TOP–NEST

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Value chain analysis of biofuels: Örnsköldsvik in Sweden

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This analysis considers the production of bioethanol at the biorefinery site in Örnsköldsvik, Sweden. Forest related industries have been important for the northern part of Sweden and the Örnsköldsvik area in particular, since the late 19th century, but the last 20 years have seen an industry transformation towards producing higher valued outputs in multiple forms.[1] The main focus in this paper will be the two central firms at the site, SEKAB and Domsjö Fabriker. Both firms originate in the previous dominant regional firm, Mo & Domsjö, which started producing ethanol in 1940. After the war, the chemicals production was terminated while pulp production continued; however, the bioethanol production has recently been re-established. SEKAB is today owned by a regional ownership consortium comprising Övik Energy, Umeå Energy, Skellefteå Power, Länsförsäkringar in Västerbotten, OK Economic Association and EcoDevelopment, while Domsjö Fabriker was bought by the Indian business group, Aditya Birla Group, in April 2011. A main reason for the acquisition was to guarantee a long-term uninterrupted supply of pulp, which has minimised the uncertainties for the Indian owners.[2]

1. Basic input/output structure

1a. Main activities/segments

Feedstock provisioning

The main feedstock at Domsjö Fabriker is softwood, of which the plant uses 1.6 million m^3 annually. The production relies on both imported and – mainly – domestically produced wood.[3]

In terms of SEKAB, it is important to distinguish between the two parts of the company (see figure 1). The activities in SEKAB Biofuels & Chemicals are primarily based on import of 1st generation ethanol from Brazil. Some years ago SEKAB used around 300,000 m^3 ethanol per year, but this figure is now significantly lower due to changes in product portfolio (abandoning the production of E85). Today SEKAB uses 150,000 m^3 ethanol per year, whereof 90% is imported and the remaining 10% is based on Swedish wood and supplied by Domsjö.[4]

SEKAB is the first company in the world which has verified their ethanol as sustainable, following these criteria:[5]

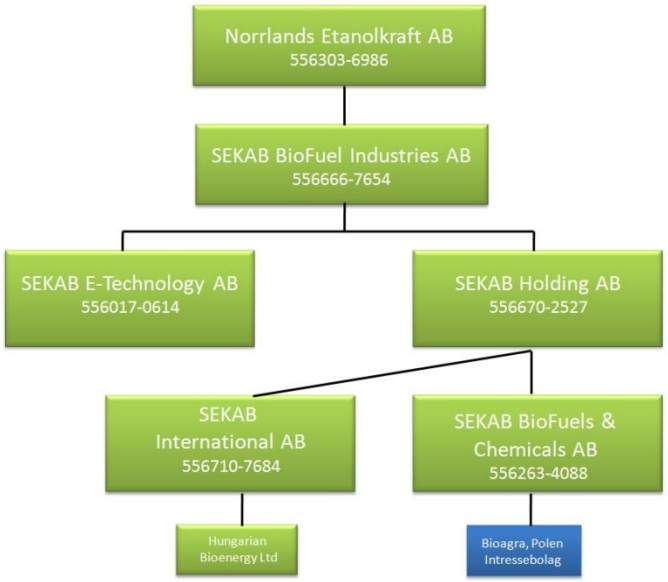
- Zero tolerance for child labour
- At least 85% reduction of fossil carbon dioxide as compared to petrol
- At least 30% mechanised harvesting today and a plan to increase the degree of mechanisation to 100% by 2014
- Zero tolerance for the felling of rainforests

[1] Coenen, L; Martin, H & Moodysson, J. (2013): Renewal of mature industry in an old industrial region: regional innovation policy and the co-evolution of institutions and technology. Working paper.
[2] http://articles.economictimes.indiatimes.com/2011-04-23/news/29466545_1_thai-rayon-aditya-birla-group-group-overseas-subsidiaries
[3] http://www.domsjoe.com/
[4] Interview 13/5 2013
[5] http://www.sekab.com

- Employee rights and safety in line with UN guidelines
- Ecological considerations in accordance with UNICA's Environmental Initiatives
- Continuous monitoring of compliance with the criteria

However, while acknowledging that the activities of SEKAB Biofuels & Chemicals have been highly influential in developing a market for biofuels in Sweden, the activities in SEKAB E-Technology AB are of greater interest for this case study, as they focus specifically on technology development of 2nd generation bioethanol. Thus, SEKAB E-Technology works specifically with producing ethanol from bagasse (leftovers of the sugar cane), straw and wood.

Figure 1. Organisation of SEKAB



Source: http://www.sekab.com

Processing (primary and secondary)

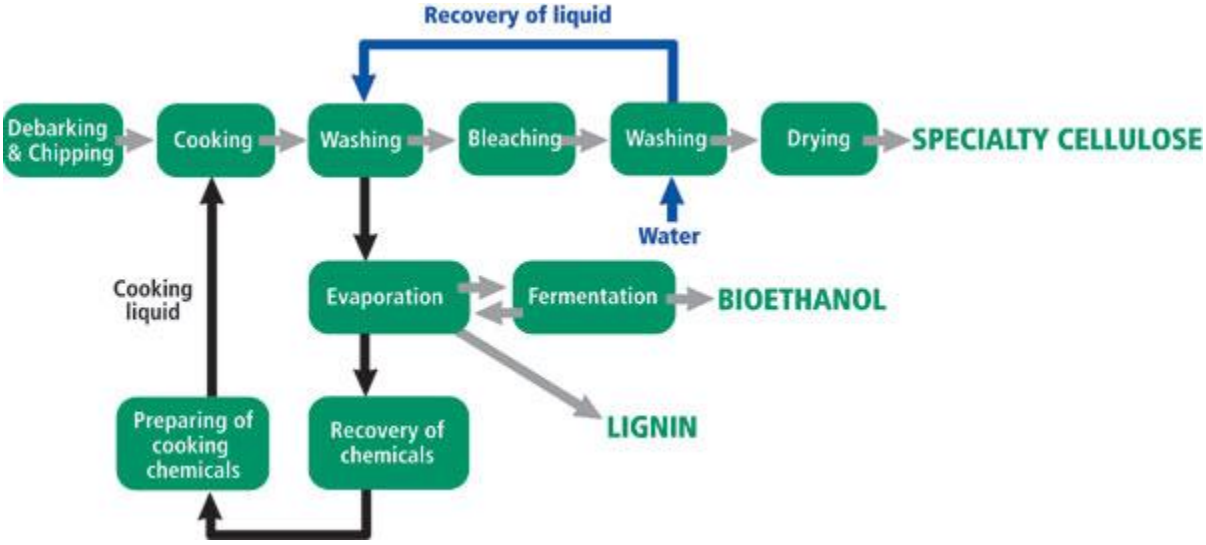
The bioethanol produced at Domsjö Fabriker can be considered a secondary product in the production process. The annual product capacity of bioethanol is 14,000 tons, compared to 120,000 tons of lignin and 255,000 tons of specialty cellulose which is mainly used for viscose textiles.

Figure 2 illustrates the processing of biomass at Domsjö Fabriker. The processing of the wood logs takes place in the following way: The wood logs are debarked, chipped and fed into digesters along with cooking chemicals. The bark is burnt and the energy is recovered in the form of steam. Following cooking, the cellulose is firstly washed and then subsequently bleached using hydrogen peroxide, in a

closed loop bleaching plant that reuses the chemicals. The bleached cellulose is then dried and shipped in bales. The whole process from log to bale takes approximately 40 hours.[6]

During cooking in the digesters, hemicellulose and lignin are dissolved. The hemicellulose is fermented with yeast and distilled into bioethanol, with carbon dioxide produced as a secondary product. The lignin is refined during the cooking process, dried and packed in big bags. The lignin production capacity was recently doubled due to the installation of a second lignin dryer.

Figure 2. Process diagram for Domsjö Fabriker



Source: http://www.domsjoe.com/

The technique for producing bioethanol applied at Domsjö Fabriker used to be a widely spread technique in Sweden. Historically, ethanol from wood raw material was produced in numerous sulphite pulp mills by separating hemicellulose from the cellulose in the pulping process. In the middle of the 20th century, there were 32 Swedish mills producing approximately 60,000 tons ethanol per year. Today, only the Domsjö mill remains, producing 14,000 tons per year.[7]

Until recently, Domsjö Fabriker had advanced plans for establishing an industrial scale 200 MWth demonstration biofuels plant based on Chemrec's – a Swedish engineering firm – black liquor gasification technology. The plant was intended to produce biomethanol and BioDME using forest harvest residues as energy feedstock. The yearly capacity was planned to be 140,000 tons of biomethanol or 100,000 tons of BioDME in a dual product plant. While €55 million had been secured from the EU in R&D support (out of a total budget of €330 million), the project was cancelled in May 2012 by Aditya Birla, the new owners of Domsjö.

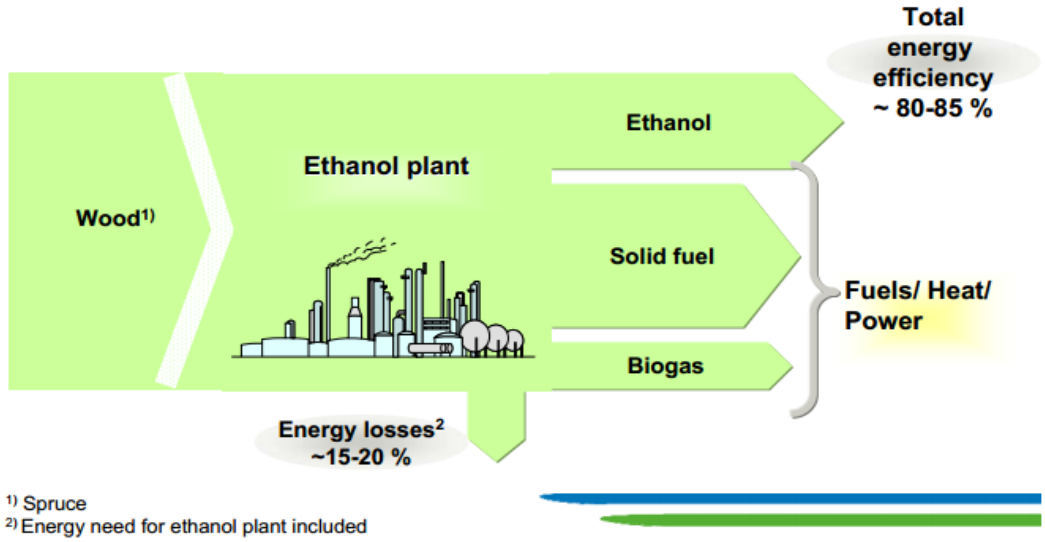
[6] Domsjö Fabriker (2012): *We make more from the tree*
[7] Joelsson, J. and T. Tuuttila. 2012. The history and current development of forest biorefineries in Finland and Sweden - Version 1.1. Örnsköldsvik: Forest Refine.

The processing at SEKAB E-Technology has been developed at the Ethanol Pilot Plant – a 200 m^3/year plant for development and demonstration of cellulosic ethanol production, which SEKAB E-Technology has been responsible for operating since the inaugurated in 2004. The plant has been funded by resources from the Swedish Energy Agency, the EU and SEKAB. At the plant, SEKAB E-Technology has carried out advanced R&D work to further develop and verify all the required steps in the process of commercialising the technology for the production of cellulose ethanol. The development work has included raw materials, chemical and biological processes, control and regulation technology and the integration with other products. Briefly described, the process proceeds in the following steps:[8]

- Steaming. Hot steam is added to preheat the raw material and expel the air
- Prehydrolysis. Hemicellulose, which comprises various sugars is dissolved in acid at high temperature, 170-200 ˚C
- Enzymatic Hydrolysis. Enzymes are added that separate the sugars from the cellulose
- Fermentation. Yeast is added and the dissolved sugar is converted to ethanol. Steps 4 and 5 take place in the same vessel
- Neutralisation
- Detoxification
- Distillation
- Bioreactors

The results of the process are ethanol, solid fuels and biogas, as depicted in figure 3.

Figure 3. Energy balance from cellulose to biofuels plant



Source: http://ec.europa.eu/energy/renewables/events/doc/2010_10_13/7_demo_jan_lindstedt.pdf

[8] http://www.sekab.com/

However, SEKAB has by the end of 2011 decided to stop its commitment in the pilot plant.[9] The reason is that, according to SEKAB, development of the technology has advanced to a stage where SEKAB has a limited need for using the pilot plant, and SEKAB E-Technology is only able to occupy the pilot plant 15-30% of the available running time. For the remaining time, external operation and financing is needed. An interview person notes that the decision also reflects the lack of commercialisation of the technology developed in SEKAB E-Technology, which would likely have stimulated a stronger need for the facility within SEKAB. Recently, the Swedish industrial research institute SP has agreed to take over the pilot plant, at least for one year, which will show if there is a sufficient continuing need for the facility. The name will change from "the ethanol pilot" to "Biorefinery Demo Plant" to stress that the focus will be broadened to e.g. green chemicals and materials. VINNOVA and the Swedish Energy Agency funds the project with a total of 28 million SEK.[10]

SEKABs withdrawal from the plant does not imply that SEKAB has given up on the technology. SEKAB continues to seek commercialisation of the developed technology for production of cellulose ethanol. The next step is a full scale plant that utilises the technology. While the size of the investment depends on the scale and the integration capabilities, SEKAB estimates that it would be around 1.2 billion SEK. SEKAB was granted €30 million from the EU for a 2. generation biofuel plant in Central Europe. The funds are available for two years, thus, SEKAB needs to find the additional funding within this period.

However, SEKAB will not necessarily be the actor that commercialises the technology, as it is evident from the following quote:[8] *"SEKAB has experience from over 30 000 hours of operation in the Ethanol Pilot, which has created a unique know-how and knowledge. SEKAB will capitalize on its know-how and experiences when up-scaling and selling the technology for production on a commercial scale."* Finally, it should be noted that SEKAB does admit that the decision to end commitment in the pilot plant will have negative consequences for the commercialisation of the technology:[11] *"The ending of the operational commitment of the Ethanol Pilot will affect the commercialization of the technology, but to what extent is hard to say today."* In line with this, an interview person pointed out that the continuation of the demoplant was of great importance for the continuing development of SEKAB's technology and contact to customers. Today SEKAB has 14 patents/pending applications on various processes and integration solutions related to the technology.

Use of waste products

At Domsjö Fabriker, the production of industrial steam and electricity for the biorefinery is based on residual products from the processes of the biorefinery, such as bark and wood chips. Further, as part of converting the bioethanol, combustible substances (e.g. methanol) are removed from the bioethanol. They are combusted, allowing a recovery of energy.

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[9] http://www.sekab.com/media?nd_ukey=c558a509958ac3b6122d3c84480e1fae&nd_view=view_pressrelease&nd_id=713995

[10] http://www.mynewsdesk.com/se/pressroom/sp/pressrelease/view/pilotanlaeggningen-i-oernskoeldsvik-blir-en-demoanlaeggning-foer-bioraffinaderi-862062
http://www.nyteknik.se/nyheter/energi_miljo/bioenergi/article3688474.ece?service=mobile&content=main

[11] http://www.mynewsdesk.com/us/pressroom/sekab/pressrelease/download/resource_attached_pdf_document/713995

Integration with other energy production technologies

SEKAB notes that integrating the cellulose-based ethanol plant with other types of industries will make it possible to utilise the energy in the raw materials as optimally as possible. Thus, if a facility for cellulosic ethanol is integrated with an existing first generation ethanol plant SEKAB estimates that the manufacturing costs will be competitive with conventional technologies.[12]

End use, distribution, marketing and sales

The three main outputs of Domsjö Fabriker are used in the following ways:

The **specialty cellulose** is primarily used in viscose clothing and hygiene products as an alternative to cotton. It is also used by the pharmaceutical and food industries as a binding agent. Domsjö Fabriker has a sales and marketing collaboration with the trading house Ekmans and Co. The main customers are manufacturers of textiles and hygiene products, primarily in Asia, which has seen strong demand over the last years due to stagnation in cotton production. Main competitors are Sappi and Bahia Pulp. Domsjö estimates its global market share in the wood-based specialty cellulose at just over five per cent. For products for which long-fibre cellulose is required, Domsjö's market share is ten per cent.[13]

Examples of use:
- Fashion: textiles, lining, filament
- Hygienics: napkins, sanatary towels, non-woven
- Food industry: salami-casings, skins
- Medicine: pills (binding agent of active substances)
- Cleaning: dish cloths, washing detergent
- Paint industry: paint (thickening agent)

Source: http://www.domsjoe.com/

The production of **lignin** (lignosulfonates) is mostly used as concrete additives in the construction sector where it works as a dispersant, reducing the use of water while maintaining the flow property. Also, lignin is used in production of bricks and other ceramic products, as well as the production of dye pigments. Lignin is also used as a binding agent in e.g. feed pellets and mineral briquettes or as a dust abatement agent used on roads. Domsjö Fabriker exports the majority of its lignin production to manufacturers of concrete additives, but it also has customers that manufacture pellets for animal feeds and minerals. The market is expanding due to increasing quality demands in the construction industry and the desire to replace oil-based products. The strongest player in the market is Borregaard. Domsjö estimates its global market share in lignin at around seven per cent

Finally, the production of second generation **bioethanol** is delivered to SEKAB which refines it further into e.g. car fuel. Domsjö Fabriker is one out of two manufactures of second generation bioethanol in

[12] http://www.sekab.com/
[13] http://www.domsjoe.com/

Europe, the other being Borregaard. The carbon dioxide resulting from the bioethanol production (6,000 tons a year) is further purified and condensed to carbonic acid at the AGA plant within the biorefinery site.

1b. Main supporting activities

Domsjö Fabriker is engaged in some activities looking towards the future. Firstly, Domsjö Fabriker has established an in-house innovation department in 2010, DomInnova, with the specific task of increasing the value added of the products within the firm's three main business areas – specialty cellulose, lignin and bioethanol – as well as to develop new business areas. Concerning the area of ethanol, focus is on improving the process of fermentation in order to increase the production volume.

Secondly, Domsjö Fabriker is involved in an educational program at Umeå University in process operation. The program includes one year of study, followed by a one year internship at one of the seven participating firms.

In terms of SEKAB, the termination of engagement in the ethanol pilot plant represents a significant step down in development activities, however, other engagements continue to exist. SEKAB is e.g. involved in an EU-funded project, DISCO, which aims at developing more efficient and cost-effective enzyme tools to produce bioethanol from lignocellulosic biomass, and understand how these enzymes work.[14] Among others, SEKAB collaborates with the Dutch R&D centre of the global biotech company Dyadic International.[15]

1.d. Lead firms

Concerning Domsjö Fabriker, the customers in the specialty cellulose market are producers of consumer goods. Regarding bioethanol, SEKAB is the customer. SEKAB itself has petrol and gas companies as its customers. Today, fuel companies have taken over purchasing and production of E85 for normal vehicles, which is available at more than 1,700 pump stations throughout Sweden, and SEKAB focuses on ED95 that targets heavy goods vehicles. SEKAB has on several occasions collaborated closely with OKQ8 AB.

2. Key technologies

2.a. Technologies for main and supporting activities and assessment of their development stage

Technologies are described above under main activities (processing).

[14] http://www.mynewsdesk.com/us/pressroom/sekab/pressrelease/view/effective-enzymes-for-the-degradation-of-cellulose-sekab-and-dyadic-in-cooperation-on-verification-792387

[15] http://www.prnewswire.com/news-releases/dyadic-and-sekab-cooperate-on-verifying-effective-enzymes-for-the-production-of-cellulosic-sugars-170971761.html

2.c. Is the technology disruptive or path-following/incremental?

The technologies used by Domsjö Fabriker and SEKAB E-Technology are disruptive compared to 1st generation ethanol production. However, it may cause some worry that both firms have recently stopped activities aimed at further developing and commercialising these technologies.

2.d. Market characteristics

As described above, SEKAB is a market leader within 1st generation bioethanol, where it has subsequently sought to be at the front of the market (e.g. implementing sustainability verification and focusing on ED95). However, the downscaling of development efforts implies that it is not guaranteed that it will maintain this position concerning 2nd generation ethanol.

Concerning Domsjö, it has a strong market position within specialty cellulose and lignin – both markets which are growing.

3. Geographic scope

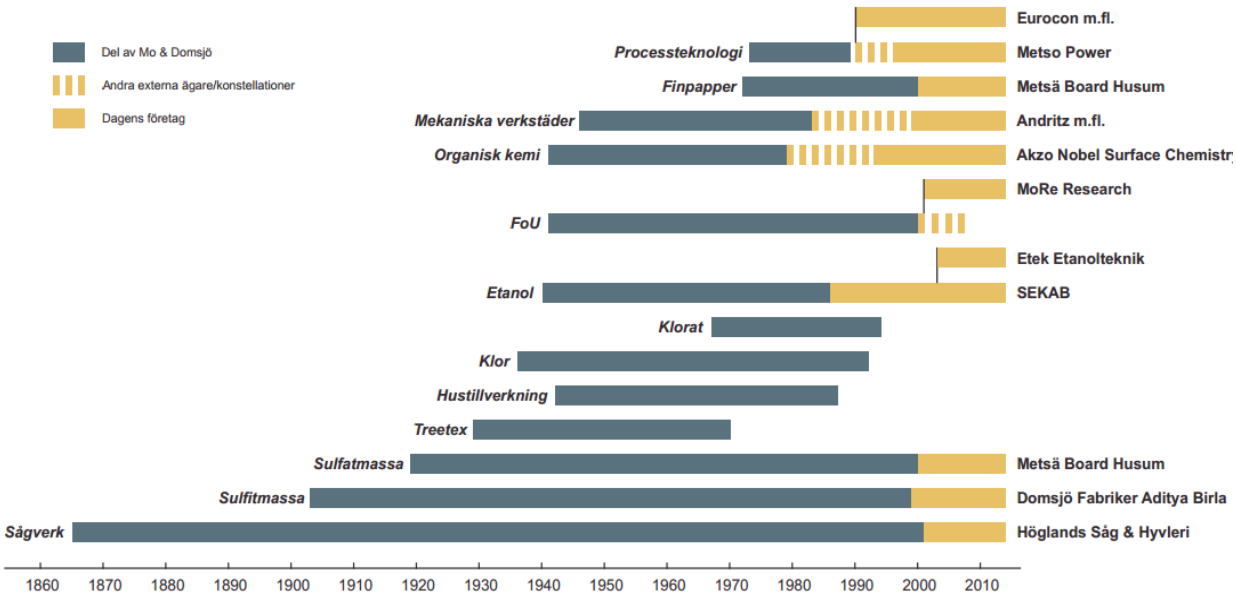
Being owned by an Indian multinational, and having important markets in Asia, Domsjö Fabriker is a truly global company. SEKAB is owned by regional actors, however, the firm is a large importer of ethanol from Brazil and it furthermore also has a subsidiary in Poland, BioAgra (since 2009) of which it owns 49%.

4. Governance and institutional context

The wider governance of the biorefinery industry in Örnsköldsvik has been greatly influenced by the Swedish policy program 'Biorefinery of the Future' (BioF). This initiative is geared to develop a strong regional innovation environment for forestry-based biorefinery development in the region, and it is hosted by Processum, the local biorefinery cluster organisation.[16] As figure 4 shows, the members of Processum are closely related to the previous dominant regional firm, Mo & Domsjö. Besides Domsjö Fabriker and SEKAB, another key player is MoRe Research. MoRe Research is a R&D firm specialized within biorefinery processes. Domsjö Fabriker is among the owners, however, it offers its services freely on the market. The spin-off of MoRe Research from Mo & Domsjö proved to be a key factor for the future development of the forest-related industry in the region, exactly because its founders already from the start made sure to establish a 'neutral' ownership structure, allowing for multiple companies to use the facility on equal terms.[17]

Figure 4. Background of actors in Processum

[16] Coenen, L; Martin, H & Moodysson, J. (2013): Renewal of mature industry in an old industrial region: regional innovation policy and the co-evolution of institutions and technology. Working paper.
[17] Peterson, C. (2011) Sweden: from large corporations towards a knowledge-intensive economy, in Hull Kristensen, P. and Lilja, K. (eds) Nordic capitalisms and globalization: new forms of economic organization and welfare institutions, Oxford: Oxford University Press.



Source: http://www.processum.se

The BioF initiative materialized in 2003, by that time in the shape of a technology park, located at the site of the pulp & paper industry in Örnsköldsvik. The municipality, the county administration, a regional technology transfer agency and a privately owned funding foundation with its roots in the region's forest-based industry provided financial support. Over time, linkages to the nearby universities in Luleå and Umeå have been established and increasingly formalized. The technology-park has evolved to a network of related firms and organisations (i.e. an innovation system) distributed over a territory much wider than the boundaries of Örnsköldsvik.

A decisive moment for the BioF initiative came in 2008 when VINNOVA (the Swedish Agency for Innovation Systems) launched a second call for regional industry development initiatives called VINNVÄXT. The consortium with representatives from industry, academia and the regional public sector made a successful application and received a ten year grant. The aim with the project was to become a leading initiative for developing biorefineries based on forest raw material and energy crops by combining historical and current strengths in traditional forestry with new cutting edge knowledge in science based technologies. Active promotion of the interplay between researchers, companies and the political public sector (i.e. triple helix) was set centre stage in the initiative. The grant allowed for expansion in scope as well as scale. One immediate consequence was that the universities became more central actors; one of the regional universities established new professorships located at the industry site. An R&D board with the aim of supporting new development projects in the region was established, with two university professors, the head of R&D at the aforementioned ethanol firm, and the CEO of the pilot plant being responsible for evaluating applications, giving advice to entrepreneurs, and distributing resources for new R&D experiments. The first two years of its existence, the board supported 74 projects with approximately 18 million SEK.

Finally, it should be noted that in addition to VINNOVA, a number of other Swedish agencies provide funding for R&D on biorefineries – the most important are the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) and the Foundation for Strategic Environmental Research (MISTRA).

5. Barriers to 2nd generation biofuels[18]

The case of Örnsköldsvik highlights the difficulties of overcoming the barriers to a wider diffusion of 2nd generation biofuels. The cancelling of Domsjö's production of biomethanol and BioDME and the (so far) non-commercialisation of the bioethanol technology developed by SEKAB E-technology points to this. Thus, upscaling has not taken place and the interviews point to a number of reasons for this.

Barrier 1: Lack of long-term policies

All interviews point to the lack of long-term policies as an absolutely crucial point. At the moment, biofuels have a tax deduction, but the Swedish Ministry of Finance decides on this from year to year. Thus, there is a very large political risk associated with the investments in full-scale commercialisation of the technologies, which has so far prevented these from taking place. In the case of Domsjö's investment, the Indian owners would have had to invest an additional €275 million with a return of investment over a long period. One interview person assessed that stable policies over 15 years are necessary to make such an investment feasible. Consequently, the investment was judged to be too risky. Several interview persons highlight that the change of ownership did not influence the outcome – the previous owners would have been forced to find the funds on e.g. the stock exchange which would also have been unlikely to happen. In the case of the commercialisation of SEKAB's technology in the potential Central European plant (planned location in Poland), the situation is very similar: some funding has been secured from the EU and additional funding must now be secured on the market. Time will show if SEKAB manages to find the remaining €100 million before December 2014.

The central role played by political negotiations is illustrated by the large effort towards influencing policymakers previously undertaken by central actors in the biorefinery. Intensive negotiations resulted in informal support from several relevant ministries (Environment, Enterprise and Rural Affairs). However, as all three ministries are led by politicians from a smaller party (The Centre Party) in the governing alliance, this support proved to be of little help when the Ministry of Finance concluded that long-term tax exemptions from the energy tax and the CO_2 tax would be too costly for the state. A lobbying effort was also made in Brussels in collaboration with external partners. This resulted in some financial support for construction of the facility, but no change in regulations which could ensure long-term profitability.

Further, the current investment climate is at the moment even worse than just a few years ago, as inquiries on fossil-free transport systems are currently undertaken by both the Swedish government and the EU. Until the results of these inquiries are known, no investments are likely to be undertaken due to

[18] This section is based on four personal interviews with representatives of central actors in the biorefinary, all carried out 13th of May 2013.

the political risk, as it is quite certain that they will lead to changes in government policies. The Swedish inquiry is expected to be completed by the end of 2013 – early 2014.

Barrier 2: Low targets for renewable energy in transport

Sweden has already achieved the EU target of 10% renewable energy in the transport sector by 2020, thus, the incentive to invest in commercialisation of the technologies is low. Contrary to Finland which has increased its target to 20%, Sweden has not set a new target beyond the vision of a fossil-free transport sector in 2050, which is too long-term and vague to stimulate investments in facilities. Thus, the informants point to the need for intermediate goals which may act as steps towards the 2050 target. Further, no distinction is made between 1st and 2nd generation biofuels in the plans, which is also a barrier to the commercialisation of 2nd generation technology. Some interviewees were of the opinion that sufficiently high targets would leave room for both 1st and 2nd generation biofuels, if additional targeted support for the first 2nd generation plants is provided, to compensate the significantly higher investments associated with the construction of the first full-scale plants. However, it was also pointed out that specified quotas for 1st and 2nd generation ethanol are necessary to make sure that high-volume 2nd generation production can be established.

Barrier 3: 2nd generation biofuels as a non-core activity

While Domsjö and SEKAB are involved in 2nd generation biofuels activities, these activities are not central to any of the firms – in fact none of the firms that are part of the biorefinery has the transition towards 2nd generation biofuels as a main interest. Domsjö's main focus is on the production of speciality cellulosic products, from which the cellulosic ethanol is a by-product. The turnover resulting from speciality cellulosic products is around 18 times higher than the turnover resulting from the ethanol production. Further, as the Indian owners acquired Domsjö to get access to a supply of pulp, their main focus is on regenerated cellulose and textile applications. While no significant change has occured yet, it was suggested in the interviews that there is now a greater focus on textile applications of the specialty cellulose. It is likely that Domsjö's R&D focus will inceasingly turn towards these fields in the long run.

As previously explained, the production of SEKAB is mainly based on imported 1st generation ethanol. Furthermore, after pulling out of the E85 market, SEKAB's main focus is on green chemicals, not biofuels, as the ED95 is only low volume. In sum, SEKAB's engagement with 2nd generation biofuels is therefore less intense now than previously. While the E-tech part of SEKAB is naturally interested in developing and selling 2nd generation technology, SEKAB's biofuels and chemicals division *"does not care where the ethanol comes from as long as it is sustainable"* as expressed in an interview. Furthermore, there is *"actually no commercial collaboration"* between the two parts of SEKAB.

Thus, SEKAB has primarily a strong interest in the continuing use of 1st generation ethanol in Sweden, as this is the firm's main commercial activity, and SEKAB will continue to import ethanol from Brazil and other countries. In fact, it is highly uncertain whether 2nd generation activities will continue to take place within SEKAB, as the largest shareholders in SEKAB (three local municipalities) has taken a strategic decision to sell all activities associated with technical development of 2nd generation ethanol. After having funded this development for 10 years (co-financed with – but with a decreasing share from – the

Swedish Energy Agency and the EU), the focus should now be on the core activity (conversion of 1st generation ethanol). Therefore, it is crucial for SEKAB E-tech that full funding for the Polish plant will be secured. As expressed by an interview person: *"If we don't manage it in 24 months, we don't manage it at all!"* Another interview person noted that SEKAB E-technology probably needs to win a large project within a couple of years if it has to survive. It is not just a question of selling the technology for this facility, but also a question of showing the attractiveness of this part of the firm to other actors that might consider investing in it.

Another actor which during the last 2-3 years has showed increasing interest for the activities at the biorefinery is the forestry sector, mainly due to the decreasing demand for paper. While the industry was actively resisting the development of wood-based ethanol 5-10 years ago, this has changed with the habits of newspaper readers. However, the forestry sector also appears to be mostly interested in high value products such as green materials and chemicals, despite a traditional preference in the sector for high volume products, which could favour biofuels over the alternatives. This is also due to the high demand for wood in this part of Sweden, which continues to be a net importer of wood. While this situation may change if some of the region's pulp producing plants are closed, the competition for wood in the region makes high value product more attractive than ethanol at this point in time. Currently the interest is at the level of research collaboration, and no commitments to large scale investments have been made, but the large companies are generally wealthy so development may proceed quickly if they take a decision to get involved. However, many of the larger firms have a global presence, so there are no guarantees that the technique will be commercialised in Sweden – it may end up as a production of 2nd generation ethanol based on eucalyptus in Brazil.[19]

As a consequence of the decreasing attention of the firms towards 2nd generation biofuels, the attention of Processum is also increasingly directed towards other fields such as green chemical and specialty cellulose. Today, around ¼ of the cluster organisation's activities are related to biofuels. The change of the pilot facility from being ethanol-focused to biorefinery-focused underlines this general movement towards a broader portfolio of products and activities in the biorefinery. Previously, only development activities related to wood-based cellulosic ethanol was allowed in the plant. Now, as stated by an interview person, it is the intention to develop *"roughly expressed, anything else than ethanol"* – e.g. other types of alcohol, proteins, fish fodder, fibers and materials.

Concluding discussion

The focus on policy and politics in the barriers described above is also a reflection of the maturity of the technology. Put bluntly, the interviewees characterise the technology as quite complete, with few significant technological challenges remaining. The negative side to this is that it is considered unrealistic that incremental technological improvements will eventually make wood-based ethanol competitive on its own. Policy support is needed to upscale the technology which could eventually make it competitive against fossil- and 1st generation-based technologies. The lack of support for upscaling is notable considering the funds provide for development and demonstration, which are easy accessible according to several interview persons. As one noted: *"[The state] funds the construction of demoplants to show*

[19] It was also pointed out that venture capitalists prefer high value products in small volumes

that a technology works, but no work is being done to make sure that the prerequisites for using this technology are there. But maybe that is not the purpose? Maybe the purpose is to develop the technology so we know that it exists when the oil dries out and becomes very expensive in x number of years? But now the technology is there…"

To conclude, the current situation is characterised by stagnation. With increasing interest in the concept of co-evolution, this case exemplifies one of a standstill where technologies and framework conditions have not evolved in similar directions. The consequence is that actors move their focus to other products and use resources there, which also implies that there is less pressure on the politicians for creating favourable framework conditions. This is exemplified by one firm which is no longer actively involved in lobbying for 2nd generation biofuels, since they do not want to *"gore themselves bloody"* trying to create a market. Thus, while it is perhaps too negative to say that the window of opportunity has closed, one can at least conclude that some momentum has been lost.