FOREST ENERGY IN FINLAND AND SWEDEN –TECHNOLOGY AND MARKET DEVELOPMENT SUPPORTING ECONOMIC VIABILITY OF FEEDSTOCK SUPPLY

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ABSTRACT:

The main recent drivers of woody biomass use and woodfuel production worldwide include energy supply and security, greenhouse gas mitigation and economic development. The EU aims to produce 20 % of its energy from renewable sources by 2020. Each member state has their own target, for example Finland should produce 38 % and Sweden 49 % of their energy from renewable sources by 2020. In this context, the development of forest energy utilization and more effective and economic supply systems plays an important role in both countries. This paper provides an overview of the driving forces behind the current technical solutions of forest energy procurement systems in Finland and Sweden and perspectives on the economic sustainability of energy biomass supply. Focus is in the primary forest residues for energy production including logging residues, stump and root wood, small diameter wood and other wood not in demand by the traditional forest industries. Finland consumed 6.9 mill. m^3 forest chips in 2010 and Sweden 8.4 mill m^3.

To create a solid basis for the sustainable and competitive forest energy systems, both Finland and Sweden have invested hundreds of millions euros in the technology and logistics development. This has been a necessity because the primary forest fuel feedstock combines difficult properties such as and great diversity in shape, bulkiness, small piece size and scattered occurrence with low relative value, heterogeneity and, often, contaminations increasing ash content, tear, wear and damage to equipment and machines. The demand for forest fuel varies throughout the year, while supply is generally stable. Consequently, it is necessary to store the biomass over a certain time and the transport economy of the material is poor due to low energy density of biomass.

Finnish and Swedish experiences show that in the market penetration phase the biomass supply can be subsidized. Differences in subsidy policy in Finland and Sweden has had a great impact in the supply volumes of energy biomass from young stands: Due to production subsidies in Finland chips made of small diameter trees has become the largest forest fuel assortment (3.2 mill. m^3/a small trees, residues 2.2 mill. m^3 /a) whereas in Sweden logging residues dominated (4.3 mill. m^3/a logging residues, 1.3 mill. m^3/a small trees). To achieve an economically sustainable long term supply, large investments are needed in the development of technology for forest fuel procurement. Finland has invested longer time for the stump wood harvest resulting in 1.0 mill. m^3 annual harvest, whereas in Sweden use of stumps for energy has commenced later being now (0.3 mill. m^3/a.

For biomass supply chain to be sustainable, all aspects of sustainability, economic efficiency, emission reduction and sustainable energy production have to be taken into account. Sustainability of the biomass feedstock supply involves ensuring that forest management and the benefits from forest derived by present generations do not compromise the opportunities for future generations to benefit in a similar fashion.

Economic sustainability of biomass production and supply for energy has often been neglected in the sustainability discussion. Competing fuels and their prices will set the limits to the willingness to pay for the biomass. Prices can be affected by different support mechanisms for biomass, such as feed-in tariffs, subsidies, heavier taxes or CO_2 emission burden for competing (often fossil) fuels.

The monetary inputs described, such as investment costs in the machinery and direct operating and labor costs are defining the factors affecting profitability of supply chains. In the long run, machine technology, logistics and fuel storage management can be developed to reduce the need of these inputs. In addition, seasonal variations in demand effects on profitability of supply chains and

entrepreneurs` capacity utilization having a great impact especially in small companies, where the return of investments is is low.

The experience in Finland and Sweden has also shown the importance of relying on proven and established technology and integration of operations to establish systems based on forest biomass for energy. According to many feasibility studies, the Nordic energy wood technology can be applied in Baltics and in Central Europe with minor modifications.

Foresight studies show that in the developed biomass markets such as Finland and Sweden and partially Central Europe, the growth of biomass demand will be from the large combined heat and power (CHP) plants and from possibly emerging large biorefineries. This calls for the development of supply chains that are cost-efficient and sustainable also when supply stretches over very long distances. The manpower requirements is estimated at over 40 000 machine operators in the EU by 2030. Labour input can be reduced by developing partial automation and systems that guide the operators towards efficient work methods.

1 MOBILIZATION OF FOREST BIOMASS REQUIRES TECHNOLOGY AND ECONOMIC VIABILITY

The demand for wood by forest industries has been estimated to increase by 15–35% in 2030 compared to 2010 (Mantau et al., 2010). At the same time, forests are becoming increasingly important for supplying wood for renewable energy production, given the targets by the European Commission (EC) to raise the share from renewable energy in energy consumption to 20% by 2020 in the EU (Directive 2009/28/EC). Forests are considered an important resource to meet these renewable energy targets, because several studies have shown that about 200 million m^3 more woody biomass could be used for direct energy generation and because the growth of forests is significantly higher than their curren utilization (Asikainen et al. 2008, Verkerk et al. 2011).

The annual consumption of forest chips in heating and power plants has already increased over five-fold since the year 2000, up to 6.2 million m^3 solid per year by 2010 in Finland (Finnish Statistical… 2012). The target set by Ministerial Working Group of the Finnish Government for climate and energy policy is 13.5 million m^3a^{-1} (90 PJ) by 2020. The technical harvesting potential of forest chips in Finland has been estimated to be 14-20 million m^3 per year (Laitila et al 2010). About 45 % of this amount could be obtained as small-dimension wood from early thinnings. The use of small diameter stem wood in heat and power plants increased remarkably in recent years and was the most important raw material for forest chips (2.5 million m^3) in the year 2010 (Finnish Statistical…2012). In Finland the subsidies for small diameter wood harvesting and comminution are essential that the harvesting is economical if compared to procurement of forest chips from logging residues (Petty & Kärhä 2011). The use of logging residues (2.2 million m^3) and stump and root wood (1 million m^3) also increased in recent years. The use of robust stem wood in 2010 was 0.5 million m^3. In 2010 forest chips were used by almost 1000 power and heating plants in Finland (Finnish Statistical… 2012). In Sweden the consumption of forest chips was 8.4 million m^3 in 2010 (Brunberg 2011). The technical harvesting potential of forest chips in Sweden is approximated to be 20-25 million m^3 per year. Half the gross supply (56 million m^3 per year) is exempt for ecological or techno-economic reasons. Logging residues have been the most important raw material for forest chips in Sweden (4.3 million m^3 i.e. roughly half the potential) in the year 2010. The use of small diameter wood was 1.3 million m^3 (20 % of the potential), stump and root wood 0.3 million m^3 (2-3 per cent of the potential) and roundwood 2.5 million m^3 in 2010. Although the full primary fuel potential of Swedish forests cannot be economically harvested, it is possible to more than double the annual utilization.

Major part of forest operations in the EU are done by small private forest machine entrepreneurs employing one or a few machine chains. The share of mechanization in cutting operations has been steadily increasing in the eastern Europe and already saturating in the Nordic countries and in UK and Ireland. The labour costs in the EU member countries has reached the level, where full mechanization of the harvesting and transport system has become competitive in practically all countries especially in the harvesting of conifers. Several studies also suggest, that profitable forest energy harvesting also calls for full mechanization of the logging operations. As a result, the investment need for the machinery has increased rapidly and financing of investments together with reliable long term contracts have become bottlenecs in the development and modernization of the European forest machinery (Asikainen 2012).

The need of manpower has been decreasing as the use of machines becomes more common. This has partially solved problem of poor availability of forest workers. On the other hand the complexity of modern forest machines calls for long training before the man-machine unit reaches its full productivity. The differences between machine operatos in productivity have been found to be large (Väätäinen et al. 2005, Ovaskainen 2009).

The objective of this paper is to illustrate different dimensions of economic viability of forest biomass supply for energy produciton. Subsequently the paper describes concrete actions that Finland and Sweden have used to promote the use of forest fuels in energy production. The technological development of harvesting and transport fleet together with other support measures for improved economic viability are presented and discussed.

2 ECONOMIC VIABILITY OF FEEDSTOCK SUPPLY

International and national drivers and energy policies aim at sustainable bioenergy use and set the goals for climate change mitigation and energy use. The main recent drivers of woody biomass use and woodfuel production worldwide include energy supply and security, greenhouse gas mitigation and economic development (FAO 2010). Sustainability of the biomass feedstock supply involves ensuring that forest management and the benefits from forest derived by present generations do not compromise the opportunities for future generations to benefit in a similar fashion (Lunnan et al. 2008).

Economic sustainability is strongly connected to other dimensions of sustainability, and it is been reviewed in the context of social and environmental impacts. Under this main principle, the economic benefits of bioenergy should be maximized, and long-term economic viability should be maintained (FAO 2010). Economic sustainability can be analyzed either through internal functions of the company or by the external effects on society and environment (Doane & MacGillivray 2001). From internal point of view, the financial performance of a company and capability to manage intangible assets are the most important. External implications of sustainability management emphasize more on company`s influence to the wider economy and how it influences and manages social and environmental impacts (Doane & MacGillivray 2001). Survey analysis made by Buchholz et al. (2009) microeconomic sustainability was considered the most important economical criterion among the bioenergy experts. Microeconomic sustainability implies the company`s ability to maintain long-term profitability (Ikonen et al 2012). The economic viability of biomass feedstock supply can be improved by two main sets of means: improving the technolgical and economic efficiency of the biomass supply chain and conversion and by creating favorable conditions for forest biomass to enter the markets and compete with other sources of energy.

3. TECHNOLOGY DEVELOPMENT FOR IMPROVED EFFICIENCY

The development of forest energy operations in Finland and Sweden reflects the need to overcome the general challenges related with economic viability of feedstock supply (Routa et al 2012). Exploitation of existing economies of scale has been facilitated through concentration of the scattered material and is a very important prerequisite for the employment of large scale operations yielding low costs but also demanding large volumes. This is done in many steps of the supply chain to allow for efficient bulk handling (Routa et al 2012).

The municipal infrastructure supports the local and regional use of forest energy. For instance, in Finland close to 1000 heat and power plants use forest chips as a fuel in Finland. This enables the collection of feedstock within a relatively radius around the plant (Finnish Statistical… 2012).

Because largest remaining potential to replace fossil fuels in energy generation is located in the big coal fired CHP plants along the coast, efficient long distance transportation is currently the most important bottleneck for increased use of forest biomass for energy in Finland and Sweden (Laitila & Väätäinen 2011). This can only be solved by even more efficient concentration, densification and improvement of material value to allow large scale transports. The low quality of the material may be improved by drying, storing, screening and sorting. This, combined with chipping or crushing will increase homogeneity, handling properties and density of the material (Routa et al. 2012).

Since the availability of primary forest fuels is largely dependent on conventional logging, integration with the main operations of forestry may be used as a means to cut costs and increase efficiency (Routa et al 2012). This already takes place in large scale in final fellings, where logging residues and in some cases also stumps are harvested for energy after industrial roundwood harvest. Also in early thinnings the industry wood is first recovered and then the remaining part of the stem and minority tree species in the stand are all harvested for energy.

All phases in energy wood supply system need to be improved incrementally in the future. An expert survey prioritized the improvement of the quality and transport density of stump wood, better storability of logging residues and more cost efficient methods for small diameter tree harvesting (Laitila et al 2010).

3 FOREST ENERGY MARKET DEVELOPMENT

In order to be competitive, energy produced from forest biomass must be as cheap as or cheaper than energy produced from competing fuels. With current fossil fuel prices and production technologies used to make wood-based bioenergy, conversion technologies and supply chains require further optimization. The profitability of different alternatives must be assessed for the whole life expectancy of the energy production plant. Biomass-based production is usually more costly to built, but more cheaper to operate than fossil fuel based plant (Alakangas et al. 1999).

In addition to technology and logistics development other measures such as emission trade and carbon credits/tax can be applied to support the take off and expansion of forest fuel supply. In economic sustainability assessments, effect of emission trade is analyzed from the beneficence point of view. When the direct benefits of biomass production and use outweigh the excess emissions and external costs in production, the production is economically sustainable (Hardisty 2010). The emission trade does not cause any direct costs in bioenergy production, which enhances the competitiveness of wood fuels against fossil fuels. As a result, plants` wood-paying ability increase and gate prices of forest biomass and chips rise (Fagernäs et al. 2006). This reduces the availability of woody biomass for plants outside the emission trade system and outside forest industry wood procurement network, especially, when the CO_2 prices peak (Ikonen et al. 2012).

In larger co-combustion (coal-wood) plants, production is not directly competitive with fossil fuel-based power and carbon credits are required to equalize against an incremental cost advantage of coal (Kumar et al. 2003). In smaller, under 20 MW plants, biomass is more often competitive against fossil fuels, because the competing fuel is light or heavy fuel oil the market price of which is markedly higher than that of wood based fuels.

There has been big expectations of emerging biorefining and especially production of liquid transport fuels for energy in Nordic countries and elsewhere in Europe (Kallio et al. 2010). If strong support measures are targeted to liquid biofuel production based on forest fuels, competition with the traditional heat and power sector on the availability of feedstocks may arise. The study to Kallio et al. (2011) reveals the impacts of potential competition on the feedstocks: Especially when industrial harvesting is on a low level and emission trade prices for CO2 are low, extensive use of forest biomass for liquid biofuels can lead to decreasing use of forest biomass in heating and power sectors (Figure

1). To avoid this kind of market disturbances the impacts of support measures must be carefully estimated before they are applied in a large scale.

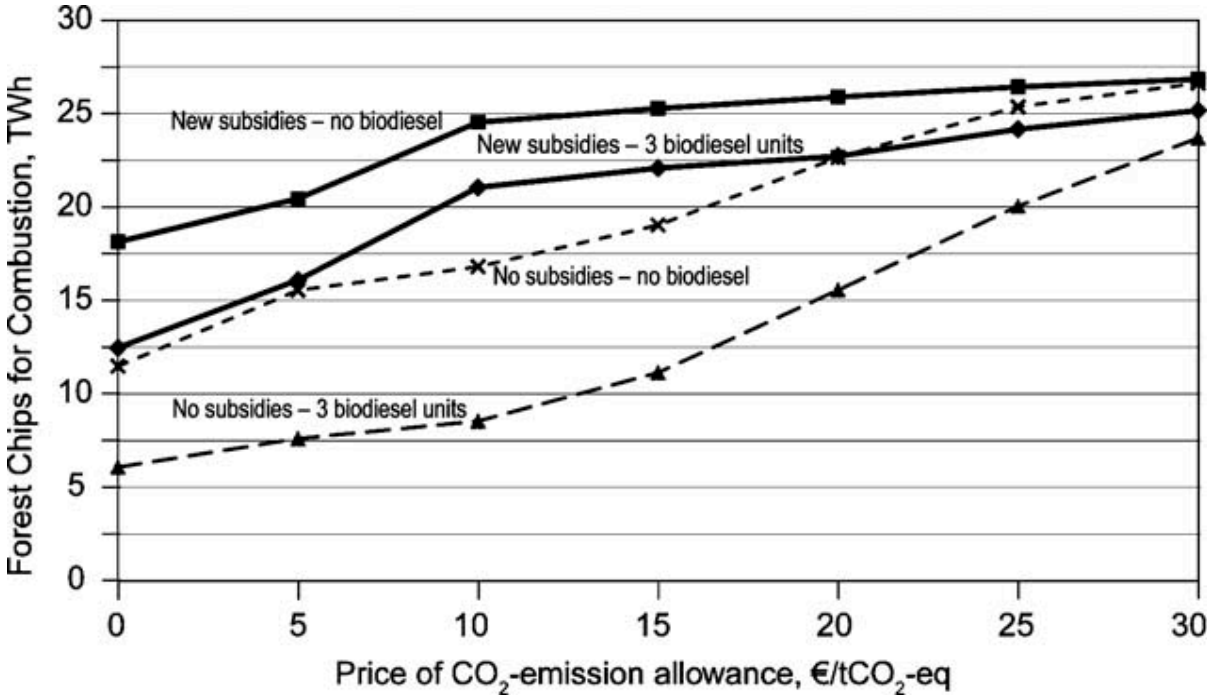

Figure 1 Supply/use of forest chips in heat and power production under alternative CO2 prices, given the level of roundwood harvests as in 2007 (Kallio et al. 2011).

4 DISCUSSION

The harvesting and transport of energy biomass needs to grow considerably, if the European Union aims to mobilize its industrial and energy wood potentials. Finland and Sweden have already mobilized close to half of their forest fuel potentials demonstrating that targets can also be materialized. Both countries have invested plenty of funds in technology development to make the feedstock supply first technically possible and then economically sustainable (Hakkila 2004).

Sweden has over a long time used carbon taxes to support the competitiveness of forest fuels, whereas Finland has used direct subsidies to bring especially wood from early thinnings to renewable fuel markets. More lately also Finland has introduced stronger carbon taxation to coal and also variable support for the production of small scale CHP based electricity. Today, impacts of different support measures can be seen in the forest fuel material mix: In Finland biomass from early thinnings is the largest source of forest energy whereas in Sweden logging residues still dominate.

Challenges in the future are the supplies of emerging biorefineries and large coal-wood co-combustion units that are often at the coast far from inland fuel sources. When support measures for these are designed, their impacts on traditional energy wood users as well as raw material supply for forest industries need to be carefully investigated. In the long run technology and method development guarantees longer lasting economic viability and subsidies and feed in tariffs should only be used in the initial stages of forest energy utilization.

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