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FINNISH FOREST ENERGY SYSTEMS AND CO_2 CONSEQUENCES

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Abstract—The development of wood fuel production technology has been active in Finland since 1993, when the Ministry of Trade and Industry started eight new energy technology research and development programmes, one of which is the Bioenergy Research Programme. The objective is to improve the competitiveness of indigenous fuels—wood fuel and fuel peat—compared to imported fossil fuels.

Due to new, effective equipment and good logistics, production costs of fuel chips from logging residues have decreased by 25%, and are now approaching the target of 8.5 USD/MWh (45 FIM) with transportation distance being up to 80–100 km. This price target was set at the start of the Bioenergy Research Programme, but it is still valid corresponding to the price level of fuel peat and coal for big power plants.

When harvesting young stands for pulp wood and energy production, whole-tree chipping and tree section logging followed by different processing methods—chain-flail techniques, MASSAHAKE-method—have been demonstrated, but they have not yet achieved wider use.

CO_2 emissions were calculated for the wood fuel production from logging residues, and emissions of production and combustion of wood fuel and coal, oil and fuel peat were compared. If the target of substituting 1.5 million tons of oil equivalent (toe) in Finland by 2010 is fulfilled, the reduction of CO_2 emissions will be 4.2 million tons, corresponding to 6.9% of the emissions in 1996. © 1998 Elsevier Science Ltd. All rights reserved

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1. INTRODUCTION

The total energy consumption in Finland from 1994 has been nearly 32 million toe per year.[1] Nearly half of that is consumed by industry, and forest industry accounts for 60% of the aggregate consumption of energy by industry.[2] Abundant forests and prosperous forest industry give good bases for the use of wood derived fuels, black liquor, bark and wood waste. The production and combustion of fuel peat, another indigenous fuel, have highly developed technology in Finland. Bioenergy accounts for over 20% of the total energy consumption. Wood derived fuels corresponded to 4.3 million toe and fuel peat to 1.8 toe in 1995.

The use of proper forest energy produced from logging residues and unmerchantable wood is still very low accounting for about 300000 m^3 (solid volume), corresponding to 500 GWh, at heat and power plants.[3] Firewood production for small houses is about 5.6 m^3 (11 TWh). There is a good challenge to increase the use of environmentally sustainable domestic forest energy. There are estimates that 8.6 million m^3 of wood fuel could be produced from logging residues and altogether at least 10 million m^3 (about 2 million toe) more wood fuel annually.[3]

The primary source of forest energy is logging residues from regeneration fellings. Precommercial and commercial thinnings of young stands are inevitable for good timber production. By integrating pulp wood and wood fuel harvesting, i.e. tree-section and whole-tree harvesting, the recovery of biomass for energy purposes can be four–five times the amount we get by conventional methods where trees are delimbed. At the same time even the yield of raw material for pulp making can increase.

In the Bioenergy Research Programme[4] the target for new large-scale production systems of wood fuel was expressed as to achieve the production potential of at least 1 million toe per year (about 5.5 million m^3 of wood fuel). Later, the government set the goal to increase the use of bioenergy by 1.5 million toe (about 25%) by the year 2005. Practically, this means mainly an increase in wood fuel.

Table 1. The production costs of three wood fuel systems, USD/m³ (solid volume), when the transportation distance is 60 kilometres

Chipping at roadside system		Chipharvester system		Chipping and transport system	
Forwarding	3.40			Forwarding	3.06
Chipping	6.33	Forwarding + chipping	11.57		
Transport	6.40	Transport	4.89	Chipping + transport	10.11
Management	1.32	Management	1.32	Management	1.32
Total	17.45	Total	17.78	Total	14.49

2. WOOD FUEL PRODUCTION FROM LOGGING RESIDUES

There are three systems in use to produce fuel chips from logging residues.[5] The most common is that residues are forwarded to roadside inventory and comminuted there by a truck-mounted chipper. The chipper blows the chips directly into the container of a truck that has to wait for the chippings. In this system idle times occur, such as when the chipper has to wait for the transportation truck and, when using several trucks, they have to wait for chippings to be loaded. However, one chipping contractor, Kotimaiset Energiat Pekka Lahti Ky, constructed a new chipper that very well meets the requirements to comminute rather incompact logging waste. The capacity of this system based on chipping at the roadside is about 43000 m³ (solid volume) of chips per year (77000 MWh).

When doing the chipping on site with a forwarder-type chipharvester and using interchangeable containers for transport to a power plant, the dependance of chipping and transport can be avoided. Oy Logset Ab, a harvester and forwarder manufacturer, constructed a new chipharvester, CHIPSET 536 C, which productivity studies have shown to be more efficient than earlier chipharvesters. Its capacity is about 20000 m³ of chips per year (36000 MWh).

Another system for fuel chips production was developed and introduced by Metsäenergia MetEr Ky, a forest energy operator. The company constructed a chipper truck MOHA-SISU that combines the comminution and transport. The base machine is modified from an all-terrain truck, equipped with a drum chipper and interchangeable containers. On easy terrain logging residues need not be forwarded at all. The whole production system is operated by one man and machine resulting in high productivity. The capasity of MOHA-SISU is about 26000 m³ of fuel chips per year (47000 MWh).

Table 1 presents the production costs when delivering fuel chips from forest to power plant by these three systems in Finnish conditions. Forwarding distance is 250 metres, 1 m³ wood fuel corresponds to 1.8 MWh, 1 USD is about 5.3 FIM. The costs do not include value added tax.

The transportation distance being from 40 to 80 kilometres, the production costs of fuel chips from logging residues vary from 7 to 10.4 USD/MWh (Fig. 1). To achieve these costs, the systems must be operated efficiently some 10 months per year, and the machinery must be properly equipped. We can see that the system where chipping and transporting is combined is the cheapest and near the target

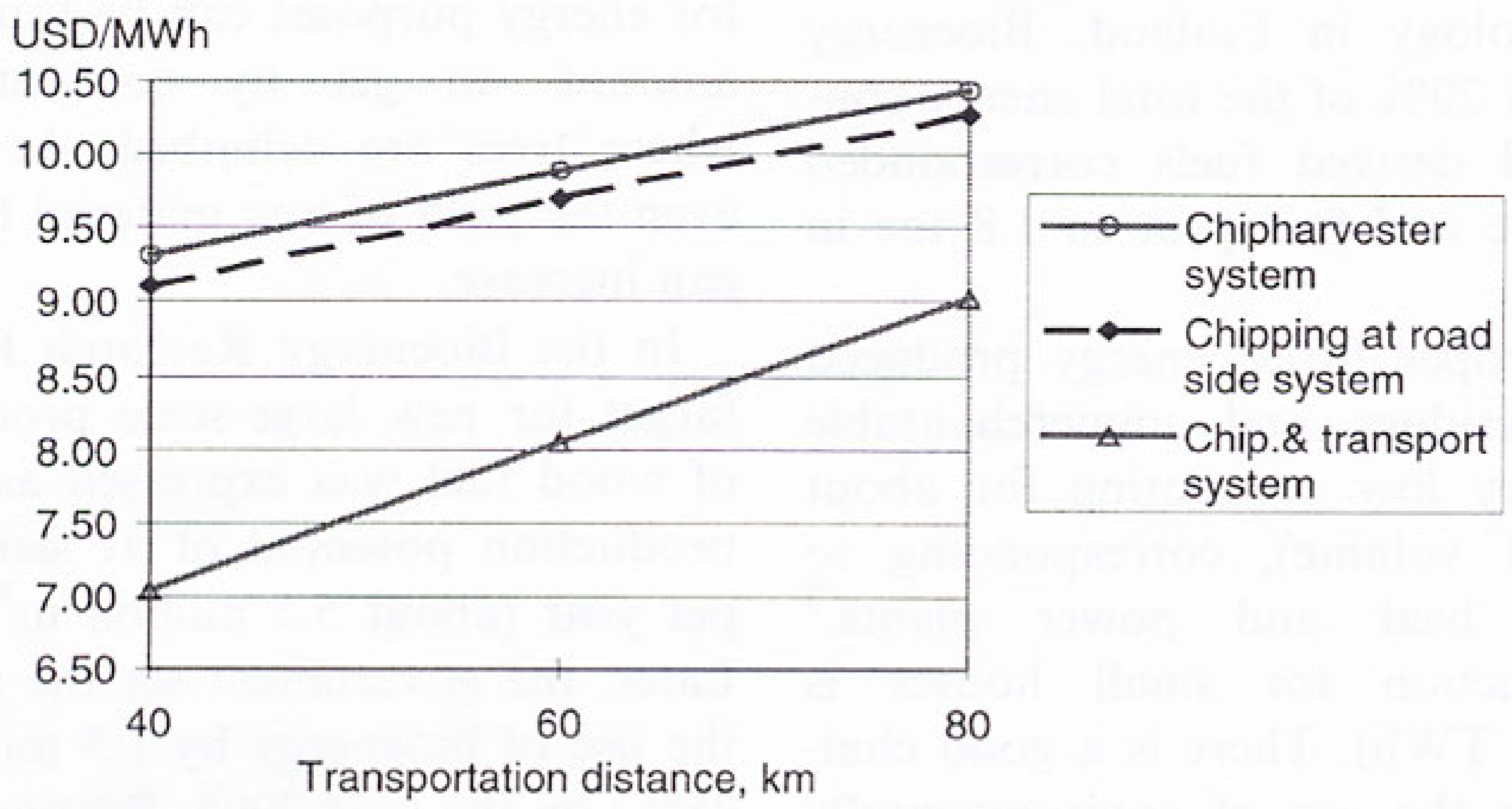

Fig. 1. Wood fuel production costs, USD/MWh, transportation distance being 40 to 80 km.

of 8.5 USD/MWh even with long transportation distances.

3. INTEGRATED PRODUCTION OF WOOD FUEL AND PULP WOOD

Pulp wood from thinnings of young stands is harvested, mainly delimbed, and cut into 5-meter lengths for transport. In the Bioenergy Research Programme several integrated methods have been studied and demonstrated. Tree-section harvesting increases the yield of biomass for energy and undelimbed tree-sections can be processed at the pulp mill by an ordinary debarking drum. This system was tried in the early 1980 s, but because of poor load size in transportation of tree sections, the quality aspects of pulpwood and the high productivity of one-grip harvesters, the tree-section method has never been widely used. Recent studies, however, show that there are means to increase the productivity of logging and transport. Trials with a multi-tree felling device and compressive load space have given promising results.[6]

In order to process small diameter pulpwood from young stands separately from other pulpwood, chain-flail technology has been applied. After contracting with a portable Peterson Pacific delimber-debarker-chipper, Pertti Szepaniak Oy constructed a pilot plant, where chain-flail processing is followed by small-scale drum debarking.[7,8] Thus the debarking result fulfils the requirements and wood loss remains tolerable. The plant is in use at mills owned by one of the largest pulp and paper manufacturers in Finland—Enso Oyj.

Whole-tree chipping has always been very tempting when harvesting small-size trees. It was tried in the 1960's, but the screening by mechanical devices did not result in product good enough for pulping. VTT Energy launched the MASSAHAKE-method,[9,10] where mechanical screening is complemented by grinding chips into loose bark and the final screening is made by optical sorter. The pilot plant started in 1996, but because it is not connected to any pulp mill and there has been recession in the pulp chip market, the plant has not yet reached full capacity.

It is a rather complicated task to study and compare the competitiveness of different integrated production systems. In Finland the price for energy components is so low that it cannot compete with the wood raw material that has industrial use, mainly for pulp production. The principle is that when introducing integrated methods, the price for pulp wood is not allowed to increase from what it would be if the conventional harvesting method were used, so the study should include even the pulp production. We have made some studies to that end in cooperation with the Finnish Pulp and Paper Research Institute.[6,11]

When applying integrated methods, we obtain more energy subjects—branches, tops, needles, bark—than through conventional harvesting. This energy component subsidises the pulp making or the production system.

In Table 2, the production costs shown are calculated on the bases of studies concerning the integrated methods above described. Because there are no steady practices, one should consider the results as preliminary. The harvesting object is a young pine stand that is in the stage of first commercial thinning. The minimum top diameter is in the conventional system 7 cm and in tree-section systems 5 cm on bark. The results show that integrated systems could be used instead of the conventional system, if more wood energy is wanted. At the moment, however, the possibility of pulp mills benefiting from extra forest energy is rather limited. Most of our pulp mills produce chemical pulp for paper products in which

Table 2. Main characteristics of integrated production of wood fuel and pulpwood from a first thinning pine stand

	Delimbed pulpwood, drum debarking	Tree-sections, drum debarking	Tree-sections, chain-flail debarking	Whole-tree chips, Massahake method
Yield, m^3/ha	40.9	59.9	59.9	70.0
Relative yield	1.00	1.30	1.30	1.71
Costs at mill, FIM/m^3	39.72	34.00	34.00	31.13
Costs per stem wood	39.72	37.92	37.92	37.74
Costs of pulp chips (e.s.)	45.72	44.38	45.28	46.32
Relative cost of pulp (e.s.)	1.00	0.96	0.98	0.94

(e.s.) means that an energy subsidy of 8.5 USD/MWh due to the solid energy component is taken into account

Table 3. CO_2 emissions of wood fuel chips production from logging residues, kg/m^3 produced wood fuel

Chipping at roadside system		Chipharvester system		Chipping and transport system	
Forwarding	2.1			Forwarding	1.9
Chipping	6.1	Forwarding + chipping	8.4		
Transport	1.9	Transport	2.0	Chipping + transport	12.2
Total	10.1	Total	10.4	Total	14.1

using the wood of young trees with short fibers is not desirable. And competitive power production from forest biomass is not always technically possible.

4. CO_2 CONSEQUENCES OF WOOD FUEL PRODUCTION

CO_2 emissions were determined by the calculation model developed at Metsäteho Oy.[12] Calculations were made for the wood fuel production from logging residues in the case where the transportation distance was 60 kilometres (Table 3). Emissions were calculated on the bases of fuel consumption of the production machinery. Fuel consumption data was measured during the production studies or given by the contractor. When calculating CO_2 emissions, the specific weight of 840 g/dm^3 diesel fuel oil and CO_2 emission of 2600 g/dm^3 fuel oil were used.[13]

When one cubic meter of wood fuel corresponds to 1.8 MWh, the CO_2 emissions of the production (including harvesting, chipping and delivery to the heat and power plant but not including forest regeneration and maintenance) of one MWh wood fuel vary from 5.6 to 7.8 kg.

Wihersaari[14] has estimated and compared the emissions of production and combustion of different fuels in Finnish conditions. In the study emissions of production, processing and refining, transport and storage, as well as combustion, were determined. For coal, CO_2 emissions were about 341 kg/MWh and for oil, 304. Fuel peat also releases a great amount of CO_2, some 400 kg/MWh.

When substituting fossil fuels and fuel peat with wood fuel we could reduce CO_2 emissions remarkably. In the case of substituting coal with wood fuel, emissions would decrease by 331 kg/MWh energy produced, and when compared to oil the benefit is 294 kg/MWh.

5. CONCLUSIONS

Integrated production of wood fuel and pulpwood cannot be increased rapidly in the near future. Pulp mills do not have the capacity to increase the use of first thinning pulpwood nor combustion of solid biofuels which means that tree-section or whole-tree harvesting for pulp mills cannot be applied. The refining of whole-tree chips has not yet reached well-working applications. So integrated methods will play only a minor part in substituting fossil fuels.

The target to increase the use of bioenergy, mainly forest energy, by 1.5 million toe by the year 2005 corresponds to some 8 million cubic meters of wood fuel. This indigenous fuel will substitute mainly oil. In the stage of full substitution the reduction of about 4.2 million tons of CO_2 emissions will be obtained. In the year 1996 the total emissions in Finland were about 61 million tons,[15] thus a reduction of 6.9% in CO_2 emissions could be achieved. By 2010, however, Finland should reach the level of emissions that in 1990 was about 53 million tons.[1]

The Bioenergy Research Programme is a very good tool with which to carry out research and technical development for improving bioenergy production and to provide information needed for decisions of energy policy. The Programme also offers a good forum for dissemination of research and experiment results between researchers and professionals who implement the results.

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