ENERGY EFFICIENCY AND CO_2-EQ EMISSIONS OF FOREST CHIP SUPPLY CHAINS IN FINLAND 2020

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ABSTRACT: The research carried out by Metsäteho Oy calculated what would be the total fuel consumption and CO_2-eq emissions of forest chip production if the use of forest chips is 24 TWh in 2020 in Finland in accordance with the target set of Long-term Climate and Energy Strategy. CO_2-eq emissions were determined with Metsäteho Oy's updated Emissions Calculation Model. If the production and consumption of forest chips in Finland are 24 TWh in 2020, then the total CO_2-eq emissions would be around 245 000 tonnes. The volume of diesel consumption was 79 million litres and petrol 1.5 million litres. Electric rail transportation and chipping at the mill site consumed 15 GWh of electricity. The supply chain with the lowest CO_2-eq emissions was logging residues comminuted at plant. Conversely, the highest CO_2-eq emissions came from stump wood when operating with terminal comminuting. Some 3% of the energy content was consumed during the forest chip production. Energy input/output ratio in the total volume was 0.030 MWh/MWh which varied from 0.022 to 0.044 between the supply systems researched. Hence, forest chip production gave a net of some 97% of the energy content delivered at the plant.
Keywords: CO_2-eq emissions, Forest biomass, Finland.

1 INTRODUCTION

The use of forest chips in Finland has increased rapidly in the 21st century: In the year 2000, the total use of forest chips for energy generation was 1.8 TWh (0.9 mill. m^3), while in 2008 it was 9.2 TWh (4.6 mill. m^3) [1]. Of this amount, 8.1 TWh was used in heating and power plants, and 1.1 TWh in small-sized dwellings, i.e. private houses, farms, and recreational dwellings, in 2008 [1].

Of the forest chips used in heating and power plants (8.1 TWh), the majority (58%) was produced from logging residues in final cuttings in 2008 [1]. Forest chips derived from stump and root wood totalled 14% and 4% came from large-sized (rotten) roundwood. 24% of the total amount of commercial forest chips used for energy generation came from small-diameter ($d_{1.3}$<10 cm) thinning wood produced in the tending of young stands [1].

According to the EU's Climate and Energy Policy, the renewable energy target is to increase the consumption of renewable energy sources to 20% of total final energy consumption by the year 2020. In Finland, this target means increasing the proportion of renewable energy sources to 38% [2]. Wood-based fuels are the most important renewable energy source in Finland, and forest chips are considered to be one of the most important wood fuel sources in the future.

In the context of the Long-term Climate and Energy Strategy in Finland [2], it is estimated that the primary use of wood-based fuels will be 97 TWh (Objective Vision) by the year 2020. The overall target set for forest chips is 12 million m^3, i.e. around 24 TWh by 2020 [2]. According to the latest calculations [3], the potential amount of techno-economically harvestable forest chips is annually 11–28 TWh, which is strongly dependent on the price level for emission rights. Kärhä et al. [4] calculated if the production and usage of forest chips in Finland are 24 TWh in 2020 in accordance with the target set of Long-term Climate and Energy Strategy [2], then the demand for new production machinery would be nearly 1,800 machine and truck units.

The research carried out by Metsäteho Oy calculated what would be the total fuel consumption and CO_2-eq emissions of forest chip production if the use of forest chips is 24 TWh in 2020 in Finland. The main results of the study are presented in this conference paper.

2 MATERIAL AND METHODS

CO_2-eq emissions were determined with Metsäteho Oy's updated Emissions Calculation Model. The model has 15 years of history in traditional wood procurement and long-distance transportation, as well as silviculture and forest improvement activities. Occasional calculations related to the forest biomass systems' CO_2 consequences have been carried out. At present, the production of forest chips has been included in the Model with full weight.

The source of emission factors and main reference of fuel and energy consumption was VTT's TYKO and RAILI Databases for working machines and traffic [5, 6]. Besides, co-operation with KCL related to EcoData calculation model [7] have long tradition.

The separate survey for determining the current fuel consumption of forest chip production machinery in Finland was conducted in the research [8]. The reports published by Metsäteho Oy concerning the fuel consumption in industrial roundwood procurement [9, 10] were also utilized when clarifying the fuel consumption of forest biomass production machinery in the study. The results of the latest productivity studies and empirical productivity data of forest chip production [11–23] were used as the productivity and performance basis for machine and truck units in the calculations of CO_2-eq emissions.

In the emissions calculations, the production and consumption of forest chips was 24 TWh in 2020. It was assumed that 45% of the forest chips used in 2020 would be produced from logging residues, 20% from stump and root wood, and 35% from small-sized thinning wood harvested in young stands (Fig. 1) [cf. 1, 3, 4, 24]. The main supply chain of chips from logging residues and small-diameter thinning wood was roadside chipping, and for stumps crushing at the plant (Fig. 2) [cf. 4, 24, 25].

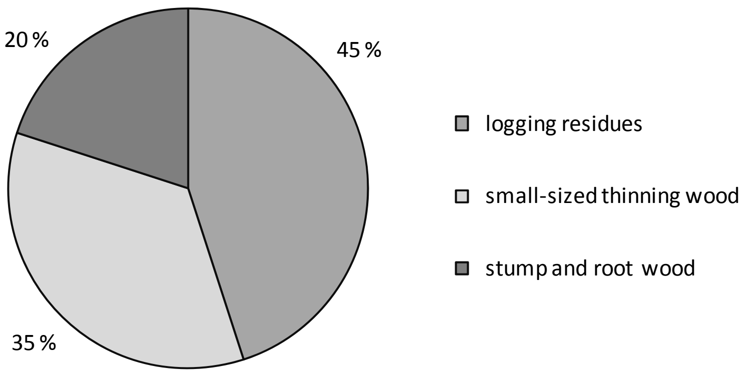

Figure 1. Distribution of forest chip supply sources in the study.

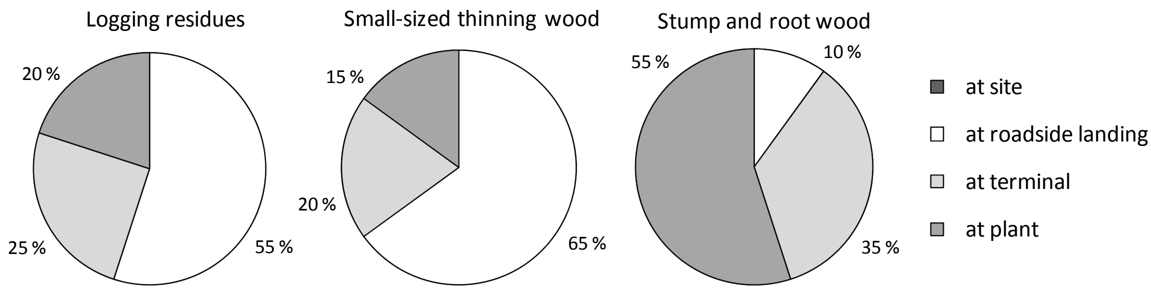

Figure 2. Distributions of comminution methods by supply source in the study.

Road transportation was the most widely used long-distance transportation method in the calculations (Fig. 3). Almost 60% of forest biomass (m^3km) was transported by truck from roadside landings to the energy plant, or to some other production mill. 12% transportation volume was by train, with either electric or diesel locomotives, and 15% by barge.

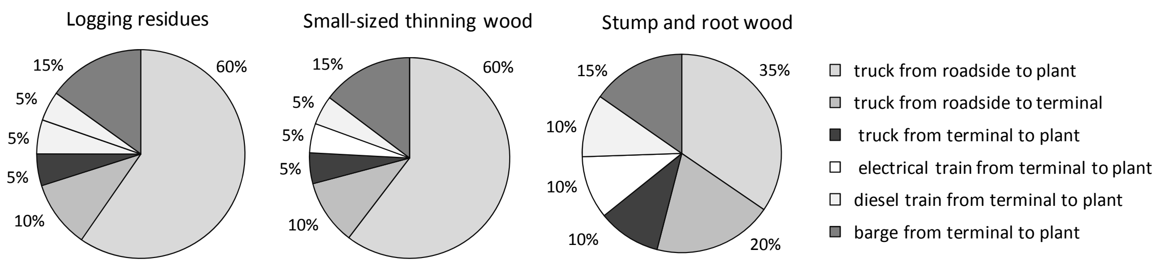

Figure 3. Distributions of long-distance transportation methods by supply source in the study.

3 RESULTS

3.1 Fuel and electricity consumption

If the production and consumption of forest chips in Finland are 24 TWh in 2020, then the total CO_2-eq emissions would be around 245 000 tonnes (Fig. 4). Of this amount, the proportion of forest chip harvesting operations was 58%, long-distance transportation 30%, silviculture and forest improvement works 2%, and production of diesel and fertilizer 10%. The volume of diesel consumption was 79 million litres and petrol 1.5 million litres. Electric rail transportation and comminuting at the mill site consumed 15 GWh of electricity.

3.2 Energy input/output ratio

In the study, the supply chain with the lowest CO_2-eq emissions was logging residues comminuted at plant (Fig. 5). Conversely, the highest CO_2-eq emissions came from stump wood when operating with terminal comminuting. In other words, the supply chains with the best energy input/output ratio were logging residues with comminution at roadside landing and plant, as well as logging residues bundles with comminution at terminal. Correspondingly, stump and root wood supply chain with comminution at terminal had the highest ratio.

Some 3% of the energy content was consumed during the forest chip production. Energy input/output ratio in the total volume was 0.030 MWh/MWh which varied from 0.022 to 0.044 between the supply chain alternatives studied (Figs. 6–8). Hence, forest chip production gave a net of some 97% of the energy content delivered at the plant.

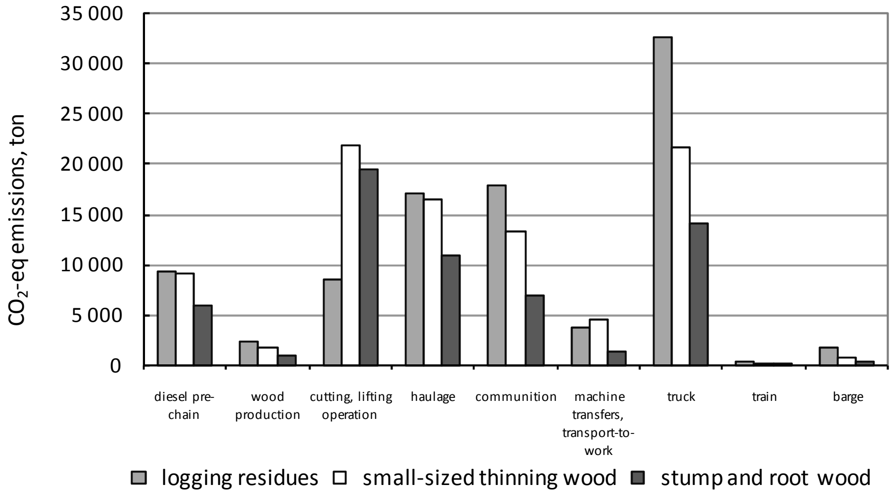

Figure 4. Volume of CO_2-eq emissions of a study, 241 000 tonnes in total, with the supply sources used.

Figure 5. Relative CO_2-eq emissions (kg/m^3) of forest chip supply chains in the study. CO_2-eq emissions of 100 = Logging residues, comminution at roadside landing.

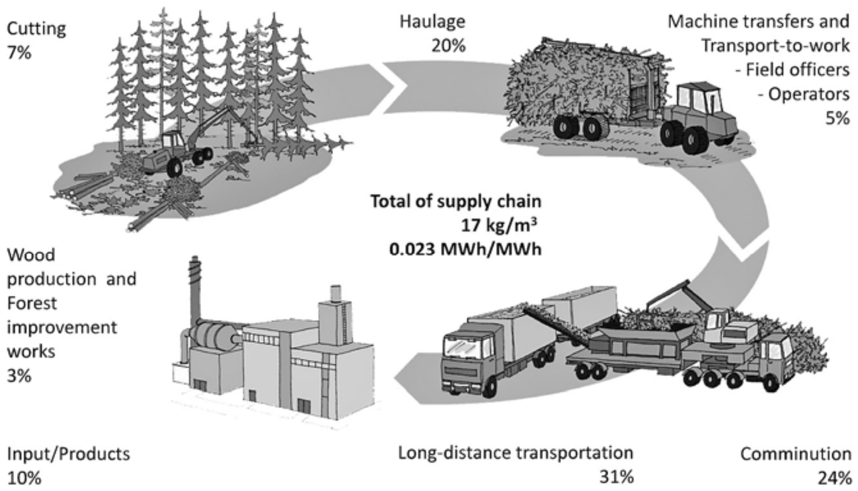

Figure 6. CO_2-eq emissions (kg/m^3) of logging residue chips with roadside comminution supply chain in the study.

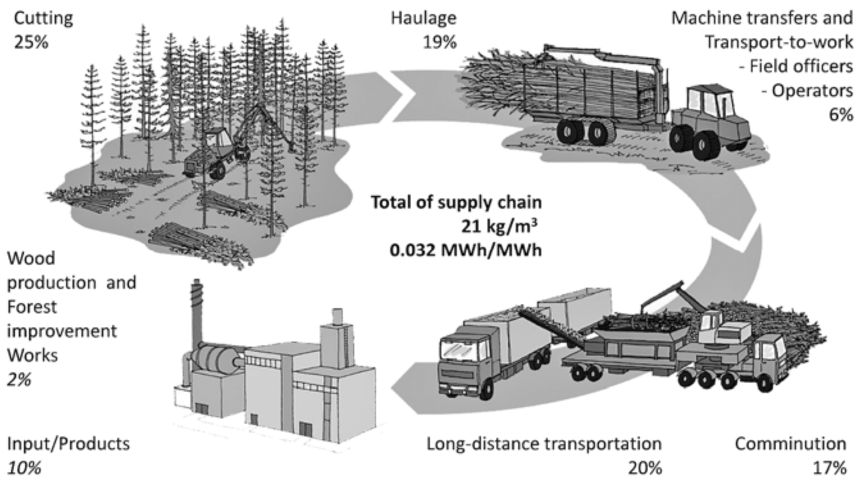

Figure 7. CO_2-eq emissions (kg/m^3) of small-diameter thinning wood chips with roadside comminution supply chain in the study.

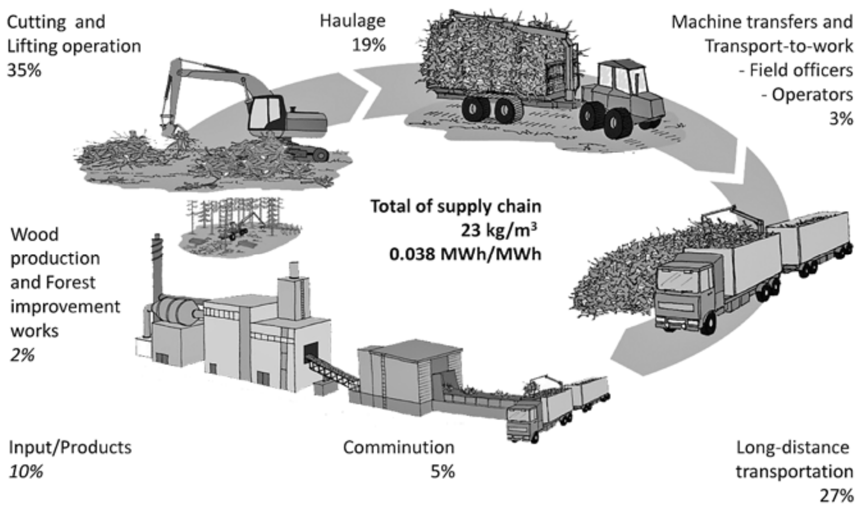

Figure 8. CO_2-eq emissions (kg/m^3) of stump and root wood chips with supply chain based on comminution at plant in the study.

4 DISCUSSION AND CONCLUSIONS

A lot of discussion about the energy efficiency of forestry production chains and the CO_2-eq emissions of different fuels have been presented. The importance of decreasing energy use, as well as monitoring and reducing greenhouse gases are a general subject for further development. Therefore, Metsäteho Oy undertook this study on the CO_2-eq emissions in forest chip production by alternative supply chains in Finland in 2020. The study results indicated that the energy input/put ratio of forest biomass is good. With our supply mix, forest chip production gave a net of some 97% of the energy content delivered at the plant. The findings are in line with the earlier CO_2-eq emissions made in Finland [26, 27].

Emissions calculations have to continue to provide information that is vital for the future development. In Finland, the comprehensive forest work studies of mechanized felling and forest haulage was carried out in the 1980's and 90's, and now is time for deep understanding of production of forest chip technology and energy efficiency, as well as realistic alternatives of forest chip supply chains in future.

This study gives a reasoned estimation of forest biomass supply sources, supply chains and machinery, as well as CO_2-eq emissions related to the target for the year 2020 (24 TWh). Calculation the CO_2-eq emissions were determined for different chip raw material flows (chips from small-sized thinning wood, logging residues, and stump and root wood), and for various supply chains (comminution at roadside landings, at terminals, and at power plants, or at some other production mills).

In the calculations, it was assumed that the share of stump wood chips will be increasing, as well as the share of terminal comminuting in the production of forest chips [cf. 3, 4, 24, 25]. The productivity levels of machines and vehicles are assumed to be almost at the same level than nowadays. In the future, development of machine and equipment technology, new technical and mechanical innovations and rationalization of working methods will help to boost the operating performance of machine and vehicle units and further to decrease the CO_2-eq emissions of forest chip production. In contrast, less favorable harvesting conditions (i.e. less removals, more difficult terrain, and longer forwarding distances) and lengthening transportation distances are obstacles to lowering energy consumption and CO_2-eq emissions of machinery [cf. 4, 24, 28].

Just for understanding of causation for differences between supply chains based on different machinery and logistics, there need to be mention some examples: Forest haulage and long-distance transportation of logging residues are more productive compared with the other forest chip supply sources. Lifting operation and comminution of stump wood consume a lot of energy. Cutting of small-diameter thinning wood is not effective from a fuel consumption point of view.

Silviculture and forest improvement activities' emissions were included into the Model, as well as machine transfers and transport-to-work and production of diesel and fertilizer. As an example, fuel consumption of truck has calculated by Metsäteho's sensitive fuel consumption model. Emissions were calculated by type of forest chip supply chain, combined with appropriate long-distance transportation methods.

As a significant part of the study, a sensitivity analysis was performed to point out the influence of different parameters and to underline the importance of data management behind the emissions calculations.

In practice, the supply chain mix depends on the availability of supply chain combinations, machinery, and machine operators. The differences of emissions are due to the productivity and fuel consumption of different kind of technology, but also because of realistic combination of supply chains and available machinery. We have to look at the whole production system, hence there is no sense to compare supply chains without realistic, comprehensive boundaries.

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