best Sustainable Bioenergy Solutions for Tomorrow

Metsäteho

D3.2.1-4 Scenarios of Energy Wood Transport Fleet and Back-Haulage

Metsätehon tuloskalvosarja 2b/2016

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Contents

1. The Objective of the Study

- The aim of this study addressing energy wood transportation fleet and back-haulage was to
    - Describe the present state and realised development in long-distance transportation fleet as well as to set up scenarios of future development
    - Describe the role of back-haulage in energy wood transportation
    - To estimate the impacts of transport fleet and back-haulage on energy wood transportation costs
- The study focuses on road transport of domestic forest chips
- The study has been carried out based on the literature available and statistical information as well as results from a questionnaire to transport companies and shippers and a case-study on transport routes
- The study was carried out in the Sustainable Bioenergy Solutions for Tomorrow (BEST) research program coordinated by CLIC Innovation with funding from the Finnish Funding Agency for Innovation, Tekes.
- The author is grateful to the Association of Forest Road Carriers and Lappeenranta University of Technology for the help in carrying out the company questionnaire as well as to all the companies answering the questionnaire and participating the case studies.

2. The Present State and Development Prospects of Energy Wood Transport

2.1 The Present State and Scenarios of Energy Wood Use

2.2 The Present State and Scenarios of Energy Wood Transport

2.1 The Present State and Scenarios of Energy Wood Use

- The total use of solid wood fuels has grown by 81 % since year 2000.
- The use of forest chips has increased almost ninefold.
- The share of heating and power plants in fuel based use of forest chips is 92 % (Ministry of Agriculture and Forestry 2015a)

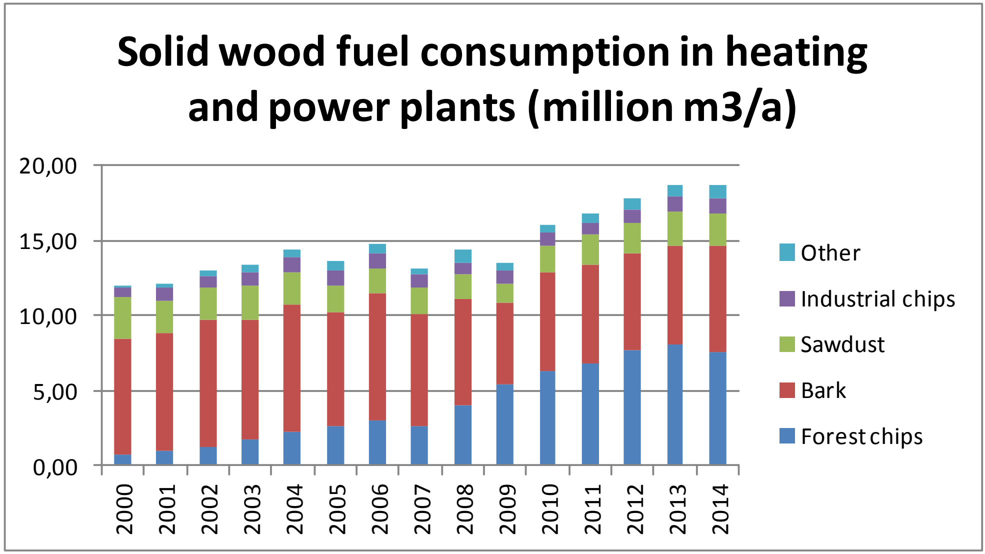


Figure: Natural Resources Institute Finland 2015

National Forest Strategy 2025

- The objectives of the National Forest Strategy 2025 (Ministry of Agriculture and Forestry 2015b)
  - The targeted energy use of forest chips in 2025 is 15 million m^3
  - The target is that by 2025, the harvest volume of branches, stumps and roots arises from 4 million m^3 to 8 million m^3 (this is included in the forest chip use target)
- According to the strategy
  - Investments are being planned in six joint production power plants and dozens of heat plants by year 2020. These plants are estimated to consume wood 5–6 million m^3.
  - The collected timber of tree trunks increases from 65 million to 80 million m^3; in the year 2013 a little less than 9 mil. m^3 of trunk tree was used to energy production (for firewood 5 mill. m^3 and for woodchips 4 mill. m^3)

Maximum sustainable yield

- The National Forestry Strategy 2025 (Ministry of Agriculture and Forestry 2015b) refers to estimations by Natural Resources Institute concerning sustainable yield
  - The maximum sustainable yield of energy wood in 2010–2019 is 21 million m^3/a (whereof stemwood 7,3 million m^3)
  - In 2025, the maximum sustainable yield is estimated to be 10 million m^3 for energy stemwood and approximately 12 million m^3/a for stumps and branches.

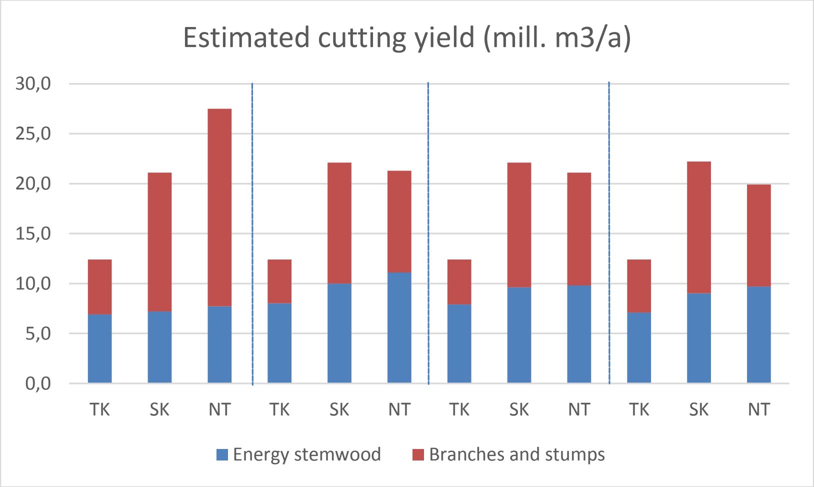


Figure: Natural Resources Institute Finland in Ministry of Agriculture and Forestry 2015b
TK = yield realised in 2008–2012
SK = the maximum sustainable yield
NT = The largest net income

National Energy and Climate Strategy

- The latest National Energy and Climate Strategy (Ministry of Employment and the Economy 2013a) was published in 2013.
- The strategy confirms the target set in the Finnish national renewable energy action plan in 2010, where the use of forest chips in the generation of heat and power in 2020 would amount to 25 TWh (about 13,5 million m^3).
  - The background scenario of the strategy (Ministry of Employment and the Economy 2013b) implies that in 2020 consumption of industrial chips is 18 TWh (20 TWh in 2010) and consumption of other wood 38 TWh (31 TWh in 2010)
- The strategy for year 2016 is currently being drafted at the Ministry of Employment and the Economy and will will be submitted as a Government Report to to the Finnish parliament at the end of the year.

The Regional Scenario of Energy Wood Use in 2020

- The 2020 regional scenario for the use of domestic energy wood (Iikkanen et al. 2014) shows that the **supply** of energy wood is notable in the Eastern and Northern Finland.
- Whereas the **demand** for energy wood is more evenly spread to different regions in Finland (the map illustrates the energy wood demand in the basic scenario for large plants only).
- Especially in the Western and Southern Finland, the regional supply of energy wood is close to the demand volumes. This increases the need to expand the supply area of energy wood and lengthen transport distances.

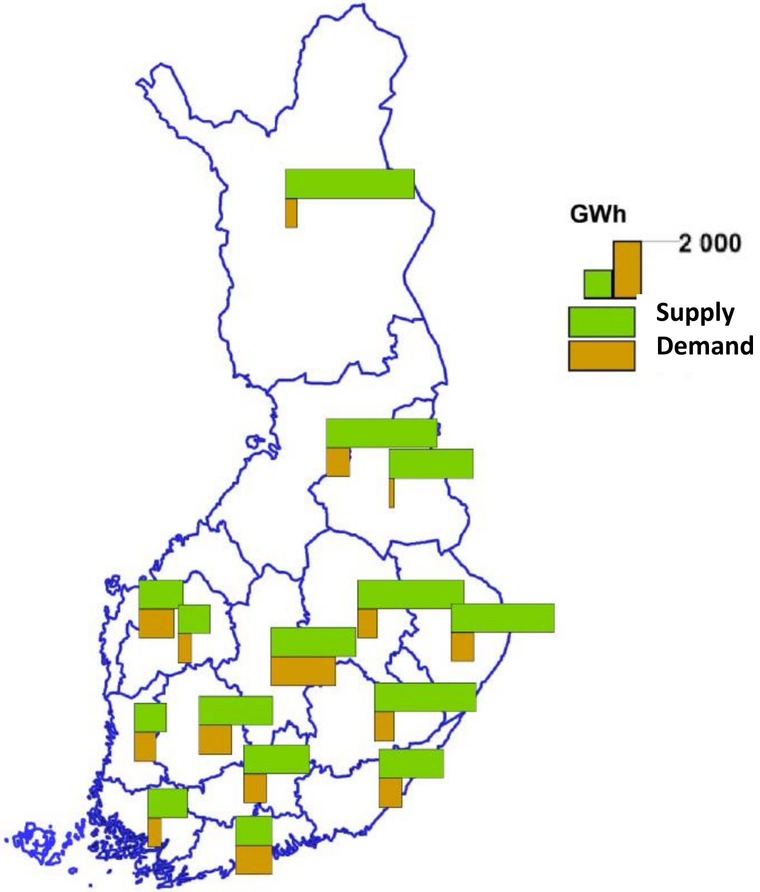


Figure: Iikkanen et al 2014

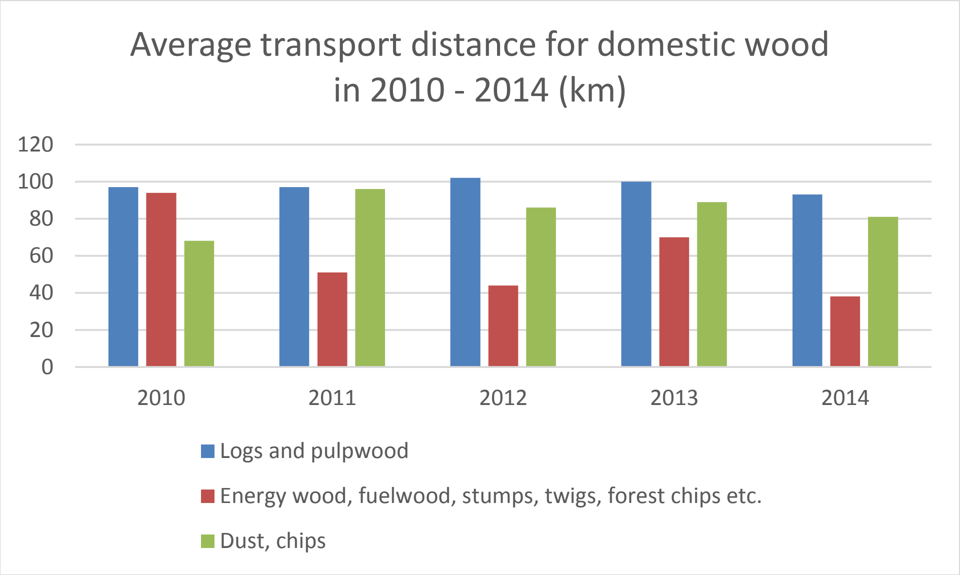
2.2 The Present State and Scenarios of Energy Wood Transport

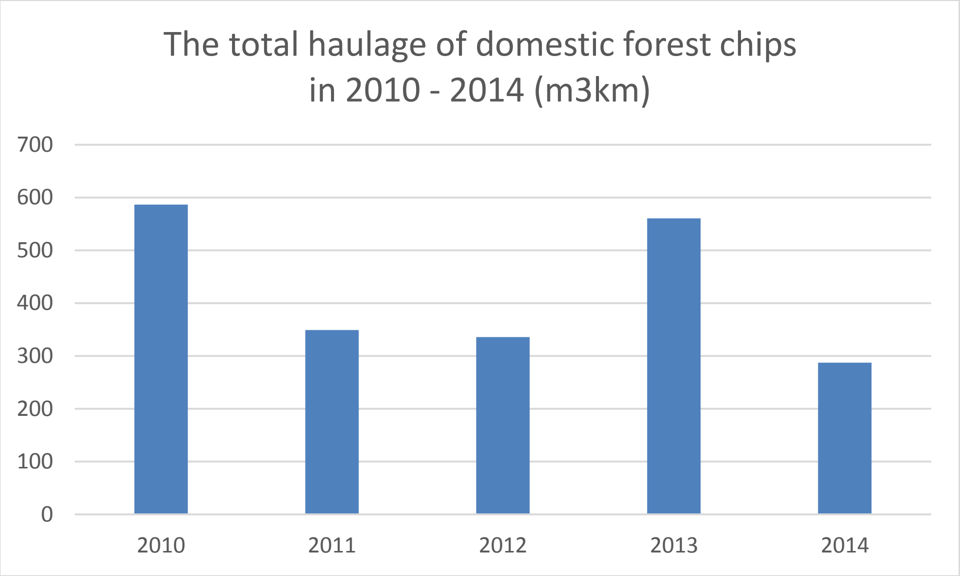
- Several factors affect on the energy wood transport volumes
  - The development of transport volumes (m^3) is affected by growth of energy wood consumption as a consequence of among other things new heating and power plant investments. Energy wood supply increases as a consequence of new forest industry production plants and growth in the use of industrial wood.
  - The total haulage of energy wood (m^3km) is affected by regional imbalances in energy wood demand and supply and variations in average transport distances caused by the imbalances. Average transport distances are also dependent on available transport modes.
  - The place of chipping affects not only to total distances of transport chains but also to total transport chain costs.
- More in-depth analysis of potential development in energy wood transport volumes calls for more comprehensive knowledge about the transport distances of different energy wood types and underlying factors.

The Total Haulage

- The average transport distance of energy wood has strong annual variations. During the past five years the distance has been in average 59 kilometres (that is considerably less than in transport of industrial wood).
- In Finland, the domestic energy wood is transported by trucks, but for example in Sweden also train and vessel transport are being used.
- The total haulage of forest chips can be estimated on the basis of average transport distance and annual consumption. In 2014 the total haulage was nearly 300 million m^{3}km.

Figures: Statistics Finland 2011–2015, Natural Resources Institute Finland 2015


Average transport distance for domestic wood in 2010 - 2014 (km)


The total haulage of domestic forest chips in 2010 - 2014 (m3km)

Chipping Alternatives

- Roadside chipping
  - The share has remained in about 60 %:
  - In order to cover relocation costs of the chipper, adequate size of stands marked for harvesting are required
- Terminal chipping
  - The share is growing
  - Requires terminal network development
  - Costs of additional unloading and loading
  - Economic in cases of short transport distances from the forest and small stands
  - Enables use of large trucks in delivery transport to points of use
- Chipping at points of use
  - Share decreasing
  - Restricted space at sites for chipping
  - Transportation of uncrushed energy wood is more expensive

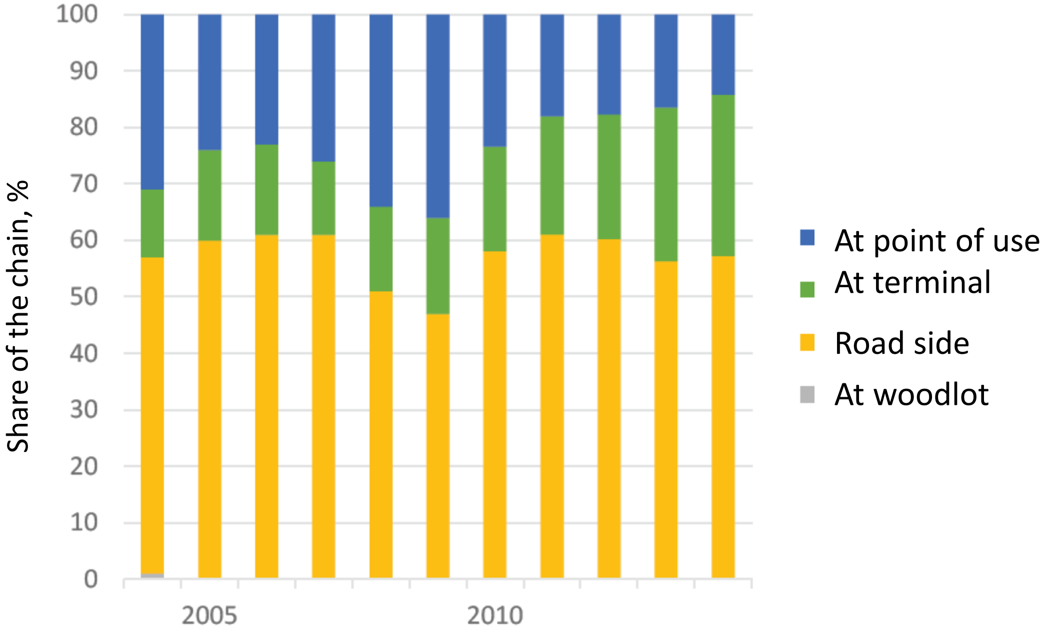


Figure: Strandström 2015a

Energy Wood Transport Optimisation Model 2020

- A study commissioned by the Finnish Transport Agency (Iikkanen et al 2014) has optimised Finland's energy wood transport
- In the basic scenario for 2020, the energy wood transport amounts to 4,7 million tonnes (12,6 TWh), divided to
    - Direct road transport 4,5 million t (11,9 TWh)
    - Train transport 0,2 million t (0,5 TWh)
    - Vessel transport 0,08 million t (0,2 TWh)
- The map illustrates transport volumes on the main road network (GWh/a) in the basic scenario for 2020

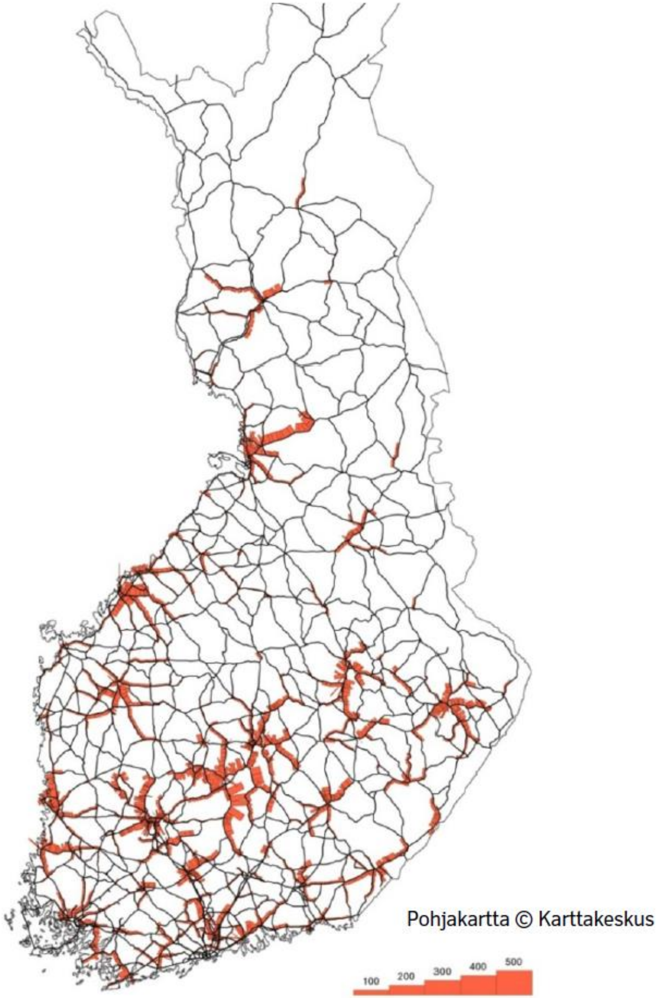


Figure: Iikkanen et al 2014

3. The Present State of Energy Wood Transport Fleet

3.1 The Present State of Transport Fleet

3.2 Questionnaire of Transport Fleet

3.3 Factors Affecting Transport Fleet Development

3.1 The Present State of Transport Fleet

- The types of transport vehicles used in energy wood transport affect on
  - Transport efficiency and costs and whereby on economic feasibility of wood in energy use
  - Planning and dimensioning of energy wood transport and terminal operations
- The types and sizes of energy wood trucks are also affected by points of chipping
- The following slides describe
  - Various types of transport vehicles used in energy wood transport and
  - Size distribution of vehicles.

Energy Wood Transport Vehicles (1/3)

- Asunmaa (2011) describes vehicles used in energy wood transport and their suitability in different situations:
  1. Combination of tractor and semi-trailer
     - Easy to handle on narrow forest roads, suitable for short transport distances with chipping directly to the vehicle
  2. Combination of tractor and trailer
     - The most commonly used vehicle type
     - Suitable also for long transport distances (to terminals)
  3. Module trucks (length more than 22 m)
     - Increasingly popular
     - At best in long transport distances (outside forest roads), such as in chip transport from a terminal to a heating plant

Energy Wood Transport Vehicles (2/3)

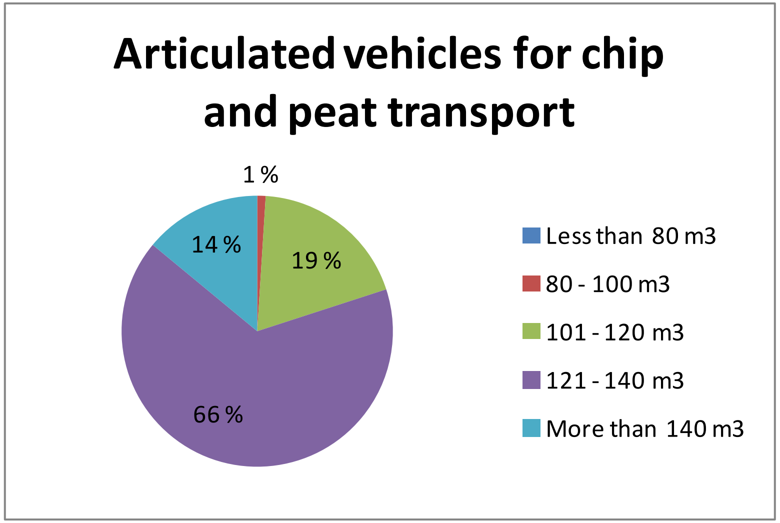
4. Solid combinations for twig and stump transportation (with payload of 132–170 m^3)
   - Suitable for logging residues, stumps, whole tree, crop processed felled and flopped tree; also wood waste and other energy usable materials; not suitable for chip transport
   - Maximised load space for light energy wood (for example trailers with lowered trunks, moving bogies)
5. Solid woodchip combinations (with payload of 130–155 m^3)
   - Also used in peat transports so they are widely available on the market
   - Vehicles with fully opening side walls are also applicable for general goods transport
   - Discharge methods include side tipping, chain discharge from the back, back tipping or walking floor
6. Fixture applicable for cross-cutting transport
   - Articulated vehicle for chip and timber transport (for example Lipe 155 m^3, Kraemer 74–86 m^3)
   - Changeable in one day from a timber truck to e.g. twig and stump combination transport or with extra equipment to general goods or woodchip transport (for example Multiforest 66 m^3 + 100 m^3)
   - Twig and stump covers that are changeable within a couple of hours replacing timber system (for example Koneurakointi T. Lääti 135 m^3)

Energy Wood Transport Vehicles (3/3)

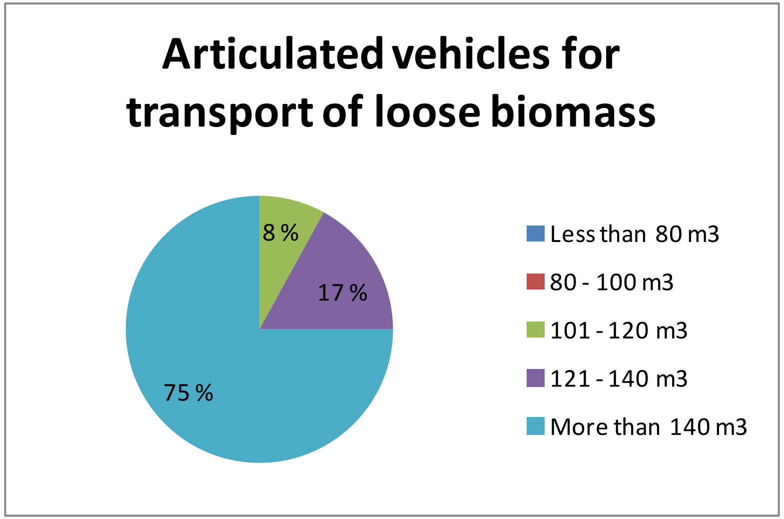
- Other supplementary solutions for transport vehicles
  - Additional sides, side covers (truck 45–65 m^3, trailer 85–110 m^3)
    - Quick attaching, timber equipment not released
    - Suitable (depending on the manufacturer) for group processed trunk tree, whole tree, stumps, and logging residues
    - Some solutions are suitable for timber transport without removal of the covers
  - Skips and containers (payload 3* 35–47 m^3)
    - Suitable to chips, stumps, logging waste, and whole tree
    - Containers designed specially for chips
    - Suitable also to train and vessel transport
  - Load compressing solutions
    - Lengthwise wall pushing model, side compressing model, straps, trucks own timber collector and possible additional weights, grab saws.

Vehicle Volumes

- The results of the questionnaire (Karttunen 2012), that was carried out before the changes in Government Degree concerning measures and masses of articulated vehicles in 2013, indicate a clear difference in volumes of load spaces
  - 84 % of chip and peat trucks have in maximum 140 m^3 load space
  - Whereas 73 % of loose biomass trucks have more than 140 m^3 load space.
- In chip trucks, the maximum allowed vehicle weight is reached faster and the load space volume can not be fully utilised.



Articulated vehicles for chip and peat transport

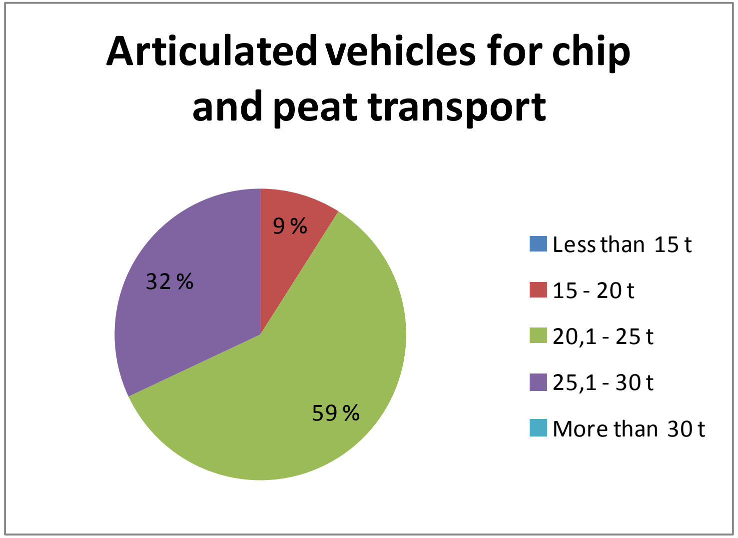


Articulated vehicles for transport of loose biomass

Figures: Karttunen et al 2012

Vehicle Own Mass

- The results of the questionnaire by Karttunen et al (2013) show that loose biomass trucks have notably higher own mass than chip and peat trucks.
- In transport of chips (with higher weight per m^3 than uncrushed energy wood) it is more critical that the vehicle is optimised for high payloads.



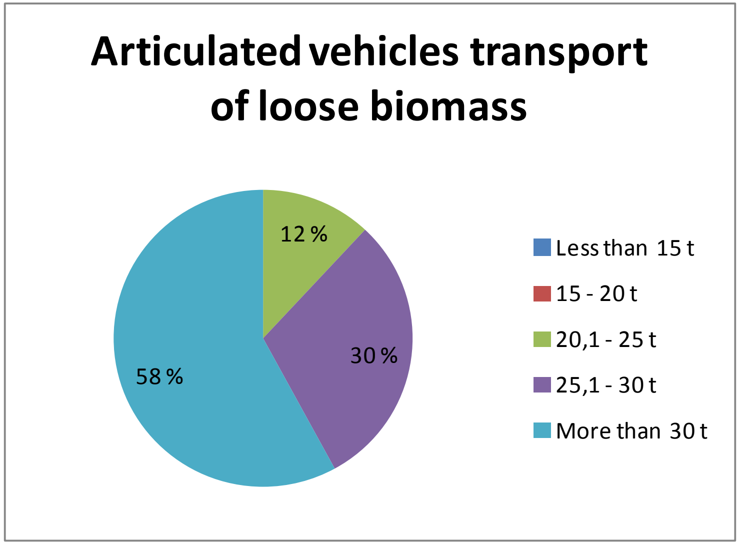


Figure: Karttunen et al 2012

Allowed masses of vehicles and combinations according to the number of axles

- On 1st October 2013, the change of Decree on the Use of Vehicles* entered into force and allowed an increase in maximum number of axles, total weight, and height of articulated vehicles
  - Before, the maximum number of axles was 7, maximum total weight 60 tonnes, and maximum height 4,2 metres (new maximum height is 4,4 metres)

Type of articulated vehicle	Prime mover t	Trailer t	Articulated vehicle t	Weight relation
3+4	*22–26*	*34–38*	*60*	*1,31–1,73*
3+4	26–28	36–38	64**	1,29–1,46
3+5	26–28	40–42	68	1,43–1,62
4+4	30–35	33–38	68	0,94–1,27
4+5	34–35	41–42	76	1,17–1,24

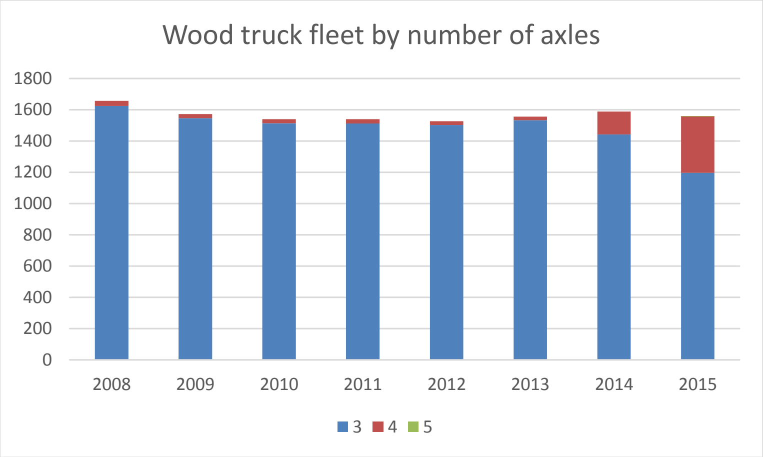
** Government Degree on changing the Decree on the Use of Vehicles on the Road 407/2013*

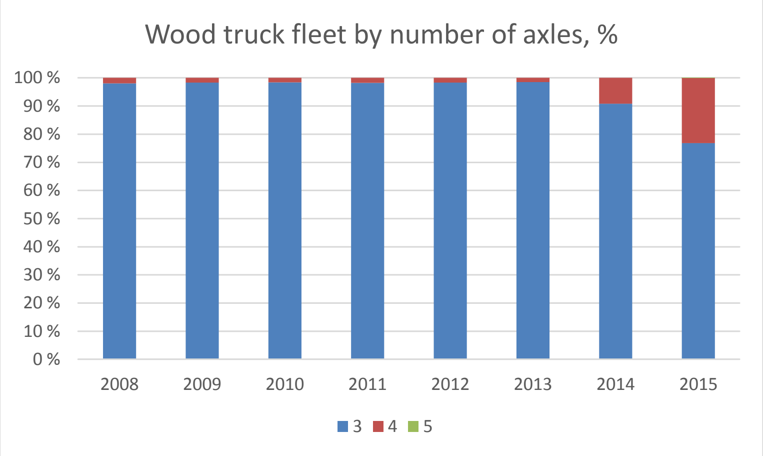
*** Until 30th April 2018*

Development of Wood Truck Fleet

- The fleet of trucks used in wood transport amounts to nearly 1 600
- At the beginning of year 2015, the share of timber trucks with four axles rose to 23 % (at that time, there was only one registered truck with five axles)

Figures: Metsätrans 2015



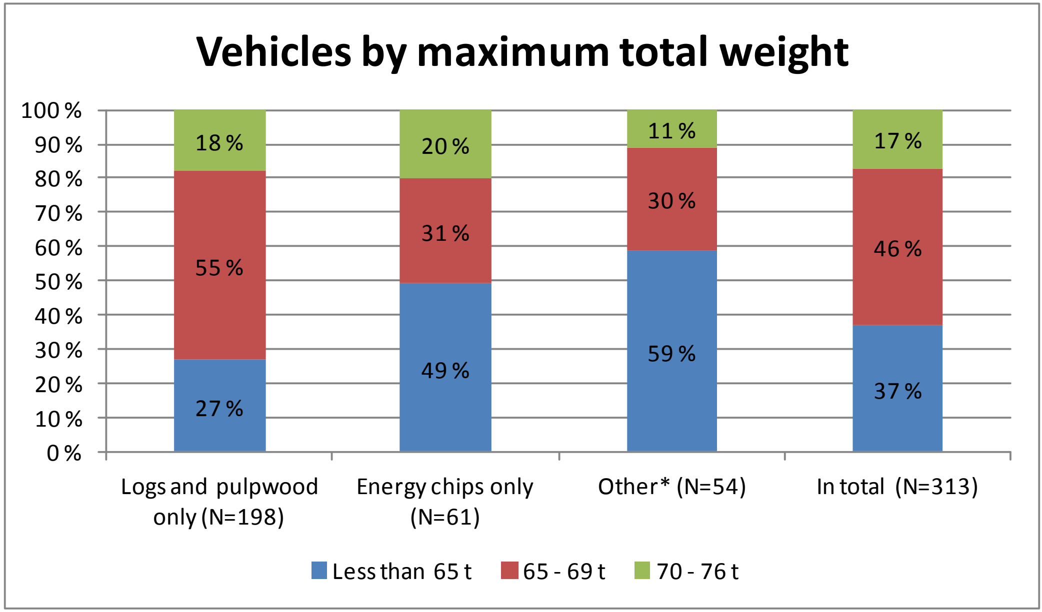


3.2 Questionnaire on Transport Fleet

- During the autumn 2015, an Internet questionnaire was sent to transport companies and shippers of both industrial and energy wood
- An internet questionnaire on wood transport fleet and back-haulage was sent to about 450 transport companies
  - The questionnaire was to sent to about 300 companies on the mailing list of Association of Forest Road Carriers and to 158 peat and chip transport companies on the list compiled by the Lappeenranta University of Technology.
  - The questionnaire was completed by 99 companies, which brings the response rate to 22 %.
  - The regional distribution of the respondents is shown in the appendix 1.
- The questionnaire was sent to transport companies of both industrial and energy wood, since the aim was to compare transport of these two groups. Further, it was assumed that new operation models are adopted faster in industrial wood transport and they are later adopted also in energy wood transport.

Size Distribution of Transport Vehicles

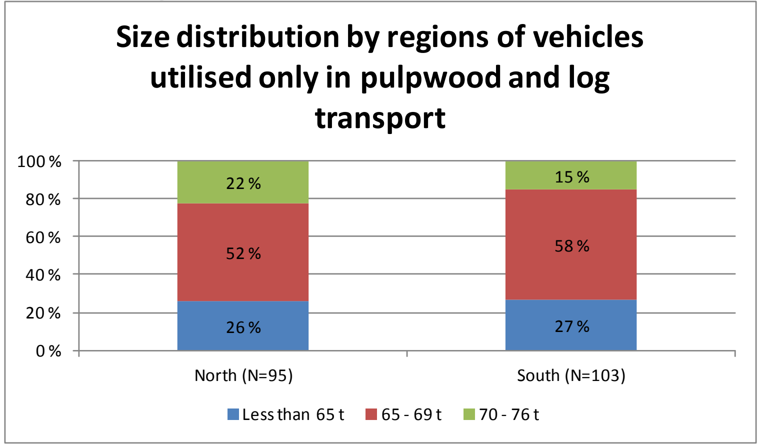
- The respondents have in total 313 vehicles used in industrial and energy wood transport
- In industrial wood transport, utilisation of smaller vehicles is notably less common
- The largest vehicle sizes are utilised to the same extent in industrial and energy chip transport
- As it concerns transport of energy chips and other energy wood, the medium sized trucks are utilised to the same extent. The differences are seen in the utilisation of small and large vehicle sized.

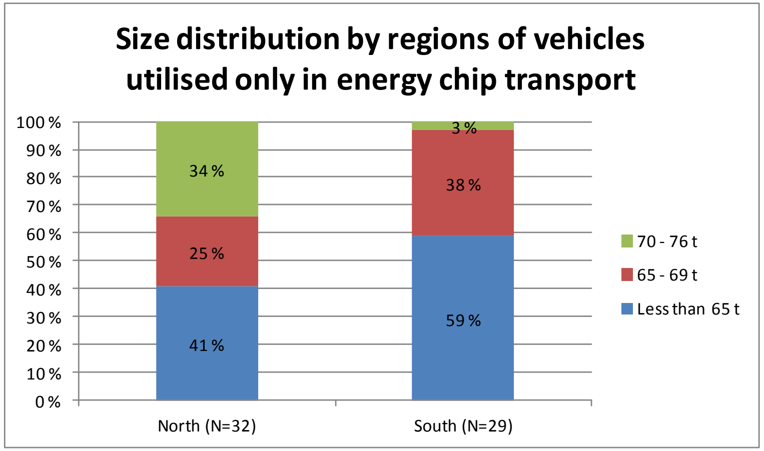


** Other vehicles utilised in transport of industrial and energy wood (for example vehicles, that are utilised in transport of uncrushed energy wood, vehicles used in transport of both industrial and energy wood, and vehicles used in transport of wood as well as other commodities)*

Regional Size Distribution of Transport Vehicles

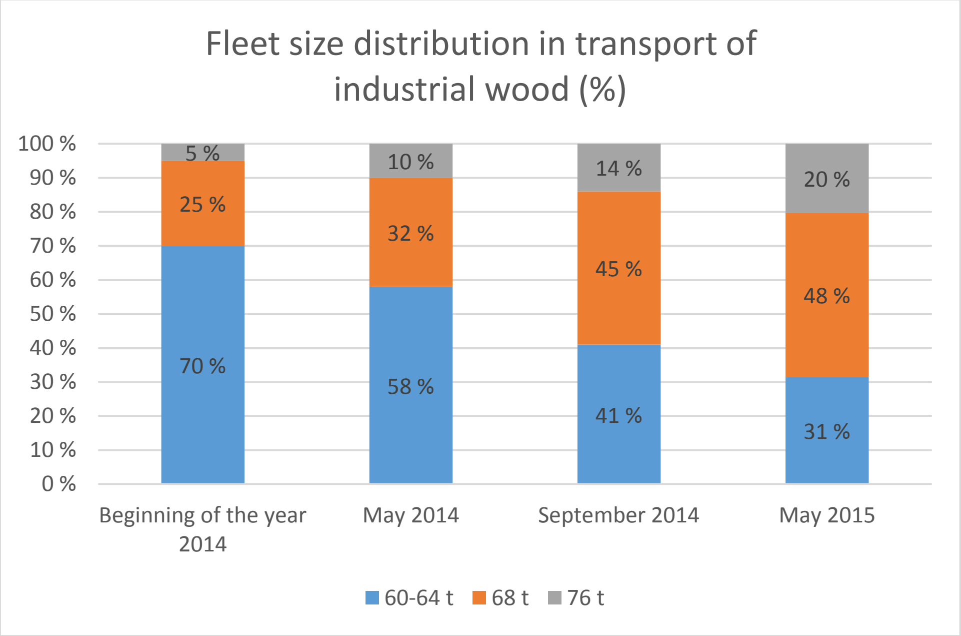
- In Northern Finland (regions in appendix 1), larger trucks are used than in Southern Finland in transport of both industrial and energy chip transport
- Larger trucks are more economic in long transport distances, which are more common in Northern Finland



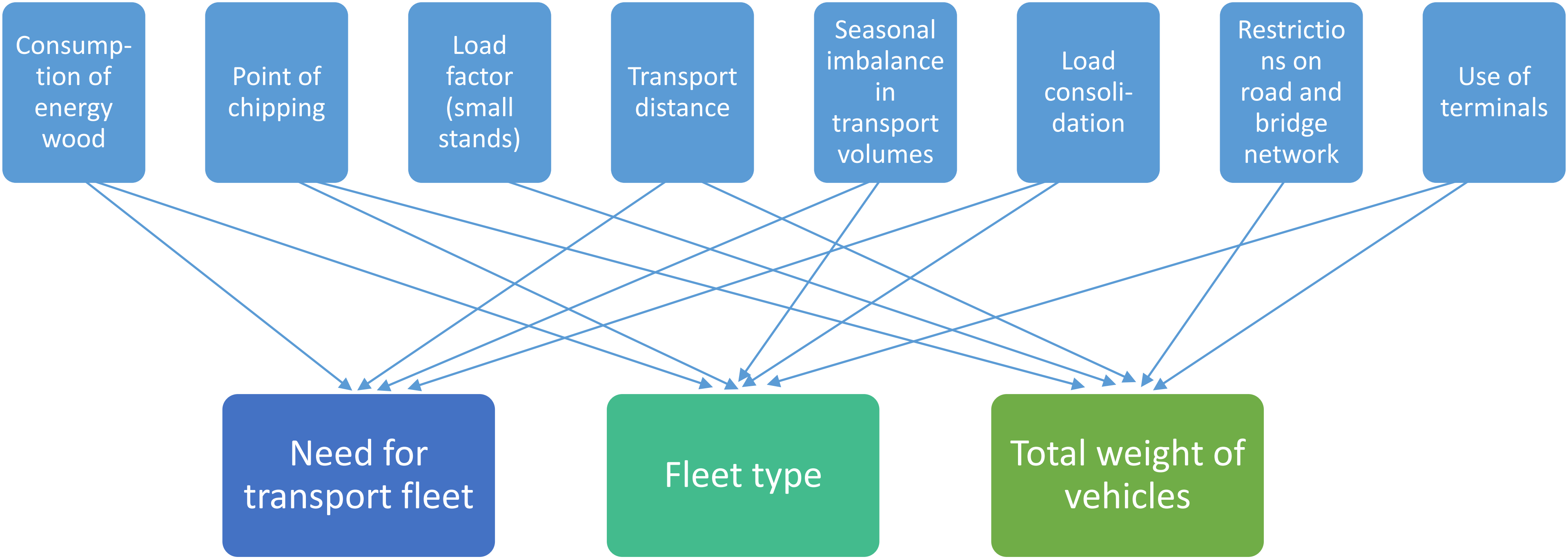


Size Distribution of Timber Trucks Arriving at Forest Industry Production Sites

- According to the questionnaires sent by Metsätaho Ltd to its' stakeholders particularly the proportion of 68-tons in timber combinations has increased after the measurement and mass reform
- The distribution of equipment in May 2015 is rather close to the previously presented distribution reported by the transport companies concerning log and pulpwood combinations (slide 24)
- The average life span for a timber vehicle is 5–7 years. Therefore, the average size of the equipment is expected to grow when equipment is renewed.



3.3 Factors Affecting Transport Fleet Development



Consumption of energy wood

Point of chipping

Load factor (small stands)

Transport distance

Seasonal imbalance in transport volumes

Load consolidation

Restrictions on road and bridge network

Use of terminals

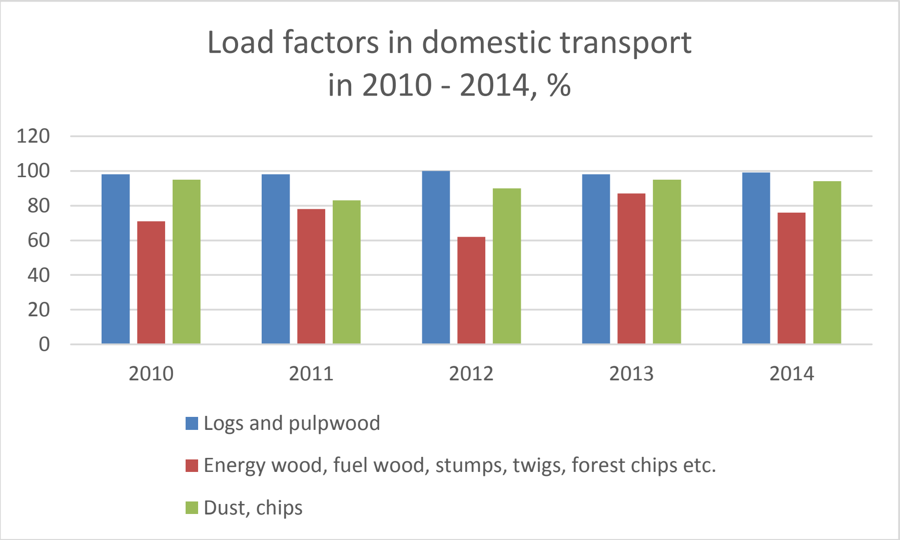
Need for transport fleet

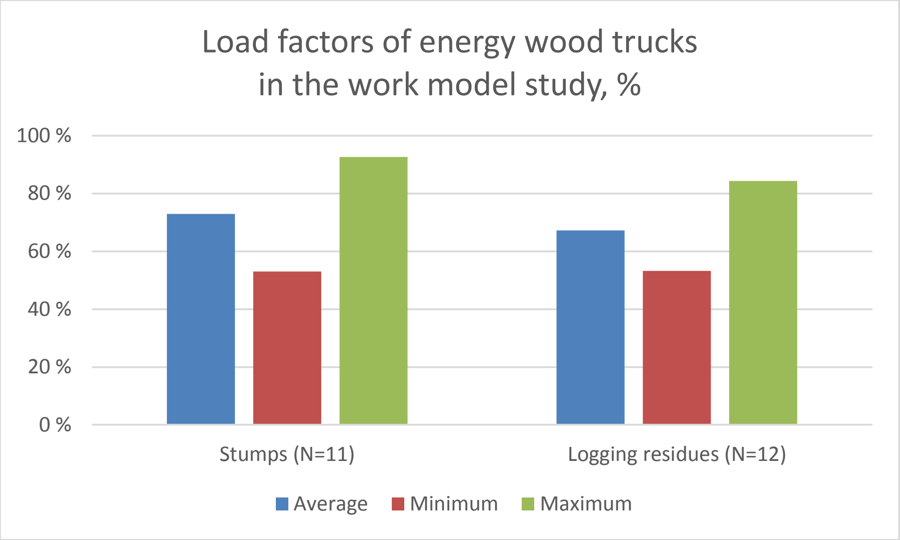
Fleet type

Total weight of vehicles

Load Factor

- The potential of larger trucks is affected by realised load factors of trucks
- In transport of logs, pulpwood, and sawdust&chips, the load factors are very high. Consequently, the higher total vehicle weights can be utilised in greater degree.
- Uncrushed energy wood has low density and thereby benefits more from larger load spaces and less from growth of vehicle’s permitted total mass. The load factors were low even in the period with lower total vehicle weights (before year 2013).


Load factors in domestic transport in 2010 - 2014, %


Load factors of energy wood trucks in the work model study, %

Figures: Statistics Finland 2011–2015,
Based on the material of Ovaskainen & Lundberg 2016

Need for Forest Chip Transport Fleet

- If consumption of forest chips would amount to 27 TWh, there would be a need for nearly 300 chip trucks and 400 energy wood trucks (Kärhä et al 2009)
- The amount of vehicles would increase by 300 vehicles from the present level
- The scenario by the Bioenergy Association of Finland anticipates 400 million € investments in logistics equipment by 2030

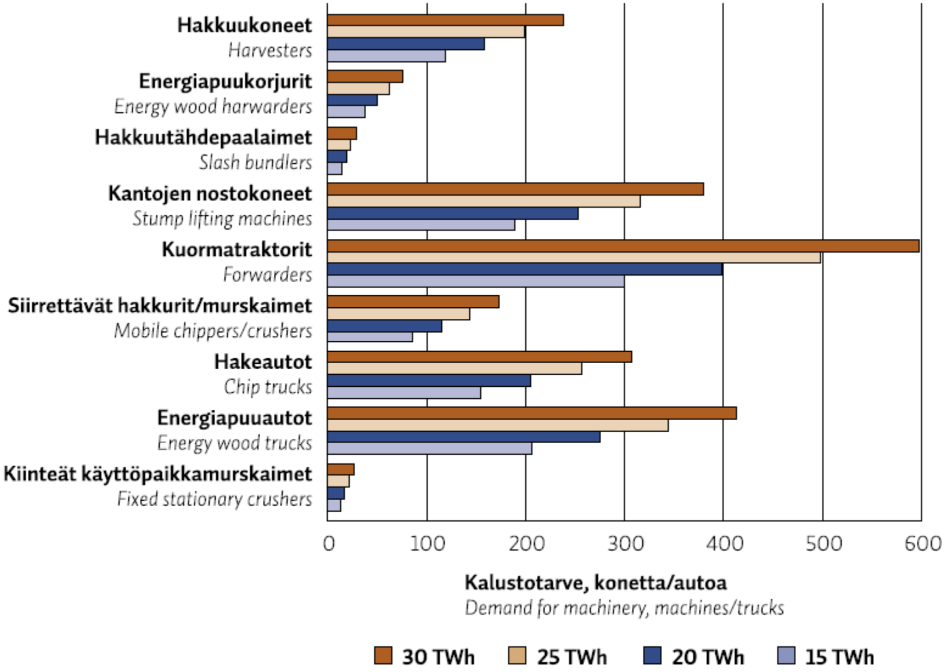


Figure: Kärhä et al 2009

4. The Present State and Scenarios of Energy Wood Transportation Costs

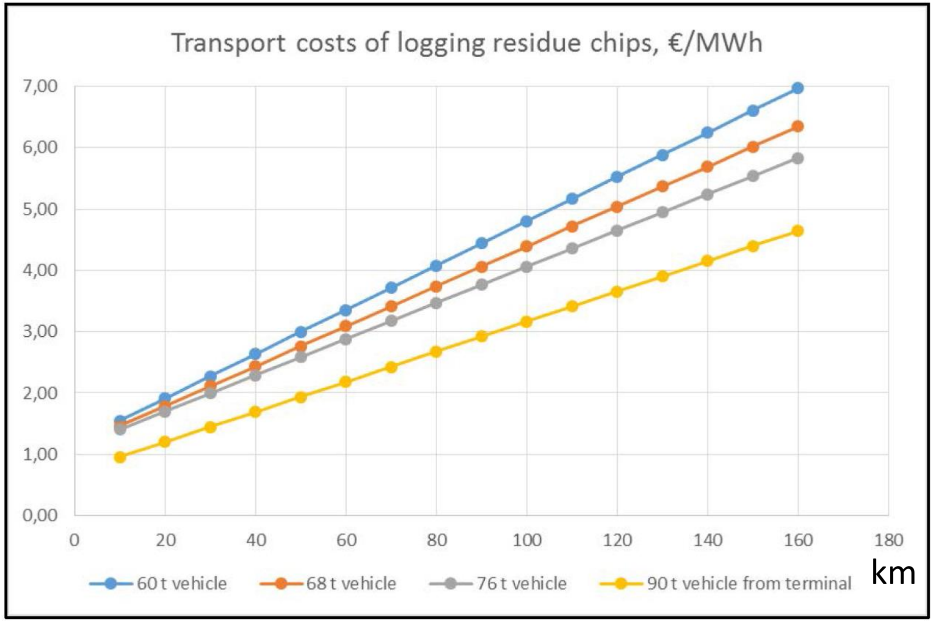
4.1 The Present State of Transport Costs

4.2 Transport Scenarios

4.1 The Present State of Transport Costs

- Larger articulated vehicles provide evident cost gains in the truck transport of the chipped energy wood (see the following slides, assumptions concerning comparative calculations are presented in appendix 2).
- Also in small tree transport increasing the overall weight provides cost gains but in the case of logging residues the differences between different size combinations are very small.
- The longer the transport distance the greater the cost gains obtained by using large articulated vehicles. In the future, transportation distances may well increase, particularly concerning large target uses of energy wood.
- For the present, domestic energy wood transport uses only trucks. If transportation distances exceed 100 kilometres, also railway and shipping become competitive in terms of costs.

Transport Costs of Forest Chips



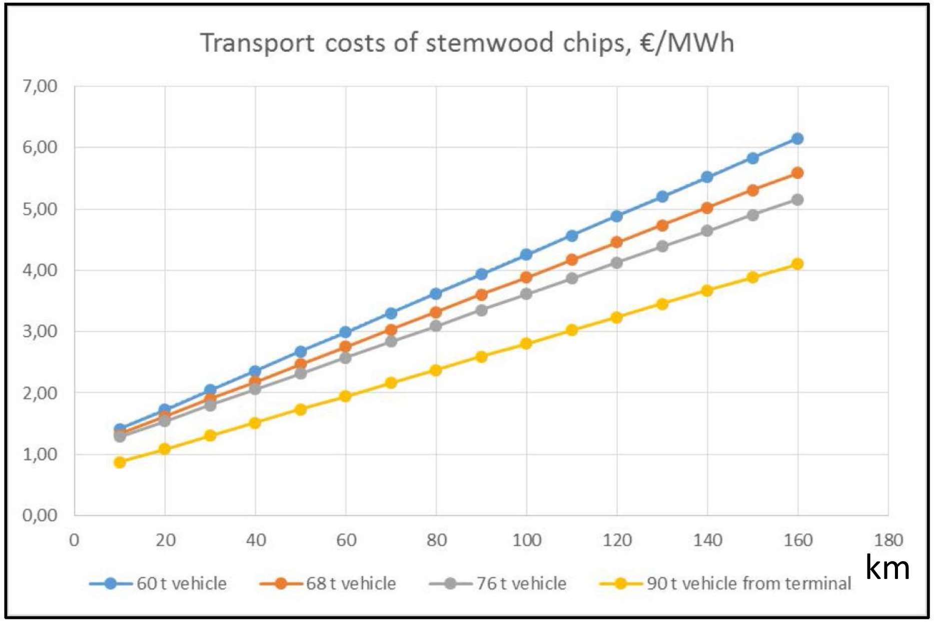


Figure: Korpilahti 2015

Transport Costs of Uncrushed Energy Wood

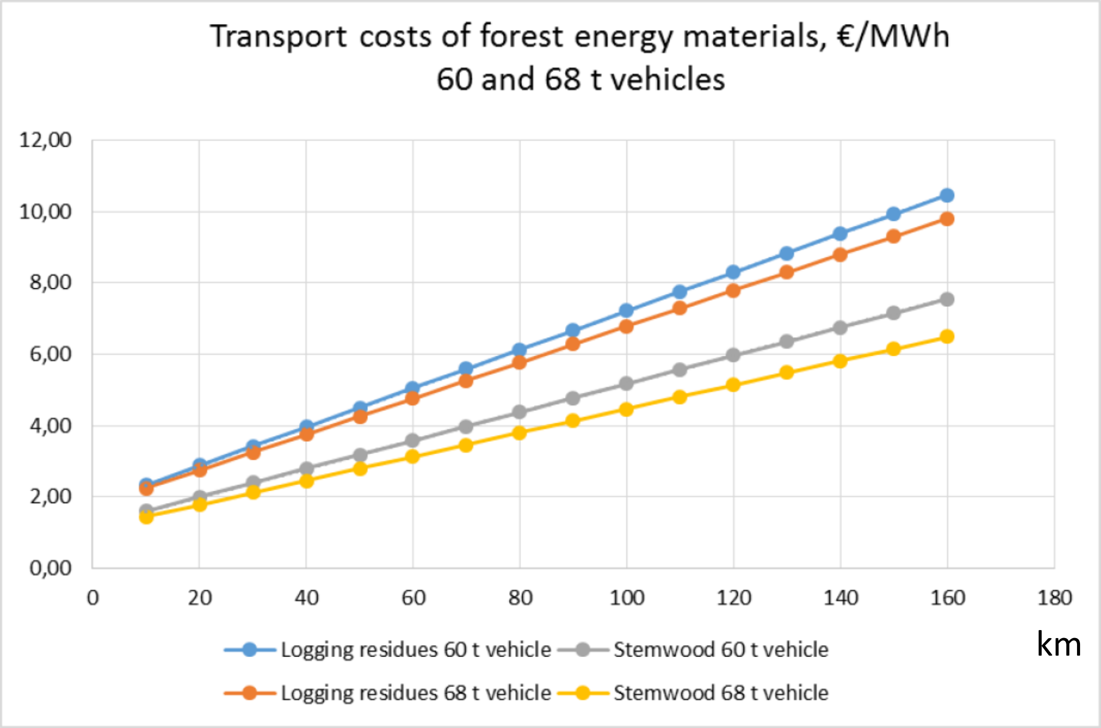


Figure: Korpilahti 2015

Costs of chipping and transport chains of energy wood

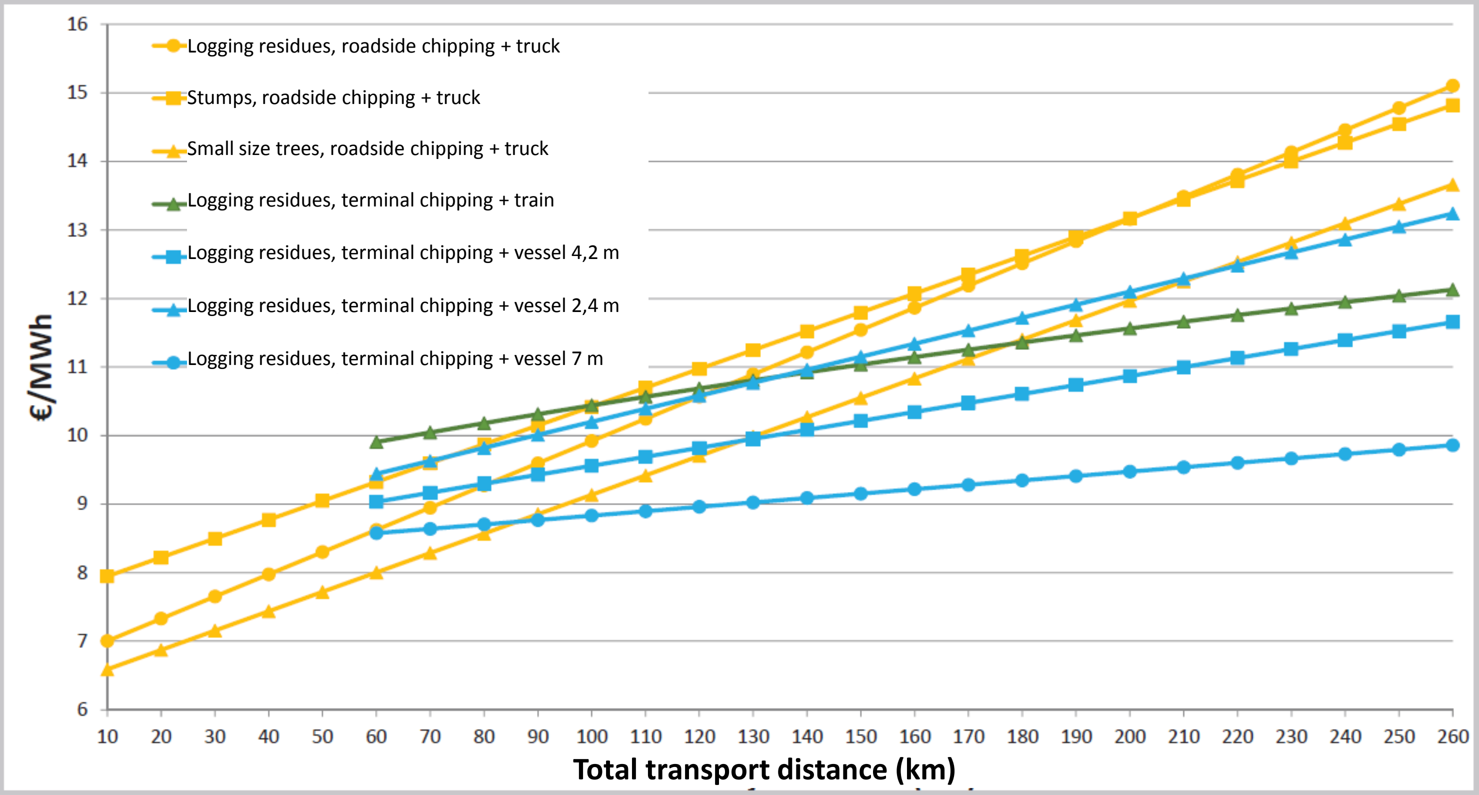


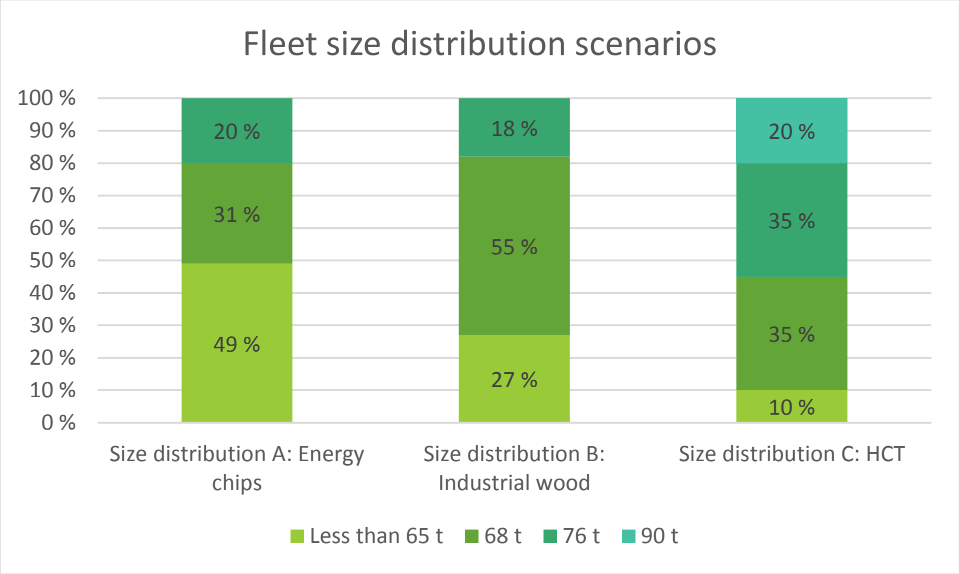
Figure: Iikkanen et al 2014. The train and vessel transport chains include pre-haulage of 50 km

4.2 Transport Costs Scenarios

- In this study energy wood transport scenarios have been evaluated according to two earlier reports:
  - Different cost levels according to sizes of articulated vehicles (Korpilahti 2015) and the equipment distribution survey that was accordingly in this report
  - Energy wood transport optimisation (Iikkanen 2014)
- In addition to the transportation costs, the use of the largest articulated vehicles is affected also by:
  - The road and bridge networks' limitations (especially in the future, if total weights are increased from current levels)
    - Total weight is also influenced by the road levels that are used when multipurpose trucks transport also other cargo than energy wood
  - Terminal wood chipping becomes more common, enabling transportation from the terminals with larger articulated vehicle combinations

Forest Chip Transport Costs Scenario

- Transport fleet's size scenarios were drafted as a background for transport costs scenarios
  - A and B represent the current situation (based on the results of the questionnaire)
  - The C scenario include also the HCT size class (90 tons). This scenario was built so that it results 10 % cost savings compared to the present situation (A).



Forest Chip Transport Costs Scenarios

- When calculated with the current vehicle size distribution (see the survey results), the transport costs of forest chips amounts to 61 million €/a.
  - With the current vehicle size distribution of industrial wood transport, the cost difference to present situation is small (with a saving of 1,9 %)
  - Transport cost saving of 10 % would be attainable for example with the size distribution of the scenario C on the previous slide. That would bring annual savings of 6 million € with the current energy chip volumes, savings of 11 million € with the targeted volume for 2020, and savings of 23 million € with the maximum sustainable volume.

FOREST CHIPS	**2014/2015**	**2020T**	**2020MS**
Forest chip volume TWh	15,2	27	58
Size distribution A: Energy chips			
Transport costs A million €/a	61	108	233
Transport costs A €/MWh	4,01	4,01	4,01
Size distribution B: Industrial wood			
Transport costs B million €/a	60	106	228
Transport costs B €/MWh	3,94	3,94	3,94
Size distribution C: HCT			
Transport costs C million €/a	55	98	210
Transport costs C €/MWh	3,61	3,61	3,61
Change A/B			
Transport costs million €/a	-1	-2	-4
Transport costs million €/a %	-1,9 %	-1,9 %	-1,9 %
Transport costs €/MWh	-0,08	-0,08	-0,08
Change A/C			
Transport costs million €/a	-6	-11	-23
Transport costs million €/a %	-10,0 %	-10,0 %	-10,0 %
Transport costs €/MWh	-0,40	-0,40	-0,40

Assumed transport distance is 100 km

T=target, MS=maximum sustainable

Unit costs per vehicle size: Korpilahti 2015

Transport Costs in the Optimisation Model

- According to the basic scenario (4,7 mill. tonnes / 12 TWh) of the energy wood transportation optimisation model presented in the slide 13, annual transport and terminal costs of domestic energy wood would amount to 97,4 mill. €, whereof
  - The share of direct road transport is 94 milj. €
  - Rail transport 1,2 milj. € and
  - Vessel transport 0,55 milj. €.
- In this case, transport costs would be 7,7 €/MWh
  - The figure is bigger than in the transport cost scenarios presented in the previous slide, since the optimisation model includes more in detail all the handling and transportation stages of energy wood supply chains.

5. The Present State and Scenarios of Energy Wood Back-haulage

5.1 Introduction

5.2 Questionnaire on Back-haulage

5.3 Transport Route Case Studies

5.4 Back-haulage Cost Scenarios

5.1 Introduction

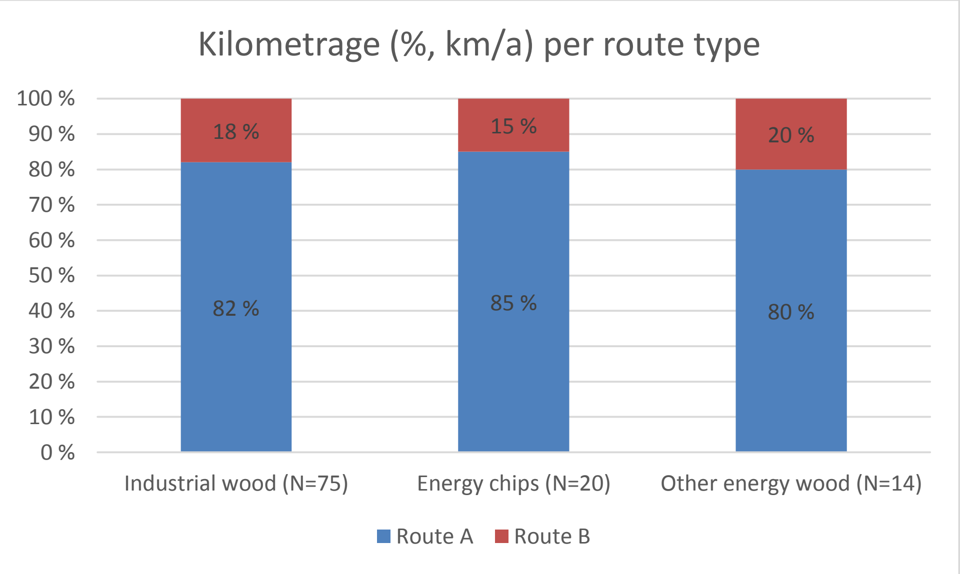
- Back-haulage refers to transport where vehicles carry load also in the return leg.
- Multi-point transport refers to transport where cargo is loaded to a vehicle at multiple pickup points prior to delivery.
- In wood transport, it is most common that vehicles drive full from forest to points of use and drive back empty.
- Back-haulage and multi-point transport improve load factors of vehicles and thereby decrease transport costs per transported tonne or cubic meter.
- Chips trucks with sides are suitable for transporting also other bulk cargo than chips in the return legs.
  - See slides 16–18 describing various types of transport vehicles

5.2 Questionnaire on Back-haulage

- One of the aims of the questionnaire addressed to transport companies (described more in detail in the Chapter 3.2) was to survey the extent of various types of transport routes both in energy wood and industrial wood transportation

Distribution by Transport Route Types

- About 80 % of kilometrage of wood transport is composed of a full outward transport leg and an empty return leg.
- The share of back-haulage and “other transport routes” is in total 20 %.
- According to the survey results, there is no major difference in route type distributions of industrial and energy wood transportation.

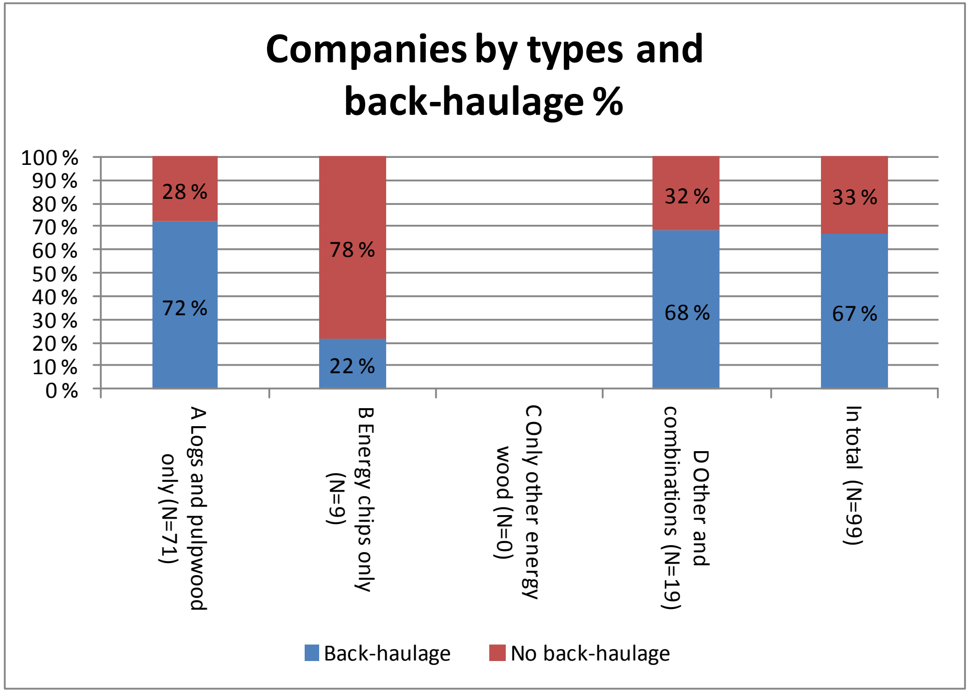


Route type A: Transport with a full outward load and an empty return leg close to the point of departure: % share of transport

Route type B: Other types of routes (for examples back-haulage, circular routes, or multi-point pickup routes): % share of transport

Back-haulage by Company Types

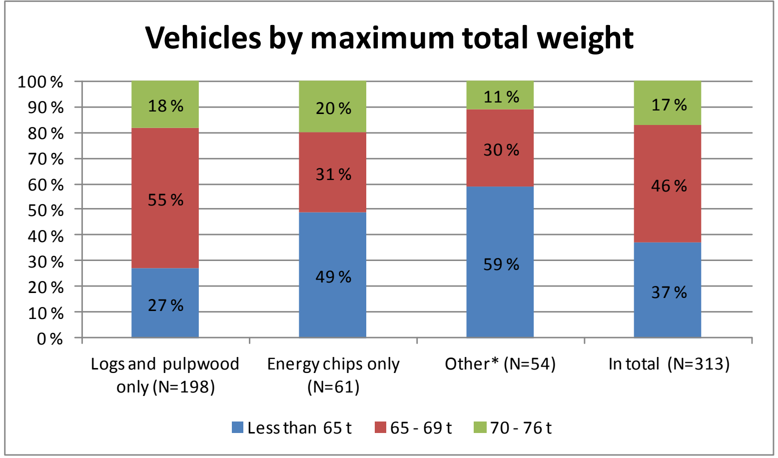
- The major share (71) of the companies who took the survey, transports only industrial wood. 72 % of these companies report to have back-haulage.
  - However, companies seem to have back-haulage only randomly, since the share of back-haulage in kilometrage is considerably lower (see slide 42).
- The respondents in the group D have nearly the same level of back-haulage.
- A number of respondents transporting only energy chips or energy wood was so small, that is not possible to make conclusions about the role of back-haulage.

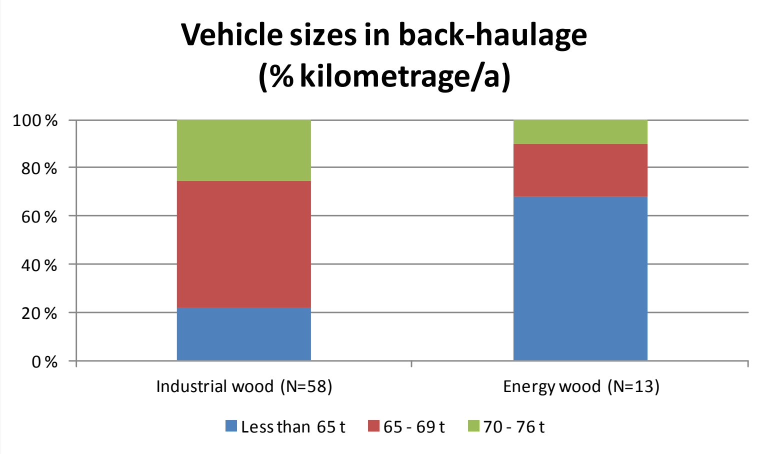


D. The company has either other or several types of vehicles for transport of industrial or energy wood

Transport Fleet Size in Back-haulage of Wood

- In back-haulage of industrial wood, larger trucks are used than in general*.
- The trucks used in back-haulage of energy wood are smaller than in transport in general. However, due to the small amount of respondents this result is not necessarily valid.





** The variables in the two figures are different. Therefore the conclusion is only directional.*

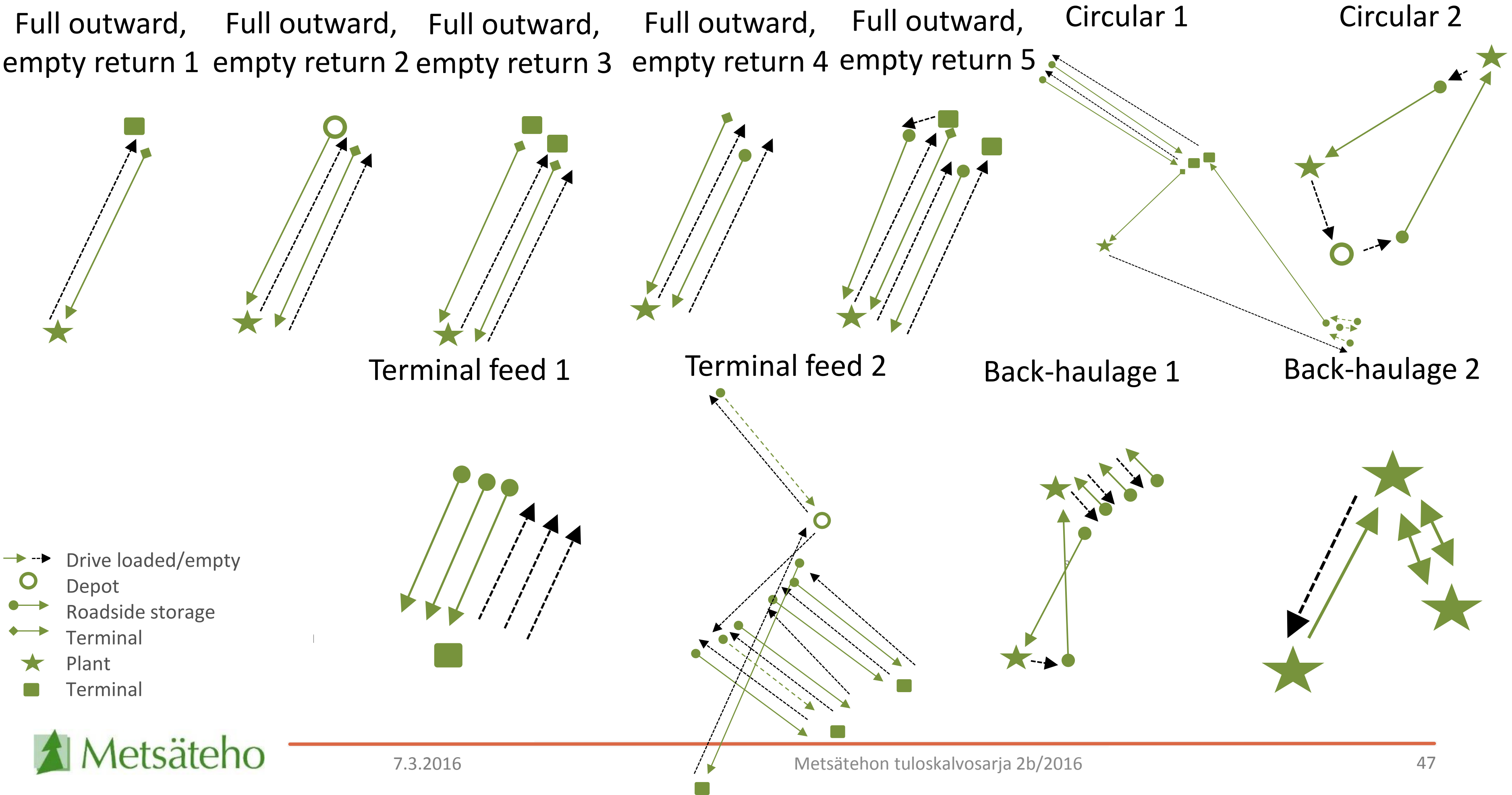
5.3 Transport Route Case Studies

- The aim of the wood transport route cases was to gain a more in-depth picture of various types of routes and their impacts on vehicle load factors.
- The cases covered both industrial and energy wood transport in order to allow comparison between the two groups.
- The aim was to collect cases with various types of routes. The share of the route types in the total transport work was not studied.
- Wood transport route cases were collected from
  - 11 routes of industrial wood transport
  - 5 routes of energy wood transport
- Some of the data was collected as a part of the BEST study on working models of loading energy wood (Ovaskainen&Lundberg 2016).
- Each case presents transport routes of a vehicle during one day (or less than a day)
- The routes are not illustrated in the same scale. The illustrated transport directions and distances are only directional.

Differences of Transport Routes

- The most typical transport routes are composed of a full (or nearly full) outward transport leg and an empty return leg. Even these route types vary in regards of whether the wood is transported directly from the forest to a point of use or from/to a terminal. The review of the whole transport chain would require inclusion of pre- and post-haulages, often taking place on different days.
- In back-haulage, the degree of empty running is at lowest about 20 %. The empty running on circular routes varies, and more advanced conclusions would demand a larger group of cases.
- Also transport routes which are composed of long distance transport legs and short local transport legs are of interest (Circular 1 and Back-haulage 1).
- Some of the routes simply include transport between two locations, whereas other routes are more complex with several points of departure and delivery.
  - So called complex routes seem to be more efficient in terms of running loaded. Therefore, an interesting topic for further research would be to study efficiency of planning complex transport routes.

Cases of Industrial Wood Transport Routes



Full outward, empty return 1

Full outward, empty return 2

Full outward, empty return 3

Full outward, empty return 4

Full outward, empty return 5

Circular 1

Circular 2

Terminal feed 1

Terminal feed 2

Back-haulage 1

Back-haulage 2

→ ⇢ Drive loaded/empty

○ Depot

●→ Roadside storage

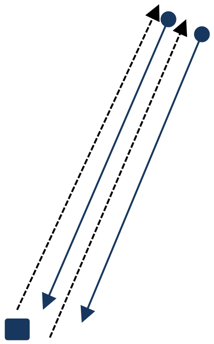
◆→ Terminal

★ Plant

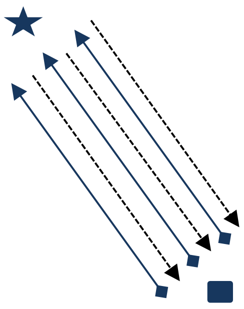
■ Terminal

Cases of Energy Wood Transport Routes

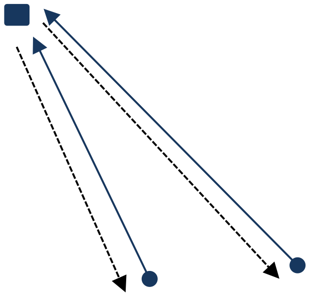
Full outward, empty
return 6



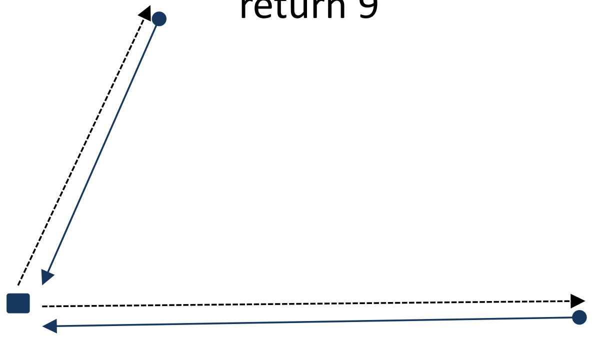
Full outward, empty
return 7



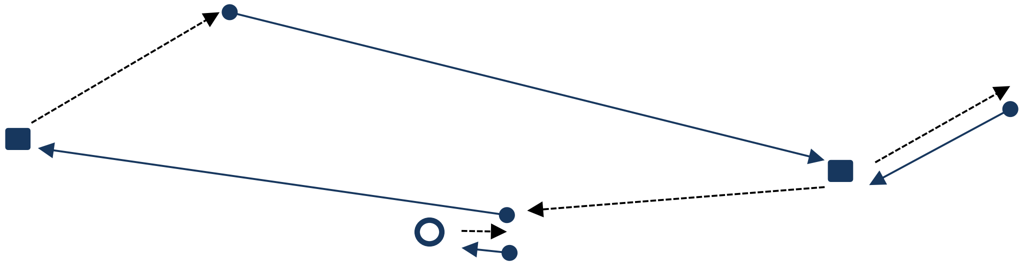
Full outward, empty
return 8



Full outward, empty
return 9



Circular 3



→ ⇢ Drive loaded/empty
○ Depot
●→ Roadside storage
◆→ Terminal
★ Plant
■ Terminal

Route Characteristics 1

Route type	Separate points of delivery	Number of deliveries	Total km driven	Km driven / Delivery	Empty running % km
Full outward – Empty return 1	1	1	169	169	42
Full outward – Empty return 2	1	2	710	355	52
Full outward – Empty return 3	1	2	683	342	46
Full outward – Empty return 4	1	2	753	377	46
Full outward – Empty return 5	1	3	965	322	52
Full outward – Empty return 6	1	2	211	106	49
Full outward – Empty return 7	1	3	73	24	48
Full outward – Empty return 8	1	2	113	57	51
Full outward – Empty return 9	1	2	217	109	50

Route Characteristics 2

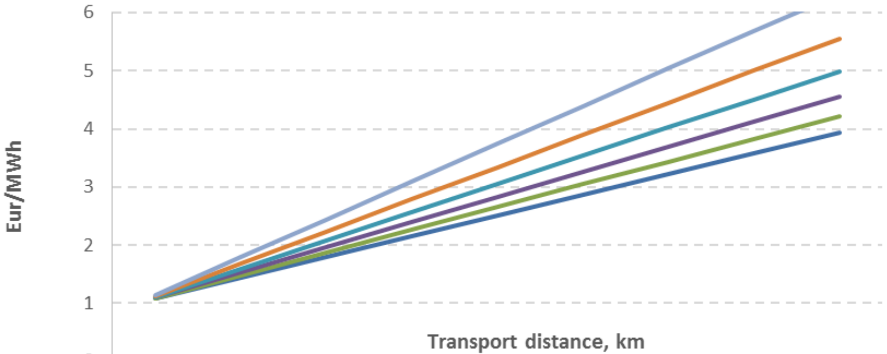
Route type	Separate points of delivery	Number of deliveries	Total km driven	Km driven / Delivery	Empty running % km
Circular 1	3	4	189	47	48
Circular 2	2	2	760	380	31
Circular 3	2	3	367	122	43
Terminal feed 1	1	3	1 350	450	50
Terminal feed 2	4	6	130	22	56
Back-haulage 1	3	5	899	180	23
Back-haulage 2	2	5	1 100	220	23
Average (incl. the previous slide)	**1,6**	**2,9**	**543**	**205***	**44**

*According to the Metsäteho Oy statistics (Strandström 2015b), the average transport distance of domestic wood by truck is 107 km

5.4 Back-haulage Cost Scenarios

- Today, transport of chips costs 3,74 €/MWh (with an assumption of 80 km transport distance and a full outward and an empty return leg)
  - For that distance full back-haulage (with 0 % empty driving) would reduce transport costs approximately by one third
- As shown in the slide 42, today the share of back-haulage is less than 15 % of total kilometrage.
- The table and appendix 3 show saving potential for various degrees of back-haulage and transport distances.
- In many cases loads for return legs have to be picked up in other locations than destinations of first loads.
  - The blue squares indicate maximum shares of empty driving for different transport distances that still bring savings in comparison to today's costs.

Transport costs of logging residue chips
68 tonne vehicle



Driving empty	0	20	40	60	80	100	120	140	160
0 %	1,07	1,43	1,79	2,15	2,50	2,86	3,22	3,58	3,93
10 %	1,08	1,48	1,87	2,26	2,65	3,04	3,43	3,83	4,22
20 %	1,10	1,53	1,96	2,40	2,83	3,26	3,69	4,13	4,56
30 %	1,11	1,59	2,08	2,56	3,05	3,53	4,02	4,51	4,99
40 %	1,12	1,68	2,23	2,78	3,34	3,89	4,45	5,00	5,56
50 %	1,14	1,79	2,44	3,09	3,74	4,39	5,04	5,69	6,34

Calculation based on transport costs in Korpilahti 2015

6. Conclusions

- Increased consumption of energy wood is supported by several EU and national level policy objectives, investment projects of new biomass power plants, as well as investment projects of forest industry production plants, which increase the demand for industrial wood and thereby increase supply of energy wood.
- Transport costs constitute a major share of total wood procurement costs. In turn, the efficient use of transport vehicles play a major role in reducing transport costs.
- There is a great potential in energy chip transport to take advantage of higher vehicle total weights due to the high density of chip loads.
  - In addition, the growing trend of chipping at terminals, which are located along better road connections than roadside storages, improves conditions to utilise larger trucks.
- There is a moderate potential for energy chip transport to take advantage of back-haulage, since chip trucks are more suitable to various types of transport than timber trucks. The various solutions, which enable modification of a timber truck to be suitable for chip transport, need further development. More extensive use of back-haulage apparently calls for new approaches in transportation planning and information exchange between different parties. Consequently, examination of planning processes of back-haulage transport is one interesting topic for further research.
- In transport of other types of energy wood (uncrushed logging residues, stumps, and small-sized trees) the larger trucks increase the size of load spaces and thereby decrease transport costs per transported unit. However, the benefits are rather modest.

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Appendices

1. Respondents of the Questionnaire
2. Assumed Characteristics of Energy Wood Trucks
3. Transport Costs of Forest Energy Chips with Different Degrees of Back-haulage

Appendix 1. Respondents of the Questionnaire

North = regions in orange colour
South = regions in blue colour

Region	Amount
Lapland	8
Northern Ostrobothnia	16
Ostrobothnia	1
Central Ostrobothnia	1
Southern Ostrobothnia	5
Kainuu	8
North Karelia	5
Northern Savonia	6
South Karelia	9
Southern Savonia	10
Central Finland	4
Satakunta	2
Southwest Finland	6
Pirkanmaa	12
Päijät-Häme	3
Tavastia Proper	0
Kymenlaakso	3
Uusimaa	0
Åland	0
In total	**99**

Appendix 2a. 60 tonne vehicle

Uncrushed materials – Vehicle own mass 31 t (with a loader)

	Logging residues	Stump wood	Small-size trees
Load space, m^3	145	145	90
Load (material), m^3_{solid}	29	29	38
Load weight, t	23.9	21.2	28.5
Gross weight, t	54.9	52.2	59.5
MWh/load	60	63	82

Comminuted materials – Vehicle own mass 25 t

	Logging residues	Stump wood	Small-size trees
Load space, m^3	105	120	115
Load (material), m^3_{solid}	42	48	46
Load weight, t	34.7	34.9	34.7
Gross weight, t	59.7	59.9	59.7
MWh/load	87	103	100

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Appendix 2b. 68 tonne vehicle

Uncrushed materials – Vehicle own mass 32,5 t (with a loader)

	Logging residues	Stump wood	Small-size trees
Load space, m^3	160	160	115
Load (material), m^3_{solid}	32	32	47
Load weight, t	26.4	23.4	35.8
Gross weight, t	58.9	55.9	68
MWh/load	66	69	103

Comminuted materials – Vehicle own mass 27,5 t

	Logging residues	Stump wood	Small-size trees
Load space, m^3	125	140	135
Load (material), m^3_{solid}	50.0	56.0	54.0
Load weight, t	41.3	40.7	40.8
Gross weight, t	68.8	68.2	68.3
MWh/load	103.5	121.0	117.2

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Appendix 2c. 76 and 90 tonne vehicles

Comminuted materials – Vehicle own mass 29,5 t

	Logging residues	Stump wood	Small-size trees
Load space, m^3	140	160	155
Load (material), m^3_{solid}	56	64	62
Load weight, t	46.2	46.6	46.8
Gross weight, t	75.7	76.1	76.3
MWh/load	116	138	135

Comminuted materials – Vehicle own mass 30,3 t

	Logging residues	Stump wood	Small-size trees
Load space, m3	181	195	195
Load (material), m3	72.4	77.9	78
Load weight, t	59.7	56.7	58.9
Gross weight, t	90.0	87	89.2
MWh/load	150	168	169

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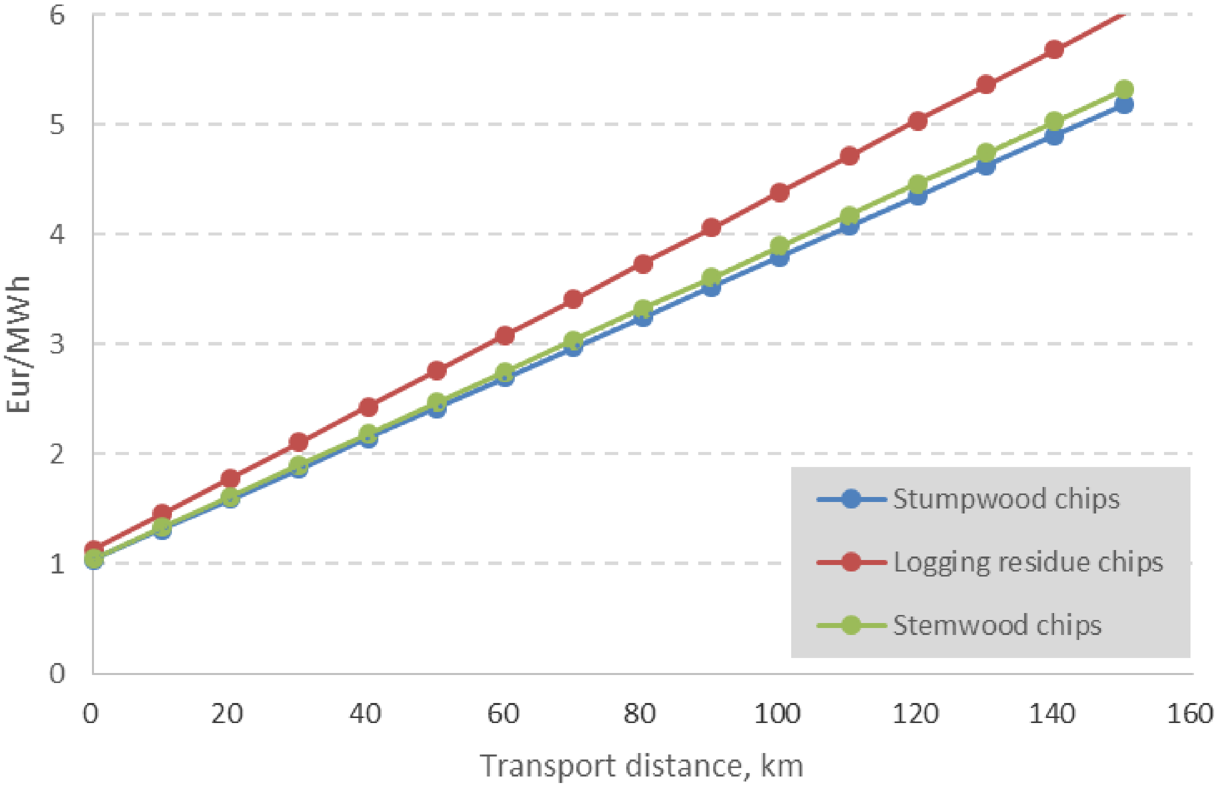
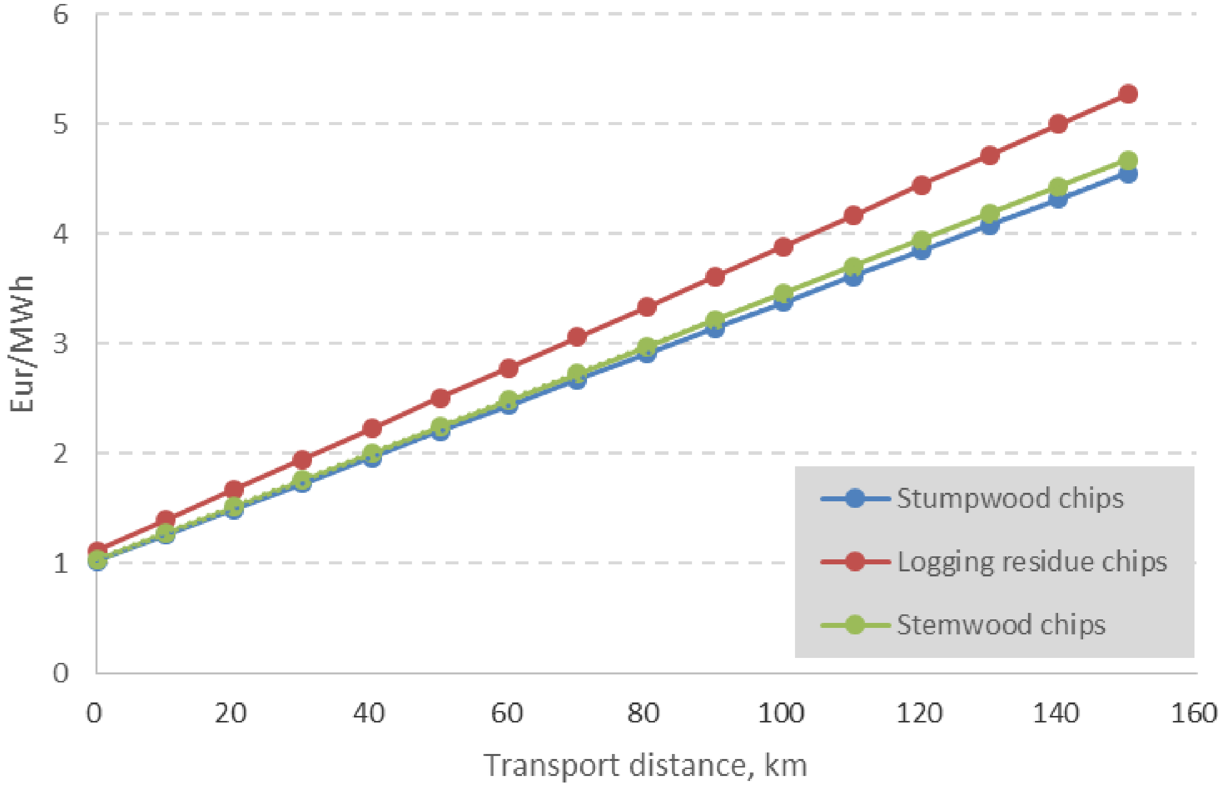
Appendix 3a. Transport Costs of Forest Energy Chips

Empty Driving = 50 % of Total Drive, 68 tonne vehicle



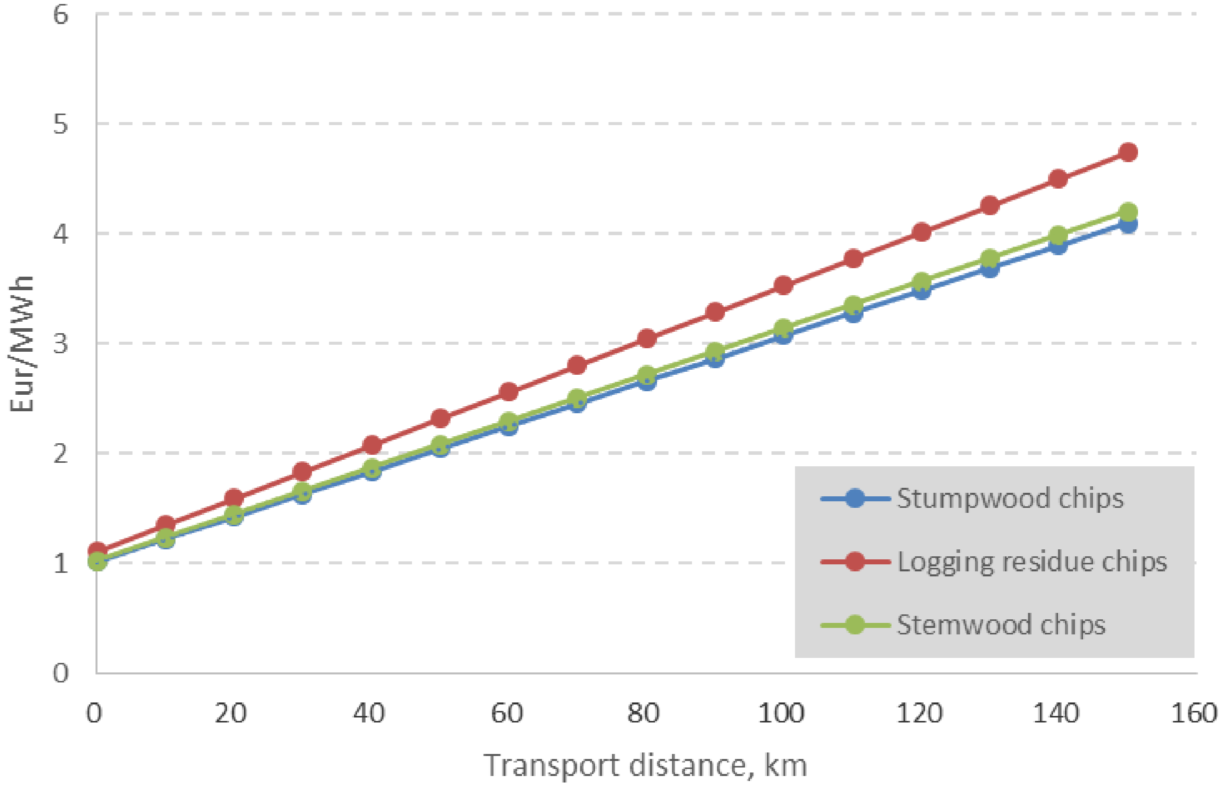
Appendix 3b. Transport Costs of Forest Energy Chips

Empty Driving = 40 % of Total Drive, 68 tonne vehicle



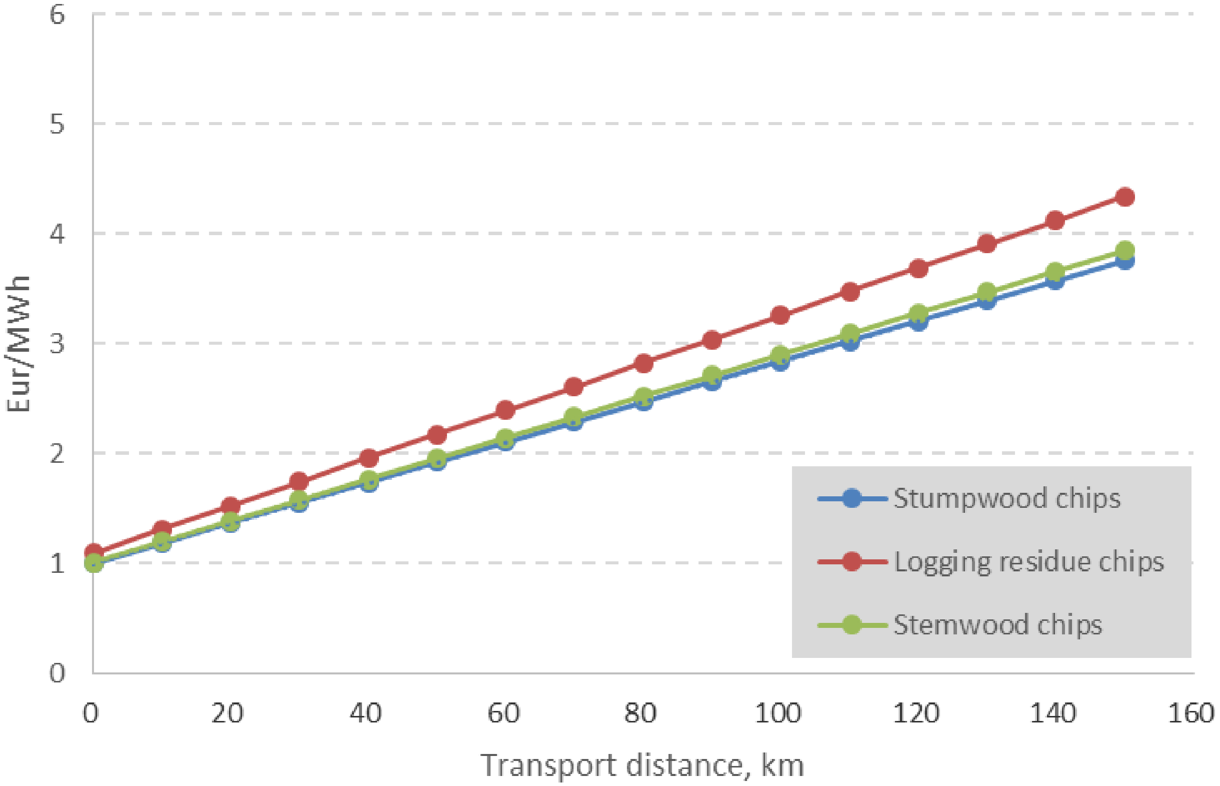
Appendix 3c. Transport Costs of Forest Energy Chips

Empty Driving = 30 % of Total Drive, 68 tonne vehicle



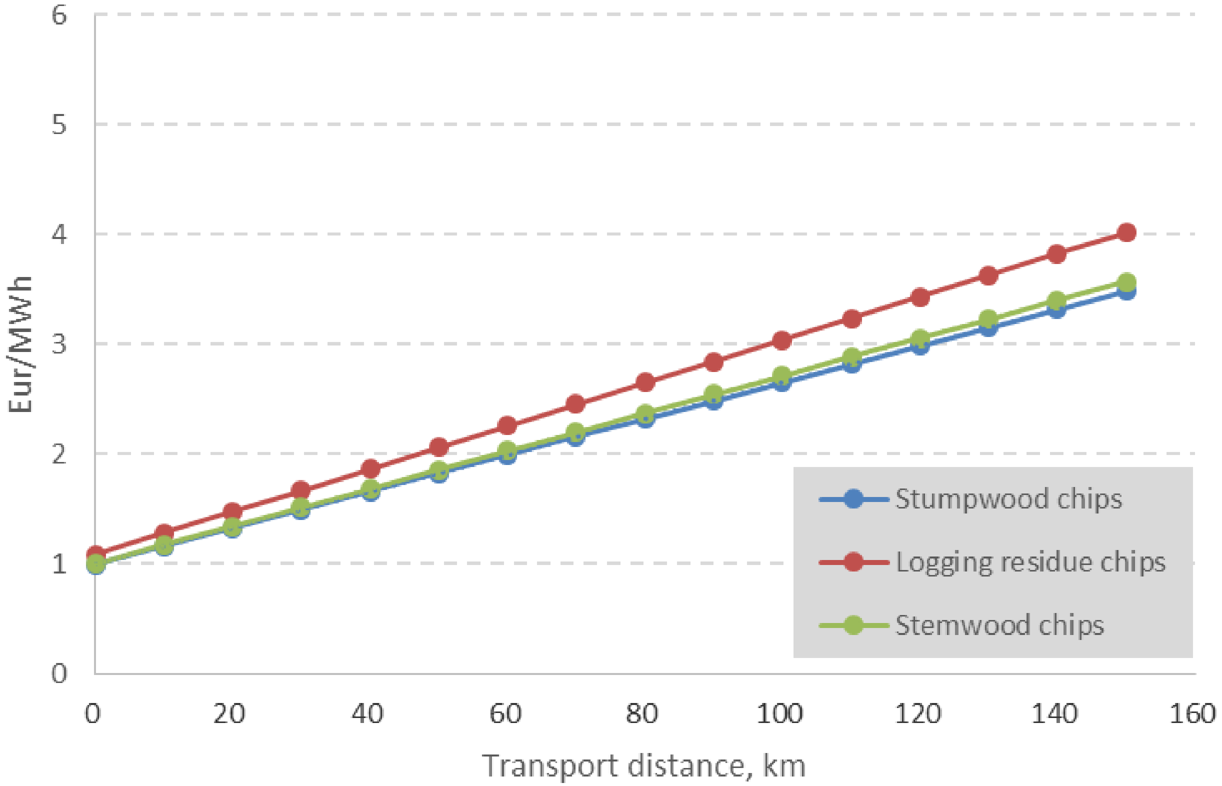
Appendix 3d. Transport Costs of Forest Energy Chips

Empty Driving = 20 % of Total Drive, 68 tonne vehicle



Appendix 3e. Transport Costs of Forest Energy Chips

Empty Driving = 10 % of Total Drive, 68 tonne vehicle



Appendix 3f. Transport Costs of Forest Energy Chips

Empty Driving = 0 % of Total Drive, 68 tonne vehicle