

Biogas in the Nordic forest industry: current state and future business potential

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Abstract

The forest industry is of great importance to the Nordic countries in terms of exports and employment. Today the industry faces tough challenges related to future higher energy prices, increased competition for wood raw material, and a declining demand for traditional paper products. However, there are also possibilities related to the transition to a bio-based economy. This paper focuses on one such avenue, the business potential in using wastewater from pulp and paper mills as a basis for biogas production. The paper identifies biogas plants at Nordic mills currently operating or under construction and, positions the mills according to their decisions on how to engage in activities related to biogas production and use. Requirements for and consequences of the different positions are discussed in terms of resources and capabilities, governance, and strategy focus.

The paper shows that cost reduction is an important driver for biogas production in the pulp and paper industry, but public financial support is needed to justify the investments. Since forest firms do not view biogas production as a core business activity, external actors that can offer turnkey solutions or run the operations may be needed to facilitate biogas production in the forest industry. While internal use of gas is an option for some mills, it is evident that external demands for biogas, i.e. as vehicle fuel, differ in the three different Nordic countries. In Norway, whose forest industry is the least significant of the three countries, the situation for external use seem to be the

most promising, emphasizing the role of public policy interventions in the transport sector for the development of biogas in the forest industry.

Introduction

The forest industry is essential for the Swedish and Finnish economies, and it plays an important role in Norway as well. The industry faces tough challenges related to future higher energy prices, increased competition for wood raw material, and a declining demand for traditional paper products. However, there are also possibilities related to the transition to a bio-based economy (Scarlat et al, 2015), with an increased proportion of bio-based fuels and materials. The Nordic forest industry could hence play an important part in strategies to reach the European Union's climate targets for 2030. Complementing their traditional core products wood, pulp and paper, many firms in the Nordic forest industry have started to diversify into other products, such as 'green' electricity, bio-fuels, and pellets. This could be viewed as an ongoing partial structural transformation of the industry in the light of a dramatically falling demand for some of its traditional products (e.g. more than 25 % decrease for newsprint in Europe since 2007). Firms within the forest industry need to both find ways to create new value for their customers, and to reduce costs to increase competitiveness. One way is to examine the waste streams from pulp and paper production to determine how the organic contents of these waste streams can be utilized as substrates for biogas production. Recent research indicates that Swedish biogas production could increase significantly through anaerobic digestion of wastewater streams from pulp and paper mills. It is technically possible to produce as

much as 100 million Nm³ biogas annually. This would mean a 65 % increase of national biogas production volumes or up to 875 GWh (Svensson, 2014). The potential is high also in Finland, while it is lower in Norway due to smaller pulp and paper.

To be able to influence industrial practices, policies have to consider the strategies of the firms involved (Cooremans, 2011; Ottosson and Magnusson, 2013; Blumer et al, 2014). However, while the technological/chemical/biological aspects of biogas production from pulp and paper mills' wastewater streams have been much discussed (e.g. Karlsson et al. 2011; Meyer and Edward 2014; Kamali and Khodaparast, 2015), considerably less attention has been oriented towards the organizational and business aspects of biogas production at pulp and paper mills. This paper aims at filling this gap, focusing on the forest firms that operate the mills. The paper identifies currently operating and planned biogas production plants at Nordic pulp and paper mills, and positions the mills/forest firms depending on decisions related to biogas production and use. It moreover uses literature on strategic management to discuss the prerequisites for and implications of these decisions. The ambition is to develop a refined and extended conceptualization, which can guide formulation of policies for biogas production at pulp and paper mills.

The coming section presents the empirical background necessary to understand the case study results, followed by a theoretical framework that discusses strategic positioning decisions. Next, we present the method followed by the result section, where we present and discuss different positions which pulp and paper mills may take in biogas production and use. The final section wraps up the paper, outlining conclusions and implications for policy.

Empirical background

Three factors that influence the potential business case for biogas production at pulp and paper mills are the current structure of the forest industry, wastewater regulations and the available wastewater treatment technologies, and national and international policies for biogas production and use.

THE NORDIC FOREST INDUSTRY

After World War 2, rapid economic growth and the construction of the modern welfare state formed the basis for a new forest industry structure in the Nordic countries. The basis for this new industry structure was the integrated and large-scale production of pulp, paper, board and sawn products intended for export. Cheap domestic electricity supply, sufficient fibre volumes, committed employees, investments in new technology, access to long-term investment capital, and favorable policies belonged to the key factors that facilitated a significant industry development and growth. Between 1950 and 1990, the Nordic forest industry grew significantly. However, around 1990, the growth declined and a process of consolidation characterized the period 1990–2005. Through restructuring, a big part of the production moved into the hands of a few big companies. As a result, SCA (Swedish), Stora Enso (Swedish-Finnish) and UPM (Finnish) soon after year 2000 belonged to the biggest forest industry-companies and paper producers globally. Metsä Group (Finnish) and Norske Skog

(Norwegian) were not far from top-10 either. In addition to having several mills in Norway, Sweden and/or Finland, most of these companies currently operate pulp and paper mills on other continents as well.

During the last two decades, the Nordic forest industry has changed its long-term strategic focus. Energy efficiency and substitution of fossil energy with renewable energy sources have become important issues for the forest firms. So has the production of green chemicals and biofuels (pellets, lignin fuel, methanol, DME, ethanol etc.), as a complement to the traditional line of business. In 2014 the Swedish Forest Industry Federation declared that: "The Swedish Forest industry is driving a growing bioeconomy that is crucial for Sweden and the rest of the world" (Swedish Forest Industry Federation 2014, p. 4). The same year the Norwegian Minister of Agriculture and Food stressed the importance of bioeconomy: "Development towards bioeconomy represents great opportunities for the forest sector. It will be decisive for the development of this sector in different countries to what extent this opportunity is utilized." (Listhaug 2014.) In Finland, the government presented a "Bioeconomy strategy in 2014, aiming to: "...generate new economic growth and new jobs from an increase in the bioeconomy business and from high added value products and services while securing the operating conditions for the nature's ecosystems." (Ministry of the Environment, 2014). Especially Sweden and Finland have political ambitions to become leaders within the forthcoming bioeconomy. The Nordic forest firms have investigated a number of measures and steps on the route towards a bioeconomy, and a few of them have been at least partly realized. This paper will focus on one – biogas production from pulp and paper mills' wastewater.

Although wastewater treatment may be considered a core process activity for pulp and paper mills, biogas is unlikely to become a core product. The revenues from biogas production will be small compared to those from pulp, paper and wood. Still, biogas production has the potential to provide additional revenues. Moreover, pulp and paper production is an energy intensive business, with significant need for both electricity and process heat. Therefore, there may be possibilities for internal use of the biogas. Hence, a forest firm that is going to engage in biogas production has to make two important decisions. The first decision is whether the mill should manage the biogas production internally or engage an external firm to operate the biogas plant. The second is whether the mill should use the biogas internally or if it should be sold to external customers.

BIOGAS FROM PULP AND PAPER WASTEWATER

Pulp and paper production generates huge volumes of wastewater, which is rich in organic material content. In order to avoid pollution, it is important to take care of the organic material before releasing the wastewater to the sea or to ambient lakes or rivers (Larsson et al. 2015). In the Nordic countries there are significant regulatory demands on the wastewater treatment processes at pulp and paper mills. Each mill has a permit that specifies the requirements on its wastewater process and the mill has to monitor the wastewater quality and report this to regional environmental authorities.

Traditionally pulp and paper mills have treated their wastewater by aerated processes. These processes are however very

energy intensive, and thus expensive. An alternative to this traditional wastewater treatment is to instead pre-treat the wastewater in an anaerobic step, followed by aerobic activation. By adding this process step, it is possible to gain four specific advantages: 1) biogas will be produced through anaerobic digestion; 2) the sludge volume will be reduced; 3) the overall ecological footprint will be smaller; and 4) the carbon dioxide emissions will be lower (Habets and Driessen, 2007). Under optimized operating conditions, such a hybrid system (i.e. anaerobic combined with aerobic treatment), “is the most appropriate option for pulp-and-paper industry to obtain a satisfactory treatment performance, reduce GHG emission and energy costs, and meet environmental regulations” (Ashrafi et al., 2015, p. 155). Instead of using substantial amounts of energy to treat the wastewater from pulp and paper production, the wastewater treatment process could actually generate useful energy.

Anaerobic treatment of pulp and paper mills’ wastewater is an established process technology that has been used at pulp and paper mills since the early eighties (Habets and Driessen, 2007). Process innovations have resulted in increasingly efficient reactors over the years (van Lier et al., 2015). In the world, there are about 250 operating applications of anaerobic wastewater treatment and biogas production at pulp and paper mills (cf. van Lier, 2008). Most of these applications however exist at mills, which use recovered fiber as input. Recovered fiber is easier than virgin fiber to handle in an anaerobic water treatment system (Habets & Driessen, 2007). Virgin fiber input dominates in the Nordic forest industry. How to handle the wastewater composition is therefore a more complicated issue at most Nordic mills (Ekstrand et al., 2013). Recent research though indicates that there are ways to handle the demanding Nordic wastewater streams (Larsson 2015; Björn et al 2016).

BIOGAS POLICIES IN THE NORDIC COUNTRIES

Policies for biogas production and use are related to national and international targets for reduced fossil fuel use and increased use of renewable energy sources. Biogas can substitute for fossil fuels in electric power and heat generation, transport and various industrial processes. In the Nordic countries, the transport sector is the most significant contributor of greenhouse gas emissions. The electric power generation is primarily based on renewable energy sources and nuclear, and the heat generation primarily use biomass and wastes. Hence, the substitution of fossil fuels in vehicular applications dominates the policy agenda. The governments in the Nordic countries have announced ambitions to make the transport system “fossil free”. Increasing the production and use of biofuels is an important part of their strategy to realize this ambition.

In terms of biogas production volumes, Sweden is currently the leader among the Nordic countries. In 2014, the Swedish biogas production amounted to 1,784 GWh. This is about three times as much as the production in Norway and 2.5 times as much as the production in Finland (Energimyndigheten, 2015; Avfallnorge, 2016; CBG100, 2016). Sweden is unique in its use of biogas for vehicular applications. As much as 57 % of the biogas produced in the country in 2014 was upgraded and used as a vehicle fuel. The percentage of upgraded biogas has risen steadily since the 1990s and in par-

ticular since 2005 (Olsson & Falldé, 2015). The use of biogas in Norway and Finland is more similar to other biogas producing countries in Europe, where heat and electric power generation dominates.

A number of political interventions have promoted increased production of biogas for use in vehicular applications in Sweden. This includes fuel tax exemptions for vehicle biofuels and public investment grants for biogas facilities, as well as several initiatives from local authorities, establishing municipal co-digestion plants and upgrading facilities, using municipal organic wastes as substrates, and implementing biogas fueled city buses in the public transport (Larsson et al. 2016). Because of a significant uptake of buses fueled by biogas and biodiesel, two thirds of the public transport in Sweden used renewable fuels in 2015. The figures for Norway and Finland are lower. However, both these countries have announced plans to increase the use of biogas in public transport buses. In Norway, the largest public transport authority Ruter – which governs the public transport in the Oslo area – has announced that their traffic will be fossil free by 2020. An important part of the strategy to realize this objective is a rapid increase in the percentage of biogas-fueled buses in operation from the current 14 % (2015) to 47 % in 2020 (Ruter 2015). Public transport authorities for other areas such Trondheim, Bergen and Ostfold have announced similar plans (Klima- og Forurensningsdirektoratet 2013). In Finland, there are plans for a 10-fold increase of the biogas upgrading capacity by 2017, making a significant part of the biogas produced in the country available as a fuel for vehicles (CBG100, 2016).

In the Nordic countries, vehicle fuel taxation is relatively high and the exemptions from these taxes have been instrumental for directing the use of biogas to transport applications. However the EU commission has questioned the persistence of these schemes, with reference to European competition laws. In December 2015, the Commission announced that the fuel tax exemption in Sweden could remain until 2020, signaling that there would be no further extensions after that.

Summing up, there is a significant pulp and paper industry in the three countries, there is a potential to produce large amounts of biogas from its wastewater streams by anaerobic treatment, and there is a political ambition to increase the use of non-fossil fuels as biomethane (the upgraded form of biogas).

Theoretical framework

Biogas is a complex industrial ecosystem, in which firms and other actors engage in a number of different activities (Tsvetkova and Gustavsson, 2012). Production, distribution and consumption of biogas constitute core activities in this system. Together with the supply of the required input material for biogas production – biomass substrate supply – these are central activities in the biogas value chain. Different firms engage in different activities in the industrial value chain. Following literature on strategic management (Grant, 2010), firms’ decisions on what activities to engage in are contingent on what they can do (resources and capabilities), are allowed and encouraged to do (governance), and what they want to do (strategies). The text below will elaborate on these aspects of individual firms’ positioning decisions.

RESOURCES AND CAPABILITIES

According to a resource-based view on firm strategy, it is the unique set of resources that a firm possesses that makes it possible to attain a competitive advantage on the market (Barney, 1991). The set of resources tends to be more stable than external factors such as customer requirements, market developments and competition. Therefore, the capabilities resulting from the firm's unique set of resources constitutes a useful foundation for the formulation of long-term future directions. This means that strategy formulation should start with an inside assessment of existing resources and how they jointly determine what the firm is capable of doing.

A firm possesses three different kinds of resources: tangible, intangible and human (Grant, 2010). Tangible resources refer to physical assets and financial resources. These are relatively easy to identify and assess. Key issues for strategy formulation based on tangible resources are to identify possibilities to economizing on their use and possibilities to employ them more profitably. Intangible resources refer to technology, including intellectual properties such as patents, copyrights, and trade secrets, as well as brand names and reputation, and organizational culture. These resources are more difficult to assess. Still they constitute valuable assets for most firms, thus being important aspects of their strategies. So are the human resources, which constitute the most fundamental building block of any organization. Human resources include the knowledge of employees, as well as different kinds of routinized behaviors, which over time have proved to be efficient.

To provide a useful basis for strategy formulation, a firm's set of resources has to result in capabilities, which enable access to a variety of markets. To facilitate a competitive advantage, the capabilities of a firm have to be difficult for competitors to imitate and provide perceived benefits for the customer. Prahalad and Hamel (1990) introduced the concept of core competence to describe such capabilities. They originally introduced this concept as a way to describe how firms can use existing capabilities as a means to successfully enter new markets, so called related diversification. However, the concept has also been used as an argument in favor of extensive outsourcing of supporting activities. By focusing on the core business, the firms can benefit from other firms' complementary capabilities. This will result in a higher degree of specialization, which in turn will result in a raised efficiency in operations. As discussed in literature on industrial symbiosis (Lombardi & Lyburn, 2012), effectively combining different firms' specialized capabilities can result in both organizational learning and more efficient material and energy flows.

GOVERNANCE

Firms operate in contexts which restrict what they can do, but also provide directions for change. Policy makers can promote sustainability in collaboration with business, arguing that better environmental performance means that firms gain competitive advantages. However, the complexity and uncertainty associated with transformations towards sustainability means that it is difficult on beforehand to assess the consequences of individual initiatives. Policy measures will often have unforeseen and unintended effects. Hence, to advance societal sustainability objectives, there is a need for steering and coordination mechanisms, which are both open, creative and

self-critical (Hendricks & Grin, 2007). Moreover, a range of interests, institutions and ideas are involved in transformations towards sustainability. Policies therefore have to acknowledge that transformations towards sustainability are political processes, engaging a variety of actors and encourage interaction between these (Meadowcroft, 2011).

Firms are exposed to political interventions and pressures, which they must comply with in order to be considered legitimate in the society. These are both formal and informal. While strict governmental regulation can be considered the most obvious instance of formal pressure, political interventions can take a number of different forms, ranging from laws and specified permits, which are enforced in a hierarchical manner and which are associated with penalties for noncompliance, to incentives, investment subsidies and industry standards, which may allow more flexibility (Treib et al, 2007). Research show that policy incentives aimed to promote sustainability may result in different responses, owing to the different capabilities of individual firms within the same industry (Ottosson and Magnusson 2013).

STRATEGIES

A firm's corporate strategy defines the scope of its operations and the markets on which it competes. Critical decisions on corporate strategy relate to the degree of vertical integration in the industrial value chain (make-or-buy decisions and value-added), and opportunities for diversification into new business areas (Grant, 2010). A prime basis for decisions on corporate strategy is the possibility to attain a competitive advantage in terms of either a lower production cost than the competitors, or in terms of product differentiation, i.e. providing unique offerings, which will justify a premium price on the market (c.f. Porter 1980).

Strategies for diversification refer to simultaneous changes in a firm's product line and the markets it serves (Ansoff, 1957). Such strategies combine the two interrelated processes of product development and market development. These processes are required to cultivate the requisite new skills and techniques, and to build up new facilities for production, distribution, service and sales. Decisions on diversification rely on estimates and forecasts of trends related to factors such as manufacturing cost, market growth, competition, and political interventions. Moreover, it is necessary to include possible contingencies such as technological breakthroughs and economic recessions in the decision analysis. To provide a solid basis for decisions on diversification, the decision analyst should compare the attractiveness to enter a new market with a new product with the estimated cost of entry (Porter, 1987). In addition, the decision analyst has to consider the relatedness between the new and existing products and markets, i.e. to what extent the potential new business will gain competitive advantage from its connection to the existing business and vice versa. This is because synergies and shared resources may result in valuable advantages that can justify decisions on diversification. It is however important to remember that it is equally important to make decisions on where and how to compete, is to decide what not to do and in what activities not to engage (Markides 2004). Going for a certain direction does not have to mean that the firm is committed to perform all the activities required. In order to reach their objectives firms increasingly engage in different constellations with other firms providing complementary resources.

Methods

The paper uses a qualitative research design in order to facilitate in-depth understanding of the contextual factors and underlying processes that influence how forest firms position their operations in the biogas value chain. The focus is on the pulp and paper mill level. The paper analyzes an ongoing transformation in the Nordic forest industry that in a few years may be of considerable importance for biogas production volumes. While there are only a few realized examples as of today, several firms have recently announced that they will erect new biogas facilities in the coming years, and other firms are investigating the possibilities. Apart from the few operating facilities, there are hence indications that biogas in the Nordic forest industry is about to take off. Consequently, our aim is to use a diverse set of data together with theory to frame and conceptualize plausible configurations of firms that could facilitate biogas production in the forest industry.

The empirical data is based on both primary and secondary sources. We have conducted workshops and interviews with different biogas-related forest industry stakeholders, and we have gathered different kinds of documents. Over the last 2 years, we have held six workshops involving representatives from firms with different stakes in forest-industry biogas production. The firms include a forest firm, a company dealing with recycling of residues from mills, a biogas producer, a supplier of biogas technology and an energy company. In addition to these representatives, the workshops also have involved a diverse set of academic researches. At four of the six workshops, there have been invited guests from relevant stakeholders outside the group in order to give their views on aspects not covered by the firms represented. We have documented the workshops with notes. At the workshops, the presentations and discussions focused on different themes related to the study.

The workshops gave inputs to our empirical research and analysis. Moreover, we used them for validation of the results. According to Van de Ven and Johnson (2006) the advantage of the workshop method is that it is a collaborative form in which academics and practitioners leverage their different perspectives and competencies to coproduce knowledge about a given phenomenon. Hence, in our case, the rationale for the workshop method was to strengthen the relevance of the results for both academia and practitioners.

In addition to the workshops we conducted semi-structured interviews with representatives from the firms at their sites. We also made an interview with a Finnish forest industry expert. At each interview, two to three researchers were present. The average length of the interviews was about two hours. At these interviews, between two and five respondents answered questions on behalf of their firms. Their roles in the firms spanned from sales and technology management, to technology development and business development. We recorded the interviews and took notes. The interviews revolved around the overall question: How can biogas production expand in the Nordic forest industry? The questions posed addressed key drivers, obstacles and success factors. The interviews were further guided by the three theoretical themes: what pulp and paper firms' can do (resources and capabilities), are allowed and encouraged to do (governance), and what they want to do (corporate strategies). We transcribed central parts of the interviews. See Table 1 for a summary of the primary data sources.

Lastly, we gathered secondary information on biogas in the Nordic forest industry. This data spans from internal company information to publicly available information at companies' homepages, annual reports, and press releases as well as newspaper articles and reports from research institutes and governmental agencies.

Table 1. Primary data sources.

Workshops		
Date	Theme	Invited guest
December 2014	Technical possibilities for biogas production at pulp and paper mills	–
March 2015	Drivers and barriers for biogas production in the Nordic forest industry	–
May 2015	Biogas production plant at Fiskeby mill, Sweden	Representative for Fiskeby mill
December 2015	The biogas value chain and strategic positions for pulp and paper mills	–
February 2016	Biogas distribution	Representative for major gas distribution company
May 2016	Biogas production plant at Skogn mill, Norway	Representative for the biogas producer involved at Skogn mill
Interviews		
Date	Firm	Respondents
May 2015	Recycling company	Key Account Manager, Sales Manager
June 2015	Biogas producer	R&D Director, Market Director, Business Developer
June 2015	Biogas technology supplier	Sales Director, Technical Director
November 2015	Forest firm	Project Manager, New Business Developer, Process and Quality Engineer, Production Engineer, R&D Manager
December 2015	University of Eastern Finland	Forest Industry Expert

In parallel to the empirical studies, we conducted theoretical studies with the ambition to define a useful conceptual framework. Since our focus was on theory development, rather than theory generation or confirmation of existing theory, we relied upon an abductive approach (Alvesson and Sköldbberg, 2009; Dubois and Gadde, 2002). This approach systematically combines theory with empirical observations. The repeated workshops together with the interviews with representatives of different stakeholders was a central part of our abductive approach. It provided repeated opportunities to reflect upon, dispute and validate different conceptual interpretations and propositions. Our analysis of data is closely related to a comparative text analysis, and we combined interview transcripts and notes with workshop notes, and secondary sources in order to identify important meanings and themes. We coded individual texts for content and then read in relation to one other, thus enabling general patterns to be detected (cf. Strauss & Corbin, 1990). By means of this approach, we developed a typology of four different positions that pulp and paper mills could take in biogas production and use.

Results: Four different strategic positions

From our inventory of biogas production in the Nordic forest industry, we could identify currently operating and planned plants at six different pulp and paper mills. Two of the currently operating plants are situated in Sweden (Domsjö Fabriker and Fiskeby) and two in Norway (Sarpsborg and Saugsbrugs). Additionally, there are two plants, which are under construction. One of them is situated at a pulp and paper mill in Finland (Äänekoski) and one in Norway (Skogn). Below we describe these six plants, categorizing them according to their biogas production (internal/external) and biogas use (internal/external). Figure 1 describes the categorization scheme as a 2×2 matrix displaying four different strategic positions that a mill can take in the biogas value chain: Biogas producer/user, Substrate supplier/biogas user, Biogas supplier, or Substrate supplier.

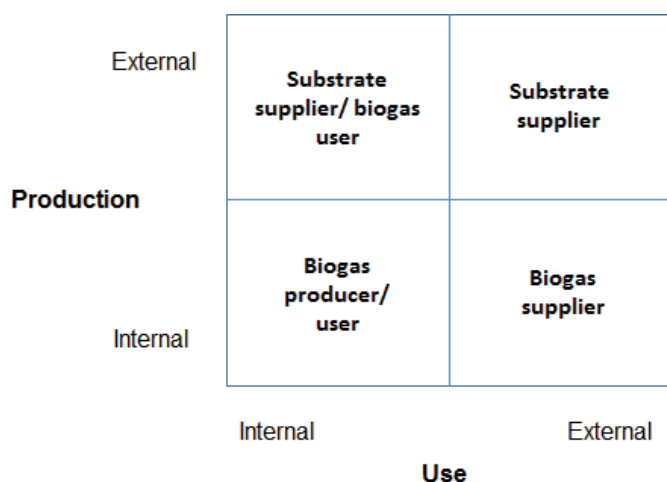


Figure 1. Four different strategic positions that a pulp and paper mill can take in the biogas value chain.

BIOGAS PRODUCER/USER

The biogas producer/user position is characterized by internal production and use of the biogas. Two of the currently operating biogas plants at Nordic pulp and paper mills have this position: Sarpsborg in Norway and Fiskeby in Sweden. Sarpsborg is a pulp and paper mill and a biorefinery situated south of Oslo in southeastern Norway, owned and operated by the firm Borregaard. The biogas plant at the Sarpsborg mill started producing gas in 2014. The initial annual biogas production volume was 35 GWh, but the plant dimension allows for a higher production volume. The plan is to increase the production to 45.9 GWh, following a planned expansion of the operations. The biorefinery uses the produced biogas as a substitute for heavy fuel oil and propane in the lignin drying process. The construction of the Sarpsborg biogas plant was part-funded by the Norwegian Energy Fund via Enova, which is a public enterprise, owned by the Ministry of Petroleum and Energy.

The plant at the Fiskeby mill started biogas production in 2015 and it has an annual production volume of 9 GWh. The Fiskeby mill is situated close to Norrköping in the southeast of Sweden. It uses recovered fiber to produce packaging board. The firm linked their new biogas-producing anaerobic process directly to the mill's existing aerobic wastewater process, as the existing wastewater treatment had reached its maximum capacity. According to a Fiskeby representative, the substrate from the wastewater sludge as well as the wastewater temperature were favorable for anaerobic digestion. The planning and construction of the biogas plant involved about 100 people and most of these were external personnel. However, as Fiskeby's own personnel were supposed to operate the biogas production plant, an important part of the project was devoted to internal competence building. Amongst others, the firm engaged a consultant to educate the personnel on gas safety issues. The project received public investment support from the Swedish Energy Agency. Presently (in 2016) the produced biogas is flared, but the intention is to use the biogas to produce heat for drying packaging board, substituting an existing process that uses electricity. This will however require additional investments in gas-fuelled drying equipment. The Fiskeby management has however delayed these investments due to the currently low price of electricity.

The biogas producer/user position represents a closed approach with limited or no external involvement in the production and use of biogas at the mill. Since the mill will not obtain any additional revenue from the biogas produced, the focus from the mill's perspective is on internal process optimization. Hence, the prime motive for this position is cost reduction, stemming from two different sources. Firstly, the reduced sludge volumes lessen the demands on the aerobic wastewater treatment, and secondly, the resulting biogas can substitute other energy sources that the mill uses. To reap these benefits, investments will be required in new facilities as well as in human resources. An important part of the investment calculation is the prize of the energy that the biogas is supposed to supersede.

SUBSTRATE SUPPLIER/BIOGAS USER

The substrate supplier/biogas user position is characterized by external production and internal use of the biogas. Currently, there are no examples of Nordic pulp and paper mills taking this position. However, there are several other examples fol-

lowing a similar logic in the forest industry. For example, Tholander & Ottosson (2011) discuss different cases where mills have outsourced the operation of boilers to energy companies. In one case, the forest firm even decided to outsource a pulp and paper mill's entire steam central, consisting of one main process boiler that combusts wood chips and two back up/top load oil burning boilers. All the steam produced by the boilers was sold back to the mill. Even if the reasons for outsourcing the steam central was financial and tax-related, the outsourcing also resulted in increased energy efficiency, due to the fact that the energy company brought in better control systems, better techniques for handling the fuel, and staff education.

The substrate supplier/biogas user position focuses on collaboration, involving partners with complementary capabilities and resources for the production of biogas. In a similar manner as the biogas producer/user position, cost reduction is a prime motive for choosing this position. However, in this case, the mill utilizes local synergies to attain the cost reductions. This approach therefore involves a wider system boundary. A specialized biogas producer manages and operates the biogas plant that uses the organic content of the wastewater for the mill as a substrate. The specialized biogas producer then sells the gas to the pulp and paper mill, which use it in their production process. The logic behind this strategic position is that the mill could outsource parts of its wastewater treatment to a firm that has biogas production as their core business. By outsourcing parts of the wastewater treatment to an external part, the mill is able to gain access to capabilities that it currently lacks in-house. Referring to the typical knowledge and routines among process engineers at a mill, a respondent from a recycling company stated: "If the biogas biology does not work properly, they sometimes do not know what to do. Therefore, the question is if the personnel at the mill really should operate the biogas plant to make it work well. There is always a need for increased knowledge and the engineers are not always good at everything." The respondent had extensive experience from working with forest firms and his statement suggests that running a biogas production plant requires a different set of expertise and skills than those required for running a pulp and paper mill.

Since biogas production hardly will be a core business for a pulp and paper mill, the substrate supplier/biogas user position could be interesting for mills that still have use for the gas. However, this implies that the mill is willing to outsource a significant part of one of its core processes – the wastewater treatment. The substrate supplier/biogas user position requires more complicated inter-organizational contractual arrangements than the biogas producer/user position. The pulp and paper mill and the specialized biogas producer have to agree on terms, conditions and responsibilities for the operation. This includes issues such as prices, quality standards and terms of delivery. In particular, they have to agree on quality criteria for the wastewater that is fed back to the mill from the biogas plant. The mill has to control the wastewater quality carefully, because it will retain the overall responsibility for the wastewater permits vis-à-vis the environmental authorities.

BIOGAS SUPPLIER

The biogas supplier position is characterized by internal production and external use of the biogas. The choice to sell the gas externally is at least partly driven by the fact that the trend

in the industry during the last decades to find substitutes for fossil fuels means there is lower amounts of fossil fuel to replace at the Nordic mills. Biomass and electricity are now the major energy carriers. However, this differs somewhat depending on the output and production process at the mills. In the recently announced major investment in a new pulp mill in Äänekoski in the center of Finland, biogas is one of many bio-based products that the Metsä Group will develop and produce (Metsä, 2016). The mill is the first new mill in the Nordic countries that has a bio-refinery strategy already from the planning and plant design. The major advantage of establishing biogas production in a completely new pulp mill is that it is possible to design the mill for biogas production from the start. In mills that already exist, there are often different practical tasks and adjustments. This means that there is a start-up period, when the installation may disturb the mill operation. The Äänekoski mill will produce up to 20 GWh biogas per year (equal to the annual fuel consumption of roughly 1,800 passenger cars) in an anaerobic process. The project is a co-operation between Metsä Group and EcoEnergy SF Oy, which is the company that will build the water treatment plant that will use sludge from the pulp production as input for biogas production. The company Gasum Oy will distribute the gas, which will be used as vehicle fuel in connection to Highway 4 close to the mill. The Finish Ministry of Employment and the Economy has granted EcoEnergy SF investment support from the government's spearhead program funds for carbon-free, clean and renewable energy.

Another example of a pulp and paper mill and biorefinery that has taken the biogas supplier position is Domsjö Fabriker, situated in Örnsköldsvik in northern Sweden (Biogasportalen 2016). Currently Domsjö Fabriker focuses on specialty cellulose for consumer products, lignin used by chemical companies and ethanol used in industrial processes. The mill has produced biogas since 1985 and it is one of the largest biogas producers in Sweden with an annual volume of 80 GWh. Apart from wastewater from the internal pulp and paper production, the anaerobic process at the mill takes care of wastewater streams from two chemical firms situated nearby. Hence, the biogas is produced through co-digestion in an industrial symbiosis solution. Domsjö Fabriker sells approximately 70 % of the gas to the municipal energy company Övik Energi which use it as a fuel for their combined heat and power plant, producing electricity and district heating. Domsjö Fabriker uses the remaining 30 % of the gas internally to produce heat for drying.

A third example is the recently announced biogas facility at Norske Skog's pulp and paper mill Saugbrug outside Halden, in southeastern Norway. The mill has used an anaerobic wastewater treatment process for some 20 years, flaring the biogas. In 2015, Norske Skog announced an investment in new facilities for gas production and upgrading, which will make them capable of selling biogas to external customers. The plant will have an annual production capacity of 26 GWh, which is sufficient as a fuel for about 80 buses and refuse trucks in the Halden area. The gas distribution company AGA will distribute the gas. The biogas plant in Saugbrug will be in full operation in 2017.

The focus of the biogas supplier position is on diversification, meaning that the forest industry firm adds biogas to its existing product line. For the forest firm, this is a more complex arrangement than internal use of the gas to replace e.g. fossil fuel or electrical drying at the mill. To be able to sell the gas

externally as a vehicle fuel, the gas has to comply with industrial transport fuel standards. This means that it is necessary to invest not only in biogas production facilities, but also in facilities for gas upgrading. However, for the forest firm, external sales bring about several advantages. A broader product portfolio means less vulnerability to external market changes. Therefore, product diversification into biogas can help strengthen the competitiveness of the forest firm. The forest industry's strength is that it has a long tradition of handling large amounts of raw materials, which also can be developed into new bio-based products such as green chemicals, bio-plastics, fabrics, composite materials, biofuels and biogas. Internally this involves focus on new business development. Investments that need to be undertaken involve both tangible resources such as new facilities and intangible resources such as education and training of staff.

SUBSTRATE SUPPLIER

The substrate supplier position is characterized by external production and use of the biogas. A recently announced example of this position can be found outside the city of Trondheim in mid-Norway. In February 2016, the biogas producer Scandinavian Biogas announced that they had signed a contract for building a plant that will be the largest producer of liquefied biogas in the Nordic countries. The plant will be situated adjacent to Norske Skog's pulp and paper mill in Skogn outside Trondheim, co-digesting substrates from the mill's wastewater and from the local fish farming industry. A representative from Scandinavian Biogas explained the decision saying that "The background is that there is a significant amount of substrates in Category 2 Fish ensilage from deceased salmon from fish farms, an established gas market that has its basis in LNG [liquefied natural gas, authors' note], and a pulp and paper mill that wants to reduce its energy consumption." The planned annual production volume is 125 GWh, and the plant will be in full operation in 2017. The biofuel producer Biokraft A/S, jointly owned by Scandinavian Biogas (majority holder) and the local energy company TronderEnergi, will operate the biogas plant. The biogas production plant will use heat and electricity from the mill. The gas distribution company AGA, the local branch of the Linde Group, will distribute the gas. The industry conglomerate has signed a long-term contract with the regional public transport authority for delivery of 70 % of the produced biogas as a fuel for buses, which will operate in the Trondheim area. According to the representative from Scandinavian Biogas, such a long-term contract was required to be able to attract funding for the project. The remaining 30 % biogas will also be distributed and sold externally as vehicle fuel. The production of liquefied biogas (LBG) makes distribution more efficient (about three times as efficient as compressed gas) but this requires a larger investment in plant facilities. According to the Scandinavian Biogas representative, investments in LBG production can only be justified for plants with an annual production of 100 GWh or more. He further described that the local environmental authorities had been helpful, relaxing the wastewater restrictions for the mill during the start-up phase of the biogas plant. However, when it the plant is operative, the mill will again have to comply with strict environmental regulations. The plant construction received Norwegian public investment grants via Enova.

The substrate supplier position represents an open approach, based on outsourcing of some (or all, even if unlikely) parts of the wastewater treatment process to a specialized biogas producer situated close to the mill. In addition to using substrate from the pulp and paper mill's wastewater streams, the biogas producer could take care of other organic degradable substrates from the region. The business potential indeed increases in this scenario, given that the increased substrate volumes mean that the biogas production may reach economies of scale. Several respondents have stated that this is the most interesting approach since it has the highest potential as a business case. As illustrated by the Skogn mill case, the higher production volume can justify investments in LBG production, which will make the distribution more efficient and make it possible to reach geographically distant market segments. For example, use of LBG as a fuel for ships has been mentioned as an interesting future application. The basic condition that make the pulp and paper mills so attractive in this scenario is not only that their waste water streams hold large quantities of organic material, but also that there are high quantities of low temperature heat available. This energy is not used optimally today and it is not even always considered a resource. However, this can be a useful resource for biogas production. Hence, the substrate supplier position could open up possibilities to optimize local energy and material flows, an approach associated with industrial symbiosis (Lombardi & Lyburn, 2012). Many examples with a similar logic exist today, which do not involve biogas production. For example, a majority of Swedish pulp and paper mills today sell excess heat to surrounding district heating systems. Investments in new culverts or heat exchangers have been necessary to enable these collaborations, and often these investments have relied on political interventions in terms of subsidies. The incentive from the mill's side is primarily cost reduction since they reduce or eliminate costs for wastewater treatment and deposit of sludge from the wastewater. The incentive may however also be increased revenue if the mill receives payment for the sludge and energy that the biogas producer will use. The mill may also decide to co-own the closely situated biogas facility and thereby gain new revenues. Partnership with a specialized biogas producer and often with a distributor means that the pulp and paper mill can continue to focus on its core business. Moreover, if the forest firm lets the external partner make the investment, this will reduce the financial risk for the mill. The mill thus gains complementary resources and capabilities through partnership. An important challenge, however is to manage the responsibilities for wastewater permits.

RESULT SUMMARY

For a pulp- and paper mill, the addition of biogas (or its upgraded form biomethane) to the present business may call for new ways to organize their operations. In terms of the number of firms involved and the need for inter-organizational collaboration, the simplest form is the biogas producer/user position. With internal production and use, the need for negotiating contracts and coordinating activities with new partners is kept at a minimum. Still, this position means that it is necessary to extend the capabilities of the existing organization. The mill has to build new facilities for biogas production and use, and the knowledge of the personnel has to embrace critical new areas

Table 2. Result summary.

	Biogas producer/user	Substrate supplier/ biogas user	Biogas supplier	Substrate supplier
Resources & Capabilities	<ul style="list-style-type: none"> – New knowledge and routines (human resources) – New production facilities 	<ul style="list-style-type: none"> – Complementary resources and capabilities through collaboration 	<ul style="list-style-type: none"> – New knowledge and routines (human resources) – New production and upgrading facilities 	<ul style="list-style-type: none"> – Complementary resources and capabilities through collaboration
Governance	<ul style="list-style-type: none"> – Investment subsidies 	<ul style="list-style-type: none"> – Responsibilities for wastewater permits 	<ul style="list-style-type: none"> – Investment subsidies – Gas quality standards 	<ul style="list-style-type: none"> – Responsibilities for wastewater permits
Strategy focus area(s)	<ul style="list-style-type: none"> – Cost reduction 	<ul style="list-style-type: none"> – Cost reduction – Partnership 	<ul style="list-style-type: none"> – Cost reduction – New business development through diversification 	<ul style="list-style-type: none"> – Cost reduction – Partnership

such as biogas process and gas safety issues. Altogether, this will require investments. Justifying these investments through potential energy savings present firms with significant challenges and, as illustrated by the Fiskeby case, part funding through public investment grants may be required.

If there is no internal use for the produced biogas at the mill, the biogas supplier position could be an option. For the forest firm this implies a diversification into a new line of business. This position poses even bigger challenges to the organization in terms of broadened capabilities. The new product – the biogas – has to be upgraded to comply with industry standards. Hence, investments in both production and upgrading facilities are required. Investment support from the state may therefore be a driver to attain profitability. Moreover, the mill has to engage in market development to identify suitable applications and users, to assess the demand and willingness to pay, and to establish an efficient distribution. A potential bottleneck is the distance between the mill and the potential users. The bigger the distance the less profitability in transporting gas to end users. The broader palette of potential applications will result in opportunities for higher profits. For instance, selling the biogas as a fuel for vehicles makes it possible to capture additional value due to governmental subsidies for vehicle biofuels. The down side, however, is that the mill will not be able to control the demand and the profits will depend on sustained political interventions to support biogas as a transport fuel.

To refrain from investments, forest firms may prefer to outsource biogas production either taking the position as a substrate supplier or (provided that they have use for the gas at the mill) as a substrate supplier/biogas user. Localizing the biogas production adjacent to the mill could result in greater possibilities to increase biogas production volumes through co-digestion of different substrates, as illustrated by the recently announced biogas plant in Skogn outside Trondheim. Co-digestion increases the potential output, which increases the potential profitability. While the pulp and paper mill could take in additional substrates from external sources and process it in an internal biogas plant, this will result in a more complex process and a need for more specialized knowledge to be able to operate the plant. Therefore, the forest firm may prefer to engage an external partner. This will result in greater possibilities to reach synergies through co-digestion, using substrates from different sources. The major advantage in both these positions is the

access to complementary resources and capabilities through collaboration. For the mills, this implies that they can focus on their core business, rather than investments in new facilities, education of staff and establishment of new routines. However, changes in the wastewaters effluents may jeopardize the mill's permits. Therefore, it will be necessary to carefully monitor and manage the responsibilities for the mills' wastewater. Table 2 summarizes how the four different positions that a pulp and paper mill can take to enable biogas production related to the three central aspects of strategic management elaborated in our theoretical framework: resources and capabilities, governance and strategy.

Conclusions and discussion

Building on strategic management literature, this paper has outlined a refined and extended conceptualization of four different strategic positions that pulp and paper mills may take in the biogas value chain. As illustrated by the identified cases of biogas production plants at Nordic mills, the four strategic positions are all plausible. Whereas they are associated with different opportunities, challenges and motives, there are also a few recurrent issues, which emerge regardless of what position the pulp and paper mill may take. In particular, we have observed three such issues. The first is that a prime motive for forest firms to engage in biogas production tends to be cost reduction. Even if the pulp and paper mill will attain the position that entails new revenue streams through diversification into a new line of business, cost reductions will still be an important motive. However, our case observations also indicate that the cost reductions tend to be insufficient to justify the requisite investments in new facilities and capabilities. All recently established or planned biogas plants at Nordic pulp and paper mills have received governmental subsidies, and our respondents generally claim that at present such support is necessary to justify the investment to construct the plant.

The second issue relates to the current operations at the pulp and paper mill. Pulp and paper production is a continuous industrial process, and material flows and throughput volumes are essential performance parameters. A forest firm will be reluctant to engage in any initiatives that will jeopardize its existing core process. This implies that, on the one hand, a forest firm will not be willing to engage in biogas if it will

disturb the operations at a pulp and paper mill that currently delivers satisfactory output volumes and follows stipulated environmental permits and regulations. If, on the other hand, anaerobic digestion of wastewater streams can help solving existing or foreseen problems related to capacity extensions, throughput volumes and process bottlenecks, engagement in biogas will likely be attractive for the forest firm. Moreover, if external partners can supply proven systems solutions, thus minimizing disturbances, this will provide additional incentives for the forest firm.

The third and final issue refers to the need to ensure a stable demand for the biogas, which the anaerobic digestion process will result in. The forest firm and its partner firms can either opt for internal or external uses. The internal option implies that the biogas will substitute other energy sources that the mill currently uses. This will result in a greater control over the demand. For the investment decision, it will be important to consider the cost of the substituted energy. The higher the cost for the substituted energy, the stronger the motive for internal use of the produced biogas. However, the strive for energy efficiency and substitution of fossil fuels in the Nordic forest industry during the last two decades have reduced the possibilities to find easy internal use targets. Whereas substitution of fossil fuel or electricity with biogas could be possible to justify, substitution of low-grade biomass such as roots and bark with biogas will not be possible to justify. In those cases, selling the biogas to external customers will be a preferred option. In Sweden, as well as in Finland and Norway, there is a strong political pressure to direct the use of biogas towards vehicular applications. However, there are some important differences between the Nordic countries. Sweden has been a clear leader among the Nordic countries in terms of biogas production. However, our study shows that Norway, with a less significant forest industry than both Sweden and Finland, has taken the initiative in biogas production at pulp and paper mills. Whereas political interventions such as public procurement and long-term contracts has made city buses a preferred entry market for biogas, municipal co-digestion plants have already captured a significant part of this market in Sweden. Hence, in this country this market segment currently shows signs of saturation. Moreover, since the EU commission have challenged the fuel tax exemptions for biofuels in the EU countries, continued support from political interventions is uncertain. By contrast, supported by various incentives, the market for biogas-fueled buses continues to grow in Norway, thus providing an attractive entry market for newly established biogas production units. This is an important explanation to the current activity in Norway.

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