



Hedmark University College

Faculty of applied ecology and agriculture

BRAGE

Hedmark University College's Open Research Archive

<http://brage.bibsys.no/hhe/>

This is the author's version of the article published in

Biomass and Bioenergy

The article has been peer-reviewed, but does not include the publisher's layout, page numbers and proof-corrections

Citation for the published paper:

Forbord, M., Vik, J., & Hillring, B. G. (2012). Development of local and regional forest based bioenergy in Norway - Supply networks, financial support and political commitment. *Biomass and Bioenergy*, 47, 164-176.

doi: 10.1016/j.biombioe.2012.09.045

Development of local and regional forest based bioenergy in Norway – supply networks, financial support and political commitment

Magnar Forbord^{a1}, Jostein Vik^a, and Bengt Gunnar Hillring^b

^aCentre for Rural Research, University Centre Dragvoll, N-7491 Trondheim, Norway, e-mail: magnar.forbord@rural.no; jostein.vik@rural.no

^bHedmark University College, Campus Evenstad, N-2480 Koppang, Norway, e-mail: bengt.hillring@hihm.no

Abstract

This paper explore reasons and explanations of growth of new bioenergy firms in Norway: Norwegian authorities have a stated goal of doubling the use of bioenergy by 2020, as both a way of developing the renewable energy sector and providing opportunities for rural employment. However studies shows that there are difficulties concerning the profitability in the sector. We approach the question from a supply chain perspective using a comparative case method. Five cases representing small to medium sized supply chains (1–5 MW) for local heating selected from three geographical regions are studied. The focal firms in the supply chains normally specialize in one or two stages in the chain, for example fuel manufacturing and heat production. In all cases national funding was a critical factor and were directed to various stages in the chains and infrastructure. Also, local political involvement was vital for the establishment of the chains.. Moreover, economies of scope and links to supply chains outside bioenergy were essential. In fact, bioenergy providers drew their main income from other sources and may therefore tolerate sparse income from bioenergy for a period. Hence, the answer to the question of why bioenergy supply increases despite poor profitability seems to be actors' pluriactivity backed by local political engagement and adequate economic support schemes at national level.

Keywords: Bioenergy; forest resources; local actors; supply chain; political commitment; financial support

¹ Corresponding author: Tel.: +47 73591736; fax +47 73591275

1. Introduction

Across Europe the bioenergy sector has developed rapidly, but unevenly (CORDIS, 2006). Resource situation, policy aims and policy instruments as well as organizational structure in the bioenergy sector vary considerably between countries (see e.g. McCormick and Kåberger, 2007; Stupak et al., 2007). Bioenergy development is a key to the future energy balance, as well as coping with climate change. Obtaining this requires viable supply chains for bioenergy (CORDIS, 2006; IEA Bioenergy, 2009; McCormick and Kåberger, 2007). This again depends on internal factors in the chains such as knowledge, technological choices, and organization, and on external factors such as policy and availability of other energy sources (Hakkila, 2006; Roos et al., 1999; Trømborg et al., 2007).

Historically the use of bioenergy in Norway has been in the form of wood-firing in houses and internal burning of wood waste in the wood industry (Norsk Bioenergiforening, 2012; Trømborg et al., 2008). Since the 1990s markets for sales of different types of biofuels and local and district heating has developed. A large share of the biomass used in district heating is waste, but the share of virgin biomass is increasing. By far most of the virgin biomass for energy comes from forestry and is used for heating. A few (larger) plants with combined production of heat and power (CHP) based on waste exist. Hence, bioenergy produced from secondary timber and logging residues is seen to represent an opportunity for production of clean renewable energy, while also bringing a source of income to rural communities (CORDIS, 2006; Gjølsjø and Hobbelstad, 2009; Hillring, 2002; IEA Bioenergy, 2009; St.meld. nr. 34, 2006-2007).

There is a solid resource base for substantial growth in the production and use of wood based bioenergy. Less than half of the gross annual increment (Schuck et al., 2002) in the productive forests is harvested (Øyen, 2008). However, it is stated that Norway's abundant access to renewable energy in the form of hydro-power and the dominating role of the petroleum sector have reduced the political emphasis on other energy sources such as bioenergy (Borup et al., 2008; Trømborg et al., 2007). Yet, on the rhetoric level, there is no lack of support. Already in the 1990s policy documents stated that Norway could not rely solely on hydropower for its

future energy supplies (Christiansen, 2002). In 2008, Norwegian authorities specified a target to double the use of bioenergy by 2020, from 14 TWh to 28 TWh.

However, the fulfilment of this target may be difficult. A study of bioenergy firms in local heating centrals in Norway in 2007 showed that most firms made deficit. The main reasons for this were high investment costs, electric heating without possibilities for water-borne heating in buildings, and low electricity prices (Norsk Bioenergiforening et al., 2007). The situation is not static though. First, the real price of electricity increased by around 30% from the 1990s to 2006 (Forbord and Vik, 2009). Since then, the electricity price has continued its upward trend with peaks both in the 2009, 2010 and 2011 winters (Statistisk sentralbyrå, 2011). Second, there is a willingness to provide economic support. This is mainly done through two public agencies: Enova is a national public institution established in 2000 owned by the Ministry of Oil and Energy. Enova provides information and decides grants to investments in renewable energy (Enova, 2012). Innovation Norway is a public, national institution providing investment grants, loans and advisory services to among others farmers and rural firms (Innovasjon Norge, 2010). In addition, as a temporary response to the financial crisis from 2008/9, Keynesian style policy instruments aimed at increasing public spending as well as activity in forestry was established in 2009. These included financial support for converting oil based heating systems to bioenergy and support for logging of wood aimed for wood chips, administered by the Norwegian agricultural authority (Innovasjon Norge, 2010; Statens landbruksforvaltning, 2011). Moreover, a new subsidy program aimed at investments in local heating centrals was introduced in 2008.

Currently, the bioenergy sector is expanding and growing in Norway. It is timely, though, to ask, why this sector is expanding when the economy in the sector has been reported to be strained, despite several support programs. In this article we investigate this topic by studying cases of local and regional supply of bioenergy. We must remark here that we did not choose this type of supply because it dominates in the Norwegian bioenergy sector. Large firms exist, e.g. in form of an increasing number of district heating companies established from the 1980s and onwards (Enova, 2011; Sandberg, 2008). Many larger, often urban district heating plants are owned by, integrated energy companies (Enova, 2012). The regional forest owners'

cooperatives deliver significant amounts of wood chips to district heating plants each year (Trømborg et al., 2008), and a large scale, global pellets producer, Biowood Norway, has newly been established (Biowood Norway, 2012).

The small-scale bioenergy supply chains – or rather, networks (see section 2) – are interesting to study of several reasons (CORDIS, 2006; IEA Bioenergy, 2009; Mårtensson and Westerberg, 2007; Olje- og energidepartementet, 2008). First, it exploits local forest resources, which may otherwise not be used. Second, such supply represents a new business opportunity for local farmers, forest owners, forest entrepreneurs and local wood industry. Third, local and regional supply is interesting for local government (municipalities) because it can improve energy supply security and reduce greenhouse gas emissions. Lastly, this type of supply is interesting because of the business organization forming around it.

With this as a background we selected five supply chain cases for study (see section 3). We analysed the characteristics and similarities of the supply chains, with regard to their regional context, structure, actors, and activities, some indicators of economic performance, as well as connections to other supply chains. We were also interested in the significance of local political backing and the influence of financial support instruments. The chains we analysed had, as mentioned, a local and regional basis, and were small and medium sized businesses (Pettenella and Maso, 2011). Products such as fuel and heat were sold commercially. Internal supply of bioenergy (in companies and farms etc.) was not included in this study.

We applied a case study method. This approach opens opportunities to identify direct influences of external factors such as local politics (Madlener, 2007) and financial support (Hillring, 1998; Thornley and Cooper, 2008; Trømborg et al., 2007), and at the same time gives room for unexpected findings.

The specific aims of the paper were:

1. To describe and analyse structure, organization and actors in selected local and regional supply chains for heating based on forest resources. What are main characteristics of the chains? How do the chains resemble and differ in terms of organization and actors?

2. Identify and discuss factors that have had substantial influence on establishment of bioenergy heating and performance in the chains.

The article is structured as follows: In section 2 we review the concept of supply chain in relation to bioenergy and literature on factors affecting bioenergy development in Europe. In section 3 we account for material and method. The five cases are presented in section 4 and analysed in section 5. Conclusions are given in section 6.

2. Theoretical perspective and previous research

2.1 Supply chain as conceptual point of departure

One definition of supply chain is that it "consists of suppliers, manufacturing centres, warehouses, distribution centres, and retail outlets, as well as raw materials, work-in-process inventory, and finished products that flow between the facilities" (Simchi-Levi et al., 2008, p. 1). Also a supply chain for bioenergy consists in principal of suppliers, manufacturing centres and warehouses, sometimes in combination, such as a chip terminal. A heating central connected to water-borne heating can be regarded a distribution centre. Wood pellets is a bioenergy product that can be bought in retail outlets. Moreover, integration of actors and service towards customers are important issues also when supplying bioenergy. What supply chain as perspective tells us is that success depends on a range of activities that must be coordinated (McCormick and Kåberger, 2007). Because the various activities in the chain may require different resources and competences, many actors can be involved (Håkansson and Snehota, 1995; Richardson, 1972).

A chain perspective has been used in earlier studies of bioenergy (CORDIS, 2006). This research has gained a better understanding of the role of such chains, the organization of chains and the various factors affecting them. One lesson is that a diverse set of factors is relevant, such as natural conditions, infrastructure, technology, competence, economy, social skills, politics, history and culture. As such the study of supply chains for bioenergy is a multidisciplinary task. A related lesson is that the conditions for development of bioenergy

vary considerably with geography and type of bioenergy. Hence, task 29 of IEA Bioenergy has as one of its objectives to provide a better understanding of the social and economic drivers and impacts of establishing bioenergy fuel supply chains and markets at, among others, the local and regional level (IEA Bioenergy, 2009).

We know from earlier studies that bioenergy in many cases is strongly linked to forestry (CORDIS, 2006; Madlener, 2007; Stupak et al., 2007). Moreover, there are several markets for bioenergy (Trømborg et al., 2008). This opens the possibility that the issue is wider than just “chain”. It may be more appropriate to talk about supply *networks* (Gadde and Håkansson, 2001). If the supply *chain* is defined vertically, there is a horizontal component of links and cooperation between stages in different chains (Lazzarini et al., 2001). For example, the provision of raw material from forest may be the same for a supply chain for fibre and a supply chain for energy. Hence, when studying supply chains for bioenergy we should be aware of productions that are *related* to bioenergy.

Specific studies of supply chains for bioenergy may nevertheless provide valuable guidance to studies of supply networks. For example, studies of logistics of various types of bioenergy supply have been undertaken (Alfonso et al., 2009; Caputo et al., 2005; Frombo et al., 2009; Gronalt and Rauch, 2007). The main goal of such studies is normally to calculate an optimal economic solution for an entire supply system, e.g. one supply chain, or supply within a geographical area involving several supply chains. For example (Gronalt and Rauch, 2007) found that in two of three areas studied in Austria, setting up decentralized terminals for chips was most profitable, while in a third area basing the supply on one large industrial terminal was most economic.

The aim of our study is not to calculate optimal logistical solutions in specific cases (see section 3), but the conceptual models underlying logistical analysis are still relevant. Five principal elements seem to underlie logistical analysis of bioenergy. Four of these elements form discrete steps in the supply of bioenergy. The first step is provision of raw material. The second step is production of energy carriers. The third step is production of energy, and the fourth step is consumption of energy. However, in order for the chain to function a fifth element is necessary – transportation and storage. These will in various ways and

combinations take place between the four (primal) steps. How transportation and storage is solved in practice will depend on the solutions for the four primal steps and the actual facilities for transportation and storage (e.g. storage facilities, quality of the road network, distances, type of vehicles and system for distribution of energy).

2.2 Studies of drivers and barriers for bioenergy development

It is also important to take into consideration the highly political nature of the bioenergy sector (as in other energy sectors). This applies to the national level, where economic instruments have been much highlighted, both in Norway (Trømborg et al., 2007), and in Europe (McCormick and Kåberger, 2007). But influences at the local political level should also be kept in mind (Madlener and Bachhiesl, 2007; Madlener and Vögtli, 2008; Mårtensson and Westerberg, 2007).

In recent years a number of studies have aimed to discuss the reasons that bioenergy has, or has not, become important in the energy market. Many of these articles examine various policy instruments (Carlén, 2006; Hakkila, 2006; Hillring, 1998; Madlener and Bachhiesl, 2007; Menanteau et al., 2003; Roos et al., 1999; Slade et al., 2009; Thornley and Cooper, 2008).

Regarding *barriers* to bioenergy development, Rösch and Kaltschmitt (1999) distinguish between 1) financial challenges, 2) administrative challenges, 3) organizational challenges and 4) the challenges associated with perceptions or ideas. Overcoming each of these challenges naturally requires efforts in very different areas. One way to solve financial challenges is financial support by the public. Organizational challenges must be solved by the actors in the supply chains, but may be aided by research and advice. Thornley and Cooper (2008) make a review of policy instruments used in Germany, Italy, Great Britain and Sweden and assess how effective they have been. The political instruments they discuss are: “feed-in” tariffs, investment subsidies, carbon taxes, energy taxation, green certificates, support for bioenergy production in the forestry sector and political commitments. Their study shows mixed experiences: fixed rates have proved to be a particularly effective instrument; taxation seems to be effective if the tax is added at a high enough level, subsidies appear to have

different effects depending on the degree of already-developed infrastructure. It is also emphasized that long-term commitments are required. Both investment decisions and the development of technological infrastructure take time. Therefore, support schemes must be given time to work. In a study from the UK, Slade et al. (2009) state that policy instruments in the bioenergy sector are highly fragmented and unstable over time and that this hampers the sector's development. In a discussion of green certificates, Thornley and Cooper (2008) hold that technology blind certificates do not seem to work, but that technology-specific certificates may. The authors show that policy instruments work differently depending on countries' energy and resource situation, and that policy instruments are highly context-dependent. In a study of renewable energy sources in general, Menanteau et al. (2003) conclude that price-based instruments (feed-in) are more effective than quantity-based, but that it will be particularly interesting to follow the development of green certificates (which are a mixture) in the future. Carlén (2006) also compared policy instruments concluding, among other things, that a number of external factors, such as future electricity prices, were critical. Hakkila (2006) studied factors that drive the development of bioenergy in Finland. This study lists a number of important factors related to the resource situation in Finland, but also investigates the importance of considerable political goodwill and an active research and development policy in the area.

In Norway, it has been claimed that the low overall electricity price and poorly developed infrastructure for central heating systems are important barriers to bioenergy development (Bjørnstad, 2011; Forbord and Vik, 2009; Norsk Bioenergiforening et al., 2007). However, these factors have in recent years changed to some extent and become less of a barrier. Thus, Trømborg et al. (2008) argue, based on a model study, that the bioenergy market in Norway is at a tipping point where several types of measures will potentially contribute to the growth of bioenergy markets. One of the most important factors in their model is the *expectation* of higher energy prices.

2.3 A research model

From the review of the literature above and the introduction (section 1) it is clear that the introduction of bioenergy depends on a number of factors. One way to sort the factors is by claiming that implementation of bioenergy depends on five basic factors: 1) There has to be a demand for energy, 2) A resource base for production of bioenergy fuels must be available, 3) Effective and affordable technology, infrastructure and competence must exist in the whole supply chain, 4) There has to be entrepreneurs interested in starting bioenergy businesses and manage these along the whole supply chain, and 5) The price of alternative energies. Financial support and local policy are factors that can affect basic factors. Typically, financial support can influence the possibilities for creating a resource base, affordable technology, and demand. Local policy may influence demand for bioenergy, infrastructure and availability of raw material. Related productions may constitute an incitement to establish bioenergy production. A research model (Figure 1) built around a conceptual model of a supply chain for bioenergy is a way to illustrate the situation and bring the factors together.

[FIGURE 1 ABOUT HERE]

3. Data and method

As explained in section 1 an aim of the study was to research supply chains with a local and regional basis. This provided criteria for the selection of empirical cases based on a multiple case design (Yin, 2003). Each case, five altogether, concerns separate supply chains. The main data for description of the supply chains were derived from business actors operating in the primary stages (“upstream”) in the chains, that is, close to the raw material. The cases were selected in cooperation with members of an expert group on the project with people from the bioenergy program at Hedmark University College, the Swedish University of Agricultural Sciences, and the County Governors of Hedmark, Møre and Romsdal and Nord-Trøndelag. An additional criterion was that the counties of Hedmark, Møre and Romsdal, and Nord-Trøndelag were represented with 1-2 cases each. These three (of altogether 19) counties

were chosen because they represented different and typical bioenergy and forestry contexts in Norway. Hedmark in the southeast part of Norway is the largest forested county in Norway and is also the county which uses the highest proportion of bioenergy in its energy supply. The share of bioenergy in stationary energy was 23% in 2006 (Forbord and Vik, 2009). Firewood and use of bioenergy in the forestry and timber industries are included in this figure. With a share of 90 per cent, woody biomass (including demolition wood) is the dominating source of fuel in district heating in Hedmark (Sandberg, 2008). In Hedmark, about 60% of forest increment is logged (Eriksen et al., 2006). Møre and Romsdal on the north-west coast is a county with comparably few forest resources. Those that exist are also less easily accessible, partly due to steep and rugged terrain. About 10% of forest increment is logged in this county (Øyen, 2008), and biomass accounts for 4% of the stationary energy use (Forbord and Vik, 2009). Nord-Trøndelag in the middle part of Norway is in an intermediate position. Like Hedmark, the county has significant forest resources. About 35% of forest increment is logged (Øyen, 2008). The share of bioenergy in stationary energy use is 18% (Forbord and Vik, 2009). Political attention on bioenergy has been higher and more long-term in Hedmark than in Møre and Romsdal, with Nord-Trøndelag in an intermediate position. At the time of selection (2009) there were few candidate cases fulfilling the criteria in Møre og Romsdal and Nord-Trøndelag. The two cases chosen in each of these counties were among the 3-4 actual cases at the time. With a stronger resource base and a longer tradition in bioenergy, Hedmark had more candidate cases. We ended up choosing one case that was relatively newly established and included a relatively small rural district heating company and a local, established wood processing firm. That wood chips happened to be the only fuel in all cases was not intended, but a consequence of this type of wood fuel being suitable for local and regional supply.

In general, case studies are suitable when the aim is to answer research questions around “how” and “why” with regard to complex current social phenomena (Yin, 2003). As supply chains for bioenergy from forest can be regarded as complex current social and also technological phenomena, and this study asks “how” and “why” questions, case study is a suitable method. Case studies have been used in socio-economic research of bioenergy, e.g. concerning district heating systems and policy evaluation (Christiansen, 2002; Madlener,

2007; Madlener and Domac, 2007). Moreover, using several cases can answer research questions more robustly and reveal nuances and differences, and it will be possible to apply the results to a broader set of situations. However, as any other case research, in terms of generalization the study is not representative in a statistical sense, but do provide possibilities for analytical generalization (Yin, 2003).

Every case is unique, and writing a credible and coherent case story requires relatively comprehensive and versatile data about the case and its context. Immediate information from involved persons combined with written information is preferable (Bryman, 2004; Yin, 2003). Hence, the most important type of data for the description of the cases was semi-structured interviews with informants in the focal firms. Through these interviews we obtained information about the focal firms and to some extent the activities of other actors in the supply chains. These data were supplemented with available written information on issues like owner structure, economic data and technical issues in the firms. Much of this information was found on the Internet from sources such as public records, annual reports, and newspaper reportages. We also received written information from informants in the form of Power Point presentations and tender documents. The interviews were conducted between November 2009 and November 2010 and lasted from around 30 minutes to 2 hours. Four interviews were conducted by visiting the informants on-site. These interviews were audio-recorded and transcribed. Four interviews were done over telephone. Of these, one was audio-recorded and transcribed.

Draft descriptions (in Norwegian) of the cases were sent to the informants for verification (Yin, 2003). Consequently, we received feedback by telephone or email, and this was incorporated into a document of case descriptions. While examining the draft reports, some of the partners gave supplemental information. In the following we present cases separately (section 4), before analysing findings across the cases (section 5). Table 1 in that section gives a summary of the cases and may be helpful when reading the cases. The names used in the text for the focal firms are our unofficial translations of the Norwegian names.

4. Cases

4.1 “Overhalla Bio chips”

“Overhalla Bio chips” is a company located in Nord-Trøndelag established in 2008. The founder and owner had many years of experience running a logging company. Together the two companies employ a total of six people. The son of the founder is also involved in the woodchips company. The contractor also operates a timber transport company together with a relative. This company transports wood to the terminal for chipping and the chips to customers. From a practical point of view, chip production and forestry harvesting go well together, because the two activities take place at different times of the year and chip production can go on when weather prevents outdoor forestry work. The terminal has a storage building with roof.

Two types of timber are used as raw materials. The first is energy wood (timber with insufficient quality for saw logs and pulpwood). The second is wood obtained from the clearing of farmland, forest roads, road verges etc. When needed, the company also buys energy wood from the forest owners association in the region (ALLSKOG). There have been several types of political and economic involvement. The local authorities were active in helping the company to become established. The firm was given an area in the local authority’s industrial park so that it could set up a terminal for wood and chips. The company built a storehouse on the terminal at a cost of around 440 000 Euro (converted from Norwegian kroner using average exchange rate NOK/EUR 8.01 for the year 2010). Enova provided a 30% subsidy, which is normal level for bioenergy investment subsidies in Norway. The terminal can store 4000 lm³ of chips. The company also benefitted from the subsidy scheme introduced in 2009 for logging of bioenergy wood. The subsidy scheme covers round wood and raw materials for wood chips for energy production (excluding firewood) from first thinnings, hardwood, young forest maintenance, logging waste (lop and top), verge clearance and landscape care. The grant aims to contribute 1.2-1.5 Eurocent/kWh to the value chain for bioenergy. The price for bioheat sold is normally 8-10 Eurocent/kWh (Statens landbruksforvaltning, 2011).

The company has a goal of producing 12 000 to 13 000 m^3 of chips per year. This corresponds to around 10 GWh of heat (Hohle, 2001). Based on a 10-year contract the company is the sole supplier of chips to the district heating plant in the nearby city of Namsos. In terms of effect the plant has a capacity of 2 MW. Enova provided a grant also to this heating plant. In addition, the company supplies chips to three smaller heating plants located within a few, and up to 150 km distance. The price of wood chips is adjusted annually according to the price group “Electricity, gas and other fuels” in the national Consumer price index (Statistisk sentralbyrå, 2012). The annual revenues in Overhalla Biochips varied from 5 000 to 124 000 Euro in the years 2008-2010 with operating results differing from -1 000 to 22 000 Euro.

4.2 “Årø Bioenergy”

“Årø Bioenergy” was established in Molde, county of Møre and Romsdal in 2006. The founder is a farmer and owner of a large farm in the area. Beyond the farmer there were no other employees on a regular basis in the company. In 2010 there were four shareholders in the company. The main source of raw material is wood and scrub from roadside verges in the region, extracted by another company, Skog-kompaniet AS. Clearing of bushes and trees near roads is part of road maintenance, and Skog-kompaniet is a subcontractor to several major companies that carry out road maintenance for the road authorities. Normally the only cost incurred in obtaining this resource is associated with its removal from roadsides. Wood and chips are transported either directly to the heating plants or to a chip terminal with capacity of 2000 m^3 of chips, which the owner has established on the farm. Årø produces chips from a quantity of 2500-5000 m^3 of wood each year.

Wood from roadside scrub increases the fraction of fine (wood) particles in the chips. This has led to combustion problems in small boilers used below their capacity. For example, one of the boilers Årø supplies has a capacity of 4.0 MW, but only exploits 1.5 MW. Årø Bioenergy has therefore started experimenting with sifting the chips in a grader, which was originally designed to sort materials like stones and sand. In this process the chips are separated into coarse chips and more fine graded qualities. The two qualities can then be used

in different heating systems, instead of one unsorted quality causing operating problems. The firm has also hired a contractor to bundle some of the wood at the roadside. This makes drying, collection and transport to the terminal easier. These two measures have meant that many of the problems of freight, moisture and fine particles have been reduced, but have on the other hand increased the cost of the wood chips. As another measure Årø Bioenergy has developed its own chip drier. This is a system that the company has produced itself that utilizes surplus heat from a local hydro power station. Investments have been subsidised by Innovation Norway and Enova.

The company supplies chips to a large district heating plant in Molde (5 MW). Årø Bioenergy also has a contract with another municipality to supply wood chips to heating plants at two schools. In addition the company has a contract with Molde municipality to supply heating to two schools from a local heating plant owned by the company. The pricing mechanisms vary between the three customers, but in all instances are composed by a mixture of energy and consumer indexes. The annual revenues in Årø Bioenergy in the period 2008-2010 varied from 120 000 Euro to 200 000 Euro. The annual operating results in the same period differed from -80 000 to -20 000 Euro.

4.3 “Innherred Bioheating”

The company “Innherred Bioheating” in Nord-Trøndelag was founded in 2006. Innherred Bioheating has 62 shareholders. Most of these are companies and persons with links to forestry industry (farmer foresters, owners of common forests, timber companies, etc). One of the main shareholders – a farmer – is employed part time in the company as manager. The company was founded as a direct result of Levanger municipality’s decision to switch from oil heating to biofuel heating at one of their local schools. The municipality announced competitive bidding. Innherred Bioheating won the bid with a solution based on a bioheat plant run by the company and wood chips mainly supplied locally. The operating plan was customised to meet several of the criteria in the bid announcement. At this school the company delivers 0.9 GWh of heat from a boiler with capacity 0.6 MW. The company later also won a contract to supply heating to another school in the same municipality. Here the

need for heat is 1.25 GWh, and the effect in the boiler is 0.5 MW. In addition the company offers chipping and sells chips to farmers who do not have their own chipper. 1500 m³ of wood raw material is needed each year.

Two thirds of the raw material is supplied by the regional forest owners' association ALLSKOG. The rest of the raw material is scrub and coppice from clearing of agricultural land, road verges etc. Innherred Bioheating tries to use local wood as much as possible. It became profitable to use wood from clearing and thinning after the government introduced specific subsidies for this in 2009 (see case 1). One of the shareholders in the company (a forest owner) has purchased equipment for felling of scrub and coppice. Innherred Bioenergi buys this wood directly without going through ALLSKOG.

Innherred Bioenergi chips the wood it buys and transports the chips to the heating plants they operate. The company also purchased a second-hand mobile chipper. Innherred Bioheating has invested in making it possible to transport this with a tractor. The chipper is usually kept on a 0.5 hectare area on the manager's farm, which serves as terminal for wood and chips. Investment in the terminal, warehouse and chipper cost around 310 000 Euro, and Enova provided a 30% subsidy. Both heating systems run by the company are defined as farmer-owned heating plants and thus received a 35% subsidy also from Innovation Norway. Annual revenues in Innherred Bioheating were 76 000 Euro in 2008 increasing to 274 000 Euro in 2010. Operating result was 5 000 Euro in 2008 and increased to 89 000 Euro in 2010.

4.4 “NorThun farmers’ bioenergy”

Another case study company was “NorThun farmers’ bioenergy” in Vanylven in Møre and Romsdal. Because this company had ceased operations at the time of writing, research on this case was carried out in a slightly different manner with interviews conducted by telephone with one of the founders. We supplemented this interview material with data from telephone interviews with the same company collected on an earlier project. The descriptions were quality checked by the manager and by the county bioenergy coordinator.

NorThun was a farm-based bioenergy firm established in 2006 by three local farmers who received funding from Innovation Norway for the construction of a pilot heating plant related

to a home for the elderly owned by the municipality. The three farmers were the only shareholders in the company. Altogether four persons were employed in the company: the three farmers plus a son of one of the farmers. One of the farmers was manager in the company. NorThun bought a container-mounted heating boiler that was set up in the centre of the village to provide heating for a local nursing home. The company handled the entire supply chain, from extracting timber to supplying heat to the nursing home. The capacity of the plant was around 0.5 MW. This corresponds to a supply of heat of about 1.25 GWh annually, which requires around 600 m³ of wood (Hohle, 2001). According to the former manager, it was important to them that “they handled the entire supply chain”. The method of operation involved extracting wood from the verges of roads and agricultural land. The harvested and collected wood was then stored and cut nearby. Wood was stored for a period of between six months and one year for drying. The timber was covered with waterproof cardboard to help it keep dry during storage. Such cover is recommended if the wood has small diameters and especially in wet climate such as that in Western Norway. The timber was then chipped in situ and transported to the heating plant. This working arrangement meant staff had to work collectively and extensively at periods. The system was laborious and could at times be difficult to combine with active farming.

NorThun has not operated since the new scheme of grants for the extraction of forest chips was introduced, so they did not receive any funding for the operation or activities, except those grants they received to set up the heating plant. The company had revenues of 77 000 Euro in 2008 and 100 000 Euro in 2009. The operating result in these years was -16 000 and 18 000 Euro respectively.

4.5 “Koppang district heating”

This case, located in the county of Hedmark, is of a different nature than the preceding ones. The supply chain, set up in 2010, enables the local company Moelven Østerdalsbruket to produce heat for the community Koppang. Moelven Østerdalsbruket is a saw mill that is part of the Moelven group and has around 50 employees. Each year the company uses 120 000 m³ of timber, mostly sourced locally. The municipality (Stor-Elvdal) has established an energy

company (SEAS) which buys a portion of the heat and distributes it via a pipe network to various buildings in the community. The rest of the heat (up to 10.0 GWh) is used internally by the company. When the pipe network was opened in November 2010, three large buildings were connected: parts of the council buildings and leisure centre, Stor-Elvdal secondary school and Felleskjøpet (an agricultural supply cooperative). The fire station, a technical services building, a nursing home and one business property including a bank will be connected during 2011. The plan is that more buildings are converted to water-borne heating and gradually connected to the network. SEAS expects to buy 2.5 GWh of heat in 2011. In the longer term SEAS expects to buy 4.5 GWh of heat annually. For a total production of up to 12.5 GWh Østerdalsbruket needs something like 6000 m³ of wood raw material, which is around 5 per cent of the total timber sourced annually.

Stor-Elvdal is a heavily forested, geographically large but sparsely populated inland municipality. Koppang, which is the centre of the municipality, has 1150 inhabitants. Building a district heating plant in Koppang was a subject of discussion for many years. Eventually a business plan was prepared which focused on renewable energy, supply chains and local production and processing. Forest production and processing is a major industry in Stor-Elvdal, but it has been challenging to dispose of the poorest quality segment of the timber (energy wood). As raw material for fuel Østerdalsbruket uses bark and scrap wood from its own production and chipped local logging residues for the most part delivered by the regional forest owners' association ("Glommen").

The climate and energy plan that the local authority prepared in 2007 and adopted in 2008, was an important undertaking and contained a number of measures. These included building the district heating plant in Koppang. Transition to district heating required three types of changes (investments). Firstly, buildings needed water-borne heating systems. This was an investment for the municipality of around 1.9 million Euro. An important factor in the decision to go for the district heating system was that Enova distributed additional funds in 2009 to counteract the financial crisis. The municipality was granted a subsidy of 440 000 Euro to convert some buildings. Secondly, a heating plant was needed. In this case excess capacity in Østerdalsbruket's existing heating plant renovated in 2002 could be used. This

plant was approved for 5.5 MW, of which the saw mill only needed 3.0 MW, while SEAS needs 1.6 MW. Thirdly, a pipe network between the heating plant and the buildings was required, and this was entirely paid for by the local municipality, an investment of around 1.25 million Euro. Moelven Østerdalsbruket had total annual revenues in the interval 14 to 17 million Euro in the years 2008 to 2010. The operating result varied from around 0.8 to 1.5 million Euro annually. Provided sales of 2.5 GWh of heat, the share of revenues from bioenergy sales in the company is around 2 per cent.

5. Discussion

Table 1 summarizes central information over the five cases. Column 1 gives the names of the focal firms in the cases, start-up year for commercial bioenergy production and average annual operating result for the years 2008-2010 in the firms. Column 2 indicates the sum capacity for heat production in the firms, included plants they eventually deliver fuel to, and corresponding volume and type of energy (heat) production. Columns 3-4 concern two other aspects of *the bioenergy supply chain*: fuel and fuel production; and supply of raw materials for fuel production. Column 5 lists related productions of the focal firms relevant to bioenergy production. Column 6 provides facts about *public support instruments and political commitment* in the cases. In this chapter we will comment on the cases in order to answer the research questions posed in section 1. We will analyse the organization in the chains (section 5.1), discuss the relevance of the chain concept and implications of this (section 5.2), and discuss more generally the impact of financial support and local political commitment in the cases (section 5.3 and 5.4).

[TABLE 1 ABOUT HERE]

5.1 Actors and activities in the supply chains

The diagram in Figure 2 illustrates activities in the five supply chains and the division of work in each case. Each separate line symbolizes an activity or sequence of activities performed by one actor, either the focal firm (thickest line) or another firm identified in the case

[FIGURE 2 ABOUT HERE]

We see that none of the five cases has the same division of work in the supply chain. In most cases the activities are performed by many actors. Only in case 4 are all activities from forest production to heat distribution performed by one firm (NorThun). This is also the least complex and smallest case in terms of heat production and number of plants supplied (only one). In the other cases many and various types of actors are involved. Some of them are engaging in only one step in the supply chain, while others cover more than one activity, but seldom more than two. Årø Bioenergi engages in three activities (logging, fuel production and heat production). Innherred Bioheating and Østerdalsbruket are engaged in two activities, and even if they are quite different types of firms, the activities they cover in the supply chain are the same – fuel production and heat production. Overhalla Bio Chips is a firm concentrating on one activity, fuel production, but the owner of the firm also owns a firm engaging in the previous stage in the chain – logging.

Hence, the parties are active *in different parts* of the supply chain. Similar actors differ when it comes to number and type of activities they cover. This applies to all the three farmer/forest-owner based firms (cases 2, 3 and 4). The fact that actors are different does not prevent them from engaging in the same type of activities in the bioenergy supply chain (cf. cases 3 and 5). It may be commented here that being involved in many parts of the supply chain seems challenging. An indication of this is that the firm with the broadest engagement in the supply chain, NorThun in case 4, terminated its activities after three years. They also had very modest profitability (see table 1). Årø engaging in three activities had even a poorer profitability in the period, in fact a negative result (-53 000 Euro, cf. table 1). However, broad engagement in the supply chain may not be the only or even best explanation of low profitability. Both firms are located in the region with the lowest forestry activity of the three regions studied with a low share of bioenergy of total energy use (cf. section 1). Whether broadness of engagement in the supply chain and type of forestry region are reliable explanations of profitability in bioenergy activity needs to be confirmed by further studies.

Another factor that we can note is that none of the five supply chains *have been built entirely from scratch*. Rather, the supply chains have been established by introducing new activities (chipping and heat production based on chips) in already existing or partly existing activity structures. Furthermore, the firms doing these activities have all a basis in the supply chains “near” the wood raw material, as forest owners (cases 2-4), through logging (case 1) or wood industry (case 5). Moreover, in four of the five cases (1-4) the new activities are performed by new firms specifically established (by established actors near the raw material, though) to perform these activities. The fifth case is different as chipping and heat production already is carried out by the focal firm. The new element is that the heat production in an existing plant is expanded and added energy sold commercially (to a local customer).

The observation of strong links between bioenergy activities and existing activities makes it natural to analyse this topic specifically.

5.2 Links to other productions – supply networks

A feature in all the cases then is that the bioenergy supply chains are closely linked to other supply chains. In fact, even *within* the supply chains it is hard to observe a pure sequence of single, discrete activities. Typically in figure 2 there are in most of the cases more than one activity at the same stage in the chain. There are reasons to this. For example, both in case 1 and case 2 the same type of chips are used in different types of heating plants, even owned by different customers. In case 3 various types of raw material from different suppliers are used to produce chips. In case 5 the same plant is used to produce heat for different customers. Therefore, to use the term supply chain for these cases is misleading. We propose that the types of cases reported here are better described and analysed as supply *networks*. This is in line with key literature on supply chains (Gadde and Håkansson, 2001; Lazzarini et al., 2001). Also within the discipline of logistics the term logistics network has been established (Simchi-Levi et al., 2008). The reason for such a shift in perspective is reinforced when we observe the links between the bioenergy activities in the chains and activities beyond. In the cases much of the raw material for chips comes as a consequence of logging for the purpose of producing fibre products. This is obvious in cases 1 and 5. Also raw material from

landscape cultivation is affected by purposes beyond energy production (agriculture, landscape, tourism). This is evident in cases 1 to 4. Other examples are use of transport and lifting facilities such as tractor in bioenergy production and other activities (cf. for example case 2).

Recognizing the network characteristics of bioenergy production chains has both substantial and methodological implications. A *substantial* implication is that the actors within bioenergy chains like those studied here, are part of business networks stretching beyond the bioenergy sector. To manage and exploit this is a task in itself. One specific benefit is linked to the use of the same production factor in bioenergy and outside bioenergy, that is, “economies of scope” (Chandler jr., 1990; Panzar and Willig, 1981). We have examples of this in the cases. In case 1 the capacity of employees is used partly in logging and partly in fuel production. In case 2 a tractor is used both in agricultural production, fuel production and transportation of fuel. In case 5 the heating plant produces both for internal and external needs. We claim that “economies of scope” is one of the factors decisive for the performance of firms engaging in local and regional supply of bioenergy. To a certain degree pluriactivity seems to be positive in that several sources of income is available, while costs and risks are spread. However, there may also be negative performance associated with applying “economies of scope” as well. How wide should the scope be? In case 4 the scope of activities for the firm NorThun seems to have been too wide. This led to that the sacrifices outweighed the benefits for the firm. It became difficult for the actors involved to do all necessary jobs and at the same time fulfil other obligations and task. This is a topic that could be pursued in further research.

The observation of “branched” supply chains (networks) also has implications for *method*. In the research underlying this paper we used a case method involving multiple cases and with empirical material mainly consisting qualitative data. Such a method was valuable for discovering the type of results presented in section 4. That notwithstanding, it would be interesting to go further in investigating economic performance in supply networks for bioenergy such as those analysed here. Here we have been able to present rather simple expressions for the economic dimensions and performance limited to the focal firms. More advanced studies of costs and benefits could be done in relation to all actors in a supply chain

and comparison of performance between different supply chains. Quantitative studies of “economies of scope” could be done in relation to specific facilities in a supply network and eventually the benefits of alternative technical and organizational solutions. Methodological tasks here would be to decide how much of the costs of a certain facility should be associated with bioenergy and other activities.

However, “economies of scope” is not the only source of economy for the actors engaged in the bioenergy supply chains, which we have studied.

5.3 Financial support

The interviews revealed that public funding was granted in all five cases, highlighting the importance of public support to start-ups in the bioenergy sector. Establishing bioenergy production without public funding would not have been economically viable in these instances given the prevailing prices of the main alternative electricity. The price that can be achieved in the market is not sufficient in itself to cover the investments and provide earnings. As we see, different types of public funding have been granted in the various cases. This is partly due to the different types of actors involved in each case. We note that funding has been provided for investments, and later also for operations, in form of the subsidy for the extraction of bioenergy wood introduced in 2009. This grant has been given in three of the supply chains (Overhalla, Årø and Innherred). The NorThun heat-producing farm company would have been eligible to receive such a grant if they had still been operating. Hence, we state that the financial support instruments used in our cases are specific rather than general, something that has been found to be effective in earlier studies (Thornley and Cooper, 2008).

Findings from previous research also suggest that financial support schemes must be given time to work (Christiansen, 2002). In the public debate – as also reflected in our interviews – there are some uncertainties as to the long-term commitments in Norwegian support schemes. Expectations are seen to be critical to bioenergy investments (Trømborg et al., 2008). However, the existing schemes directed at easing financial challenges related to investments have been relatively stable during the last 3-5 years.

In all the cases we studied, funding for investments was granted, and this was important. Innovation Norway has assisted in the investments of Årø, NorThun and Innherred. It is part of Innovation Norway's remit to help with funding for bioenergy investments where farmers and forest owners are involved, while Enova normally assists in larger bioenergy investments. As we have seen, investments in various parts of the supply chain have been part-funded by public sources: fuel production (chip terminals and storehouses in the cases of Overhalla, Årø and Innherred), heat production (Overhalla, NorThun, and Koppang), heat distribution (favourable loans for the Koppang district heating) and end-use (funding to convert heating in buildings in Koppang).

One may note that a second and related feature seems important here, a feature which we touched on in the previous section. The smaller bioenergy providers are made up of parties who draw their main income from other sources. This means that they are able to cope with deficit or small income from bioenergy activities for a period. It therefore appears that bioenergy companies capitalize on having main activities in other industries and links to other supply chains. There is a set of factors which is based partly on assumptions that the situation will change (for the better) over time and partly on idealism and political will. Thus, our findings support earlier research highlighting the importance of expectations around future increases in energy prices (Carlén, 2006; Trømborg et al., 2008). Yet, at the current price level, it is questionable whether the economy in the bioenergy sector is able to stand on its own feet, that is, without economic support of some kind.

5.4 Political commitment and local adaptation

Another factor shown to be significant in our cases was *commitment from local authorities and politicians and local adaptation*. This is also in line with previous research on critical factors in the bioenergy sector. Local political commitment seemed essential because it influenced perceptions and ideas (Rösch and Kaltschmitt, 1999) in the local society about bioenergy, thereby motivating firms and other actors. Actors' feeling of having political goodwill (Hakkila, 2006) from local politicians is important. An important feature and motivation for local political engagement is the multifaceted nature of bioenergy. Most

explicitly expressed in the Koppang case, but also in the other cases, local politicians and authorities regard bioenergy as a remedy to secure supply of energy that is renewable and as a platform for local business. Local policy is also important in obtaining practical adaptations. Typical local and important adaptations concern infrastructure for distributing heat (all five cases), area management to facilitate bioenergy businesses (case 1), and inclusion of bioenergy in tenders for energy supply (e.g. cases 3 and 5). However, political commitment and local adaptation would have had little effect without entrepreneurship among local and regional business actors.

Similar findings have been made in studies in central Europe (Madlener, 2007). Here, too, political *will* seemed to exist primarily at the local level, while *financial instruments* were found at the national level. A difference between the two levels, however, is that the local level has two functions with regard to bioenergy, not only as facilitator, but also as customer. Hence, in all five cases there are examples of the municipality as buyer of heat. In cases 3 and 4 one municipality is customer. In cases 1 and 2 two municipalities are customers, while in case 5 a company owned by the municipality is the customer. In none of the cases are state institutions customers. Part of the local municipality being customer is the application of long-term contracts between heat providers and the municipality and the inclusion of specific price regulating instruments in the contracts. Our study therefore shows that local policy contributes to two of the three critical factors for development of new renewable energy put forward by (Christiansen, 2002): stimulation of the demand side and creation of stable public priorities.

6. Conclusion

A study of five specific cases does of course not tell the story of the whole bioenergy sector. However, a small-N, case based research approach does provide an opportunity to draw conditional conclusions. It also offers ideas on how to, and how not to, structure supply and networks for bioenergy. The study also indicates areas of interest for further research. One of the questions we began with was why more and more businesses had started operating in the bioenergy sector despite most of them agreeing that a significant increase in energy price is

needed for such businesses being economically viable. In section 2.3 we suggested five basic factors for development of bioenergy. Answers to this question can be sought in at least three topics, which is of interest both in its own value and for further in-depth studies:

Financial support. Various types of public funding have been crucial in all the cases and has influenced several of the basic factors: demand for bioenergy, the resource base for biofuels, and technology and infrastructure. Both the focal companies and other companies along the supply chains have received grants from public institutions such as Enova and Innovation Norway for various types of investments. Government grants that reduce the price of raw material have also been a significant factor. The grant for extracting bioenergy wood (“the chip grant”) is a key factor here. There is a similar factor in the cases which exploit scrub from verge clearances, where the road authorities are motivated to undertake this activity for reasons other than energy production (road safety). In these cases, the raw material comes as a by-product, but handling the raw material in a way that makes it suitable for bioenergy production involves costs that cannot be covered solely by sales in the market. All in all, a conclusion is that the new support instruments introduced from 2008 and the continuation of instruments introduced earlier have contributed positively to the establishment of the bioenergy cases analysed in this paper. Moreover, even if the figures vary from year to year and firm to firm, there are by and large fewer “red figures” among “our” firms than those analysed in the 2007-study mentioned in section 1 (Norsk Bioenergiforening et al., 2007). However, financial support is not a goal in itself. If the price of electricity increased by another 30%, the tipping point for the market for bioenergy suggested by Trømborg et al. (2008) could be changed so that bioheat might be profitable without support. Yet, so far, despite investment subsidies, the profitability of the *bioenergy activity* among the firms studied is not stable and very lucrative. Therefore, financial support alone cannot account for the establishment of the bioenergy supply chains we have studied.

Supply networks and economies of scope. In all the cases, bioenergy production occurs as part of a supply network rather than a pure bioenergy chain. The activities in the supply chains are linked to activities outside the chain, especially forest activities. A reason for this is the ability of the entrepreneurs and managers in the chains to combine resources in existing and new

(bioenergy) activities (cf. basic factor 4). This insight has at least three implications. First, the links mean that expertise already existing in various fields can be employed in supply chains for bioenergy. This includes technical know-how, the ability to innovate, and other relevant knowledge brought by the parties. Second, the links also mean that existing machinery and equipment can be used in the bioenergy business. This reduces start-up costs and the need for investments. Third, the companies' bioenergy activities do not generally seem capable of generating income and profits large enough for the actors to survive on these alone. In the cases presented however, bioenergy is interesting as a business activity for the actors in combination with other, related sources of income. In addition comes the fact that many of the focal actors regard bioenergy as a growing sector and important to enter in order to learn for strategic purposes. Moreover, we should not forget the effect of learning on profitability in the bioenergy sector (Junginger et al., 2005), even if a pure market for bioenergy without public intervention is hard to foresee in the near future.

Local commitment. Local authorities and politicians have been active in developing conditions for the establishment and operation of the supply chains for bioenergy. This occurs through motivation and drawing attention to bioenergy as a solution to local needs. Local authorities have been crucial also in two other respects: through investments and adaptations in infrastructure and as customer, that is, two of the basic factors suggested in section 2.3. However, there is no indication that the municipalities have explicitly favoured some suppliers over others. The normal practice is to advertise for bids on bioenergy deliveries.

The solution to the somewhat paradoxical development of growth in a sector with modest incomes and somewhat weak profitability therefore, in our type of cases, appears to be explained by a combination of elements: financial support programs, local political commitment and adaptations, and the financial security and economic benefits from involvement in economic activities related to bioenergy. These elements have influenced the basic factors and can explain why bioenergy was realised in our cases. However, it does not say anything about the strength of these influences, for example how much of the profitability in the firms that can be linked to the different factors. Some of the factors are also complicated to measure quantitatively. Moreover, whether the connections found in this study

also apply to larger firms in the bioenergy sector is an open question. Methodological suggestions in this study could however be used in such research.

Acknowledgements

The authors will thank the organizations financing the project “Making words into deed: Analyzing supply chains for bioenergy and factors for development in different regions” where the research for this paper was carried out. The financers were: The Research Council of Norway (Grant no. 188915/I10), The research fund of the Agricultural Act (“Jordbruksavtalen”), the County Governor of Nord-Trøndelag and the County Governor of Møre og Romsdal. Discussions of the research with the various members of the reference group of the project were very inspiring and helpful. The authors are also grateful for helpful comments and suggestions from three anonymous reviewers of the paper.

References

Alfonso, D., C. Perpiñá, A. Pérez-Navarro, E. Peñalvo, C. Vargas and R. Cárdenas (2009). "Methodology for optimization of distributed biomass resources evaluation, management and final energy use". *Biomass and Bioenergy* 33(8): 1070-1079.

Biowood Norway (2012). "Biowood Norway--web page." Retrieved 10.08.2012, from <http://www.biowood.no/>.

Bjørnstad, E. (2011). *Adoption of Bioenergy Technologies for a Sustainable Energy System. Faculty of Natural Resources and Agricultural Sciences*. Uppsala: Swedish University of Agricultural Sciences. **Doctoral Thesis No. 2011:39**.

Borup, M., P. D. Andersen, S. Jacobsson and A. Midttun (2008). *Nordic energy innovation systems - Patterns of need integration and cooperation*. Oslo: Nordic Energy Research.

Bryman, A. (2004). *Social research methods*. Oxford: Oxford University Press.

Caputo, A. C., M. Palumbo, P. M. Pelagagge and F. Scacchia (2005). "Economics of biomass energy utilization in combustion and gasification plants: effects of logistic variables". *Biomass and Bioenergy* **28**(1): 35-51.

Carlén, B. (2006). *A Comparative Analysis of Policy Instruments Promoting Green Electricity under Uncertainty*. Stockholm Department of Economics, Stockholm University.

Chandler jr., A. D. (1990). *Scale and Scope. The Dynamics of Industrial Capitalism*. Cambridge Mass./London: The Belknap Press of Harvard University Press.

Christiansen, A. C. (2002). "New renewable energy developments and the climate change issue: a case study of Norwegian politics". *Energy Policy* **30**(3): 235-243.

CORDIS (2006). "Energy wood production chains in europe (ECHAINÉ). Final reports from Work Package 7 - socio-economic analysis." Retrieved 22.08.2012, from http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=6396977.

Enova (2011). *Enovas Varmerapport 2010. Enova rapport 2011:6*. Trondheim.

Enova (2012). *Enova Annual Report 2011*. Trondheim.

Eriksen, R., S. M. Tomter and A. Ludahl (2006). *Statistikk over skogforhold og -ressurser i Hedmark. Landsskogtakseringen 2000-2004*. Ås: NIJOS/Norsk institutt for skog og landskap.

Forbord, M. and J. Vik (2009). *Bioenergi mellom nasjonal politikk og regional variasjon - en sammenlignende studie av omfang og drivkrefter i Hedmark, Møre og Romsdal og Nord-Trøndelag. Rapport 6/09*. Trondheim: Norsk senter for bygdeforskning.

Frombo, F., R. Minciardi, M. Robba, F. Rosso and R. Sacile (2009). "Planning woody biomass logistics for energy production: A strategic decision model". *Biomass and Bioenergy* **33**(3): 372-383.

Gadde, L.-E. and H. Håkansson (2001). *Supply Network Strategies*. John Wiley & Sons, Ltd.

Gjølsjø, S. and K. Hobbelstad (2009). *Energipotensialet fra skogen i Norge. Rapport 09/2009*. Ås: Norsk institutt for skog og landskap.

Gronalt, M. and P. Rauch (2007). "Designing a regional forest fuel supply network". *Biomass and Bioenergy* **31**(6): 393-402.

Hakkila, P. (2006). "Factors driving the development of forest energy in Finland". *Biomass and Bioenergy* **30**(4): 281-288.

Hillring, B. (1998). "National strategies for stimulating the use of bioenergy: policy instruments in Sweden". *Biomass and Bioenergy* **14**: 425-437.

Hillring, B. (2002). "Rural development and bioenergy--experiences from 20 years of development in Sweden". *Biomass and Bioenergy* **23**(6): 443-451.

Hohle, E. E. (2001). *Bioenergi - miljø, teknikk og marked*. Brandbu: Energigården.

Håkansson, H. and I. Snehota, Eds. (1995). *Developing Relationships in Business Networks*. London: International Thomson Business Press.

IEA Bioenergy (2009). "TASK 29. Socio-Economic Drivers in Implementing Bioenergy Projects. Work Programme 2010 - 2012." Retrieved 23.08.2012, from http://www.task29.net/assets/files/Work_Programme_2010_2012.pdf.

Innovasjon Norge (2010). "Årsrapport 2009." Retrieved 10.08.12, from <http://www.innovasjon Norge.no/Om-Oss/Arsrapporter/Arsrapport-2009/>.

Junginger, M., A. Faaij, R. Björheden and W. C. Turkenburg (2005). "Technological learning and cost reductions in wood fuel supply chains in Sweden". *Biomass and Bioenergy* **29**(6): 399-418.

Lazzarini, S. G., F. R. Chaddad and M. L. Cook (2001). "Integrating supply chain and network analyses: The study of netchains". *Journal on Chain and Network Science* 1(1): 7-22.

Madlener, R. (2007). "Innovation diffusion, public policy, and local initiative: The case of wood-fuelled district heating systems in Austria". *Energy Policy* 35(3): 1992-2008.

Madlener, R. and M. Bachhiesl (2007). "Socio-economic drivers of large urban biomass cogeneration: Sustainable energy supply for Austria's capital Vienna". *Energy Policy* 35(2): 1075-1087.

Madlener, R. and J. Domac (2007). "Introduction to the special section "Modeling socio-economic aspects of bioenergy use: methodologies, case studies, and policy evaluation and guidance" (Vol. 35, No. 12)". *Energy Policy* 35(12): e1-e4.

Madlener, R. and S. Vögtli (2008). "Diffusion of bioenergy in urban areas: A socio-economic analysis of the Swiss wood-fired cogeneration plant in Basel". *Biomass and Bioenergy* 32(9): 815-828.

McCormick, K. and T. Kåberger (2007). "Key barriers for bioenergy in Europe: Economic conditions, know-how and institutional capacity, and supply chain co-ordination". *Biomass and Bioenergy* 31(7): 443-452.

Menanteau, P., D. Finon and M.-L. Lamy (2003). "Prices versus quantities: choosing policies for promoting the development of renewable energy". *Energy Policy* 31(8): 799-812.

Mårtensson, K. and K. Westerberg (2007). "How to transform local energy systems towards bioenergy? Three strategy models for transformation". *Energy Policy* 35(12): 6095-6105.

Norsk Bioenergiforening (2012). *Analyse av norsk bioenergistatistikk - forslag til kvalitetsheving*. Oslo.

Norsk Bioenergiforening, Norsk Varmepumpeforening and Norsk Petroleumsinstitutt (2007). *10 år med røde tall. Barrierer for økt utbygging av lokale varmesentraler og nærvarmeanlegg*. Oslo: Nobio.

Olje- og energidepartementet (2008). *Strategi for økt utbygging av bioenergi*.

Panzar, J. C. and R. D. Willig (1981). Economies of Scope. in *Papers and Proceedings*. American Economic Association. **May**: 268-272.

Pettenella, D. and D. Maso (2011). Networks of Small-Medium Enterprises Operating in Forestry: Some Theoretical Concepts and Empirical Evidence. in G. Weiss, D. Pettenella, P. Ollonqvist and B. Slee *Innovation in Forestry -Territorial and Value Chain Relationships*. Oxfordshire, UK: CAB International: 35-47.

Richardson, G. B. (1972). "The Organisation of Industry". *The Economic Journal* **82**: 883-896.

Roos, A., R. Graham, B. Hektor and C. Rakos (1999). "Critical factors to bioenergy implementation". *Biomass and Bioenergy* **17**: 113-126.

Rösch, C. and M. Kaltschmitt (1999). "Energy from biomass--do non-technical barriers prevent an increased use?". *Biomass and Bioenergy* **16**(5): 347-356.

Sandberg, E. (2008). *Grønn Varme fra Hedmarkskogen. Sluttrapport 2003-2008 med analyse*. Hamar: Fylkesmannen i Hedmark, Landbruksavdelingen.

Schuck, A., R. Päivinen, T. Hytönen and B. Pajari (2002). *Compilation of Forestry Terms and Definitions. Internal Report No. 6, 2002*. Joensuu, Finland: European Forest Institute.

Simchi-Levi, D., E. Simchi-Levi and P. Kaminsky (2008). *Designing and managing the supply chain: concepts, strategies, and case studies*. Boston: McGraw-Hill/Irwin.

Slade, R., C. Panoutsou and A. Bauen (2009). "Reconciling bio-energy policy and delivery in the UK: Will UK policy initiatives lead to increased deployment?". *Biomass and Bioenergy* 33(4): 679-688.

St.meld. nr. 34 (2006-2007). *Norsk klimapolitikk*. Miljøverndepartementet.

Statens landbruksforvaltning (2011). "Skogsflis blir bioenergi." Retrieved 27.9., 2011, from <https://www.slf.dep.no/no/eiendom-og-skog/skogbruk/energiflistilskudd/Skogsflis+blir+bioenergi.15595.cms>.

Statistisk sentralbyrå (2011). "Noe dyrere strøm for husholdningene." Retrieved 10.08.12, from <http://www.ssb.no/elkraftpris/>.

Statistisk sentralbyrå (2012). "Konsumprisindeks - tabell 03013 - Gruppe "Elektrisitet, fyringsoljer og annet brensel"." Retrieved 28.8.2012, 2012, from <http://statbank.ssb.no/statistikkbanken>.

Stupak, I., A. Asikainen, M. Jonsell, E. Karlton, A. Lunnan, D. Mizaraite, K. Pasanen, H. Pärn, K. Raulund-Rasmussen, D. Röser, M. Schroeder, I. Varnagiryte, L. Vilkriste, I. Callesen, N. Clarke, T. Gaitnieks, M. Ingerslev, M. Mandre, R. Ozolincius, A. Saarsalmi, K. Armolaitis, H. S. Helmisaari, A. Indriksons, L. Kairiukstis, K. Katzensteiner, M. Kukkola, K. Ots, H. P. Ravn and P. Tamminen (2007). "Sustainable utilisation of forest biomass for energy--Possibilities and problems: Policy, legislation, certification, and recommendations and guidelines in the Nordic, Baltic, and other European countries". *Biomass and Bioenergy* 31(10): 666-684.

Thornley, P. and D. Cooper (2008). "The effectiveness of policy instruments in promoting bioenergy". *Biomass and Bioenergy* 32(10): 903-913.

Trømborg, E., T. F. Bolkesjø and B. Solberg (2007). "Impacts of policy means for increased use of forest-based bioenergy in Norway--A spatial partial equilibrium analysis". *Energy Policy* 35(12): 5980-5990.

Trømborg, E., T. F. Bolkesjø and B. Solberg (2008). "Biomass market and trade in Norway: Status and future prospects". *Biomass and Bioenergy* 32(8): 660-671.

Yin, R. K. (2003). *Case study research : design and methods*. Thousand Oaks, Calif.: Sage.

Øyen, B.-H., Ed. (2008). *Kystskogbruket : potensial og utfordringer de kommende tiårene. Oppdragsrapport 01/2008*. Ås: Skog og landskap.

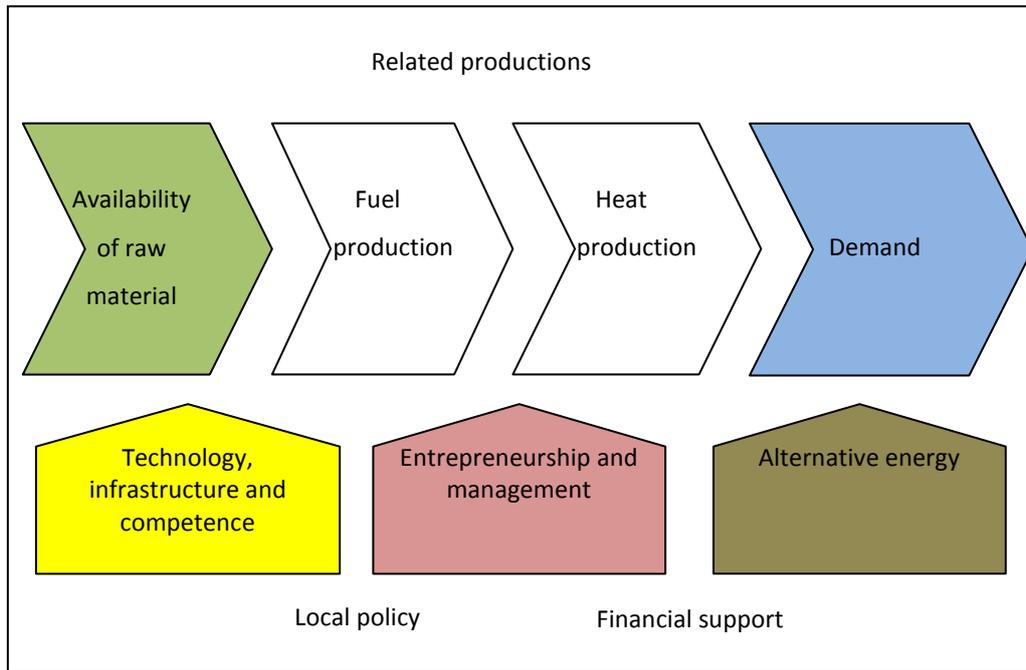


Figure 1: Factors affecting implementation of bioenergy – a research model

Activity ^a Case and focal firm in the case	Forest production	Logging	Fuel production	Heat production	Heat distribution
Case 1 “Overhalla Bio chips”	—	— —	—	— —	— —
Case 2 “Årø Bioenergy”	—	—	—	—	— —
Case 3 “Innherred Bioheating”	—	— —	—	—	— —
Case 4 “NorThun farmers’ bioenergy”		—			
Case 5 “Moelven Østerdals-bruket saw mill”		— —	—	—	—

^a Each line symbolizes the activity/ies of one actor. Thick line indicate focal actor.

Figure 2: Actors and division of work in the five supply chains

Table 1: Basic information about the bioenergy cases

Focal firm, startup year, and annual operating result 2008-2010	Capacity, annual production of energy and distribution of heat	Fuel and fuel production	Raw material for fuel production	Focal firm's links to other productions	Public support and political commitment
<p>“Overhalla Bio chips”</p> <p>2007</p> <p>7000 Euro</p>	<p>2-4 MW</p> <p>Delivers chips to local heating centrals and a district heating plant.</p> <p>5-10 GWh</p>	<p>Terminal with chips storehouse.</p> <p>Wood dries covered.</p> <p>-2010: Leases chipping.</p> <p>2011-: Own chipper.</p>	<p>Verge- and clearing wood cut by the firm.</p> <p>Energy wood from own felling and from the forest owners' association.</p>	<p>Logging and transportation.</p>	<p>Funding for felling bioenergy wood.</p> <p>Funding for chips terminal and district heating.</p> <p>Municipal involvement.</p>
<p>“Årø Bioenergy”</p> <p>2006</p> <p>-53000 Euro</p>	<p>2-4 MW</p> <p>Delivers chips to local heating centrals and energy company operating district heating.</p> <p>Supplies heating to a school from own local heating central.</p> <p>5-10 GWh</p>	<p>Terminal with storehouse for chips.</p> <p>Chipping with own chipper.</p> <p>Sorting and drying of chips, partly in a special drier.</p>	<p>Verge- and clearing wood delivered by a local firm.</p> <p>In the longer term: use own energy-, verge- and clearing wood.</p>	<p>Agriculture and forestry.</p>	<p>Funding for terminal, chipper and drying facilities.</p> <p>Municipal involvement.</p>
<p>“Innherred Bioheating”</p> <p>2006</p> <p>35000 Euro</p>	<p>1-1.5 MW</p> <p>Heat produced in two own heating centrals delivered to two primary schools.</p> <p>Sells chips and chipping to farmers.</p> <p>2.5-3.0 GWh</p>	<p>Two terminals.</p> <p>Chipping with own chipper.</p> <p>Storage building planned.</p>	<p>Energy wood delivered by the forest owners' association.</p> <p>Verge- and clearing wood delivered by local actors.</p>	<p>Agriculture and forestry.</p>	<p>Funding for felling bioenergy wood.</p> <p>Funding for chipper and chips storage building.</p> <p>Municipal involvement.</p>
<p>“NorThun farmers' bioenergy”</p> <p>2006</p> <p>1000 Euro</p>	<p>Ca. 0.5 MW</p> <p>Produced ca. 1.25 GWh at own heating central delivered to municipal nursing home.</p>	<p>Leased terminal without storehouse.</p> <p>Wood dries covered.</p> <p>Chipping with own chipper.</p>	<p>Local verge- and clearing wood cut by the firm.</p>	<p>Agriculture, forestry and logging.</p>	<p>Funding from Innovation Norway for local heating central (pilot plant).</p> <p>Municipal involvement.</p>
<p>“Moelven Østerdals-bruket”</p> <p>2010</p> <p>1 135 000 Euro (incl. sawmill)</p>	<p>5,5 MW</p> <p>Up to 12.5 GWh production of heat at own plant distributed to local district heating and own use.</p>	<p>Raw chips produced by the company.</p> <p>Some industrial chips in own store.</p>	<p>Energy wood from local forest owners and forest owners' association.</p> <p>Verge- and clearing wood from local forest owners.</p>	<p>Lumber industry.</p>	<p>Funding for combustion plant.</p> <p>Funding for conversion of buildings.</p> <p>Favourable loans for district heating</p> <p>Municipal involvement.</p>