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THE REGIONAL BALANCE OF WOOD FUEL DEMAND AND SUPPLY IN FINLAND

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ABSTRACT: The demand and supply balance of wood fuels will be evaluated both without the effect of emission trade and when the price level of emission reduction units is 20 €/tonCO_2 in 2010. The demand for wood fuels was estimated to double by the year 2010, being almost 50 TWh. The forest chip share of the demand was one third, i.e. 17 TWh. In 2010, the supply potential of by-products was estimated to be 28 TWh, of which 11 TWh was marketable outside the internal use of the forest industry. Correspondingly, the theoretical potential of forest chips was estimated to be 51 TWh and the techno-economical potential 24 TWh. As a result of the regional optimization model, the energy use of wood fuels was 29 TWh, which was 59% of the potential demand. In the emission trade situation the demand was 33 TWh, which was 68% of the potential demand. Regionally, the potential demand for wood fuels for energy use was higher than the supply in all provinces.

Keywords: wood fuels, emission trade, optimization model

1 INTRODUCTION

Challenging targets have been set to increase wood fuel use in Finland. In its governing policy, the Finnish Government has committed to promote the usage of renewable energy sources. According to the updated Action Plan for Renewable Energy 2003–2006, the target is to increase bioenergy use to 97 TWh by the year 2010 [1]. The increase in use is 31% (23 TWh) above the year 2001 level. Additional use of biofuels will be divided into forest industry by-products (34%), forest chips (45%) and recycled fuels 15% and agro biomasses (6%). The targeted growth of forest chips (firewood use excluded) annual use by the year 2010 is 10.6 TWh, i.e. some 5 million m^3, which would mean quadrupling the use from the year 2001 level.

The wood fuel market is in a major state of change. In recent years, the demand for wood fuels has clearly increased the amounts of supply, which has caused a rise in wood fuel prices. Along with the incentives for wood fuel production and use and the recently started emission trade, it seems evident that also in the future the demand for wood fuels at the national level will be higher than the exploitable supply. In addition, large regional and user-based variation exists both in wood fuel use possibilities and potential availability. The majority of the wood fuels market supply comes from the by-products of mechanical forest industry. Therefore, the potential supply largely fluctuates according to the forest industry business cycles. From the by-products, the bark is usually used directly within the plant area in producing heat and steam, the sawdust and industrial chips are used as a raw-material for pulp, board and pellet production. The increased price for wood fuels also affects the situation of by-products' competition between the raw-material and energy use. In practice, the possibilities of additional use of forest industry by-products for energy production are very restricted and therefore most of the increase will be based on forest chips.

In 2003 the approved EU's directive on greenhouse gas emissions will boost the process to implement the actions planned for the renewable energy sources. The emission trade according to the EU's directive on greenhouse gas emission allowance started at the beginning of 2005. This will increase the demand for wood fuels because of the additional value of CO_2-neutrality compared to fossil fuels. The emission trade will affect at the same intensity all plant types, linearly according to the price of emission reduction units. For example, the price level of 10-20 €/tCO_2 will have an effect of 3.8-7.6 €/MWh to the paying ability of a power plant using peat. In 2005, the competitiveness of peat in the production of heat will be improved especially when compared to coal, by the canceling of the excise tax, 1.59 €/MWh.

It has been estimated that the availability of wood fuels will be lower for plants outside the emission trade system and municipal plants, which do not have a close link to forest industry energy wood procurement organizations. Energy plants within the forest industry have better chances to secure wood fuel supply primarily to their own plants by controlling intra-group by-product flows and developing the forest chip supply system to be more integrated into timber supply. In the municipal sector the energy wood supply side is characteristically very scattered, which makes it more difficult to secure the supply. Typically, there are many small-sized suppliers, who can only make short and uncertain delivery agreements from the end users' point of view.

The target of this study is to evaluate the development of the demand and supply of wood fuels from the year 2002 to 2010 both at a national and a provincial level. The starting point for the evaluations is the WM-scenario of the Ministry of Trade and Industry [2]. As initial data for the scenario, the demand of electricity consumption in Finland and the heating demand at a local and an industry plant level have been collected, which have been covered by using the Electrowatt-Ekono's boiler database. The demand potential has been calculated both for the cases without emission trade (0 €/tCO_2) and for the situation with emission trade (20 €/tCO_2) in 2010. This study is based on the results of the project financed by the Ministry of Trade and Industry and companies in the energy sector [3].

2 MATERIALS AND METHODS

2.1 Evaluation of the potential demand for wood fuels

The evaluations of fuel consumption for individual boilers were made with the help of the databases of Electrowatt-Ekono Ltd. The database included some 1700 boilers, which covered some 96% of the fuel consumption in energy production in Finland. In addition to the current boilers, the database also included boilers, which are currently or are going to be retrofitted or are to be new investments in the future. The techno-economic potential of individual boilers was evaluated separately both for forest chips and forest industry by-products. The techno-economic potential corresponded to the amount of wood fuels, which the plant could use without any major investment in the fuel receiving systems or boiler technology.

Forest chips were able to use varying shares of the whole fuel usage depending on the boiler technology. Burning of pure forest chips caused problems in the superheaters of boilers by fouling their surfaces and hindering the transfer of heat. For the new bed and grate boilers, which were constructed after the year 2000, the potential was evaluated at a higher level than for the old ones because of the developed boiler technology. When using by-products these problems were minor. The relatively high moisture content of wood compared to peat was the biggest problem, which caused losses in power output and growth in combustion gas flows. Therefore, by-products were also typically co-combusted with other fuels, such as peat. In this study, the maximum share of wood fuels from the whole fuel mix was estimated to be 90% with fluidized-bed and 80% with grate-technology. For the pure forest chip fraction the potential was lower. For pulverized fuel combustion boilers using coal as the main fuel, the share of wood fuels (sawdust) was estimated to be less than 10%. The technical demand potential of wood fuels was calculated by multiplying the maximum wood share by the total estimated fuel consumption (Table 1).

Table 1. Development of the potential demand of the wood fuels.

	Use	**Demand (20 €/tCO_2) 2010**	
GWh	**in 2002**	**Wood fuels**	**Forest chips**
Municipal heating plants	2 210	3 900	2 270
Municipal CHP-plants	3 750	12 630	4 130
Industrial steam heating plants	3 040	3 990	1 410
Industrial CHP-plants	13 740	24 730	8 240
Condensing plants	1 410	2 930	930
In total	**24 150**	**48 180**	**16 980**

Wood fuel consumption in heat and power production was 24 TWh in 2002. By the year 2004 the consumption had increased to 27 TWh [4]. From this fuel volume, the share of by-products was 83% and forest chips 17%. Subtly over half of the fuel use was internally supplied and consumed in the same plant area and the rest was supplied from the market, as were all of the forest chips. In the year 2010, the demand for wood fuels in both cases (0/20 €/t CO_2) was estimated to double by the year 2010, being almost 50 TWh. The forest chips share of the demand was one third, i.e. 17 TWh. It was estimated that the supply of by-products would not increase much and therefore the outside supply from the market will increase. The potential demand in the situation of emission trade compared to the case without emission trade differed only at the condensing plants. The lower competitiveness to produce condensing power using peat and wood mixture compared to coal or gas diminished the wood fuel volumes to those plants using peat and wood fuels.

2.2 Evaluation of the potential supply of wood fuels

The supply potential was divided into forest chips and solid by-products from the forest industry. The forest chip sources included small diameter energy wood from young forests and logging residues and stumps from regeneration felling sites. All the enterprises in Finland producing by-products, i.e. sawmills, plywood and board mills, pulp mills and the wood product industry producing sawdust, bark, shavings, etc. were involved in this study. The plant data were based on Jaakko Pöyry Ltd's forest industry plant databases, which were complemented by making plant visits and holding interviews.

When analyzing the demand and supply potential of forest industry by-products, only part of the potential was actually marketable. This market potential consisted of by-product lots, which were sold outside the plant area. The internal energy use or pellet production, which was going to take place in the same area or near the plant area, was taken out of the total supply. Also, those by-product lots which go for raw-material use in the forest industry, such as a pulp and particle board production, were taken out.

The supply potential calculations of logging residues and stump biomass were based on databases of regeneration felling stands. Stand data was gathered from regeneration fellings of forest integrates from the year 2000 [5]. This data was evaluated to be valid to use in the calculations for the year of 2002 and 2010, since neither major changes in the volumes of felling areas nor the composition of stands are going to happen.

The stand data included position data and attribute data of stands, such as felling method, felled roundwood volumes by tree species, felling time of year, felling validity, forwarding distance and felling area. The stand data of forest integrates (140 000 ha) was complemented by adding other player's felling data, such as fellings of the Association of the Finnish Sawmills, i.e. independent family-owned sawmills, fellings of the Forest Management Associations and fellings of the Finnish Forest and Park Service, which is the state enterprise operating within the administrative sector of the Ministry of Agriculture and Forestry. The felling data (ha) of other players from the year 2000 was compiled at the forestry centre level

[6]. The volumes per hectare and the effect of stand selection criteria for logging residues and stump biomass were extracted by using the original stand data for each forestry centre separately. The calculated potential of other players was divided into municipalities by using the statistics of annual regeneration felling volumes in 2000 [7] and further located and added into original stand data within each municipality.

Both the theoretical and techno-economical potential were calculated for forest chips. The theoretical potential of logging residues based on felling residues collected from regeneration fellings, where the recovery rate was estimated to be 65%. Stump biomass was also collected from regeneration fellings, where 5% of stumps were assumed to left in the stand as a shelter-zone. Part of the stands were restricted from further calculation based on stand selection criteria (Table 2). The techno-economical potential was the result of this query including only the most favorable stands.

Table 2. Stand selection criteria.

Criterion	**Logging residues**	**Stumps**
Felling method	final fellings	clear fellings
m^3-volume/stand	$\geq$ 40	$\geq$ 40
m^3-volume/ha	$\geq$ 30	-
Forwarding distance	$\leq$ 350	$\leq$ 300
Composition of stand	-	spruce dominant
Stand size, ha	-	$\geq$ 1
Felling validity	-	no winter-validity
Others	-	stoniness, - 20%

The estimated accumulation of forest chips from young forests was based on sample plot data from the 8th and 9th national forest inventories (NFI 8 & 9) of Finland. Forestry district level NFI data was converted to the municipal level by using multi-source NFI data. Calculations of forest fuel resources were made for the advanced seedling stands and young thinning stands having need of improvement fellings within a five-year period.

Trees more than 9 cm diameter at breast height were classified as industrial roundwood and trees less than 9 cm and more than 4 cm diameter at breast height were classified as energy wood. Trees less than 4 cm diameter were not included in the total stem wood accumulation. The crown mass was added to the total stem wood accumulation using crown mass factors [8]. The mass was then further converted to volume using density factors [9]. The crown mass includes living branches and needles. In the total accumulation trees were not classified as industrial roundwood or pure energy wood because all trees were harvested by the whole-tree method for energy. In the calculation the recovery percentage was 100%.

Different stand/sample plot selection criteria were applied in the final summing [10]. These criteria were:

1. Maximum accumulation of industrial roundwood 25 m^3/ha
2. Minimum accumulation for energy fraction 25 m^3/ha
3. Nutrient criterion: Peatland stands and stands on mineral soil with sites poorer than the Myrtillus-type were excluded
4. Medium size of stem: Stem volume has to be at least 10 dm^3
5. Felling priority. The suggested cutting was urgent or delayed

The theoretical potential of forest chips from small diameter wood was based on criterion-level 1 and techno-economical potential level 5 in 2002. In 2010 the techno-economical potential was based on criterion-level 3, i.e. the nutrient criterion.

The availability of forest chips was calculated as a function of supply cost from different energy wood sources based on techno-economic potentials. It was assumed that all forest chips from the potential procurement area are freely available without prior sorting between different players. The roadside cost was defined for each energy wood source before the chipping and transporting phase. Stands were bound into the forest road network and the driving distance was calculated along a road-network from the origin point to the end-user site. The supply chain was based on the roadside-chipping supply method, where the energy wood was transported to the end-user site in the form of chips.

2.3 Implementation of the optimization model

The effect of competition to the potential availability and supply cost of energy wood for the end-user sites was evaluated by using the optimization model. The optimization was based on maximizing the profit for the forest chip producer, where the energy wood lots were delivered to the end-user having with the best paying ability. The starting point for the optimization was the different paying ability and fuel needs of the end-users. The paying ability of wood fuels defined the maximum price-level, which the end-user was willing to pay before exchanging it for a cheaper fuel option. In practice, the paying ability was determined on the grounds of peat price, excise tax of peat, energy wood production subsidies, electricity production support for wood and in the emission trade situation also on the grounds of the price of emission reduction units.

Both in the case of emission trade and without it, the demand for the optimization process was defined on the grounds of the techno-economical potential of wood fuels use. The optimization model only calculated the potential supply for the by-product lots going outside the plant area, which were treated as a market supply. Optimization was first carried out for by-products. After that it was attempted to fill the remaining demand using forest chips but at the same time taking into account the restrictions set for forest chips at the plant level. Stump biomass was dropped out of the optimization, since the economical supply chain for stumps based on end-use crushing stations were only available at a few power plants.

Optimization was executed nationally by defining the computational procurement areas around each end-user site by setting the maximum transport distance of 120 km. This made it possible to also take into consideration the effects of potential demand and supply from outside the normal procurement area.

3 RESULTS

According to Electrowatt-Ekono's forest industry database the total supply of by-products for energy use from sawmills, the wood pulp industry, the plywood and board industry and the wood products industry was 27 TWh in 2002. By the year 2010 the total supply of by-products was evaluated to increase steadily to the level of 28 TWh, from which the share of bark was 15 TWh (52%), sawdust 10 TWh (37%) and industrial chips 3 TWh (11%). Correspondingly, the market supply was a total of 11 TWh in 2002, from which the share of bark was 3TWh (25%), sawdust 6 TWh (55%) and industrial chips 2 TWh (20%). In 2010 the market supply was evaluated to stay almost unchanged at a level of 11 TWh (Table 3).

Table 3. Total and market supply of the forest industry by-products in 2002 and 2010.

	Total supply		**Market supply**	
GWh	**2002**	**2010**	**2002**	**2010**
Bark	14250	15100	2680	2730
Sawdust	9980	10440	5850	5970
Industrial chips	2700	2780	2080	2110
In total	**26930**	**28320**	**10610**	**10810**

The theoretical supply potential of forest chips was evaluated to be at a level of 51 TWh and that of techno-economical 24 TWh in 2010 (Figure 1). The theoretical supply potential divided evenly between logging residues, stumps and small diameter energy wood, each being 17 TWh. The largest share of the techno-economical potential came from logging residues 11 TWh (46%), whereas the share of stumps was 6 TWh (24%) and small diameter energy wood 7 TWh (30%). The techno-economical potential was mostly concentrated in the areas of Eastern and Central Finland (Figure 2).

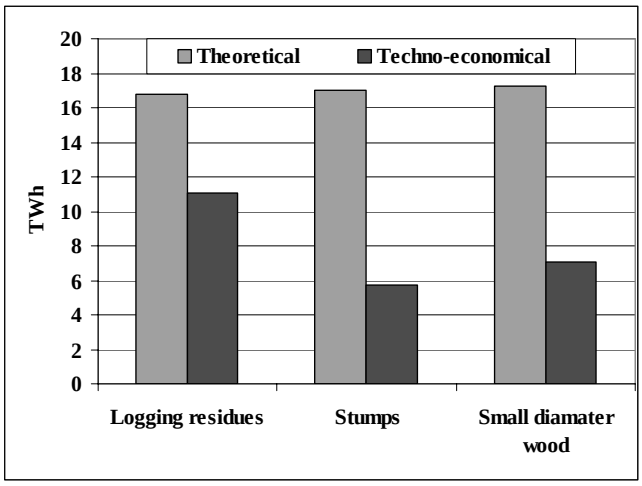

Figure 1. The theoretical and techno-economical supply potential of forest chips.

As a result of the regional optimization model, the optimal wood fuel use was 29 TWh, which accounted for 59% of the demand from outside the plant area in the situation without emission trade in 2010. In the situation with emission trade the use was 33 TWh, which accounted for 68% of the potential demand. Regionally, the potential demand for wood fuels for energy use was higher than the potential supply in all provinces.

In the situation without emission trade the optimal use of wood fuels was divided between by-products 22 TWh (76%) and forest chips 7 TWh (24%). In the emission trade situation the use of by-products was 23 TWh (69%) and forest chips 10 TWh (31%) correspondingly. The better paying ability within plants belonging to the emission trading system made it possible to increase wood fuel use. According to the results of the optimization model the largest use of wood fuels were in the provinces of South-Karelia and Central-Finland. The wood fuel demand and supply was met in the best way in the provinces of South-Karelia, Kanta-Häme and North-Savo, in which the wood fuel deliveries accounted for over 78% of the potential demand. The largest delivery problems were in the provinces of North-Ostrobothnia and Central-Ostrobothnia, where deliveries met less than 45% of the potential demand (Figure 3).

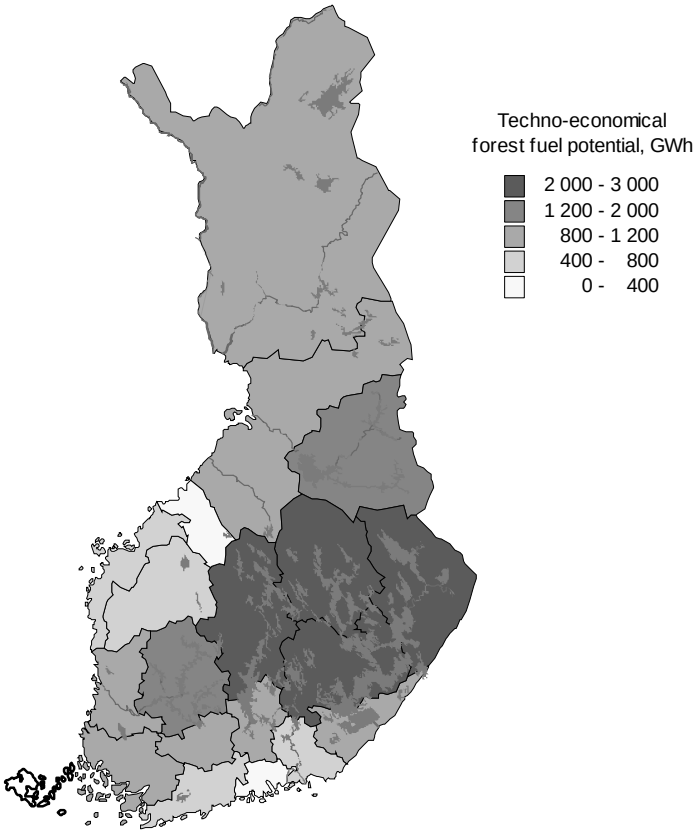

Figure 2. The techno-economical supply potential of forest chips at a provincial level in 2010.

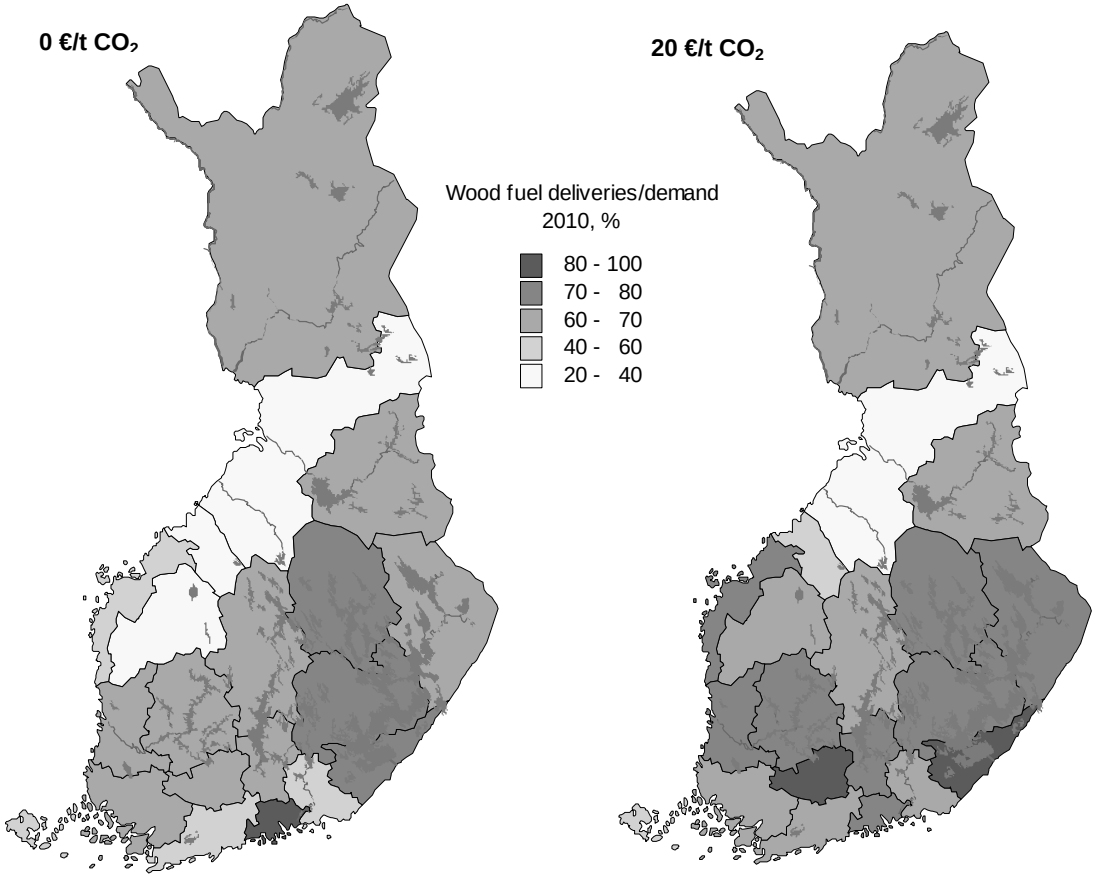

Figure 3. The wood fuel deliveries against the potential demand of wood fuels according of the optimization model at a provincial level in 2010.

4 CONCLUSIONS

In 2010, the demand for wood fuels outside that for the internal use of the plant area has been estimated to be 36 TWh without the emission trade and 35 TWh with the emission trade situation. The marketable by-products from the Finnish forest industry (11 TWh) and the techno-economical potential of forest chips (24 TWh), will not meet the demand in either case in 2010. In the long-term, the growth rate of wood fuel demand will be affected by the investment rate of wood fuel receiving systems in the new power plants and the choices of boiler technology and the potential competition between power plants and wood fuel refiners (pellets, liquids) from the same raw-material. Regionally, the balance in meeting the demand and supply varies greatly, which affects the planning process of locating the potential new end-user sites. The potential growth of wood fuel supply comes from small diameter energy wood sites, stump biomass and importing energy wood from Russia and the Baltic states, whereas the growth potential of the by-products of the forest industry and the logging residues from regeneration fellings is minor. The use of stump biomass will concentrate on regions, where there are crusher stations either in terminals or at end-user sites. In practice, agrobiomass can complement forest chip deliveries only to some extent.

The change in the ability to pay for wood fuels among power plants, which is accrued from the emission trade, will also reflect on wood fuel deliveries. On the one hand the emission trade will increase the competitiveness of wood fuels compared to other fuels, but on the other hand their deliveries will move more and more from plants outside the emission trade to plants within the trade. For example, wood fuel deliveries can move from municipal plants to industrial plants within the forest industry with the help of their wood supply organizations. This will decrease the potential wood fuel availability for municipal heating stations. Plants outside the emission trade system and the pellet factories buying their raw-material from the outside market will be the largest potential losers in the wood fuel supply market.

Increasing the targeted wood fuel use presupposes finding new raw-material sources but also new logistical supply solutions like other transport modes (train, shipping) and regional buffer storage networks. This makes it possible to widen the traditional procurement area based on truck transportation. The magnitude of supply security and the quality needs of end users will also be highlighted with wood fuels, if their share of fuel usage is to be increased. Wood fuels have to be available all the year round and they have to meet the quantity and quality demands of different kinds of end-users.

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