

# D6.3 Possibilities of Low-Carbon Logistics Systems in Finland

## Part 1: General Section and Work Machinery

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# Summary

- This study describes low-carbon solutions for domestic timber logistics chains. The study presents a situational overview of:
  - emission reduction targets related to transport and work machinery;
  - key regulations concerning emission reduction;
  - the current status and development outlook of low-carbon solutions for different timber transport modes and for terminal work machinery; and
  - the impacts of low-carbon solutions on emissions and costs.
- The study is aimed at stakeholders in timber transport chains who are considering the adoption of low-carbon solutions, including shippers, timber transport companies, and terminal operators.
- A key emission reduction measure for transport and work machinery has been the statutory renewable fuel distribution obligation.
  - In rail transport of timber, the share of electric locomotives has been significant for a long time.
  - In timber road transport, LBG-fuelled trucks have been introduced.
  - HVO has been used on a limited basis in different transport modes and in work machinery.
  - At production facilities, large work machines powered via cable connection have been in use for a longer period.
  - In addition to new propulsion systems, a significant emission reduction measure is the use of larger transport equipment, such as HCT vehicle combinations, longer trains, and larger rail wagons.
- When comparing the emission impacts of different solutions, and especially of different propulsion systems, it is important to harmonise calculation principles.
- The study was carried out as part of the Accelerating Climate Efforts and Investments (ACE) project.



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# 1. Introduction

- This study describes low-carbon solutions for domestic timber logistics chains. The study presents a situational overview of
  - emission reduction targets related to transport and work machinery
  - key regulations concerning emission reductions,
  - the current status and development outlook of low-carbon solutions for different timber transport modes and terminal work machinery, and
  - the impacts of low-carbon solutions on emissions and costs.
- The study consists of four sub-reports, which are available on the website <https://www.metsäteho.fi/possibilities-of-low-carbon-logistics-systems-in-finland/>
- The study is aimed at stakeholders in timber transport chains who are considering the adoption of low-carbon solutions (shippers, timber transport companies, and terminal operators).
- The study updates and complements Metsäteho's earlier review of emission reduction measures in Finnish timber transport (Venäläinen et al. 2023).
  - This study places particular emphasis on rail-based timber transport, which has received less attention in previous studies.
- The study was carried out as part of the Accelerating Climate Efforts and Investments (ACE) project, which aims to support the achievement of carbon neutrality, including in heavy-duty transport in Finland.
  - Project website <https://hiilineutraalisuomi.syke.fi/en/projects/accelerating-climate-efforts-and-investments-ace-life/>



# Scope and Implementation of the Study

- The study focuses on
  - the transport, loading and unloading stages of domestically sourced industrial roundwood (partly also covering by-product wood chips), and
  - new and emerging emission reduction solutions.
- The study does not address
  - emissions related to the manufacturing of transport and terminal equipment, or
  - emissions from the construction and maintenance of transport and storage infrastructure.
- The study has been carried out mainly on the basis of information from research publications, news articles, and company websites.
  - In preparing the situational overview of distribution infrastructure for alternative fuels and in the calculations for HCT vehicle combinations, information requests were also submitted to companies.
  - The current status of propulsion systems used in timber truck transport and in work machinery at production facilities was examined through a survey conducted among Metsäteho's shareholder companies.



# Emission Reduction Targets

## EU

- EU Climate Law (cf. 1990)
  - 2050: Climate neutrality
  - 2040: **-90%** greenhouse gas emissions
  - 2035: **-66%** greenhouse gas emissions
  - 2030: **-55%** greenhouse gas emissions
- 2030: RED III Directive
  - Transport GHG emissions **-14.5%** or share of renewable energy in transport **29%**
    - Renewable energy = non-fossil energy (biogas, biodiesel, renewable hydrogen, and electricity)
  - Share of advanced biofuels and RFNBO fuels (= e-fuels) in renewable energy used in transport: **5.5%**

## Finland

- Climate Act (cf. 1990)
  - 2050: **-90%** combined greenhouse gas emissions from the Effort Sharing and Emissions Trading sectors
  - 2040: **-80%**
  - 2030: **-60%**
  - 2035: Climate neutrality in greenhouse gas emissions caused by human activities
- Effort Sharing Regulation
  - 2030: **-50%** emissions in the effort-sharing sector (including transport and certain work machinery) (cf. 2005)

*Greenhouse gas emissions = carbon dioxide, methane, and nitrous oxide*



# Timber Transport Climate Roadmap

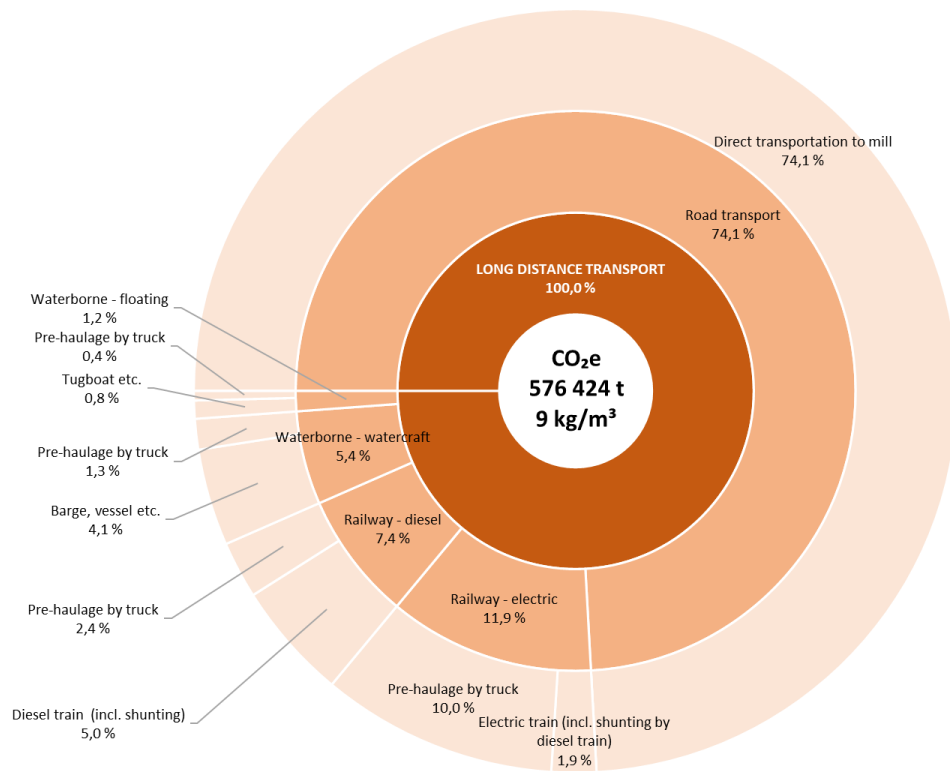
- In the transport climate roadmap study commissioned by the Finnish forest industry (AFRY Management Consulting 2025), some of the most effective emission reduction measures for timber transport are assessed to include shifting transport from road to rail and the renewable fuel distribution obligation (see table).
- The roadmap assesses the emission reduction potential of the different measures for the year 2035.

Emission Reduction Measure for Timber Transport	Impact 2035 ktCO <sub>2</sub>
From road to rail	-70
Renewable Fuel Distribution Obligation	-51
HCT vehicle combinations	-28
Propulsion Systems for Road Transport	-10
Energy Efficiency of Road Transport	-6
Rail Network Electrification	-4
Energy Efficiency of Terminal Machinery	-1
FuelEUMaritime	-1
Floatage	<-1



# CO<sub>2</sub>e emissions from industrial roundwood transport in 2022

- Total emissions from long-distance transport of domestically sourced industrial roundwood amounted to 580,000 tonnes of CO<sub>2</sub>e (Poikela and Strandström 2024).
  - Of the total emissions, 74% originated from direct road transport,
  - 19% from rail transport chains, and
  - 7% from waterborne transport chains.
- Emissions from the transport chains include road-based pre-haulage, timber loading at terminals, unloading at production facilities, and shunting operations.



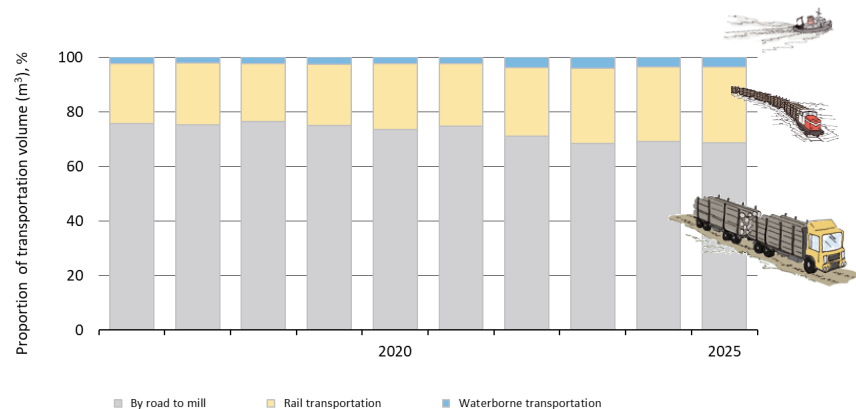
Poikela and Strandström 2024



# Modal split and emissions by transport mode

- Direct road transport accounts for approximately three quarters of domestic industrial roundwood transport (see figure).
  - Following the end of imports from Russia, the share of rail and waterborne transport, which are competitive over long distances, has increased.
- CO<sub>2</sub>e emissions per tonne-kilometre for rail and waterborne transport chains are 34–79% lower than for direct road transport (see table).
  - When calculated per cubic metre, emissions from diesel rail and waterborne transport chains are higher due to their longer average haul distances.

*Poikela and Strandström 2024, \*Strandström 2023*

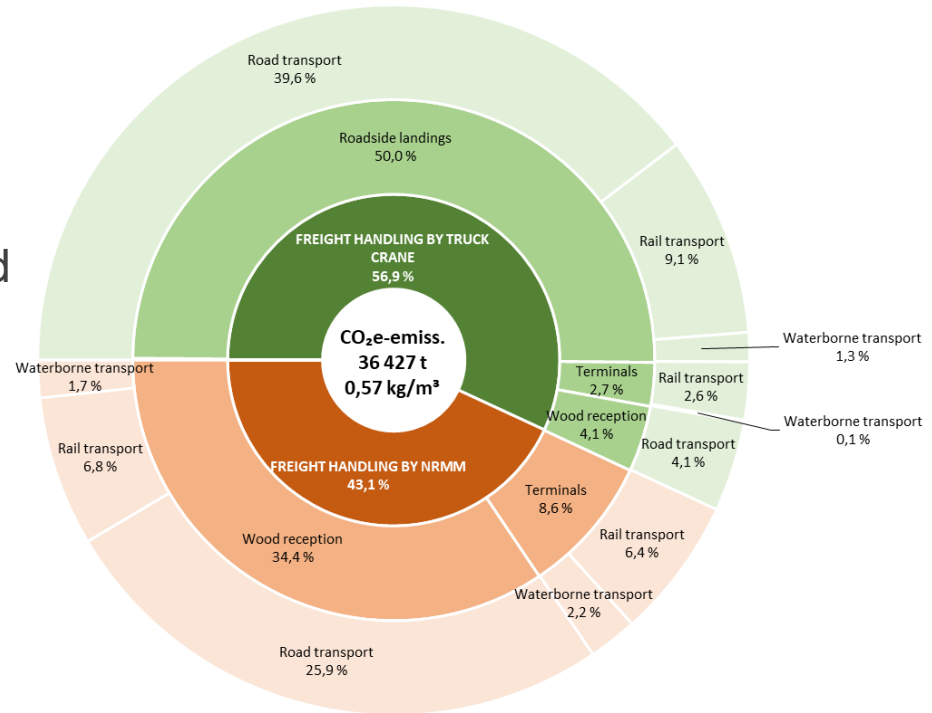


*Strandström 2026*

Transport mode	CO <sub>2</sub> e emissions g per tkm 2022	CO <sub>2</sub> e emissions kg per m <sup>3</sup> 2022	Average transport distance km 2022*
Road	48,5	4,25	104
Rail – electric	10,0	3,02	347
Rail – diesel	25,8	7,79	347
Vessel	32,2	10,72	367
Floatage	20,8	5,49	367

## 2. Low-Carbon Solutions for Work Machinery

- Emissions from load handling in industrial roundwood transport chains amounted to 36,000 t CO<sub>2</sub>e in 2022 (see figure).
  - Of these emissions, 43% originated from work machinery, with the remainder resulting from handling by truck-mounted loaders.
- CO<sub>2</sub> emission limits for work machinery are not defined under the Stage emission classification.



Poikela and Strandström 2024

NRMM = Non-road mobile machines



# a) Propulsion Systems for Work Machinery 1

- The types and propulsion systems of work machinery used in industrial roundwood transport chains were examined in an earlier survey by Metsäteho (Venäläinen et al. 2024).
  - In timber loading for rail and waterborne transport, no propulsion systems other than fuel oil were in use.
- The table presents the propulsion systems of work machinery used in timber reception based on a new survey.
  - In total, more than 60 machines were operating with a propulsion system other than standard fuel oil.

*Propulsion Systems of Work Machinery in Timber Reception in 2025 (number of responses)*

Type of Work Machinery	Electric or hybrid	HVO
Material handling machines	14	5
Log handlers	2	16
Wheel loaders	2	8
Gantry cranes	2	0
Forklift and telescopic handlers	1	0
Terminal trucks	1	9
Wagon mover	2	1

# Examples of Propulsion Systems for Work Machinery

Machine type	Propulsion	Machinery makes and models	Operational examples
Material handling machine	Electric (battery)	Atlas 200MH ACU (21 t), Komatsu PC210E-11	Metsä Group Äänekoski, Stora Enso Uimaharju
Material handling machine	Electric (cable)	Liebherr, Sennebogen 850 E (62–100 t)	
Material handling machine	Electric (battery+cable)	Fuchs Terex, Mantsinen	
Material handling machine	Hybrid (electric+diesel)	Sennebogen 850 G Hybrid (68,5 t)	
Log handler	Hybrid	EdiLog (300-960 kW)	
Wheel loader	Electric	CASE 580 EV, Caterpillar 950 GC prototype (19,7 t), Komatsu LeTourneau, LiuJong 856HE (22 t), Volvo L120H (20 t)	Koskisen Kärkölä, Stora Enso (ACE pilot), UPM Pietarsaari
Pyöräkuormaaja	Metaani	CASE (concept)	
Pyöräkuormaaja	Vety	JCB	
Forklift	Electric (battery)	Hyster J10-18XD (10–18 t), Kalmar ECG 180 (18 t), Linde (10–18 t)	
Forklift	Hybrid	SOCMA (25 t)	
Terminal tractor	Electric	Gaussin, Kalmar Ottawa T2E+ (35–90 t), MAFI	
Port crane	Electric	Mantsinen	Halla port timber storage yard
Terminal truck	Electric	Converted by eTruck	UPM Pietarsaari (ACE pilot)

# Propulsion Systems for Work Machinery 2

- **Objectives**

- The Medium-Term Climate Plan (KAISU) (Ministry of the Environment 2025) proposes several measures to reduce emissions from work machinery. Proposals related to individual propulsion systems are described in the respective sections on those systems.
  - General policy measures included in the KAISU package include an RDI project on new technologies and solutions that promote low-emission work machinery and the wider availability of alternative distribution infrastructure, and a promotion programme for low-emission work machinery and fuel-saving working practices.
- Under the new Green Deal agreement period for the work machinery sector (2026–2030), the aim is to increase the use of low-emission work machinery in Finland.

- **Development outlook**

- Emissions trading is expected, among other factors, to increase the availability of new propulsion systems for work machinery. Production facilities in the forest sector have large handling volumes, which means that a shift in propulsion systems is likely to become more common as new propulsion options become available in larger machinery size classes. In other timber transport terminals, the transition is slowed by smaller volumes.

- **Impacts**

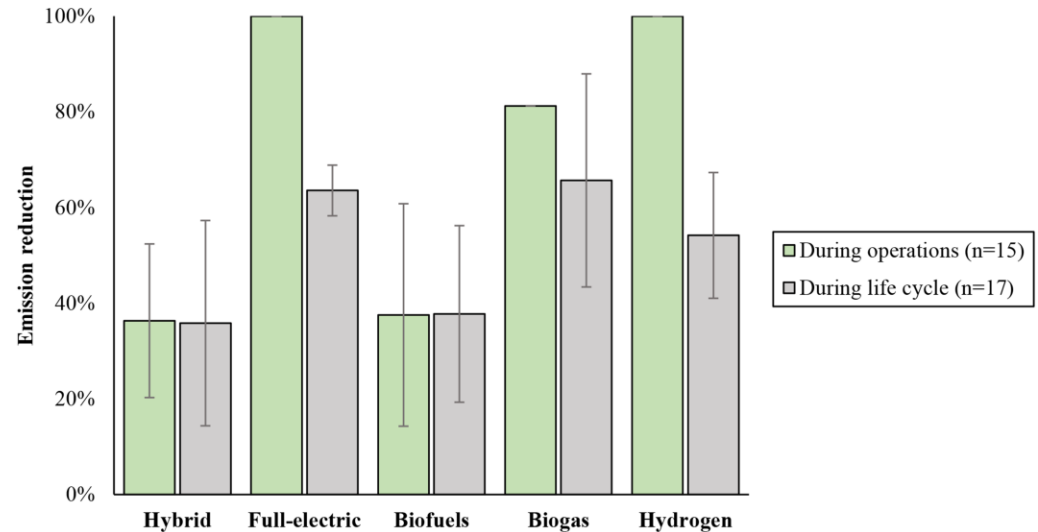
- During operation, electricity and hydrogen are zero-emission propulsion systems. More detailed emission impacts are presented in the following slide. Cost impacts will need to be assessed more comprehensively in the future.



# Emission Reduction Impacts of Propulsion Systems

- Emission reductions achieved by different propulsion systems for work machinery have been reviewed by Pesonen et al. (2025) based on the research literature (see figure).
- There is a need to refine emission reduction impacts at national level, for example due to differences in distribution obligations and the shares of renewable electricity.
- The need to further develop emission calculation methods for work machinery is also highlighted in the KAISU3 report (Ministry of the Environment 2025).

*Emission reductions achieved by different propulsions systems for work machinery compared with diesel (operational and life-cycle emissions)*



*Pesonen et al. 2025*

# Bio-based Fuel Oil and HVO

- **Current situation**

- The biofuel distribution obligation for fuel oil used in machinery is 8% in 2026, 9% in 2027, and 10% in 2028 and thereafter.
- According to Metsäteho's survey, HVO is used in nearly 40 work machines involved in timber reception (slide 11).

- **Objectives**

- The Medium-term Climate Policy Plan (KAISU) (Ministry of the Environment 2025) proposes increasing the bio-content distribution obligation for fuel oil to 15% by 2030.

- **Development outlook**

- The wider uptake of HVO is constrained by its high price. The development of bio-fuel oil use therefore depends largely on changes in the distribution obligation. Electric work machinery is becoming an increasingly cost-competitive option for reducing emissions.

- **Impacts**

- Cost impacts have not been assessed in this study.



# Electric and Hybrid 1

- **Current situation**

- According to Metsäteho's survey, 24 electric and hybrid work machines were in use in timber reception in 2025 (slide 11). Most of these were material-handling machines.
- Electric and hybrid machines in the largest size classes are cable-charged. Battery-electric machines are currently available only in smaller power classes (see slide 12).

- **Objectives**

- The Medium-term Climate Policy Plan (KAISU) (Ministry of the Environment 2025) proposes several measures to promote the use of zero- and low-emission work machinery.



# Electric and Hybrid 2

- **Development outlook**

- Electric work machinery is already available in several types of machinery used in timber transport chains (see slide 12), and its use can therefore be expected to increase, particularly in timber reception. Within the ACE project, Toijala Works is developing an electric log handler, which will enter pilot use in 2027.
- There are still technical challenges associated with the use of electric work machinery (including battery weight and a lack of standardisation), but these are expected to diminish over the long term, as solutions developed for the electrification of heavy-duty road transport can also be applied to work machinery. Another challenge, particularly for battery-electric machinery, is the lack of charging infrastructure. Investments in charging infrastructure will become more cost-effective if synergies with the electrification of road transport can be utilised.

- **Impacts**

- Emission impacts are described in slide 14. The report by Auvinen et al. (2025) assumes that the purchase cost of a large electric wheel loader is 85% higher than that of a diesel-powered equivalent, and that of a large electric forklift is 50% higher. There is a need to assess cost impacts more comprehensively.



# Other Propulsion Systems

- **Current situation**

- According to Metsäteho's surveys, work machinery using other propulsion systems (gas, hydrogen) is not yet in use in timber transport chains in Finland, although such machinery is already available on the market to a limited extent (slide 12).

- **Objectives**

- The Medium-Term Climate Policy Plan (KAISU) (Ministry of the Environment 2025) mentions the inclusion of biogas and e-fuels in the fuel distribution obligation for work machinery, but this is not included in the plan's action programme.

- **Development outlook**

- In the near future, barriers to hydrogen use include its high cost and limited availability, as well as the fact that hydrogen-powered work machinery is mainly available in smaller size classes (Pesonen et al. 2025). Auvinen et al. (2025) estimate that hydrogen use in work machinery in Finland will increase after 2030. Hydrogen is particularly suitable for heavy industry, where machinery has high energy demand and long operating hours. Hydrogen distribution will be supported by the implementation of Gasgrid's hydrogen network.
- An EU-level distribution obligation will be introduced for RFNBO fuels in road transport. Although the production of RFNBO fuels remains expensive, over the longer term supply could also emerge for use in work machinery.

- **Impacts**

- Emission impacts are presented in slide 14. Assessing cost impacts would require a dedicated study.



# b) Propulsion Systems for Shunting Equipment 1

- **Current situation**

- Shunting operations refer to the movement of trains and rail wagons in rail yards, roundwood loading sites, ports, industrial areas, and between operational locations.
- Shunting is carried out partly using mainline diesel or electric locomotives, and partly using dedicated shunting locomotives and robots, or by gravity (hump shunting). CO<sub>2</sub>e emissions from shunting operations associated with domestic timber rail transport amounted to 10 tonnes in 2022 (Poikela and Strandström 2024).
- Shunting operations are mainly carried out using diesel-powered equipment, but equipment using other propulsion systems is also available (see slide 20).
  - A wide range of electric and hybrid solutions is already available, while machinery powered by hydrogen or methane is still limited in number.

- **Objectives**

- The Medium-Term Climate Policy Plan (KAISU) (Ministry of the Environment 2025) sets out general objectives related to low-emission work machinery.



# Propulsion Systems for Shunting Equipment 2

Propulsion System	Examples of makes and models
Hybrid (diesel + electric)	Alstom Traxx Shunter CFD Shunter Series Windhoff Tele-Trac DAE
Electric	Alstom Traxx Shunter (overhead line + battery) Siemens Vectron Zephir Lok E, Zephir CRAB EZ
Electric (battery)	Colmar SL200E Vollert Shunting Robot Standard/Pro/Pro Eco Wabtec Electric Shuttlewagon Windhoff Tele-Trac AEM
Electric (overhead line)	Mantsinen robotic shunting locomotive (not in serial production) Windhoff Tele-Trac EM
Methane	CFD Shunter Series
Hydrogen	PESA (prototype) Alstom Traxx Shunter (hydrogen + battery)

# Propulsion Systems for Shunting Equipment 3

- **Development outlook**

- In shunting operations, the transition to new propulsion systems is easier than in mainline train services, due for example to shorter travel distances, lower operating speeds, and the easier implementation of distribution infrastructure (Tikka et al. 2024).
- The use of batteries in shunting operations is supported by long idle times of the equipment, which allow ample opportunity for charging, as well as by their suitability for terminals where overhead line electrification is not feasible due to work machinery. In terminals, battery charging may also offer synergies with shore-side electricity for vessels and charging of road vehicles (Tikka et al. 2024).
- Various hybrid solutions are also suitable for shunting operations where yards are partially electrified (electric and cable-charged hybrids or diesel–electric hybrids) (Tikka et al. 2024).

- **Impacts**

- The emission and cost impacts of propulsion systems used in shunting equipment have not been assessed in this study.



## c) Emissions Trading and Taxation

- The EU emissions trading scheme for fossil fuel distributors (ETS2) will be launched in 2028 and will also cover fuels used by work machinery.
- The Act on Excise Duty on Liquid Fuels (1472/1994) defines the tax level for light fuel oil used in work machinery.
- Electricity consumption is subject to energy tax, which consists of excise duty and a security-of-supply fee. Electricity generation and energy storage are subject to separate taxation requirements.



# 4. Conclusions and Further Research Needs 1

- Road, rail and waterborne transport are used for the transport of domestically sourced timber in Finland. Timber is handled using work machinery both at production facilities and at larger terminals within transport chains. This study has focused in particular on the impacts of different propulsion systems on emissions and costs related to transport and load handling. The need to reduce emissions arises not only from the targets of companies and their customers, but also from increasingly stringent emissions regulation.
- A key emission reduction measure for transport and work machinery has been the statutory renewable fuel distribution obligation. The use of fully renewable HVO fuels has been constrained by their high price, despite the advantage that they are compatible with the existing vehicle and machinery fleet. Road transport fleets are renewed more frequently, meaning that emission reduction requirements applying even to diesel vehicles affect emissions in the short term. In other transport modes and in work machinery, fleet renewal cycles are clearly longer, and short-term emission reductions can therefore be pursued through measures such as improved operational planning and fuel-efficient driving practices.
- In rail transport of timber, the share of electric locomotives has been significant for a long time. New propulsion systems have gradually begun to emerge in other transport chains as well. In timber road transport, LBG-fuelled trucks have been introduced. HVO has been used on a limited basis across different transport modes and in work machinery. At production facilities, large cable-powered work machines have been in use for some time. Battery-electric work machinery is now becoming available also in larger size classes. Their use is likely to increase at production facilities where charging infrastructure can be implemented in a functional location that is also suitable for road traffic and at reasonable cost.
- The uptake of new propulsion systems is influenced by developments in both acquisition costs and operating costs. Equipment using new propulsion systems has only recently become available in larger size classes, and there is therefore as yet little information on, for example, maintenance costs and residual values. Propulsion system costs are affected by factors such as global market conditions, emissions trading, and future taxation decisions. It will remain necessary to update cost comparisons between different solutions, as investment thresholds for new equipment are high, especially for small transport and terminal operators. Various support measures have therefore been discussed to ensure that the transition to new propulsion systems is also feasible for smaller companies.

# Conclusions and Further Research Needs 2

- Finland's northern conditions, long transport distances and low freight volumes pose particular challenges for the transition to new propulsion systems.
  - The impact of temperature on the energy consumption of different propulsion systems needs to be studied in order to support both cost comparisons and the practical planning of operations.
  - Long transport distances limit the range of feasible propulsion options, especially in sparsely populated areas where distribution infrastructure networks are limited. The areas most suitable for an initial transition to new propulsion systems need to be identified through cooperation between shippers, transport and terminal operators, infrastructure providers, and regional authorities.
- In addition to new propulsion systems, significant emission reduction measures also include, for example:
  - efficient utilisation of vehicle capacity and fuel-efficient driving practices, which are addressed for road transport in Metsäteho's Energy Efficiency Guide. Comparable guidance material is needed for timber terminal work machinery. The Low-Emission Work Machinery training package by Motiva would serve as valuable background material for such guidance;
  - larger transport equipment (HCT vehicle combinations, longer trains, and larger rail wagons). The use of such equipment is subject to infrastructure-related constraints, which are currently being examined in dedicated research projects.



# Conclusions and Further Research Needs 3

- Standardising calculation principles is important when comparing the emission impacts of different solutions, and especially of different propulsion systems. Calculation assumptions need to be defined partly at national level, for example due to country-specific renewable fuel distribution obligations and the share of renewable electricity. The calculations should also be as simple as possible for small transport and terminal companies. Development of calculation methods should be carried out in cooperation between the private sector, public authorities, and the research community.
- In this study, the different solutions have been examined solely from the perspective of emission reductions. An additional advantage of electric equipment is its low noise levels, which can support electrification in operational areas located close to residential areas. More scientifically substantiated information on noise impacts should be made available.
- This study did not assess the potential of digitalisation, automation, or artificial intelligence in reducing emissions in timber transport chains.
  - The utilisation of new propulsion systems requires more detailed operational planning than before. As emission reporting requirements become more stringent, the need to identify emission reduction measures and to measure their impacts at company level will also increase. The current state and development needs of tools used for planning, operational control, and reporting should therefore be examined in a dedicated project.



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