Sunshine. A Business History of Solar Energy. Working Paper 12-105. Harvad Business School.

and energy consumption.[4] The oil crisis further stimulated major shifts in governmental energy policies. However, to our knowledge, the way changes in relative prices of energy carriers and governmental energy policies have altered the conditions and strategies in energy intensive industries has still not been explored in business historical research.

Indeed, both energy and the environment represent key headwinds for future economic growth.[5] Energy and environmental issues are closely interwoven as energy extraction (and generation) and energy use based on fossil fuels is linked to the emission of carbon dioxide, sulfur dioxide, nitrogen oxide and other emissions. Resource depletion is an additional implicating unsustainable aspect of the use of fossil fuels which has been widely debated ever since the oil crises of the 1970s. This debate was further partly fuelled by the book "The limits of growth" by the Club of Rome published in 1972.[6]

Since the early 1970s, energy policies and environmental regulations have added a new institutional dimension to the business environment that has changed managerial conditions and added new managerial challenges.[7] Energy and environmental issues are closely interwoven as energy extraction (and generation) and energy use based on fossil fuels and nuclear power contributes to various emissions, risks and hazardous wastes. Not only the energy production but also the end-use of energy, essentially in energy intensive industries, affects the environment even to a large extent. This relation is obvious to firms today.[8]

Although energy as such has not caught much attention among business historians, there has been a growing interest to incorporate environmental issues in business history research.[9] Already in 1999, a special issue on the theme 'Business and the Environment', edited by Christine Meisner Rosen and Christopher C. Sellers was published in *Business History Review*.[10] Since then, a growing number of scholars have integrated environmental issues in business historical analysis and leading journals within the field have continued to raise the

[4] Kander et. al. *Power to the People*, p 258 ff. John R McNeill, *Something is New Under The Sun. An Environmental History of the Twentieth Century* (W.W Northon, 2000).
[5] Robert J. Gordon. *Is US Economic Growth over? Faltering Innovation Confronts the Six Headwinds*. Working paper 18315. National Bureaus of Economic Research. 2012, p 17.
[6] Meadows, D.H., Dennis, L., Meadows, J.R., & Behrens, W.W. *The limits to growth*. (Universe Books,1972).
[7] E.g. Andrew J Hoffman and Marc J Vantresca. *Organizations, Policy and the Natural Environment: Institutions, and Strategic Perspectives* (Stanford University Press, 2002).
[8] Energy has to an ever-increasing degree been incorporated in the green (climate) strategy of many firms and constitutes a core issue of sustainable production strategies. See e.g. Andrew J Hoffman and John G Woody
[9] See Business History Review (Winter, 1999).
[10] Christine Meisner Rosen and Peter Sellers (1999) "The Nature of Firm: Towards an Ecocultural History of Business", *Business History Reveiw*, (Winter; 1999): 577-600. Drawing on a theoretical and empirical research from different disciplines, such as business history, environmental history and the history of technology, the editors concluded that few efforts generally had been made to understand businesses internal processes in relation to environmental issues. They even argued that business historians had tended to treat the environmental dimension of business development as if natural goods and supplies (including pollution and other harms) were "externalities to the enterprise of business history itself" (Ibid. p 586).

question on the research agenda.[11] Much of the research has paid attention to time periods before the environmental awaking in the 1960s, the implementation of modern environmental regulatory frameworks and the energy crises.[12] Even if environmental aspects of energy production, not the least within the oil industry has been in focus for some studies, the energy use and the dynamics use energy and environmental impacts of businesses has not yet been incorporated in this research field.[13]

Heavy industries, including pulp and paper and basic metal production formed a backbone in the Swedish industrialisation from the 1890s and onwards. This in turn implied an industrial structure that was very energy intensive. Since Sweden is not endowed with oil or coal resources, the energy supply was heavily dependent on a massive import. Even though Sweden do have big reserves of hydropower, oil accounted for 72 percent of the total energy balance in the Swedish economy in 1973.[14] The pulp and paper industry, which is the case study for this study, accounted overall for 40 percent of the total industrial energy consumption in Sweden making the sector the largest energy consumer in the economy.[15] The pulp and paper industry has for long been and still is a dominant energy user in Swedish industry.

However, in the awake of the first oil crisis in 1973 until the late 1980s, the use of fossil fuels within the pulp- and paper industry was reduced by 70 percent. The lion share of this reduction was at an aggregated level achieved by the substitution of oil by internal (wood waste) biofuels. As an indirect effect, emissions of carbon dioxide were at the same time reduced by 80 percent.[16] Only seen from the perspective of carbon dioxide this meant great environmental improvements. The substitution however also implied other improvements, such as reduced wood waste.

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[11] See the special issue in *Enterprise and Society* 'Business and Nature: Doing Business History in the Age of Global Climate Change'. See also editorial note by Walter A Fridman and Geoffrey Jones, *Business History Review*, 85 (Spring, 2011).

[12] For an recent overview, see Geoffrey Jones and Christina Lubinski, "Making 'Green Giants: Environment sustainability in the German chemical industry, 1950s-1980s." *Business History*, (available online, 2013)

[13] Studies focusing on the oil industry, see Keetie Sluyterman "Royal Dutch Shell: Company Strategies for Dealing with Environmental Issues," *Business History Review* 84 (Summer, 2010): 203-226 and Hugh Gorman, *Redefining Efficiency: Pollution Concerns, Regulatory Mechanism and Technological Change in the US Petroleum Industry*. (The University of Akron Press, 2001).

[14] Lee Schipper, Frank Johnsson, Richard Howarth, Björn Andersson, Bo Andersson and Lynn Price. "Energianvändningen i Sverige. Ett internationellt perspektiv" (Energy use in Sweden. An international perspective). Nutek. Närings- och teknikutvecklingsverket. Report No R 1994:10, p 23.

[15] Kortsiktsprognos över energianvändning och energitillförsel 2013-2015, Hösten 2013, Energimyndigheten, ER 2013:15, p 19.

[16] Magnus Lindmark, Ann-Kristin Bergquist and Lars-Fredrik Andersson, "Energy transition, carbon dioxide reduction and output growth in the Swedish pulp and paper industry: 1973-2006", *Energy Policy 39* (9, 2011): 5449-5456

By the time of the first oil crisis in 1973, also an environmentally driven reconstruction of the business sector had been initiated in response to a new regulatory framework enforced in 1969.[17] Environmental pressure combined with rising costs for energy and wood, and increasing international competition put pressure on the Swedish pulp and paper industry to transform.[18] The 1970s overall implied new challenges relating to both energy and the environment and the aim of this paper is to investigate how the energy transition was accomplished in this challenging context. The paper will provide an overview of the organization of the knowledge-building and technological development underpinning the changes in the energy mix in the short and long run. We will further investigate the importance of the interplay between the energy policy and the strategies developed within the industry sector. The investigated period can be seen as formative period for energy-related R&D of importance to meet the challenges and opportunities faced by the industry sector today.

2. THE OIL CRISES AND THE PULP AND PAPER INDUSTRY: SOME ANALYTICAL IMPLICATIONS

Since the run-up in energy prices that begun in 1973, the world has been flooded with suggestions of how to reduce the energy inputs or substitute one source of energy with another. These proposals have often suggested the substitution of nonrenewable sources with renewable ones. It has been proven though, that the adoption of new technologies is a costly and uncertain process since a large fraction of the total energy use in industrial societies is embedded in long-lived capital equipment. Adjusting to changes in energy availability and price may therefore be a slow process, often stretching over decades when it comes to industrial plants.[19]

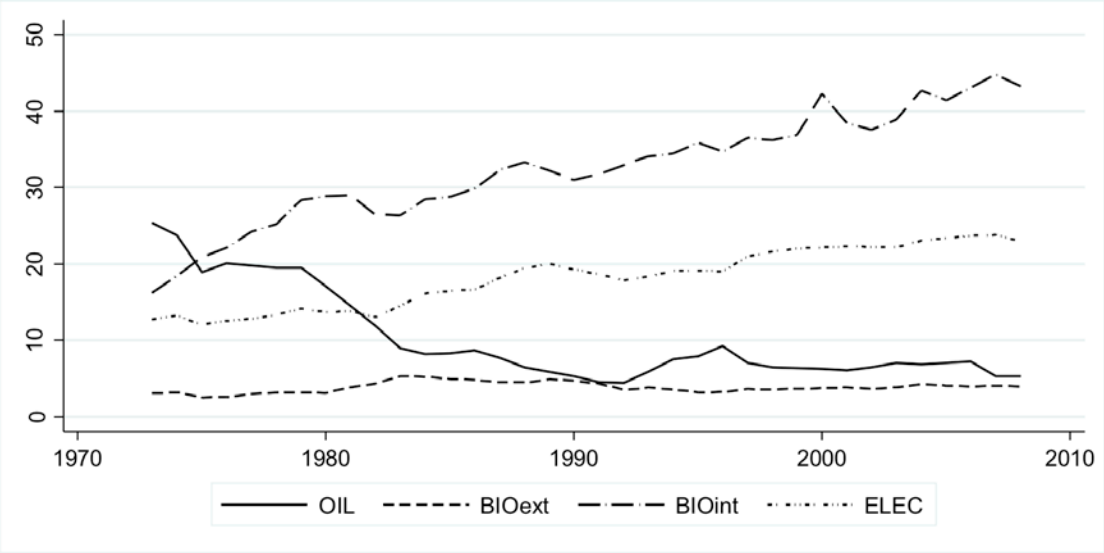
Production of pulp and paper is an energy-intensive process whereupon energy represents significant costs in the manufacturing process. The 1970s therefore meant that energy became one of the most critical issues within energy intensive industries. The oil crisis also stimulated major shifts in energy policies in many Western governments, and Sweden was no exception in this case. Increased energy efficiency and expansion of nuclear power programs for

[17] This collaborative tradition was established already when the first external pressure to reduce pollutants occurred in the early 1900s.Ann-Kristin Bergquist & Kristina Söderholm. ”Green innovation systems in the Swedish industry” 1960-1989. *Business History Review*, (Winter, 2011): 677-698.
[18] Kristina Söderholm & Ann-Kristin Bergquist, “Firm collaboration and Environmental Adaptation. The case of the Swedish Pulp and Paper industry 1900-1990”. *Scandinavian Economic History Review* 60 (2012): 183-211.
[19] Nathan Rosenberg, *Exploring the Black box. Technology, economics, and history*. (Cambridge University Press, 1994). Se essentially chapter 9 on Energy-efficient technologies: past and future perspectives, p 163-164.

electricity production were accessible and preferred strategies to reduce dependence of oil and saving costs. While motives within the Swedish industry were primary to save costs, the important policy goal for the Swedish government was to prevent a rapidly deteriorating balance of payments. [20]

Figure 1 below shows the energy transition experienced by the Swedish pulp and paper industry in the wake of the first oil crisis in 1973. As can be seen in the figure below, the large-scale substitution of oil took place during the 1970s and 1980s, and was mainly achieved through increased use of bio fuels. Oil inputs were reduced by approximately 20 000 Twh between 1973 and 2006, while internal bio fuels (BIOint) increased by 30 000 TwH. This was, however, not an even process over time. Rather, the substitution was most important between 1973 and 1984.

Energy mix in pulp and paper industry (1000 TwH) 1973-2006



Source: Magnus Lindmark, Ann-Kristin Bergquist and Lars-Fredrik Andersson "Energy transition, carbon dioxide reduction and output growth in the Swedish pulp and paper industry: 1973-2006", *Energy Policy 39* (2011): 5449-5456, Figure 1.

Oil was mainly replaced with internal organic residual products in the form of bark and black liquor[21], where incineration of bark for natural reasons is limited to the pulp industry and incineration of black liquor to the chemical pulp industry. In the mid-1970s, 60% of the pulp and paper industry's total fuel requirements were already met by internal fuel in the form of

[20] For the Swedish case, see Evert Vedung, *Energipolitiska Utvärderingar 1973-81*. Stockholm: Delegationen för energiforskning (DFE), 1982, Rapport No 52.
[21] Black liquor is produced in the manufacture of pulp according to the sulphate process and consists of the spent cooking chemicals and from the wood released wood substances.

black liquor and bark.[22] While the use of oil was going down, the use of electricity increased by 23.4 TWh. [23] One main reason for the moderate increase in electricity consumption since the 1970 is that mechanical pulp production, which is electricity intensive, has gained a growing share of pulp production although Kraft pulp[24] still accounts for the largest share. The expansion in mechanical pulp production was due to the fact that the wood is exploited better in the production of mechanical pulp and that products with high wood yield have been most competitive with respect to competing countries, such as North America, were the wood was relatively cheaper. In 1975 the industry's own back-pressure turbine power generation[25] covered about one-third of the need for electrical energy. The large need for energy also contributed to the fact that much of the energy had to be purchased and that a large part of production costs originated from this; in 1974 the cost for external energy in the form of electricity and fuel constituted 12% of the industry's total production costs, which can be compared with 4.1% for all manufacturing industry that year.[26] A fundamental prerequisite for the industry's competitiveness may therefore be placed in the context that access to electrical energy at reasonable prices was decisive.[27]

While the energy consumption of the pulp and paper industry increased moderately, from about 60 to 70 TWh between 1970 and the early 2000s, pulp and paper production increased by 70% and 127% respectively, which reflects overall improved energy efficiency within the sector over the period.[28] Explanations for this development can be seen in terms of ongoing

[22] *Energibesparingar inom industrisektorn*, Sektorrapport från Expertgruppen för energihushållning, Ds 1 1977:11, Industridepartementet Energikommissionen, p 38ff.
[23] *Effektiv energianvändning. En analys av utvecklingen 1970-1998*, Energimyndighet (2000), 33ff.
[24] Strong, unbleached pulp, prepared according to the sulphate method.
[25] When electrical energy is produced by means of available temperature fall in plants that produce steam - primarily relevant for industry that has great need of heat at low temperature, which applies to the pulp and paper industry. By producing steam from burning volatized cooking liquor and bark waste in 1973 the industry produced as much as 85% of Sweden's total production of electrical power through back-pressure turbine power generation. Without back-pressure turbine power generation of electricity the pulp and paper industry's dependence on imported fuel would have been considerably greater (Rydin, Bo. Energianvändningen i industrin. *Svensk papperstidning* No 1, 1980; Energikrisen i massa och pappersindustrin. *Svensk papperstidning* No 18, 1973).
[26] Energibesparingar inom industrisektorn, Sektorrapport från Expertgruppen för energihushållning, Ds 1 1977:11, Industridepartementet Energikommissionen, p 38ff.
[27] A small number of very large electric utilities dominated the Swedish electricity market in the 1970s, and these were in the midst of investing in nuclear power and thus had to secure a continued market for electricity. Largely these utilities kept down the price of electricity whereas the consumption of electricity increased exceptionally in Sweden compared to other European countries, especially in the 1970s and the 1980s (Högselius and Kaijser, 2007). Sweden's first commercial reactor Oskarshamn 1 was put into operation in 1972 at the Oskarshamn nuclear power plant. Five more reactors were put into operation in the 1970s and six in the 1980s, divided into four power plants of which one is taken out of operation (2005). Nuclear power accounts for about 40% of Swedish electricity production (www.IAEA.org). There are currently ten reactors, which makes Sweden the nuclear densest country in the world. Sweden is the only country that has more than one reactor per million inhabitants (www.world-nuclear.org/).
[28] Effektiv energianvändning. En analys av utvecklingen 1970-1998, Energimyndighet (2000), 33ff.

structural rationalizations to fewer and larger production units, which in turn contributed to improved possibilities to take advantage of economies of scale. The concentration of production units, which included a higher degree of integrated pulp and paper production, also meant that the pump pulp (at integrated mills) was less energy-intensive than pulp to be sold.[29]

At the time of the oil crises in the 1970s, the Swedish pulp and paper industry also underwent a green reconstruction driven by environmental legislation and the environmental awaking in the 1960s. The technology development underpinning the shift to greener technologies within the sector became based on inter-firm and state-firm collaborations in environmental R&D. The "spring-cleaning" was completed in the 1970s through continued process improvements and through process changes and installation of different kinds of purification works. The environmental investments undertaken by the Swedish pulp and paper producers during the 1970s and the 1980s rendered, as in many other western countries, considerable emission cuts. One example is Chemical Oxygen Demand (COD), which decreased from approximately 2.3 to 0.4 million tons annually over the period 1970-1995.[30] While the modern environmental regulation was framed in Sweden during the 1960s, energy policy was not an independent policy field before the first oil crises in 1973. Instead, energy issues were integrated with the industry policy with the basic goals to ensure cheap energy, a favourable balance of trade and energy security in the case of international conflicts.[31]

3. THE FRAMING OF THE ENERGY POLICY AND THE INDUSTRIAL SECTOR

As the pulp and paper industry's energy consumption had implications for the whole national energy system, the government and other authorities comprehended the energy issue as much less sectorial compared to the environmental issue. Issues about R&D in the energy area constituted an important feature in the energy policy debate that started after the threat of an acute energy supply crisis during the first quarter of 1974.[32] Already in 1973, an Energy program committee, with the task of producing a program for R&D, was appointed by the government. The committee reported for the first time on its work in 1974 in the study "Energy research – programme for research and development" (SOU: 1974:72). A central principle in the inquiry was the key significance of government support for R&D. It was

[29] Ibid.
[30] "Firm collaboration and Environmental Adaptation. The case of the Swedish Pulp and Paper industry 1900-1990". *Scandinavian Economic History Review* 60 (2012): 183-211.
[31] Evert Vedung "Energipolitiska Utvärderingar 1973-1981". (DFE Rapport Nr 52,1982).
[32] Regestad, Sixten. Skogsindustriella forsknings- och utvecklingsprojekt inom energiområdet, *Svensk papperstidning No 14 1977.*

perceived that the risk faced by individual companies when taking on expensive, long-term projects was too high, and risked blocking necessary development in the alternative energy technology. The report was supplemented in 1975 with an inquiry on the need for prototype and demonstration plants (PoD) within the energy area. The reports then formed the basis for the government's energy proposition, which was submitted in the spring of 1975 and resulted in the initiation of the government Energy programme that same year (Prop. 1975:30).

As a research programme, the Energy programme was unique in the history of Swedish technology policy, given that support was given to *one* certain area (energy). The programme was also unique in Sweden in terms of size and degree of interaction. A total of five different government agencies were responsible for various parts of the Energy programme. These included: *Swedish Board for Technical Development (Styrelsen för teknisk utveckling*, STU); *Transport Delegation (Transportdelegationen*, TFD); *Swedish Building Research Council (Svenska Byggforskningsrådet*, BFR); *National Energy Administration (Nationella Energiadministrationen*, NEA); and *Energy Research Board (Energiforsknings-nämnden*, EFN). The programme ran for three years, and the budget was initially 366 MSEK, where the National Board for Industrial Development (Statens Industriverk, SIND) received 42 MSEK for PoD. Already by 1976 the budget was increased by the new right-winged coalition government to 415 MSEK. New research programmes were then initiated every three years during the 1970s and '80s.[33] In parallel other research programmes were also initiated with an energy focus, such as: *Oil replacement programme* 1980-83 and 1984-87; *Investment programme* 1983-84; *Fuel environment fund* 1983-87; *Technology development programme* 1986-88; *Energy technology fund* 1988 and *Technology procurement programme for electrically efficient technology* 1988-1993.[34]

Industry was indeed in focus. Between 20-25% of the Energy programme's resources were devoted to the industry each year. During the early years, the majority of this funding was directed to research institutes and private companies, where the pulp and paper industry received most of the subsidies. This was partly because the industry was the largest energy consumer, but also because the industry started early to initiate R&D projects in the energy field. The subsidies went to process measures as well as prototype and demonstration plants.[35]

[33] See the 1981 programme (prop. 1980/81:90), focusing on incineration technology, new electrical production technology and biofuel. The programme that had the biggest budget (1400 MSEK).
[34] Marklund, 1994, s. 139-140.
[35] The private companies received their highest share between the years 1981-84 (over 30%); by 1991 this share had been reduced to almost nothing. This was in line with the governmental policy during the late 1980s, leaving a greater share of responsibility to industry in dealing with development activities within the energy technology area. The institutes' share has thus been relatively stable and stayed at between 20-25% over the period while the

In parallel with the continuous launching of new Energy programmes also additional studies with a focus on energy-related R&D was enforced. SIND and STU were the central agencies for grants and investigatory work, in which the forest industry's interests had a central place.[36] Thus, the relevant agencies had a continuous exchange of information with the pulp and paper industry's central industry organizations in energy issues throughout the entire investigation period of this paper.

Also energy taxes and fees also had a major role as control agents in Swedish energy policy. In parallel with control taxes certain types of energy were also subsidized, primarily domestic fuels, such as forest fuel and peat. Thus energy taxes and the fees on coal and oil were raised while wood burning was subsidized. In addition to raising taxes and fees on oil and coal, subsidies and favourable loans via the Oil replacement fund were also granted. Control of fuel selection also occurred via the new Solid Fuel Act, and the municipal energy planning was worked out with clear directives to increase the use of domestic fuels.[37] Thus, despite that Sweden is known for expanding the nuclear program during the 1970s, the energy policy developed in the 1970s and 80s embraced much more complex measures, not the least favoring increased utilizations of bio fuels.

4. TECHNOLOGICAL CHALLENGES AND STRATEGIES

In the 1970s, energy issues came to the forefront for the Swedish pulp and paper industry to a quite different extent than previously. As a direct response to the first oil crises, different options were available and debated in within the sector. One option was to simply increase the use of coal. Even though the possibility of replacing oil with coal was emphasized by some people the industry, and in the early 1980s several paper mills even made renovations and new construction of boilers to replace oil with coal, the majority thought that coal would make plant and environmental protection costs too high: most types of coal had high sulphur content and would therefore require expensive scrubber (abatement) systems.[38] The Swedish pulp and paper industry therefore chose early on to invest heavily in replacing oil with domestic fuels (black liquor, bark, forest fuel and peat), but the industry also made major progress in the issue of improved secondary heating systems and reduced steam

universities' share has increased greatly, from about 25% in 1975 to nearly 70% in 1991.Marklund, 1994, s. 140 ff.

[36] Se bl.a. "Tätorternas och den tunga industrins energiförsörjning" (Statens Industriverk No 3/1976); Industridepartementet Energikommissionen, *Energibesparingar inom industrisektorn. Sektorrapport från Expertgruppen för energihushållning.* Ds I 1977:11; Skogsindustri – Skogsenergi (Statens Industriverk No 2/1983).

[37] Slaget om energin avgör skogsindustrins framtid, *Svensk papperstidning* No 5, 1982.

[38] Sundblad, Erik. Skogsindustrin och energifrågorna. *Svensk papperstidning* No 9, 1977.

consumption.[39] Bark began to be utilized to a greater extent than before and boiler capacity was expanded on solid fuel boilers. In addition to this, also bark presses and later bark dryers were installed. As far as the liquor was concerned, in part the dry content was raised to the soda boiler and the quantity of fuel to the liquor system was increased through the introduction of oxygen bleaching technology as of the late 1970s (see also under footnote 49). Organic material that previously had gone to runoff in the bleaching process could now be returned to the liquor system.[40] Among the firms measures were also about reviewing procedures and 'thinking' more in terms of saving energy. Simply by making sure that all instruments and processes functioned optimally, results of ten percent reductions in energy consumption could be achieved.[41] It was perceived to be more difficult to minimize electricity consumption than heat consumption, in part because electricity consumption was divided into a much larger number of relatively small consumption sites.[42] The external need for electrical energy could instead, it was believed, be reduced through increased expansion of the back-pressure turbine power produced by the industry sector. In 1973 the industry already produced about 30% of its need for electrical energy in this way and the possibilities to increase production further were considered great. In this context prominent individuals in the industry, managers and professors of cellulose technology, emphasized the benefits if government support in this area as the technical prerequisites for an introduction already existed. There was also a working group appointed by the industry organization *Swedish Cellulose and Paper Mill Association* (SCPF) whose task was to inventory the experiences with and potential of back-pressure turbine power generation and to create conditions for additional electricity production.[43] In this context it is also relevant to point out that there was a general understanding that the industry, in order to manage exports, in part needed to increase wood yield and refine the pulp, all of which required more electrical power.[44]

[39] By the mid-1970s several mills had started using secondary heat, in part to heat their own premises. A surplus of heat could also be used in a paper machine (in integrated mills) or for residential heating around a mill or for electricity production. Furthermore attempts were made to reduce the need for fresh steam during evaporation by introduction of more evaporation steps, by expanding/renovating to more presses, double screens, etc. on drying and paper machines (Industridepartementet Energikommissionen, *Energibesparingar inom industrisektorn. Sektorrapport från Expertgruppen för energihushållning.* Ds I 1977:11, pp. 117-131).
[40] Mejlväxling med Anders Eliasson, Energi o Processkonsult, Eurocon, Feb. 13 2014.
[41] Rydin, Bo. Energianvändningen i industrin. *Svensk papperstidning* No 1, 1980. At one company they were able for example to reduce oil consumption considerably simply by heightening the control of all process variables that in some way affected the need for heat or oil. In this connection the increased commitment and interest in energy issues among personnel also had central importance (Robertsson, Olle. Energibesparande åtgärder i sulfatfabriker, *Svensk papperstidning* No 1, 1975).
[42] Interview with Hans Norrström 2013-05-06.
[43] Sundblad, Erik. Skogsindustrin och energifrågorna. *Svensk papperstidning* No 9, 1977; Hartler, Nils. Energisnåla massa- och pappersprocesser, *Svensk pappertidning* No 1, 1978.
[44] Sundblad, Erik. Skogsindustrin och energifrågorna. *Svensk papperstidning* No 9, 1977.

In an introductory phase, the mobilization of the industry on the energy area naturally concerned the kind of actions that gave immediate results, while in the medium term this concerned actions that changed and improved existing technology. In the long-run however, completely new technology needed to be introduced for the purpose of energy conservation. In a report compiled by the Expert group for energy management within the 1970s Energy commission[45], "Energy savings within the industrial sector (1977)[46]", a number of such development projects are listed related to, in part, the bleaching stage[47] and high concentration technology.[48] Again it was perceived that it was through long-term R&D work and effectively directed support from subsidy-granting organizations that significant energy gains in the pulp and paper industry could be achieved.[49]

It was also perceived that increasing the use of recycled paper could be a suitable energy-conserving measure, simply because the energy use for production of recycled pulp from recycled paper was no less than one-fifth of the energy use in production of mechanical pulp from wood. The fact that the methods were improved for removing ink and other contaminants, such as plastic, from the recycled paper it was possible to increase the use of

[45] The Energy Commission, the name of two government energy policy investigations during the 1970s and 1990s respectively, both with parliamentary composition. The first Energy Commission was appointed by the conservative government only a month or so after it took office in the fall of 1976. The Commission had the task of producing during 1977 an all-inclusive basis for an energy policy for the 1980s. In practice it was an attempt to find a compromise between the conservative parties' strongly divergent opinions on nuclear energy.

[46] Energibesparingar inom industrisektorn, Sektorrapport från Expertgruppen för energihushållning, Ds 1 1977:11, Industridepartementet Energikommissionen.

[47] The industry had expended extensive R&D work on bleaching with oxygen during the 1960s and early 1970s, both within the framework for common research institutions, such as STFI, IVL and SSVL, and in individual companies' R&D labs, such as MoDo. The technique, which was established at Swedish mills in the late 1970s and early 1980s (early from an international perspective), reduced the lignin content in the unbleached pulp by half, where the released organic substance is used instead for energy production. In this way the oxygen technique was an important energy-conserving as well as emissions-reducing measure for the industry. The fact is that the oxygen technique constitutes the very core of the entire chlorine-free bleaching process where Swedish mills were the first to produce chlorine-free pulp after the international dioxin crisis in the late 1980s (Bergquist & Söderholm, 2014). The report (1977) shows that the industry assumed that through continued R&D it would also be possible to reduce energy consumption with the production of bleaching chemicals, and it was thought that bleaching works waste liquor containing chlorine, through more effective chlorine separate methods, could be returned to the re-use cycle. In reality however it would turn out in time, during the early 1990s, that the pulp could be bleached completely without chlorine, upon which the bleaching works could be shut down completely (Bergquist & Söderholm, 2014).

[48] As far as the high concentration technology was concerned the industry expected that continued R&D would contribute to reduced electricity consumption. The target was that fibre concentration would be increased strongly in all stages of fibre suspension before the paper machine. Development potential was also considered to exist in the question of drying and paper machines wet sections with a significantly higher dry content and improvement heat economy on outgoing roll. A continued development of press technology was also expected to be applied to pulp washing and produce less diluted lye for evaporation and better heat economy in all sub-processes with lye extraction and bleaching (Axelsson, Lars-Erik. Massa- och pappersindustrin visar vägen mot oljeoberoende. *Svensk papperstidning* No 5, 1983).

[49] The report was based in part on early investigations by National Board for Industrial Development (SIND) of the industry's energy management (SIND 1976:3 and SIND 1977:6) and on material gathered from the pulp and paper industry's so-called Energy committee.

such paper. The growing need could be met by increasing the collection domestically.[50] Thus, whereas waste paper was not used at all in Swedish paper production before 1975, it is an important raw material in the manufacturing of paper today.. A key prerequisite to be able to increase the use of waste paper was though the introduction of a compulsory collection system in Sweden for sorted waste paper from the households, which started in 1975.However, besides energy, another important interplaying factor behind this development was the fear of shortage of wood. [51]

To manage the new FoU challenges, the Swedish pulp and paper industry already in 1973 installed a standing energy committee consisting of 12 members from among management and technical personnel within the industry. A major function of the committee was to encourage energy conservation measures with such a design that they simultaneously improved mill performances. Other functions included the collection and diffusion of information about such ongoing measures within the industry, and the appointment of representatives to investigate special subjects as well as to represent the industry in public bodies and investigations. The committee further generally to promoted the industry's interest in the governmental energy policy process and to assisted firms in grant-applications to government authorities.[52] Of central importance was further that the committee regularly (about every five years between 1974 and 2001[53]) had performed energy studies based on statistics from all Swedish pulp and paper manufacturers. Through these, individual mills got the opportunity to compare their energy performance with other mills.

During 1974, the committee also produced a list of the kinds of projects the government could be expected to be willing to support. The projects treated back-pressure turbine power generation, incineration of bark and other forest waste and the possibility of exploiting gas produced through the abovementioned incineration as replacement for oil. The projects were coordinated to a great degree with already ongoing projects at other collaborative R&D plattforms; the *Swedish Pulp and Paper Research Institute* (STFI) and *Forest Industries' Water and Air Pollution Re-search Foundation* (SSVL). In addition to this, one project investigated best existing technology as far as existing installations for pulp and paper were concerned with the manufacturing of four standard grades. By accounting in this way for what

[50] Industridepartementet Energikommissionen, *Energibesparingar inom industrisektorn. Sektorrapport från Expertgruppen för energihushållning.* Ds I 1977:11, s. 117-131.
[51] Ekheimer, Patrik. *Tidningspapper av returpapper - Den svenska massa- och pappersindustrins omvandling under senare delen av 1900-talet*, (Chalmers University of Technology, 2006).
[52] Marklund, Göran. *Institutions and appropriation in Swedish technology policy*. Graphic Systems, Stockholm 1994, s.143-144.
[53] See e.g. Svenska Cellulosa- och Pappersbruksföreningen, Energiförbrukning i massa och pappersindustrin 1973 (Stockholm 1974).

was practically achievable for modern mills the committee wanted to produce a data foundation that could serve as a practical handbook for technicians in the industry.[54] The Steam Generator Association [Ångpanneföreningen] was commissioned to conduct the model mill study, which resulted in four books, one for each primary type of mill: kraft liner mill, tissue paper mill, sulphate mill for bleached commercial pulp and newsprint mill.[55] The books came to function as a kind of role models for energy optimizations among the existing and projected mills.

It was not just the energy committee that initiated and coordinated projects. In 1974, SCPF also appointed special working group with industry professionals to conduct an inventory over which projects, aiming for energy savings that were extra urgent by the industry. The inventory was thereafter continuously updated and published in catalogues issued in the industry every second year. Most projects were actually carried out and it is reasonable to believe that the catalogue played an important role in motivating energy research within the industry.[56] The above described regular evaluation of R&D projects and energy performance within the industry are illustrative examples of the open exchange of information between companies within the Swedish pulp and paper industry. Early on, the pulp and paper industry, through this work, developed a quite purposeful policy on energy savings not least through the way the work was very well adapted to STU's grant policy.[57] The material in addition formed a valuable basis for the numerous official reports conducted within the context of the Energy program.

In 1977 it could be observed in the industry that since the oil crisis in 1973, no less than 50 energy projects had been started or proposed. In an article in the industry journal *Svensk Papperstidning* [Swedish Paper Journal],the projects were classified in two groups, Energy conservation (37 projects) and Energy generation (14 projects). Here it is shown how actors, in addition to STFI, SCPF and the Steam Generator Association contributed. Such these included universities (The Royal Institute of Technology in Stockholm and Chalmers in

[54] Om FoU på energiområdet. *Svensk papperstidning* No 9, 1975; Protokoll No 8 fört vid sammanträde med styrelsen för Stiftelsen Cellulosa- och Pappersforskning 23 januari 1973. Stiftelsen Cellulosa- och Pappersforskning protokollskopior. 1970-1993. Industrihistoriska arkivet.
[55] Sven-Erik Jönsson, Johan Nygaard, Rolf Wiberg, Modeller för energihushållning i massa- och papperstillverkning. Sulfatfabrik för blekt avsalumassa. Stockholm: Ångpanneföreningen, 1976; Sven-Erik Jönsson, Johan Nygaard, Rolf Wiberg, Modeller för energihushållning i massa- och papperstillverkning. Kraftlinerbruk. Stockholm: Ångpanneföreningen, 1976; Sven-Erik Jönsson, Johan Nygaard, Rolf Wiberg, Modeller för energihushållning i massa- och papperstillverkning. Mjukpappersbruk. Stockholm: Ångpanneföreningen, 1977; Sven-Erik Jönsson, Johan Nygaard, Rolf Wiberg, Modeller för energihushållning i massa- och papperstillverkning. Tidningspappersbruk. Stockholm: Ångpanneföreningen, 1977.
[56] Marklund, 1994, s.143-144; Om FoU på energiområdet. *Svensk papperstidning* No 9, 1975.
[57] Marklund, 1994, p. 144.

Gothenburg), institutes outside the industry (Värmeforsk [Thermal Engineering Research Institute][58] and the Institute for Surface Chemistry) as well as individual companies (e.g. MoDoCell, and the Billerud Group) were also involved in the projects.[59] The research organization NEFOS (merged with Värmeforsk in 1985) was also conducted several projects that concerned the pulp and paper industry.[60] The industry was indeed eager to increase the contact with the universities. For one thing, in the mid-1970s the industry provided relevant departments at universities and technical colleges with a list of more than 30 pressing R&D projects at the same time as they were encouraged to apply for subsidies from STU, SIND and other sources of financing.[61] In this way technology development was supported by an inventory of needs and technology from inside the industry.

Besides the knowledge sharing and R&D efforts made jointly, individual companies contributed significantly to the changes in the energy area, typically by developing and testing new machinery and new processes in full scale. Also applied research went on to some extent. As the government started giving significant subsidies for prototypes and demonstration plants by the energy policy decision in 1975, such activity increased, and the companies could receive state subsidies of 50% to introduce new technical processes on a factory-wide scale. The state subsidies for prototype and demonstration plants contributed to making the results of such activity available to everyone, because the subsidies prescribed formal, publicly accessible reporting.[62] The work in the majority of the research laboratories that were connected to individual companies was directed at energy issues. This shown in the annual report in 1974 from the SCA Group, one of the leading forest industries in Sweden:

> The operation […] has primarily been marked by the increased demands in recent years for improved internal and external environment and the need to make better use of resources with regard to energy and fibre raw materials. […] The possibilities to reduce the need for external energy sources may be judged as good in the longer term. The areas that are being investigated are increased recycling of process water, reduced water consumption in warmer process steps and more efficient incineration of black liquor.[63]

[58] Half state/half industry funded research organization. Formed in 1968 by major manufacturers of energy plants and the owners and users of such facilities in the power and process industries (NE).
[59] *Svensk papperstidning* No 14, 1977.
[60] Marklund, 1994, s.143, reference No 28.
[61] Wohlfahrt, Göran. Energihushållningen i massa- och pappersindustrin. Om pågående utredningsverksamhet på branschnivå, *Svensk papperstidning* No 1, 1977.
[62] Erik Sundblad, ”Skogsindustrin och Energifrågorna”, *Svensk papperstidning* No 9, 1977; Sixten Regestad, ”Skogsindustriella forsknings- och utvecklingsprojekt inom energiområdet”, *Svensk Papperstidning* No 14, 1977.
[63] Svenska Cellulosa Aktiebolaget (SCA), Annual report (1974), p 20.

Focus on energy and environmental issues was maintained in the industry's individual research laboratories during the 1980s as well, and this applied to pulp and paper manufacturers as well as to machinery suppliers.[64] Even greater possibilities to limit energy consumption in a mill existed for natural reasons in parallel to renovations and new constructions. At one of SCA's mills, rebuilt in 1974, it was possible to reduce annual consumption of oil from about 63,000 m3 to 38,000 m3, and the annual need for electricity supplied from outside from 200 million kWh to 120 million kWh in combination with production expansion. Part of the need for energy was satisfied after the renovation by technical measures such as increased incineration of lye and bark and through increased generation of back-pressure turbine power.[65] For the purpose of saving raw materials and energy during 1974, the same mill also joined all Scandinavian manufacturers of newsprint and reduced the long-established standard weight for newsprint from 52 to 48.8 grams per square meter. This measure was received well on the market, which soon demanded even thinner grades.[66]

The companies could also send their personnel for technical training in energy issues. The industry's Energy Committee devoted considerable interest to training issues. In 1979 the committee produced an extensive training programme, where in the 1980s courses were held at the Forest Industry's training centre in Markaryd. The government also stressed the significance of training by making considerable resources available for this purpose.[67]

As the energy policy encouraged (in part through subsidies) the use of domestic fuels, there was generally increased interest in wood incineration. The growing pressure on the forests worried the forest industry, who feared that the practically accessible quantities of forest fuel would be over-subscribed, which would threaten the access to raw materials for the industry.[68] The industry thought that it was unrealistic to expect competition on equal terms under such conditions and encouraged the government to direct policy measures according to the goals simultaneously set for economic development, i.e., that industry production was assumed to increase significantly.[69] However, in parallel with this worry, the forest industry

[64] See e.g., STORA, Årsrapport (1981), p 17; SCA, Årsrapport (1981), p 24f.
[65] Stora, Årsredovisning, 1974, p 34-35.
[66] Stora, Årsredovisning, 1974, p 10.
[67] It was SIND that administered and coordinated the government contributions in the training area. Axelsson, Lars-Erik. Energiutbildning för bättre energihushållning, *Svensk papperstidning* No 5, 1982.
[68] Slaget om energin avgör skogsindustrins framtid, *Svensk papperstidning* No 5, 1982.
[69] Konkurrens på lika villkor nämns även i artiklarna: Slaget om energin avgör skogsindustrins framtid, *Svensk papperstidning* No 5, 1982;Wohlfahrt, Göran. Grafströmska utredningen och skogsindustrin, *Svensk papperstidning* No 5, 1982. Se också Rydin, Bo. Energianvändningen i industrin, *Svensk papperstidning* Nr 1, 1980.

itself began to gather and utilize forest fuel to a growing extent in the early 1980s. This occurred on a broad front and basically all companies with forest assets started such activity. At the same time, some companies also prepared peat production.[70] The investments gained returns, and a large part of the reduced need for oil was achieved by expanding the use of biofuel; the use of biofuel increased by 25% between 1983 and 1995.[71] The growing interest in biofuel in parallel with continuing work in heating economy was reflected in the energy strategy of the SCA Group (formulated in an annual report) in 1981:

> The energy strategy includes […] that each mill to begin with shall carry out the additional conservation measures that are commercially correct. This involves in part the exploitation of new technology for transforming low-value waste heat in various processes to high-value heat for reuse, e.g. by means of heat pumps. An expanded supply of waste heat to municipal district heating networks is also included in this part of the action programme. In another stage the strategy includes a transition to solid fuels such as forest fuel in the form of logging waste, clearance timber and peat. […] The development of systems for collection and transport of forest fuel has come a long way. […] [A]lready today forest fuel is being utilized as a part of the Forest division's normal operations. In Sweden, not least on SCA's land, there are large peat assets. For utilization on a larger scale however extraction methods as well as dewatering technology must be further developed. This work is ongoing.[72]

The energy strategy also states that the company counted on continued transition to wood-conserving technology. It was noted that this would involve increased electricity consumption but that it happened with the assumption that Sweden would also continue to have good access to electrical power at an internationally competitive price.[73] In this respect, the nuclear program was important.

The Stora Group, owned by the Wallenberg family, stated in their annual report 1983 that during the past 6-7 years, extensive energy-conserving measures had been undertaken at the company's mills so that fuel consumption could be reduced significantly. In parallel, the need for oil had been reduced among their mills by the use of other fuels. Of particular importance for STORA was also the transition to solid fuels. The company reported that it had been proven to be economically feasible to utilize forest waste among the company's mills in the form of branches and tops that normally had been left behind after cutting, and not previously utilized.. Such fuel was now, in 1983, to some extent supplied to industry and likewise solid fuel-fired boilers had been put into use at two mills during the year. These

[70] Axelsson, Lars-Erik. Massa- och pappersindustrin visar vägen mot oljeoberoende. *Svensk papperstidning* No 5, 1983.
[71] Effektiv energianvändning. En analys av utvecklingen 1970-1998, Energimyndighet (2000), 33ff.
[72] SCA, Årsredovisning, 1981, p 17.
[73] SCA, Årsredovisning, 1981, p 17.

could be fired with coal as well as with chips, shavings, bark[74] and peat. Through the transition to solid fuels, these mills would save 50,000 and 80,000 m3 of oil annually. Calculated per thermal unit the average price of solid fuel amounted to about half of the price for fuel-oil.[75] The consumption of fuel-oil at mills held by the Stora Group in Sweden in 1979 amounted to about 140,000 m3. Through conservation measures, transition to other fuels and through utilization of electric boiler power, the annual requirement for oil had in four years been reduced to below 25,000 m3. The systems that existed among the mills within the Stora Group in 1983 had become much more flexible, and it was possible to use different types of fuels. This was valuable both from an economic perspective as well as in the events of shortage situations of different energy carriers. The Stora Group had furthermore established cooperation with municipal energy works in a few places for heat deliveries.[76] In this context it may be noted that the company three years earlier, in 1981, had received government subsidies for energy-conservation measures of 9.4 MSEK.[77]

At the firm level, there was in many aspects a close connection between the work with energy-conservation measures and investments in pollution reduction technologies. As mentioned before, the oil crisis coincided with an ongoing greening of the industry. One concern however, was that the use of cleaner technology could imply an increased need for energy. This situation was clear to the STORA group, who already in 1973 stated that: "The environmental protection measures have increased the company's variable production costs, not least due to increased energy consumption".[78] This fact was also emphasized in 1977 by the government expert group for energy conservation as a possible obstacle in the forest industry's energy-conservation work. The group maintained that: "Thus it can be difficult to maintain or increase production and at the same time satisfy the strict environmental requirements with unchanged or reduced energy supply".[79] At the same time the opposite condition in terms of 'win-win' could just as well apply, i.e., that an energy-serving measure simultaneously could lead to environmental improvements. When the Stora Group in 1974 purchased a new paper machine for one of its mills that had recycled paper instead of wood as raw material, it was stated that the machine: "[was] not only an environmental protection

[74] The boilers would in part be fired with large quantities of bark that was already stored at the industries as the previously used bark-firing boilers did not have sufficient capacity to accommodate all the bark that resulted from earlier pulp production. In addition the new boilers would be fired with fuel chips that were produced with clearing and logging in the forest. It was noted that this concerned significant cost reductions.
[75] STORA, Årsredovisning, 1983. "Minskat oljeberoende - förbättrad energiekonomi".
[76] STORA, Årsredovisning, 1983. "Minskat oljeberoende - förbättrad energiekonomi".
[77] STORA, Årsredovisning, 1981, p 28.
[78] Stora, Årsredovisning (1973), p 13.
[79] Energihushållning. Huvudrapport från expertgruppen för energihushållning, p 103f. ds1 1977:10.

effort. It also involves energy consumption that is less than half compared with paper manufacturing with wood as raw material".[80]

In the mid-1980s another Swedish pulp company within the MoDo Group invested in a bioenergy plan according to the recently developed Anamet method, to cut emissions of COD. This concerned an extensive investment expense, over 70 MSEK. However, besides the fact that system could gradually reduce the mill's BOD7 emissions from 45 to 6 tons per day, it also reduced the mill's oil consumption by about 40% through methane gas production.[81] Moreover, as an example for the pulp industry as whole, bark was actually a waste problem which had to be stored and thereby caused environmental problems at the site. Thus, by using bark for energy generation a waste problem was simultaneously solved.

All in all, depending on the type of mills, production processes and structure, different measures were undertaken, but it all had the same purpose and goal: to phase out the oil by substitution to other energy carriers, and to save energy. In the last section below we will sum up how the overall transition was accomplished.

5. SUMMARY AND CONCLUSIONS

The run-up in energy prices during the 1970s meant that the energy issue gained strategic importance in the Swedish pulp and paper industry. Already in 1973, the industry associations immediately initiated collaboration aiming for the support of individual mills to swiftly reduce the consumption of oil. Collaboration became a key feature in the organisation of the energy transition within the Swedish pulp and paper sector throughout the 1970s and the 1980s. The sector already had a tradition of industry-wide collaboration in environmental R&D at the time of the first oil crisis in 1973. This was due to the enforcement of a new environmental regulatory framework in 1969, which had initiated an environmentally driven reconstruction of the business sector. The ongoing 'green' reconstruction among the Swedish pulp and paper mills became strategically based on an industry-wide collaboration in environmental R&D, driven by the need to share costs and risk associated by clean technology development and pool competence within the sector.

In the wake of the first oil crisis, there was an urgent need to reduce the use of oil in the whole Swedish energy system; oil accounted for no less than 70 percent of the Swedish energy supply. Sweden therefore saw a period of rapid expansion of the energy policy from

[80] STORA, Årsredovisning (1974), p 34.
[81] Growing Green and Competitive—A Case Study of a Swedish Pulp Mill, Kristina Söderholm and Ann-Kristin Bergquist.

the mid-1970s, which embraced all sectors in the economy; transport, households, the building sector and of course the industry. As the pulp and paper industry was the biggest energy consumer in the country, the sector was of great concern for the government. Supportive policy measures were formed to push the technology development and the diffusion of technologies.

Initially, and as a direct response to the oil crisis in 1973, oil reductions were accomplished by relatively small measures among the pulp and paper mills. Much of the knowledge to use internal biofuels for energy generation, such as burning bark and chips and black liqueur for energy generation was already known before the oil crisis. However, as oil before the 1970s was cheap, there were few incentives to explore further possibilities to use internal (wood waste) fuels for energy purposes. At the same time, utilizing the wasted wood for energy generation meant that other problems could be solved. Bark was an actual waste problem which had to be disposed, stored, and thereby caused environmental problems at the site. Thus, by using bark for energy generation, a waste problem simultaneously got solved.

There was also other major nexus' between energy efficiency gains, oil reduction and environmental gains. In parallel of struggling to cut energy costs, there was a need to cut costs and emissions from the bleaching process in the pulp manufacturing, why the Swedish pulp and paper industry put a lot of efforts to develop methods of oxygen delignification as an alternative to elemental chlorine as a bleaching agent. This method not only reduced the use of chlorine, but also released organic substance which could be utilized for energy production.

Substituting oil with internal biofuels proved to be the overall most reasonable way out from the oil dependence and to cope with the overall energy crisis that occurred in 1975, two years after the oil embargo. Other options were of course available and discussed. An easy way out would have been to simply substitute oil with increased use of external electricity, which was not technically impossible. Another way would have been to increase the use of coal. However, even though some plants considered coal, the overall perception within the sector was that coal would imply problems with sulphur emissions, which the sector already was struggling with because of environmental legislative requirements. Coal would also still mean dependence of imports. And when it comes to the purchase of electricity, this would imply future uncertainties about costs and risks that could force the sector out of the market, at least the pulp mills.

There was, however, a great need for long-term R&D to push the technology development further, and inter-firm and state-firm collaborations was strategically important in this context to share both the risks and costs related to technological development. When it

comes to the organisation of the sector's collaboration in energy related R&D, an important step was taken when the *Swedish Pulp and Paper Association* formed the 'Energy Committee' in 1973. The committee was to initiate and coordinate R&D projects in the business sector and to coordinate these with R&D projects already operating within other R&D platforms connected to the industry. Such important R&D platforms included the *Swedish Pulp and Paper Research Institute* (STFI) and the *Swedish Forest Industries' Water and Air Pollution Committee* (SSVL). Moreover, also more novel programs with focus on energy were formed in collaboration between the existing research institutes outside the immediate sector as well as with consultant companies, equipment suppliers, individual firms and not least universities. These collaborations and exchange of knowledge was directly supported by, and interplayed with the energy policy and the many different R&D programs that were launched within the policy framework.

Much of the energy policy that was framed in Sweden during the 1970s came to be directed on supportive measures for R&D, directly to the industry or indirectly via the universities or other research institutions. Of importance to the policy development were the statistics and project information generated and diffused by the industry itself. The Swedish authorities incorporated this information as a part of the work with the investigations around the needs of energy related R&D in the Swedish society. The industry-based investigations conducted by associations of the Swedish pulp and paper industry therefore formed the basis for many of the energy research programs that were launched by the Swedish Government in the 1970s and the 80s. The pulp and paper industry therefore became on important stakeholder in the framing of the energy policy in Sweden.

The Swedish government early recognized the risks and costs for individual firms to carry through experimental and long-term R&D projects on the energy area. Based on the 'motto' that state aid was necessary for pushing the technology development forward, by minimizing the risk of individual companies, around a quarter of the energy policy resources were devoted to subsidies for industrial process alterations and to prototype and demonstration plants. Of all the governmental funds that went into manufacturing, the pulp and paper industry received the biggest share. It is therefore reasonable to assume that the state funding was central to the pulp and paper industry's strategy to embark on research to accomplish reductions of oil consumption. Many projects had not been reasonable without financial support. In addition to energy related R&D programs, also taxes and subsidies of energy effected the transition. Thus, taxes on fossil fuels and subsidies for domestic wood

fuels and peat naturally worked in favour for the government strategy to reduce oil consumption in favour of biofuels.

However, the pulp and paper industry could accomplish the reduction of oil, including lower energy intensity in the manufacturing process, based on different measures, where some technological details has been highlighted in this study. But taken all together, it was the increased use of biofuels; internal wood waste from the manufacturing process and an increased use of peat and external wood waste that had previously not been harvested in the forests that would constitute the main substitute of oil. Also the increased use of recycled waste paper should be mentioned in this context as it demanded less use of energy in the paper manufacturing process. The oil crisis in the 1970s truly meant that focus was directed on both energy efficiency and more efficient materials use, and the potential for improvements proved to be comprehensive. Not only the increased oil prices, but also changes in taxation of different energy carriers, favouring biofuels, stimulated this development.

The whole transition from oil dependence within the sector sheds important lights on the dynamics between changes of prices on energy carriers and more sustainable production processes. It is indeed interesting to notice that the potential to use biofuels, which for this sector was a resource not priced on the market but just simply more or less a waste problem, hadn't been utilized to a greater extent before the oil crisis. The process experienced here thus clearly relates to the academic discussion of the Porter-hypothesis, which states that a strict environmental policy, based on market based instruments like taxes, can stimulate improved productivity by directing focus on unutilized potentials at the level of firms. It was simply no economic rational to direct focus on the use of internal or external biofuels instead of oil, especially since the social (environmental) costs of burning fossil fuels had not yet priced by the environmental policy.

In the case of the pulp and paper industry, the dynamics between energy prices, energy use and the environmental impact of business activities clearly proved to be comprehensive. Understanding how businesses enter new technological and more sustainable production paths is complex, and is not always intentional from start. Already in 1973, and even before the second oil crisis, the industry was unified and determined to let go of the dependence of oil, and by doing so, also other environmental improvements were solved. However, at that time, there was no awareness of the impact of carbon dioxide emissions and climate change, even though emissions were cut considerably. The dynamic process of energy transition experienced in this case illustrates the central role changes in energy prices can play for

industrial transformation, and the dynamic interplay between energy use and environmental impacts. It also illustrates the central role government played, and can play, to support and push industries into new technological paths.