INNOVATION, NEGOTIATION AND PATH DEPENDENCIES IN INDUSTRY AND POLICY - Environmental and technology policy induced innovation in the Netherlands

PETER S. HOFMAN
Center for Clean Technology and Environmental Policy, CSTM University of Twente
P.O. Box 217, 7500 AE Enschede, The Netherlands
Tel + 31 53 4894541 Fax +31 53 4894850
Email: P.S.Hofman@cstm.utwente.nl

ABSTRACT

The paper illustrates that in industry sometimes path dependencies have developed both through industrial linkages and through policy standards based on current technological configurations that can hamper the development of new, more environmentally benign, technological paths.

Key words: environmental policy, environment oriented technology policy, innovation, lock in mechanisms, path dependency.

1. INTRODUCTION

While both environmental policy and environment oriented technology policy have clearly intensified in the last decades it is becoming more clear that most policies have not been able to foster fundamental changes in production and consumption now deemed necessary to escape environmental threats, such as climate change, from accumulating. Evidence is growing that most environmental measures, technologies and policies have been built on the accumulated technologies and competencies that have brought forth technological systems entrenched in various institutional structures and embedded in society. As these measures, technologies and policies grow out of this system they have often only been able to improve these systems without being able to bring forth a transition towards a different kind of system. Lock-in mechanisms have developed that strengthens the way the old system works and prevents the emergence of a new system. Lock-in mechanisms can occur due to regulations that have developed in a way that benefits a certain technological configuration. Or they can occur when a system develops with various actors in different parts of the chain interwoven to each other in a system that develops over decades. In the case study we present in this paper these two mechanisms are apparent. The case study[1] involves a printing company seeking ways to eliminate the use of volatile organic compounds (VOCs), specifically toluene, in its production process. Engravings printing companies around the world make use of inks based on toluene, but have to deal with both negative environmental and safety aspects. At RSD most of this toluene is re-used through

[1] This case study is part of a European Union funded research project under the EC programme Targeted Socio-Economic Research . In this project, Envinno (Towards an Integration of Environmental and Ecology-oriented Technology Policy. Stimulus and Response in *Env*ironment Related *Inno*vation Networks), the influence of environmental policy and technology policy on innovations in companies and the role of networks in this process are studied.

a recovery installation with a return of more than 99%. Toluene also is emitted through the printed matter, with several litres per tonne product (Novem, 1998). Within the covenant between industry and government on VOC, called VOC 2000, the aim is to reduce emissions of VOC for industrial sources by 62% in 2000 relative to 1985 while further reductions are planned for the period until 2010 (Projectbureau KWS 2000, 1995). Apart from the environmental burden of these emissions of this volatile organic compound (VOC), it also has a negative impact on labour conditions. Several Scandinavian countries have stringent standards for the emissions of toluene out of printed matter. In Denmark, for example, buyers demand that products contain less than 300 mg per kilo. At RSD, products for the Danish market are therefore stored for several days to let toluene dissolve. In Scandinavia the use of engravings print is limited because, apart from environmental standards, not many large issues are being printed. This was the principal cause for RSD to start the development of engravings printing through water based ink. Engravings printing with ink on waterbasis has not yet been applied anywhere in the world.

While both environmental policy and environment oriented technology policy foster the search towards elimination of VOCs (section 2), they have also created lock in towards solutions based on the established technological configuration in the whole printing chain. The company and the innovation is further introduced in section 3, and actors involved in the innovation network in section 4. We end with a concluding paragraph.

2. ENVIRONMENTAL CONCERNS AND THE DUTCH PRINTING INDUSTRY

The printing industry in the Netherlands consists of around 3500 companies with a total of around 50000 employees. Total turnover of the sector was roughly around 5 billion Euro per year (VNG et al, 1993). A large part of the sector, more than 70%, concerns small companies with less than 10 employees. The sector is well organised, around 90 % of the printing companies is member of the branch association KVGO (EZ & VROM 1995). Environmental issues became more important items on the agenda of the KVGO during the eighties. Increasing public environmental awareness and the image of the printing industry as a significant polluter led KVGO to actively look for ways to improve the environmental image of the sector. According to KVGO, discretion in government intervention and related excesses of pollution in individual printing companies were damaging for the sector as a whole. Therefore KVGO set out a strategy in which negotiations on environmental standards and measures to be taken would take place at the branch level and not at the individual company level, and through which more harmonised environmental rules could be realised for the sector as a whole. It was also expected that this strategy would reduce time lost by individual companies in supplying information for a.o. environmental permitting procedures (Verbeek, 1998; Le Blansch, 1996). Some other, not publicly expressed, motives were that moonlighting companies would also be reached through this approach, unfair competition would be reduced, and barriers to entry for the sector would be increased[2]. Increasing dissatisfaction with the effectiveness of direct regulation[3] and the worrisome picture of the Dutch environmental state (RIVM, 1988) led the Dutch

[2] These motives were expressed by a branch expert involved in the development and implementation of the voluntary agreement in a presentation at the University of Twente in 1997.
[3] An evaluation of the Dutch environmental permitting system in 1979 found at that time that of 320,000 companies 25% had a sufficient permit, 15 % of the companies did not have a sufficient permit, and 60 % of companies did not have a permit at all (Twijnstra & Gudde, 1979).

government in the eighties to develop a new strategy, the target group policy[4]. In the first National Environmental Policy Plan implementation was announced through the development of voluntary agreements between industrial branches and government (VROM 1989, 1990). The printing industry was the first sector to sign a declaration of intent with the Dutch government in which they committed themselves to environmental targets for 2000 and 2010. The declaration of intent was signed on June 5, 1990 and the following was agreed (VNG et al, 1993):

- reduction targets for emissions for the whole sector to be realised in 2000 and 2010;
- broad outlines regarding the measures through which these targets could be realised;
- the way in which goals of the branch would be accommodated;
- the way in which measures will be implemented throughout the branch;
- a structure for the target group consultation for the printing industry.

On the basis of this declaration and the consultations that followed, an environmental policy agreement was concluded in 1993 between the sector and government[5]. This implied the realisation of the first voluntary agreement or covenant under the target group policy, a policy initiated with the publication of the first Dutch national environmental policy plan in 1989. In an earlier stage the printing industry had committed themselves to reduce the emissions of volatile organic compounds (VOCs) by agreeing, along with other industrial branches, to the 'control strategy for the emissions of volatile organic compounds' that was submitted to Dutch parliament in February 1989[6] (Projectbureau KWS 2000, 1995). From 1993 onwards, this implementation strategy for the reduction of VOCs became part of the environmental policy agreement. For engravings printing it was agreed that by 1996 the maximum loss of toluene throughout the production process should not exceed 8.5%. Under the agreement companies were also obliged to make regular toluene balances through which toluene loss as a percentage of input could be established (VNG et al, 1993). In 1997 an evaluation of the environmental policy agreement for the printing industry took place. It was concluded that the agreement has improved the environmental attitude in companies and accelerated the implementation of measures. Next to this, the agreement has resulted in better relationships between responsible authorities and companies. Most of the measures due to be implemented by 1997 were realised. In order to reach the overall targets for 2000, significant measures still need to be realised, especially for VOC's in specific parts of the printing sector (Schelleman & Kuil, 1997).
The printing sector is also party in a voluntary agreement regarding the re-use of paper. In the covenant packaging II of December 1997 it is agreed between government and actors

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[4] This renewal of environmental policy was initiated in the 1982-1986 term of office of Winsemius in the Department of Housing, Spatial Planning and Environment.
[5] This agreement was signed on April 8, 1993 by the KVGO (branch association printing industry), Kartoflex (branch association packaging printing companies), Ministerie van EZ (Ministry of Economic Affairs), Ministerie van VROM (Ministry of Environmental Affairs), Ministerie van V&W (Ministry of Transport and Public Works), IPO (Inter Provincial Consultation Body), VNG (Association of Dutch Municipalities), UvW (Union of Waterboards).
[6] This policy was formulated in the period between May 1986 and April 1988 to reduce the emissions of volatile organic compounds from industry, small businesses and households. The control strategy constitutes an agreement between national and local authorities and industry. The strategy consists of reduction plans for specific sectors. For various types of companies the measures required to reduce VOC-emissions are listed. For uncertain measures an effort is made to gradually reduce undertainties, for instance through research (Projectbureau KWS 2000, 1995).

in the paper chain to collect and re-use 85% of used paper[7] by 2001 (Staatscourant, 1997). This follows the covenant packaging of 1991, and a declaration of intent regarding the system of collection and re-use for used paper in 1995. The printing sector also agreed to the paper fibre covenant that contains provisions for a fee on bought paper for actors in the paper chain when the price of used paper on the world market is too low too sustain the collection of used paper (KVGO, 1999).

Several environment oriented technology policy initiatives are relevant for the printing industry. In the framework of the 'control strategy for volatile organic compounds' a number of projects aimed reducing uncertainties regarding measures and removing technological obstacles are subsidised. Between 1989 and 1994 a total of seventy research and demonstration projects received funding and have been completed (Projectbureau KWS 2000, 1995). Around 12 of these projects were initiated by actors from the printing industry with project subsidies roughly between 50,000 and 100,000 Euros[8].
The technology programme Environmental Technology was initiated in 1989 by the ministries of Environment, Agriculture and Water Management with an average annual budget of 4 million Euro (Arentsen & Hofman, 1996). Throughout the years its focus has been to elevate technological bottlenecks to reach environmental policy goals set in the national environmental policy plans. In 1990 a subprogram was started that focussed specifically on bottlenecks for the printing industry to reach environmental targets set in the declaration of intent of 1990 and later the environmental policy agreement of 1993. In the period 1990-1995 a total of 15 projects in the printing industry were subsidised[9]. Some of the technologies developed in the project later become part of the environmental policy agreement. An important characteristic of voluntary agreements is the mechanism that newly developed technologies which become state of the art for respective branches are integrated into the handbooks that provide member companies information on the measures that they are expected to implement. Table 1 provides information regarding technology projects funded through the program Environmental Technology and the linkage to the handbook of the printing industry.

Table 1 Linkage of developed technologies in technology program to the handbook of the printing industry[10] (Source: Memo by VNG to NOVEM, interview with program director NOVEM)

Total projects/technologies	**18**
Already entered in handbook	2
To be entered in handbook	4
Possibly in the near term to be entered in handbook (additional research needed)	9
Not to be entered in handbook	3

This gives evidence for the earlier described mechanism through which change in the state

[7] In Dutch called 'old paper'.
[8] The percentage of subsidy of total project costs varies according to the nature of the project. Feasibility studies receive the highest percentage (90%), R&D between 50 and 60 %, and demonstration projects 35%.
[9] Average project subsidy was around 50,000 Euro, subsidy ranges from 25,000 to 250,000 Euro. The percentage of subsidy of total project costs varies according to the nature of the project. Feasibility studies receive the highest percentage (80%), R&D projects 50 %, and demonstration projects 35%.
[10] Projects in the period 1993-1998. The project by Roto Smeets Deventer is classified under 'possibly in the near term to be entered in the workbook (dependent on development).

of the art in the respective branches leads to change in the implementation plan of the environmental agreement. Adoption of new developed technologies that are environmentally superior to predecessors in the workbook of the printing industry takes place. The workbook provides the basis for the requirements under the permitting system, which implies that companies need to adapt their performance according to the changed state of the art. In this sense this mechanism has the potential of inducing the continuous improvement necessary to reach the targets set in the voluntary agreement. An assessment of the kind of innovation which has been realised, however, shows that most are of an incremental nature, and do not tend to lead to radical change in the printing industry.

Summarising: Standards for reducing VOC emissions and increasing recycling of paper have developed incrementally towards less VOC use in processes and increasing recycling levels. Standards have developed in a process of negotiation between government and various industrial parties. Incremental changes have occurred due to optimisation of existing technologies, and use of recovery systems for solvents, without fundamentally changing the dominant technological trajectory in the printing sector based on the use of solvent based inks. In the middle of the eighties environmental policy was initiated to reduce emission of volatile organic compounds. With several other sectors the printing industry was one of the targeted industries. Another major policy goal in which the printing sector is party concerns the increases of the percentage of re-use of old paper. In the nineties goals of the VOC 2000 plan were integrated in the agreement at the branch level between government and industry. These were accompanied by environment oriented technology programs that specifically subsidised projects initiated to relieve technological bottlenecks for realisation of targets set in the environmental agreements.

3. THE ENVIRONMENT ORIENTED INNOVATION

3.1. Motives for the innovation

Both international and national environmental policy pressures are important motives for Roto Smeets Deventer and its mother company to engage in the project with water based inks. As explained before, the use of toluene both incorporates negative health, safety and environmental aspects. The principal reason to start research on the use of water based inks were standards with regard to toluene in the Danish market. The Scandinavian and Danish markets are the main markets for export of Roto Smeets printing products. Even though Roto Smeets Deventer had installed a recovery system for toluene, the amount of toluene initially trapped in the paper that would evaporate after products were delivered to Danish customers was too high. These were principally standards regarding labour conditions. Nevertheless, the fact that both Dutch National policy and European policy was aimed at further reduction of the use of VOCs like toluene, made an alternative even more attractive. Thirdly, the fact that use and storage of toluene inks also incorporates danger of explosions, something that is removed with the use of water based inks. The current toluene balance of RSD shows a loss of toluene of 5 % of total toluene use or around 500,000 litres per year, losses that occur partly during the production process, and partly through the end products. Current exports to the Danish market decrease toluene by storing the product for around a week in which toluene evaporates, or through a vacuum extraction installation, both costly methods

In order to reduce the use of VOC’s Roto Smeets Deventer started research in 1996 to develop printing with ink on water basis applied for engravings print. To make sure that the new process was environmentally superior to the traditional process, RSD decided that one of the first steps should be to analyse and compare the environmental impacts of the whole process of printing based on toluene with printing based on water ink. Figure 1 provides an overview of the process. The analysis was done by a life cycle analysis (LCA) carried out by a consultancy firm. It was concluded that overall impacts of printing based on water ink are lower. Expected direct positive effects (at RSD) included (Nederlandse Diepdruk Industrie, 1996):

- the 100% reduction of emission of VOC's (500 tonnes per year as compared to 8,000 tonnes for the printing packaging industry in the Netherlands);
- a 5% reduction of energy use;
- a 30% reduction of water use (25,000 m3);
- a 30% reduction of hazardous waste (15,000 kilo)

One negative effect is the emission of ammonia (around 25,000 kg per year). Ammonia is used in water based ink as thickener. The concentration does not exceed environmental standards, while through R&D the company aims at further lowering the amount of ammonia used.

For the whole production and consumption chain expected effects throughout the chain include a reduction of energy use (13%), material use (9%), water use (36%, VOC emissions (66%), and reduction of hazardous waste (39%).

The LCA however also made clear that introduction of the new technique in the established technological configuration of printing paper, collecting used paper, de-inking used paper, and recycling it, could lead to problems with regard to the de-inking of paper. De-inking of paper takes place through a system based on flotation characteristics of the solvent-based inks that are stirred by use of certain chemicals. This system of de-inking has been optimised in the last decades and paper companies have invested heavily in equipment based on this technique. Thus a technological configuration has emerged in the last decades in which printing, production and recycling of paper has been optimised based on solvent-based inks, and know-how and competencies regarding this system has been accumulated. However, de-inking of paper printed with water based inks with the current flotation technology and chemicals is problematic. This significantly deteriorates the overall LCA balance.

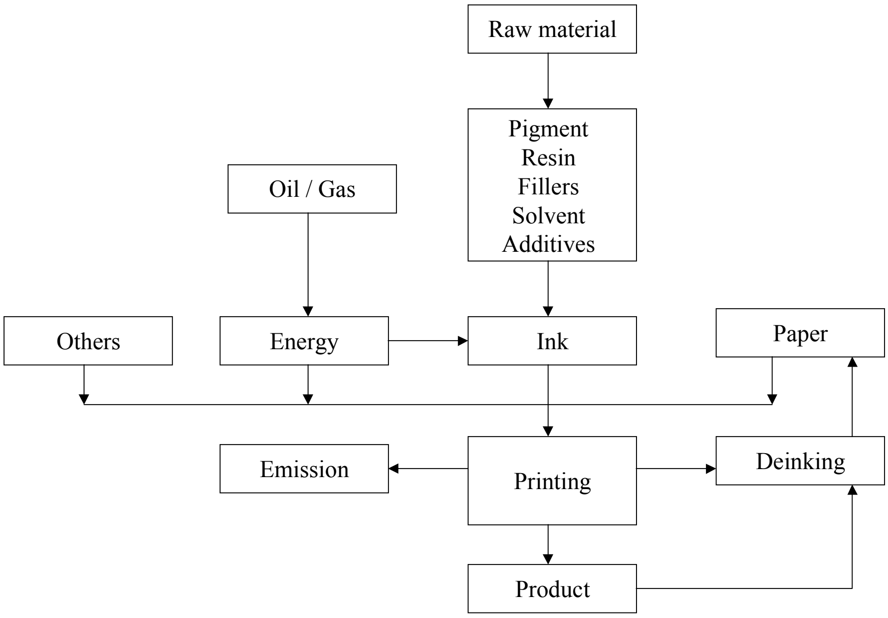


Figure 1 Life cycle scheme of the rotogravure printing process

However, the positive outcome of the LCA combined with the estimated potential for improvement led Roto Smeets Deventer to further pursue the development of the new technique. It is expected that the new technique will further establish the image of RSD as an innovative, environment friendly printing company. Moreover, it is hoped that it will create new markets, lead to cost savings and better labour conditions (Nederlandse Diepdruk Industrie, 1996).

3.2. The engravings print production process: traditional and new

In rotation engravings ink is applied on the printing form. Through rotation the printing form puts ink on the paper. When the paper is dried the next ink colour can be applied. In regular engravings print toluene is used as solvent for the ink. The solvent causes a good transfer of ink to the paper, without deforming the paper. In the drying unit the organic solvent vaporises and is transported to an adsorber to make recovery of the solvent possible, with an effectiveness of around 98%. However, some of the toluene will remain on the paper and emit in a later stage, around 3 kg toluene per 1000 kg product (Roto Smeets Deventer, 1998). Engravings print with toluene based inks is a mature technique that has existed on the market for decades. It is still in further development in order to reduce costs, increase recyclability, and reduce emissions. For several actors the possible competition of another type of engravings printing has led to increasing attention to reduce environmental impacts of printing with toluene, also due to incentives from environmental policy and environment oriented technology policy. This is clearly one of the mechanisms that make introduction of the new technique even more difficult. In terms of alternatives, the technique with water based inks developed by Roto Smeets Deventer is closest to market introduction[11]. With the use of water based inks instead of toluene adjustments

[11] Sun Chemical representative, personal communication March 2000.

need to take place throughout the production process. The following table lists the main problem areas for the new technique to realise both good quality and cost effectiveness.

Table 1 Critical technical success factors (Sources: Nederlandse Diepdruk Industrie, 1996; Roto Smeets Deventer, 1997)

Critical Elements	Areas for further R&D
- complete ink transfer	Transfer is less effective through conductive characteristics of water and composition of ink.
- paper characteristics	Paper surface and composition influence the flowing of ink, form stability is critical.
- drying	Water with styrene acryl resin has lower drying speed. Drying system for toluene presses is not optimal for drying of water ink.
- ink characteristics	Water ink needs higher pigmentation, lower ammonia concentration, higher drying capacities, and suitability for de-inking.
- machine efficiency	Other production and cleaning techniques are necessary. Paper loss is too high. Machine efficiency is crucial for improved cost effectiveness.
- de-inking	De-inking is less optimal for waterink because of used chemicals and technology.

Table 1 makes clear that the introduction of this new technique requires research and development in various areas and is complex due to the different actors that play a role in the process. RSD has been able to built a network with various actors that play a role in the research on the critical elements of the new technique. Figure 2 provides an overview of these actors.

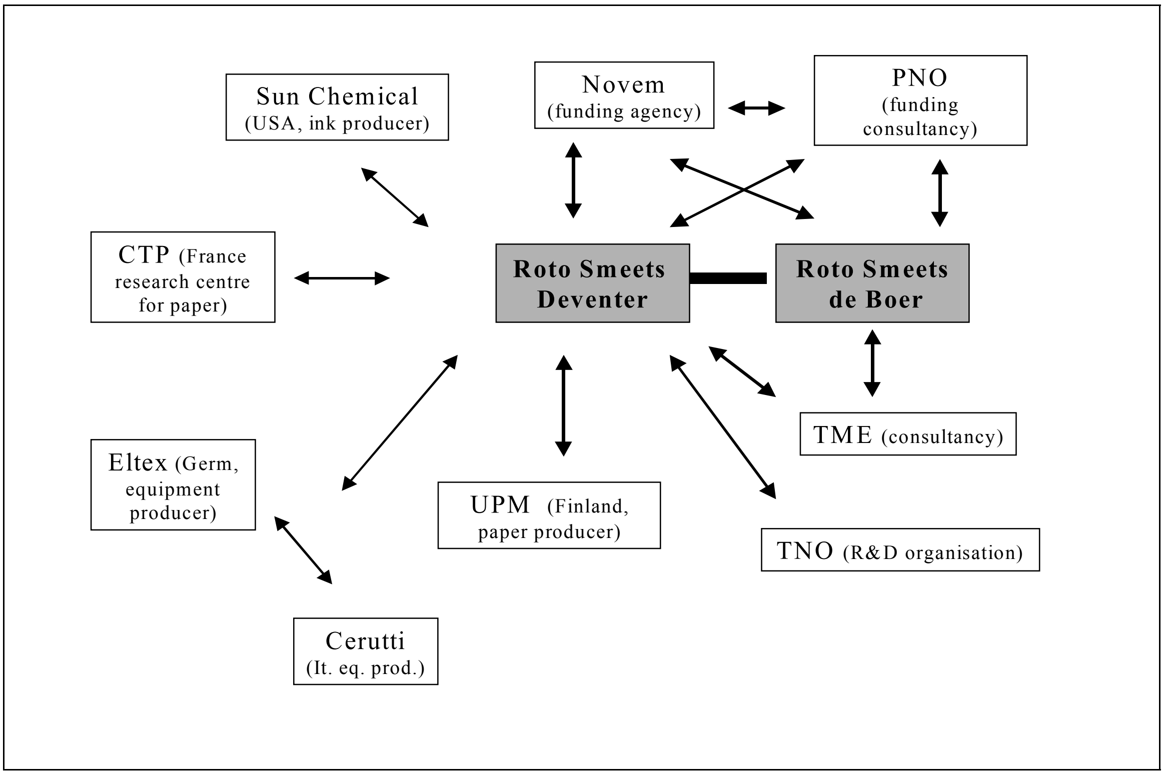


Figure 2 Actors involved in the development of the new technique

In the first phases of the development of the new technique, collaboration between RSD and ink producer Sun Chemical took place to assess the potential of engravings print with water based inks. Initial studies were performed in 1995 and 1996. Parallel to this RSD initiated a life cycle analysis for printing with water based inks in order to make sure that the new technique was environmentally superior. Roto Smeets and Sun Chemical had already previously established close relation-ships. In 1994 they made an agreement regarding the delivery of inks by Sun Chemical to Roto Smeets de Boer. Part of the agreement was a joint R&D program regarding the technical and commercial possibilities of engravings print with water based inks. Successful results of initial tests led to a further declaration of intent in 1996 to test at practical scale in the facility at Roto Smeets Deventer. Sun Chemical agreed to make inks available for the project and to adapt the characteristics of inks based on the test results (RSDB, 1996). The collaboration of the two companies enabled large-scale practical tests in 1997 and 1998, in a project subsidised by Novem (227,000 Euro on total project costs of 515,000 Euro) that included other actors in the paper chain. In this project significant progress was made in the development of the new technique. Products costs were estimated to drop from 140% to 115% as compared to the 100% of production with toluene based inks. The project, however, made RSD more aware of non-technical barriers that surround the innovation project (see table 3). In order to make the innovation market ripe, several actors need to collaborate and exchange details regarding characteristics of products they deliver and the way they are produced. However, companies are often not keen on sharing this information. According to RSD, success of the new technique will depend on intensive interaction between and dedication of the various players in the chain, because characteristics of inputs such as ink, paper and equipment need to be fine-tuned in an iterative process. While this process has been started in the project, further progress is hampered because visions of companies differ with regard to importance and prospects of the new technique. A second major barrier for the introduction of the new technique is related to problems with regard to de-inking that occur in a later stage in the chain. There is a high level of scepticism in the printing and paper sector with regard to the use of water based inks, while various initiatives have been taken to establish the relative low environmental impact of the current technological configuration relative to the emerging configuration based on water based inks. In order to make progress with regard to the de-inking of water based inks from paper, Roto Smeets Deventer is depending on the R&D activities of actors relative outside its scope. These actors are reluctant to participate in the development of the new technique because it implies changes in the way they are used to work and possibly significant investments if water based inks are used on a larger scale.

Table 3 Critical organisational success factors (Sources: Nederlandse Diepdruk Industrie, 1996; Roto Smeets Deventer, 1998)

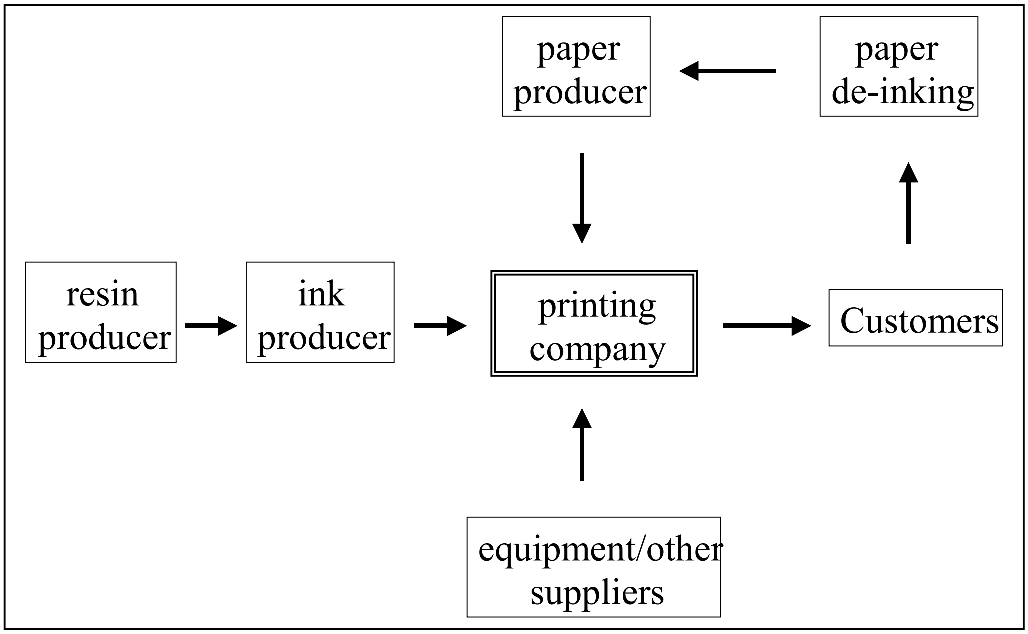
Critical Elements	Areas for further R&D
- Cluster technology and co-makership	Collaboration with companies within technology chain and material chain is indispensable
- Resistance in sector	Sceptical attitude regarding the use of water based ink at customers, paper producers, and de-inkers.

4. ACTORS AND NETWORKS IN THE INNOVATION PROCESS

4.1. Actors in the process of printing and recycling paper

Figure 2 depicts the various actors that play a role in the printing process. With most of these actors RSD has regular contacts. In the innovation process actors from the economic network (with actors from the production of intermediate products such as ink and paper, to equipment suppliers and customers) play a prominent role. Demand factors were important to develop the new technique, producers of ink and paper have adapted characteristics of their products to the new technique, and equipment suppliers especially needed to focus on drying and speed of the printing presses.

Figure 2 Actors in the economic network



The ink producer Sun Chemical[12], a US company with an affiliate in the Netherlands, has a longstanding relationship with Roto Smeets de Boer and is a key player in the innovative process. The company is trying to develop water-based ink with characteristics that are feasible for printing. Some of the problems that need to be solved include the quality printing, flowing and drying of the inks. Sun Chemical is world leader in the manufacturing of inks and coatings for all graphic arts applications. The US company began to expand its ink operations overseas in the early 1970s. During the ensuing years, the company built a strong presence in the European marketplace. By the 1990s, Sun Chemical-Europe has assumed its present position as the largest ink manufacturer in Europe (Sun Chemical, 2000). According to a company's representative Sun Chemical is actively participating in this project because its strategy is to have the lead in ink development. The company acknowledges that the water based inks publication gravure currently developed together with RSD is closest to realisation as compared to other alternatives. But, the gravure process with toluene based inks is in a much more mature

12 Sun Chemical Headquarters is located in Fort Lee, USA. The company is a subsidiary of DIC, Japan, since the 80s.

stage, having existed in the market for decades now, and is currently also under further development. The main aspects being tackled in the traditional process are costs, recyclability and emissions. Sun Chemical is currently involved in R&D for the RSD project, and has invested at least hundred thousand Euro in R&D related to this project according to a company source. Part of its R&D is taking place in its R&D laboratories in the USA while the company is also involved in several other projects related to the development of water based inks. While it is yet unclear whether the new process will enter the market, it is clear, according to a company representative, that more experience needs to be gained, and thus longer runs with the new process need to be produced. Through economies of scale cost effectiveness needs to be improved, just as happened in the last decades with the toluene based production process.

Also paper characteristics have to be adapted to the new technique. Paper should for example not absorb the water too quickly. For this part of the project the paper supplier UPM Kymmene from Finland is involved. UPM-Kymmene is one of Europe's biggest forest industry groups. The production of printing paper is its main business area and accounts around half of the group's annual sales. Magazines, newspapers, catalogues, advertising material, books and office papers are examples of end uses where its different paper grades are used. The company has 13 mills located in Finland, the UK, France, Germany and the USA that manufacture almost 8 million tonnes of paper annually. In the company environmental issues are treated as being part of everyday business. The company investigates its environmental impacts with the help of life cycle assessments. Its paper mills are set to be certified for ISO-14001 by the year 2000 while the company also co-operates with other actors the paper supply chain in order to develop ecologically sustainable products (UPM-Kymmene, 1998, 2000). Representatives of UPM-Kymmene are in close contact with Roto Smeets Deventer regarding the project. The main role of UPM is to supply grades of paper that have the characteristics that make them suitable to print with water based inks. The prints should have similar quality to those based on toluene inks. Furthermore, characteristics of both paper and inks determine the characteristics of the de-inking process. UPM has several plants that recycle used paper, for example in France and Germany, and therefore can provide information on those characteristics that make de-inking successful. Important motives for UPM-Kymmene to participate in the project include the reduction of environmental impacts through the introduction of the new process. Moreover, the company wants to be ahead of competitors in terms of new developments, and considers participation in this project and important strategic issue. According to a representative of UPM, successful introduction of the new technique would be revolutionary in the sector, which already for long has been dominated by the printing technique based on toluene inks.

Machinery in the printing process and especially printing presses also need to be adapted to the new technique. They need to be fast while still maintaining the capacity to dry. Cerutti, a large Italian manufacturer of presses, together with Eltex-Elektrostatistik, a German company that develops drying equipment, are involved in this part of the project. They developed an electrostatic drying support for the printing presses. Cerutti is world-wide supplier of rotogravure presses, in more than 50 countries of the world, over thousand Cerutti rotogravure presses are utilised to produce gravure products (Cerutti, 2000). Eltex is a German company that is leader in the field of electrostatic systems.

In overview, it has become clear that actors throughout the printing collaborate in the innovation process. The economic network is highly international, and the players are companies with significant shares in the world market for their respective product or service. The various actors give however different weight to the project initiated by Roto Smeets Deventer. Sun Chemical clearly is a crucial actor in the process, and the company is said to be involved because of the possibility of further application of water based inks throughout the sector. It wants to make sure that it is well equipped and positioned to service printing companies with both the product and the expertise necessary when for example legal developments make rotogravure with toluene based inks even more unattractive. The company has invested several tonnes of Euro in the project, and is also involved in similar projects in the USA, some of them which develop other alternatives for toluene based inks[13]. According to a company representative it is yet unclear how the new technique will develop, mainly because other actors in the printing sector are less positive or committed.

4.2. The knowledge network

Various actors also are involved in the innovation process outside the economic network. The relationships of these actors with Roto Smeets Deventer are different than with those of the economic network. Research institutes have been approached by RSD to find possible direction of solutions for specific technical problems. One of these problems includes the de-inking of paper. During the innovation process it became clear that de-inking of water based inks is more problematic with current techniques. The main problem is that solvent-based inks are separated from the paper fibre and water through a flotation technique. This is possible due to the hydrophobe character of the inks. However, water based inks are soluble in water and cannot be separated with flotation. Therefore, if the share of used paper with water based ink rises above 5 to 10%, the process of de-inking will not succeed to deliver recycled paper with an acceptable degree of whiteness[14]. Research on de-inking is carried out by the Centre du Technique du Papier (CTP) in Grenoble, France. In 1998 a specific symposium was held by CTP in which various paper producers presented outcomes of research into the de-inking of waterbased ink products

Overall, the knowledge network can be seen as being supportive for the actors in the production process (the economic network). Crucial developments have been initiated and taken further by the actors in the production process themselves, but in order to overcome certain obstacles actors from the knowledge network have been drawn into the project. Clearly, the clearance of the most obvious obstacles for further improvement of the technique and for market introduction (de-inking and costs) will foremost have to come from the economic network.

In summary: it has become clear that various parties are involved in this innovation. Co-operation of various actors in the printing process is necessary to make the innovation successful. This includes actors throughout the printing chain, from paper producers to ink suppliers to equipment developers and de-inking companies. The international nature of the printing industry has also made the involved network one that crosses various national boundaries. Most, but not all, companies involved also have affiliates or representatives in the Netherlands. In order to improve the quality and yield of printing based on water inks,

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[13] For example the use of hot melt inks (solid inks) in rotogravure printing.

[14] Roughly speaking, the degree of whiteness of the paper should be between 68 and 80%, in order to have readable printing matter.

RSD has organised regular workshops in which the outcomes of different production runs are evaluated, new set ups are discussed, and next steps for improvement are planned. At the companies' highest levels there is regular contact with policy actors, also through the strong representation of RSDB in the branch association KVGO.

5. AN OVERVIEW: PATH DEPENDENCY AND CONFLICTING POLICIES AND INTERESTS

Environmental policy plays a crucial in the innovation process because it creates expectations regarding the conditions under which printing will have to take place in the future. Developments to reduce emissions of volatile organic compounds have already been set in motion by environmental policies. Overall, these policies serve as a driver of innovative activities in the sector. The innovation by RSD was more specifically induced by product standards from the Danish market.
Environment oriented technology policy has been important because it has provided partial funding for a technological development of which, at the onset, the outcome was insecure. During the process it became evident that risks regarding this innovation were manifold and both of a technical and organisational nature. Both environmental policy and environment oriented technology policy stimuli do not seem to be able to remove organisational barriers for the innovation. The highly international nature of the innovation network and economic network makes it plausible that co-ordination of policies at the European level could facilitate the reduction of these barriers. Currently, Dutch national environmental policies sent conflicting signals to the innovation process. Whereas VOC policy is aimed at full reduction of VOC and therefore applauds the development of water based inks, waste policy is aimed at maximal recycling of used paper, a goal that is more difficult to attain when water based inks are introduced.

An overview of the innovation also makes clear that the problem is also one of accumulated infrastructure and investments regarding a specific life cycle path for paper. The sector has fully invested in a specific de-inking technique based on certain characteristics of paper and ink. Therefore here we see clear indications of what in co-evolutionary theories[15] of technological change is called path dependence[16]. The development path of the sector has led to accumulation of investments, infrastructure and knowledge in solvent based printing and de-inking, and this has made it much more difficult to diverge from this path, although this divergence might in the longer term be beneficial both in environmental and economic terms. It is also a question of irreversibility, as through processes of adoption and standardisation in the printing process, "in the sense that the artefact or system cannot be easily dismantled after it has been put together" (Rip & Kemp 1998: 338). A well-known case with regard to this is the example of the QWERTY keyboard[17] that was unable to change to a configuration that was generally expected to be much more productive (faster typing through different lay out of the keyboard). Due through accumulation of competencies (peoples' ability to type based on the QWERTY keyboards), accumulated investments, standards, etc., various improvements of the keyboard faced rejection by the market (David, 1985). The

[15] Co-evolution in terms of social and technological change
[16] See for example Dosi et al (1988), especially chapter 26 by Arthur on Competing Technologies.
[17] The lay out of the QWERTY keyboard was designed in a way that prevented the typebars to clash and jam if struck in rapid succession (David 1985: 333).

development of the cycle of printing and re-using paper shows similar features. Technologies of the whole paper chain from production to the recovery of used paper are harmonised with the use of solvent-based inks. De-inking technologies have matured in the last decades and have been based on characteristics of paper with close to 100% solvent-based inks. Thus the de-inking technique is based on solvent based inks and becomes ineffective when the share of paper with water based ink is roughly above the 5% to 10 % level. Of course this is a threat for those producers of paper who predominantly recover used paper, f.e. for newspapers. Paper production is capital-intensive and emergence of water based inks is therefore threatening their survival. It is yet unclear how these various developments and forces will outplay each other. But this case study indicates that policies are inadequately designed to deal with these types of change in this specific sector. While incentives in the Netherlands to develop waterbased inks are well developed, incentives to stimulate market introduction of the technique are less effective, just as incentives to develop adoption of this innovative technique throughout the sector. Fine-tuning of incentives between European countries and at the European level only takes place to a limited extent. Roto Smeets Deventer is driven towards innovative behaviour both by market forces and environmental regulation. It sees environment friendly products as an important and growing market segment in the printing industry. However its innovative activities are partly frustrated because several other actors within the innovation networks have less incentives to develop new techniques for printing based on water inks. The case study gives insight in technological development that only can be successful when actors along the whole chain of production provide input, and work collaboratively towards a new system of printing and paper recovery. The innovation process is complex because network actors are highly international, and dependency and power relations play an important role. Furthermore, the establishment within the paper industry considers the development of waterbased inks as threatening, because it could imply a change in the now established routines of dealing with the whole chain of paper production, printing and recycling. Policies that can accommodate changes in the printing and paper sector towards this more environment friendly process seem to be lacking.

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