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Estimation of supply and delivery cost of energy wood from Northwest Russia

Yuri Gerasimov and Timo Karjalainen

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Abstract

Possibilities for energy-wood supply and delivery costs for the eight regions in Northwest Russia have been assessed. By-products from harvesting and mechanical wood processing were considered as sources for energy production based on actual harvesting, sawmill and plywood production in 2006 and was estimated at 30.7 million m^3. Nearly 30.5 million m^3 of the energy wood could be transported, and the rest of the energy wood was inaccessible due to lack of road infrastructure in the Republic of Komi and the Arkhangelsk region. About 70% of the energy wood was from harvesting, consisting of non-industrial roundwood, unused branches and tops, defective wood resulting from logging, spruce stumps removed after final felling, and 30% from sawmills and plywood mills, i.e., chips, sawdust and bark. The delivery cost of energy wood to the potential border-crossing points in Finland was analyzed for three means of transport. The delivery cost of energy wood by railway varied from 28.9 to 43.5 €/m^3. Volume was estimated as 27.8 million m^3 and maximum distance as 2110 km to the border station. The cheapest means of delivering energy wood was by road. Delivered cost for energy wood by road varied from 15.8 to 18.5 €/m^3. However, the volume was limited to a 200-km belt along the border between Russia and Finland and was 1.6 million m^3. The most expensive means of delivering energy wood was by waterway. Delivery cost for energy wood by waterway varied from 45.0 to 47.9 €/m^3. The volume was estimated at 0.8 million m^3 from a remote area without feasible access to railway in the Lake Onego area.

It should be emphasized that we have estimated supply and delivery costs, not prices which are defined by the market based on supply and demand.

Keywords

logging residues, non-industrial roundwood, wood procurement, road, railway, waterway

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Preface

This study is a continuation of our earlier work on the energy-wood resources in Northwest Russia. This work was part of the project "Global forest energy resources, certification of supply and markets for energy technology" at the Finnish Forest Research Institute (Metla). The aim of the project was to estimate the availability of forest biomass for energy production, and to evaluate the certification status and the long-term sustainability of the forest biomass supply. The project was carried out by Metla in cooperation with the Technical Research Centre of Finland (VTT) and Lappeenranta University of Technology (LUT). It was funded by the Finnish Funding Agency for Technology and Innovation (Tekes) programme "Business Opportunities in Mitigating Climate Change" (ClimBus) and was co-financed by John Deere Forestry Oy, Metso Power Oy, Neste Oil Oyj, Pentin Paja Oy, Stora Enso Oyj, and Vapo Oyj.

In Joensuu,

Yuri Gerasimov and Timo Karjalainen

1 Introduction

1.1 Overview of the forest sector

In Northwest Russia, the forest area is approximately 85 million ha and the growing stock is 10 billion m^3 (Kareliastat 2008). The Republic of Komi, and the Arkhangelsk and Vologda regions have the largest forest resources (Figure 1). The actual harvest was about 50 million m^3 in 2006, while the allowable cut exceeded 100 million m^3. By-products from logging such as non-industrial roundwood, unused branches and tops, defective wood resulting from logging, spruce stumps removed after final felling, may be left on site after harvest (later *energy wood*) but could be converted to energy.

A large share of the wood-processing industry is concentrated in the Arkhangelsk, Komi and Karelia regions due to the large forest resources in these regions. The wood industry consists of 10 pulp mills, 28 panel mills, 25 big sawmills and more than 3000 small sawmills, which altogether utilize nearly 35 million m^3 of industrial roundwood per year.

In 2007 the industry produced 3.8 million tons of wood pulp. The production of the panel industry can be divided into two branches: total annual production of plywood was 1.2 million m^3 and that of wood-based panel products included a 1.2 million m^3 production of particleboard and 76.8 million m^2 production of fibreboards. Total annual sawn timber production was about 6.4 million m^3 in 2007 (Kareliastat 2008).

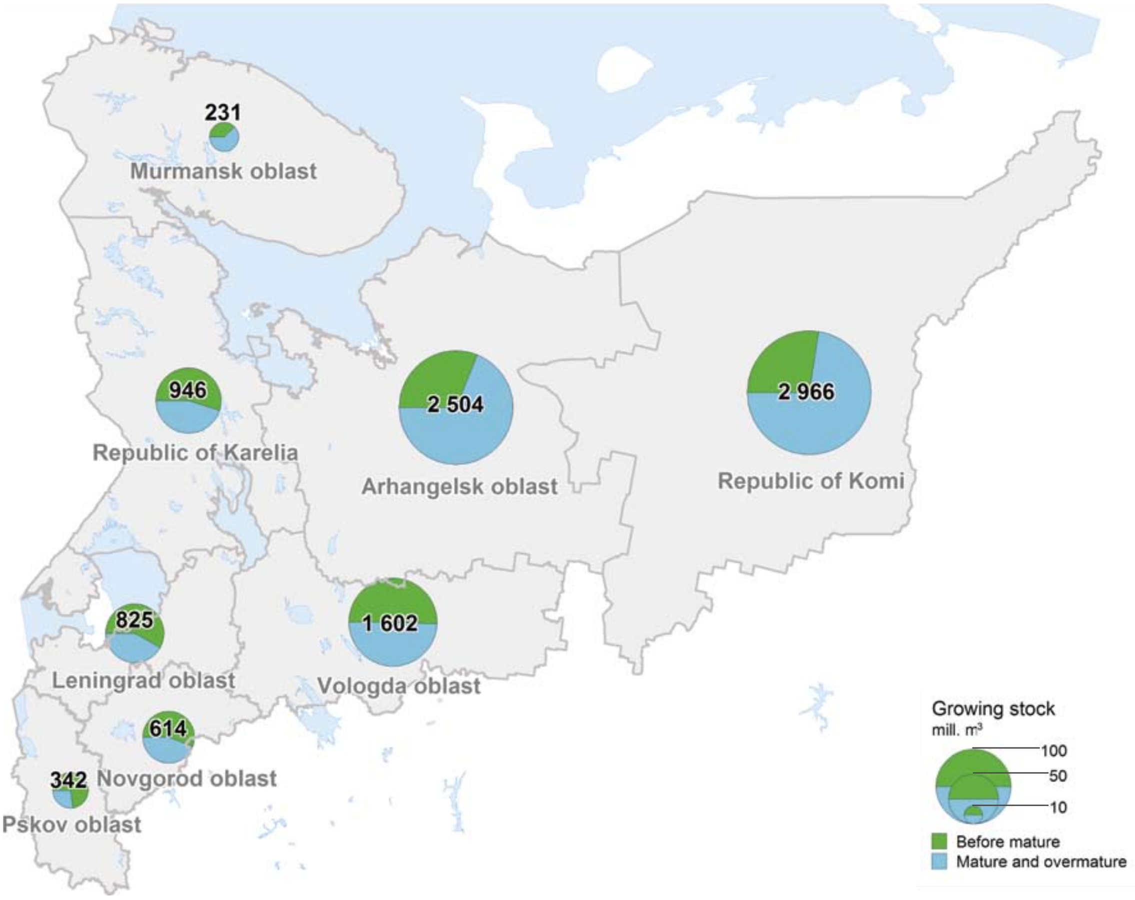

Figure 1. Location and distribution of forest resources in Northwest Russia.

Sawmill and plywood sites produce a number of by-products, such as chips, sawdust and bark that could be also used for energy production.

An assumption of a 55% conversion efficiency in sawmills provided 7.9 million m^3 of by-products based on 2007 production, and a 63% conversion efficiency in plywood mills provided 0.7 million m^3 of by-products, respectively. Thus, the total amount of by-products from mechanical wood processing in 2007 was 8.6 million m^3.

Currently, wood chips are usually sold to pulp and panel manufacturers, while bark and sawdust are usually used for bioenergy, with sawdust in particular used for producing pellets for the export market.

1.2 Bioenergy

Russia is the world's biggest producer and exporter of energy, but a major disadvantage is that vast fossil-fuel resources are in Siberia, far from population, industry and export markets. As well, Northwest Russia uses significant amounts of fossil energy: 19.7 Mtoe of natural gas, 10.8 Mtoe of oil, 1.4 Mtoe of coal, altogether 31.9 Mtoe or 364 TWh (Russia Energy Survey 2002). There is a risk in being too dependent on high fossil-fuel prices and high transport costs from Siberia. In addition, emissions from burning fossil fuels are a major source of greenhouse gas emissions, and thus a significant contributor to global warming. Reduction of greenhouse gas emissions is an essential national and international goal to meet the commitments on mitigating climate change (IPCC 2007). Efficient use of energy wood as a renewable energy resource could help to replace non-renewable and imported energy sources.

The use of fossil fuels dominates the energy consumption in Northwest Russia (Arabkin 2003), while renewables and wood have a minor role:

- natural gas – about 44%
- liquid and fossil fuels – about 36%
- nuclear and hydropower – about 18%
- wood and other sources – about 2%.

Currently, wood provides a visible energy supply only in the Karelia and Pskov regions, as shown in Figure 2 (Grigoryev 2007). Almost all energy wood is converted by combustion to provide heat energy. The wood-processing industry is the major consumer of forest biomass, and the other significant users are residential wood burners/district heating plants.

Reasons often cited for the low use of wood by-products for energy are the availability of energy wood and their supplies, and the uncertainty concerning the cost of this supply.

The type and size of sawmills and plywood mills within the study area have an impact on by-products available for bioenergy. The conversion efficiency from roundwood to different wood products varies. Many sawmills already use a large proportion of their by-products for heat. These by-products compete with energy wood and have, therefore, an opportunity cost associated with them if the by-products are utilized for bioenergy.

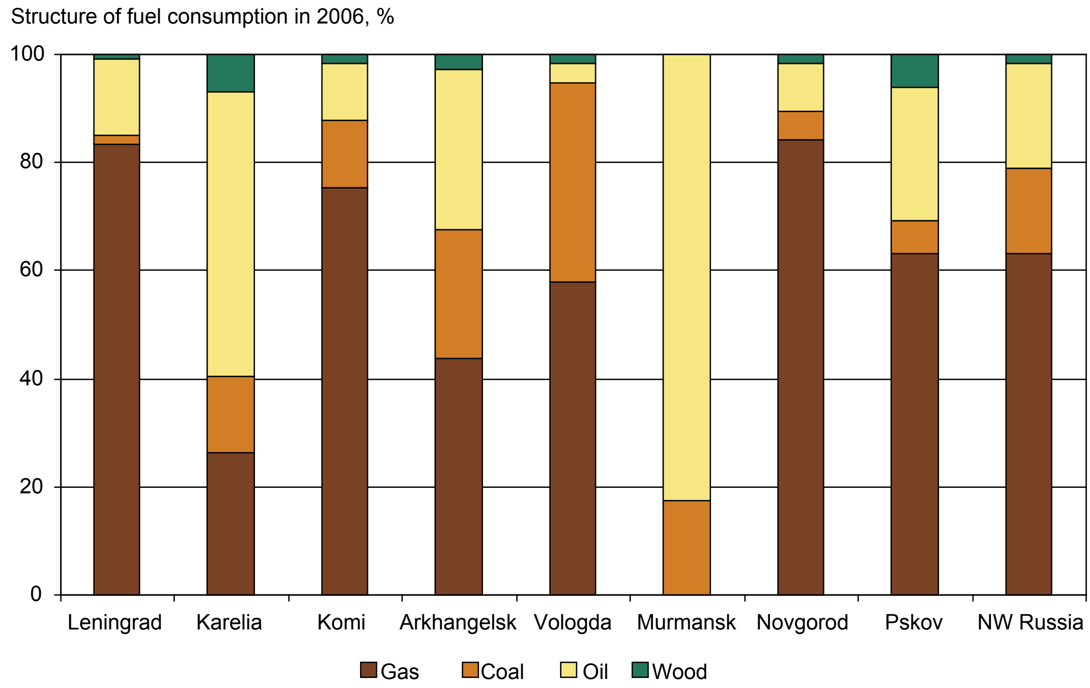

Figure 2. Fuel consumption in Northwest Russia, share of the total consumption in 2006.

1.3 Objectives

The main objective of this study was to estimate the availability and delivery cost of energy wood from harvesting and mechanical wood processing in Northwest Russia.

2 Data and method for estimating the delivery cost of energy wood

The delivery cost for energy wood depends on the means of transport, transport distance to the bioenergy plant, state of the road network, distribution of forest resources, etc. Scattered geographical distribution of energy-wood supply potential has raised interest in using the Geographical Information System (GIS) for analyses. GIS has been used in a number of studies for evaluating energy-wood supply and estimation of delivery cost to the power plant (e.g. Nord-Larsen and Talbot 2004; Van Belle et al. 2003; Voivontas et al. 2001).

The GIS-approach was applied in this study when estimating the cost of energy wood delivered to the border-crossing points in Finland for three different energy-wood transport streams: by railway, by road and by waterway. The following steps were utilized:

- creation of GIS layers for
  - cutting areas on the level of forest units
  - sawmill and plywood production sites
  - roads, railways and waterways
  - railway stations, ports, border points between Russia and Finland
  - border-crossing points

- estimation of distance from a cutting area to the nearest border-crossing point
- estimation of distance from a sawmill or plywood mill to the nearest border-crossing point
- estimation of collection and chipping costs
- estimation of transport costs
- customs duties
- estimation of opportunity costs.

As a result, cost supply curves for each of the three energy-wood transport streams were created.

2.1 Location of the cutting areas

The geographic location of the forest units, railway stations and ports in the study area was done in MapInfo. Statistics from logging companies and forest units were used to estimate the average transporting distance between the cutting area and the terminal at a railway or waterway (Gerasimov et al. 2005; Gerasimov et al. 2006; Ilavsky et al. 2007; Raitila et al. 2009). This background information was then used to estimate the average point from which energy wood would be transported. The points from which energy wood could be transported were dependant on data available:

- in the case of railways, the average distance to the nearest railway station
- in the case of roads, the average distance to the nearest border-crossing point
- in the case of waterways, the average distance to the nearest port.

2.2 Location of the sawmills and plywood mills

The geographic location of the major sawmills in the study area was done in MapInfo based on their physical address, using publicly available information (Kareliastat 2008; Karvinen 2006). Small- and medium-sized sawmills were located on the basis of administrative districts using unpublished information from the regional branches of the Federal State Statistics Service in Karelia, Arkhangelsk, Leningrad, and Komi.

2.3 Identification of the border-crossing points

The locations of border-crossing points were decided based on transport streams. If the delivery was by waterway, the border-crossing point was located in the Lake Saimaa area, if by railway then at the Vjartsilia/Niirala border-crossing point, and if by road then at the nearest border-crossing point. Thus, several border-crossing points were analyzed for the study (Table 1).

Table 1. Border-crossing points for energy-wood delivery in the study area.

#	Means of transport	Border-crossing point	Delivery region
1	Railway	Vjartsilia/Niirala	All
2	Road	Lonka	Karelia
3	Road	Niirala	Karelia
4	Road	Vartius	Karelia
5	Road	Inari	Karelia
6	Road	Kuusamo	Karelia
7	Road	Ruhovaara	Karelia
8	Road	Parikkala	Karelia
10	Road	Imatra	Leningrad
11	Road	Salla	Murmansk
12	Water	Lake Saimaa area	Karelia, Vologda

2.4 Estimation of the collection and chipping cost

The collection and chipping cost of energy wood has been estimated for a number of different harvesting systems in Northwest Russia. Gerasimov et al. (2006) estimated the cost for collection and chipping of by-products from logging as 9.4–15.4 €/m^3, depending on the machinery used and the type of forest operations (thinning, clear-cutting) in the Leningrad region.

Ilavsky et al. (2007) analyzed three harvesting areas that had differences in forest area, forest distribution and topography and for nine harvesting systems in the Tikhvin district of the Leningrad region. Estimated cost of collecting and chipping by-products from logging was 17.4–25.8 €/m^3.

In a pre-feasibility study of a biomass power plant in Kostomuksha by Raitila et al. (2009), the roadside chipping method had the lowest procurement costs. The estimated cost of collecting and chipping by-products from logging was 8.14–8.61 €/m^3. Estimates from Raitila et al. (2009) have been used in this analysis, as it was the most recent and practice-oriented study available for the cost of collecting and chipping by-products from logging.

Thus the collection and chipping costs were for:

- *By-products from logging*: the cheapest option was to chip the residues at the roadside, load chips into a truck, and transport them to the bioenergy plant. The estimated collection cost was 5.5 €/m^3 and chipping cost was 4.6 €/m^3, and the total cost was 10.1 €/m^3 (Raitila et al. 2009).
- *Lump by-products from mechanical wood processing*: assumed to be available in the saw mill or plywood mill without additional collection cost. The estimated chipping cost was 2.4 €/m^3 (Raitila et al. 2009).
- *Sawdust*: assumed to be available in the sawmill without additional collection or chipping cost.
- *Bark*: assumed to be available in the sawmill or plywood mill without additional collection or chipping cost.

2.5 Estimation of the transport costs

The following information was required for estimating the transport costs:

- location of forest units in the study area
- location of sawmill and plywood production sites
- location of border-crossing points
- road network
- transport cost in €/km/m^3
- energy-wood supply.

A GIS of the study area was created to locate border-crossing points, forest units, sawmills, plywood mills, roads, railways and waterway networks. MapInfo software was used for this purpose.

Transport costs by road: Raitila et al. (2009), Ilavsky et al. (2007), and Gerasimov et al. (2006) estimated the cost of transporting the residues using different average transport distances from 20 km to 180 km in the Karelia and Leningrad regions.

Gerasimov et al. (2006) estimated the transport cost for chips from 0.04 to 0.9 €/km/m^3 in the Leningrad region for 20 to 150 km of road-transporting distances. Ilavsky et al. (2007) also estimated the cost from 0.06 to 0.11 €/km/m^3, transporting the chips 20 to 100 km.

Raitila et al. (2009) also estimated the cost from 0.07 to 0.15 €/km/m^3, transporting the residues 30 to 80 km. The average transporting distance of energy wood was 118 km, and the weighted average procurement cost of chips was 25.2 €/m^3. Regression dependence based on the Raitila et al. (2009) study has been used for estimating the cost for transporting chips.

Transport costs by railway: The Russian Railway company regulates the export tariff for wood chips and it was 3.4–29.1 €/m^3 for transportation distances from 210 to 2110 km in 2008 for 40 tons of cargo (Russian Railways 2008).

Transport costs by waterway: Freight charges from Lake Onego to Lake Saimaa in the 2008 season were 19.4–22.4 €/m^3 (Ministry of Economic Development of Karelia 2008).

In order to estimate total delivery cost of energy wood for each transport stream, the distance from the energy-wood supply (cutting area, sawmill or plywood mill) to the border-crossing point, and the available energy wood for each stream is required.

The available energy-wood supply was estimated on the basis of the model as described in Gerasimov and Karjalainen (2009).

2.6 Customs duties

Under Russian government decree no. 75, issued in February 2007, all industrial roundwood for export (except birch logs < 15 cm diameter) is subject to export duties from 1 July 2007. The schedule for raising duties was: 15 €/m^3 from 1 April 2008, and 50 €/m^3 from 1 January 2009. The last raise was postponed by 12 months until 1 January 2010 under the new decree no. 982/2008.

In theory, birch logs having a diameter less than 15 cm will initially be exempt and should only become subject to the 50 €/m^3 duty from 1 January 2011. However, this exemption is of little practical importance because logs should be sorted by diameter, which is expensive to carry out in practice.

Export duties for aspen were set at 5 €/m^3 from the beginning of July 2007 until the end of 2009. However, a duty of at least 50 €/m^3 will be applied to aspen from 1 January 2010.

Export duties for fuel wood were 4 €/m^3. Export duties for wood chips were 5% of the customs value.

2.7 Estimation of the opportunity cost

The opportunity cost of energy wood is defined as the purchase price of the material at the forest landing, central processing yard or sawmill/plywood mill (i.e., excluding transport costs), or what is expected to be received for the energy wood regardless of its use. The opportunity cost has been included for by-products from logging (non-industrial roundwood, unused branches and tops, defective wood resulting from logging) and by-products from mechanical wood processing (sawdust, bark and chips), as they can also be used for other purposes. If they are to be used for energy, the bioenergy plant would have to purchase the energy wood at similar price levels. Thus, the opportunity costs for different energy-wood sources were estimated:

Non-industrial roundwood: In 2008, the average price of non-industrial roundwood at the logging company terminal without transport cost (Komistat 2008):

– price of fuel wood for population varied from 6.5 to 8.4 €/m^3
– price of fuel wood for industry was 11.2–13.0 €/m^3
– price for wood chips for industry was 21.6–23.6 €/m^3
– price of deciduous pulpwood varied from 22.0 €/m^3 to 26.4 €/m^3.

It was assumed that the deciduous non-industrial roundwood would be delivered to the particle-board mill, therefore the opportunity cost for energy wood was 25.3 €/m^3 for each cutting area. In this study, 21.6 €/m^3 was used as the opportunity cost for energy wood.

Logging residues (unused branches and tops, defective wood resulting from logging): do not currently have a market and are therefore assumed to be available without an opportunity cost.

By-products from mechanical wood processing: very little data is publicly available on the purchase price of sawdust and bark, due to commercial sensitivity. The average *sawdust* price was 10.8 €/m^3 in Karelia in 2008 (Ministry of Economic Development of Karelia 2008). The opportunity cost for *sawdust* and *bark* in the Komi, Arkhangelsk, Murmansk, and Pskov regions was lower than in the Leningrad, Vologda and Novgorod regions, due to the production of pellets, although the opportunity cost for chips remained the same.

3 Results

3.1 Study area

The study area in Northwest Russia covers eight administrative regions: the Republics of Karelia and Komi, and the Arkhangelsk, Leningrad, Murmansk, Novgorod, Pskov and Vologda regions. There are altogether 200 forest units in the study area. Figure 3 shows the location of forest units, sawmills, plywood mills, and potential border-crossing points for energy-wood export along the Finnish border. Altogether approximately 30.5 million m^3 of energy wood is available in the study area.

3.2 Energy-wood supply

Energy-wood supply was estimated for the two sources: energy wood from harvesting and energy wood from mechanical wood processing. The distribution of potential energy wood from harvesting, sawmilling and plywood production in the Northwest Russian regions based on the actual production in 2006 (Gerasimov and Karjalainen 2009) is presented by the type of residue in Figure 4.

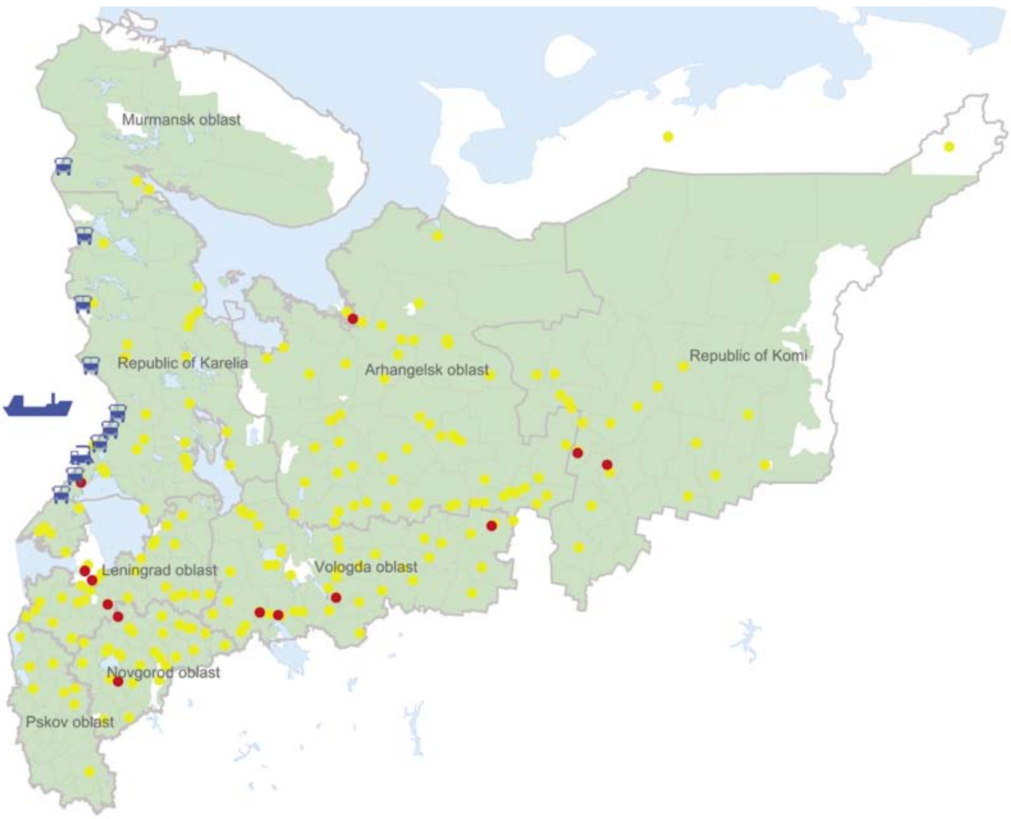

Figure 3. Location of the forest units (green), sawmills (yellow), plywood mills (red) and potential border-crossing points (blue).

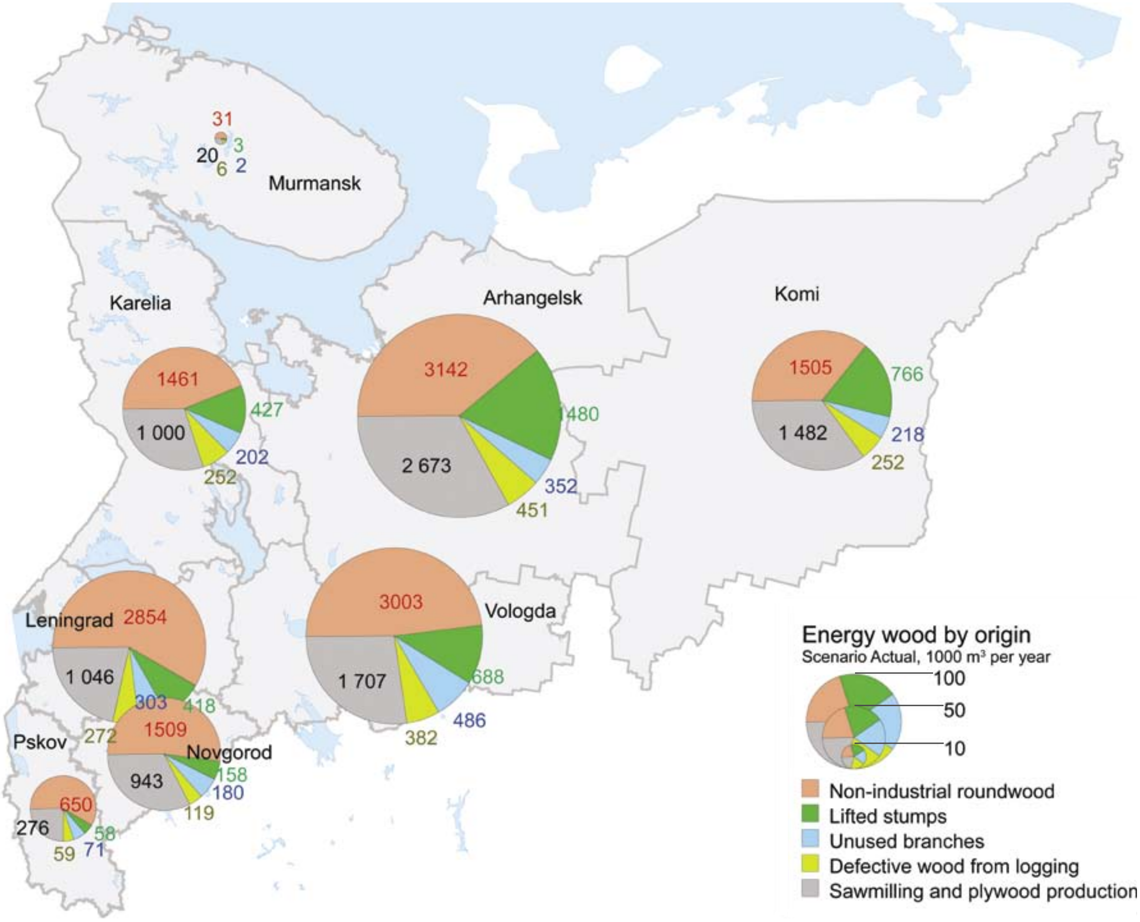

Figure 4. Distribution of potential energy wood from harvesting, sawmilling and plywood production in the Northwest Russian regions based on the actual production in 2006 presented by the type of residue.

3.2.1 Energy-wood supply from harvesting

Results from the harvesting survey indicated that the total amount of energy wood generated is about 20.5 million m^3/yr. This is presented for each region in Figure 5 by the distance to the border-crossing points, and variation in supply is due to logging capacity, tree species distribution, etc. About 65% of the energy wood is non-industrial roundwood, 16% logging residues and 19% spruce stumps.

3.2.2 Energy-wood supply from mechanical wood processing

Results from the sawmill survey indicated that the total amount of energy wood generated is about 9.8 million m^3/yr. This is presented for each region in Figure 6 by the distance to the border-crossing points, and variation in supply is due to sawn timber and plywood production. There is a substantial amount of energy wood available from a distance of 1100–1200 km, and this is due to several big sawmills in the neighbourhood of the Arkhangelsk town. About half of the residues are chips, 30% sawdust and 20% bark (Devyatkin 1999).

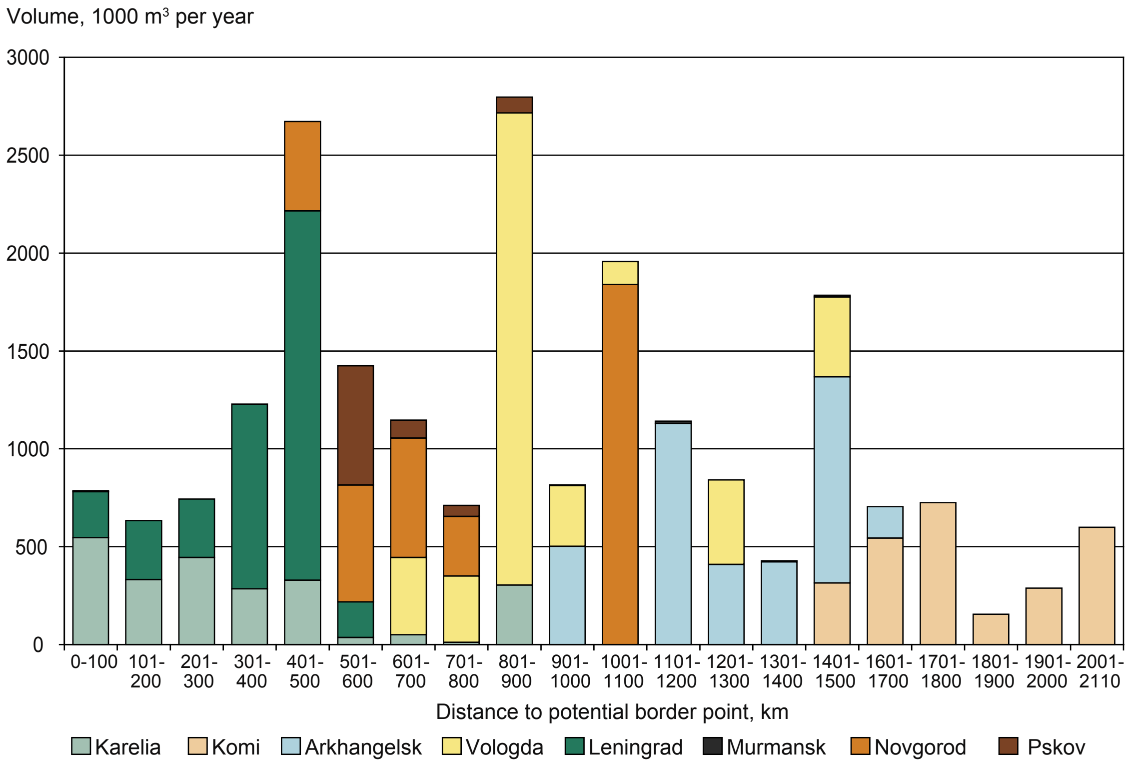

Figure 5. Energy wood supply from harvesting by transportation distance to the potential border-crossing point.

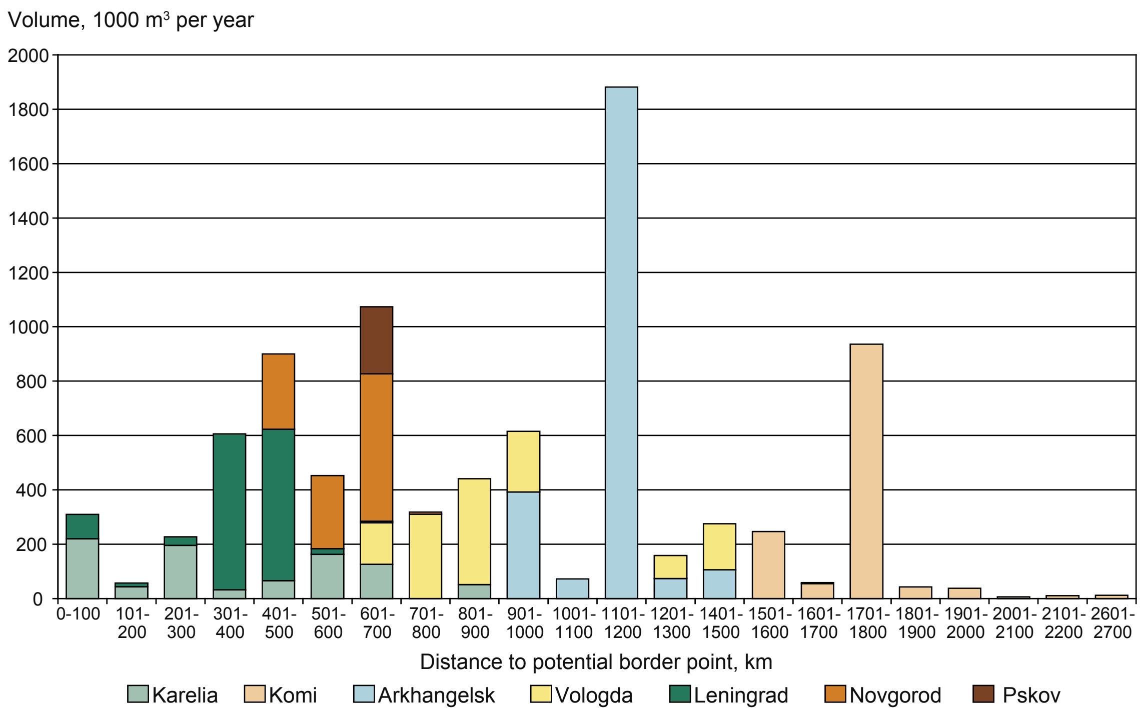

Figure 6. Energy wood supply from mechanical wood processing by transportation distance to the potential border-crossing point.

3.3 Delivery cost of the energy wood

The delivery cost of the energy wood was estimated for each means of transportation, i.e., by railway, road and waterway (Table 2).

Table 2. Energy-wood supply by source and means of transport in 2006, 1000 m^3.

Means of transport	Harvesting	Sawmills and plywood mills	Total
Railway	19 479	8 309	27 788
Road	268	1 339	1 607
Water	764	164	928
Total	20 511	9 812	30 323

3.3.1 Delivery cost of energy wood from harvesting

The cost of energy wood by means of transport from each forest unit is calculated, and then a running average is estimated, from low cost to high cost, to provide the cumulative average delivery cost. The total amount of energy wood varies by year and delivery cost varies by border-crossing point. Estimated average delivery cost of the total energy-wood supply varies from 15.8 to 57.5 €/m^3. This is presented for each means of transport, and variation in supply is due to location of the procurement site, i.e., transportation distance. The delivery cost for energy-wood supply to the Vjartsilia/Niirala border-crossing point by railway varies from 27.2 to 57.5 €/m^3, with the cumulative average delivery cost shown in Figure 7. The delivery cost for energy-wood supply by road to the border-crossing point varies from 15.8 to 22.2 €/m^3, with the cumulative average delivery cost shown in Figure 8. The delivery cost for energy-wood supply by waterway to the Lake Saimaa area varies from 45.0 to 47.9 €/m^3 from the Lake Onego area.

The cumulative average cost indicates the average cost for a particular amount of energy wood. For example, if a bioenergy power plant needs 5 million m^3 of energy wood, Figure 7 indicates that the average cost for this amount of energy wood is about 36 €/m^3 with a maximum distance of 532 km by railway.

The delivery cost of energy wood by means of transport varies, since means of transport have different profiles for the delivery cost. Figure 8 shows the average cost of energy-wood collection/chipping at the cutting area and direct transport to the border-crossing points. Delivery of chips by road directly to the border-crossing points was the cheapest option to deliver energy wood. Figure 7 shows the average cost of energy-wood collection/chipping at cutting area, road transport to the terminal at the railway station and cost of railway transport to the border-crossing point. The collection/chipping and the opportunity cost is the same for each means of transporting energy wood, but the transport costs vary with the location of the cutting area, i.e., transportation distance to the terminal at the railway station and transportation distance to the border-crossing point.

3.3.2 Delivery cost of energy wood from mechanical wood processing

The delivery cost of energy wood by means of transport from sawmills and plywood mills is first calculated, and then a running average is estimated, from low cost to high cost, to provide the cumulative average delivery cost. The total amount of energy wood varies by year, and the

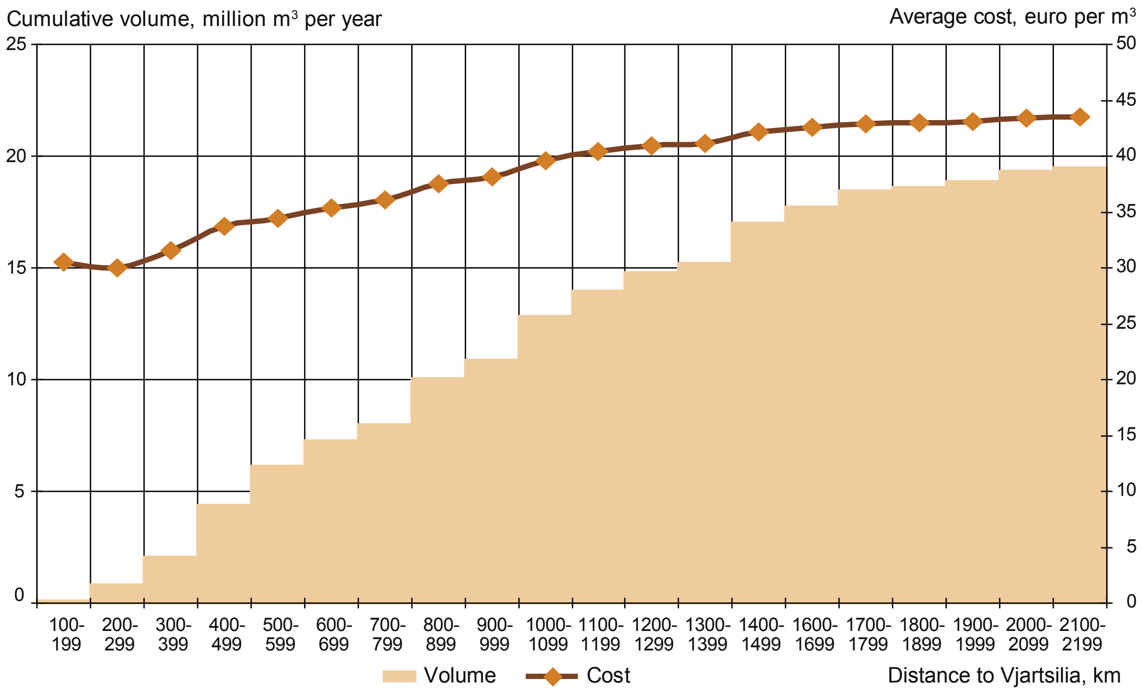

Figure 7. Cumulative average delivery cost for energy wood from harvesting to the Vjartsilia /Niirala border-crossing point by railway (distance is to Vjartsilia railway station on the Russian side).

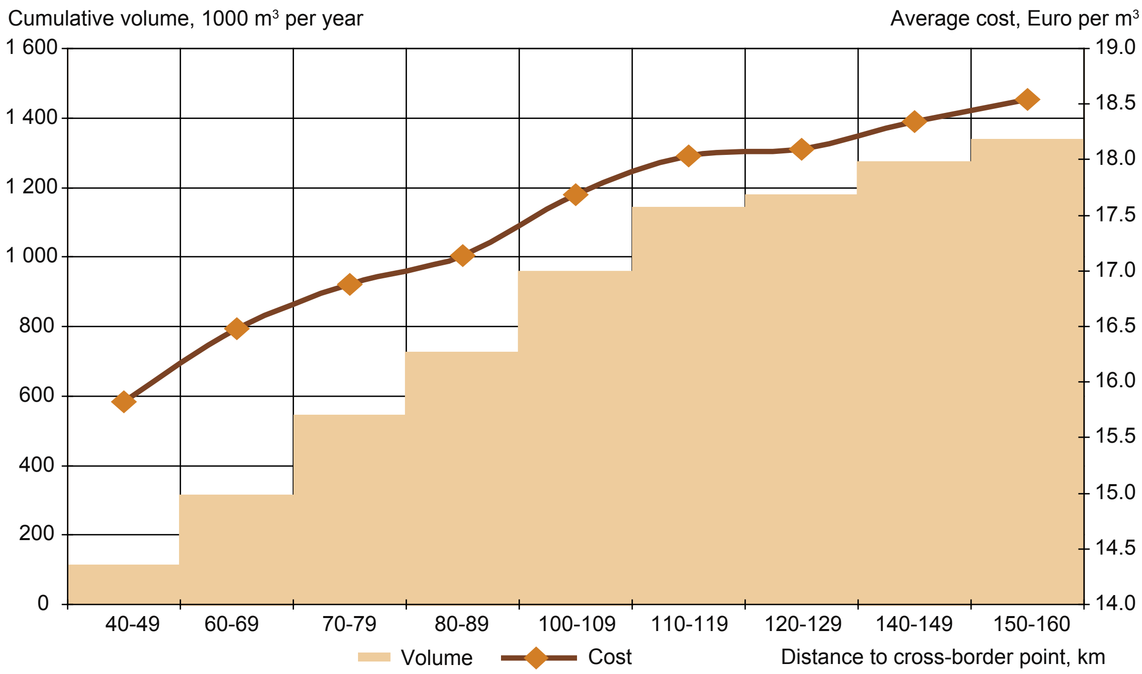

Figure 8. Cumulative average delivery cost for energy wood from harvesting to the border-crossing point by road. Note that x-axis is not linear.

delivery cost varies by the border-crossing points. The estimated average delivery cost of the total energy-wood supply varies from 9.6 to 47.3 €/m^3. This is presented for each means of transport (Figures 9 and 10), and variation in supply is due to production of the mills. The delivery cost of energy wood to the Vjartsilia/Niirala border-crossing point by railway varies from 11.7 to 47.3 €/m^3, with the cumulative average delivery costs shown in Figure 9. The delivery cost of energy wood to the border-crossing point by road varies from 9.6 to 15.4 €/m^3, with the cumulative average delivery costs shown in Figure 10. The delivery cost of energy wood by waterway to the Lake Saimaa area is around 28 €/m^3 from the Lake Onego area.

The cumulative average delivery cost indicates the average cost for a particular amount of energy wood from saw and plywood mills. For example, if the potential bioenergy power plant needs 4 million m^3 of energy wood, Figure 9 shows that the average cost for this amount of energy wood is about 20 €/m^3 with a maximum distance of 900 km by railway.

The delivery cost of energy wood by means of transport varies. Each means of transport of energy wood has a different profile for the delivery cost. Figure 10 shows the average cost of chipping at the mills and direct transport to the border-crossing points. Delivery of chips by road to the border-crossing points was the cheapest option to deliver energy wood. Figure 9 shows the average cost of collection/chipping at the mills, road transport to the terminal at the railway station if necessary and the cost of railway transport to the border-crossing point. Also for this source of energy wood the chipping and opportunity costs were the same for each means of transporting energy wood, but the transport costs vary due to the location of the mill, i.e., transport distance to the border-crossing point.

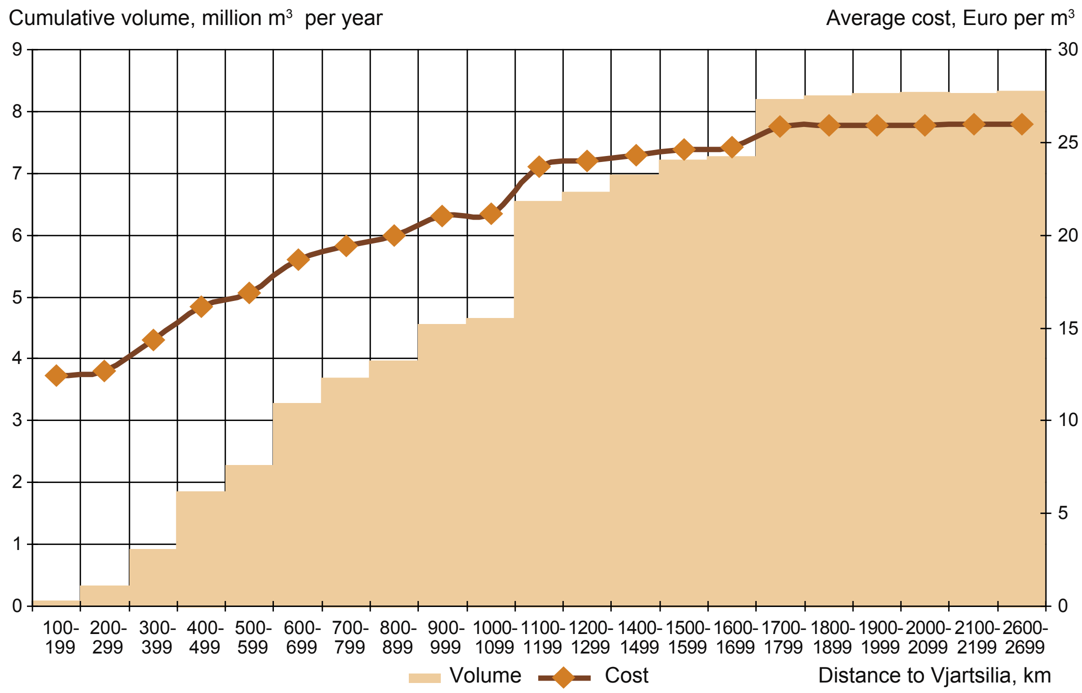

Figure 9. Cumulative average delivery cost for energy wood from saw and plywood mills to the Vjartsilia/Niirala border-crossing point by railway. Note that x-axis is not linear.

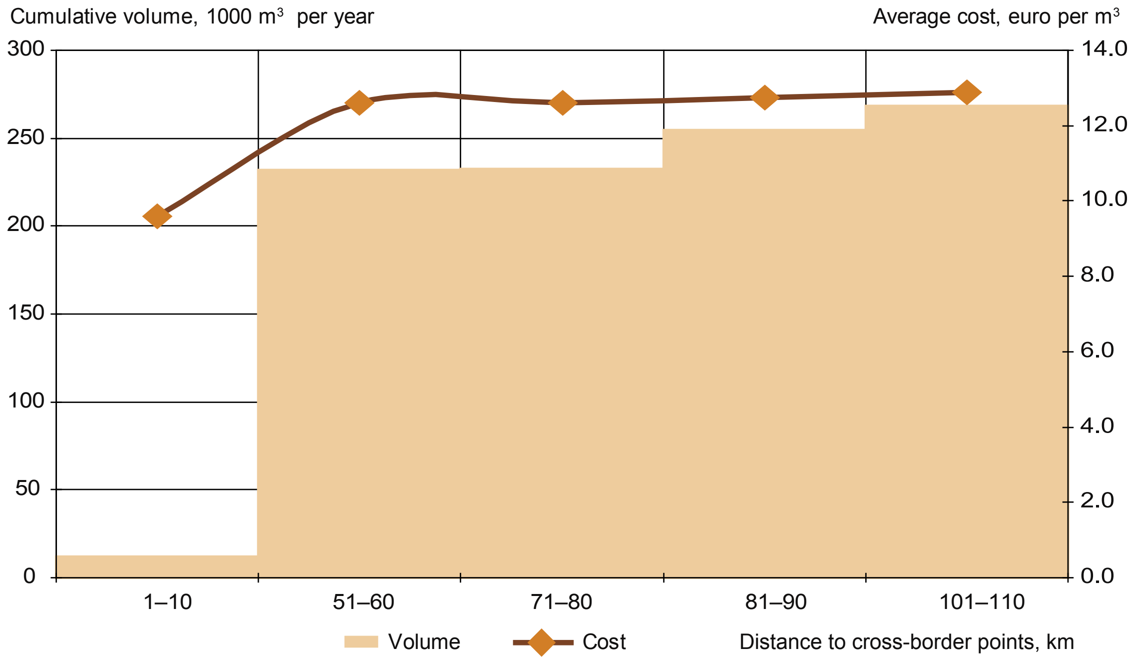

Figure 10. Cumulative average delivery cost for energy wood from saw and plywood mills to the border-crossing point by road. Note that x-axis is not linear.

4 Conclusions

The main purpose of this study was to estimate the availability and delivery cost of energy wood from harvesting and mechanical wood processing in Northwest Russia. A developed model provided a framework for estimating the delivery cost of energy wood available for potential bioenergy plants in Finland, and how the cost of collection/chipping, opportunity costs and transport costs vary. It should be emphasized that we have estimated supply and delivery costs, not prices which are defined at the market, based on supply and demand.

Several assumptions had to be made, mainly due of lack of data, but more detailed studies and analyses could provide better results:

- The annual average transport distance from the cutting area to the terminal at the railway station provided by logging companies and forest districts was used. A better option would be to include company data at stand level for all forests, but in some cases this may not be possible.
- The cost of transporting energy wood is based on data received from a logging company in 2007–2008. Changes in fuel prices and other costs influence the supply and delivery costs.
- The same transport cost per kilometre regardless of the type of road surface was applied. In practice, the cost may vary with road surface.
- Collection and chipping cost. The available data relate to particular systems used in the Republic of Karelia and the Leningrad region. More research is required to ascertain these costs and if these costs can be reduced.
- There is no published data for the opportunity costs associated with sawdust, bark and chips. The data used was very good for the particular regions of interest, as they were based on real local information, but they may not be applicable to other regions, thus region-specific information on the opportunity costs would be necessary.

The energy-wood supply possibilities and delivery costs for the eight regions of Northwest Russia were assessed. By-products from harvesting and mechanical wood processing were considered for energy production based on actual harvesting, sawmill and plywood production in 2006 and was estimated at 30.7 million m^3. Nearly 30.5 million m^3 of the energy wood could be transported, and the rest of the energy wood was inaccessible due to the lack of a road infrastructure in the Republic of Komi and the Arkhangelsk region. About 70% of the energy wood was from harvesting, i.e., non-industrial roundwood, unused branches and tops, defective wood resulting from logging, spruce stumps removed after final felling, and 30% from sawmills and plywood mills, i.e., chips, sawdust and bark. The delivery cost of energy wood to the potential border-crossing points in Finland was analyzed for three means of transport. The delivery cost of energy wood to the Vjartsilia/Niirala border-crossing point by railway varied from 28.9 to 43.5 €/m^3. The estimated volume was 27.8 million m^3, and the maximum distance was 2110 km to the border station. The cheapest option to deliver energy wood to the border-crossing point was by road. The delivery cost of energy wood by road varied from 15.8 to 18.5 €/m^3. However, the volume was limited to a 200-km belt along the border between Russia and Finland and was 1.6 million m^3. The most expensive means to deliver energy wood to the Lake Saimaa area was by waterway. The delivery cost of energy wood by waterway varied from 45.0 to 47.9 €/m^3. The volume was estimated at 0.8 million m^3 from remote areas without feasible access to a railway in the Lake Onego area.

Results of this study could/may be used by those who are planning delivery of energy wood from Northwest Russia to Finland. Developed model, however, could/may be applied for planning of energy wood delivery in Russia and also to other export destinations than Finland. This was a preliminary study and more thorough study should be carried out for practical applications.

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