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Co-ordination and technological strategies in the Swedish pulp and paper industry 1973-1990

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Abstract

This paper examines the transition towards renewable energy in the Swedish pulp and paper industry (PPI) during the 1970s and -80s. In the wake of the first Oil Crisis until the late 1980s, the use of fossil fuels was reduced by 70 percent in this sector. The lion's share of the reduction was achieved by substituting oil by biofuels in terms of rest products from the pulp manufacturing process. The reduction was made possible also by efficiency improvements and increased internal production of electricity through back-pressure turbine power generation. Sweden was highly dependent on oil when the first Oil Crisis broke, and the run up in oil prices put pressure on the Swedish government and the energy intensive PPI to reduce dependency. Of central importance for the transition to be implemented was a highly collaborative strategy of the sector as well as between the sector and the corporatist Swedish state administration. The Swedish government chose a proactive strategy by emphasizing knowledge management and collaboration with industry along with the substitution of oil with biofuels. The transition was further fueled by the fact that focus was directed towards unutilized potentials in the sector, where a previous waste problem now could be transformed into energy savings, i.e., the strong version of the Porter hypothesis. Also energy taxes and fees played a major role as control agents in the Swedish energy policy of the 1970s and 80s. Thus, the study illustrates the central role of governments and their ability to push industries into new technological paths through a wide palette of interplaying policy instruments. The study further points at the importance of a more holistic understanding of the interplay between different policies and impacts in the longer run.

Keywords: Energy transition, oil crisis, bio fuels, pulp and paper, Sweden

1. INTRODUCTION

This paper explores industry and policy strategies to accomplish an energy transition in the Swedish pulp and paper industry (PPI) in the wake of the Oil Crisis in 1973. The PPI is both big in size and energy-intensive and its' energy consumption has been covered in voluminous literature from different sciences. The industrial sector counts for 26 % of the total energy consumption in the EU out of which the PPI counts for as much as 11 %. The Swedish PPI is further the third largest in Europe after Germany and Finland (SFIF, 2011) and counts for 45 % of the industrial energy use in Sweden (SEA, 2012). Several previous studies have accordingly focused on the Swedish PPI, addressing policy implications and short-term changes of energy efficiency within the sector (e.g. Ottosson and Magnusson, 2013; Henriksson et al., 2012; Eriksson et al. 2011), as well as trends in energy performance, shifts in energy use and changes in CO_2 emissions over time (e.g. Stenqvist, 2015; Henriksson and Lundmark, 2013; Lindmark et al., 2011). Thus Lindmark et al. (2011) reports that the biggest reduction of CO_2 emissions, and shifts in energy carriers of the Swedish PPI occurred in the 1970s and 80s. Over this period, oil consumption was reduced by no less than 70 %, mainly by the substitution of biofuels for oil. From a climate policy perspective, this shift and especially why and how the substitution was accomplished should be of great interest.

In 1990, the Swedish PPI was a world leader in terms of CO_2 efficiency (IEA, 2007:194), while also Fracoro et al. (2012) reports that the Swedish and the Finnish P&P industries' energy efficiency was higher than in other major pulp producing countries such Brazil, the United States and Canada. Important explanations to the differences may be different reactions by industry to the run up in oil and energy prices in the 1970s, as well as differences in policy styles between countries. Overall, the Arabic oil embargo and the run-up in energy prices during the 1970s had major impact on energy-intensive industries, energy systems and energy consumption around the world as a whole (Kander et al., 2013; McNeill, 2000). The oil crises in the same way clearly stimulated major shifts in national energy policies, which also have altered the conditions and strategies of end-users since the 1970s. Since it takes time for policies to get fully implemented and for policy effects to become clear, we believe a long-term perspective to be useful in this context. A central delaying factor being the fact that a large fraction of the total energy use in industrial societies is embedded in long-lived capital equipment, where it often is a costly, uncertain and slow process to adopt new technologies, stretching over decades when it comes to industrial plants (Rosenberg, 1994). Thus a post perspective will help us get a fuller picture of causes and effects as well as of strategies. Further, the period covered in the article, 1973 to 1990, can be seen as formative for industrial energy-related R&D of importance to meet the challenges and opportunities faced by the industry sector today. Hence, the objective of the article is to explore the strategies of the PPI sector to accomplish an energy transition in the wake of the Oil Crisis in 1973 and up to 1990, and further if and how Swedish policy reinforced this transition. Specifically, in the article we: *i*) investigate how the short and long run strategies of the PPI, to change the energy mix, was organised and carried out over the studied period; *ii*) analyse the relation between the energy policy and the strategies and achievements of the PPI in changing the energy mix; *iii*) explore eventual interrelations between strategies (of both the sector and authorities) to overcome the parallel energy- and environmental challenges in Swedish industry and particularly the PPI; and *iv*) discuss what general lessons can be learned from the historical case for efforts by central governments and industry actors to phase out non-renewable energy.

Below follows an overview of methods used and other key points of departure. Thereafter we begin the examination, first of the policy development followed by industry strategies (both inter-firm and firm-individual strategies) to accomplish the transition. In the final section of the article we discuss our findings.

2. KEY POINTS OF DEPARTURE

We use the historical case study method since it allows lessons to be drawn from post-industry- and policy strategies. According to Meadowcroft (2011), much can be learned for sustainable transitions "by examining […] earlier transitions […] as well as ongoing and historic struggles over issues of the environment and sustainable development" (Meadowcroft, 2011:75). The case study was conducted by qualitative analysis of mainly first hand sources, such as: 1) policy documents (reports, program descriptions, Government Bills etc.) from Swedish authorities (the Swedish Energy Agency, Ministry of Industry, Energy Commission, Delegation for Energy Research, and SIND); 2) individual company's annual reports; 3) articles in the main journal of the Swedish PPI (*Svensk papperstidning*); 4) reports and committee minutes from industry-wide organizations (Stiftelsen Cellulosa- och Pappersforskning; Svenska Cellulosa- och Pappersbruksföreningen). The case study is also based on complementary secondary sources from Swedish social science. The choice of the PPI in the 1970s and 80s as case is based on the fact that the sector's oil consumption was reduced by 70 % over this period. Sweden has further an energy-intensive industrial structure where the P&P and basic metal sectors have formed a backbone in the Swedish industrialisation from the 1890s and onwards, and still today the PPI accounts for 40 percent of the total industrial energy consumption in Sweden, making the sector the largest energy consumer in the Swedish economy (Swedish Energy Agency, p 19).

Governments have major impact on businesses and the way they define and approach problems and possible solutions, however, corporate strategies diverge between countries due to different institutional settings (e.g. Mikler, 2009; Gunningham et al., 2003; Wallace, 1995). Thus Sweden proves major differences to, for instance, the US in business-state relations due to different institutional settings. Accordingly, there is a tendency of adversarial relations in the US and a model of political cooperation and active state intervention on the market in Sweden (Hall and Soskice, 2001). And it has been suggested that more information sharing- and collaborative market models foster more proactive green strategies (Mikler, 2009). The corporatist Swedish state administration was a main strategy of the Swedish government throughout the 1930s to the 1970s, to address social and welfare issues (Rotstein, 1992; Lewin, 2002). This further included joint research institutes with the purpose of strengthening the Swedish industrial competitiveness. Thus, in the mid-1940s, the Swedish state e.g. formed the Swedish Pulp and Paper Research Institute (STFI) in collaboration with the PPI to pursue research on forest products (Sörlin, 2006).

At the same time as the Swedish society underwent the energy crises it undertook a green reconstruction driven by a new environmental regulatory framework enforced in 1969, and also in this context the Swedish state administration relied on business-state relations built on cooperation and trust. Important new arenas for collaboration and research on the green reconstruction were the state-industry funded *Institute for water and air protection* (IVL), founded in 1966, and the *Forest Industries' Water and Air Pollution Research Foundation* (SSVL), founded in 1963 by the forest industry alone, however, partly funded and represented by state agencies (Bergquist and Söderholm, 2011; Söderholm and Bergquist, 2012). Through these arenas, extensive amounts of information were developed and exchanged between environmental authorities and industry actors, such as the PPI. Swedish environmental regulators based this collaborative and even consensus-seeking policy style on the view that rational and balanced decisions could only be reached when each party knew and understood what the other wanted (Lundkvist, 1977).

The collaborative and knowledge-oriented strategy of the corporatist Swedish state administration up to the 1970s is in fact closely related to central competencies highlighted in the governmentality literature for the central government of the modern society. According to this literature the central government has three main types of policy instruments to promote change in businesses and society as a whole, i.e., through legislation, coordination and knowledge management. Legislation forms the institutional frames and through its coordinative role the government arranges structures and arenas for collaboration and meetings, such as between government- and business actors. Knowledge management as a policy tool in the modern society aims to promote development and diffusion of new knowledge through a soft and open collaborative process of governing. Collaboration is essential as the government, in democratic states, is far from the only knowledge provider (Dean, 2001).

Also within the Swedish PPI there is a long tradition of industry-wide collaboration in environmental R&D, which actually started already in the early 20th century. This tradition, in combination with the consensus-seeking state administrative strategy, underpinned the successful shift to greener technologies in the sector over the 1970s and 80s; environmental investments in the sector rendered in considerable emission cuts, such as of Chemical Oxygen Demand (COD) (Söderholm and Bergquist, 2012). In the green transformation of the Swedish PPI in the 1970s and 80s, there were even situations where environmental regulations increased not only the environmental performance of a company, but also its' economic performance by directing focus to unutilized potentials (Söderholm and Bergquist, 2013) i.e., the strong version of the Porter hypothesis (Porter and van der Linde, 1995). Below we will instead focus on the energy transition in the sector, the strategies of the Swedish state administration and PPI to accomplish the transition and whether the energy policy facilitated (or worsened) the ability for the sector to transform. The contemporary (with here studied period) industry-wide collaboration in environmental R&D within the sector motivates us to mainly focus on the industry level. Networking within the same industrial sector has further shown to be important also for effective energy management (Thollander and Ottosson, 2008; Johansson, 2013). Below we start by examining the policy strategies of the Swedish state administration.

3. THE FRAMING OF ENERGY POLICY POST 1973

The oil crises caused major shifts in the energy policies of a number of Western governments, and Sweden was no exception in this case. Energy policy was not an independent policy field in Sweden prior to the oil crises, but saw a period of rapid expansion from the mid-1970s, embracing all sectors in the economy, from transport to households and the industry. Some energy issues had been integrated with the industry policy before this, however, then really only with the basic goals to ensure cheap energy for the industry and a favourable balance of trade and energy security in the case of international conflicts (Vedung, 1982). Despite big hydropower reserves in Sweden (and lack of significant oil or coal resources), oil accounted for as much as 72 percent of the national energy consumption in the beginning of the 1970s, which made the Swedish economy heavily dependent on a massive import of fossil fuels (Schipper et al., 1994). Thus, after the threat of an acute energy supply crisis in the first quarter of 1974, a central short-term policy goal for the Swedish government was to prevent a deteriorating balance of payments from reducing the dependence of oil. As the Swedish industry accounted for a large part of the consumption of oil and thus had major impact on the national energy system and balance of payments, an industry-related energy policy debate was soon initiated were research, development and demonstration constituted an important feature (Regestad, 1977).

Actually, already in 1973, an Energy program committee with the task of producing a program for R&D had been appointed by the government. And when the committee reported on its work in 1974, government support for R&D was highlighted as of key significance. It was 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 (Ministry of Industry, 1974). The report was supplemented in 1975 with an inquiry on the need for prototype and demonstration plants (PoD) within the energy area. The reports formed the basis for the government's energy proposition which was submitted in the spring of 1975, and which further resulted in the initiation of the government Energy programme that same year (Government Bill, 1975:30).

As 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 from a Swedish perspective 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 (Energiforskning-snämnden*, EFN). The programme ran for three years and the budget was initially 366 MSEK, of which 42 MSEK were given the National Board for Industrial Development (Statens Industriverk, SIND) for the funding of PoD. Already by 1976, the budget was however increased by the new right-winged coalition government to 415 MSEK. New research programmes were thereafter initiated every three years during the 1970s and ’80s.[1] In parallel, other research programmes with energy focus were also initiated, such as the: *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 (Marklund, 1994).

Industry was in focus for the energy policy and 20-25 % of the Energy programme’s resources were each year devoted to individual companies, research institutes and universities to deal with industry-related energy issues. During the early years, most of the industry-focused funding was directed to research institutes and private companies, where the PPI received most of the subsidies. Over the years, the universities’ share however increased greatly, whereas the private companies’ share of the industry-focused funding was 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 (Marklund, 1994:140). The great industry focus can be understood in light of the extensive energy consumption of industry, especially the PPI. Industry was however also quick to respond by initiating energy-related R&D projects. Subsidies were given both to process measures and PoD (Marklund 1994:140 ff). In parallel to the continuous launching of new Energy programmes also additional studies with focus on energy-related R&D was enforced. SIND and STU were the central agencies for grants and investigatory work, and also here the interests of the PPI were very much in focus (SIND, 1976:3; SIND

[1] See e.g. the 1981 program (Government Bill 1980/81:90), focusing on incineration technology, new electrical production technology and biofuel. This programme had the biggest budget so far, i.e., 1400 MSEK.

1983:2). Through the funding and inquiry work by the relevant agencies, authorities continuously throughout the entire investigation period of this study, exchanged information in energy issues with individual firms and central industry organisations of the PPI. Thus, through a report (Swedish Ministry of Industry, 1977b) compiled by the public so-called Energy Commission of the 1970s, we can confirm that the authorities knew of and could list a number of on-going energy-related development projects of the PPI, such as related to the bleaching stage[2] and the high concentration technology. The report further concluded that it was only through long-term R&D work and effectively directed support from subsidy-granting organizations that significant energy gains could be achieved in the PPI (SIND 1976:3 and SIND 1977:6). On the whole, there has been a strong believe in research, development and demonstration as an engine of change in the Swedish energy policy, and the per capita spending on RD&D has also been fairly high in Sweden relative other IEA countries (Nilsson et al., 2004). However, also energy taxes and fees played a major role as control agents in the Swedish energy policy of the 1970s and 80s.

If we take a closer look at the stance of the Swedish energy policy of the 1970s and 80s, except from the great focus on research, development and demonstration within the energy technology area, a general increase in energy efficiency and expanded nuclear power programs for electricity production were accessible and preferred strategies for the Swedish government. However, another long-term strategy of the central government, and fairly overseen in previous literature, was a rather successfully implemented policy for the increased production and use of renewable energy, preferable biofuels. Later, when the resistance to nuclear power increased as a reaction to the incident in Harrisburg in 1979, and Sweden decided to phase out nuclear power, bioenergy got an even bigger role in the Swedish energy policy.[3] The focus on bioenergy was reflected in the direction of energy taxes and fees. Thus whereas taxes and fees on coal and oil were raised, domestic fuels, such as forest fuel and peat were subsidized by, for instance, the *Oil replacement fund*. This fund further granted favourable loans for development projects on the increased use of domestic fuels. Fuel

[2] The industry conducted extensive R&D work on bleaching with oxygen during the 1960s and early 1970s, both within industry-wide research institutions and in R&D labs of individual companies', such as the MoDo Group. 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. See Söderholm and Bergquist (2013).

[3] Policies to phase out fossil fuels for bioenergy concerned all sectors and there were even long-term ambitions in the 1970s and 1980s (although never realized) to phase out petroleum as motor fuel with methanol made of organic substances. For the Swedish case, see Vedung (1982), Mårald, (2011).

selection was further controlled through the new *Solid Fuel Act*, which, for instance, contained clear directives to municipalities to increase the use of domestic fuels in the local energy planning (Svensk Papperstidning, 1982).

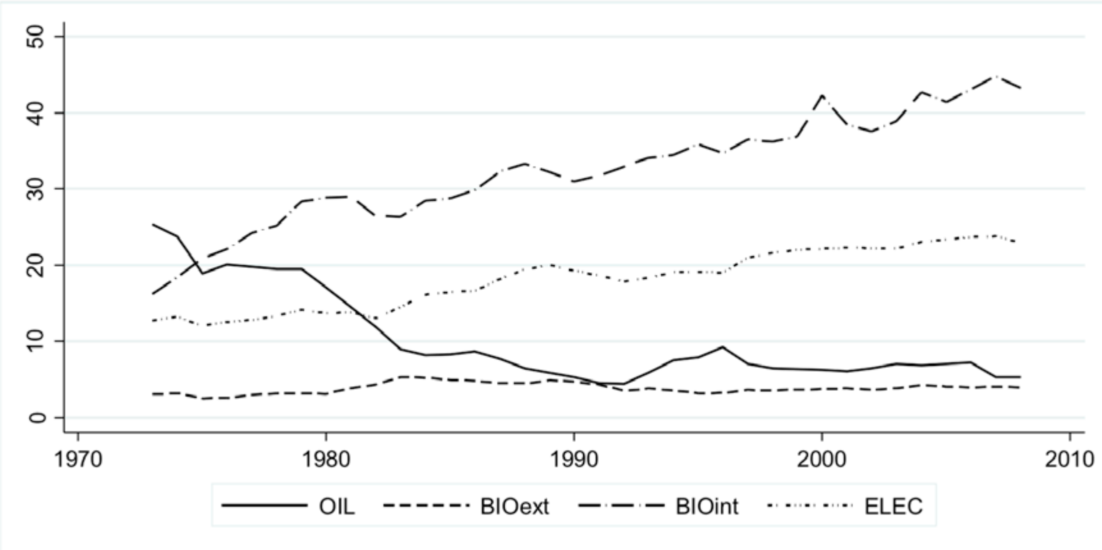
As the energy policy accordingly increased the interest in wood incineration, the forest industry (including the PPI) feared that the practically accessible quantities of forest fuel would be over-subscribed, which in turn would threaten the access to raw materials for the PPI (Svensk Papperstidning, 1982; Wohlfahrt, 1982). However, the forest industry itself to a growing extent began to gather and utilize forest fuel in terms of forest waste and small timber. This occurred on a broad front in the early 1980s, and basically all companies with forest assets started such activity. Some companies also prepared peat production (Axelsson, 1983). The investments (see further in section 4) gained returns and a large part of the reduced use of oil in the 1980s was achieved by an increased use of forest fuel, which increased by 25 % between 1983 and 1995 (SEA, 2000: 33ff).

Partly as consequence of the fear of shortage of wood and partly as energy conserving measure, both the authorities (Swedish Ministry of Industry, 1977b) and the PPI (Ekheimer, 2006) further worked for an increased use of recycled paper in pulp production. The energy use for production of recycled pulp from recycled paper was as little as one-fifth of the energy needed for making mechanical pulp from wood. As methods were improved for removing ink and other contaminants, such as plastic from the recycled paper it was further possible to increase the use (Swedish Ministry of Industry, 1977b). Thus whereas waste paper was not used at all in Swedish pulp production prior to 1975, it came to be an important raw material. The introduction in 1975 of a compulsory collection system for sorted waste paper from the households was a key prerequisite for this development (Ekheimer, 2006).

4. BUSINESS STRATEGIES AND TECHNOLOGICAL CHALLENGES

Figure 1 below shows the energy transition in the Swedish PPI in the wake of the first Oil Crisis in 1973. As can be seen, the large-scale substitution of oil took place during the 1970s and 1980s, and was mainly achieved through increased use of biofuels. Oil inputs were reduced by approximately 20 000 Twh between 1973 and 2006, while internal biofuels increased by 30 000 TwH. This was, however, not an even process over time. Rather, the substitution was most important between 1973 and 1984. While oil inputs were reduced we can also see an increased use of electricity from the early 1980s. This was mainly because of the growth of the more electricity intensive mechanical pulp production, as compared to the otherwise common Kraft pulp[4] production. Wood is however exploited better in mechanical pulp production and as wood was relatively cheaper in competing countries, such as North America, mechanical pulp production was considered more competitive.

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.

There was also overall improved energy efficiency within the sector throughout the period. Thus, although P&P production increased by 70 % and 127 % respectively between 1970 and the early 2000s, the total energy consumption of the sector only increased moderately, from about 60 to 70 TWh (Swedish Energy Agency, 2000). In the 1970s and 80s, this process of improved energy efficiency coincided with an on-going structural change in the industry, to fewer and larger production units and improved ability to take advantage of economies of scale (Järvinen et al., 2013). The concentration of production units allowed, among other things, a higher degree of integrated P&P production where less energy-intensive pump pulp (compared to pulp to be sold) was used (Swedish Energy Agency, 2000). We can further assume that new energy technology possibly was embedded in the overall renewing of capital

[4] Strong, unbleached pulp, prepared according to the sulphate method.

following the structural rationalization. Still, what were the actual strategies of the Swedish PPI to accomplish an energy transition?

4.1 Different strategies to decrease the external need for energy

In the 1970s, energy issues came to the forefront for the Swedish PPI on a different scale than before. As a direct response to the first oil crisis, different options were available and debated within the sector. Thus were, for instance, the possibility discussed to simply increase the use of coal. This alternative was emphasized by some within the sector and still in the early 1980s, several paper mills even made renovations and new construction of boilers to replace oil with coal. Most of the sector however found the related costs too high: most types of coal had high sulphur content and would therefore require expensive scrubber (abatement) systems (Sundblad, 1977). The Swedish PPI instead early on chose to invest heavily in replacing oil with domestic fuels (black liquor, bark, forest fuel and peat) in parallel to improving secondary heating systems and reduce steam consumption (Swedish Ministry of Industry, 1977b: 117-131). Thus bark was incinerated to a greater extent than before and boiler capacity was expanded on solid fuel boilers. In addition, bark presses and later bark dryers were installed in order to increase incineration capacity. As far as the liquor was concerned, the dry content was in part 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 footnote 5). Organic material that previously had gone to runoff in the bleaching process now returned to the liquor system (Eliasson, 2014).

The electricity consumption was considered more difficult to minimize than heat consumption, in part because electricity consumption was divided into a large number of relatively small consumption sites (Norrström, 2013). However, it was believed that the external need for electrical energy could be reduced through increased back-pressure turbine power generation.[5] In 1973, the sector already produced about one-third of its needed electrical energy this way, and the possibilities to increase production further were considered great. At this time the cost for external energy in the form of electricity and fuel constituted as much as 12 % of the sector’s total production costs, which can be compared with 4.1 % for all

[5] Back-pressure turbine power generation: 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 PPI. By producing steam from burning volatized cooking liquor and bark waste in 1973, the industry produced as much as 85 % of Sweden’s total back-pressure turbine power production of electrical power. Without the generation of electricity through back-pressure turbine power the sector´s dependence on imported fuel would have been considerably greater. Rydin (1980).

manufacturing industry that year (Swedish Ministry of Industry, 1977:38ff). There was further a general understanding that the sector, in order to manage exports needed to increase wood yield and refine the pulp, which in turn required even more electrical power (Sundblad, 1977). We know that this was a correct perception as electricity consumption would come to increase from the early 1980s due to expanded mechanical pulp production. Thus access to electrical energy at reasonable prices was decisive to the sector.[6] Consequently, prominent individuals of the sector, such as managers and professors of cellulose technology emphasized the benefits if government support in this area, especially since technical prerequisites already existed, i.e., the back-pressure turbine power generation. The *Swedish Cellulose and Paper Mill Association* (SCPF) further appointed a working group to inventory the potential of expanded back-pressure turbine power generation (Sundblad, 1977, Hartler, 1978).

We have so far in general terms discussed the strategies of the PPI to decrease the external need for energy. In the following we will go more in depth on strategies, first on an inter-firm level and later a private company level. We will see how strategies involved industry-wide inventories and the diffusion of information together with technological development at various stages. Thus, initially, the mobilization typically concerned the kind of actions that gave immediate results, such as go through procedures and learn to "think" more in terms of saving energy. Simply by making sure that all instruments and processes functioned optimally, results of 10% reductions in energy consumption could be achieved (Robertsson, 1975; Rydin, 1980). In the medium term, strategies instead concerned actions that changed and improved existing technology while in the long-run completely new technology was introduced for the purpose of energy conservation.

4.2 Inter-firm initiatives

To manage the new energy-related challenges the Swedish PPI (industry-wide) already in 1973 appointed a standing Energy committee consisting of 12 members from among management and technical personnel within the sector. A major function of the committee was to encourage the development of energy conservation measures with improved mill performances built-in. Other functions included the collection and diffusion within the sector

[6] 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).

of information about such development, and the appointment of representatives to investigate special subjects and to represent the industry in public bodies and investigations. The committee further promoted the interest of the sector in the governmental energy policy process, and assisted firms in compiling grant-applications (Marklund, 1994:143-44). Eventually the committee, with financial support from the government, also engaged in training programmes where companies could send their personnel for technical training in energy issues (Axelsson, 1982).

After a few months in operation the committee had compiled a list of development projects that were already running within the sector and were of such kinds that the government could be expected to be willing to support them, such as on expanded back-pressure turbine power generation, the incineration of bark and other forest waste, and the possibility of exploiting gas produced through the incineration (SP, 1982; PPRF, 1973). The projects were conducted at inter-firm (sector-wide) and partly state-industry collaborative R&D platforms established in the 1940s and the 1960s with the primary purpose to pursue research on forest products respectively the environment; STFI and the Forest Industries' Water and Air Pollution Research Foundation (SSVL). Only a few years later, in 1977, no less than 50 new energy projects had been started or proposed within the sector. Those involved 37 energy conservation- and 14 energy generation projects, most conducted/proposed in collaboration between organisations closely associated with the sector, such as STFI, SCPF, and the Steam Generator Association [Ångpanneföreningen], but also universities and research institutes outside the sector e.g., Värmeforsk, the Thermal Engineering Research Institute (Marklund, 1994:143 reference no 28). Another proactive strategy of the sector as the universities' share of the industry-focused public funding increased over the second half of the 1970s, was to provide relevant university departments with a list of more than 30 (for the PPI) pressing energy-related research projects. At the same time the departments were encouraged to apply for subsidies from different sources of public funding (Wohlfahrt, 1977). Of course also individual companies contributed to the projects, typically by developing and testing new machinery and new processes in full scale but to some extent also by conducting applied research. As the government assigned significant subsidies for prototypes and demonstration plants by the energy policy decision in 1975, such activity further increased greatly. New processes and technology on a factory-wide scale could be subsidised by as much as 50 % (Sundblad, 1977; Regestad, 1977).

In this way, knowledge of energy-saving technologies and processes was diffused within and beyond the sector. However, other activities focused exclusively on collecting and spreading knowledge and managed to make it successfully across the sector. Thus, e.g., the Energy committee regularly –about every five years between 1974 and 2001– (Viberg, 1974) had performed energy studies based on statistics from all Swedish P&P manufacturers. The results were widely diffused within the sector whereby individual mills could compare their energy performance with other mills. Another project by the committee investigated best available technology in the manufacturing of four standard grades, i.e., in modern kraft liner mills, tissue paper mills, sulphate mills for bleached commercial pulp and in newsprint mills. By accounting in this way for what 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 (SP, 1975; PPRF, 1973). The Steam Generator Association [Ångpanneföreningen] was commissioned to conduct the model mill study which resulted in four role-model books – one for each primary type of mill – for energy optimizations in existing and projected mills (Jönsson, 1977a; 1977b). Also, in 1974, SCPF appointed a special working group with industry professionals to conduct an inventory over which projects, aiming for energy savings that were considered extra urgent by the sector. The inventory was thereafter continuously updated and published in catalogues issued within the sector every second year (Marklund, 1994:143-44). Those are all illustrative examples of the open and well-structured exchange of information and R&D collaboration between companies within the PPI, which has been established also when it comes to the parallel environmental adaptation of the sector. The importance of the regularly performed and widely diffused energy studies with statistics, the inventories and the four role-model books, for the energy transition in the PPI probably cannot be overemphasized. By making information of the best-available energy-saving measures available to all mills, a mill could basically develop a model factory with the best pieces across (Norrström, 2013). Early on the high knowhow and collaborative platforms of the sector further meant it developed a quite purposeful policy on energy savings in terms of promoting the interest of the sector in the governmental energy policy process and in obtaining grants. Thus the work was very well adapted to STU's grant policy (Marklund, 1994:144). The collected information further formed a valuable basis for the numerous official reports conducted within the context of the Energy program. In the next section we will focus on the individual company, i.e., the actual level of investments in energy-saving measures underpinned by the above described knowledge diffusion.

4.3 The individual companies

In the wake of the first Oil Crisis in 1973, focus soon was on energy and environmental issues in the research laboratories of both manufacturers and machinery suppliers in the PPI, and this maintained during the 1980s. Basically it was about making a better use of resources with regard to energy and fibre raw materials (SCA, 1974; STORA; 1981). Opportunities to achieve environmental and energy gains were greatest in parallel to renovation and new construction. Thus, in 1974, a renovated mill of the company Stora Group managed – while at the same tame expanding production – to reduce the 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. This was in part achieved by technical measures, such as through increased incineration of black liquor and bark, and increased generation of back-pressure turbine power (STORA, 1974:34-35). The mill further joined all Scandinavian manufacturers of newsprint, and agreed on reducing the long-established standard weight for newsprint from 52 to 48.8 grams per square meter. This measure was well received on the market, which soon demanded even thinner grades (STORA 1974:10).

Although 60 % of the total fuel requirements of the sector already were met by black liquor and bark in the mid-1970s (SMI, 1977b), the interest in biofuel continued to increase over the 1970s together with work for improved heat economy. Thus for the company SCA in 1981, the energy ambition was to transform low-value waste heat in various processes to high-value heat for reuse and also to expand the supply of waste heat to municipal district heating networks. The strategy further was to increase the use of forest fuel in the form of logging waste, clearance timber and peat. The company had already come a long way with the development of systems for collection and transport of forest fuel. There were also large peat assets on company land waiting to get extracted only extraction methods and dewatering technology was further developed. This work was on-going in 1981. In parallel to the energy conserving measures SCA however at the same time counted on continued transition to wood-conserving technology although it was noted that this would involve increased electricity consumption. The company however assumed that Sweden would continue to have good access to electrical power at an internationally competitive price (SCA, 1981:17). In this respect, the nuclear program was important.

In 1983 the Stora Group could establish that since the mid-1970s, extensive energy-conserving measures had been undertaken at the company mills. Fuel consumption had been reduced significantly and oil had been partly exchanged to other fuels. Of particular importance in this respect was the transition to solid fuels. The company reported in its annual report of 1983 that it had been proven economically feasible to utilize forest waste in the form of branches and tops that normally had been left behind after cutting, and not previously utilized. Such fuel was now to some extent supplied to the mills. Likewise, solid fuel-fired boilers had recently been put into use at two mills. These could be fired with coal as well as with chips (produced with clearing and logging in the forest), shavings, bark and peat. The boilers was in part 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. Thus the company noted that the new boilers concerned significant reductions in costs and oil consumed (STORA, 1983). Very likely the boilers were furthermore partly financed by government subsidies as the Stora group had received 9.4 MSEK in subsidies for energy-conservation measures in 1981 (STORA, 1981).

Through the transition to solid fuels the two mills of the Stora Group saved 50,000 respectively 80,000 m3 of oil annually. Together with other energy conservation measures and the increased use of back-pressure turbine power generated electric power, the annual requirement for oil was between 1979 and 1983 reduced from about 140,000 to 25,000 m3 at mills held by the Stora Group. Calculated per thermal unit the average price of solid fuel amounted to about half the price for fuel-oil. The company further concluded that the flexibility of the new system in terms of the possible use of different types of fuels was valuable in the events of shortage situations of different energy carriers. At some mills of the Stora Group, energy conserving measures also included cooperating with municipal energy works for heat deliveries (STORA, 1983).

At first there was a general concern within the sector, related to the on-going greening of the industry, that the use of cleaner technology would imply an increased need for energy (STORA, 1973: 13). Also the government expert group for energy conservation was in the 1970s concerned that this was a possible obstacle in the energy conservation work of the PPI (SMI, 1977a). However, instead a ‘win-win’ situation would apply from the great transition from oil to biofuels, as this meant both heavily reduced emissions of carbon dioxide and the overcoming of a previous waste problem, of bark, which earlier had to be stored and thereby caused environmental problems at the site. This often win-win relation between energy conserving measures and those aiming for environmental improvements, as both commonly concerns efforts to use resources better with regard to energy and raw materials would soon become generally known in the sector. Thus, for instance, in 1974 the Stora Group invested in a new paper machine at one of its mills. The machine used recycled papers instead of wood as raw material and after been in use for a while the company established that the machine not only contributed with environmental gains but also involved halved energy consumption (STORA, 1974: 34). In the mid-1980s, a pulp mill within the MoDo Group with the goal to cut emissions of COD in turn invested extensively in a bioenergy plan according to the recently developed Anamet method. In addition to reduced emissions of BOD7, from 45 to 6 tons per day, the new method, from producing methane gas, reduced oil consumption by about 40 % (Söderholm and Bergquist, 2013).

5. Discussion

The Swedish PPI managed to decrease the consumption of fossil fuels by 70 % up to the late 1980s, and the lion's share of this reduction was achieved between 1973 and 1984, from substituting oil by internal organic residual products such as bark and black liquor, and eventually also forest fuel. The reduction was made possible also by a general energy efficiency improvement and increased internal production of electricity through back-pressure turbine power generation. Thus the change of energy-mix in the PPI was overall about improved utilization of raw materials and energy efficiency, where the potential for improvements proved to be comprehensive. Much of the basic knowledge to generate energy from burning internal organic residual products and through back-pressure turbine power generation was already known before the oil crises. However, as the oil-price was low before the 1970s, there had been few incentives from an industry perspective to explore this further and from a policy perspective to support such exploration.

The study shows how a central strategy of the Swedish PPI throughout the 1970s and the 80s, to achieve the change in energy mix was by knowledge-building and technological development. A key feature of this R&D work was in turn the way it mainly was organized and carried through in industry-wide collaboration. The sector already had a long tradition of industry-wide collaboration in environmental R&D, driven by the need to share costs and risks associated with green technology development and to pool competence within the sector. Thus the still on-going – at time for the energy crises – green reconstruction of the sector was strategically based on industry-wide R&D collaboration within a number of different platforms. For the energy-related R&D, the most important platform for the industry-wide collaboration was the 'Energy Committee', formed by the central organisation of the sector in 1973. The committee initiated and coordinated energy-conserving R&D projects. Often those projects were directly coordinated with R&D projects already operating within other collaborative R&D platforms of the sector. However, also more novel projects were formed within these platforms as well as in collaboration with research institutes, universities, consultant companies and equipment suppliers outside the immediate PPI. In this way, knowledge of energy-saving technologies and processes was diffused within and beyond the sector. The individual firms typically contributed by developing and testing new machinery and new processes in full scale. Other activities of the Energy Committee focused exclusively on collecting and spreading knowledge across the sector in terms of industry-wide inventories, energy studies and role-model studies. The importance of such regularly performed inventories and widely diffused knowledge on best-available technology for the change in energy mix and general efficiency improvements cannot be overemphasized. Individual mills/companies got hand of benchmarks and could, basically, develop a model factory with the best pieces across.

Initially, oil reductions were accomplished by relatively small measures, such as by securing the optimal functioning of all instruments and processes. In this way, up to ten-percent reductions were reached. Soon, however, and although other options were available, such as substituting oil with external electricity or coal, it was the increased use of biofuels in terms of bark, black liquor, peat and external wood waste that would constitute the main substitute of oil. It is notable that the sector had not previously taken advantage of the great potential that the internal biofuels accounted for the sector, especially since bark was a significant waste problem. Still, it was not economic rationale for the sector to reduce the use of oil before the rise in oil prices and the forming of an energy policy that favoured reduced use of oil. This situation sheds important light on the dynamics between price-changes of energy carriers and the development of more sustainable production processes, and clearly relates to the strong version of the Porter hypothesis essentially arguing that 'properly-designed' environmental regulations, such as market based instruments like taxes, increase not only the environmental performance but also the economic performance of industries by directing focus to unutilized potentials.

The energy policy formed in Sweden during the 1970s came to favor reduced use of oil by several different means. Thus the Swedish government enforced important regulatory measures in terms of energy taxes and subsidies, which together with generally increased prices on oil stimulated the change in energy-mix of the PPI. Hence, taxes on fossil fuels and subsidies for domestic wood fuels and peat naturally worked in favour for the government strategy to substitute oil by domestic biofuels. Other regulations stimulated the reduced use of energy, such as the introduction, in 1975, of a compulsory collection system for sorted waste paper: when used for making mechanical pulp, recycled waste paper meant much less energy use than if pulp was made from wood. However, since a central 'motto' of the Swedish government was that state aid was necessary for pushing the technology development forward – by minimizing the risks for the individual firm – the most important mean by which the energy policy came to favor a reduced use of oil was supportive measures for R&D. Through a number of R&D programs and R&D directed funds, not least for prototype and demonstration plants, the Swedish government facilitated the development and diffusion of energy-conserving technology. Such targeted funding presupposed a good insight into the industry's needs and prerequisites and there was a good basis for such transparency through the corporatist Swedish state administration and long tradition of close collaboration and knowledge-exchange with not least the PPI. This collaboration had recently been deepened by the ongoing green reconstruction of the sector, through collaborative platforms. Thus the government had good insight into the many ongoing inter-firm and state-firm collaborative R&D projects with environmental as well as general efficiency focus, some of which could be partly redirected towards increased energy focus. This insight, together with the industry-wide inventories, energy studies and role-model studies conducted by the PPI, formed a valuable knowledge basis for the government and its many R&D programs launched within the energy policy framework. Hence the PPI became an important stakeholder in the Swedish energy policy framework, particularly in the 1970s, and early on the sector developed a purposeful energy-conserving policy in terms of promoting the interests of the sector in the governmental energy policy process. Accordingly, of all the governmental energy funds that went into manufacturing, the PPI received the biggest share. Funds which the sector managed to transform to innovations in the energy field, largely through the already established infrastructure for collaborative R&D projects. The great influence of the sector on the Swedish energy policy must of course also be understood by its major influence on the nation's energy consumption. We can further conclude that the success in terms of phasing out oil in the PPI should be understood also from the perspective that the sector experienced benefits from directing focus to unutilized potentials.

We have already on several occasions addressed the issue of whether there were interrelations between the strategies of the sector and authorities to overcome the parallel energy- and environmental challenges. Thus, especially in the 1970s, both the industry sector and authorities reused platforms and R&D projects previously addressing mainly environmental and efficiency issues as, knowledge sources and development arenas also to address energy issues. Put another way, there were new energy technology embedded in the overall renewing of capital following the parallel greening and overall structural rationalization of the sector. The study further clearly illustrates the dynamic nexus between energy- and environmental challenges through the interrelation related to energy savings with parallel disposal of waste (bark and newspaper) and emissions (carbon dioxide, organic substances and elemental chlorine). Hence, from the phasing-out of oil several environmental problems were simultaneously solved. However, when businesses enter new technological and more sustainable production paths, it is complex and not always intentional from start. Accordingly, from phasing out oil the sector reduced its emissions of carbon dioxide considerably even before the climate change was raised on the global agenda and the Swedish CO_2 tax was introduced in 1991.

6. Conclusions and Policy implications

The Swedish PPI experienced an extensive energy transition between 1973 and 1990. Rising costs for oil put pressure on the Swedish government and the energy intensive PPI to reduce oil dependency. And in this case, focus was directed towards unutilized potentials. Of central importance for the transition to take place was a collaborative strategy within the sector (industry-wide) as well as between the state and the sector, which to a large extent had been formed in connection to the parallel greening of the sector. Thus while addressing energy issues, both authorities and the industry sector benefited from the R&D platforms and -projects already recently formed to address environmental issues. Also new collaborative platforms and R&D projects were established to address energy issues. We believe that the collaborative policy strategy and comprehensive exchange of information and transparency with industry reasoned focus on R&D subsidies, such as for prototype and demonstration plants. The proactive collaborative policy strategy of the Swedish government was based on the corporatist Swedish state administration of the 1930s to the 1970s. However, according to the governmentality literature, knowledge management and coordination are possible and even preferred strategies also for governments of the modern society. Also energy taxes and fees played a major role as control agents in the Swedish energy policy of the 1970s and 80s. Thus, the study illustrates the central role of governments and their ability to push industries into new technological paths through a wide palette of interplaying policy instruments. This bigger picture of the Swedish energy policy and energy transition in the PPI implies that rather than focusing on impacts from individual policy instruments, such as energy taxes, it might be important with a more holistic understanding of the interplay between different policies and impacts in the longer run, such as on technological development.

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