

Feedstock Supply Chain CO₂-eq Emissions

A Case Study on Forest Biomass for 2nd Generation Liquid Traffic Fuel



As a part of climate and renewable energy policies, national targets are being set for minimum shares of renewable fuels of total traffic fuel consumption. The EU is planning to introduce sustainability requirements including minimum targets for greenhouse gas (GHG) reduction to be achieved by liquid traffic biofuels. Forest residues have been gaining interest in being used as a feedstock for liquid biofuels. There are only a few comprehensive studies on GHG emissions available, therefore Metsäteho Oy undertook a case study of the feedstock supply chain GHG emissions in forest chip production. Feedstock supply chain is only a part of the entire “stump-to-wheel” production chain of liquid traffic biofuel. Nevertheless, forest residues already look promising as a feedstock for biomass-to-liquid traffic fuel in terms of GHG reduction and energy efficiency.

In addition to climate change, the target of increasing self-sufficiency of energy supplies is high on many countries political agenda. Renewable biomass is already an established, important source of power and heat. The forest industry is the world’s biggest producer and user of biomass-based energy. In OECD countries, the forest industries share is over 50%.

First generations of liquid biofuels, mainly ethanol and diesel, have relied on oil, sugar or starch from foodstuff raw materials. In addition to concerns over interfering with food-chains, the achieved GHG reduction in so-called well-to-wheel comparisons with traditional fossil traffic fuels have been claimed to be too low. Reliable availability and sustainability of non-food cellulosic feedstock like forest residues are increasingly in focus when developing more environmentally beneficial 2nd generation liquid traffic fuels.

Stora Enso and Neste Oil have formed a joint venture company, NSE Biofuels Oy, which is testing and developing gasification of forest biomass followed by Fischer-Tropsch– synthesis. It produces biocrude-oil from synthesis gas, which is

mainly comprised of hydrogen and carbon monoxide. These primary F-T liquids will be upgraded to diesel fuel at a refinery.

In this case study calculation, the CO₂-eq emissions were determined for different chip raw material flows (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). The calculations covered, with some exceptions, full supply chains of 1 Mill. m³ (solid) of forest chips, based on preconditions of one Finnish pulp and paper integrate of Stora Enso within a radius of 100 to 120 kilometers.

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 emission calculations. Emissions were calculated by type of chip supply chain, combined with long-distance transportation methods available around the selected integrate. Also, silviculture and forest improvement activities’ emissions were included into the model.

Logging residues were assumed to make more than half of the case's volume of forest chips.

Proportion of stump and root wood was almost 1/3 and small-sized thinning wood only 1/10 of the needed 1 Mill. m³ (solid) total volume.

The most commonly used comminution location, in this study case, was comminution at terminals.

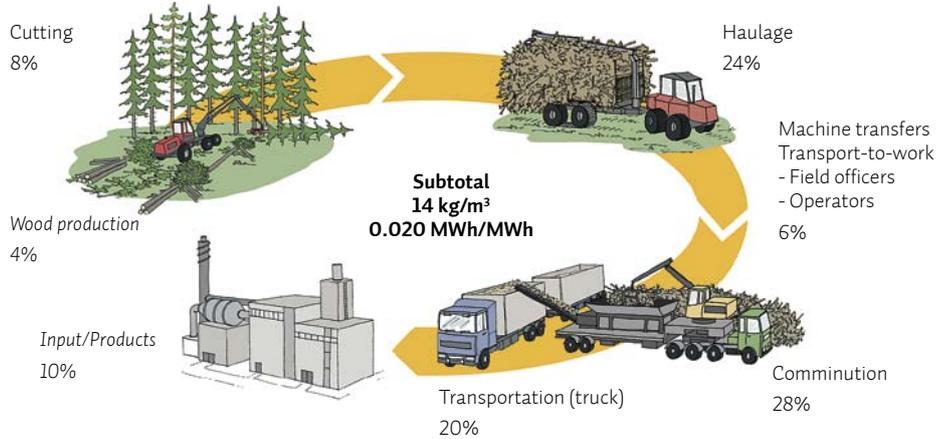
Mobile chippers were mainly used. In the near future, larger and even electric powered chippers maybe utilised. Both comminution at roadside landing and at the plant covered ca. 1/3 of the total volume.

Road transport was the most widely used long-distance transport method and will remain the same in future.

More than half of forest biomass (m³) was transported by truck from roadside to the mill. One fourth of transportation volume (m³km) was by train, with either electric or diesel locomotives. The proportion of waterway transportation by barge was also 1/4. Promising new tests have been made on barge transportation of forest chips in the Finnish lake district.

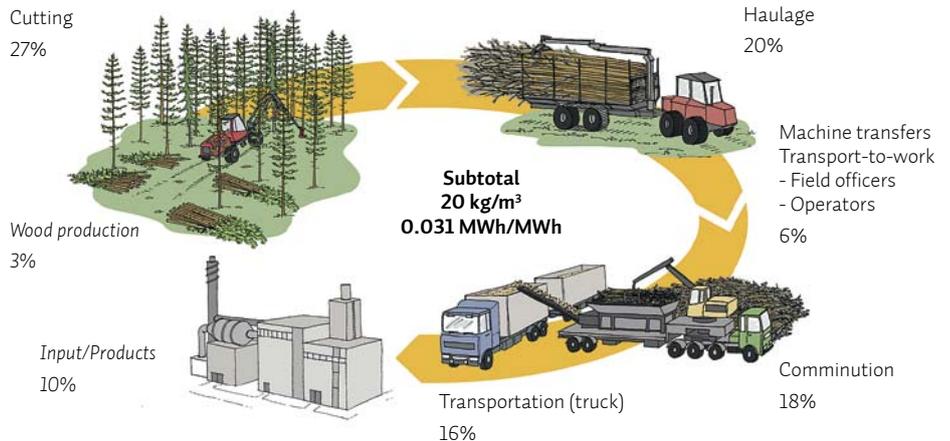
Emissions of Major Supply Chains of the Case Study

■ **Logging residues comminuted at roadside landing**



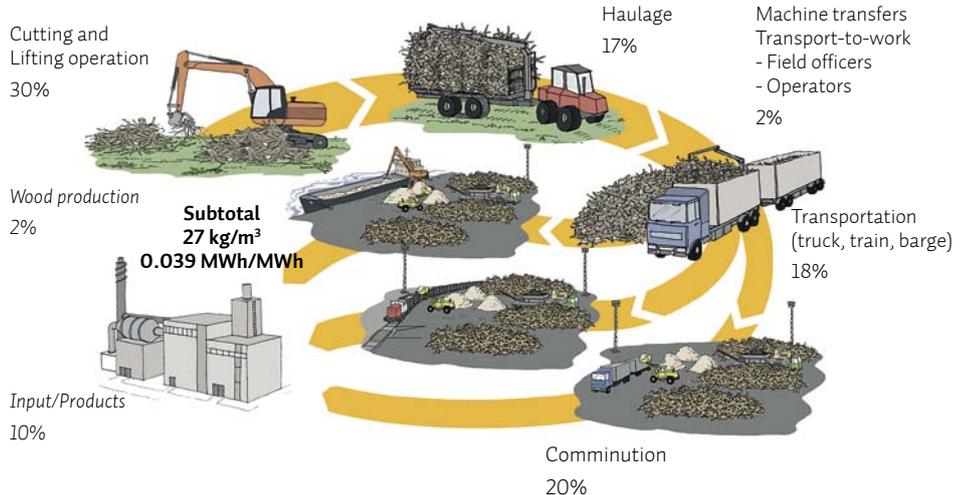
This example represents 24% of the total volume.

■ **Small-sized thinning wood comminuted at roadside landing**



This example represents 5% of the total volume.

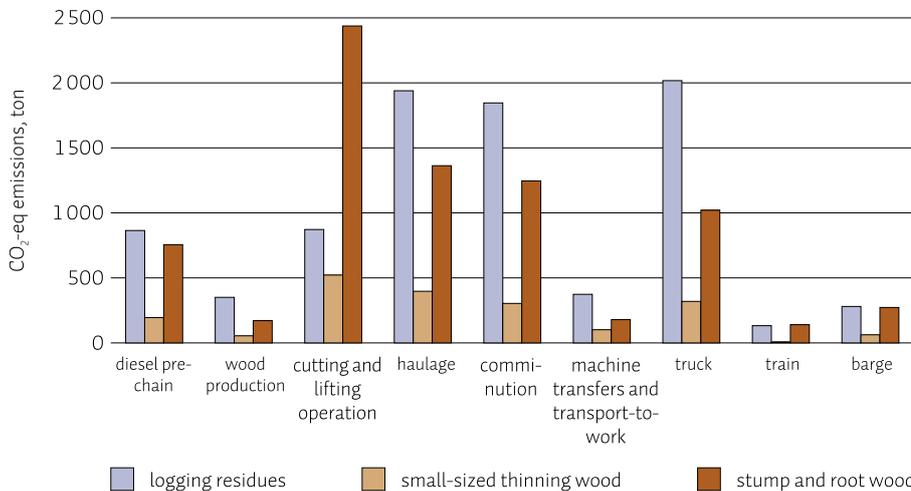
■ **Stump and root wood comminuted at terminal**



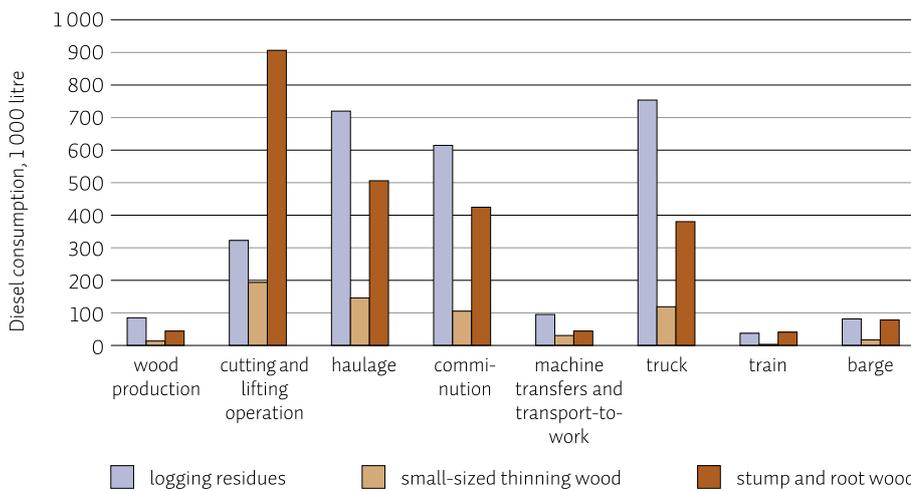
This example represents 21% of the total volume.

Results of the Case Study

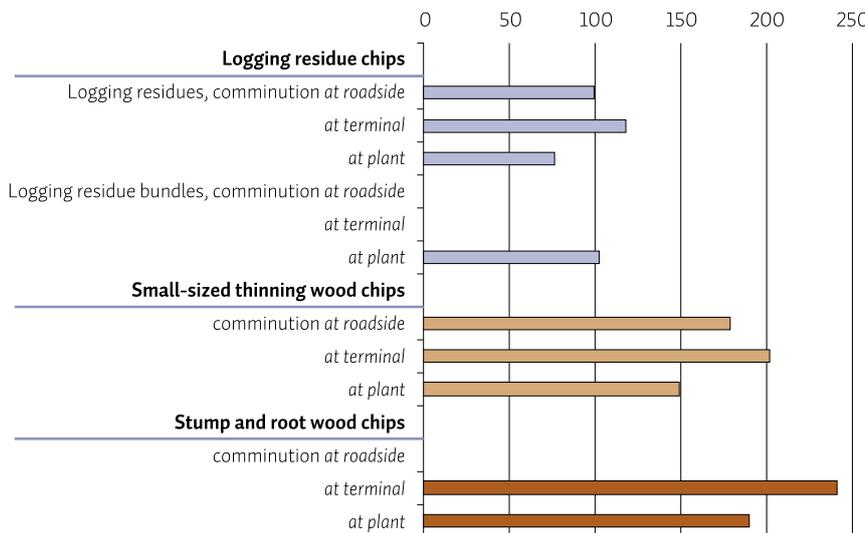
■ Volume of **CO₂-eq emissions** of the case study, 18 200 ton total, with the supply chains presented on page 2.



■ Volume of **diesel consumption** of the case study, 5.8 Mill. litre total, with the supply chains presented on page 2.



■ **Chip supply chains' relative CO₂-eq emissions** in the case study. Logging residues, comminution at roadside = 100.



The total amount of CO₂-eq emissions were some 18 000 tons for one million m³ of chip procurement.

The forest chip supply chains are presented on page 2. The volume of diesel consumption is about 5.8 million and petrol some 138 000 litres. Electric rail transportation and chipping at the mill site consume 1.6 GWh of power.

The amount of emissions varied considerably between chip supply chains based on different machinery and logistics.

Production of chips from logging residues was the most climate friendly supply source. This is due to more productive forest haulage and long-distance transportation. 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.

Only 2.7% of the energy content was consumed during the forest chip supply.

Energy input/output ratio was 0.027 MWh/MWh concerning the total volume. This varied from 0.018 to 0.039 between the available supply chain alternatives. Hence, forest chip procurement gives a net of some 97% of the energy content delivered at the mill. This ratio is on level with that of earlier reports (e.g. Wiheraari 2005).

Authors

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Energy efficiency of forest biomass is promising

In the studied calculation case, with more than half of the chips from logging residues, less than 3% of the energy content of the forest biomass was consumed, when producing and delivering the chips to the mill.

The differences of CO₂-eq emissions of the alternative supply chains are due to the differences in productivity, as well as fuel and energy consumption of different kind of technologies. In practice, the supply chain mix depends on the availability of supply chain combinations, machinery, and machine operators. In this case, production of chips from logging residues was the most climate friendly supply source. This is due to more productive forest haulage, and long-distance transportation. In general there is no sense in comparing supply chains without realistic and comprehensive boundaries. A sensitivity analysis-driven calculation model, which is based on actual data, is essential for proper results.

Parameters like fuel or energy consumption and productivity of machines are, naturally, crucial. In addition, many conversion factors related to for example units of volume,

moisture content, and heat value can have a significant influence on the results.

Thus, emission figures are always closely linked to all parameters used in the calculation, and make every calculation unique. Range of emission figures is more applicable than single figure representing only very specific or an exceptional case.

This was only the first section of a “stump-to-wheel”-CO₂-eq emission calculation of a forest biomass-based Fischer-Tropsch-diesel production. The total GHG reduction achieved depends on process technology choices like eventual plant self-sufficiency in electricity vs. power from grid.

It already looks that biomass-to-liquid traffic fuel production integrated with pulp and paper making can be very competitive in terms of GHG reduction and energy efficiency. Producing and delivering 1 Mill. m³ of forest chips produces only a total of some 18.2 thousand tons of CO₂-eq with the supply preconditions of the chosen Finnish pulp and paper integrate.

CO₂-eq emissions were calculated 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 energy systems' CO₂ consequences have been carried out (e.g. by Korpilahti in 1998). At present, production of forest chips has been included in the model with full weight.

Literature:

- Korpilahti, A. 1998. Finnish forest energy systems and CO₂ consequences. *Biomass and Bioenergy* 15(4/5): 293–297.
- Kärhä, K. 2007. Supply Chains and Machinery in the Production of Forest Chips in Finland. In: Savolainen, M. (Ed.). *Book of Proceedings. Bioenergy 2007, 3rd International Bioenergy Conference and Exhibition, 3rd–6th September 2007, Jyväskylä Paviljonki, Finland.* Finbio Publications 36: 367–374.
- Wihersaari, M. 2005. Greenhouse gas emissions from final harvest fuel chip production in Finland. *Biomass and Bioenergy* 28(5): 435–443.