



Industry Strategies for Energy Transition in the Wake of the Oil Crisis

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This paper employs the Swedish pulp and paper sector in the 1970s and 1980s as a case study to explore industry strategies for accomplishing energy transition in the wake of the 1973 oil crisis. Over this period, the use of fossil fuels was reduced by 70 percent within the sector. The lion's share of the reduction was achieved by the substitution of biofuels for oil. Besides cutting the cost of energy production, this substitution also resulted in significant environmental improvements. Substituting biofuels for oil proved to be the most reasonable way to decrease the use of oil, even though alternatives such as coal were considered. Initially, reductions in oil consumption and improvements in energy conservation were accomplished by relatively small measures, but there was a great need for long-term R&D to push technology development further. Inter-firm and state-firm collaborations therefore became strategically important. The strategies for substitution further interacted strongly with institutional changes in the energy policy field, the ongoing "greening" of the industry, as well as an urgent need to enhance international competitiveness. Our study concludes that the oil crises enforced more sustainable production in a dynamic way, where government strategies to support and push technology development further played a central role.

Introduction

This paper explores strategies to accomplish energy transition in the Swedish pulp and paper industry in the 1970s and 1980s. For decades economic historians have paid attention 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

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modern economic growth.¹ However, 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 consumption has not attracted much interest from business historians. Needless to say there exists a voluminous literature investigating entrepreneurship and growth of major companies within the oil and electricity production industries.² Recently, historians have addressed emergent industries and examined key entrepreneurs within sustainable energy production.³ Clearly the Arab oil embargo and the run-up in energy prices during the 1970s had major impact on the global oil industry, countries' energy systems, and energy consumption.⁴ The oil crises further stimulated major shifts in governmental energy policies. However, to our knowledge, the way that changes in relative prices of energy carriers and governmental energy policies have altered the conditions and strategies in heavy energy consuming industries has been overlooked in business historical research.⁵

There has, however, been a growing interest⁶ in incorporating environmental issues into business history research, although much of this research has paid attention to time periods prior to the advent of modern environmental debate and

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

² See for instance, the work by Stephen Howarth, Joost Jonker, Keetie Sluyterman and Jan Luiten van Zanden, *The History of Royal Dutch Shell* (Oxford, 2007); Alfred D. Chandler Jr., *Scale and Scope. The Dynamic of Industrial Capitalism* (Cambridge, MA, 1990); Geoffrey Jones, *The State and the Emergence of the British Oil Industry* (London, 1981).

³ Geoffrey Jones and Loubna Bouamane, "Historical Trajectories and Corporate Competences in Wind Energy," *Working Paper 11-112*, Harvard Business School, 2011. Geoffrey Jones and Loubna Bouamane, "Power from Sunshine. A Business History of Solar Energy," *Working Paper 12-105*, Harvard Business School, 2012.

⁴ Astrid Kander, Paolo Malamina and Paul Warde, *Power to the People. Energy in Europe over the Last Five Centuries* (Princeton, 2013), p. 258 ff; John R. McNeill, *Something is New Under The Sun. An Environmental History of the Twentieth Century* (New York, 2000).

⁵ There are exceptions, see e.g. Martin Chick, *Electricity and Energy Policy in Britain, France and the United States since 1945* (Cheltenham, 2007); Richard Vietor, *Energy Policy in America since 1945: A Study of Business-Government Relations* (Cambridge, 1984).

⁶ 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*. Christine Meisner Rosen and Peter Sellers, "The Nature of the Firm: Towards an Eco-cultural History of Business," *Business History Review* 73, no. 4 (1999), 577–600. Drawing on 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 have 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). Since 1999, a growing number of scholars have integrated environmental issues in business historical analysis and leading journals within the field have continued to raise the question on the research agenda. 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. Friedman and Geoffrey Jones, *Business History Review* 85, no.1 (2011), 1–8.

legislation, as well as the energy crisis itself.⁷ 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.⁸ Energy and environmental issues are further 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.⁹ Not only the energy production but also energy consumption, essential in energy intensive industries, influences the environment to a large extent, and this relation is obvious to firms today.¹⁰ Even though environmental aspects of energy production, not the least within the oil industry, have been the focus of some studies, energy use and the dynamic interrelation between energy use and the environmental impact of business activities has not yet been incorporated into this research field.¹¹

Heavy industries, including pulp and paper and basic metal production, have formed the backbone of Swedish industrialization from the 1890s and onwards. This implied an industrial structure that was very energy intensive, and since Sweden was not endowed with oil or coal resources, the energy supply was heavily dependent on massive oil imports. Even though Sweden had large reserves of hydropower, oil accounted for as much as 72 percent of the total energy balance in the Swedish economy in 1973.¹² The pulp and paper sector accounted for 40 percent of total industrial energy consumption in Sweden, making the sector the largest energy consumer in the economy.¹³ However, in the wake of the first oil crisis in 1973 until the late 1980s, the use of fossil fuels within the pulp and paper sector was reduced by 70 percent. The lion's share of this reduction was achieved by the substitution of internal (wood waste) biofuels for oil. As an indirect effect, emissions of carbon dioxide

⁷ For a recent overview, see Geoffrey Jones and Christina Lubinski, "Making 'Green Giants: Environment sustainability in the German chemical industry, 1950s-1980s." *Business History* 56, no. 4 (2013), 623–649.

⁸ See for instance, Andrew J. Hoffman and Marc J. Vantresca. *Organizations, Policy and the Natural Environment: Institutions, and Strategic Perspectives* (Stanford, 2002).

⁹ Resource depletion is an additional unsustainable aspect of the use of fossil fuels that has been widely debated 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. Donella H. Meadows, Dennis L. Meadows, Jorgen Randers and William W. Behrens, *The limits to growth* (New York, 1972).

¹⁰ 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 for instance, Andrew J. Hoffman and John G. Woody. *Climate Change: Whats Your Buisness Strategy?* (Cambridge, MA, 2008). Both energy and the environment indeed further represent key headwinds for future economic growth. See 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.

¹¹ Studies focusing on the oil industry, see Keetie Sluyterman, "Royal Dutch Shell: Company Strategies for Dealing with Environmental Issues," *Business History Review* 84, no. 2 (2010), 203–226; and Hugh Gorman, *Redefining Efficiency: Pollution Concerns, Regulatory Mechanism and Technological Change in the US Petroleum Industry* (Akron, OH, 2001).

¹² 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] (Stockholm, 1994), p. 23.

¹³ *Kortsiktsprognos över energianvändning och energitillförsel 2013-2015* [Short-term forecasts of energy consumption and energy supply 2013-2015], The Swedish Energy Agency (Stockholm, 2013), p. 19.

were reduced by 80 percent.¹⁴ From the perspective of carbon dioxide production, this chance resulted in great environmental improvements. The substitution however also resulted in other improvements, such as reduced wood waste.

By the time of the first oil crisis in 1973, an environmentally-driven reconstruction of the business sector had also been initiated in response to a new regulatory framework initiated in 1969.¹⁵ Environmental pressure combined with rising costs for energy and wood, and increasing international competition, put pressure on the Swedish pulp and paper sector to transform.¹⁶ New challenges relating to both energy and the environment emerged during the 1970s, and the aim of this study is to examine how energy transition was accomplished in this challenging context. The paper will provide an overview of the knowledge building and technological development that underpinned changes in the energy mix in the short and long terms. We will further investigate the importance of the interplay between the energy policy and strategies developed within the pulp and paper industry. The period under investigation can be seen as a formative era for energy-related R&D that remains of importance for meeting the challenges and opportunities faced by the industry sector today.

The Oil Crises and the Pulp and Paper Industry: Some Analytical Implications

Since the run-up in energy prices that began in 1973, the world has been flooded with suggestions of how to reduce energy inputs or substitute one source of energy with another. These proposals have often suggested the substitution of renewable sources for nonrenewable ones. Adjusting to changes in energy availability and price has, however, proven to be a slow process, often stretching over decades when it comes to industrial plants. This is because 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.¹⁷

In the 1970s, energy became a critical issue within energy-intensive industries such as the pulp and paper sector where energy acquisition represents a significant cost in the manufacturing process. The oil crises further stimulated major shifts in energy policies in many western governments and Sweden was no exception. Increased energy efficiency and expansion of nuclear power programs for electricity production were preferred strategies for the Swedish government to reduce dependence on oil and decrease costs. While Swedish industry was motivated primarily by cost savings, the Swedish government's primary policy goal was to arrest the nation's rapidly deteriorating international balance of payments situation.¹⁸

¹⁴ 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, no. 9 (2011), 5449-5456.

¹⁵ This collaborative tradition was already established when the first external pressure to reduce pollutants occurred in the early 1900s. Ann-Kristin Bergquist and Kristina Söderholm, "Green innovation systems in the Swedish industry 1960-1989", *Business History Review* 85, no. 4 (2011), 677-698.

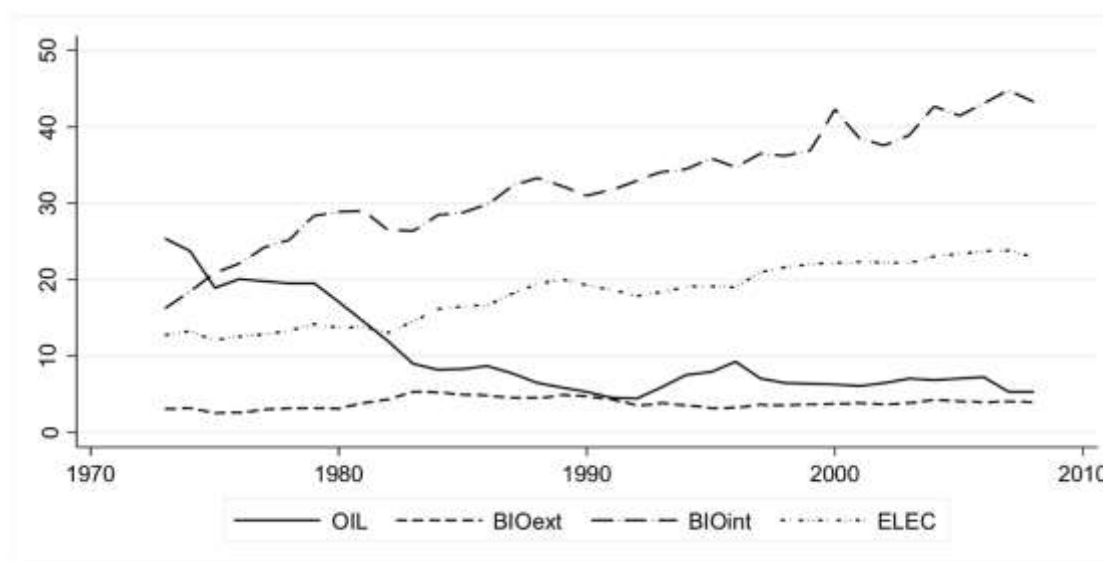
¹⁶ Kristina Söderholm and Ann-Kristin Bergquist, "Firm collaboration and Environmental Adaptation. The case of the Swedish Pulp and Paper industry 1900-1990," *Scandinavian Economic History Review* 60, no. 2 (2012), 183-211.

¹⁷ Nathan Rosenberg, *Exploring the Black box. Technology, economics, and history* (Cambridge, MA, 1994). See essentially chapter 9 on Energy-efficient technologies: past and future perspectives, p. 163-164.

¹⁸ For the Swedish case, see Evert Vedung, *Energipolitiska Utvärderingar 1973-81* [Energy policy Evaluations 1973-81] (Stockholm, 1982).

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 other energy sources for oil took place during the 1970s and 1980s, and was achieved primarily through increased use of biofuels. Oil inputs were reduced by approximately 20,000 Twh (terawatt-hours) between 1973 and 2006, while internal biofuels (BIOint) increased by 30,000 TwH. This was, however, not a steady process over time. Rather, the bulk of the substitution process took place between 1973 and 1984.

Figure 1: 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.

Internal organic residual products in the form of bark and black liquor¹⁹ were mainly substituted for oil. Incineration of bark was limited to the pulp industry (for natural reasons) and incineration of black liquor was limited to the chemical pulp industry. By the mid-1970s, 60 percent of the pulp and paper industry’s total fuel requirements were already being met by internal fuel in the form of black liquor and bark.²⁰ While the use of oil was declining, the use of electricity increased by 23.4 TWh.²¹ One primary reason for the moderate increase in electricity consumption since the 1970 was that mechanical pulp production, which is electricity intensive, has gained a growing share of pulp production, although Kraft pulp²² still accounts for the largest share. The expansion in mechanical pulp production was due to the fact that the process exploits wood resources more efficiently, and products with high wood yield have been most competitive with respect to competing regions, such as North

¹⁹ Black liquor is produced in the manufacture of pulp according to the sulfate process and consists of the spent cooking chemicals and from the wood released wood substances.

²⁰ The Swedish Energy Commission, *Energibesparingar inom industrisektorn: Sektor-rapport* [Energy savings in the industrial sector: Sector report] (Stockholm, 1977), p 38ff.

²¹ The Swedish Energy Agency, *Effektiv energianvändning. En analys av utvecklingen 1970-1998* [Efficient energy. An analysis of the years 1970-1998] (Stockholm, 2000), 33ff.

²² Strong, unbleached pulp, prepared according to the sulfate method.

America, where wood was relatively cheaper. In 1975, the industry's own back-pressure turbine power generation²³ covered about one-third of the need for electrical energy. The other two-thirds of the energy had to be purchased, however, which represented a significant portion of the production costs. In 1974, external energy expenses for electricity and fuel constituted 12 percent of the industry's total production costs, which can be compared with 4.1 percent for all manufacturing industry that year.²⁴ Access to electrical energy at reasonable prices was, therefore, a fundamental prerequisite for the industry's competitiveness.²⁵

While energy consumption in the pulp and paper sector increased moderately, from about 60 to 70 TWh between 1970 and the early 2000s, pulp and paper production increased by 70 percent and 127 percent, respectively, which reflects improved energy efficiency within the sector over the period.²⁶ Ongoing structural rationalization to fewer and larger production units, which in turn contributed to improved possibilities for taking advantage of economies of scale, contributed to the development. 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 sold to other mills.²⁷

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 resulting from the environmental awakening of the 1960s. Technology development underpinning the shift to greener technologies within the sector was based on inter-firm and state-firm collaborations in environmental R&D. As in many other western countries, the environmental investments undertaken by the Swedish pulp and paper producers during the 1970s and the 1980s resulted in considerable emission cuts. One important metric is chemical oxygen demand (COD), which decreased from approximately 2.3 to 0.4 million tons annually over the period 1970-1995.²⁸ While modern environmental regulations were formulated in Sweden during the 1960s, energy policy was not considered to be an independent policy field prior to the first oil crisis in 1973. Instead, energy issues were integrated within state industrial policy, with the basic goal of

²³ When electrical energy is produced by means of available temperature fall in plants that produce steam – primarily relevant for industrial activities with a great need of heat at low temperatures, which applies to the pulp and paper industry. In 1973, by producing steam from burning volatized cooking liquor and bark waste, the sector produced as much as 85 percent 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. Bo Rydin, "Energianvändningen i industrin," *Svensk papperstidning*, no 1 (1980); "Energikrisen i massa och pappersindustrin." *Svensk papperstidning*, no. 18 (1973).

²⁴ The Swedish Energy Commission, *Energibesparingar inom industrisektorn: Sektorrapport*, p 38ff.

²⁵ 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. Per Högselius and Arne Kaijser. *När folkhemselen blev internationell, avregleringen i historiskt perspektiv* (Stockholm, 2007).

²⁶ The Swedish Energy Agency, *Effektiv energianvändning*, 33ff.

²⁷ Ibid.

²⁸ Söderholm and Bergquist, "Firm collaboration."

ensuring cheap energy, a favorable balance of trade, and energy security in the event of international conflicts.²⁹

Framing an Energy Policy in 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 recognized that the energy issue was much less sectorial compared to the environmental issue. Soon R&D 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 1974.³⁰ Already in 1973, the government had appointed a national energy program committee with the task of producing a program for R&D. The committee reported for the first time on its work in 1974 in the study: "Energy research – program 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 perceived that the risk faced by individual companies when taking on expensive, long-term projects was too high, and this threatened necessary development of alternative energy technologies. The report was supplemented in 1975 with an inquiry on the need for prototype and demonstration plants (PoD) within the energy sector. The reports formed the basis for the government's energy proposal, which was submitted to the parliament in the spring of 1975 and resulted in the initiation of a national energy program that same year (Prop. 1975:30).

As a research agenda, the energy program was unique in the history of Swedish technology policy given that support was provided to *one* specific area (energy). The program 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 program. These included: the Swedish Board for Technical Development (*Styrelsen för teknisk utveckling*, STU); the Transport Delegation (*Transportdelegationen*, TFD); the Swedish Building Research Council (*Svenska Byggnadsforskningsrådet*, BFR); the National Energy Administration (*Nationella Energiadministrationen*, NEA); and the Energy Research Board (*Energiforskningsnämnden*, EFN). The program 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-wing coalition government to 415 MSEK. New research programs were initiated every three years during the 1970s and 1980s.³¹ In parallel, other research programs with an energy focus were also initiated, including: an oil replacement program (1980-1983 and 1984-1987); an investment program (1983-1984); a fuel environment fund (1983-1987); a technology development program (1986-1988); an energy technology fund (1988); and a technology procurement program for electrically efficient technology (1988-1993).³²

Industry was indeed a central focus of the policy efforts. Between 20 to 25 percent of the energy program's resources were devoted to industry each year. During the early years, the majority of this funding was directed to research institutes and private companies. The pulp and paper industry received most of the subsidies. This was

²⁹ Vedung, *Energipolitiska Utvärderingar*.

³⁰ Sixten Regestad, "Skogsindustriella forsknings- och utvecklingsprojekt inom energiområde," *Svensk papperstidning*, no. 14 (1977).

³¹ See the 1981 program, Government Bill 1980/81:90, *Om riktlinjer för energipolitiken* (Stockholm, 1981). This program had the biggest budget (1400 MSEK).

³² Göran Marklund, *Institutions and appropriation in Swedish technology policy* (Stockholm, 1994), p.139-140.

partly because the industry was the largest energy consumer, but also because the industry started to initiate R&D projects in the energy field early on. The funds subsidized research into production processes, as well as development of prototype and demonstration plants.³³ In parallel with the continuous launch of new energy programs, additional studies with a focus on energy-related R&D were also funded. SIND and STU were the primary agencies for issuing grants and supporting research. Throughout the investigation period of this study, these organizations exchanged information on energy issues continuously with the pulp and paper sector's central industry organizations. Statistics and project results developed and diffused by the industry sector thus came to form the basis for much of the energy policy strategies in which the interests of the pulp and paper sector had a central place.³⁴

Energy taxes and fees also played a major role as control agents in Swedish energy policy. In addition, certain types of energy were subsidized, primarily domestic fuels such as forest fuel and peat, and the Oil Replacement Fund granted favorable loans. Thus energy taxes and fees on coal and oil were raised while wood burning was subsidized. Control of fuel selection also occurred via the new Solid Fuel Act. Municipal energy planning was worked out with clear directives to increase the use of domestic fuels.³⁵ Thus, while Sweden is recognized for having expanded its nuclear program during the 1970s, the government's energy policy developed during the 1970s and 1980s embraced much more complex measures, including favoring increased utilizations of biofuels.

Technological Challenges and Strategies

In the 1970s, energy issues came to the forefront for the Swedish pulp and paper industry to a much greater extent than in previous eras. As a direct response to the first oil crisis, different options were debated 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 within the industry – several paper mills even made renovations and constructed new boilers to burn coal instead of oil – the majority of industry participants thought that coal would make plant expenses and environmental protection costs too high, since most types of coal had a high sulfur content and would therefore require expensive scrubber (abatement) systems.³⁶ 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). In parallel, the industry made major progress improving secondary heating systems and reducing steam consumption.³⁷ Bark began to be utilized to a greater extent than before, and boiler

³³ The private companies received their highest share between the years 1981-1984 (over 30 percent). 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 to 25 percent over the period, while the universities' share has increased greatly, from about 25 percent in 1975 to nearly 70 percent in 1991. Marklund, *Institutions*, p. 140 ff.

³⁴ See e.g. SIND, the Swedish Industrial Agency, Series of publications, 1976:3 (Stockholm, 1976); SIND, the Swedish Industrial Agency, Series of publications, 1983:2 (Stockholm, 1983); The Swedish Energy Commission, *Energibesparingar inom industrisektorn: Sektorrapport*, p 38ff.

³⁵ "Slaget om energin avgör skogsindustrins framtid," *Svensk papperstidning*, no 5 (1982).

³⁶ Erik Sundblad, "Skogsindustrin och energifrågorna," *Svensk papperstidning*, no. 9 (1977).

³⁷ 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

capacity was expanded for solid fuel boilers. In addition to this, bark presses and later bark dryers were also installed. Further, the dry content of the black liquor was increased via a soda boiler, and the quantity of fuel needed to power the liquor system was decreased by the introduction of oxygen bleaching technology in the late 1970s. Organic materials that previously been disposed of in the bleaching process could now be returned to the liquor system.³⁸ Firms also began reviewing procedures and “thinking” more in terms of saving energy. Simply by making sure that all instruments and processes functioned optimally, ten-percent reductions in energy consumption could be achieved.³⁹ 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.⁴⁰ 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. In 1973, the industry already produced about 30 percent of needed electrical energy in this manner and observers believed that further increases were possible. Prominent individuals in the industry, including managers and professors of cellulose technology, emphasized the benefits of government support for turbine development, as the technical prerequisites already existed. There was also a working group appointed by the Swedish Cellulose and Paper Mill Association (SCPF) tasked with inventorying experiences with, and the potential of, back-pressure turbine power generation and promoting the conditions necessary for additional electricity production.⁴¹ There was a general understanding that the industry, in order to manage exports, needed to increase wood yield and refine pulp, all of which required more electrical power.⁴²

In the introductory phase, industry mobilization on energy matters centered on actions that gave immediate results, while in the medium term the industry focused on improved existing technologies. In the long-run, however, completely new technologies were needed for energy conservation. In “Energy Savings within the Industrial Sector (1977),”⁴³ a report compiled by the Energy Commission’s⁴⁴ expert group for energy management, a number of such development projects relating to, in

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. The Swedish Energy Commission, *Energibesparingar*, pp. 117-131.

³⁸ Email correspondence with Anders Eliasson, Energi och Processkonsult, Eurocon, Feb. 13 2014.

³⁹ Rydin, “Energianvändningen.” At one company they were able 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. Olle Robertsson, “Energibesparande åtgärder i sulfatfabriker,” *Svensk papperstidning*, no. 1 (1975).

⁴⁰ Interview with Hans Norrström in Stockholm 2013-05-06.

⁴¹ Sundblad, “Skogsindustrin”; Nils Hartler “Energisnåla massa- och pappersprocesser,” *Svensk papperstidning*, no. 1 (1978).

⁴² Sundblad, “Skogsindustrin.”

⁴³ The Swedish Energy Commission, *Energibesparingar*.

⁴⁴ *The Energy Commission*, the title 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.

part, the bleaching stage⁴⁵ and high-concentration technology are listed.⁴⁶ The report argued that through long-term R&D work and effectively directed support from subsidy-granting organizations, significant energy gains in the pulp and paper industry could be achieved.⁴⁷

It was perceived that increasing the use of recycled paper could also be a suitable energy-conserving measure, simply because the energy used to produce pulp from recycled paper was as little as one-fifth of the energy used to produce pulp from wood. Methods were improved for removing ink and other contaminants, such as plastic, from the recycled paper, making it was possible to increase the use of such paper in the production process. The growing need for refuse paper could be met by increasing domestic collection.⁴⁸ Thus, whereas waste paper was not used at all in Swedish paper production before 1975, it has become an important raw material for paper manufacturing today. A key prerequisite for this development was the 1975 introduction of a national compulsory collection system for sorted waste paper from households. However, besides energy saving, another important factor behind this development was a growing fear of wood shortages.⁴⁹

To manage the new R&D challenges, in 1973 the Swedish pulp and paper industry installed a standing energy committee consisting of 12 members drawn from managerial and technical personnel within the industry. A major function of the committee was to encourage energy conservation measures by introducing new technologies simultaneously to improve 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 promoted the industry's interest in the governmental energy policy process and assisted firms in grant applications to government authorities.⁵⁰ Of central

⁴⁵ The industry conducted extensive R&D work on bleaching with oxygen during the 1960s and early 1970s, both within industry-wide research institutions, such as STFI, IVL and SSVL, and in R&D labs of individual companies, 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, and the released organic substance was instead used for energy production. In this way the oxygen technique was an important energy-conserving as well as emissions-reducing measure for the industry. Ann-Kristin Bergquist and Kristina Söderholm, "Transition to Greener Pulp. Regulation, Firm Strategies and Path Dependency in Sweden in Contrast to the US," Under review (2014) for *Business History*.

⁴⁶ 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 the fiber concentration would increase strongly in all stages of fiber 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. Lars-Erik Axelsson, "Massa- och pappersindustrin visar vägen mot oljeberoende," *Svensk papperstidning*, no. 5 (1983).

⁴⁷ The report was based in part on early investigations by the 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.

⁴⁸ The Swedish Energy Commission, *Energibesparingar*, pp. 117-131.

⁴⁹ Patrik Ekheimer, *Tidningspapper av returpapper - Den svenska massa- och pappersindustrins omvandling under senare delen av 1900-talet* (Göteborg, 2006).

⁵⁰ Marklund, *Institutions*, pp.143-144.

importance was the committee's regular (about every five years between 1974 and 2001⁵¹) survey of industry energy performance based on statistics from all Swedish pulp and paper manufacturers. Through these surveys, individual mills could compare their energy performance with each other and the industry as a whole.

During 1974, the committee identified of the kinds of energy projects that the government would be expected to support. These included back-pressure turbine power generation, incineration of bark and other forest waste, and the possibility of exploiting gas produced through the abovementioned incineration as a replacement for oil. The projects were coordinated to a great degree with on-going efforts at other collaborative R&D platforms such as the Swedish Pulp and Paper Research Institute (STFI) and the Forest Industries' Water and Air Pollution Re-search Foundation (SSVL). In addition, one project investigated the best available technology for manufacturing four standard grades of paper based on equipment already in widespread use. By accounting for what modern mills could achieve practically, the committee produced a collection of data that could serve as a practical handbook for technicians in the industry.⁵² 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, sulfate mill for bleached commercial pulp, and newsprint mill.⁵³ The books came to function as a best practices guide for energy optimizations among existing and projected mills.

It was not just the energy committee that initiated and coordinated projects. In 1974, SCPF also appointed a special working group with industry professionals to conduct an inventory of energy saving projects that were of great importance for the industry. The inventory was continuously updated and published in catalogues issued every second year. Most projects were actually carried out to fruition and it is reasonable to believe that the catalogue played an important role in motivating energy research within the industry.⁵⁴ 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

⁵¹ See for example, Rolf Wiberg, *Energiförbrukning i massa och pappersindustrin 1973: rapport från undersökning av specifik bränsle- och kraftförbrukning för olika massa- och pappersslag samt totalt för branschen* [Energy consumption in the pulp and paper industry in 1973: report from the investigation of the specific fuel and power consumption for various pulp and paper types and for the sector in total](Stockholm, 1974).

⁵² Om FoU på energiområdet. *Svensk papperstidning* No 9, 1975; Minutes taken at the meeting of the Board of Stiftelsen Cellulosa- och Pappersforskning [Pulp and Paper Research Foundation], January 23 1973. Copies of minutes, 1970-1993. Minutes, no. 8. Stockholm: Industrihistoriska arkivet [Archive of Industry History].

⁵³ Sven-Erik Jönsson, Johan Nygaard, Rolf Wiberg, *Modeller för energihushållning i massa- och papperstillverkning. Sulfatfabrik för blekt avsalumassa* [Models for energy conservation in pulp and paper production. Kraft pulp mill for bleached market pulp] (Stockholm 1976); Sven-Erik Jönsson, Johan Nygaard, Rolf Wiberg, *Modeller för energihushållning i massa- och papperstillverkning. Kraftlinerbruk* [Models for energy conservation in pulp and paper production. Kraft liner mill] (Stockholm 1976); Sven-Erik Jönsson, Johan Nygaard, Rolf Wiberg, *Modeller för energihushållning i massa- och papperstillverkning. Mjukpappersbruk* [Models for energy conservation in pulp and paper production. Tissue mill] (Stockholm 1977); Sven-Erik Jönsson, Johan Nygaard, Rolf Wiberg, *Modeller för energihushållning i massa- och papperstillverkning. Tidningspappersbruk* [Models for energy conservation in pulp and paper production. Newsprint paper mill] (Stockholm 1977).

⁵⁴ Marklund, *Institutions*, pp. 143-144; "Om FoU på energiområdet." *Svensk papperstidning*, no. 9 (1975).

purposeful policy on energy savings that was very well adapted to take advantage of STU's grant policy.⁵⁵ Additionally, the material provided a valuable foundation for the numerous official reports conducted within the context of the state 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 into two groups: energy conservation (37 projects) and energy generation (14 projects). The projects illustrate how a number of actors, in addition to STFI, SCPF and the Steam Generator Association, contributed to the projects. These included universities (The Royal Institute of Technology in Stockholm and Chalmers in Gothenburg), institutes outside the industry (*Värmeforsk* [Thermal Engineering Research Institute]⁵⁶ and the Institute for Surface Chemistry), as well as individual companies.⁵⁷ The research organization NEFOS (merged with *Värmeforsk* in 1985) also conducted several projects that concerned the pulp and paper industry.⁵⁸ The industry was indeed eager to increase its contact with universities. 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, they were encouraged to apply for subsidies from STU, SIND and other sources of financing.⁵⁹ In this way, technology development was supported by an inventory of knowledge and technologies from inside the industry.

Besides joint knowledge sharing and R&D efforts, individual companies contributed significantly to changes in the energy area, typically by developing and testing in full scale of new machinery and processes. Applied research also took place to some extent. As the government started offering significant subsidies for prototype and demonstration plants, resulting from the energy policy decision in 1975, such activity increased. Companies could receive state subsidies of 50 percent 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 activities available to everyone, because the subsidies prescribed formal, publicly accessible reporting.⁶⁰ The work in the majority of the research laboratories that were connected to individual companies was directed at energy issues. This is shown in the 1974 annual report from the SCA Group, one of the leading forest industries firms 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.⁶¹

⁵⁵ Marklund, *Institutions*, p. 144.

⁵⁶ 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.

⁵⁷ Sixten Regestad, "Skogsindustriella."

⁵⁸ Marklund, *Institutions*, p. 143, reference no. 28.

⁵⁹ Göran Wohlfahrt, "Energihushållningen i massa- och pappersindustrin. Om pågående utredningsverksamhet på branschnivå," *Svensk papperstidning*, no. 1 (1977).

⁶⁰ Sundblad, "Skogsindustrin"; Sixten Regestad, "Skogsindustriella."

⁶¹ SCA, Annual report, 1974, p. 20.

The industry's individual research laboratories (both pulp and paper manufacturers as well as to machinery suppliers) maintained their focus on energy and environmental issues during the 1980s.⁶² Major renovations of mills and new construction offered even greater possibilities for reducing energy consumption. At one of SCA's mills, rebuilt in 1974, production expanded while annual consumption of oil was reduced from about 63,000 cubic meters (m³) to 38,000 m³ and annual demand for electricity supplied from outside decreased from 200 million kWh to 120 million kWh. After the renovation, energy needs were met through technical measures, such as increased incineration of lye and bark, and through increased generation of back-pressure turbine power.⁶³ To save raw material and energy in 1974, the mill joined with all other Scandinavian newsprint manufacturers and reduced the long-established standard weight for newsprint from 52 to 48.8 grams per square meter. This measure was well received by the market, which soon demanded even thinner grades.⁶⁴

The companies also sent 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 program, where in the 1980s courses were held at the Forest Industry's training center in Markaryd in the southern part of Sweden. The government also stressed the significance of training by making considerable resources available for this purpose.⁶⁵

As the energy policy encouraged (in part through subsidies) the use of domestic fuels, general interest in wood incineration increased. The growing pressure on the forests worried the wood products industry, who feared that the practically accessible quantities of forest fuel would be over-subscribed, which would threaten the industry's access to raw materials.⁶⁶ 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).⁶⁷ However, in parallel with this concern, the forest industry itself began to gather and utilize forest fuel to an increasing extent in the early 1980s. This occurred on a broad front and basically all companies with forest assets engaged in such activity. At the same time, some companies also prepared peat production.⁶⁸ The investments showed returns, and a large part of the reduced need for oil was achieved by expanding the use of biofuel. Its use increased by 25 percent between 1983 and 1995.⁶⁹ 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

⁶² See e.g., STORA, Annual report, 1981, p. 17; SCA, Annual report, 1981, p. 24f.

⁶³ STORA, Annual report, 1974, p. 34-35.

⁶⁴ STORA, Annual report, 1974, p. 10.

⁶⁵ It was SIND that administered and coordinated the government contributions in the training area. Lars-Erik Axelsson, "Energiutbildning för bättre energihushållning." *Svensk papperstidning*, no. 5 (1982).

⁶⁶ "Slaget om energin," *Svensk papperstidning*.

⁶⁷ Competition on equal terms is also mentioned in: "Slaget om energin," *Svensk papperstidning*; Göran Wohlfahrt, "Grafströmska utredningen och skogsindustrin," *Svensk papperstidning*, no. 5 (1982). See also Rydin, "Energianvändningen."

⁶⁸ Axelsson, Lars-Erik. Massa- och pappersindustrin visar vägen mot oljeberoende. *Svensk papperstidning* No 5, 1983.

⁶⁹ The Swedish Energy Agency, *Effektiv energianvändning*, 33ff.

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 program. 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 on-going.⁷⁰

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. However, it was assumed that Sweden would continue to have good access to electrical power at an internationally competitive price.⁷¹ In this respect, the nation's nuclear program was important.

The STORA Group, owned by the Wallenberg family, stated in their 1983 annual report that during the past 6 to 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 the transition to solid fuels. The company reported that it had been proven to be economically feasible to utilize forest waste, in the form of branches and tops that normally had been left behind after cutting, in the company's mills. By 1983, such fuel was to some extent supplied to the industry, and solid fuel-fired boilers had been put into operation at two mills during the year. These could be fired with coal as well as with woodchips, shavings, bark,⁷² 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.⁷³ 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 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 event of energy shortages. The STORA Group had furthermore established cooperation with municipal energy works in a few places for heat deliveries.⁷⁴ In this context it may be noted that three years earlier (1981), the company had received government subsidies for energy-conservation measures of 9.4 MSEK.⁷⁵

At the firm level, there was in many aspects a close connection between energy-conservation measures and investments in pollution-reduction technologies. As

⁷⁰ SCA, Annual report, p. 17.

⁷¹ SCA, Annual report, 1981, p. 17.

⁷² 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 involved significant cost reductions.

⁷³ STORA, Annual report, 1983. "Minskat oljeberoende - förbättrad energiekonomi".

⁷⁴ Ibid.

⁷⁵ STORA, Annual report, 1981, p. 28.

mentioned earlier, the oil crises 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, which stated in 1973 that: “The environmental protection measures have increased the company’s variable production costs, not least due to increased energy consumption.”⁷⁶ This fact was also emphasized in 1977 by the government expert group for energy conservation as a possible obstacle to the forest industry’s energy-conservation work. The group maintained that “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.”⁷⁷ At the same time, the opposite condition in terms of “win-win” could apply just as readily (i.e., that an energy-serving measure simultaneously could lead to environmental improvements). When the STORA Group purchased a new paper machine for one of its mills in 1974 that utilized recycled paper instead of wood, company officials stated that the machine: “[was] not only an environmental protection effort. It also involves energy consumption that is less than half compared with paper manufacturing with wood as raw material”.⁷⁸

In the mid-1980s another Swedish pulp company within the MoDo Group invested in a bioenergy plan utilizing the recently developed Anamet method to cut emissions of COD. This plan involved an extensive investment expense, over 70 MSEK. However, the new system gradually reduced the mill’s BOD₇ emissions from 45 to 6 tons per day, while also reducing the mill’s oil consumption by about 40 percent through methane gas production.⁷⁹ Moreover, as an example for the pulp industry as whole, the process, which utilized waste bark, solved a long-standing industry problem, since waste bark had to be stored and caused environmental problems at production sites. Thus, by using bark for energy generation, a waste problem was simultaneously solved.

In all, depending on the type of mills, production processes, and so on, different measures were undertaken with the same purpose and goal, namely, to save energy and to substitute other energy carriers for oil. In the final section, we will summarize how the overall transition was accomplished.

Summary and Conclusions

The dramatic increase in energy prices during the 1970s meant that the energy issue gained strategic importance in the Swedish pulp and paper sector. Already in 1973, industry associations initiated collaboration with the goal of helping individual mills to swiftly reduce their consumption of oil. Collaboration became a key feature in the organization of the energy transition within the Swedish pulp and paper sector throughout the 1970s and 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

⁷⁶ STORA, Annual report, 1973, p. 13.

⁷⁷ The Swedish Energy Commission, *Energihushållning. Huvudrapport från expertgruppen för energihushållning* [Energy conservation. Main report of the expert group on energy conservation] (Stockholm, 1977).

⁷⁸ STORA, Annual report, 1974, p. 34.

⁷⁹ Kristina Söderholm and Ann-Kristin Bergquist, “Growing Green and Competitive: A Case Study of a Swedish Pulp Mill,” *Sustainability* 5, no. 5 (2013): 1789–1805.

by the need to share costs and risk associated with 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 state's energy policy from 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 sector was the nation's biggest energy consumer, the sector was of great concern for the government. Supportive policy measures were formed to push the further development and diffusion of technologies.

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

There was another major nexus between gains in energy efficiency, reduction in oil consumption, and improvements in the environment. In parallel with efforts to cut energy costs, the industry needed to cut costs and emissions from the bleaching process in pulp manufacturing. This helps to explain why the Swedish pulp and paper industry devoted considerable efforts to developing 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 internal biofuels for oil proved to be the most practical way to ease oil dependence and cope with the larger 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 external electricity for oil, a process that 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 use would lead to problems with sulfur emissions, which the sector already was struggling with due to environmental legislative requirements. Coal would also still mean dependence on 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.

There was, however, a great need for long-term R&D to push technology development forward. Inter-firm and state-firm collaborations were strategically important in this context in order to share both the risks and costs related to technological development. One important step was taken by the sector when the Swedish Pulp and Paper Association formed the Energy Committee in 1973. The purpose of the committee was to initiate and coordinate R&D projects within the business sector and to coordinate sector R&D efforts with outside projects pursued by those with connections 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, more novel programs with a focus on energy were also formed in collaboration with individual firms, consultant

companies, and equipment suppliers as well as with research institutes and universities outside the immediate sector. These collaborations and knowledge exchanges were directly supported by, and interconnected with, the state's energy policy and the many different R&D programs that were launched within the policy's framework.

Much of the Swedish energy policy during the 1970s focused on supporting industry R&D efforts directly or indirectly via the universities and 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 into broader R&D efforts related to energy production for Swedish society. The industry-based investigations conducted by associations of the Swedish pulp and paper industry formed the basis for many of the energy research programs that were launched by the Swedish government in the 1970s and 1980s. The pulp and paper industry therefore became an important stakeholder in the framing of Swedish energy policy.

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

As shown in this study, the pulp and paper sector accomplished a reduction in oil consumption, complimented by increased efficiency in the manufacturing process, through a number of different measures, from "thinking more in terms of saving energy" to the development, diffusion, and implementation of new energy saving and "oil out-phasing" technologies. In all, it was the increased use of biofuels such as internal wood waste from the manufacturing process and 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 crises in the 1970s truly reoriented state and sector focus towards increased energy efficiency and more efficient materials use, and the potential for improvements proved to be comprehensive.

The transition sheds further light on the dynamics between changes in prices of energy carriers and more sustainable production processes. It is especially interesting to note the economic benefits for the industry of utilizing internal biofuels, which prior to the oil crises had been considered a waste problem. The process addressed in the paper 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 firm level. It had simply not been rational economically to direct resources to investigate the use of internal or external biofuels instead of oil within the industry, especially since the social (environmental) costs of burning fossil fuels had not yet

been established by environmental policy. It is also difficult to study how businesses enter new technological and more sustainable production paths, which may not always be obvious to industry leaders at the start of the process. Already in 1973, and even before the second oil crisis, the industry was unified and determined to let go of its dependence of oil, and, by doing so, 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. In addition to the dynamic interplay between energy use and environmental impacts, the dynamic process of energy transition experienced in this case illustrates the central role that changed energy prices and government strategies can play in pushing industries into new technological paths. A probable prerequisite for a successful outcome is that governmental and industrial interests coincide. In this case, government and industry shared a strong interest in phasing out oil consumption, albeit for different reasons.