Cost-Effective and Sustainable Harvest Methods

Baltic ForBio

Accelerating the Production of
Forest Bioenergy in the Baltic Sea Region

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Edited by Pasi Poikonen

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USED ABBREVIATIONS AND TERMINOLOGY

Chipping	=	Comminuting wood using sharp blades
Comminuting	=	General verb for chip production not depending on the technique used
Crushing	=	Comminuting wood with blunt tools at high speed
Dbh	=	Tree diameter at breast height - 1.3 metres from the level of the root neck
DH	=	District heating
Grinding	=	Comminuting wood with blunt tools
HFO	=	Heavy fuel oil
m^3 sub	=	Wood volume in solid cubic metres measured under bark
Pre-commercial thinning	=	Harvesting under 8 cm dbh trees is called pre-commercial thinning and over 8 cm dbh is called thinning.
Shredding	=	Comminuting wood with blunt tools at low speed
Small trees	=	In the Finnish statistics, small trees include delimbed trees, whole trees, and pulp wood for energy generation purposes. In the Estonian context, this refers to harvesting the underlayer or second layer and is used for smaller trees and bushes. In Germany, the term "small round wood" is used for delimbed trees, whole trees, pulp wood, and round wood for energy purposes.
Strip road (logging trail)	=	Wood transportation corridor inside the forest during harvesting operations.

Table of Contents

PREFACE

Forest biomass is a highly important source of renewable energy in the Baltic Sea Region. Forest harvests produce a huge amount of residues, of which a large share could be used for energy purposes but are currently often left in forests due to economic and ecological reasons. There is a large potential in tackling the increasing demand for renewable energy by increasing the harvest of logging residues and small trees in pre-commercial thinning. This handbook aims to increase production of renewable energy in the Baltic Sea Region by improving the capacity of public authorities, forest and energy agencies, organisations of forest owners and entrepreneurs and forest advisory organisations to promote the harvest and use of logging residues and small trees cut in early thinning.

This handbook consists of five chapters to provide an overview of the role of forest bioenergy in the Baltic Sea region countries – Estonia, Finland, Germany, Latvia, Lithuania, and Sweden. The specific conditions related to each forest growing phase are described from technological, economic, and environmental viewpoints. The handbook provides knowledge on the current harvesting methods in the partner countries and finally recommends best practices for the stakeholders. The aim is to learn about new approaches to the forest bioenergy individually and organisationally.

Authors

The Number of the Issues in the Different Forest Sites Raised and Discussed in the Handbook:

Forest Sites in the Operations	Technological	Economic	Environmental	Total
Young Stands	16	7	5	28
Thinnings	3	2	3	8
Final Fellings	11	2	11	24
Total Number by Aspect	30	11	19	60

1. BACKGROUND

1.1 State-of-the-Art of the Bioenergy Sector in the Baltic Sea Region Countries

Estonia

The use of biomass in Estonia has grown year by year. In 2017 the share of biomass in the primary energy supply was 15.4% and in final energy consumption it was 14.4%. Heat production from renewable energy sources accounted for 57% in 2017, with biomass accounting for almost 46% of production. While in 2010, the share of electricity produced from renewable energy sources in Estonia was 10.4%; in 2017 it was almost twice as high – 18%. The share of biomass in electricity production was only 2.5%.[1] Wood, including waste from the forest industry and wood industry, makes a significant contribution to the Estonian fuel economy. Low quality wood and wood industry residues play an increasing role in both heat and electricity production.

In the field of energy, the Forestry Development Plan defines the climate change target, which is as follows: "The use of wood as a renewable raw material and renewable energy source is preferable to products with higher CO_2 emissions and non-renewable energy sources".[2]

Due to the rapid development of renewable energy sources using wood as a source of energy in recent years (including the introduction of logging waste), the use of wood in energy has by now exceeded the planned level in the Forestry Development Plan for 2020 (Figure 1). Estonian volumes for 2017 were 690,000 m^3 of branches and 3,700,000 m^3 of low quality round wood that can be used for energy (by chipping or burning or making pellets). Most energy wood comes from clear cuttings. Estonian sawmills produced 2,200,000 m^3 of waste (sawdust, tree sides etc.) These are the numbers that are be most likely to be sustained for the long term.[3]

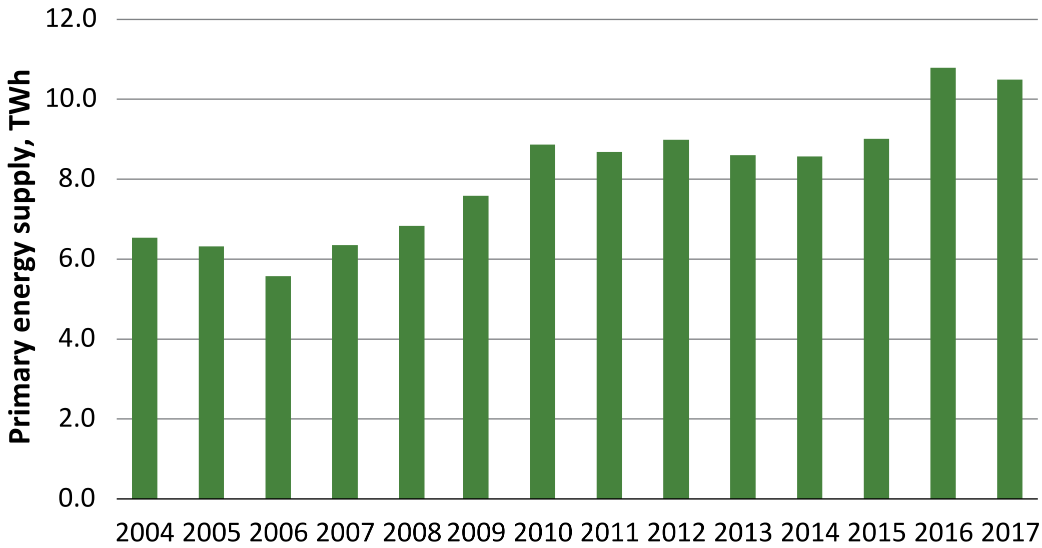

Figure 1. Primary energy supply: Wood fuel 2004–2017[1].

When using wood for energy purposes, its sustainability aspects cannot be ignored. Sustainable forest management in Estonia is ensured by the Estonian Forestry Development Plan until 2020 and the Forest Act[4]. A substantial part of energy wood comes from grey alder stands. 7.7% of the manageable (areas that are not under protection) forest stock is grey alder. Slightly more valuable black alder additionally accounts for 3.5% of the overall stock. For most of the grey alder stands there is no other use than energy wood. It is often harvested with guillotine harvesting heads that are mounted on excavators. 100% of the material is used for energy. Grey alder stands are mainly on old fields that have been abandoned in past. After harvesting some grey alder stands are planted with suitable other species (mainly spruce) and some are left for natural regeneration with grey alder. As grey alder stands are sometimes harvested when they are about 25 years old, there are economic reasons for not planting new stands. Overall the area of grey alder stands should be decreasing. In areas with low quality soils, as well as parts of Northern and Western Estonia there are areas where all the trees (mainly grey alder) are used for chips, but in general the conditions are similar all over Estonia.

Finland

The production of renewable energy is largely integrated into forestry and the forest industry in Finland. The total consumption of wood energy was 104 TWh in 2018, which is 27% of the total energy consumption, and accounted for ¾ of the renewables in Finland. The heat and power production consumed 20 million m^3 of wood-based solid biomass, of which forest chips accounted for 7.4 million cubic metres. The use of forest chips amounted to 4.7 million m^3 in the combined heat and power production (CHP) and to 2.7 million m^3 in the generation of heat. Together with the forest chips consumed by farms and small-dwellings (0.7 million m^3), the total consumption of forest chips reached 8.0 million m^3. Additionally, private houses used 6.5 million m^3 firewood in their stoves.[5]

About half or 3.9 million m^3, of the commercial forest chips were produced from small-diameter thinning wood originating from the management of young stands, and 2.7 million m^3 was produced from logging residue from final fellings. The use of stumps as raw material for forest chips amounted to 0.4 million m^3 and large non-merchantable roundwood came to 0.4 million m^3 in commercial heat or power production.[6]

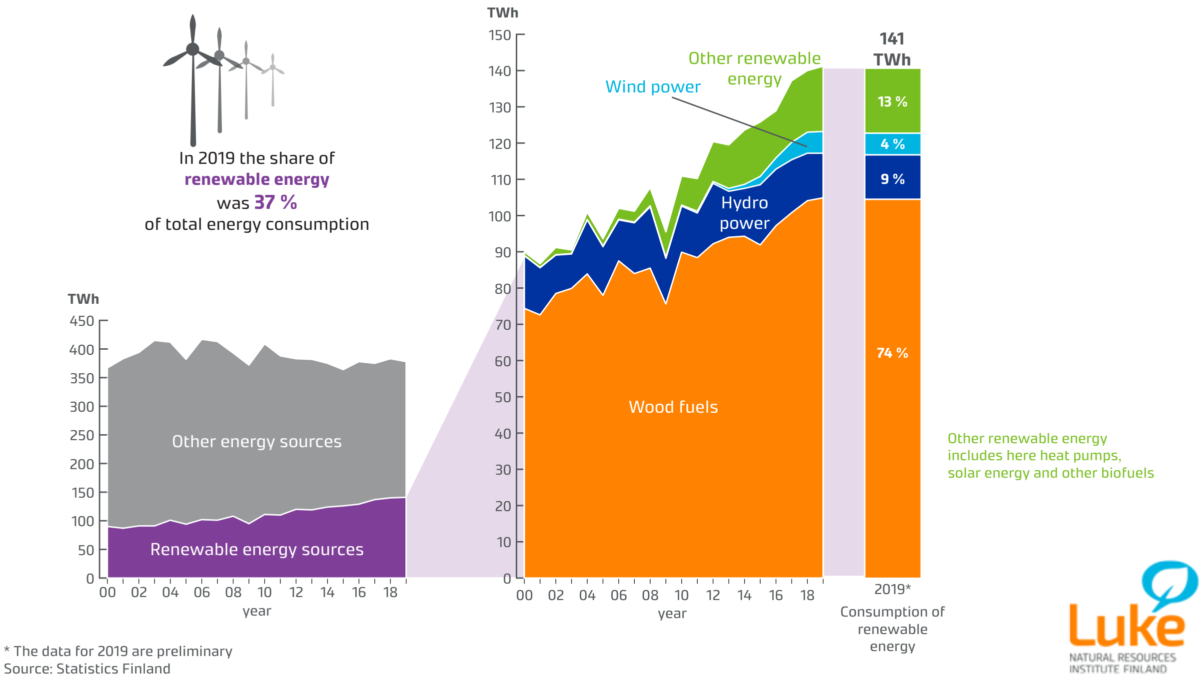

Figure 2. Use of solid wood fuels from the total energy consumption.[5]

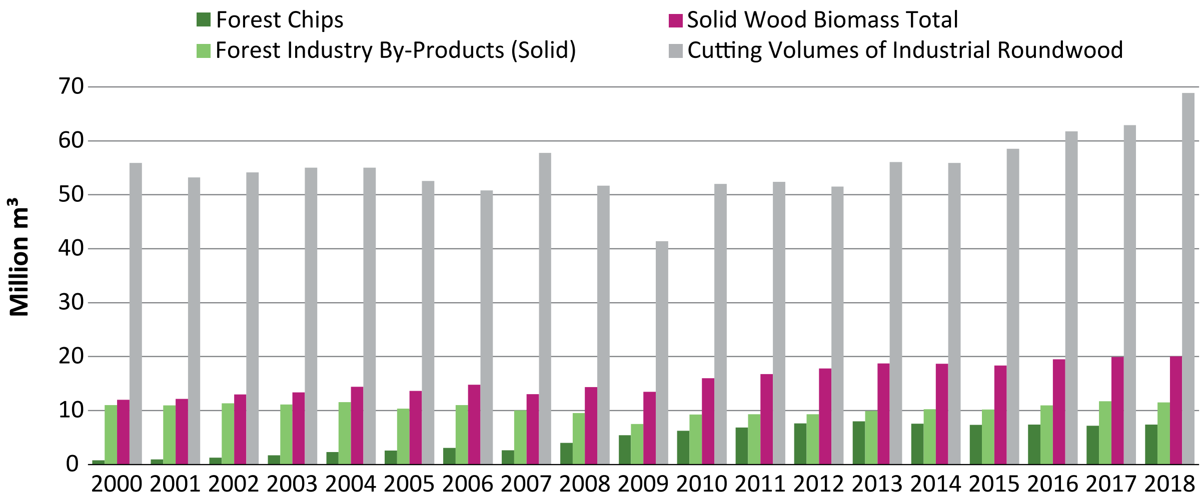

Figure 3. Use of solid wood biomass in heat or power production and the annual harvesting volumes of roundwood in Finland during 2000 – 2018.[7]

The annual use of forest energy is dependent on the weather in the wintertime, when a colder winter increases the use of forest energy.

Germany

Bioenergy has become a significant economic factor in Germany over the last years. In 2017, bioenergy accounted for a share of 7.1% of the total primary energy supply (TPES).[8]

Wood fuel production from German forests doubled between 2003 and 2013. During recent years, the officially registered harvesting of forest fuel amounted to about 9 – 11 million m^3 annually. However, these statistics represent only part of the actual forest fuel production.[9]

German forests remain net carbon sequestration objects, although the forest fuel production has been increasing. Approximately 58 million tons of net CO_2 equivalent were sequestered in German forests in 2014[10]. Since forest fuels substitute fossil fuels, forest bioenergy is considered to help towards the mitigation of climate change. In the future, extreme weather events and subsequent calamities might damage the forests to such an extent that they will start to emit more carbon than they can tie up. With the growing timber and wood fuel extraction from forests, sustainable forest management with respect to the nutrient supply, future forest development (growth and quality) and nature protection has become a matter of public interest.

Latvia

According to the sustainable development strategy of Latvia until 2030, in 2020 40% of the final energy consumption should be provided by renewables. Currently Latvia has the third largest share of renewable energy sources in energy production in the EU. Data from 2017 indicates that renewable resources have been used to produce 39% of the final energy consumption (17.5% in the EU on average) Figure 4.

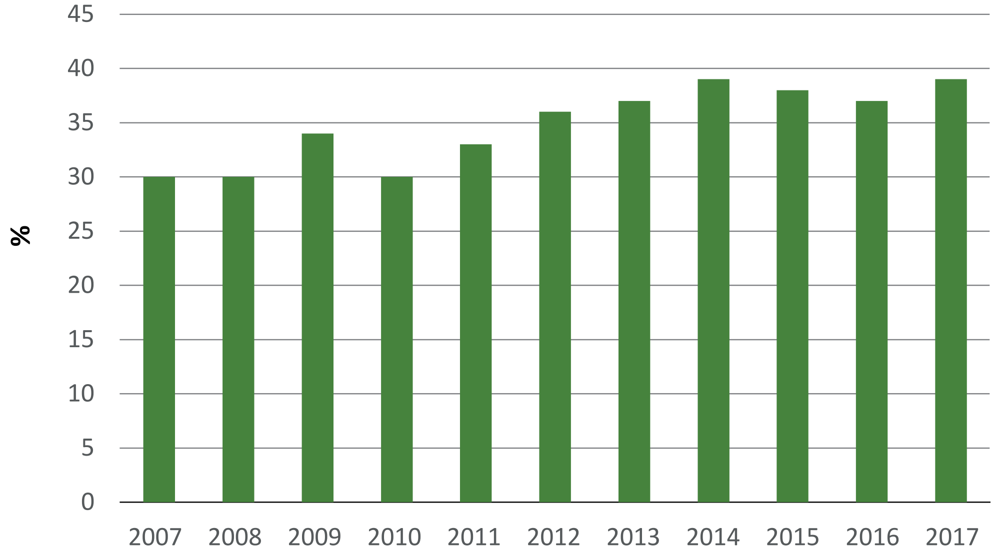

Figure 4: Share of energy from renewable source in Latvia.

Lithuania

RES provide the most promising source of energy for the development of domestic energy production. The most widely used type of biofuel for heat production in Lithuania are wood chips. The National Energy Independence Strategy provides for financial non-financial measures to reduce environmental pollution[11]. In 2016, renewable energy sources accounted for about 25.5% of the final energy consumption in Lithuania. Firewood and wood waste consumption are increasing in industry and agriculture. Public CHP plants and heat plants are using more and more firewood and wood waste for energy production. The biofuel and municipal waste part in central heating systems during the last decade has strongly increased (Figure 5). The use of biofuels for heat production has doubled in the last 5 years – from 33.4% in 2014 to 68.6% in 2017 (in 2007 only 2%). The consumption of electricity from RES in 2016 was about 17%, and in the total heat consumption – about 46%, and in the transport sector – about 4%. A significant share of resources for energy production comes from wind and biofuels (solid and liquid). By 2025, at least 38% of electricity consumed in Lithuania will be produced from RES and will constitute no less than 5 TWh.

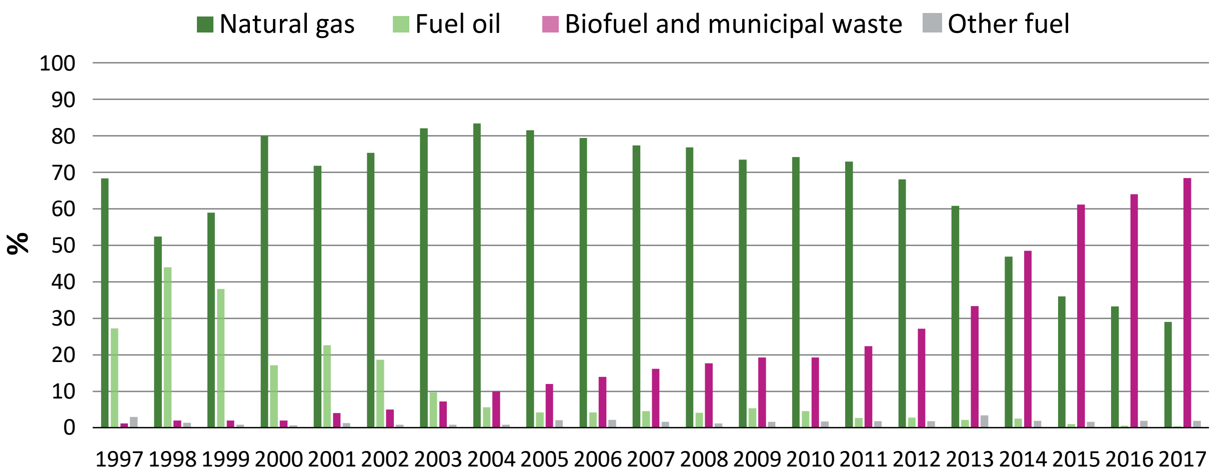

Figure 5. Structure of primary fuel in the Lithuanian district heating sector.[12]

About 25-30% of prepared merchantable round wood amount are stumps, logging residues, small trees etc. and only 10-15% is collected and used for biofuel production. Sales of forest felling residues have increased (fig.6), but still about 80% of the volume of tree branches, stumps and bushes remains in the forests to decompose[15]. Annually only 65% of total wood increment is used in Lithuania, although the potential for sustainable farming is approximately 90-95%. In the future, harvesting of low-value stands dominated by grey alder and poplar for wood fuel seems inevitable. At the moment only one third of it is used for fuel. This segment may increase in the future, as there are plans to increase the cutting rate in Lithuania to intensify the use of low-yielding stands. In order to increase the collection of logging waste, it is necessary to increase the economic attractiveness of this activity.

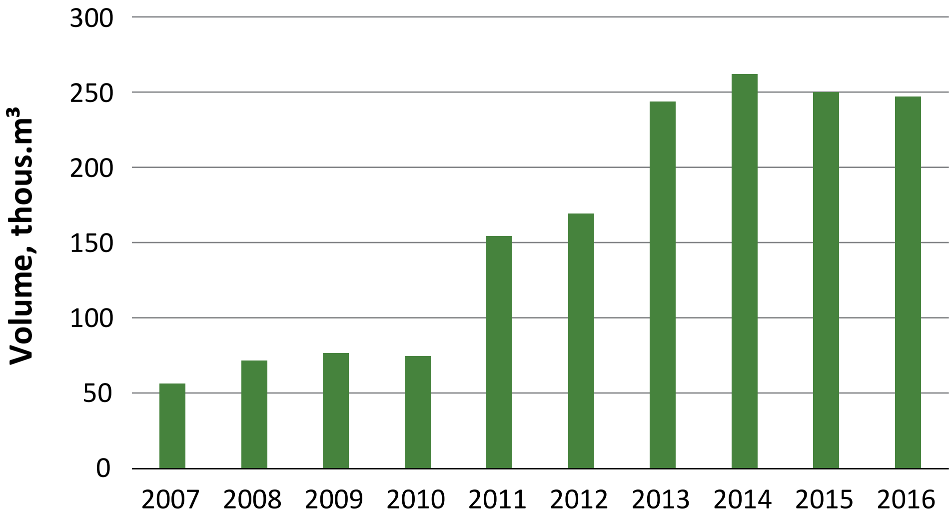

Figure 6. Sales of forest felling residues in state forests, 2007-2016.[14]

Sweden

In total, around 370 TWh of energy is consumed in Sweden per year for heating and electricity generation. About 150 TWh of this is bioenergy, of which about 19.5 TWh (5% of Swedish energy consumption) are primary forest fuels. The district heating potential in Sweden is already almost fully developed, but we see a potential for smaller heating systems, for example in schools and multifamily housing. Additionally, private houses use 9.5 TWh of energy wood in their stoves. In general, we can note that the domestic extraction and use of primary forest fuels has fallen from the levels prevailing during the "record years" of 2009-2011. The use of logging residues was at its largest in 2011 and then stood at just over 12,000 GWh, compared to 8,467 GWh in 2017. The removal and use of small whole trees culminated in 2009-2010 and stood then at about 2,500 GWh, while the levels in 2017 were down to 835 GWh. The forest fuel market has stabilised over the past two or three years.

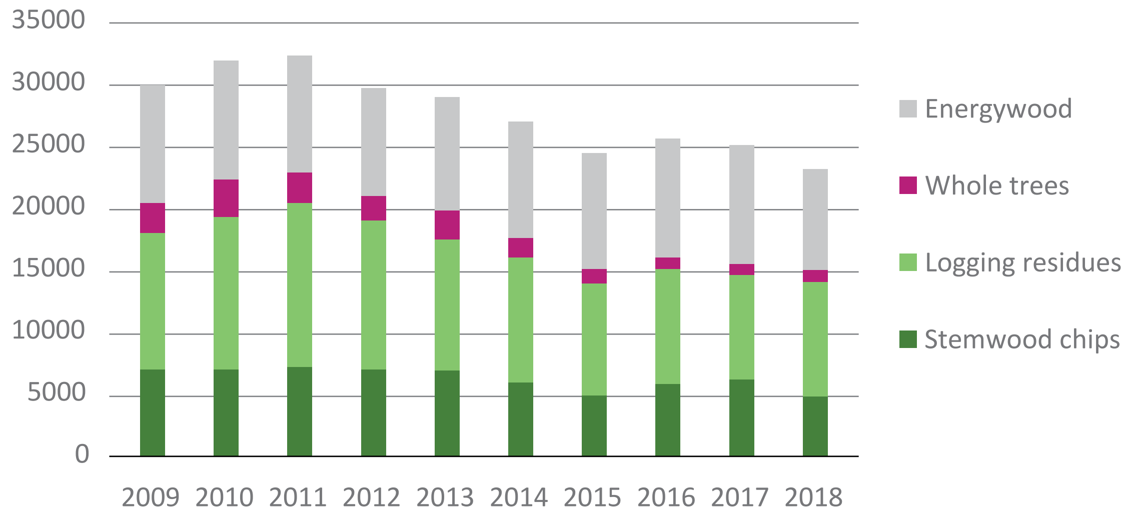

Figure 7. Production of indigenous chipped primary forest fuels with distribution by range.

Although there is a large potential amount of biomass, Sweden is a net importer and imports about 2 TWh of unprocessed wood fuel yearly, as well as 2 TWh of processed wood fuel (pellets) and 2-3 TWh of recycled wood.

Key questions discussed in this part of the handbook:

1. What is the total volume of forest chips (theoretical and practical)?
2. Where is the potential the highest in your country, if any where?
3. What phases of forest growth are the most important for energy wood harvesting?
4. How are small trees defined in your country context? Is there any other specific energy-wood-related terminology in your country?

1.2 Estimated Theoretical Volume for the Business and Restrictions to be Noted

1.2.1 National-level Targets

Estonia

The Estonian National Energy and Climate Plan until 2030 is largely based on the Energy Sector Development Plan 2030 (ESDP) adopted by the Estonian parliament, the Riigikogu, and on the Basics of Climate Policy until 2050[18]. Accordingly, Estonia's national energy and climate targets should be as follows:

- The share of renewable energy in final consumption in 2030 should be 50%.
- Power generation from renewable sources in 2030 should account for 50% of final electricity consumption.
- The share of renewable energy sources in the heat economy should account for 80% of final heat consumption.
- The share of renewable energy sources in the transport sector should be about 14% of the final consumption of transport fuels.

Vision for the Estonian energy sector in 2050

In 2050, Estonia will mainly use domestic resources to meet its energy needs; this includes the heat generation and transport sector in addition to electricity production.

Using modern and green technologies, Estonia will become an energy exporter in the established Northern-Baltic energy market. The state budget resources allocated to energy efficiency, development of domestic fuel production and knowledge-based economy will serve as drivers of economic growth and long-term competitiveness of the country through tax revenue, increased employment rates and an improved foreign trade balance.[15]

Finland

Forest biomass will be the largest growing renewable energy source from 2015 to 2030.[16] In Finland, the by-products of the woodworking industry are already fully utilised. Therefore the additional volumes for energy generation are only possible to receive from forest chips. An active round-wood trade in the local forest industry is a prerequisite for achieving the targets for renewable energy.[17]

The total consumption of forest chips will grow clearly more than tree harvesting volumes, because the additional volumes will be received from logging residues and a smaller part also from stumps. The total consumption of domestic forest chips has been estimated to be 12.7 – 14.2. million m^3 by 2030.[16]

The estimated additional use of wooden biomass in energy generation has been based on forest industry investments in new production with the reflection to the additional supply of side-products and further forest chips. The basic scenario according to the energy and climate strategy states that in 2030 combined heat and power generation should be 29 TWh corresponding 14.5 million m^3 forest chips.[16]

All the impacts which wood-based energy generation could have should be taken account. These include the construction of infrastructure and power plants, and the production of the material to be burnt with direct and indirect influences when assessing the emissions in the whole energy generation chain.[16]

Germany

By the year 2050, bioenergy could have a share of 28% of the domestic total primary energy supply. The harvestable volume of forest fuel is estimated to be between 23 and 35 million m^3 annually (years 2020 to 2050), of which logging residues could have a share of 5 – 12 million m^3 annually[18]. Pre-commercial thinning is expected to remain an important source of forest fuel. The term "small roundwood" is used for delimbed trees, whole trees, pulp wood, and roundwood for energy purposes. The increasing share of deciduous trees in German forests might provide opportunities for the bioenergy sector in the future. Forestry, wood products and bioenergy from woody biomass play an important role in the national Climate Action Plan 2050.

Picture 1. Logging residues waiting for chipping in Altlandsberg forests in the Brandenburg region, Germany. (Photo: Holger Hartmann)

Latvia

Latvia has a high potential to increase the use of forest biomass. However, in order to promote more efficient use of forest bioenergy in the development of state energy, changes should be made in wood utilisation policies. Creating joint ventures, which include owners of wood resources, energy producers and consumers, could be one of the solutions in order to ensure a stable and complete energy cycle.

Lithuania

According to the National Energy Independence Strategy,[11] one of the main aims in the energy sector is to increase energy efficiency and the use of RES. By 2025, at least 38% of electricity consumed in Lithuania will be produced from RES and will constitute no less than 5 TWh. Taking into consideration the assessment of the development trends in technology, it is estimated that this will mean at least 15% from biofuel (by 2030, no less than 16% – from biofuel energy produced in highly efficient cogeneration power plants). Lithuania seeks to become an energy sustainable and independent state by 2050. For this end, it is necessary to develop effective and non-polluting energy production, supply, storage/accumulation, and consumption technologies. The aims of the Lithuanian energy sector are shown in Figure 8.

A national heating sector development programme for 2015-2021 has aimed to reduce the heating prices and environmental pollution giving priority to local and renewable resources to create a fuel balance. The aim is to update the heating network, reduce transmission losses up to 14% by 2021, and to renew old, non-biofuel plants using EU funding.

Private householders are encouraged to use biofuel instead of gas or coal. Private householders can buy biofuel with 5% VAT (VAT for companies is 21%) and they can use EU funding to change their coal, gas or inefficient biofuel boilers to new fuel-efficient boilers.

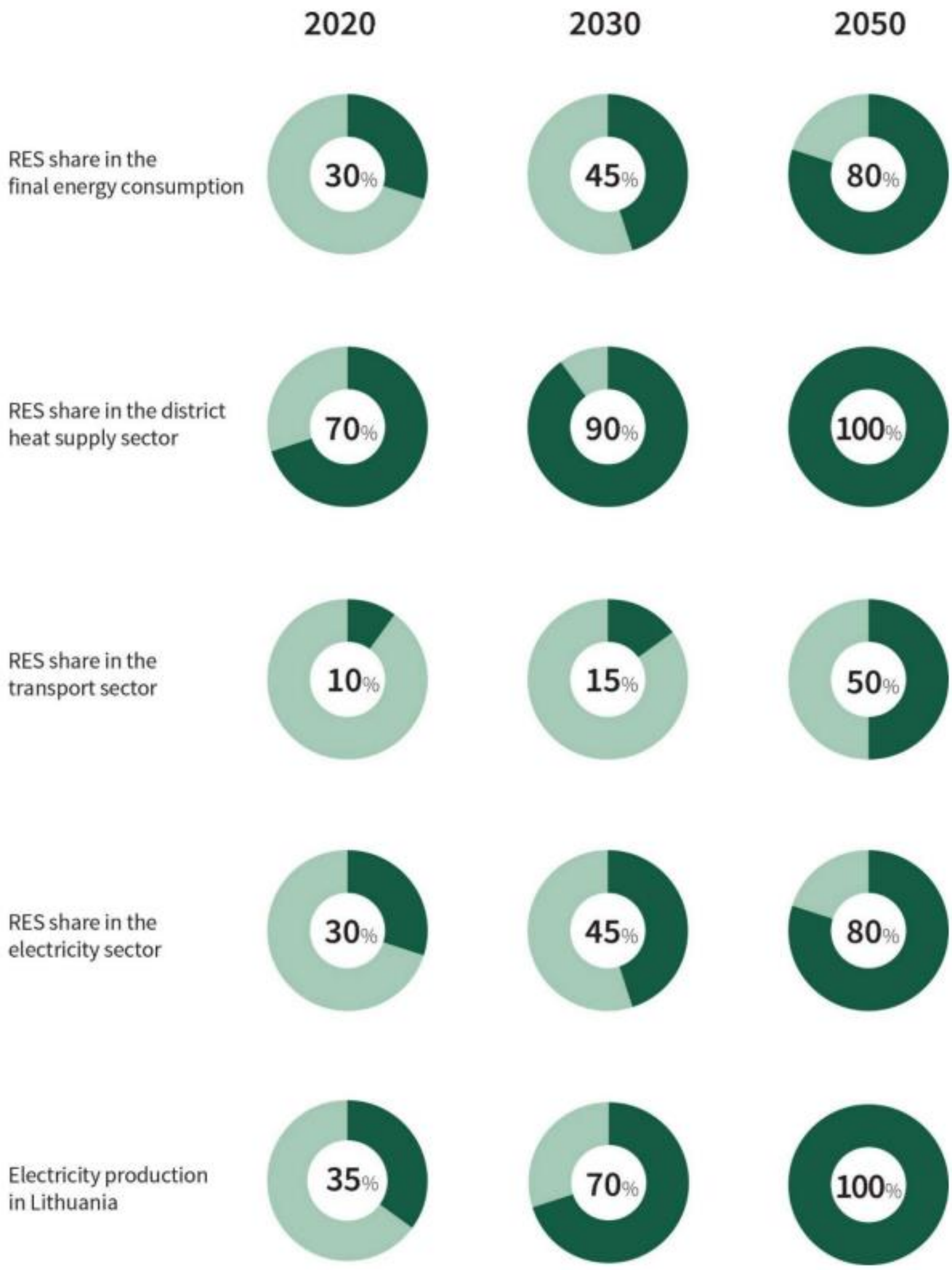

Figure 8. The results being sought in the Lithuanian energy sector for the years 2020, 2030 and 2050.[19]

Sweden

Bioenergy is Sweden's largest source of energy and accounts for 38% of Sweden's energy use today. The use of bioenergy has more than doubled since the beginning of the 1990s. We can double that again, by 2045. Between 2000 and 2017, the use of bioenergy increased by 3.5 TWh per year. The growth of productive forest land has steadily increased by about 1% per year and is currently around 450 TWh per year. This contributes to the binding of biogenic carbon, corresponding to more than the entire Swedish end use of energy. The overall potential for the increased supply of domestic biomass for energy from the forests is estimated by Svebio to be 42 TWh in the short term and 74 TWh in the longer term (2050).[20]

Within the framework of the government's "Fossil free Sweden", initiative the various sectors of the Swedish business community have produced an impressive set of roadmaps for a fossil free Sweden. The roadmaps show that there are technical solutions to replace virtually all uses of fossil fuels by 2045. Business organisations and other stakeholders have identified two main solutions to replace fossil fuels and reduce climate impact: electrification and bioenergy. Based on the requirements in these roadmaps, about 50 TWh more electricity and 100 TWh more bioenergy will be needed.

Key questions discussed in this part of the handbook:

1. Are there any concrete action plans related to the forest bioenergy with the target numbers in your country?
2. Are there clear statements in your country showing that forest bioenergy promotes the mitigation of climate change?

1.2.2 *Current Forest Bioenergy Plants*

Estonia

The table below (Table 1) shows that the number of wood fuel fired boilers has decreased in 2017 compared to 2010 (15%), but the installed capacity and production of heat increased by 19% and 55%, respectively.

Table 1. Number of boilers using wood fuel, for the total power and heat production[1]

	2010	2011	2012	2013	2014	2015	2016	2017
Number of boilers	851	853	828	798	874	844	862	722
Capacity, MW	864	719	719	832	933	1,010	1,161	1,028
Heat production, GWh	1,581	1,827	1,703	1,522	1,644	1,834	2,425	2,449

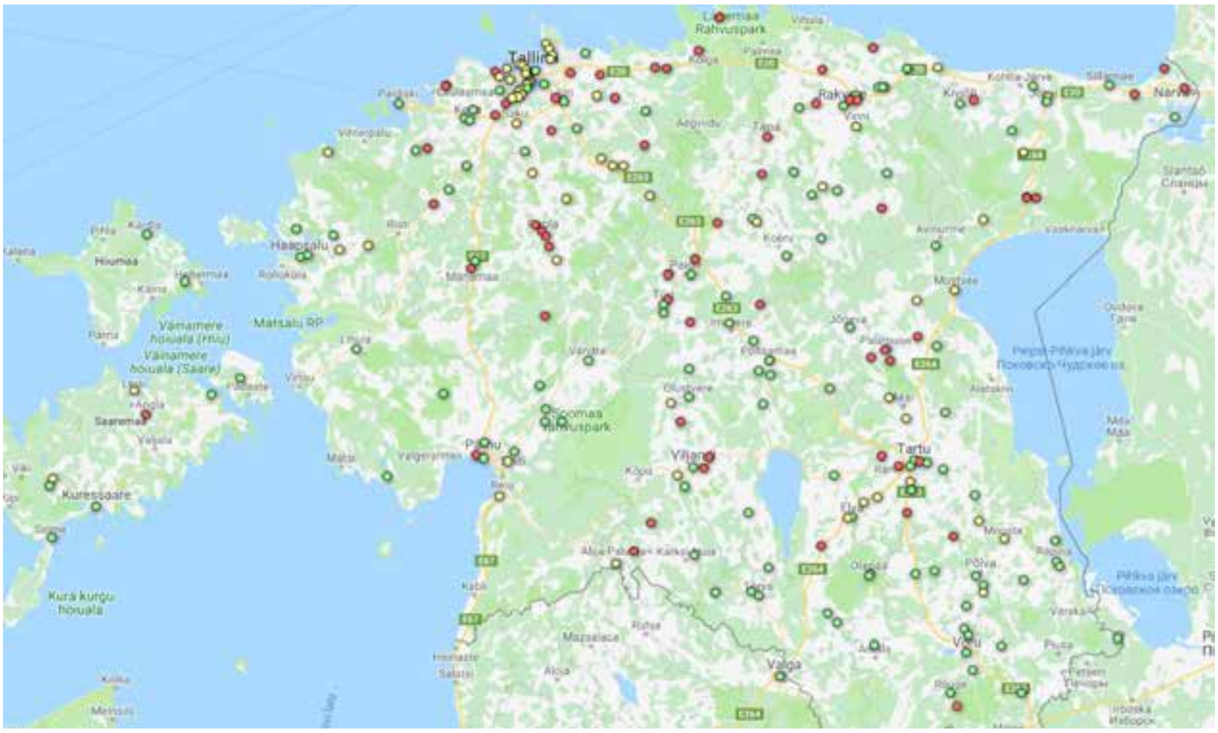

Figure 9. Locations of district heating networks and the price of district heating in Estonia. The different coloured points indicate the district heat price: Green - 0... 74.15 € / MWh; yellow - 74.15... 86.67 € / MWh; red - 86.67... 109 €/MWh as of 2015.[21]

In Estonia, there are currently quite small (just a few MW or under 1 MW) bioenergy units (heating plants) under construction. The company N.R. Energy is building one plant in Rõngu and one in Loksa. The one in Loksa will be 5 MW and it will replace an old one that was using oil. The company Adven Eesti is building 0.7 MW in Püssi.

Finland

Forest chips and other wood-based fuel material utilising energy generation plants have increased remarkably, and there were about 1,000 plants in 2009 compared to the number at the beginning of this century (250 plants).[22] In Finland, publicly available information (2014) shows how wooden biomass using energy plants are decentralised and located all over the country.

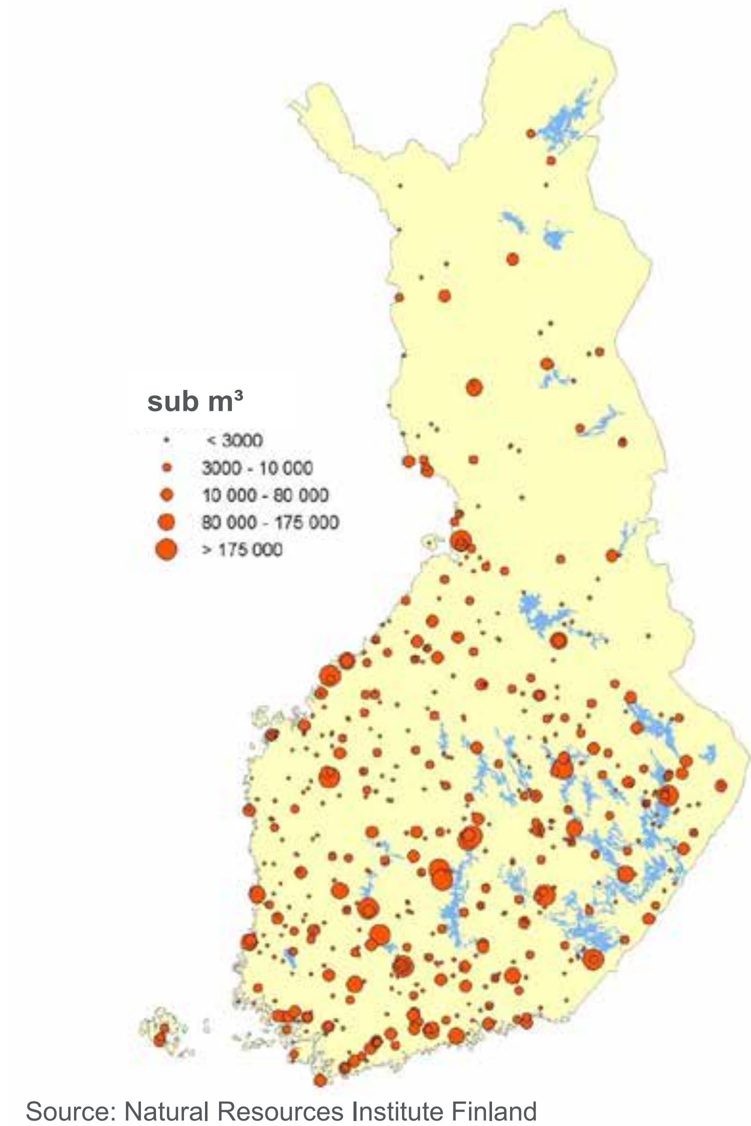

Figure 10. Forest energy users in Finland, 2014.

In 2020, the 50 largest energy plants used more than 80% of all the forest chips.

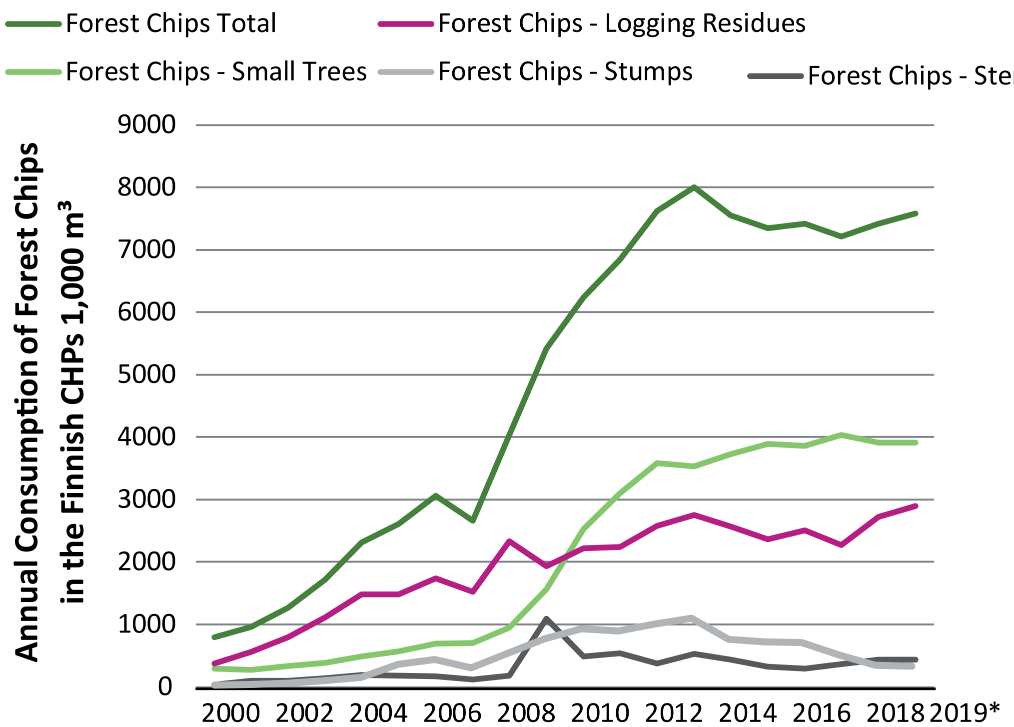

Figure 11. The annual consumption of forest chips in heat and power production in Finland. Forest chips produced from small trees are the main energy source for the local heating plants.

Picture 2. A local heating plant located in Central Finland. (Photo: Juha Laitila)

Germany

The number of heat and power plants fuelled by wood biomass has grown from less than 50 in the year 2000 to about 700 in 2015.[23]

Latvia

During the 2007-2017 period the number of combined heat and power stations in Latvia has increased about five times. In 2017 there were 204 combined heat and power stations, of which only 24% used wood chips as the main raw material for energy production. The amount of wood chips used from 2012 (17%) to 2017 (29%) has increased, whereas the share of natural gas in the amount of fuel consumed in home boilers has decreased.[24]

The location of heating supply companies and the amount of wood fuel consumed in tons is shown in Figure 12.

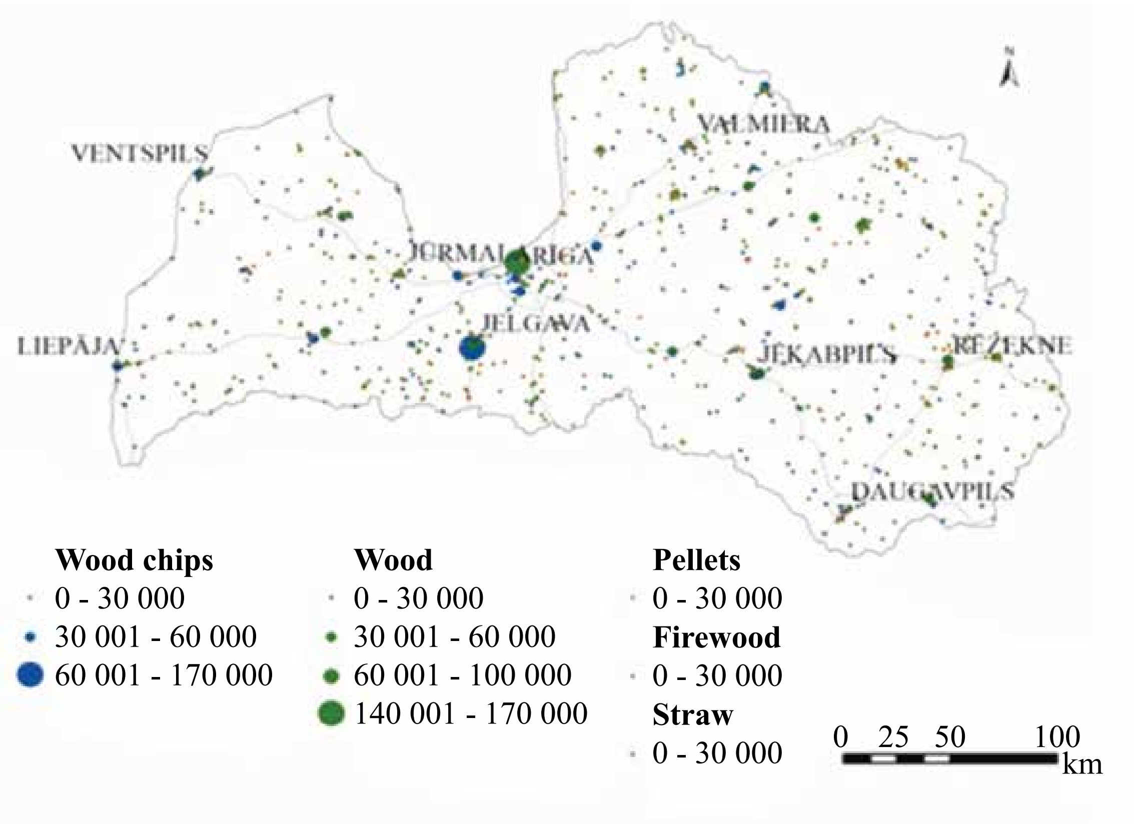

Figure 12: Location of wood biofuel heat supply companies in Latvia (tons).

Lithuania

The amount of bioenergy plants in Lithuania is growing. 199 bioenergy plants were operating in 2010. In 2016 we already had 332 biofuel plants. The installed capacity of biomass boilers increased from 395 MW in 2010 to 990 MW in 2016 (figure 13).

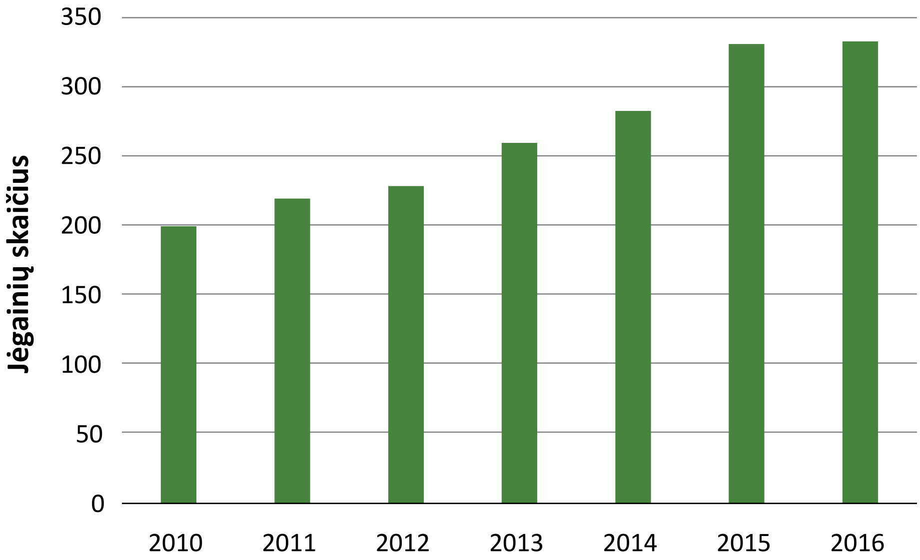

Figure 13. The number of biomass installations in Lithuania.[25]

In power plants using RES, in total 1,510 TWh of electricity was produced in 2014. This represented 12.6% of the total domestic consumption of electricity.[26] The technical potential exists only through the beneficial use of heat, i.e. connecting biofuel power plants to existing DH systems. The technical potential is about 350 MW.[27]

Sweden

The total installed power in Sweden is just over 4,300 MW. The normal annual production for these bio power plants is around 18.7 TWh. However, real electricity production from biopower was lower in past years, depending on the economic conditions. On average, biopower plants are estimated to use approximately 4,000 hours of the year's total of 8,760 hours for a normal year's production. The operating time of an industrial plant can be up to 8,000 hours per year.

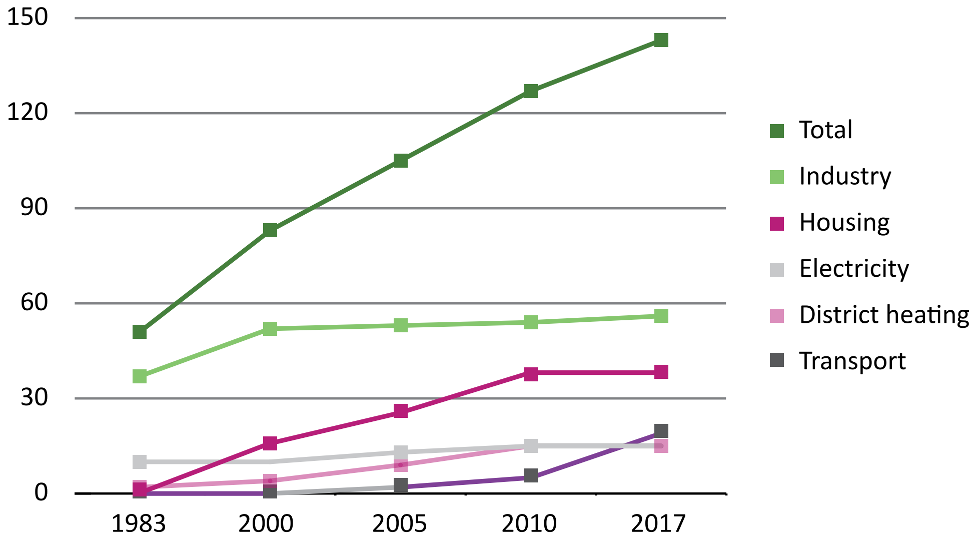

Figure 14. The use of biofuels by sector from 1983, in TWh.[28]

Svebios Bioenergy's map contains 230 bio-cogeneration plants in operation and 15 plants planned or being built in Sweden in 2019. The map includes plants that generate electricity using biofuels, peat and those which use waste as fuel.

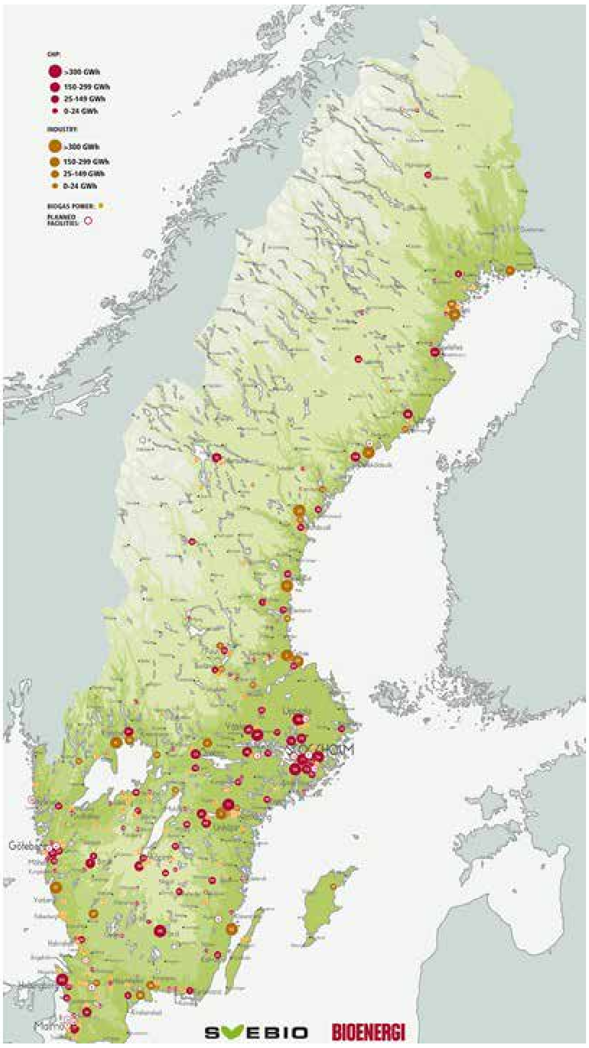

Figure 15. Forest energy users in Sweden, 2019.

Key questions discussed in this part of the handbook:

1. Is a thematic map available showing energy plants and the share of forest bioenergy (or a pie diagram) in their use?

1.2.3 Potential for New Energy Generation Plants

Estonia

The potential for the co-generation of electricity and heat has been realised in Estonia in regions with high thermal intensity, but there is still sufficient potential for establishing co-generation plants based on peat or biomass in smaller settlements or cities. In addition, there is potential for the co-generation of electricity and heat in industries with stable heat consumption, such as the cellulose and wood industries. In conclusion, the estimated potential for additional co-generation of electricity and heat is 150 MW, with possible generation of about 500 GWh of electricity. The economic cost-effectiveness is currently the main limiting factor that prevents the utilisation of this potential, which is why it will depend on technological development and market conditions.[15]

Finland

Significant investment in forest energy generation is not visible. The big investment decisions require long-term government-level commitment to supporting policy for renewable energy and emissions trade. The Turku Regional Energy Company invested in a CHP plant in Naantali with a capacity of 430 MW in autumn 2017 and the Lahti Energy Company invested in the Kymijärvi III heating plant with a capacity of 310 MW in autumn 2019. Helsinki City is planning to renew its energy supply. Forest chips can be utilised in these plants, but the current investments are located in the regions, where forest energy use is already high. There are also other energy sources available such as agricultural biomass, recycled waste material and coal.

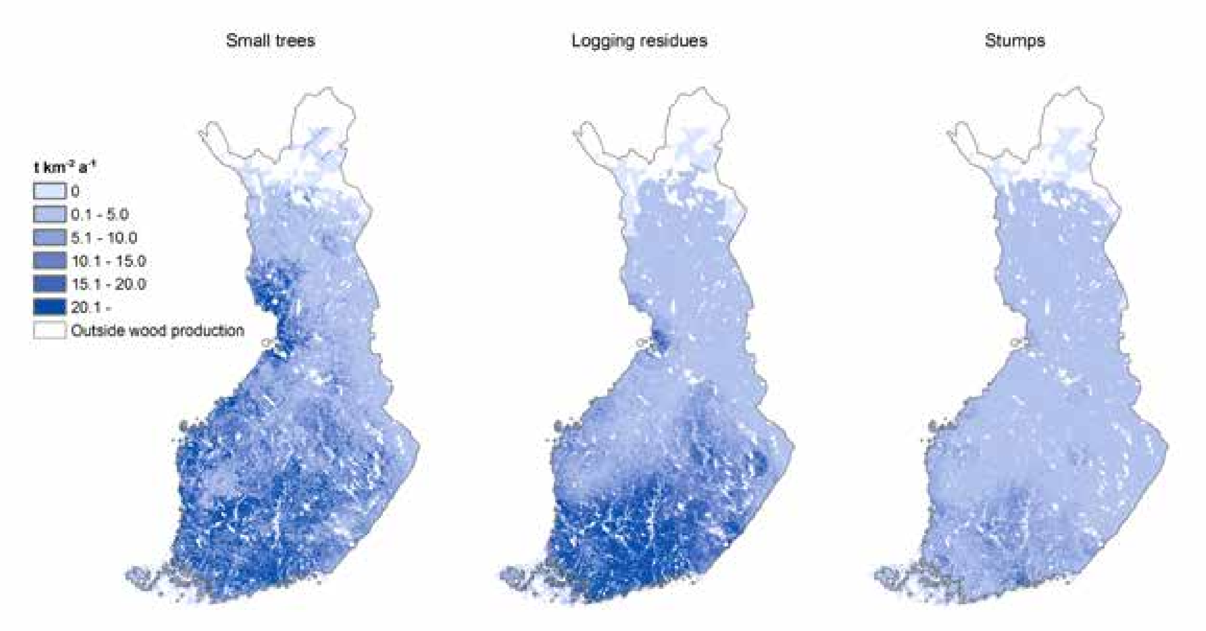

Figure 16. Spatially explicit demand for small trees (left), logging residues (centre) and stumps (right) according to the scenario in 2030.[29]

The total energy consumption has decreased in Finland and emissions trading and competing fossil fuels have negatively influenced the demand for solid wood energy sources. The reduced need for the total energy consumption has been promoted by the common economic situation, improved energy efficiency and mild winters. District heating plants have also invested in the new technology for flue gas scrubbers. New large CHPs have not been constructed, but local heating plant investments have been continued.

Germany

By the year 2050, bioenergy could have a 28% share of the domestic total primary energy supply (TPES) (1,915 PJ) according to the scenarios by Prognos[30] and woody biofuels could provide 687 PJ of primary energy.[31] In the Biomass Strategy of the State of Brandenburg, the potential for ligneous biomass is estimated at 11.4 PJ, not including small private forests (SPF) with an acreage of less than 20 ha.[32] In the Energy Strategy 2030 of the State of Brandenburg[33] a share of 20% (24 PJ) of the total primary energy supply for 2020 is attributed to bioenergy (the goal for 2020).

Latvia

Latvia has high potential to increase the use of forest biomass. Creating joint ventures which include owners of wood resources, energy producers and consumers could be one of the solutions to ensure a stable and complete energy cycle.

Picture 3. Latvia has high potential to increase the use of forest biomass. Logging residues in a pile in a Latvian state forest after regeneration cutting. (Photo: Valentīns Lazdāns)

Lithuania

There are not many wood-based energy generation plants planned or under construction. A new biofuel plant (48 MW) near Vilnius has been opened in 2019. It is an example of private equity-funded infrastructure to mitigate climate change.

There are many plants under reconstruction (gas boilers are being converted to wood fuel boilers etc.) using EU funds. The company AB „Panevėžio energija“ recently rebuilt one of the city’s boiler houses. The installation of a new 8 MW biofuel boiler combined with a 1.8 MW condensing economizer has replaced the operation of the previously used natural gas fired boilers. The new boiler started to operate in July 2019. The next AB „Panevėžio energija“ boiler is under reconstruction and should be ready in 2020.

Sweden

Svebio’s biopower platform (2016)[34] shows that it is possible to expand 10 GW of biopower with an annual production of 40 TWh. This can be compared to today’s production of about 13 TWh of bio power (including electricity from waste and peat). District heating is already to a large extent based on biofuels and biogenic waste, accounting for about 70 percent, including residual heat from the bio-based industry.

The restructuring of the industry, with the phasing out of fossil fuels, will lead to a sharp increase in the demand for biofuels. Already today, biofuels are the largest energy source in Sweden’s industry, but their use is highly concentrated in the forest industry. When changing other industries, large quantities of biofuels will also be needed.

Key questions discussed in this part of the handbook:

1. Do you have knowledge of the active plans in your country to increase forest bioenergy based plants, if any?

1.2.4 Available Forest Biomass Resources

Estonia

Half of Estonia’s land area (51.4%) is forest land. In 2017, the total area of Estonian forest land was 2.33 million hectares. The most common stands were pine forests (32.1% of the total area of stands), birch forests (30.1%), spruce forests (17.5%) and grey-alder forests (9.0%).

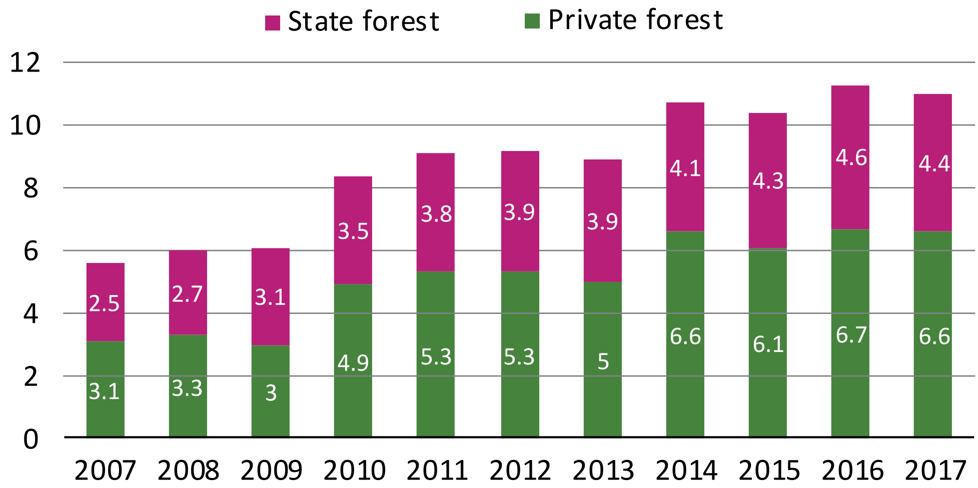

Figure 17. Cutting volumes by forest owners (in private and state forests).[35]

Compared to 2000, both the total forest stock and the forest stock per hectare, as well as the rate of the wood stock growth have gradually increased.[35] Because of the relatively high proportion of mature stands in Estonian forests, the felling rate could be even higher from the forest management perspective. According to the Forestry Development Plan for the last decade, the optimum level of timber supply was 13.1 million m^3.[2] The largest amount of mature wood stock is situated in the counties of Southeast Estonia – in Jõgeva, Tartu, Põlva, Võru and Valga counties. From the annual cutting volume, thick and fine timber accounts for 4.2 million solid m^3, firewood 2.8 million solid m^3 and paper wood 2.6 million solid m^3. The share of logging residues in the volume of marketable wood from the renewal cuttings is 15%. The volume of logging residues is 1.3 million m^3 per a year.

Due to poor weather conditions, timber cannot be extracted from the forest at roadside storage sites. Additionally, some of the roadside storages are not accessible with big trucks. The roadside storage sites are often on gravel roads that cannot support heavy machinery during wet seasons. Even some tarmac roads cannot support big machines in the current weather conditions (February 2020).

In addition to logging on forest land, a significant amount of wood is also used from non-forest land. This is particularly the case with wood chips entering the energy sector[35]. The use of energy wood has gradually increased as a result of the transformation of local boiler houses from oil and gas to wood chips. Knowledge that wood chips are the most affordable source of heat in district heating networks has become a well-known fact and this affects local governments in choosing new types of fuel for heating.

The addition of new, large, wood-consuming energy consumers to the Baltic Sea region will provide additional export opportunities and demand. Given the general trend towards energy from renewable sources, it is likely that investments in wood-based energy solutions will continue and demand is expected to increase.[15]

Finland

Forest chips consist of wooden material, which is not possible to use in other products of the forest industry. The reasons for this may be due to quality or market related issues or problems in tree harvesting on the site. The kind of wood used for forest chips are whole small diameter trees or delimbed stems originating from young stands, as well as decayed stem wood and stumps from final fellings. Strong link to industrial wood procurement concerning energy wood availability raises problems for forest energy users.[17]

The potential to increase the use of forest chips for energy has been evaluated in different parts of Finland. The theoretical maximum potential consists of wood biomass from silvicultural thinnings, the round wood left in a forest site during harvesting operations, branches and tree tops as well as stumps and other root wood in the soil. The harvest volume of small trees for energy was 6.2 million m^3 (harvested as delimbed stems), 8.3 million m^3 (harvested as whole trees) and 6.6-10.4 million m^3 (integrated harvesting with pulp wood). The potential logging residues which could be used for energy varies between 4.0 – 6.6 million m^3 depending on the logging volumes, and the utilisation of stumps for energy would amount to 1.5 – 2.5 million m^3. Based on the balance calculations (potential current use) the largest potential way to increase the forest chip harvest would be to use more small trees. In the coastal regions in Western Finland practically all available logging residues are currently used for energy.[22]

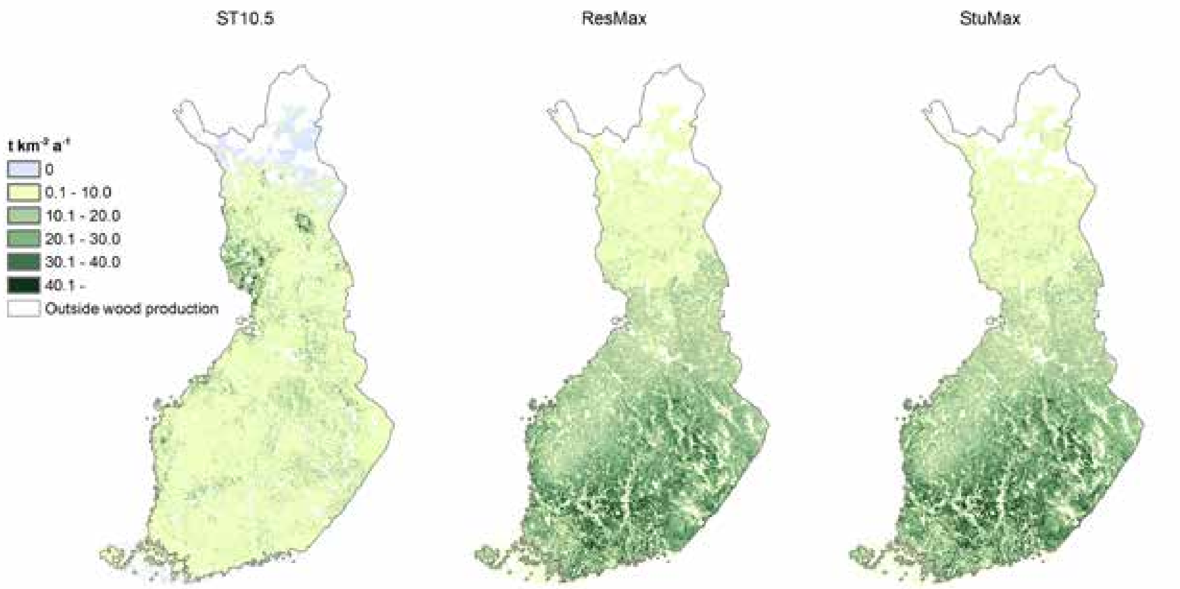

Figure 18. Spatially explicit technical harvesting potential of small trees (left), logging residues (centre) and stumps (right).[29]

The theoretical potential cannot be fully utilised as this depends on technical, economic, ecological and social factors. The technical aspects are related to how efficiently the harvesting residues are collected from a logging site, as well as the storage loss, quality requirements for the raw material, the minimum area for a logging site and the accrual per hectare. The social factors involve the willingness of forest owners to sell energy wood, while the ecological factors concern silvicultural and harvesting recommendations which aim to minimise the negative impacts of harvesting operations on forest growth and the environment. A further essential factor is the price competitiveness of forest chips compared to other fuel alternatives (e.g. waste energy) from the economic point of view.[36]

In certain circumstances, pulpwood is used annually for energy generation purposes due to the small accumulation of commercial wood and the price level for the energy wood. If the demand for pulpwood and waste wood from forest industry by-streams will increase, then the availability of energy wood will decrease.

Germany

Depending on the predominating forest management scheme, the harvestable volume of forest fuel can be estimated between 23 and 35 million m^3 annually (years 2020 to 2050), of which logging residues could have a share of 5 – 12 million m^3 annually[18]. Pre-commercial thinning is expected to remain an important source of forest fuel. The increasing share of deciduous trees in German forests may provide opportunities for the bioenergy sector in the future.

Latvia

The first cycle of the National Forest Inventory (2004–2008) determines the potential biofuel resources that can be produced in forest thinning within the limits of legal and technical restrictions of forest management. The extraction of biofuel in pre-commercial thinning now is possible in an area of up to 161,000 ha. The total extractable above ground biomass is 4.9 million m^3 of stem-wood including 21% of resources located in coniferous dominant stands. This calculation includes the biomass of trees thicker than 4 cm. Economically efficient biofuel extraction can be done in Latvia in 53,000 ha with the total extractable above ground biomass of about 1.8 million m^3 (36% of the total potential in pre-commercial thinning).

The delaying of the last pre-commercial thinning in combination with more intensive first pre-commercial thinning is an important factor to increase the feasibility of the biofuel extraction, because the stem volume of extractable trees is six times larger in areas where an average tree is 12 metres tall in comparison to areas with 6-metre-tall trees. Therefore, silvicultural studies should be concentrated on the evaluation of delayed thinning to find synergies between forest management and biofuel production. Accessibility of the biofuel seems not to be a problem. Only 19% of biofuel can be extracted only in winter when the soil is frozen.[37]

The average price of wood chips to the end consumer over a period of 10 years varied from 7-11 EUR/m³ or 8.8-13.8 EUR/MWh. Changes in the wood chip price in recent years have not been significant.[38]

Lithuania

In 2017 the total forest land area in Lithuania was 2,189,600 ha, covering 33.5% of the country's territory. Scots pine occupies the biggest share in Lithuanian forests – 713,200 ha. Norway spruce stands covers 429,500 ha. Birch stands cover the largest area among deciduous trees accounting for 456,600 ha. The area of black alder is 156,100 ha. The area of grey alder is 121,600 ha. The area of aspen stands have expanded to 93,800 ha. Changes in felling rates in state forests have not been significant over last five years.

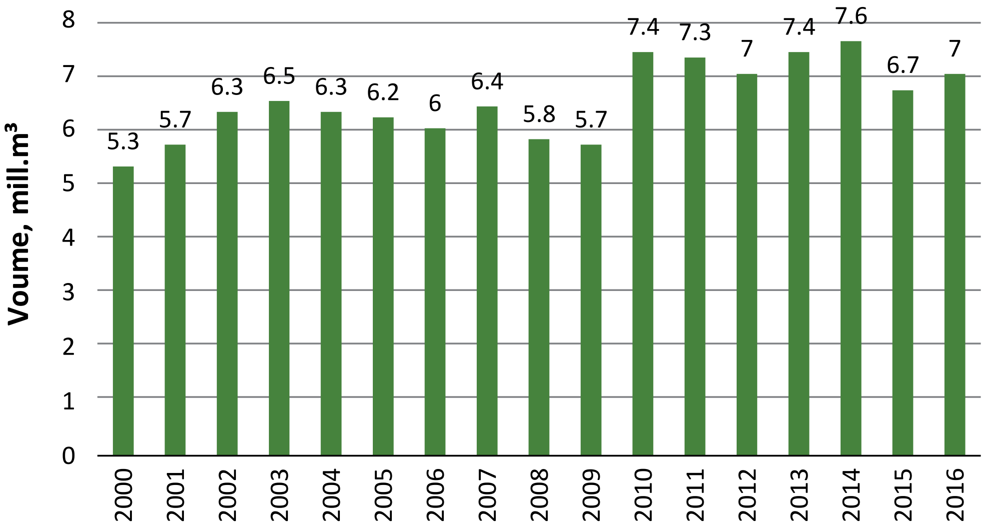

Figure 19. Fellings in state and private forest in total, 2000-2016.[15]

In Lithuania, the average harvestable wood fuel volume has been estimated to be 5.8 million m³ annually.[13] Firewood can amount to 1.8 million m³ annually of this amount. This quantity corresponds to 21% of the volume of the round wood being prepared. The theoretical volume for forest chips is 4 million m³. There is potential to make wood chips from 0.85 million m³ of roundwood logging residues, 0.3 million m³ of stumps, 0.3 million m³ of young stand treatment biomass, 0.25 million m³ of short rotation coppice biomass, 0.6 million m³ of low-value stand reconstruction biomass, 0.2 million m³ of park and landscape treatment biomass per year. Currently only 15-20% of logging waste is collected and used for biofuel. According to scientists about 50% could be used without violating eco-sustainability requirements.[39]

Picture 4. Scots pine occupies the biggest share in Lithuanian forests. (Photo: Vita Arlickienė)

Biofuel processors are still preparing a lot of raw materials from abandoned fields and ditches, which farmers often give away free of charge, while others are not interested. For this reason, biofuel processors have not been willing even to pay a few extra euros for logging residuals. There is a lack of human resources for making biofuel because of low salaries.

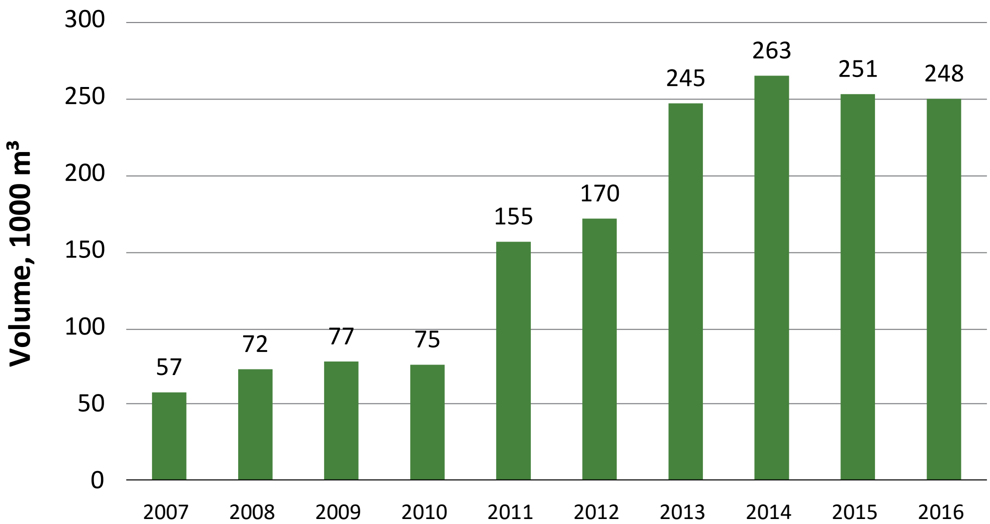

Figure 20. Sales of forest felling residues in the state forests of Lithuania, 2007-2016.[14]

From the beginning of May 2018 solid biofuel quality requirements have been applied to all manufacturers, importers, traders or users of solid biofuels in Lithuania.[40] Over the last ten years, Lithuania has made significant progress in converting its heating sector from fossil fuels to renewable biofuels, and biofuels today account for two-thirds of the total combustion in district heating and the share of biofuels in households is even higher. It is necessary to control the solid biofuel quality to reduce environmental pollution.

Sweden

According to estimates, there is an opportunity to extract more forest fuels from the forest amounting to about 60-65 TWh. There is a potential to increase the use of logging residues in harvests from approximately 8.5 TWh today to a level of 29 TWh during the period 2020-2029. The balance shows that the potential for logging residues, after deduction according to the recommendations of the National Forest Board, is on the order of 3–4 times greater than the use in 2013. The assessment made regarding ecological restrictions is of great importance for the amount of energy you can extract from the forest. The recommendations mean that harvesting logging residues and stumps from certain stands is excluded and that 20 percent of the logging residues and stumps are assumed to remain in the forest stands. No stumps of deciduous trees would be removed. Additionally, stumps would not be removed in thinning.

Key questions discussed in this part of the handbook:

1. What other factors/challenges/constraints can you find from your country? How should the reasons and consequences be presented?

1.2.5 Current District Heating Systems and Investment Needs in the Baltic Sea Region Countries

Estonia

In 2016, the annual output of heat was estimated to be 6.5 TWh, of which 44% of the heat was generated in large power plants and about 56% in boiler houses. About 70% of the heat produced went into district heating, 9% were network losses and the rest was used in industrial processes. Households accounted for 42% of final heat consumption. The following figure provides an overview of the fuels used for district heating in 2017.[1]

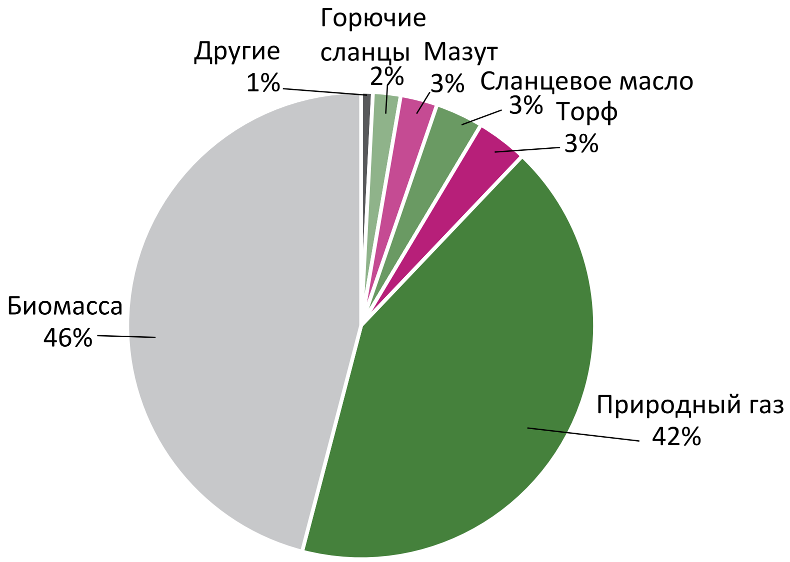

Figure 21. Heat produced by type of fuel used in Estonia, 2017.

Boilers using shale oil are extensively replaced with equipment that uses more affordable biomass. Nevertheless, the number of heating plants that use shale oil for heat production remains relatively large.

In June 2016, the Estonian Government proposed amendments to the District Heating Act[41], which would provide heat producers with regulatory guarantees and additional motivation, which is needed to increase the use of renewable sources and peat while reducing the use of more expensive fossil fuels.

Finland

Typically, there are heat or combined heat and power plants in most of the densely populated settlements in Finnish municipalities. They use wood-based fuel such as chips, bark, sawdust or pellets, peat or mixed combinations. It is a recommendable feature, if the energy plant can use different fuel alternatives or their mixtures. There are different risks related to the fuel types, which include their availability, price, or environmental legislation. One safe and reliable heating plant solution is based on two separate units (plants) in the municipality settlement, which operate independently. The advantage is that the smaller unit can support the work of the larger one during technical maintenance and disturbance periods as well as energy demand peaks.[42]

Lithuania

The district heating sector (DH) in Lithuania accounts for more than 50% of the total heating sector of the country. The remainder consists of individual heating consumers, mainly using gas or solid fuel boilers. More than 40 independent heat producers were operating in the DH production market in 2017. In the same year, 49 licensed heat supply companies were operating in the DH sector.

The total length of the pipelines, supplying the Lithuanian DH sector is approximately 2,846 km. Over the period 2007-2013, using EU structural funds, about 12% of the total length of the DH pipelines have been updated. Piping replacement is a slow payback investment. Heat transfer losses in the pipeline system can reach up to 15.5%.[43]

Sweden

Combined heat and power plants or heating plants are very well established in most of the Swedish municipalities in their densely populated settlements. They use wood-based fuel such as chips, bark, sawdust or pellets, or their mixed combinations. It is a recommendable feature if the energy plant can use different fuel alternatives or their mixtures.

1.3 Policy Instruments with the Key Elements Promoting Forest Energy Business

General Statement

In practice, the development of forest management procedures are affected by many factors, of which the aims to mitigate climate change is the one. Other incentives can be legislation, recommendations, instructions, subsidies, wood demand and technical progress in the forest sector and they have own influence on the forests. It is essential to follow what kind of influence different means together have.[16]

The Baltic ForBio project used the support of the S2BIOM[44] project in order to be able to list all the policy instruments by the partner countries. In the context of Finland, all together 48 instruments were listed and four of them were assessed to be relevant for forest bioenergy production.

Table 2. Policy Instruments in the partner countries and the most relevant ones for forest bioenergy utilisation.

Partner Country	S2biom Project List*	Forest Bioenergy Relevant Instruments**
Estonia (EST)	20	5
Finland (FIN)	48	5
Germany (GER)	24	6
Latvia (LV)	12	4
Lithuania (LT)	15	6
Sweden (SWE)	14	4

**Internet search operator provided by the S2BIOM Project: https://s2biom.vito.be/.*
***Here the number refers to the analysis of the questionnaire mentioned in the above chapter from the Baltic ForBio project point of view concerning logging residues, stumps, wood with no industrial use and short-rotation plantations.*

Estonia

Biomass is the most widespread type of renewable energy in Estonia and has been used in the heat industry for centuries, even without subsidies. With the help of various state subsidies, the transition from fossil fuels to biomass, especially wood chips, has been accelerated.

Support for renewable energy has gradually begun with the help of investment financing and operating grants. The Ministry of Economic Affairs and Communications, the Ministry of Finance and the Ministry of the Environment and the Ministry of Rural Affairs (formerly the Ministry of Agriculture) have been the main implementers of state measures supporting the introduction of renewable energy sources. The Environmental Investment Center (KIK), the KredEx Foundation and the Agricultural Registers and Information Board (ARIB) have acted as implementing entities.

In Estonia, there is subsidy for thinning stands under 30 years old. This is a subsidy for forest owners. The other energy-related subsidies are subsidies paid to the power plants.

Currently, in Estonia the only state support for the use of biomass for energy production is the operating aid. This support is established by the Electricity Market Act. According to the Electricity Market Act, a producer of renewable electricity is able to receive support from the transmission system operator in the case of equipment using a net capacity not exceeding 125 MW. Renewable energy sources within the meaning of the Electricity Market Act are: water, wind, sun, wave, uplift, geothermal, landfill gas, waste gas, biogas, and biomass.[45]

The subsidy paid by the transmission system operator (TSO) to the electricity producer using renewable sources is 57.3 €/MWh, with the foreseen support paid for 12 years from the start of production.

According to the law, the subsidies are paid by the transmission system operator - AS Elering. The cost of financing the support is borne by the consumer by paying a renewable energy charge. In the case of wood, support may be applied for electricity produced in cogeneration mode.

There are active plans by the state to pay state energy companies subsidies for using bioenergy instead of oil shale. The estimated subsidy funding volume is annually 5.0 million €. It could increase the usage in those plants by 250,000 m^3/year but about 100,000-200,000 m^3 is more realistic.

Finland

The state supports the following activities with subsidies: sustainable management and use of forests; timber production, biological diversity, forest ecosystems and other appropriate measures.

The “Energy Subsidies for Small Diameter Trees” are subsidies for harvesting small diameter trees from thinning operations. The aid is paid for timber which is obtained in connection with forest management from young stand tendering and first thinning sites.

Forest owners can receive state subsidies for young stand treatment and small-sized tree harvesting, which is paid additionally regardless of how much wood purchasers pay for the wood. The average prices for energy wood were 20.56 euros per cubic metre and the stumpage price was 3.54 euros. This subsidy has an effect on stand treatment decisions and the profitability of the taken actions. The paid state subsidy was 430 euros per hectare in 2017, which is about 9 euros per cubic metre.[5]

The requirements for subsidy payment are: a) a minimum area 2 hectares, b) that the growing trees after the operation are at least 3 metres high, c) the average diameter of the trees before and after operation should be not more than 16 cm at breast height, d) the number of removed trees with of least 2 cm in diameter at the stumps should be at least 1,500 trees per a hectare, e) the stand should be maintained in good condition 10 years after the subsidised operation and f) the harvested volume of the trees should be at least 35 cubic metres per hectare for an additional small tree subsidy of 200 euros per hectare.

Production subsidies for renewable electricity including: wind, biogas and small-scale woody biomass based electricity generation are supported by a feed-in tariff mechanism. The plants must be new to be eligible. For electricity produced in a woody biomass or a biogas CHP plant, an increased tariff is paid in the form of a heat premium if heat is produced for utilisation and the overall efficiency of the plant meets the required standards. The applicable biomass types are limited to primary energy wood which is “delivered directly from forests” (branches, tops, stumps, small diameter wood). The regulation was adopted to ensure that wood suitable for the forest industry will not be used as an energy source. The maximum duration for both mechanisms is 12 years.

Germany

The national Climate Action Plan 2050 underlines the importance of wood and wood products, on the one hand, and the protection and development of forests, on the other hand, for carbon sequestration in the fight against climate change. The Charta for Wood 2.0 of the Federal Ministry of Food and Agriculture details several fields of action to increase the use of wood and wood products during the forthcoming years. National and regional forest policies focus on forest preservation, adaptation of forestry to climate change and nature preservation matters. The use of forest fuels (such as pellets, chips, and logs) for domestic heating is heavily promoted by the government. Since the beginning of the year 2020, investments in modern small heating systems using wood biomass (pellets, wood chips or logs) are being funded with up to 45% of the eligible investment costs (Market Incentive Programme for Renewable Heat Production).

Latvia

In order to promote more efficient use of forest bioenergy in the development of state energy, changes should be made in the wood utilisation policies. Creating joint ventures, which include owners of wood resources, energy producers and consumers, could be one of the solutions in order to ensure a stable and complete energy cycle. Concrete measures are listed in the National Climate and Energy Action Plan 2021-2030 and in the Rural Development Programme, but biomass needs more attention.

Lithuania

The main measure to support the production of green electricity is a buying tariff, which is based on the obligation to buy this type of energy at a fixed price. Electricity generation using wind, biomass, solar power plants and hydropower plants with a capacity of up to 10 MW is encouraged in Lithuania. Renewable power plants are connected to the electricity grid according to the law, with a 40% discount on the connection fee for producers.

The Law on the Heat Sector provides that the state (municipalities) will encourage the purchase of heat produced from biofuel for heat supply systems. If the heat price is the same, the supplier may buy heat from independent heat producers in this order.[46]

1. heat from combined electricity and heat installations using RES;
2. heat produced from renewable and geothermal energy sources;
3. waste heat from industrial plants;
4. heat from high-efficiency cogeneration units;
5. heat from fossil fuel boiler plants.

Companies and private stakeholders who submit documents proving the use of biofuel, are exempt from tax on environmental pollution from stationary pollution sources for the emissions caused by the use of biofuel.[47] Energy products made from or containing biological material are eligible for excise duty relief.[48]

On 2nd September 2019 the National Energy Regulatory Council (NERC) started the first auction for a premium exchange price. This was the first technology-neutral auction, open to all technologies ranging from sun, wind, biogas, and biomass. The auction winner will get the possibility to get a premium exchange price. These auctions will promote the development of renewable energy.[19]

There are some EU programmes promoting changing old, polluting, fossil fuel boilers into biofuel boilers using financial support. Private household can buy biofuel at low VAT rates. Small companies and private forest owners can apply as part of the “Investments in forest development and improvement of forest vitality” scheme and get support for the implementation of round wood and wood biofuel production technologies.

Key questions discussed in this part of the handbook:

1. What kinds of subsidies and their functionality in practice can you present from your country? In your country language version of handbook, is it possible to present your domestic subsidy procedures and in this English version the titles of each country and perhaps some details of the best ones in order to give working examples?

2. FOREST ENERGY HARVESTING AS PART OF YOUNG STAND TREATMENT, FIRST AND ADVANCED THINNINGS

2.1 Technology-Related Aspects in Forest Bioenergy Harvesting

As forest situations can vary between the Baltic Sea region countries (depending on the climate, forestry practices etc.), this part of the handbook provides an overview of the benefits of different methods, which could help to make decisions concerning the forest.

The presented statements are based mainly on the Nordic countries' experience. They are presented at the general level because the price levels and operating environments can differ between the countries. The country-specific conditions are referred to in certain cases when they are worth mentioning. The presented approaches provide the possibility for the learning at the organisational level or at the individual level.

This chapter aims to answer the following key question: Why is it appropriate to choose a certain technological solution based on a productivity and profitability analysis or are there other common-level statements for the technical development of the chosen method?

2.1.1 Energy Wood Production as Part of Treatment Implementation in the Young Stands

Note for Early Silvicultural Measures in Spruce Stands

Young stand treatment can be implemented leaving 4,000 – 5,000 trees per hectare for energy wood harvesting during the first commercial thinning. Extra trees for energy wood production can include birches with a density of 1,000 – 3,000 pieces per hectare with the maximum height of the dominant spruce trees. This operation is recommended to implement at the height of 2.0-2.5 metres of the main growing spruce seedlings at the latest. If the treatment operation will be implemented more than ten years after the planting of the seedlings, it will be too late and the birches will clearly be taller than spruce trees.[49]

Optimal Timing of the Silvicultural Measures

Finnish field tests have proven the most optimal growing phase for young stand treatment is for the height of spruce stands to be 1.5-2.0 metres, so that the broadleaved species do not disturb the growth of spruce saplings by the first thinning measures, when the height of the dominant spruce trees are at a height of 8-12 metres. Most commonly this is implemented in young spruce seedling stands, where artificially regenerated spruce or pine saplings are left with naturally regenerated silver birches. The left additional trees are not allowed to be higher than the dominant length of the spruce seedlings. The soil fertility conditions are quite good in natural spruce stands and therefore the potential for energy wood growth is high. The whole tree method is not recommended and therefore it is better to delimb trees and leave the branches on the forest ground in order to prevent possible nutrient and growth losses.[49]

Picture 5. The extra trees for energy wood production are naturally regenerated birches with a density of 1,000 – 3,000 pieces per hectare with a maximum height similar to the dominant spruce trees. (Photo: Pentti Niemistö)

2.1.2 Multi-Stem Cutting

General Approach

The choice of technology usually focuses on the productivity of different systems, i.e. efficient utilisation rates and the economic profitability of machinery. One should also take into account the flexibility, the quality of work performed and the product, as well as the environmental impact and the management result with regard to damage and the nature of the remaining stand.

In young growing forests, there are many technical solutions for cutting and delimbing which have an influence on the harvesting yield as commercial and energy wood as well as logging residues left at a forest site.[50]

A typical energy wood harvesting object is a broadleaved dominated young forest, where most of the removed trees are below pulpwood dimensions. In the first thinning sites, trees are tall and narrow and the number of the removed trees is high per hectare. One option for these objects is to integrate energy wood harvesting with pulpwood. Integrated harvesting also includes the removal of the trees below pulpwood dimensions and the treetops.[17]

Picture 6. Logging operations are done with a harvester equipped with grapple to be able to handle multiple stems at a time. (Photo: Erik Viklund)

Possibilities to Improve Thinning Operations from the Productivity Viewpoint – Geometric or Selective Thinning

One way to substantially increase productivity when thinning dense young stands is to employ some form of geometric harvest between strip roads, i.e. felling all the trees in narrow boom corridors extending from the strip road. The corridors can be harvested with a felling head that can accumulate trees upright. In comparison to conventional, selective thinning, studies show that boom corridor thinning using current technology increases logging productivity and profitability, and that more forest fuel can be harvested efficiently. With further development, boom corridor thinning can become even more competitive and may be applied in even lower diameter stands of even thinner trees with no loss of profitability.[51]

Multifunctional Harvesting Heads

Many harvesting entrepreneurs are operating both in commercial wood harvesting industrial round wood and energy wood production and therefore the technology providers have designed the harvesting heads to be able to process both industrial round wood and energy wood.[51]

High Logging Costs as a Challenge

Thinning young stands is necessary for creating sound and productive future forests. It is expensive, but many dense, young forests can yield sufficient volumes of forest fuel to cover much of the cost or even generate a surplus. There is great potential to increase the harvest of forest biomass for fuel in early thinnings, where small trees are removed, but the assortment has become less attractive due to high logging costs in combination with falling demand and prices for forest fuel.[51]

Picture 7. Thinning or cleaning of young stands is necessary to create sound and productive future forests. (Photo: Maria Iwarsson Wide)

Different Kinds of Raw Material Forms Possible – Whole Trees, Delimbed Trees or Pulpwood

Forest fuel from small trees can be harvested in various ways, such as whole trees, delimbed tree parts (energy wood) and as pulpwood. The fuel should be of good quality thanks to a high proportion of stem wood. It is also relatively unproblematic to handle when storing, chipping, and transporting.[51]

Picture 8. Three technical cross-cutting solutions are used for felling small trees with a harvesting head. (Photo: Maria Iwarsson Wide)

Technical Solutions for Tree Cutting in Young Thinning Stands

Three technical cross-cutting solutions are used for felling small trees with harvesting grapple. These are: shears, a circular saw, or a chain saw. Each has its advantages and disadvantages, but the most important aspect is the performance of the unit as a whole, not least how the trees are handled after felling.

→ Shears are robust in rocky terrain but slower in cross-cutting.
→ Circular saws are faster in cross-cutting, but more sensitive to rocky terrain.
→ Chain saws, which are used in traditional logging, are flexible since one can easily switch between pulpwood and energy harvesting, but they are more expensive when harvesting very small trees.

Picture 9. A special harvesting head for multi-tree handling of small diameter trees provides efficiency in tree felling. (Photo: Maria Iwarsson Wide)

Efficiency in Tree Felling and Bunching Phases

A suitable unit should be capable of felling and bunching several trees in each boom cycle, holding the bunch together, and should be able to compact and, when necessary, feed and cut the bunch into lengths suitable for off- and on-road transportation.[51]

Forwarding through the Strip Road Network to the Roadside Landing

Undelimbed stems with all the branches are laid in the bundles along the strip road, either in full lengths or divided into sections, and are then being forwarded to the roadside. Usually, storage and chipping take place at the roadside, and the chips are then transported directly, or via a terminal, to the customer.[51]

Picture 10. Storage and chipping takes place at the roadside, and the chips are then transported directly, or via a terminal, to the customer. (Photo: Lars Eliasson)

Accessibility is a significant concern in the Baltic countries. In many cases, a good forest stand for energy wood cannot be used for collecting (energy) wood as it cannot be accessed due to lack of forest roads. There is a real need for improvements in the forest road infrastructure.

Advantages of Harwarders

For mechanised harvesting of small trees, in addition to the traditional two-machine system with a harvester and a forwarder, it is also possible to use so-called energy harwarders that both harvest and transport the trees to the roadside. Studies have shown that energy wood harwarders are more profitable than the two-machine system for short forwarding distances (<150 m), low average stem volumes(<0.02 m^3), low volumes per ha in the assortment (main stem), (<55 m^3 sub / ha) and for small harvesting objects (<100 m^3 sub / stock).[51]

Picture 11. An energy harwarder is more profitable than a two-machine system at short forwarding distances or on small stands. (Photo: Juha Laitila)

Better Employment for the Machinery

The competitiveness of the harwarder is also based on the large proportion of the cutting work in relation to forwarding. The harwarder is a secure choice for starters in the business. Later the business can be expanded flexibly by installing a felling-loading head on a separate felling machine and using the harwarder base machine as a conventional forwarder. The dual-purpose machine method enables better employment of the machinery, because it is easier to find work for one machine than two machines and keep machine capacities in balance.

Picture 12. The traditional two-machine method – with a harvester for felling and cutting, and a forwarder for short distance transportation to the forest site storage location. (Photo: Juha Laitila)

How to Triple the Productivity?

For harvesting in very dense stands prototypes of continuous harvester heads have been developed. These work with continual cutting and accumulation, which allows geometric corridor thinning, for instance. According to theoretical simulations, this principle could even triple productivity in very early thinnings with small stem volumes of the removed trees. Field tests of the functionality and performance of the prototype felling head show that there is potential to increase harvester performance in early dense thinning.[51] However, in practice it still requires a lot of research, time, funding and device development in order to triple the productivity.

How to Increase Productivity Related to the Crane Operations – Nine Trees per Boom Cycle

In order to streamline forwarding and onward transport in the thinning of small trees, different bundling units have been developed. Much of the harvester's time in stands of small trees is spent on crane operation. The hope is that this can improve productivity while thinning small trees.[51]

Picture 13. Much of the harvester's time in stands of small trees is spent on crane operation. Birches are removed and spruces are left. (Picture: Örjan Grönlund)

The key to the viability of harvesting small trees in thinning is the capacity to handle more than one tree at a time. All of the small tree harvesting today is done using multi-tree equipment. With the current technology, productivity can be increased by 15-30% if the number of trees per boom cycle is increased from today's 3 to 6-9. Improved working methods, for example reducing the amount of crane work by cutting trees in the correct order can further increase productivity without increasing the workload of the operator.[51]

With an accumulating harvester head with a feed roller it is quick to switch between harvesting pulpwood and forest fuel. This means great flexibility when harvesting in the early or the first thinning stands. At present, the most common machine systems used for the first thinnings are harvester-mounted harvesting heads with a chain saw and additional multi-tree equipment. Long cranes are more common than shorter ones and are usually better suited as they allow more trees to be reached from the same site in the strip road. This also means that a relatively large base machine is required to be able to handle several trees at full crane length.[51]

Picture 14. It is quick to switch between harvesting pulpwood and forest fuel with an accumulating harvester head equipped with feed rollers. (Photo: Juha Laitila)

2.1.3 Forwarding

Efficiency for Forwarding – How to Maximise the Solid Content in the Load

For efficient forwarding, it is important that the felled trees are concentrated into a few, large piles along the strip road. The productivity in forwarding of small-dimension, delimbed tree sections is nearly as great (approximately 95%) as in pulpwood forwarding. The slightly lower payload is due to the greater air content in the load because of the very small-dimensioned wood. Corresponding figures for partly delimbed tree parts are 80-90%, and for uncompacted tree sections (e.g. tree tops and whole trees) are approximately 65%.[51]

Picture 15. The slightly lower payload is due to greater air content in load because of the branches and very small-dimensioned wood. (Photo: Maria Iwarsson Wide)

Picture 16. This is the right way to assemble roadside storages of energy wood, where the piles are as high as technically possible and appropriate from the work safety viewpoint . The frontside should be straight and the top part of the pile functions as rain cover. (Photo: Juha Laitila)

Long-Distance Transportation

Multi-stem handling of trees that are partially delimbed and cut into suitable lengths for transport is a common task. Depending on how well delimbed the material is, it can possibly be run on ordinary timber trucks, otherwise transport is recommended on biomass trucks with covered sides or extra supports. As the stems in the stand approach the thinning stage it can be an opportunity to integrate pulpwood and forest fuel harvesting.[51]

Picture 17. Depending on how well delimbed the material is, it can possibly be run on ordinary timber trucks. Biofuel produced from small sized trees in pre-commercial thinnings of birch stands is delivered to a pellet factory in Jēkabpils city, Latvia. (Photo: Andis Lazdiņš)

Picture 18. Undelimbed energy wood or loose logging residues can be transported to a terminal or end-users on biomass trucks with covered sides and bottom. (Photo: Juha Laitila)

Further Processing and Deliveries of Energy Wood Materials to the End-Users

Forest chip procurement schemes should be designed once a decision has been made as to where the chipping process of the wooden material will be implemented and further in what form the material will be transported to the energy plants. In cases where the chipping will be implemented beside the energy plant or in a specific terminal, the annual volumes are big, the relative utilisation level of machines is high and as a consequence the chipping costs are lower. This approach leads to a decision about whether after the forwarding and roadside storing phase, the uncomminuted material will transported by truck to the plant or the terminal.[17]

Picture 19. A forest chip procurement scheme is designed after a decision has been made about where the chipping process of the wooden material will realised. (Photo: Juha Laitila)

In an energy plant and terminal chipping a small load size in transportation is a weakness if material is not compacted, which increases the costs. The means for increasing the load size include the following technical solutions: packing the logging residues as branch logs, delimbing trees from thinnings and cutting them to the same length, splitting and pre-crushing stumps and root wood.[17]

Because of high investment costs chipping beside an energy plant or in the terminal is possible only for large power plants. Additionally, the noise and dust problems may restrict the chipping operations, if there are people living in the area. Terminals can serve different sizes of energy plants and work as a buffer storage when weather and terrain conditions are poor preventing the deliveries directly from the forest. However, additional transportation needs and material handling increase the costs. Chipping terminals are normally located close to forest chip utilisation plants or close to peat production places. Terminals can also be used for storing produced chips.[17]

The chipper and transporting unit need to work closely together, which means that chipping and transporting should be implemented in a certain order, and therefore waiting times cannot be avoided. Roadside chipping can also disturb other traffic on the road. Roadside chipping provides the possibility to fully utilise the bearing capacity of the truck with a maximum load. The method is efficient also for long distance transportation and it is suitable for large and small energy plants. The major part of Finnish forest chips are produced at roadside storage sites.[17]

Picture 20. The major part of forest chips are produced at the roadside storage sites – here the unloading and piling of logging residues is ongoing. (Photo: Lars Eliasson)

2.2 Economy-Related Aspects of Forest Bioenergy Harvesting

Competitiveness of Forest Chips Compared to the Other Sources, e.g. Peat or Coal

Forest chips can substitute peat in small-scale energy plants if the peat availability is questionable. For larger energy plants in coastal areas, it is more obvious to use coal instead of milled peat and forest chips.[52]

Small Trees as a Raw Material for Forest Chips

During early or first thinning operations the most common timber assortments are pulp and energy wood. The first thinnings are not highly profitable because of the high procurement costs due to the small stem volume and low harvesting yield per hectare. The fibre quality of the timber from the first thinnings is also rather low for the purposes of pulp and paper production.[50]

Procurement costs for the utilisation of small trees for energy purposes often exceed the average forest chip price level, and therefore volumes should be boosted by subsidising the whole production chain (harvesting, chipping) or incentives should be provided in the form of energy taxes.[52]

In particular, an integrated energy wood harvest offers relatively large energy wood potential and the most valuable part of the wood from these logging sites can be directed to industrial use.[22]

Forest Site Specific Decision Making in Improving Forest Chips Competitiveness

The economic sustainability in small trees procurement can be improved by harvesting forest stands with a bigger diameter and e.g. with integrated harvesting of pulpwood and energy wood. This means decrease the costs related to the harvesting operations both for energy wood and pulpwood.[52]

Small trees are expensive to harvest. The biggest cost factor is felling and bunching, which accounts for 60–75% of the costs. A large part of the biomass in young stands is found in branches and tops. Compared to traditional pulpwood logging, in the early first thinning the extracted volume increases by at least 50% in forest fuel operations.[51]

Picture 21. Compared to traditional pulpwood logging, in early first thinning the extracted volume increases by at least 50% in forest fuel operations. (Photo: Erkki Oksanen)

The Importance of Cleaning Harvesting Sites Beforehand

Energy wood harvesting sites should be pre-cleaned using brush saws before the main operations in order to increase the productivity of logging operations and to reduce the harvesting damage to the remaining trees.[17]

Pre-cleaning of the smallest trees (<4 cm diameter at breast height) increases the mean volume during the harvesting, and thereby improves the productivity of the logging. This is a standard measure and is often carried out even though it is not always necessarily financially viable.[51] Therefore, pre-cleaning operations should be concentrated on stands with dense undergrowth on fertile soil grounds. According to Finnish experience, pre-cleaning of the undergrowth before machine harvesting is done for under the half of the logging sites. It should also be noted that pre-cleaning is an additional cost for a forest owner of about 300-400 euros per hectare.

Picture 22. A large part of the extra biomass in young stands is found in the branches and tops, when harvesting is integrated with pulpwood harvesting. (Photo: Erkki Oksanen)

How About Selling the Whole Available Volume of the Stand as Energy Wood?

It is possible to change the length, quality, and diameter requirements according to the market situation and harvesting conditions affecting the accumulation of pulpwood and energy wood from the operation site. Pulpwood typically commands a higher price level than energy wood, and therefore pulpwood is not commonly used for energy generation purposes. However, in young stands the pulpwood accumulation is so small or the quality is so poor, that the whole volume is profitable to sell and harvest as pure energy wood.[17]

Picture 23. In young stands the pulpwood accumulation is so small or the quality is so poor, that the whole volume is profitable to sell and harvest as pure energy wood. (Photo: Maria Iwarsson Wide)

If pine and birch dominated first thinning stands are growing on fertile enough soil, it is allowable to also harvest energy wood with branches according to the current recommendations. The total cutting removal is divided into commercial pulp wood and energy wood depending on the minimum diameter for the pulp wood. In Finnish conditions, the minimum diameter is 6 cm for pine, 6 cm for birch and 6-8 cm for spruce depending on the industrial use. If the minimum diameter requirement for pulp wood is increased by one centimetre to 8 cm, it clearly changes the volume for the energy wood.[50]

Picture 24. Forest storage sites after integrated harvesting in the first thinning – pulpwood on the left side and energy wood on the right side. (Photo: Juha Laitila)

Pricing Peculiarities between Pulpwood and Energy Wood in the Baltic Countries

In the Baltic countries, pulpwood should be exactly three metres in length. The reason for this is due to the transportation by ship mainly to Finland or Sweden. When exporting round wood abroad, fixed dimensions are more commonly used in order to optimise the volumes in long distance transportation. In the Nordic Countries, the pulpwood length depends on contract terms varying between 2.7 – 5.5 metres. In practice, quite often in the thinning of young tree stands the only option is to cut three-metre-long stems for pulpwood, even if a suitable stem would be four metres in length.

As forest chips are not subsidised, they are always cheaper than pulpwood. In many cases, it is not wise to harvest just 10 m^3 of pulpwood. In addition to pulpwood and chips, normal firewood for heating private houses is also produced. However, this comes mostly from the final fellings or the second thinnings as the diameter of the firewood trees should vary between 10-30 cm.

Picture 25. Different timber assortments on a logging site in Lithuania including energy wood. (Photo: Valda Gudynaitė-Franckevičienė)

Picture 26. Pulpwood and delimbed stems at a logging site beside a strip road. (Photo: Juha Laitila)

Working Methods to improve the Profitability of Energy Wood Harvesting – Thinning in Sections

In order to realise the potential for multi-tree handling a working method for thinning in sections has been developed. An evaluation has shown that a consistent thinning method can increase productivity by up to 18%.[51]

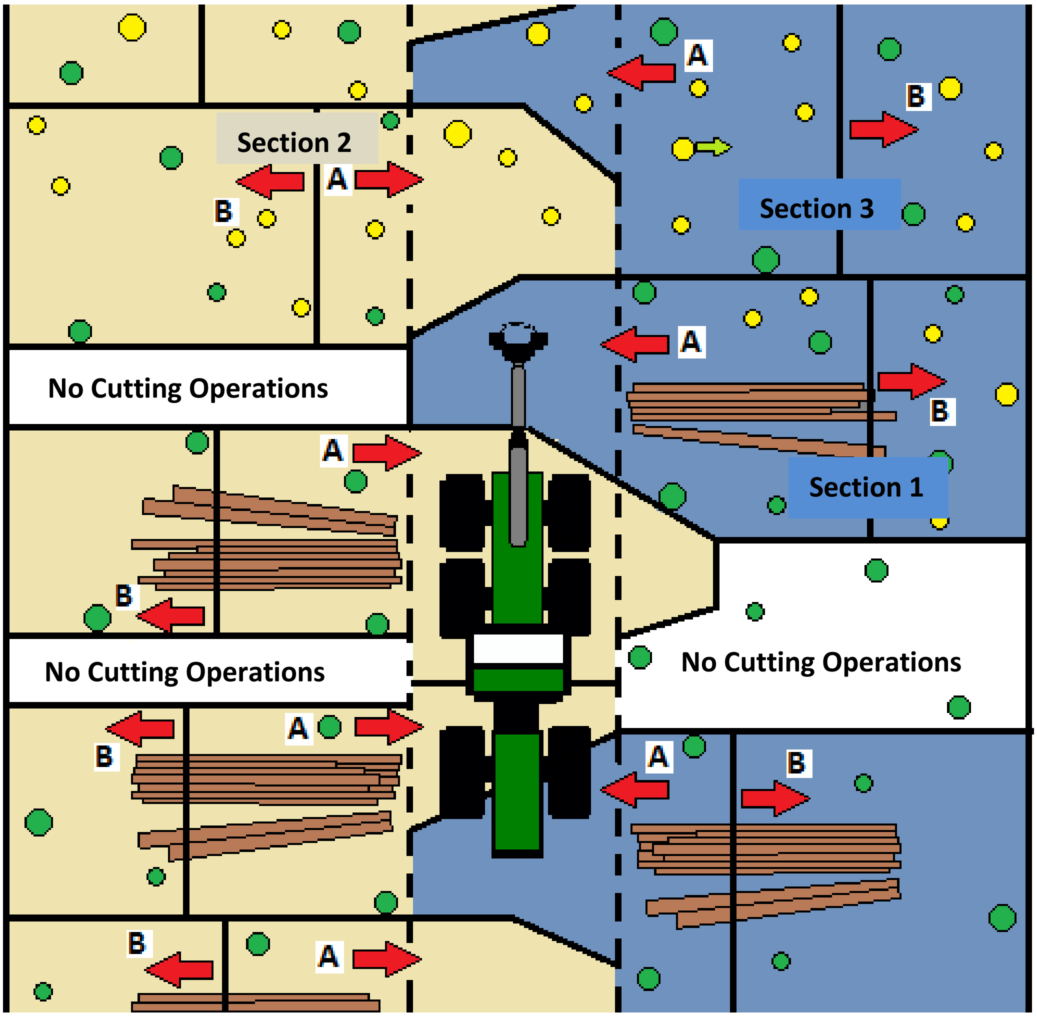

Figure 22. Working method principle for thinning in sections. (Source: Skogforsk)

Green circles = Trees continuing growth
Yellow circles = Trees to be harvested
Round wood in the piles on the left side has been harvested from the light brown areas, and respectively the round wood in the piles on the right side has been harvested from the blue areas. Arrows describe the felling directions in the sections (A and B).

Key questions discussed in this part of the handbook:

1. Are the subsidies and price competitiveness for the forest chips the same in the Baltic Sea region countries?
2. Are there any other critical issues for supporting energy wood procurement than price?

2.3. Environment-Related Aspects in Forest Bioenergy Harvesting

Environmental Note to be Taken into Account – Insects, Recycling and Seasonal Timing

Energy wood storage and logistics should be organised so that there will be no insect damage in the surrounding forests including young stands. Ash material from wood burning should be recycled as much as possible and returned to the forest to improve the growth of the remaining trees.[55] However, fertilising the forest is not allowed with ash in Estonia. The main reason for this is to avoid negative effects on waterbodies, however, using wood ash is considered a fertilizer.

According to studies by the Estonian University of Life Sciences there should be a regulation which allows the use of wood ash, but it was noted that dry wood ash has some health risks for people working with it. Therefore a recommendation was made which concluded that granulated wood ash should be allowed for use as a forest fertilizer.

The key measures in preventing harvesting damage to the remaining trees or soil surface are the seasonal timing of harvesting operations, spreading of e.g. urea to the cutting surfaces on conifer tree stumps and covering energy wood piles during storage at the roadside landings.

Nutrients in the Different Tree Parts

In spruce trees which are 6-12 centimetres in diameter at breast height, the branches, tops, and needles account for about 45-55% of the biomass of trees. The corresponding proportion for birch and pine trees is between 25-40%. Roughly speaking, one third of the trees' nitrogen is in the needles, branches, and tree tops. The green parts contain much more nutrients than the stem wood. The removal of undelimbed tree parts therefore entails considerably greater nutrient losses than for pulpwood only.[51]

***Picture** 27. One third of the trees' nitrogen is in the needles, branches and tree tops. (Photo: Lars Eliasson)*

Remove the Green Biomass or Not?

Growth reductions of 7-17% during the first 10 years in stands thinned with complete whole tree harvests indicate that the available nutrients in the soil are affected by the removal of green biomass. The harvest of whole trees increases the extraction of nutrients compared to just a stem harvest. Each percentage increase in a biomass harvest increases the nutrient output by about 2-3% for pine, 3-4% for spruce and about 1.5% for leafless deciduous trees.[51]

Picture 28. The harvest of whole trees increases the extraction of nutrients compared to just a stem harvest. (Photo: Maria Iwarsson Wide)

In practice, part of the biomass (branches and needles) will remain in the forest ground. If energy wood biomass is dried in piles for one month at the logging site, this increases the nutrient accumulation at the forest site, and contributes to less corrosion of the heating plant metal structures on the other hand.

How Can Green Biomass Removals Be Compensate for?

Compensation treatment in the form of ash recycling on peatlands and nitrogen fertilisation on mineral soil stands are possible but entail costs, which should be included in the calculation for a forest fuel harvest. Over-intensive harvesting of forest fuel can also lead to the need for nitrogen fertilisation as compensation. Recycling of stabilised ash is a very suitable method for compensating for lost nutrients and is not considered to have a negative impact on soil or plants.[51]

Are There Other Negative Consequences on the Operation Site after Small Tree Removals?

There is concern about an increased risk of damage caused, primarily, by snow and wind when dense stands of small trees have been thinned. However, in inventories of 14 stands, two to four years after first thinning, on average only 3.6% of the stems were affected by such damage. 0.9% of the trees showed felling damage, and 0.7% had some damage of unknown cause.[51]

Picture 29. There is concern about an increased risk of damage caused, primarily, by snow and wind when dense stands of small trees have been thinned. (Photo: Rimantas Gudynas)

3. INTEGRATED FOREST ENERGY HARVESTING DURING AND AFTER FIRST AND ADVANCED THINNINGS

General Challenges

The major challenges facing forest chip procurement from harvest sites are related to increasing harvest costs, promotion of machine operators' professional skills, the availability of the labour force and integration of harvesting methods.[54]

Generally, there is no harvesting for logging residues during thinning, but all forest fuels from thinnings are harvested as delimbed energy wood or as tree tops and small trees in integrated harvests along with pulp wood in the first thinning. The last option is rather rare today since the price for forest fuel has been low over the last 5-7 years.[51]

3.1 Technology-Related Aspects in Forest Bioenergy Harvesting – Fuel Quality and Sustainability

Delimbed Stem Method

The delimbed stem method is becoming increasingly popular and is leading to better forest chip quality and makes it possible to forward more compact payloads. Using this method means that the nutrients are left at the forest site and this has a positive influence on the forest growth.[52]

The delimbed stem method is suitable for all forest vegetation types and reduces nutrient removals from the site. Delimbing reduces the accumulation of the harvested volume, but the difference compared to the whole tree method decreases when the stem volume is bigger, and the relative share of branches is reduced from the total volume of the stems.[17]

In small diameter stands, additional volumes at harvest that include forest fuel are significant compared to just pulpwood extraction. The coarser the average stem in the stand, the smaller this supplementary volume will be. Table 3 shows how the additional volume can typically increase in the case of reduced average stem volume in the harvest when extracting partly delimbed energy wood together with pulpwood. If the extraction would be for whole tree parts, the additional volumes would be even larger.[51]

Picture 30. In small diameter stands, the additional volumes at harvest that include forest fuel are significant compared to just pulpwood extraction. (Photo: Maria Iwarsson Wide)

Table 3. The additional volume in the form of partial delimbed energy wood increases with reduced average stem volumes in the stand.[51]

Mean stem volume, litres	20	30	40	50	60
Additional volume, percentages	120	75	40	20	10

Whole Tree Method

Pine and broadleaved dominated forests with the maximum diameter 9 cm of the removed trees are the best suitable objects for harvesting using the whole tree method. The whole tree method is not recommended for young spruce stands on any forest vegetation types because of nutrient loss.[17]

Compared to the extraction of pulpwood only, the volume usually increases by 20-40% when including tree tops and branches. This increases the productivity of felling by 15-40% When taking out the whole tree, the harvested volume can increase by more than 50%. [51]

Picture 31. Compared to the extraction of pulpwood only, the volume increases by 20-40% and the productivity of felling by 15-40% when including tree tops and branches. (Photo: Maria Iwarsson Wide)

Advanced Thinnings – Leave Logging Residues on the Strip Roads in order to Improve Bearing Capacity

In the case of advanced later thinnings, energy wood harvesting has not typically been implemented. However, there is a high theoretical potential for energy wood in the form of logging residues per hectare. The annual harvesting area for advanced thinnings is about 200,000 ha in Finland.[50] In practice, logging residues are needed to protect strip roads in order to improve their bearing capacity. Therefore, biomass harvesting is not implemented for energy wood harvesting purposes in advanced thinnings.

Picture 32. In practice, logging residues are needed to protect strip roads in order to improve their bearing capacity. A view of a pine stand after the first thinning. (Photo: Erkki Oksanen)

Picture 33. In practice, logging residues are needed to protect strip roads in order to improve their bearing capacity. Therefore, biomass harvesting is not implemented for the energy wood harvesting purposes in the advanced thinnings. (Photo: Erkki Oksanen)

Key question discussed in this part of the handbook:

1. Do all the partners agree with the statement that the delimbed stem method can be preferred as a harvesting method for energy wood? Are there any other methods worth mentioning?

3.2 Economy-Related Aspects in Forest Bioenergy Harvesting

Comparisons between Different Tree Harvesting Methods as Whole Trees – Energy Wood, Stem Wood or Pulpwood

Much of the biomass in young stands is in the small stems, branches and tree tops. These tables show the coefficient between the different tree parts concerning pine and birch. These coefficients are valid in stands at a breast height of 8-10 cm using the multi-tree processing harvest method.[51]

Table 4. Coefficient table for the different tree parts for different harvesting methods in pine stands with an 8-10 cm diameter at breast height.

	Whole tree	Energy wood	Stem wood	Pulpwood
Whole tree	1.00	0.79	0.74	0.69
Energy wood	1.21	1.00	0.95	0.88
Stem wood	1.35	1.06	1.00	0.93
Pulpwood	1.46	1.15	1.08	1.00

Table 5. Coefficient table for the different tree parts for different harvesting methods in birch stands with an 8-10 cm diameter at breast height

	Whole tree	Energy wood	Stem wood	Pulpwood
Whole tree	1.00	0.86	0.72	0.62
Energy wood	1.17	1.00	0.84	0.73
Stem wood	1.40	1.20	1.00	0.88
Pulpwood	1.60	1.38	1.15	1.00

To read the table, for example, read the first row from left to right. If energy wood is harvested, it accumulates 86% of the total volume compared to the whole tree method and respectively the stem wood method accumulates 72% and finally the pulpwood method accumulates 62%.

The Importance of Price in Wood Assortments for Net Calculations of the Overall Profitability

The price relationship between pulp wood and energy wood is crucial to determining which assortment will generate the highest net value in the harvesting. To analyse how the price relationship between pulpwood and energy wood, expressed as energy price percent of the pulpwood price, affects the net income per hectare, is shown in the figure below. The average stem in the pulpwood harvest is 0.05 m³ sub and 1,000 stems per hectare are harvested. In the energy harvest, the corresponding average stem is about 0.04 m³ sub, and 1,500 stems are harvested per hectare. The additional volume of energy is thus about 20%. Here it can be seen that with today's costs, the break-even point is at an energy price (EUR/m³ sub) which is higher than 80% of the softwood price (EUR/m³ sub).[51]

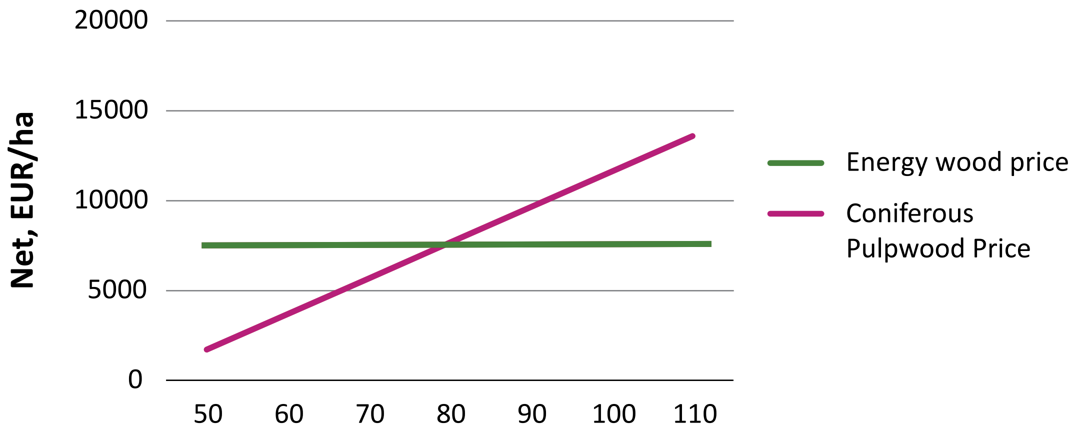

Figure 23. It is profitable to harvest only energy wood at the current price level in mixed coniferous stands if the stems have a volume of 0.05 m³ (solid volume under the bark) and the price level for the energy wood is at least 80% of the pulpwood price level.[51]

In stocks with an average stem volume over 0.05 m³ sub in the removal, pulpwood normally pays off. For the small diameter stands with a mean stem volume of 0.02-0.03 m³ sub in the removal, you get the highest net value if the removal is harvested as forest fuel. If the broadleaved share in the removal is greater than 50%, or the average stem volume is below 0.035 m³ sub, energy wood removal should be considered.[51] In Finland, the state subsidises the harvesting of small-sized wood with a subsidy of about 10 EUR/m³ of the harvested timber volume.

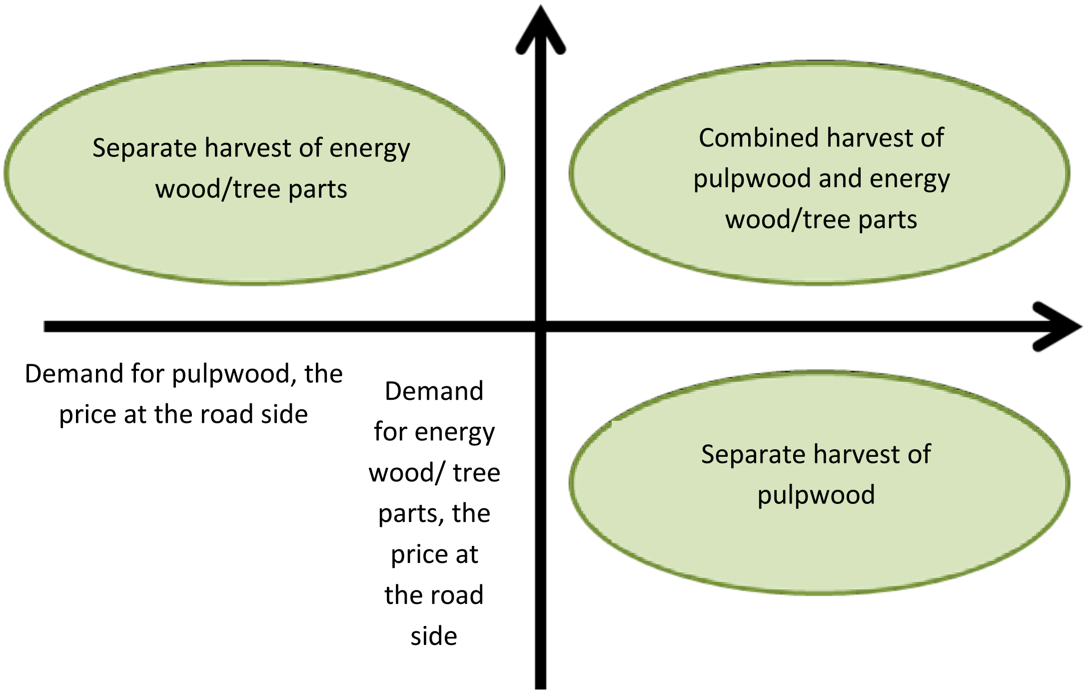

Figure 24. The demand and price for the pulpwood and energy wood/tree parts guide the decisions concerning which timber assortments are the most suitable to harvest from the forest.[51]

The combined extraction of pulpwood and energy wood may be interesting if the total removal is at least 35 m^3 sub per hectare and the extraction of the smallest assortment is at least 10 m^3 sub per hectare. However, the more assortments there are, the more expensive the forwarding is in separate forwarder loads.[51]

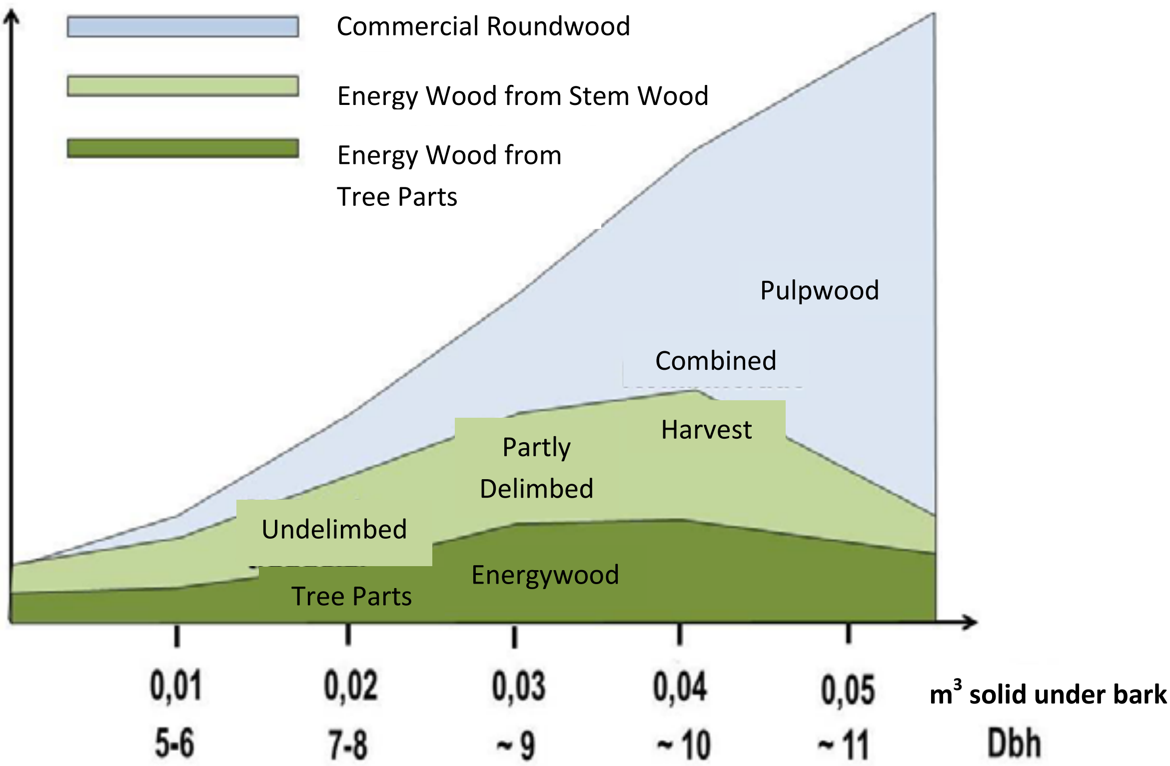

Figure 25. The figure shows how harvestable forest energy wood is compared to commercial round wood in volumes per hectare when the average stem volume increases in harvesting operations. The calculations have been made with a volume estimation instrument called "Flis av Flis".[51]

3.3 Environment-Related Aspects in Forest Bioenergy Harvesting – Some Novel Aspects

Forest Fire Risk Can Be Reduced by Collecting Logging Residues

The most essential environmental issue in wood harvesting is the leaching of nutrients on the forest site and preserving the fertility of the site. It is a fact that nutrients will decrease during harvesting operations at the site level, but on the other hand these nutrients are a potential source for the growth of the remaining trees. If the nutrients move away from the original site, it will have a negative environmental impact. However, if the nutrients from the logging residues are utilised by the remaining stand, the environmental impact will be lower. In Finland, there is not enough research data to provide adequate evidence on the issue.[51] When the logging residues are removed from a site, there are also advantages related to the reduced risks of forest fires or insect-borne diseases on the thinned forest sites.

Picture 34. When logging residues are removed from a site, there are also advantages related to the reduced risks of forest fires or insect-borne diseases on the thinned forest sites. (Photo: Lars Eliasson)

Leave Valuable Key Habitats Untouched as well as Dead Coarse Wood

When extracting energy wood, valuable environments should be preserved. Certified criteria must be followed in certified forests. Examples of valuable habitats can include: environments around springs and streams and herbaceous peatlands, etc. Other aspects that should be kept in mind include: leaving nature conservation trees, valuable and unusual tree species and dead coarse wood in place.

Picture 35. Leave nature conservation trees, valuable and unusual tree species, and dead coarse wood in place. (Photo: Pasi Poikonen)

Consider the Recreation Values of Forests Close to Densely Populated Areas

Consideration should also be given to outdoor hiking trails and paths, as well as to cultural environments and historical sites. In urban surroundings, special consideration should be given, as fully forested areas are often essential in hiking areas. Additionally, be sure to leave protection zones next to watercourses and other water conservation areas.[51]

Picture 36. Consideration should also be given to outdoor hiking trails and paths, as well as to cultural environments and historical sites. (Photo: Pasi Poikonen)

Key question discussed in this part of the handbook:

1. What is the real environmental effect of energy wood harvesting?

4. FOREST ENERGY HARVESTING DURING AND AFTER FINAL FELLINGS

4.1 Technology-Related Aspects in Forest Bioenergy Harvesting

Spruce Stumps should be Removed because of Surface Roots

Stumps are harvested mainly from spruce final felling sites. Spruce has lateral surface roots, large stump diameters and high wood accumulation per a hectare. Stump removal might prevent the spread of root disease in the next generation young stand. Stump removal is harder in pine stands because of deep roots and rocks and other impurities that will be brought along with the harvest to energy plant storages from the harvesting sites.[17]

Picture 37. A stump on a forest site in Lithuania. (Photo: Valda Gudynaitė-Franckevičienė)

Stump Lifting should be Organised during Unfrozen Soil Conditions between Harvesting and Forest Regeneration Work

The stumps are lifted, split and collected in the piles with excavators equipped with a special device for these specific operations. Stump removal is implemented during the unfrozen season from May to November-December. The split stumps are collected into piles to improve forwarding. The stump removal is typically implemented in a time frame which is regulated by the harvesting of timber and logging residues as well as forest regeneration work.[17]

Picture 38. The stumps are lifted, split and collected into piles with excavators equipped with a special device for the specific operations. Stump extraction after the regenerative felling of spruce stands was one of the first stump extraction trials in Latvia. (Photo: Valentīns Lazdāns)

Excavators as Base Machines

Excavator-based machines have proven to be strong enough, cost competitive solutions for stump lifting and removal.[52]

Picture 39. A heavy excavator is stable and strong enough for stump lifting. (Photo: Juha Laitila)

Storing Arrangements

During the summer season the split stumps are left on site for a couple weeks for drying and cleaning before forwarding to the roadside storage.[17]

Picture 40. A special forwarder structure has been developed for stump transportation to roadside storage sites. (Photo: Juha Laitila)

Impurities and Particle Size are Challenges

The largest challenge linked to increasing the volume of stump chips, especially for small heating plants, is to remove impurities in all phases of production chain (lifting, forwarding, storage, transporting and crushing).[54] The particle size distribution of crushed stumps can also be unsuitable for conveyers and boilers of small heating plants.

Picture 41. During summer season, split stumps are left on site for a couple weeks for drying and cleaning before forwarding to the roadside storage. (Photo: Juha Laitila)

The challenges in the procurement of stumps from final felling sites are related to the quality of ground stump chips, improvements in its usability and particle size distribution, reducing the mineral soil content, efficiency of long distance transportation. It is also important to increase the payload sizes and reduce the time consumption of loading and unloading.[53]

Picture 42. Stumps are crushed at an appropriate location before deliveries to energy plants. (Photo: Juha Laitila)

Logging Residues

Energy Wood Harvesting Concentrates on the Final Felling Spruce Stands

The harvesting of logging residues is mainly implemented on final felling spruce sites where the yield is bigger than in thinnings and the harvesting is technically easier. At the final felling sites there are other energy wood parts such as decayed stem wood and stem wood parts which are technically unsuitable for other industrial use.[17]

Picture 43. At the final felling sites there are other energy wood parts such as decayed stem wood and stem wood parts which are technically unsuitable for other industrial use. (Photo: Pasi Poikonen)

Leave One Third of the Biomass on the Site

In field studies, it has been found that 30% of the forest tree top biomass should be left on the site regardless of the harvesting method or technology.[52] In Estonia, the approach is that some growing and dead trees must be left on clear cutting sites with a minimum volume of 5 m^3/ha. On a few forest site types with very thin soil, it is not allowed to take any branches out of the forest, but it is recommended to leave them on the forest ground to improve the soil quality.

Energy Wood Material should be Gathered Directly into Piles during Harvesting Operations

During final felling operations the harvester should gather the branches and tree tops into piles alongside the logging trail. If forest energy material is not harvested, the material should be left on the logging trail in order to protect soil surface and to improve its bearing capacity. When the logging residues are placed directly into piles during the logging operations, it improves the volume yield, as well as the efficiency of the harvesting work and prevents stones and mineral soil mixing with the logging residues.[17] When planning the work, it must be noted that the energy wood piles should be collected before soil scarification and artificial forest planting takes place.

Picture 44. When logging residues are placed directly into piles during the logging operations, it improves the volume yield, as well as the efficiency of the harvesting work and prevents stones and mineral soil mixing with the logging residues. (Photo: Erkki Oksanen)

Energy Wood should be Used within Two Years after Harvesting in order to Keep the Energy Content Optimal

Logging residues should be used for energy generation during the next heating season (autumn, winter, spring) if the harvesting operations are completed by the end of July. Stumps and small trees can be dried in the storage for a longer time, but not more than two years because of the decaying process in storage. Drying on site improves the quality of logging residues, as well as the energy content and storability.[17]

Picture 45. Stumps and small trees can be dried in the storage for a longer time, but not more than two years because of the decaying process in storage. (Photo: Maria Iwarsson Wide)

Needles Should be Left at the Forest Site

On-site drying of the logging residues is recommended whenever possible. At the beginning of the summer season the minimum time for drying is two weeks and at the end of the summer season four weeks is recommended before the forest transportation to roadside storage sites. The forest energy wood material should be handled so that as large a share of the foliage and needles as possible remains on the site to maintain the nutrient balance in the soil. This is also better for the burning technology in the CHP plants, because in this way the needle content will not cause corrosion problems in the super-heating technology.[17]

Energy Wood Harvesting from the Final Fellings Improves the Starting Conditions of the Next Tree Generation

Advantages of forest energy wood harvesting from the final felling sites include improving the quality of soil scarification, better conditions for forest planting, reduced risk of root disease for the next tree generation and improved walking conditions in the site area for recreation purposes. Energy wood harvesting also improves possibilities for natural regeneration in the forest.[17]

Picture 46. Energy wood harvesting improves the possibilities for natural regeneration in the forest. (Photo: Lars Eliasson)

In the Baltic Countries, as a result of the land use history a lot of grey alder stands are growing on old agricultural fields. In the young stands the trees are quite small and there is lot of under vegetation that would have to be cleared before mechanical harvesting operations. Clear cutting is usually done on 25-35-year-old stands but can be done on even younger stands. The harvested material is mainly used for energy generation purposes and the harvested site can then be regenerated for more valuable tree species (spruce).

Picture 47. In the Baltic Countries, as result of the land use history a lot of naturally regenerated broadleaved stands are growing on old agricultural fields. Extraction of biofuel in abandoned overgrown farmlands with a felling head in central Latvia. (Photo: Andis Lazdiņš)

Picture 48. Harvesting logging residues improves many future measures on logging sites. (Photo: Juha Laitila)

Key question discussed in this part of the handbook:

1. Does the research in the other partner countries support the theory of leaving 30% of the green biomass on a forest site after harvesting operations?

4.2. Economy-Related Aspects in Forest Bioenergy Harvesting

Price Competitiveness and Price Definition Principles

Economic sustainability is a challenge for forest energy deliveries, which is an issue both in harvesting and in transportation to the power plants. The competitiveness of forest chips produced from logging residues is already good and stump chips are competitive in areas with the high demand for forest chips.[52]

Picture 49. Economic sustainability is a challenge for forest energy deliveries, which is an issue both in harvesting and in transportation to the power plants. (Photo: Maria Iwarsson Wide)

The price for logging residues and stumps is paid on an operation site area basis, or it is derived/calculated as a relative coefficient of accrued commercial timber from the site. Decayed (rotten) stem wood is measured and paid for on the basis of harvester measurements. Delimbed stems and whole trees are measured and paid for mainly based on crane scale measurement.[17]

The price paid for commercial wood from thinnings is interconnected to the harvested volumes and subsidies for energy wood harvesting. The larger the total volumes per hectare, the better the prices are.[17]

Special Characteristics related to the Economic Issues in the Baltic Countries with the Smaller Geographical Dimensions

In the Baltic States the geographical location (distance) is not a very large problem. There are many small energy plants using some of the timber. Most of the forest is still within 100 km of some larger plants. The biggest problems are access to the forest and options for transporting the energy wood out of the forest. Sometimes all the available energy wood material has to be used for the bottom of forwarding roads so that there is almost nothing left for collection.

Picture 50. In the Baltic States the largest problems are access to the forest and options to transport the energy wood out of the forest. A forest view of a site situation in Southern Sweden. (Photo: Lars Eliasson)

The storage area may not always be large enough or suitable for storing energy wood for longer periods. Typically, fields and houses are next to the roads and the forests are located behind the fields. The costs for maintaining the storage areas can be a real cost for forestry with after operation cleaning needs in order to ensure the field soil structure is suitable for agricultural purposes. During warm and wet winters, the poor condition of gravel roads has become a critical issue and trucks are not always able to take timber to power plants.

Key question discussed in this part of the handbook:

1. Is the geographical location of a forest harvesting site compared to the power plant location the only critical issue for rational energy wood harvesting?

4.3 Environment-Related Aspects in Forest Bioenergy Harvesting

Leave Coarse Dead Stem Wood on the Forest Site

Energy wood harvesting reduces the biomass potential on forest sites, which can change the forest flora and fauna species, especially if coarse dead wood is harvested. Silvicultural recommendations emphasise leaving it on the harvesting site.[16]

Leave Specific Terrain Objects Untouched during Stump Lifting Operations

During stump lifting and removal it is recommended that 25 - 50 stumps are left per hectare. They should be also left to harvest in steep slopes, rocky terrain, water protection zones, close to ditches, wet soils, harvest side edges and close to living trees. Decayed fresh stumps should not be left on the terrain despite water protection zones and ditches.[17]

Especially Note the Water Protection Zones

Stump lifting and removal is harmful to water basins – rivers and lakes. The process increases erosion of the organic particles, which is already increasing due to the effects of climate change. The whole tree method with stump lifting especially increases organic nutrient leaching including metals.[16]

Picture 51. Stump lifting is harmful to water basins – rivers and lakes. (Photo: Henrik von Hofsten)

Final Felling, Soil Preparation and Stump Lifting have the Same Environmental Impacts

In the different parts of Finland the environmental impact of stump removals have been studied in several areas after operations, but it has been found that there is no remarkable difference compared to the environmental impacts of final felling and soil preparation operations (scarification). It has been also reported that the total removal of stumps and logging residues from forest sites does not seem to affect the soil acid content or ground water nutrients any differently compared to traditional final felling and soil preparation operations. Stump removal contributes to preventing the spread of root disease, although one third of the stumps are left on-site according to the Finnish rules. Stump storage sites do not promote the spreading of the insects. The most essential aspect in this sense is to carry out the soil preparation as well as possible.[52]

Nutrient Losses have an Influence on the Forest Land Surface Vegetation

The removal of logging residues influences the growing species on the ground. Species which are suited for growth in poor soil will grow better and more nutrient-demanding species will disappear (fireweed, raspberry). The forest energy biomass usually takes 4-6 weeks to dry at the final felling site. The majority of the needles will fall onto felling site ground leaving the nutrients on the site. Additionally, the same effect improves the possibilities to store forest chips as well as their quality from the energy plant point of view. Decayed trees should be left on the forest site to promote biodiversity. Strip roads should be planned in order to avoid driving over decayed trees.[52]

Logging residues removals have not a big influence on the success of the next tree generation growth

In the Finnish studies, there has not been influence on the growing success of the planted spruce seedlings, whether the logging residues (slash) has been collected or not from the forest ground. In Finland, it is recommended that more than one third of the logging residues were retained on site. More influence on the success of the seedlings growth was seen in the technical quality of forest ground scarification than whether logging residues are collected or not.[54] In Swedish studies, it has been reported that the logging residues removals will have an effect on the forest growth during the first 15 years of the next tree generation.[56]

Picture 52. A regenerated logging site with spruce seedlings one year after the final felling and removal of logging residues. (Photo: Pasi Poikonen)

Large Stem Wood is better to Leave on the Logging Site from the Ecological Point of View

Large stem wood should be left on the logging site from the ecological point of view if not harvested as energy wood (this refers to decayed wood, dead wood, or wood which has dried or been stored for too long). This kind of wood does not fulfil the requirements for commercial round wood.

Before Energy Wood Extraction Check Environmental Conditions, Water Protection Needs, Insect Risks and Nutrient Balance in the Soil

Forest energy wood should only be harvested from sites where environmental factors, water protection, insect risks and the nutrient balance in the soil are taken account. Harvesting tracks can cause problems during the time when the soil is not frozen. The harvested biomass includes nutrients, which should be taken account. This has an effect on the growth of the next tree generation or on the remaining trees in the thinning sites. Slightly dry forest mineral lands and more fertile soils and respective peatlands are suitable for harvesting logging residues. Coppice forest growth is partly a problem on the stump lifting sites. Stump lifting does not replace the soil preparation work related to the forest regeneration.[17]

Picture 53. Harvesting tracks can cause a problem during the time when the soil is not frozen. (Photo: Rimantas Gudynas)

Differences in the Approach to Collecting Logging Residues of Hardwoods or Not

Harvesting logging residues after final felling is not thought to be a significant risk factor for reduced biodiversity compared to the traditional harvesting of stem wood. However, logging residues from hardwoods (particularly aspen, oak, and other broadleaved species) should be left on top of sunlit stacks and can provide a breeding substrate for many beetle species that require conservation measures. This wood should therefore be excluded from collection and left on the cutover during the time when the eggs and larvae can be found in the material. Even when logging residues from softwoods are harvested, the Swedish Forest Agency recommends that the harvest should be limited to 80% of the gross quantity of logging residues. In areas with particular pools of threatened species (e.g. pastoral landscapes with old oaks), it may be necessary to develop locally adapted methods and rules.[51]

Ash Can be Recycled on the Forest Site in order to Reduce Acid Neutralisation

A pronounced environmental effect of logging residue harvesting is the risk of a reduced acid neutralising capacity (ANC), which is a measure of the buffering capacity of water in the soil. A reduction of ANC can be counteracted by returning ash to the soil in a form that dissolves slowly, e.g. hardened and crushed wood ash. Dosages equivalent to 1.5-3 tons of dry ash per hectare are common.[51]

A Stump Harvest Can Have a Negative Impact on Ground Stability and Soil Chemistry

The environmental consequences of stump harvesting have been investigated in a major research programme, at the Swedish Agricultural University, SLU. Stump harvesting only moderately increases the removal of mineral nutrients and base cations. Current knowledge suggests that stumps are a substrate of limited significance for wood-living species that require conservation measures. On the present scale of stump harvest (< 1% of the annual regeneration cutting area), the effects at the landscape level should be negligible. However, an extensive stump harvest would reduce the amount of coarse dead wood in the forest landscape. Compensation for stump harvesting by leaving valuable high stumps may increase the supply of a suitable substrate for species needing conservation measures. Stump harvesting can have a negative impact on ground stability and soil chemistry. Extra caution should be taken on moist cutover sections that are rich in organic material and adjacent to water environments, where it has been shown that rutting and soil disturbance can lead to methylation of mercury.[51]

5. CONCLUSIONS ON THE BEST PRACTICES IN COUNTRY-SPECIFIC CONDITIONS

5.1 Best Practices by Country

Estonia

Many towns have local energy plants (CHPs) working mainly on forest chips. The consumption of wood and peat reduces dependence on imported fuels and provides jobs for local fuel producers. Diversification in electricity production reduces transmission losses and national energy security risks.

Picture 54. The Finnish listed company Fortum operates the Pärnu CHP plant at the Niidu industrial site. The used fuel is based mainly on wood chip biomass. (Photo: Pasi Poikonen)

Finland

The best results are achieved when good forest management is combined with energy wood production in young forest stand treatment and harvesting operations, e.g. integrated harvesting of industrial roundwood and energy fractions. Energy wood production creates additional income flows for the main process. Typically, processing logging residues for energy generation purposes from the final felling sites has proved a good experience, while at the same time it is easier to implement forest regeneration works at the site.

Picture 55. The best results have been achieved when good forest management is combined with energy wood production in young forest stand treatment. All broadleaved tree species have been removed as energy wood from the spruce stand at the age of 20 years. (Photo: Pasi Poikonen)

Germany

Forestry, wood products and bioenergy from woody biomass are a part of the national Climate Action Plan[10]. The analysis of greenhouse gas sequestration in German forests shows that forests remain net carbon sequestration objects, although the forest fuel production has been increasing. Since forest fuels substitute fossil fuels, forest bioenergy is considered to help the mitigation of climate change.

Picture 56. In Germany, there are nearly half a million heating boilers fuelled by pellets. (Photo: Valda Gudynaitė-Franckevičienė)

Until 2016, the number of bioenergy plants from 1 MW an up (CHP plants and heating plants fuelled by woody biomass) had increased to more than 500 plants and an installed electric capacity of about 1,700 MW_{el}.[23] Additionally, there are more than 35,000 small plants (below 1 MW, without private households) and nearly half a million heating boilers fuelled by pellets[57]. In the wood fuel supply of small bioenergy plants, logging residues and roundwood from forests together have a share of about 45%. Although there are still considerable regional differences regarding the quality and knowledge of the production and use of forest fuel, supply chains for bioenergy plants and private household are established everywhere in Germany and are well functioning. Capacity for chipping, transportation, and the storage of chips is available. Pellets are mainly produced and used in Germany for households, single buildings, or small district heating units, but not for electricity production in large plants.

Picture 57. In Germany the capacity for chipping, transportation and storing of chips is available. (Photo: Mareike Schultze)

Big bioenergy plants play an important role in producing energy wood from used wood and from inferior quality energy wood from forestry and landscape preservation measures. The capacity for the combustion of contaminated used wood has been developed to such an extent that Germany is able to import large quantities for energy production from the other European countries.

Standards for sustainable forest management are widely accepted. Many forest owners submit themselves to even stricter regulations than those defined in the applicable laws (Federal Forests Act and forest laws of the federal countries). Large areas of German forest are certified either according to PEFC standards or to FSC standards. Treetops are only used on soils with a good nutrient supply and a certain amount of dead wood remains in the forest for ecological reasons. Stumps are not removed from forests at all.

Latvia

The technical issues concerning the preparation and processing of small-dimensioned wood have been successfully addressed in the Nordic countries, particularly in Sweden and Finland, and the technologies developed in those countries can also be used in Latvia. However, quality requirements for small-dimension wood assortments significantly differ, and therefore limit the advantages of multi-tree handling and the production of pulpwood and energy wood of different lengths. Local forest research is examining the development of forest machine tracks in order to reduce soil damage and to increase the accessibility to the forest resources on soils with a low load-bearing capacity.

Picture 58. *Compact sized forest machines have demand in the Baltic countries. In this picture, Swedish forest machinery is working on a forest site in Latvia. (Photo: Guntis Saule)*

Latvia has been also a good market for compact sized forest machines with a weight up to 6 tons and a width of 2 metres, which are used in the first thinning and other forest operations, i.e. sanitary thinnings, regenerative and deforestation fellings in grey alder stands, particularly on abandoned farmlands. In commercial thinning, the most appropriate technology are machines for the production of biofuel of partly delimbed stems, which are comminuted at the roadside and delivered to energy plants as chips. The harvester with an accumulating felling head is the best suited technology for the production of biofuel in thinnings. Compact sized harvesters are recommended if the diameter of the harvested trees is below 20 cm. Stump extraction lacks a local market for profitable implementation, but it has positive, scientifically-proven effects on the reduction of root rot. Certification of biomass is a significant tool for promoting production and for the export of biofuel, particularly pellets, by opening new markets and expanding the existing ones.

Lithuania

In the countryside of Lithuania, heat produced by plants running on wood fuel are often the only available options due to the lack of other heat energy sources.

Picture 59. The best results are received when good forest management is combined with energy wood production in the timely implemented harvesting operations. This pine forest is in the good growth after intermediate thinning in Lithuania. (Photo: Valda Gudynaitė-Franckevičienė)

Sweden

Of the timber delivered to the forest industry, about half will be used for energy and half will be utilised for other products, and timber harvesting is the driving force in all production of primary forest fuels. The main part used for this purpose are logging residues, but when forest companies need to come up with new volumes fast, they tend to harvest small trees along roadsides.

When the forest utilisation is intensified through the increased harvest of biomass, future production may be affected negatively because the supply of accessible plant nutrients is reduced. In principle, this also reduces the ability of forest soil to withstand acidification because the base cations are removed. If carried out incorrectly, the harvesting of forest biofuel can entail greater ground damage, resulting in a negative impact on water quality. An extensive harvest of logging residues, small-dimension trees and, above all, stumps can also reduce the supply of substrate for certain species requiring conservation, particularly wood-living beetles.[51]

5.2 Challenges faced by the Stakeholders

Estonia

The use of wood in the energy sector could be expanded further. The market for energy wood can have an impact on the raw material base of several other sectors. The preferential development of renewable energy has not resulted in drastic drops in competitiveness in other industries competing for the same resources. The market prices of wood fluctuate depending on the situation.

In Estonia, a few years ago there were plans to build a biorefinery factory, which led to local protests and to the breakdown of the factory plans. Currently, there is noticeable gap between the forest industry and the greens, which was named the "forest war" by the media. In Estonia, there are a lot of logging residues left in the forests and their utilisation is quite accepted in society.

The wood market is also affected by developments in the neighbouring countries. The countries in the northern parts of the European Union do not have obvious problems meeting the domestic renewable energy targets for 2020, but Central European countries still have to make some serious efforts to meet them. This will also mean an increased demand for wood. Estonia's wood fuels will have a considerable export potential even from the perspective of 2030 and the realisation of that potential will depend on the regional and global market outlook.

Finland

Bioenergy decisions are seen as a concrete tool to influence national and regional development. Forests are a renewable and safe alternative to solve energy generation challenges. The use of locally renewable energy resources reduces the dependence on energy imports. The EU is tightening its energy objectives, and biomass is replacing fossil fuels in the electricity, heat, and transportation sectors. How the use of coal and other fossil fuels can be reduced or substituted by biomass is unclear because of the high costs of the conversion process. In densely populated areas, domestic fireplaces and heaters are considered the worst sources of soot dust. The utilisation of logging residues in energy generation is widely accepted, whereas the stumps should be left at the logging sites. The last alternative for energy generation would be industrial round wood use as a pure energy source instead of processing it.

Most diseases with a connection to air pollutants are dependent on the micro particles in the air. The largest sources of micro particles are domestic firewood burning and road traffic emissions. Micro particles in the air are a major reason for many deaths and diseases.[16]

In Finland, there has been an analysis of bioenergy production, climate change and the forests concluding that the Finnish forests remain net carbon sequestration objects, although the forest-based energy production will increase.[22] The leading idea is to substitute fossil fuels with renewable ones.

Although forest owners are willing to sell energy wood, there may be constraints on how sustainable in the long run the operations are, and what the real consequences are for the forest environment. The public attitude remains critical, whether we are discussing harvesting biomass from thinnings, stumps or logging residues from final fellings. In addition, the security of the fuel supply needs to be enhanced.[54]

Germany

Since forest fuels substitute fossil fuels, forest bioenergy is considered to help the mitigation of climate change. In future, extreme weather events and subsequent calamities might damage the forests to such an extent that they will start to emit more carbon than they can tie up. With the growing timber and wood fuel extraction from forests in the last years, sustainable forest management with respect to the nutrient supply, future forest development (growth and quality) and nature protection has become a matter of public interest.

The increasing wood extraction and soil degradation in forests have motivated the federal states to monitor the conditions of forest soils and formulate recommendation regarding the use of treetops and logging residues. The ongoing monitoring and supply of detailed and easily accessible information for forest owners will remain an important challenge in the forthcoming years. Parts of the German population support the abandonment of forest management in favour of nature protection. Numerous test and demonstration sites for natural forest development have been established in order to improve the integration of nature protection in forest management. According to the German FSC-standard, 10% of the forest area with trees must remain untouched as a nature forest development area or an area specifically for nature protection. This together with the ban of using wood with a diameter smaller than 7 cm has considerable effects on the availability of energy wood in some regions.

The use of small roundwood and high-quality by-products from sawmills for energy production in large bioenergy plants reduces the availability of these raw materials for industrial use. Therefore, it is not supported by the government. Instead, the Climate Action Plan and the Charta for Wood 2.0 clearly state a preference for the use of wood as raw material for industrial use. Inferior wood qualities should preferably be used as raw materials in new bioeconomy applications. However, energy production in small plants and households is considered to play an important role for the decarbonisation of the heat supply and value creation especially in rural areas and therefore it is supported.

The use of logging residues in small combustion plants is regulated by a number of laws and influenced by subsidies (for instance, subsidies according to the Renewable Energy Law, and regulation by the Federal Emission Control Act). In order to prevent air pollution from bioenergy plants, the Emission Control Act has been recently revised and standards have been tightened. This especially affects small plants, who cannot easily invest in costly filter systems. The regulations for funding bioenergy plants according to the revised Renewable Energy Act are also seen as a barrier to investments in small bioenergy plants.

Latvia

There is a need for more efficient harvesting solutions for pre-commercial thinning in Latvia, and the quality criteria for biofuel and pulpwood assortments should be discussed with other stakeholders to equalise the conditions between the Nordic countries. Local forest research has prioritised the following issues for further investigation in the near future: a) extraction of biofuel during pre-commercial thinning operations, and b) extraction of harvesting residues and firewood assortments in commercial thinning. These areas of focus require more information on the available resources, forestland water regimes, material storage procedures, drying times, quality projections, material losses during storage and transportation. It is also important to reduce the cost of the transportation of biofuel by increasing the load limits.

Lithuania

Energy independence is being discussed in Lithuania, however imports of Belarussian chips is rapidly increasing. Imports from Belarus currently account for about 40% of the Lithuanian market share (LITBIOMA). Although Lithuania has great potential for biofuels, cheaper Belarussian biofuels are traded on the Baltpool Energy Exchange, which increases Lithuania’s energy dependency on Belarus. Belarussian companies cannot sell biofuels directly on the exchange, but Lithuanian and Latvian companies, which buy Belarussian biofuels and resell them on the Baltpool Energy Exchange, can do so.

Large quantities of biofuels come from Belarus due to an *Ips acuminatus* outbreak, which affected a large part of European forests. Belarussians are selling biofuels for the transport costs or just a little higher. Belarussian export volumes regulate the Lithuanian domestic prices. Currently Lithuania pays Belarus about 20 million euros per year for timber. Lithuania has sufficient biofuel resources and imports are not necessary, so that 20 million euros could remain in the domestic market.

Picture 60. Large quantities of biofuels come from Belarus to Lithuania due to an Ips acuminatus outbreak. The insect lives under the pine bark in the logging residues, treetops, windfalls and weakened trees. (Photo: Luke MetInfo)

According to EU market pressure, from 2020 all wood used in power plants will have to be certified, but Belarus already started to certify its forests in 2010. Over ten years, large parts of the forest were certified. FSC certification is well-established in Belarus mainly due to the export market demand.

Small biofuel producers in Lithuania have laid off workers and have gone bankrupt because of the situation in the country. Currently 42% of the biofuel market is owned by four companies. The biofuel market has become oligopolistic. Customs or other import restrictions should be the natural response to low-priced exports of foreign-sponsored businesses. However, Lithuania does not have any customs duties or other restrictions on Belarussian wood based on the Bilateral Trade Agreement between the two countries. Currently, there is no legal basis for limiting Belarussian biofuel exchange trading and the Ministry of Energy has no plans to introduce any measures in the near future.

Sweden

Sweden has set a goal to be fossil-free until 2045. Bioenergy is the largest contributor of renewable energy in Sweden, but the potential for a growing market and use is still very big. There has been and still are discussions on the balance between bioenergy production, biodiversity and how to use the forest best to meet the climate challenge. The Swedish Government, forest companies and private forest owners consider bioenergy from the forest as an important part of the future Swedish bioeconomy.

The guarantees made by forest companies to protect the forest ground when harvesting has affected the possible volumes of logging residues. This has resulted in a growing interest in harvesting energy along roadsides in some parts of the country. The northern parts especially struggle with financial challenges to achieve profitability since the price levels have been low over the last 5-7 years. The assortment is extra challenging when it comes to logistics and storage. In southern Sweden there are large volumes of bark beetle damaged wood which has a strong influence on the market.

5.3 Further Steps in the Near Future

Finland

In Finland, the harvestable forest chip volume from logging residues, small trees and stumps has been estimated to be 12-21 million m^3 (solid) annually depending e.g. on the annual cuttings and the wood consumption in the forest industry, the harvesting method of small diameter energy wood and how much pulpwood dimensioned timber is used for energy purposes. The importance of young stand biomass has become one of the most important forest energy assortments and its use can be increased further.[52]

Investments in forest bioenergy plants are dependent on a range of issues, including: the raw material need for burning, the forest industry use of round wood, the availability of logging residues and forest industry by-products at the regional level, their procurement costs, demand, prices, sustainability criteria, forest chip subsidies and the locations of the industry. Forest bioenergy production will also be based on logging residues, stem wood and forest industry by-products in the future.[16]

In Finland, the key possibilities are related to Helsinki Region energy generation solutions and how the coal substitutes can be found for energy generation plants in Southern Finland. In Central and Northern Finland, the key question is to solve, is how peat can be substituted with the other energy sources.

Germany

The future availability of energy wood from the German forests depends on the forest management procedures and the wood markets for inferior wood assortments (industrial roundwood, forest residues). The modeling of wood production based on different forest management scenarios and wood market scenarios[18] leads to the conclusion, that no large increase in forest energy production will be possible in future. Taking into account the ongoing conversion of coniferous forest stands to mixed stands, the overall wood production will decrease in future, but the production of forest fuel may still increase[57] unless much more dead wood is left in the forest for nature protection. A new element of uncertainty in the estimation of forest fuel availability are the effects of climate change on the forest sector. On the one hand, storms and biotic calamities will lead to increased quantities of inferior roundwood assortments on the market. On the other hand, new climatic conditions will probably lead to lower productivity of forests. The preservation of forests and their adaptation to new climatic conditions are therefore the most important issue in forest management. Pre-commercial thinning (and harvesting of small trees) is considered an important measure to stabilise forest stands against storms.

The most promising option to boost the forest energy market are small bioenergy plants and the use of wood energy in private households. Local supply chains with high amounts of value creation by upgrading wood fuel from forestry and landscape preservation measures to high-end, quality wood fuel products could be one of the best means to mobilise the unused energy wood potential in private forests. In order to complement the wood fuel potential from forestry, wood fuel production on agricultural land will be further developed (on short rotation plantations or along with new forms of land use such as agro-forestry).

Latvia

Different forest biofuel harvesting technologies are being evaluated in Latvia in thinnings and regenerative felling. The most promising technology for extraction of small-sized trees is the production of pulpwood and partly delimbed stems using small and medium-sized harvesters. The concept "partly delimbed stems" is to be understood as a stem that is delimbed, but the top is left. Because the biofuel resources available in final felling are highly varied, their method of extraction also differs. Operators need to avoid processing stems which are too small to produce at least one pulpwood log. Multi-tree handling still needs to be adopted by buyers and by harvesting companies to improve performance.

In the near future, Latvia will focus on measures aiming at reducing of biofuel harvesting costs and improving the related logistics. The availability of soil moisture maps helps efficient planning of biofuel procurement. Education and training in making improvements to the biofuel supply chain are needed for forest owners and machine operators. The optimisation of low grade biomass use in energy generation will support the overall development of the sector. Greenhouse gas (GHG) emissions need to be highlighted in decision making to increase the forest biomass in energy use.

Lithuania

Two large co-generative power plants are currently under construction. In 2019 the Kaunas co-generative power plant will start to operate. The electric capacity is about 24 MW and the heat production capacity about 70 MW. This capacity will allow the rational use of about 200 thousand tonnes of municipal waste generated in the region after sorting and will produce about 500 GWh of heat and about 170 GWh of electricity. The power plant will be able to produce about 40% of the heat demand for Kaunas city. A co-generative power plant in Vilnius will open in 2020. The total electrical capacity of the power plant will be about 92 MW and the thermal power about 229 MW.

Municipal and industrial waste will be used for power generation and this could reduce the need for biofuels (especially in the summertime). The power plant in Kaunas will use only municipal and industrial waste. The power plant in Vilnius will use municipal and industrial waste in addition to biofuel as well. The biofuel will be used in winter or when there is a shortage of waste. Waste shortages are possible because Lithuania has three cogeneration plants that use waste. According to the EU, this number is too large for Lithuania, and that's why Kaunas power plant was built with the help of private investors. The import of waste from other countries is prohibited.

Heat suppliers and potential independent heat producers can apply for EU funding according to the "Promotion of low power biofuel cogeneration" measure. This measure started from the 30th of December in 2019. The EU has supported activities such as: the installation of new high-efficiency biofuel cogeneration units, upgrading existing cogeneration units, replacement of existing cogeneration units with cogeneration units in district heating systems of up to 5 MW of electrical capacity and a total rated thermal input from 1 MW to 20 MW. The measure has attracted considerable interest in previous years. Many low-power boilers were reconstructed using the available support.

Picture 61. Well-managed forests are also attractive for wild animals. Lynx is walking in the harvested pine forest for natural regeneration purposes in Lithuania. (Photo: Vita Arlickienė)

Sweden

The district heating potential in Sweden is already almost fully developed, but we see a potential for smaller heating systems, for example in schools and multifamily housing. The by-products of the woodworking industry are already fully utilised in Sweden. What will probably happen is that sawdust will be used for other purposes, for example pyrolysis oil, and that will result in more need of primary forest energy for energy production for industry. This is already a fact, and the need for extra energy will grow at the mills that take out and use or sell the lignin as raw material for other products.

Already today, biofuels are the largest energy source in the industry, but their use is highly concentrated in the forest industry. When changing other industries, large quantities of biofuels will also be needed for them. The restructuring of the industry, with the phasing out of fossil fuels, leads to sharply increased demand for biofuels. Roadmaps for the Swedish industry show the need for an extra 25-28 TWh annually. If we also include the need for renewables in the fazing out of fossils in all transport and electricity the need has been calculated to an extra 100-120 TWh yearly. The potential increase has been assessed as requiring an additional 74 TWh from forestry and 54 TWh from agriculture by 2050.

Over 1.4 million hectares of forest in Sweden has not been pre-commercially thinned, so there is a great need to find less costly technologies and methods for harvesting small trees in early thinnings, and this is a driver for further development work.[51]

However, if current knowledge is applied, it should possible to greatly increase the harvest of forest biofuel without unacceptable consequences for the environment and biodiversity. Compensation and cautionary measures can be applied and developed further to ensure that greater utilisation of forest biofuel can take place without serious environmental effects.[51]

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Baltic ForBio

Accelerating the Production of
Forest Bioenergy in the Baltic Sea Region

Cost-Effective and Sustainable Harvest Methods

Appendix

Edited by Pasi Poikonen

Table of Contents

Appendix 1

ESTONIA COUNTRY REPORT DETAILED INFORMATION ON FOREST BIOENERGY

1. BACKGROUND

1.1 State-of-the-Art of the Bioenergy Sector in Estonia

Although Estonian electricity production is mostly based on oil shale, which accounts for nearly 90% of its electricity production, electricity generation from renewable sources has increased strongly in recent years and this has somewhat reduced the share of oil shale.[1]

The wood used in Estonian energy is procured predominantly from Estonian forests, but in connection with the development of renewable energy, wood fuels (pellets, wood chips, etc.) have been traded on the world market, the price of which is formed by the balance between global demand and supply.

Figure 1 shows the consumption of biomass by sector. The highest consumption of wood fuels (mainly wood chips) was in heat production sector, then in households (mainly firewood), ca 7.2% in other sectors (service, agriculture and industry, etc.), and only 1.6% of the total inland consumption was used for electricity production.

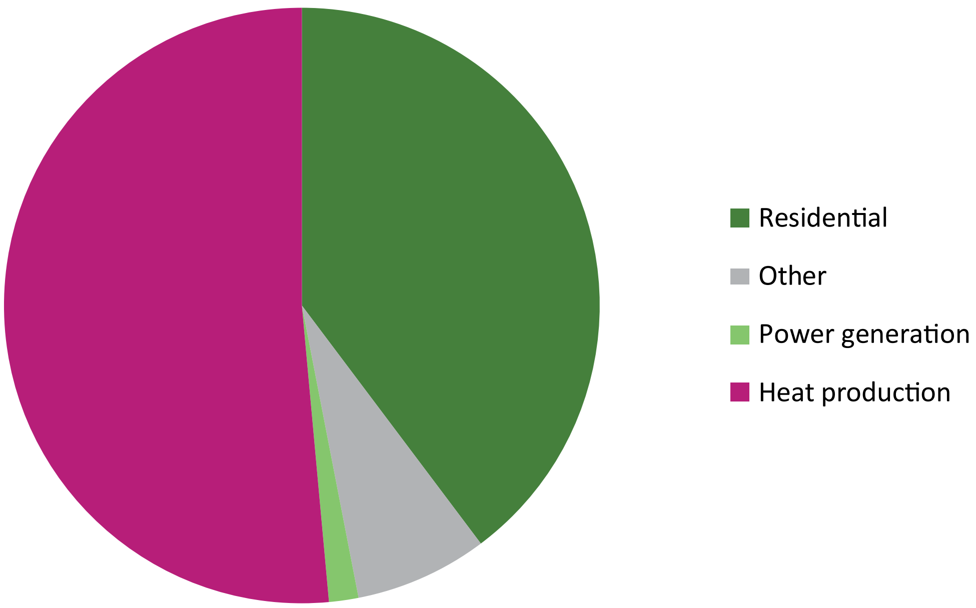

Figure 1. Total consumption of wood fuel in Estonia in 2017.[1]

The indicator for the use of wood fuels in energy production has been defined as an indicator of this target, according to which the volume of wood fuels should increase from 6.1 TWh (2009) to 8.3 TWh (2020). It should be added that only the volume of the stem tree is taken into account in the calculation of this volume and no wood from non-forest land or wood industry waste is taken into account.

When using wood for energy purposes, its sustainability aspects cannot be ignored. Sustainable forest management in Estonia is ensured by the Estonian Forestry Development Plan until 2020[8] and the Forest Act[11]. Further EU legislation may be added in the future to regulate the origin of timber in the fulfilment of national renewable energy targets and support for wood.

The increased use of wood in energy production can have a negative impact on the binding capacity of the forestry sector and greenhouse gas emissions and hence on Estonia's ability to meet its international obligations and to participate in the international market for greenhouse gas emissions[5].

The annual potential energy resource of wood biomass and forest waste from forest and non-woodland areas amounts to 44 PJ (12.3 TWh). In 2017, 31.57 PJ (8.77 TWh) of the potential resource was used, including 27.5 PJ wood chips (7.65 TWh)[5].

1.2 Estimated Theoretical Volume for the Business and Restrictions to be Noted

1.2.1 National-Level Targets

The Estonian National Energy and Climate Plan until 2030 (hereinafter NECP 2030) has been drafted to meet the requirements of Article 9 (1) of the EU Energy Union and Regulation (EU) 2018/1999 on the management of energy measures (hereinafter EU Regulation 2018/1999) which require countries to submit their national energy and climate plan every 10 years to the European Commission[14].

Vision for the Estonian Energy Sector in 2050

In 2050, Estonia will mainly use domestic resources to meet its energy needs; this includes the heat generation and transport sector in addition to electricity production. Investments in the energy sector will result in redoubling the efficiency in the use of local primary fossil fuels compared to the current level. In accordance with the targets of the EU energy roadmap 2050, the level of CO_2 emissions in the energy sector will be reduced by over 80% (compared to 1990 level). Locally produced Estonian gas products will be more competitive in the developed regional gas market and the production levels will be sufficient to cover up to one third of Estonia's gas consumption needs.

Using modern and green technologies, Estonia will become an energy exporter in the established Northern-Baltic energy market. Estonia's energy independence and securing it in the long term will become the main foundation of economic welfare for the country's residents, the competitiveness of local businesses and Estonia's energy security.

The government will have developed a solid policy on resource ownership with a long-term vision to support the development of Estonia's industrial sector. The public revenue from the use of energy resources will be invested mainly in programmes promoting a sustainable energy supply, which will ensure the continued energy independence of the country after the exhaustion of fossil fuels.

1.2.2 *Current Forest Bioenergy Plants*

The following table provides a list of existing electricity and heat co-generation plants (Table 1).

Table 1. Wood-based combined heat and power (CHP) plants in Estonia.[2,3]

Location	Fuel	Heat output, MWh	Supplier	Thermal capacity, MW	Power capacity, MW
Tallinn	Wood chips, peat	1,785	Tallinna CHP, Väo I (Utilitas)	67	25
	Wood chips, peat		Tallinna CHP, Väo II (Utilitas)	76	21
	MSW including 50% biomass		Iru CHP (waste energy unit), Eesti Energia	50	17
Tartu	Wood chips, peat	456	Fortum Tartu CHP	60	22.1
Pärnu	Wood chips, peat	174	Fortum Pärnu CHP	46	20.5
Kuressaare	Wood chips	66	Kuressaare Soojus CHP	9.6	2.3
Paide	Wood chips	51	Pogi CHP	8	2
Rakvere	Wood chips	51	Rakvere CHP (Adven Eesti)	4	1
Rakvere	Wood chips	-	ES Bioenergia CHP	10	1
Valka	Wood chips	21	Enefit Power&Heat Valka CHP	8	2.4
Valga County, Patküla	Wood chips	128	Helme CHP, Graanul Invest	16	6.5
Võru County, Sõmerpalu	Wood chips	97	Osula CHP, Graanul Invest	27	10
Järva County, Imavere	Wood chips	206	Imavere CHP, Graanul Invest	27	10
Viljandi County, Võhma	Wood gas	5	Võhma gas engine 2019 not in operation)	0.46	0.25
Harjumaa, Kehra	Wood chips, black liquor	205	Horizon Pulp and Paper CHP	125	10
Ida Viru County, Püssi	Wood chips	20	Püssi CHP	4	2
Pärnu County, Biomax Selja	Wood chips	-	Gas engine	0.3	0.15

1.2.3 Available Forest Biomass Resources

Half of Estonia's land, or 51.4%, is forest land. In 2017, the total area of Estonian forest land amounted to 2.33 million hectares and the forest reserve of forest stands or stands was 486 million m^3 (Table 2). The area of the stands came to 2.16 million hectares. The growth of managed forest land has grown in the last years and reaches 14 million tons annually. Cutting volumes have fallen and were 11 million tonnes in 2017 (Table 2).

Table 2. Area of forest land and annual growth of managed forests (Source: Environmental Agency)

	2000	2005	2010	2015	2016	2017	2017/2000
Forest land, thousand ha	2,245	2,270	2,221	2,310	2,313	2,331	103.8%
Area of stands, thousand ha	2,096	2,107	2,080	2,146	2,143	2,157	102.5%
Total stock of stands million m^3	428	432	449	484	485	486	112.2%
Annual growth of managed forests, thousand m^3	12,832	12,975	13,244	14,164	14,143	14,094	109.8%

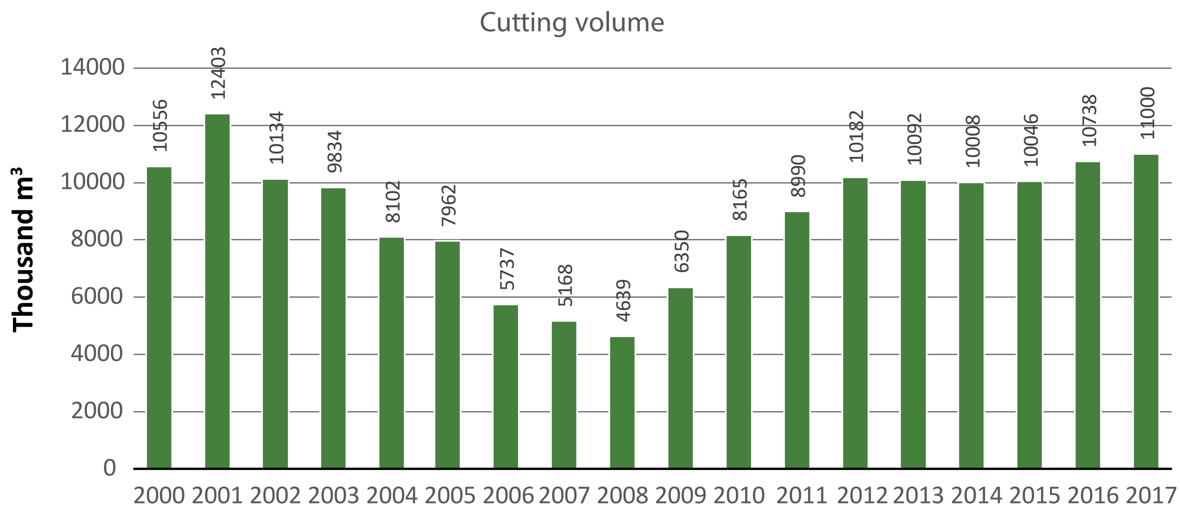

Figure 2. Cutting volumes according to statistical forest inventory.[1]

According to the United Nations Food and Agriculture Organization, Estonia ranks sixth in Europe in terms of forest coverage (share of forest land out of the total land) in Finland, Sweden, Slovenia, Montenegro and Latvia. About 34,000 jobs in the forest sector are directly related to the forest and indirectly this is also the case for many jobs in the tourism, sports, transport and other sectors. There are over 100,000 private forest owners who are self-employed in Estonia[11].

In this decade, the basis for the development of forestry is the Estonian Forestry Development Plan until 2020, according to which the main objective of forestry will be the productivity and viability of forests and the diverse and efficient use of forests. In order to achieve this goal, in the long term, among other things, the aim is to increase the volume of timber, to increase the volume of reforestation work, to keep at least 10% of the forest area under strict protection and to improve the representativeness of the protected forests. The share of strictly protected forest in the total forest area was 13.1% in 2017, and efforts to ensure the representativeness of different types of forests in areas with strict protection are still to be made. At the end of 2017, the Minister of the Environment initiated a procedure for the establishment of 64 new salmon and larch forest conservation areas. A total of approximately 33,000 hectares of state forest land is under strict protection. 90% of the strictly protected forests are located on state lands. The total protected forests account for a quarter of the total forest area in Estonia.

One of the options for assessing the sustainability of forestry is to compare the harvesting rate with the annual growth of the tree stems on the managed forest land. If the amount cut exceeds the growth in the long run, it threatens biodiversity and the sustainability of the supply of raw materials for the forest sector. However, a low share of logging compared to the growth means an inefficient use of the accumulated wood resources. The felling rate fell by over 60% between 2001 and 2008, reaching 4.6 million solid m^3. Thereafter, the felling rate gradually increased and remained at the level of 2012-2016 10 million solid m^3 (a total of 10.7 solid m^3 was cut in 2016). In 2016, the cutting capacity increased to 10.7 million m^3. While in 2008 the share of logging in the growth of managed forest land was 36%, in 2016 it was 75%.

Since errors resulting from the use of a statistical forest inventory (SMI) felling estimation statistical method are high, the Environment Agency has made expert estimates of logging volumes when analysing logging records and remote sensing data, which also shows that the cutting volume has moderately increased in recent years. According to this estimate, 10.1 million m^3 of timber were cut in 2015, 11.3 million m^3 in 2016 and 11.0 million m^3 in 2017. In this decade, 12 to 15 million solid m^3 per year are considered to be optimal. The lively social debate on the sustainable volume of forest use that began in 2016 continued in 2017 as well. It is likely that this topic will be one of the main issues in the next decade of the development of the Forestry Development Plan[8].

In order to analyse the wood stock suitable for wood production, the counties of Estonia were divided into six regions (Figure 3 & Table 3). The total area of mature stands suitable for wood production amounts to 495 thousand ha and would produce 164 million tons of wood, where 11.6 million m^3 per year of renewal and thinning can be carried out in the next decade.

Figure 3. Mature forests for timber production required by regions (groups of counties).[9]

The total number of mature stands suitable for wood production is 495 thousand ha or 164 million m^3 and it is possible to cut in total of 11.6 million m^3 of wood per year over the next decade (Table 3). The largest mature wood stock is situated in the counties of Southeast Estonia – in Jõgeva, Tartu, Põlva, Võru and Valga Counties.

Table 3. Forest land and felling by region[9]

Region	Forest land	Stands	Mature forests		Felling		Thinning	
	1,000 ha	1,000 ha	1,000 ha	1,000 m³	ha	1,000 m³	ha	1,000 m³
Harju, Lääne, Rapla County	352	320	108	32,666	7.5	2,128	4.6	250
Ida-Viru and Lääne-Viru, Järva County	391	344	107	34,699	7.4	2,252	4.2	244
Jõgeva, Tartu, Põlva, Valga Võru County	480	425	140	50,531	8.8	2,981	5.4	343
Pärnu, Viljandi County	318	284	89	30,522	6.0	1,949	3.1	177
Hiiu County	55	50	16	4,849	1.0	293	0.9	50
Saare County	132	119	34	10,828	2.6	767	3.1	183
Total	**1,728**	**154**	**495**	**164,124**	**33.3**	**10,370**	**21.1**	**1,246**

The largest wood stocks are the share of thick and fine firewood in Saaremaa, the proportion of pulpwood in Pärnu County and Viljandi County, and the proportion of firewood in the forests of Lääne-Viru and Ida-Viru County, Järva County (Table 4):

Table 4. Annual felling in Estonian counties, 1,000 m^3 and share of assortment.[11]

	Logs	%	Paper wood	%	Fire-wood	%	Total
Harju, Lääne, Rapla County	829	42.2	528	26.9	607	30.9	1,964
Ida-Viru and Lääne-Viru County, Järva County	852	41.3	568	27.6	643	31.2	2,065
Jõgeva, Tartu, Põlva, Valga Võru County	1,318	47.6	748	27.0	704	25.4	2,770
Pärnu, Viljandi County	713	40.9	490	28.2	538	30.9	1,741
Hiiu County	133	47.1	71	24.9	79	28.0	283
Saare County	390	49.7	188	23.9	207	26.4	785
Total	**4,236**	**44.1**	**2,594**	**27.0**	**2,778**	**28.9**	**9,602**

It is estimated that in 2016 the amount of wood obtained from logging (excluding industrial chips) was 1.1 million m^3. It is well known that only 180,000 m^3 of this originated from RMK, the rest came from private property. It is very difficult to draw a border between forest and non-forest land. The quantity of timber from non-forest land has been estimated based on expert judgment [11].

Demand for Energy Wood

The price level offered by foreign buyers of wood chips has been extremely modest over the past few years, which is why Estonian companies may now find it difficult to meet delivery obligations at a fixed price during a market downturn. Given the general trend towards energy from renewable sources, it is more likely that investments in wood-based energy solutions will continue and demand is expected to increase[5].

The Estonian Forest and Wood Industry Association, Estonian Power and Heating Association and Estonian Private Forest Centre foundation estimated the growth of wood demand up to 2019 with 17 companies using wood chips and wood waste for energy production. A year ago, the surveyed companies evaluated their wood needs by 2018 to be total of 9.3 million m^3, while this year's the survey showed the need for 10.1 million m^3 in 2018 and 10.7 million m^3 of wood in 2019 for the surveyed companies in total (Table 5)[11].

Table 5. Wood use forecast in surveyed companies 2016-2019.

Wood consumption volume, million m^3	2016	2017	2018	2019	Volume growth
Production of sawn timber	3.43	3.79	4.36	4.49	1.06
Plywood production	0.33	0.40	0.49	0.58	0.25
Paper production	0.92	0.97	1.05	1.30	0.38
Wood fuel production	2.30	2.89	2.48	2.60	0.30
Energy production	1.40	1.58	1.75	1.80	0.42
Total	**8.35**	**9.63**	**10.13**	**10.76**	**2.41**

1.2.4 Current District Heating Systems and Investment Needs in Estonia

The National Development Plan of the Energy Sector until 2020 identified upgrades to existing production installations and reduced fragmentation in the district heating price monitoring as the key issues in the district heating sector. Wider utilisation of the co-generation of electricity and heat and diversification of the production portfolio were established as separate targets. The support measures adopted to achieve those targets have resulted in increased replacement of old boiler installations with new, more efficient systems. Boilers using shale oil have been extensively replaced with equipment that uses more affordable biomass. Nevertheless, the number of heating plants that use shale oil for heat production remain relatively large.

Estonia had 215 municipalities in 2014 and district heating was used in 149 of them. There were 239 district heating network areas. Today, there are only 79 local governments in Estonia after the administrative reform of 2017, of which 15 are towns and 64 municipalities (parishes). As of the beginning year 2017, the Competition Authority had data on 145 district heating network areas, for which the length of the district heat piping was 1,455 km.

According to the analyses prepared by the Ministry of Economic Affairs and Communications and the Estonian Development Fund, the following factors inhibited or had a significant impact on the development of the district heating market:

1. Lack of motivation for identifying cost-effective district heating solutions and for increasing the internal efficiency. The price regulation applied to district heating does not motivate producers to look for solutions which would reduce district heating prices. The investments that facilitate reductions in the price of heat for the end users are not reflected in improved financial results of the companies; the achieved effect is fully transferred to the users;
2. The unstable regulatory environment does not promote long-term investment. The price regulation criteria, specified in the methodologies of the Competition Authority, are very strict and are subject to frequent amendment;
3. Business operators and the Competition Authority both have doubts about the sustainability of some district heating regions;
4. The addition of parallel production, or local production installations, reduces the long-term efficiency of the district heating network.

In order to adapt to changes in the housing sector (implementation of energy efficiency measures, adoption of new building standards), the government has to take steps towards the liberalisation of the previously monopolistic district heating market. Consumers should be provided with efficient and cost-effective heating solutions, while motivating business operators to implement cost-effective solutions that would be competitive in the long term[5].

The political choices and measures implemented in the heating sector should be based on the long-term sustainability of the heating sector without the need for additional investment or activity support beyond regular economic activities. Heat should be produced mainly from local and renewable fuels and fuel-free energy sources. Due to the energy efficiency investments in buildings and higher efficiency of heat production, the use of fuels for heat production will decrease by more than 40% by 2050 compared to 2012 level[5].

1.3. Policy Instruments with the Key Elements Promoting Forest Bioenergy Business

Investment Grants

Table 6. Grants processed by Estonian Environment Investment Fund during the period 2007-2013 (investment support).

Area	Project	Cost, million €	Amount of support, million €	Percentage
Increased use of renewable energy sources for energy production (ERDF funding)				
All projects	21	24.77	8.69	35.1%
Implementation of biomass in DH	4	9.40	3.65	38.8%
Building of biogas operating CHPs	2	7.88	1.88	25.3%
Energy funding (RIS)				
All projects	79	108.40	56.93	52.5%
Building of new CHPs	5	24.41	9.81	40.2%
Building of wind farms	2	24.23	12.46	51.4%
Implementation of boilers using biomass	24	15.09	7.42	49.2%

Table 7. Grants from 2014 onwards.

Area	Project	Cost, million €	Amount of support, million €	Percentage
Renovation or implementation of district heating boilers and fuel switch (CF financing)				
All projects	51	37.9	17.90	47.2%
Support for the use of bio methane in production or/and in transport (CF funding)				
All projects	16	9.85	3.33	33.9%
Building of filling stations	15	7.60	2.66	35.0%
Use of bio-methane in bus traffic	1	2.25	0.67	30.0%
Use of energy efficiency measures and renewables in local government kindergarten (ETS financing)				
All projects	52	24.78	14.71	59.3%
Preparation of heating sector development plans (financing by CF)				
All projects	119	0.52	0.45	86.1%

Operating grants for the production and use of wood fuels in Estonia.

In 2007, operating subsidies for electricity produced from renewable sources commenced in Estonia. On July 1, 2007, the Electricity Market Act (EMA) amendment came into force providing support for the supply of electricity produced from renewable energy sources, and the creation of biomass-based cogeneration plants accelerated.

Biomass is defined as the biodegradable fraction of products, waste and residues from agriculture and forestry and related industries, and the biodegradable components of industrial and municipal waste. In addition, it is important to consider that liquid biofuel is only considered a renewable energy source if it meets sustainability criteria. All other options to obtain support from the use of renewable sources require production using CHP. In this case, with the use of biomass, from 1 July 2010, it is possible to get support without a limit of 100 MW.

Operating subsidies have accelerated the building of the Tallinn Power Plant (67 MW_{th}, 2009), Tartu Power Plant (65 MW_{th}, 2009), Pärnu Power Plant (50 MW_{th}, 2011), Kuressaare Power Plant (9.6 MW_{th}, 2013), Paide Power Plant (8.0 MW_{th}, 2014) and several smaller co-generation plants.

Table 8. Grants for electricity produced from renewable sources for 2007-2018, million € according to AS Elering

Energy source	Support, million €
Wind	176.77
Hydro	10.62
Solar	0.58
Biogas	13.77
Biomass	229.69
Total	**431.42**

In almost all years in the 2010-2017 period (with the exception of 2015), the largest support payments were made for biomass for electricity producers, e. g. payments amounted to 41.3 million euros in 2017.

As of 1 July 2010, the rate of support for electricity produced from biomass in cogeneration will be 53.7 €/MWh. Thus, if electricity is produced from biomass in condensing mode, no support will be paid. However, a producer who started production with a production plant that uses biomass as a source of energy after 31 December 2010 may receive support only for electricity produced under an efficient cogeneration mode.

If electricity is produced using an efficient cogeneration method in a power plant with an electrical capacity not exceeding 10 MW, the subsidy for the electricity produced irrespective of the type of fuel used is 32.0 €/MWh.

2. CONCLUSIONS ON THE BEST PRACTICES IN THE COUNTRY-SPECIFIC CONDITIONS

2.1. Best Practices in Estonia

OÜ Utilitas Tallinn Power Plant
The main activity of the OÜ Utilitas Tallinn Power Plant is the production and sale of heat and electricity. The company operates two CHP plants operating on biofuels in Tallinn. The company produces 100% energy from domestic chips and peat in a cogeneration process. In the summer, the heat generated by the plant is sufficient to meet the needs of the entire district heating network in Tallinn. The first CHP plant opened in 2009 has a thermal capacity of 67 MW and an electrical capacity of 25 MW. In autumn 2016, Utilitas' second wood-based combined heat and power plant was also launched. Thanks to the new plant, the installed capacity and the planned production of both heat and electricity have increased. The plant's thermal capacity, together with the flue gas condenser, is 76.5 MW and the electrical capacity is 21.4 MW. In total, these two stations supply nearly 45% of the annual need for the district heating network in Tallinn. The electricity produced in the same process is sufficient to satisfy the electricity consumption of more than 130,000 households, i.e. all apartments in the district heating network in Tallinn.

Picture 1. External view of the AS Utilitas Tallinn CHP plants. [A]

Fortum Pärnu CHP plant

Pärnu CHP plant has been in operation since January 2011. The capacity of the plant is 24 MW of electrical and 48 MW of thermal power. The annual sales volume is 170 GWh of electricity and 220 GWh of heat. The power plant uses local wood fuels (wood chips and wood waste) and milled peat. The consumption of wood and peat reduces the dependence on imported fuels in Estonia and provides jobs for local fuel producers (approximately 300 people are employed). Diversification in electricity production reduces transmission losses and national energy security risks. The introduction of a highly effective and environmentally friendly circulating fluidized bed boiler enabled the waste generated in Pärnu CHP to be minimised and has reduced the impact on the environment. The best available technology is also used for cleaning of flue gas. With the input of additives into the furnace it is possible to reduce the nitrogen oxides (NO_x) and sulfur dioxide (SO_2) content in the leaving flue gas. Almost 100% of the solid particulates are removed from the flue gas with fabric filters before the stack. The cogeneration plant owner is Fortum Termest AS, and the electricity is sold on the Nordic power exchange – Nord Pool.

Picture 2. Pärnu CHP plant. [B]

[A] Photo: https://www.utilitas.ee/ou-utilitas-tallinna-elektrijaam/
[B] Photo: https://parnu.postimees.ee/4338395/niidu-koostootmisjaama-lugu

Fortum Tartu CHP plant
The electrical capacity of the Tartu CHP plant is 25 MW and the thermal capacity is 65 MW (including flue gas condenser 15 MW). The electricity production is 158 GWh and the thermal energy production amounts to 304 GWh per year. The boiler steam production is 28.5 kg/s, the maximum water consumption is 5 m^3/h and the maximum water preparation capacity about 30 m^3/h. The annual average efficiency of the plant is (excluding flue gas condenser) 88%. The volume of the investment was 66 million €, the volume of the support investment was 2.8 million €. The plant uses mainly woodchips, wood residues and slightly milled peat (about 10%). In 2017, the fuel consumption totalled 520 GWh. All the heat produced by the plant is sold to the Tartu district heating network and the electricity is sold mainly on the electricity power exchange and to a lesser extent, through direct contracts with end users.

Picture 3. Fortum Tartu CHP. [C]

[C] Photo: Risto Mets.

Helme CHP plant
The Helme CHP plant has been in operation since August 2012. The electrical capacity of the plant is 6.0 MW of and thermal capacity of 15.5 MW, the total capacity is 21.5 MW. The Helme cogeneration plant was the first industrial co-generation plant in Estonia. The power station was chosen specifically for pellet industry needs, keeping technical requirements in mind. The production process links energy production to the production of granules. The heat produced by the plant is mainly used for drying the raw materials for pellet production. Part of the electricity produced by the CHP is used for the pellet factory and part of the electricity is sold by the network to other factories in the consortium.

Picture 4. Helme CHP. [D]

[D] Photo: Maru Tahm.

AS Kuressaare Soojus Kalevi Boiler House	
Before renovation **Kalevi Boiler House**: up to 120,000 m^3 of wood chips and 500 tons of shale oil per year. **Luha Boiler House**: a peak load boiler house, fuel consumption: 600 tons of shale oil per year. Length of district heating pipelines: 33.8 km, including renovated sections 16 km; heat production: 75.15 GWh; heat sold: 62.37 GWh; heat loss: 17% Backup or emergency boilers are available. The price of heat is about 43.40 €/MWh (without VAT). Starting from 01.02.2013, a new combined heat and power plant has been operating on wood chips. Kalevi Boiler House: runs from + 5°C outside air temperature; Luha boiler plant, operates from -5° C outside air temperature (both plants are peak load plants). District heating pipelines – no change after renovations; fuel consumption – 120,000 m^3 of wood chips and 475 tons of shale oil; heat sales plan – ca 66.8 GWh and ca 9.6 GWh of electricity; no change in the heat loss after renovations. Fuel storehouse – 800 m^3 of wood chips. CO_2 emissions before renovations were about 4,800 tons per year. After renovations, the estimated CO_2 emissions were around 1,400 tons.	
	
Picture 5. External view of the Kuressaare CHP plant. [E]	**Picture 6.** AS Kuressaare Soojus new combined heat and power plant. [F]

[E] Photo: Arvid Peel.
[F] Photo: Ülo Kask.

Muhu

Before renovations

Until 1996, the Liiva boiler house of Muhu Municipality operated on coal, in 1996-2008 it used wood chips and peat. If necessary, a boiler operating on fuel oil was used as a peak load boiler. From 2008, the boiler house only uses wood chips. The length of the non-renovated district heating pipelines was 678 meters, with several different fuel boilers. Heat was produced at 1,440 MWh, sold at 1,200 MWh and the heat losses were 240 MWh, or 20%.

Situation after renovation

Since 2008, the new boiler house only uses wood chips. The main boiler is a REKA HKRSV 750 and the peak load boiler is a REKA HKRS 500. Since 2010, the district heating pipeline with a total length of 678 meters has been renovated. The amount of wood chips used is about 2,200 m^3 per year, the heat production is about 1,400 MWh per year and the heat limit price is 58 EUR/MWh (real price in 2019 is 47 EUR/MWh). In 2013, a new social centre joined the district heating network. The capacity of the wood chips silo is 1,000 m^3 of wood chips. After renovation of the Liiva boiler house there are practically no calculated CO_2 emissions.

Picture 7. Exterior view of Muhu Liiva boiler house.[G]

Picture 8. Reka boiler in Muhu Liiva boiler house.

[G] Photo: Ülo Kask.

Further Steps in the Near Future

There are no plans to build new large cogeneration plants in Estonia in the coming years. However, within the next two years, it will be possible to receive subsidies from the Environmental Investment Center for converting boilers from fossil fuels to biomass. Due to the high CO_2 price of oil shale electricity, the government plans to amend the Electricity Market Act so that half of the amount of oil shale burned in the Narva power plants can be replaced with biomass. According to the Auvere Power Plant's existing Environmental permit[16] the plant is allowed to burn up to 1.3 million m^3 of biofuels per year (ca 2.3 TWh).

According to the Energy Sector Development Plan 2030[5], the utilisation of wood biomass, which is suitable for energy production, should not be restricted by the lack of available resources. According to the Forestry Development Plan until 2020, the annual prescribed cut volume will be 12-15 million m^3 and 9 million m^3 of this can be used for energy production, which would correspond to about 18 TWh. On the other hand, as a result of energy efficiency measures, the energy consumption in the sectors where wood has been the main source of energy, including the housing sector and industry will decrease enabling new consumers to enter the biomass market.

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Appendix 2

LATVIA COUNTRY REPORT
DETAILED INFORMATION ON FOREST BIOENERGY

1. BACKGROUND

1.1 State-of-the-art of the Bioenergy Sector in Latvia

Combined production of heat and power is one of the most efficient and economically beneficial energy production types. Information gathered by the Central Statistical Bureau of Latvia shows that the total energy consumption in Latvia in 2017 was 195 PJ (54 TWh) and it has not changed significantly over the last 10 years (ranging from 184 PJ in 2011 to 197 PJ in 2008). The concept "the total energy consumption" has to be interpreted as energy consumption in the production of heat and electricity and final energy consumption (includes all economic sectors and households). The amount of energy used for the production of heat and electricity and sales in 2017 is on average 53 PJ (15 TWh) of energy were consumed, producing 30 PJ (8 TWh) of heat and 11 PJ (3 TWh) of electricity[1]. More than half of the primary energy is used for the production of heat for central heating systems (Parliament of the Republic of Latvia, 2010).

1.2 Current Forest Bioenergy Plants

During the period 2007-2017 the number of combined heat and power stations in Latvia increased about five times. In 2017 there were 204 combined heat and power stations, of which only 24% used wood chips as the main raw material for energy production. The total amount of fuel consumed in combined heat and power stations also increased during the period from 2012 (30.4 PJ) to 2017 (40.8 PJ). Although the total amount of fuel consumed by boiler-houses (general service and companies) in 2017 (9.5 PJ) compared to data obtained in 2012 (12.6 PJ) decreased, the amount of wood chips used from 2012 (17%) to 2017 (29%) increased. Whereas the share of natural gas in the amount of fuel consumed in boiler-houses decreased from 32% in 2012 to 14% in 2017 (Figure 1)[2].

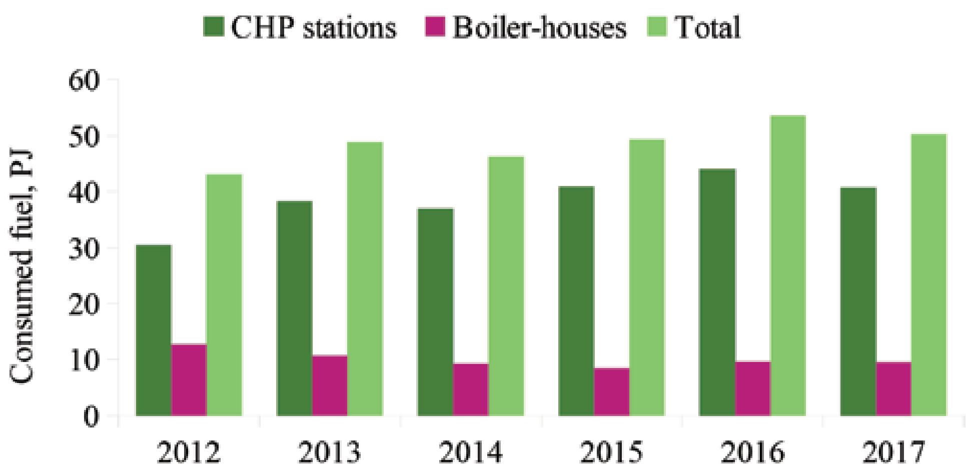

Figure 1: Fuel consumed in boiler houses and CHP stations in Latvia.

The information gathered on the structure of energy consumption in the transformation sector, which includes combined heat and power stations and boiler-houses, shows that over the last years (from 2012 to 2017) the situation has changed significantly. The share of natural gas consumption decreased by 17% and accordingly wood chip consumption as a biofuel increased three times[1].

In 2012 in combined heat and power stations natural gas was the main raw material for energy production (86% or 26.1 PJ) and the share of wood chips was only 6% (1.7 PJ) out of the total amount of raw materials, whereas in 2017 the amount of natural gas used dropped to 61% (24.6 PJ), and the amount of wood chips increased five times, reaching 30% or 12.1 PJ of the total fuel used in combined heat and power stations.

The distribution of fuel wood consumption according to fuel types from 2010 to 2017 in heat supply companies in Latvia is shown in Figure 2. The highest proportion (from 45 to 56%) of the total wood fuel consumed comprises wood chips, and their consumption has continued to increase each year from 2011.

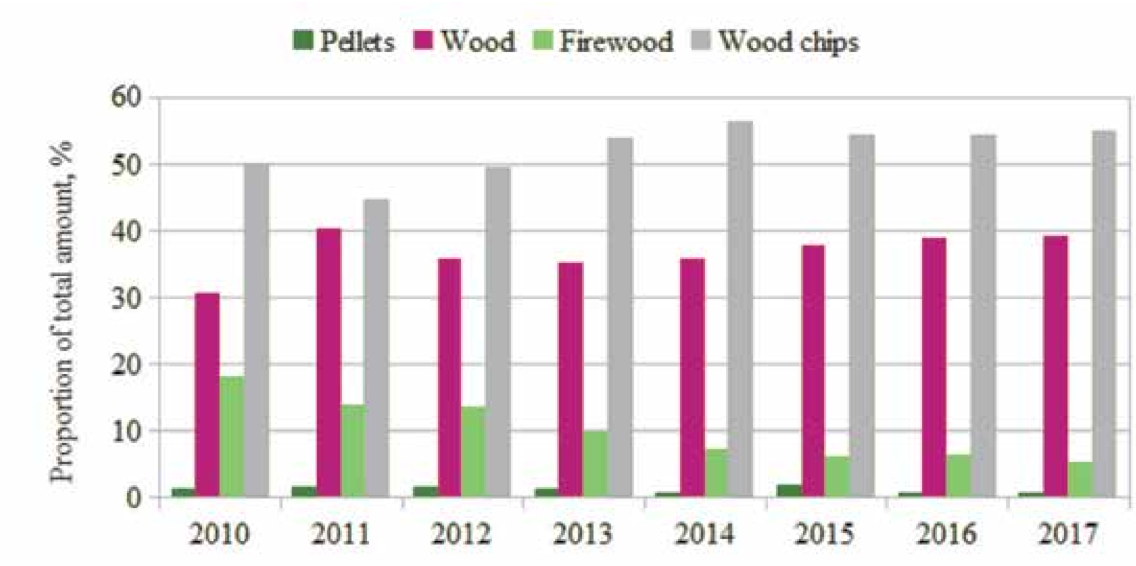

Figure 2: Distribution of fuel wood consumption in heat supply companies in Latvia.

1.2.4 Available Forest Biomass Resources

In the study, the aim was to determine the potential biofuel resources that can be produced in forest thinning within the limits of legal and technical restrictions of forest management, data from the first cycle of the National Forest Inventory (2004-2008) were used.

Changes in wood chip prices in recent years have not been significant (Figure 3)[3].

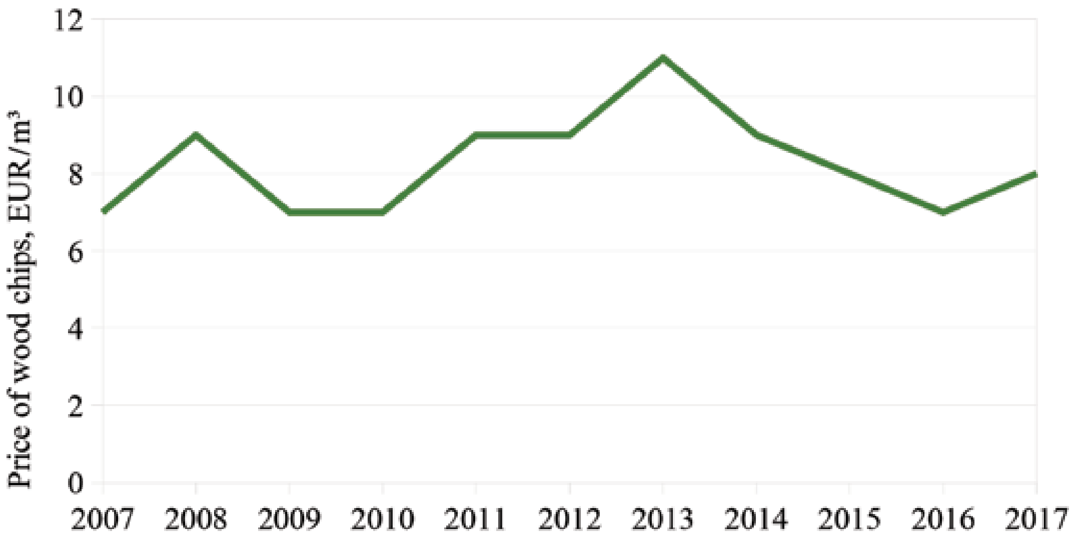

Figure 3. Price changes for wood chips.

2. LATVIAN FOREST RESEARCH RECOMMENDATIONS FOR THE CHOICE OF THE SUITABLE TECHNOLOGY IN FOREST BIOFUEL HARVESTING

The choice of technological process of logging is determined by the wood type to be transported from the forest, whereas the type of logging process is determined by the location of preparation for production. Studies show that three technological logging processes are applied in the industrial production of wood in Latvia, which are intended for forwarding whole and delimbed stems and prepared logs[12].

The use of whole stem technology, which is intended for forwarding whole stems together with branches to maximise the use of resources, would be profitable. However, several studies have shown disadvantages of the technology[5]. Forwarding of delimbed stems is technologically more complicated and involves relatively high costs of adaptation of road transportation vehicles. Additionally, the removal of logging residues is not always permitted, mainly due to ecological and logging requirements. Lastly, this sort of logging technology in Latvia is still experimental[5,12].

Technological solutions for delimbed stems is more widespread in forestry practice than whole stem technology[12]. However in Latvia and Europe in general, there is a tendency to move from stem technological processes to the preparation of logs, which ensures more efficient use of resources, reduces the time of wood preparation and transportation and allows to adjust maximally to the demands of the end users at the same time as showing a higher economic benefit[4,12].

Wood chip technology is mainly used on felling sites where the main raw material obtained are fine stems. It is used also used in removal of shrubs and re-using of logging residues and other less valuable wood (Table 1[12]).

Table 1: Variations in technological processes for logging.

No.	Technological process	Types of forwarded timber	Types of delivered timber
1.	Whole stem technology	Whole stems	Whole stems
2.	Delimbed stem technology	Whole stems Delimbed stems	Delimbed stems
3.	Assortment technology	Whole stems Delimbed stems Assortments	Assortments
4.	Wood chip technology	Whole stems Delimbed stems Assortments Technological wood chips	Wood chips

Assortment technology is the most widely used type of wood processing technology in Latvia – in pre-commercial thinning, where small dimension wood is obtained, in commercial thinning and in final felling. In order to mobilize this resource economically, technically and environmentally suitable systems of forest machines should be built. Several solutions of technological processes, which can be used in thinning are described in the literature[11, 14 & 15], but nowadays the most widely used method involves hand tools (chainsaws with and without special equipment) or standard medium sized harvesters and forwarders[6, 11, 12, 13 & 16].

Small-dimension wood is the main biofuel resource that can be obtained in pre-commercial thinning, however it is considered a significant biofuel resource also in commercial thinning. The wood stock from undergrowth trees in fertile forest types can be large enough to make biofuel extraction economically viable. Undergrowth (for conifers up to 9-10 cm, for deciduous trees up to 12 cm on average) makes it difficult for harvesters to operate, so it is usually cut with hand tools before harvesting, but this operation significantly increases the cost of biofuel production. Technological corridors are not usually marked before final felling, therefore the collection of small dimension trees at the side of the corridors (as it can be done during thinning) without changing clear cutting working methods is complicated and laborious. Studies conducted in Latvia show that although the tree undergrowth is high, it makes up only a small part of the forest stands.

In 2006 in Latvia a study titled "Evaluation of energy wood resources, their processing technologies and costs in thinning of 20-40 years old forest stands" was conducted, whose aim was to analyse in detail the collection and processing technologies of small-dimension wood and logging residues from thinning as well as to assess their productivity and costs.

The conclusion of the study was that the amount of unused small-dimension wood is significant and in pre-commercial thinning it constitutes from 700 to 900 thousand m^3 annually. It is beneficial to collect small-dimension wood in commercial thinning to prepare energy wood if the amount of small trees felled is at least 1,000 per a hectare, excluding trees with diameter less than 6 cm. In such young stands from 30 to 110 m^3 of small-dimension wood per a hectare can be extracted. It is also important that the area of the stand to be thinned is at least 2-3 ha, which would ensure that amount of small-dimension wood in the landing site is at least 100 m^3.

In commercial thinning small dimension stems (diameter at breast height = 6-10 cm, stem volume ranges from 0.01 to 0.03 m^3) constitute 50-60% of the total number of trees to be felled or 10-30% of the yield. The yield of pulpwood and firewood assortments in thinnings is small and does not exceed 30-50% of the yield of small-dimension wood and stunted trees. Energy wood chips produced from small-dimension wood have a higher proportion of wood and higher heat capacity compared to wood chips made from logging residues obtained in final felling.

Mechanized commercial thinning when preparing assortments in stands with up to 60% of the yield constituting small-dimension wood, has high costs (up to 35 EUR/m^3), so therefore it is more economically justifiable to collect whole fine stems for biofuel production. In general study results show that in thinnings in 20-40-year-old forest stands it is possible to obtain a significant additional amount of raw material for energy wood, by collecting and processing small-dimension wood into energy wood chips. However, the use of small-dimension wood for biofuel production is restricted by the costs of preparation and processing, which in pre-commercial thinning, performed by hand, is 2-3 times higher than in final felling, when mechanically collecting logging residues[8].

As there are no technical obstacles to the extraction and processing of small-dimension wood, the main problem is economic efficiency. In order to solve this problem, there are still ongoing studies in Latvia with the aim to find the most suitable method for preparing small-dimension wood mechanically, which would allow significant increases in productivity. The market price for biofuel also has a significant impact on profitability.

Logging residues are one of the cheapest and largest types of forest biofuel resources in Latvia, and have been used for many centuries in heating. On an industrial scale, the harvesting of logging residues in Latvia resumed in the middle of the last decade and is currently taking place in private and state forests.

Collecting logging residues is possible if it is not necessary to use them on forwarding strip roads. Another important factor is the distance from the forest stand to where they will be stored. Logging residues are collected both mechanically (during harvesting) and by hand. Extraction manually is practised only in private forests. Logging residues after collection can be dried at the felling site, preserving nutrients from the leaves and needles in the forest, or forwarded immediately.

It was concluded in the study that the largest amounts of logging residues in commercial thinnings can be obtained from 30-40 old birch stands, 20-60 years old spruce stands and 30-70 years old pine stands. After clear felling around 20-30% of the total amount of extracted above-ground wood parts are left in the forest, which constitutes 2.5 million m^3 of logging residues for biofuel. This share of resources could be collected and used with the latest logging technologies, using harvesters, forwarders, residue packers, chippers and wood chip carriers. These technologies would allow the extraction of energy wood at a low cost, which can compete with both other types of firewood and fossil fuels.

The collection of logging residues can be considered profitable if their forwarding distance to the landing area does not exceed 1.5 km (forwarding costs are up to 3.12 EUR/m^3). The choice of landing area for small-dimension wood and logging residues is more complicated in thinning than in final felling, because large open fields to unload logging residues and small-dimension wood for drying and processing may not be found nearby. The forwarding distance is often larger when collecting energy wood during thinning operations than in final felling, where logging residues can be unloaded for drying at least in the felling area[8].

In Latvia it is possible to collect logging residues of small-dimension wood in *Hylocomiosa*, *Oxalidosa*, *Myrtillosa* forests and in forests on drained mineral soils which are suitable for the stable movement of forest machines, and where logging residues are not needed for strengthening the access roads. In the rest of the forest types preparation of energy wood is possible under frosty conditions when the root systems of the remaining trees are not damaged. Forest types, where the collection of logging residues is possible without using logging residues on strip roads, constitute around 66% of the total area of the forest[8].

Removing logging residues from forest stands on poor soils can cause soil depletion. However the experience gained from studies of preparation of energy wood in clear fellings in forest types on poor soils show that collection of energy wood in these forest types is not economically reasonable, because the amount of wood is small. Logging residue collection technologies allow to remove no more than 60-70% of logging residues, which also decrease the risks of soil depletion in forests on soils with high humus content[8].

According to the collected information, in 2016 and 2017, 368 and 428 thousand m^3 of biofuel, respectively, were processed in forest areas managed by Latvian state forests. As it is concluded in several studies that were carried out over the last ten years, a sharp increase in the production of energy wood from the current forest areas, using forestry solutions typical to Latvia, is not possible, therefore the increasing demand for energy wood should be satisfied more rationally and completely using new technological methods, using the available resources.

Until 2005 it was not possible to use more progressive forest thinning machines (harvesters) in Latvia, because according to the Regulation of the Cabinet of the Ministers of the Republic of Latvia No. 217 (29.05.2006) the total area of strip roads established during thinning could occupy only 12% of the total stand area. Consequently, the distances between strip roads could not be smaller than 30 m, and the harvesters in use could not ensure that the forest belt between two strip roads was thinned evenly or that the logging residues were collected for the preparation of energy wood.

Since March 15, 2005, when changes in the Regulation of the Cabinet of the Ministers of the Republic of Latvia No. 217 (Regulation of the Cabinet of Ministers No 187) were made, when collecting small-dimension wood for processing into energy wood, a dense network of strip roads should be established, which may occupy up to 20% of the stand area. In forest belts between strip roads according to the regulatory requirements (Regulation of the Cabinet of Ministers No 935), a sufficient number of trees or a minimum basal area should remain in the stand. The network of strip roads established in new stands ensures rational stand management for the whole growth period and reduce losses that may occur when establishing them in stands following commercial thinning. The changes made in the law and the new regulations significantly increase the efficiency of harvesters in thinning, ensuring the extraction of all the wood to be felled on the basis of thinning at the strip roads, as well as the preparation of roundwood assortments and collection of logging residues for the preparation of energy wood.

The aim of the study that was conducted in Latvia in 2012, was to compare biofuel production technologies in thinning, final felling and forest infrastructure using data from literature, and to determine the most suitable biofuel production technology and delivery method depending on the felling type.

Within the scope of the study experts evaluated technological processes using a 5-point grading scale (5 points was the highest grade and 1 point was the lowest, accordingly). The evaluation of each operation consists of an independent, subjective assessment of 2-3 experts, which is expressed in the total evaluation as the average value.

Five criteria were taken into account in the technology assessment:

- Economic criteria, which include investment costs, a wide range in the use of machines and a broad assortment production possibilities;
- Forestry criteria related to the quality of thinning (damage to the remaining trees, the potential risks of spreading of etc.);
- Technical aspects, including assessments of the level of mechanisation and technical indicators of the base machines used;
- environmental impacts, including fuel consumption, pressure on the soil and other types of pollution;
- ecological aspects, including the noise level and the impact on biological diversity (deadwood, biologically valuable trees etc.[9]).

In general 14 technological solutions for the preparation of timber and biofuel in pre-commercial thinning were identified in the study. The technology which processes partly delimbed stems got the highest rating. The concept "partly delimbed stems" is to be understood as a stem that is delimbed but the top is left.

The experts also recognised that this is best done with a chainsaw with a high handle. Technological solutions which for chipping forest biomass at the felling site, which is one of the most commonly used solutions in plantations in Central Europe, but is practically not used in the Nordic countries, got lowest rating. The main downside of this technology were the lack of suitable machines, as well as the lack of experience and skilled operators to carry out the necessary work.

In general 12 technological solutions for biofuel extraction have been identified in commercial thinning for the conditions in Latvia. According to expert judgment, in commercial thinning the most appropriate method would be to use technological solutions for partly delimbed stems. As up to five different biofuel assortments can be obtained in commercial thinning, a harvester with an accumulating felling head or a chainsaw is best suited for this sort of preparation. In commercial thinning processing partly delimbed stems was evaluated as more useful than processing logging residues. As the best solution for biofuel preparation from logging residues, experts recommend using a harvester or customized excavator with a standard harvester head.

The technology assessment shows that in commercial thinning as well as in pre-commercial thinning it is necessary to pay more attention to the delivery organisation of partly delimbed stems. In the last commercial thinning the production can considerably differ and logging residues can play a greater role. Currently in Latvia there is a lack of scientifically based information on the preparation of biofuel in commercial thinning and how it is affected by growing conditions, tree dimensions, intensity of the thinning and the technique used.

In general, fifteen technological solutions for extraction have been identified in final felling. Because the biofuel resources available in final felling vary significantly, their method of extraction also differs. In order to use these resources, the most appropriate technologies for the forest growth conditions and the type of resources should be put into use. According to expert judgment, the final felling should be mechanised (Table 2[9]).

Table 2: Choice of technologies for biofuel preparation and delivery for different felling types.

Residues in the operation	Suitable technology for biofuel extraction	Suitable technology for biofuel forwarding	Suitable technology for biofuel delivery
Pre-commercial thinning			
Small trees	Chainsaws with a high frame. Harvesters with standard felling heads.	Forwarder for logs (wheeled) - partly delimbed stems.	Log truck - partly delimbed stems. Chip truck- wood chips.
Commercial thinning			
Small trees	Harvesters with accumulating felling heads. Chainsaws.	Forwarder for logs (wheeled) - partly delimbed stems.	Log truck - partly delimbed stems. Chip truck- wood chips.
Logging residues	Harvesters with accumulating felling heads. Chainsaws.	Forwarder for logging residues (wheeled).	Chip truck - wood chips.
Final felling			
Small trees	Harvesters with accumulating felling heads. Harvesters with standard felling heads.	Forwarder for logs (wheeled) - partly delimbed stems.	Log truck - partly delimbed stems. Chip truck- wood chips
Logging residues	Chainsaws. Excavators equipped with harvester heads.	Forwarder of logging residues (wheeled).	Chip truck- wood chips.

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Appendix 3

QUESTIONNAIRE RESULTS FOR LATVIAN FOREST HARVESTING COMPANIES AND REMOVERS OF BRUSH AND TREE OVERGROWTH[1]

A total of 37 companies providing energy wood preparation and supply services to private forest owners answered these questions during 2019. The questionnaire was prepared, and interviews were conducted by the Latvian Rural Advisory and Training Centre (SIA Latvijas Lauku konsultāciju un izglītības centrs).

Does your work involve the following:

Type of action/operation	Number of respondents (37=100%)
Logging operations in final felling	32 (86%)
Removal/thinning of overgrowth (shrubs and trees) in overgrown agricultural lands (in deciduous forests which have been established on originally open or partly/semi open agricultural lands, pastures and meadows)	29 (78%)
Small-dimension tree felling in thinning operations/young stand thinning	22 (59%)

1. ENERGY WOOD PRODUCTION IN THINNING OPERATIONS
(Thinning operations in up to 20-year-old stands.)

1. *Do you have experience in the production of energy wood while carrying out thinning operations (tree composition thinning operations in up to 20-year-old stands)?*

	Number (31=100%)
Yes	14 (45%)
No	17 (55%)

1 **Overgrowth** = With shrubs and trees in natural overgrown agricultural lands.

2. *What is your choice concerning production when working in 20-30 years old tree stands?*

Type of assortment harvested in thinnings	Reason	Number (33=100%)
Assortments	Higher profit.	14 (42%)
Assortments and energy wood	Economic factors (location of the site, its size, tree species, assortment price). The tree stand is cleared, and the growth of valuable trees is encouraged.	14 (42%)
Energy wood	Complete wood processing. Basic occupation.	5 (15%)

3. *What harvesting techniques have you used?*

Harvesting technique in thinnings	Advantages	Disadvantages	Number (18=100%)
Chain Saw	Greater assortment output. Operational activity. Ability to work in complex and difficult-to-access felling areas. Quality material. Less damage to residual stands.	Lack of labour. Low yields. Unable to work in changing weather conditions. Slower than using harvesting machinery	13 (72%)
Harvester	High yields. Can work in bad weather and darkness.	Smaller assortment output. Large tracks remain.	3 (17%)
Assortment + branches in rows	The fertilizer for the stand remains.	Difficult felling regeneration.	2 (11%)

4. *Which 20-30-year-old forest stands are suitable for thinning with the sole purpose of obtaining energy wood?*

Characteristics of forest stands which are suitable for thinning with the sole purpose of obtaining energy wood	Coniferous stands/ deciduous stands/ mixed stands:	Average diameter of the forest stand starting from:	Density of the forest stand, felling intensity:	Estimated volume of energy wood (bulk m^3/ha) beginning from:
1.	Coniferous stands/ deciduous stands/ mixed stands	5 cm	After assessment in nature	Depending on forwarding distance
2.	-	12 cm	With large forest stand density	-
3.	Mixed stands	6 cm	Leaving basal area above average	100 $m^{3(loose)}$of the total volume
4.	Deciduous stands	15 cm	10%	100 $m^{3(loose)}$/ha
5.	-	10 cm	-	100 $m^{3(loose)}$/ha
6.	-	10 cm	10%	100 $m^{3(loose)}$/ha
7.	Deciduous stands	4 cm	5%	50 $m^{3(loose)}$/ha
8.	-	15 cm	10%	-
9.	-	10 cm	Medium-thick and thick stands	-
10.	Deciduous stands/ mixed stands	5 cm	12%	150 $m^{3(loose)}$/ha
11.	Coniferous stands/ deciduous stands/ mixed stands:	5 cm	Density 15, intensity 1 times	100 $m^{3(loose)}$/ha
12.	-	12 cm	10%	-
13.	-	12 cm	10%	-
14.	Deciduous stands	8 cm	15%	-
15.	Deciduous stands/ mixed stands	-	50%	-
16.	Mixed stands	-	-	-
17.	Coniferous stands/ deciduous stands	-	-	-
18.	Deciduous stands	4-14 cm	-	30-70 m^3/ha

5. *What parameters and conditions of the forest stand make the harvesting process more difficult?*

Factors affecting the harvesting process	Number (35=100%)
Forest growing conditions type	12 (34%)
Terrain	12 (34%)
Forwarding distance	5 (14%)
Soil carrying capacity	4 (11%)
Weather conditions	2 (6%)

6. *Is the production of energy wood profitable from thinning operations of young stands or 20-30-year-old forest stands?*

	Number (21=100%)
Yes	12 (57%)
No	9 (43%)

7. *If the production of energy wood in the thinning operation of young stands is currently not profitable, what should be the minimum price for one loose cubic meter at the roadside landing?*

Minimum price of energy wood in thinning operation at the roadside storage in EUR per $m^{3(loose)}$	Number (18=100%)
7.0	2 (12%)
7.75	1 (6%)
8.0	2 (12%)
9.0	2 (12%)
10.0	3 (18%)
12.0	3 (18%)
13.0	1 (6%)
14.0	1 (6%)
15.0	2 (12%)
Dependent on development cost	1 (6%)

8. *What are the optimum preparation costs for energy wood in the felling area?*

Optimum preparation costs for energy wood in thinnings, in EUR per $m^{3(loose)}$	Number *(13=100%)*
2.5	5 (38%)
3.0	2 (15%)
4.0	2 (15%)
6.0	1 (8%)
6.5	1 (8%)
7.0	1 (8%)
10.0	1 (8%)

9. *What are the optimum energy wood forwarding costs to the roadside storage site?*

Optimum energy wood forwarding costs to the roadside storage site for thinnings, EUR per $m^{3(loose)}$	Number (18=100%)
2.5	7 (39%)
3.0	5 (28%)
4.0	2 (11%)
5.0	2 (11%)
Other	2 (11%)

10. *Do you see potential in the future? What would promote development in this sector?*

	Number (12=100%)	Recommendations
Yes	9 (75%)	Upgrading the mechanised extraction of energy wood. Educating forest owners. Increasing the price of energy wood. Independent energy wood outlets. Substitution of fossil fuels with energy wood for heat energy.
No	3 (25%)	

11. *Would the production of energy wood in young stands be able to replace the thinning operations of young stands?*

	Number (18 = 100%)
Yes	3 (17%)
No	9 (50%)
Partly	6 (33%)

2. ENERGY WOOD PRODUCTION FROM OVERGROWTH

12. Do you have experience in the production of energy wood from overgrowth?

	Number (36=100%)
Yes	30 (83%)
No	6 (17%)

13. What harvesting techniques have you used? List their advantages and disadvantages.

Harvesting techniques in cutting overgrowth	Advantages	Disadvantages	Number (32=100%)
Chain Saw	Greater assortment output. Work is more qualitatively done. Lower development costs. After development, the stand is cleaner. Access to hard-access logging areas. Less damage to the stand. Development takes place through human resources.	Lack of labour. Low productivity. Alcohol abuse problems among employees. Human factor.	22 (69%)
Harvester	High yields. Easier development. You can work in all weather conditions. It is also possible to work at night. Less human resources needed.	Low-quality stumps remain. Cumbersome release assortments. Not suitable for large dimension trees. High cost of work. Lack of skilled workforce. After development, there are many felling residues that interfere with further operations.	10 (31%)

14. What circumstances make the harvesting process more difficult?

Factors affecting the harvesting process of overgrowth removal	Number (37=100%)
Weather conditions	14 (38%)
Forwarding distance	4 (11%)
Forest growing conditions type	4 (11%)
Problems with the labour force	4 (11%)
Terrain	4 (11%)
Seasonality	2 (5%)
Soil condition	2 (5%)
Other conditions	9 (24%)

15. *Do you additionally produce assortments during the process of overgrowth removal?*

	Number (30=100%)
Yes	29 (97%)
No	1 (3%)

16. *What are the minimum overgrowth parameters to achieve profitable energy wood production (the estimated volume of energy wood, outcome of assortments, soil bearing capacity, terrain)?*

Minimum parameters of overgrowth	Number (16=100%)
The stand age must be at least 10 years old.	2 (13%)
The minimum area of overgrowth must be at least 1 ha.	2 (13%)
The minimum volume of chips to be harvested is 90 $m^{3(loose)}$.	2 (13%)
The minimum volume of chips to be harvested is 200 $m^{3(loose)}$.	2 (13%)
The average diameter of overgrowth trees > 5 cm.	1 (6%)
The minimum volume of roundwood to be harvested is 100 m^3.	1 (6%)
The minimum volume of roundwood to be harvested is 50 m^3/ha.	1 (6%)
The minimum area of overgrowth must be between 0.5 and 1 ha and be located close to a roadside landing.	1 (6%)
The minimum volume of chips to be harvested is 100 $m^{3(loose)}$.	1 (6%)
The minimum volume of chips to be harvested is 250 $m^{3(loose)}$.	1 (6%)
The minimum volume of chips to be harvested is 300 $m^{3(loose)}$.	1 (6%)
The average tree height in overgrowth must be at least >6 m.	1 (6%)

17. *What are the optimum preparation costs for energy wood in the logging area?*

Optimum preparation costs for energy wood during overgrowth removing operation	Number (23=100%)
6.0 EUR/m^3	1 (4%)
6.5 EUR/m^3	1 (4%)
7.0 EUR/m^3	1 (4%)
10.0 EUR/m^3	1 (4%)
13.0 EUR/m^3	2 (9%)
1.5 EUR/$m^{3(loose)}$	1 (4%)
2.0 EUR/$m^{3(loose)}$	4 (17%)
2.2 EUR/$m^{3(loose)}$	1 (4%)
2.5 EUR/$m^{3(loose)}$	6 (26%)
2.7 EUR/$m^{3(loose)}$	1 (4%)
3.0 EUR/$m^{3(loose)}$	3 (13%)
5.0 EUR/$m^{3(loose)}$	1 (4%)

18. *What are the optimum forwarding costs for energy wood to the roadside landing?*

Optimum forwarding costs of energy wood during overgrowth removal	Number (26=100%)
2.0 EUR/$m^{3(loose)}$	4 (15%)
2.5 EUR/$m^{3(loose)}$	10 (38%)
3.0 EUR/$m^{3(loose)}$	7 (27%)
3.5 EUR/$m^{3(loose)}$	1 (4%)
4.0 EUR/$m^{3(loose)}$	3 (12%)
5.0 EUR/$m^{3(loose)}$	1 (4%)

3. PRODUCTION OF ENERGY WOOD FROM LOGGING RESIDUES AT THE FINAL FELLING

19. *Do you have experience in the production of energy wood from logging residues during the final felling?*

Contractors	Number (35=100%)
Yes	28 (80%)
No	7 (20%)

20. *What harvesting techniques have you used? List their advantages and disadvantages.*

Harvesting techniques	Advantages	Disadvantages	Number (22=100%)
Chain saw	More careful work and cleaner felling area after operations. Greater assortment output. Easier to restore forest stand. Lower costs. Branches are stacked neatly in piles.	Unemployment. Problems with alcohol among employees. Labour shortages. Low productivity. Human factor. Lack of qualifications.	15 (68%)
Harvesters	Can work in bad weather conditions and darkness. High productivity. After operations, a larger amount of felling residues remains.	Smaller assortment output. It is not possible to handle large dimension trees. Forest strip roads are more difficult to harvest, and energy wood may be covered with mud that makes it worthless.	7 (32%)

21. *What felling site conditions are suitable for forwarding logging residues?*

Suitable conditions for forwarding logging residues in final felling	Number (37=100%)
Dry-type forests	19 (51%)
Length of forwarding road	16 (43%)
Frost conditions	4 (11%)
Possibility to coordinate the forwarding and roadside landing	3 (8%)
Terrain	2 (5%)
Other	3 (8%)

22. *What conditions influence the choice to forward logging residues for the production of energy wood?*

Factors influencing the delivery of logging residues for the production of energy wood in final felling	Distance of forwarding	Volume of estimated wood in $m^{3(loose)}$/ha	Quality of energy wood (compositions of species, other)	Accessibility of roadside landing	Value of logging area purchase	Company's need for energy wood	Logging area owner's requirements	Other
1.	500 – 700 meters	Any	Deciduous trees, with conifer impurity up to 20%	If there is an opportunity to match with the forest owner				
2.	X	X	X	X		X		
3.	X		X	X			X	
4.	X			X	X		X	
5.	X			X				
6.		X	X					
7.	X		X	X	X	X	X	
8.	X	X	X	X	X	X	X	
9.	X		X	X			X	
10.	X			X	X			
11.	X	X						
12.	X	X	X	X		X	X	
13.	X	35 m^3		X	X		X	Strip road width
14.	X	X	X	X		X	X	
15.	X	X	X	X		X	X	
16.	X	X		X				
17.	X							
18.	Up to 1 km	200 $m^{3(loose)}$	Deciduous trees	Closer to removal roads		Contractual obligations		

Table 22 continuing

Factors influencing the delivery of logging residues for the production of energy wood in final felling	Distance of forwarding	Volume of estimated wood in $m^{3(loose)}$/ha	Quality of energy wood (compositions of species, other)	Accessibility of roadside landing	Value of logging area purchase	Company's need for energy wood	Logging area owner's requirements	Other
19.	X	50 $m^{3(loose)}$		X				
20.	X	X	X	X	X	X	X	
21.	Up to 800 meters	300 $m^{3(loose)}$	X	X			X	
22.	X	50 $m^{3(loose)}$	All kinds of timber	X	Depending on wood quality			
23.	Up to 1 km	50 $m^{3(loose)}$	All kinds of timber	X			X	
24.	X	X	X	X	X	X	X	
25.	X	150 $m^{3(loose)}$	Deciduous trees	X	X		X	
26.	X			X			X	
27.	X	X					X	
28.	X			X			X	
29.	Up to 500 meters		X		X			
30.	X			X				Soil carrying capacity
31.		X						

23. What are the optimum forwarding costs of energy wood to the roadside landing?

Optimum forwarding costs of energy wood in final felling	Contractors (24=100%)
2.0 $EUR/m^{3(loose)}$	4 (17%)
2.5 $EUR/m^{3(loose)}$	8 (33%)
3.0 $EUR/m^{3(loose)}$	5 (21%)
3.5 $EUR/m^{3(loose)}$	1 (4%)
4.0 $EUR/m^{3(loose)}$	3 (13%)
4.5 $EUR/m^{3(loose)}$	2 (8%)
5.0 $EUR/m^{3(loose)}$	1 (4%)

24. What conditions determine the forwarding of felling residues immediately after felling, or leaving them in the felling area to dry out and delivering them later?

List the advantages, disadvantages and circumstances from your experience.

Harvesting technique in final felling	Advantages	Disadvantages	Contractor *(29=100%)*
Forwarding at once	Lower cost of machinery relocation. Felling residues are quickly used. An immediate closure of the logging area is possible. More biomass is collected.	Conifers must wait 6-12 months before they can be chipped. Roadside landing occupancy. Low material quality. High moisture percentage. Timing of harvesting with additional risk of machine damages or jamming.	23 (79%)
Forwarding later	The drying process in the felling area is faster. A round assortment roadside landing can be used when forwarding. Reduction of green mass. Felling residues can be collected simultaneously from several clos felling areas. Increased MWh.	Machinery units must be reported to the felling site. Dry branch piles have a high risk of ignition.	6 (21%)

25. *Do forest certification requirements influence the opportunity to produce energy wood from felling residues? Which are the main requirements which determine the choice? (SBP, FSC, PEFC)*

	Number (19=100%)
Yes	11 (58%)
No	8 (42%)

How long have you been active in the sector?	**Number (37=100%)**
Up to 5 years	**2 (5%)**
5–10 years	**9 (24%)**
More than 10 years	**26 (70%)**

Age of machinery	**Number (40=100%)**
Up to 5 years	10 (25%)
5–10 years	14 (35%)
More than 10 years	16 (40%)

Operational regions	**Number** *(37=100%)*
Vidzeme	22 (59%)
Latgale	22 (59%)
Zemgale	6 (16%)
Kurzeme	3 (8%)
Entire Latvia	1 (3%)

Appendix 4

LITHUANIA COUNTRY REPORT
DETAILED INFORMATION ON FOREST BIOENERGY

1. BACKGROUND

1.1 State-of-the-art of the Bioenergy Sector in Lithuania

During the last 20 years Lithuania has become an example of energy independence and the development of renewable energy for other countries. The aim of National Energy Independence Strategy of Lithuania is to increase energy efficiency and the use of renewable energy sources (RES) as part of the daily life of each consumer, business or industry that purchases electricity, gas, biofuels or other fuels/raw materials. RES provide the most promising source of energy for the development of domestic energy production. Therefore, development of RES and improvement of energy efficiency in line with reduction of environmental pollution will be supported by financial and non-financial measures[13].

The National Energy Independence Strategy sets ambitious goals, but Lithuania is ready to achieve them. In 2016 Lithuania has already reached the targets of the EU Directive regarding the Incentives for Consumption of Renewable Energy Resources for Lithuania to increase this rate to 23% until 2020. In 2016, for the first time, more than half of the energy produced in Lithuania was transformed from renewable sources. Already since 2012 Kaunas city (second largest city in Lithuania) about 90% of district heating is covered with biomass, when almost all heat demand was covered with natural gas. Most of all small towns have biomass district heating and it is very often, that biomass energy covers 100% of necessary heat. The use of biomass for energy production in industry sector is also increasing.

Biomass energy industry in Lithuania has grown itself during the last decade. More than 7,500 people are employed in technological companies and production and supply of biomass. The export of technological equipment reached 100 million EUR in 2017 but is expected to grow up. More than 200 companies work in the whole bioenergy chain (from biomass producers and suppliers till science). About 20 companies are producing and exporting bioenergy technologies.

Table 1. Firewood and wood waste consumption.[4]

	th. m³		
	2015	2016	2017
Gross consumption of firewood and wood waste	6,123.5	6,130.0	6,401.7
Energy transformation:	2,967.3	2,966.3	3,362.8
Public CHP plants (mainly to produce electricity)	776.2	703.8	854.8
Public heating plants (mainly to produce heat)	2,071.6	2,141.8	2,358.7
In boilers of industrial enterprises	119.5	120.7	146.8
Other (Transformation by charcoal plants etc.)	5.1	5.6	2.5
Final consumption	3,151.3	3,158.4	3,108.8
Industry	429.3	460.5	485.5
Construction	7.6	8.9	8.8
Agriculture	46.8	53.0	69.3
Commercial and public services	162.5	165.7	145.2
Households	2,505.1	2,470.3	2,400.0

In 2009 the Ministry of Energy of the Republic of Lithuania predicted that the share of renewable energy in the gross final energy consumption will increase from 17.6% in 2010 to 23.3% in 2020[14]. However, already in 2016, renewable energy sources accounted for about 25.5% of the final energy consumption in Lithuania. Firewood and wood waste consumption increased in industry and agriculture (Table 1). Public CHP plants and heating plants are using more firewood and wood waste for energy production. The biofuel and municipal waste part of the energy used in the central heating system during last decade strongly increased. The use of biofuels for heat production has doubled in the last five years—from 33.4% in 2014 to 68.6% in 2017 (in 2007 only 2%). The consumption of electricity from RES in 2016 was about 17%, and in the total heat consumption it was about 46%, and in the transport sector it amounted to about 4%. A significant share of the resources for energy production come from wind and biofuels (solid and liquid).

By 2025, at least 38% of electricity consumed in Lithuania will be produced from RES and will constituted no less than 5 TWh. Taking into consideration the assessment of the technology development trends, it is estimated that at least 15% electricity from 5 TWh could come from biofuel.

The most widely used type of biofuel for heat production in Lithuania are wood chips. During the 2018-2019 heating season 272 thousand tons of biofuel were purchased from the Baltpool Energy Exchange in total. In the 2018-2019 heating season 69% of the fuel supplied consisted of 2nd quality class wood chips, 22% 3rd quality class wood chips, 8% 1st quality class wood chips (Fig. 1). There are approximately 200 local biofuel (pellets and/or chips) sellers on the Baltpool Energy Exchange (including state and private companies) and approximately 90 buyers. Private companies can buy biofuel directly from the producers. Central heating system (CHS) companies and other state companies have to buy biofuel using the Baltpool Energy Exchange.

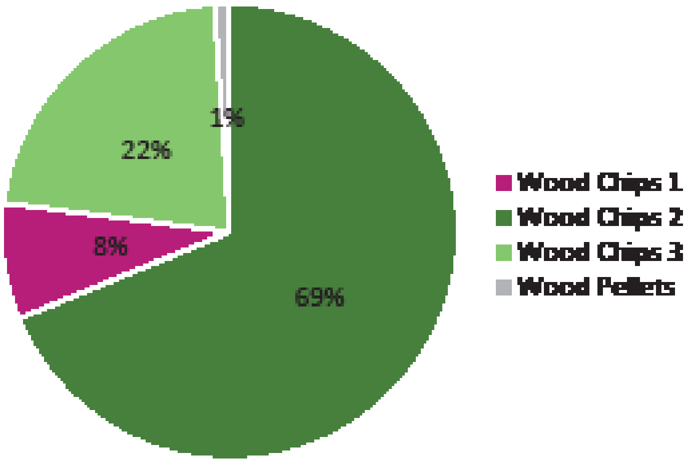


Figure 1. Distribution of biofuels for the 2018-2019 heating season in percentages.[3]

Lithuania has great potential for biofuel production. The amount of prepared merchantable round wood increased and amounted to 7.0 million m^3 in 2016. The volume of wood produced during commercial thinning decreased by 1% to 587,000 m^3 and constituted 15% of the total harvests in 2016. About 25-30% of the prepared merchantable round wood were stumps, logging residues, small trees etc. and only 10-15% of this is collected and used for biofuel production. Sales of forest felling residues increased, but still about 80% of the volume of tree branches, stumps and bushes remain in the forests to decompose[14]. Annually only 65% of total wood available in Lithuania is used, though the potential for sustainable forest farming is approximately 90-95%. In the future, harvesting low-value stands dominated by grey alder and poplar for wood fuel seems inevitable. At the moment only one third of this resource is used for fuel. This segment in the future may increase, as there are plans to increase the cutting rate in Lithuania in order to intensify the use of low-yielding stands. It is estimated that it would be possible to produce twice as much logging residues as currently produced, which would amount to about 1.7 TWh of energy.

The raw material for biofuels only provides small additional earnings of about 10-15% in state forests. In order to increase the collection of logging waste, it will first be necessary to increase the economic attractiveness of this activity at the primary level.

1.2 Estimated Theoretical Volume for the Business and Restrictions to be Noted

1.2.1 National-Level Targets

According to the National Energy Independence Strategy one of the main aims in the energy sector is to increase energy efficiency and the use of renewable energy sources (RES) as part of the daily life of each consumer, business or industry that purchases electricity, gas, biofuels or other fuels/raw materials. By 2025, at least 38% of the electricity consumed in Lithuania will be produced from RES and will constitute no less than 5 TWh. Taking into consideration the assessment of the technology development trends, it is estimated that at least 15% of this will be derived from biofuel. By 2030, no less than 16% of the country's energy should be produced from biofuel in highly efficient cogeneration power plants. Lithuania seeks to achieve sustainable energy and be a fully energy-independent state in 2050. There are two main objectives of the strategy: firstly, 80% of the country's energy needs should be generated from non-polluting sources (with zero emissions of greenhouse gases (GHG) and air pollutants) and secondly there should be 100% local electricity production for the country's gross electricity consumption. To achieve these aims it will be necessary to develop effective and non-polluting energy production, supply, storage/accumulation and consumption technologies.

The national heat sector development 2015-2021 programme provided reduce the heat price and environmental pollution. Local and renewable resources must be a priority in the energy balance. In the period of 2015-2021 heating network will be renewed, losses of energy transmission already reduced up to 14%. Using EU funding old non-biofuel plants will be renewed.

Private householders are being encouraged by the government to use biofuel instead of gas and coal. Private householders can buy biofuel with 5% VAT (21% VAT for companies) and they can use EU funding to upgrade their coal, gas or ineffective biofuel boilers to new fuel-efficient boilers.

1.2.2. Current Forest Bioenergy Plants

The number of bioenergy plants in Lithuania is growing. 199 bioenergy plants were operating in 2010. In 2016 there were already 332 biofuel plants. The installed capacity of biomass boilers increased from 395 MW in 2010 to 990 MW in 2016 (Table 2). Approximately 260 biofuel plants belong to the central heating system in Lithuania[6]. All other plants are independent heat suppliers. In 2016, 55 industrial companies had bioenergy plants for their own use. Their capacity reached 20 MW (Table 3). One of most powerful boilers belongs to a private company Pajūrio mediena whose installation capacity is 64 MW. From 2008 to 2016, the biomass installations in industry all together used 120,000 tons of oil equivalent biomass.

Table 2. Installed capacity of biomass boilers.[6]

	Year	2010	2011	2012	2013	2014	2015	2016
Installations, MW	District heat suppliers (heating utilities)	395	440	520	716	749	990	990
	Independent heating suppliers	123	126	146	323	432	537	599
	Total	518	566	666	1,039	1,181	1,527	1,589

Table 3. Biomass installations in industry.[6]

	Year	2010	2011	2012	2013	2014	2015	2016
Number of installations	Capacity, MW	148	166	167	218	264	300	320
	< 1 MW	16	16	16	16	16	16	16
	1 - 5 MW	19	18	19	20	22	23	24
	> 5 MW	5	6	6	9	11	12	15
	Total	40	40	41	45	49	51	55

In power plants using RES in total, 1,510 TWh of electricity was produced in 2014. This represented 12.6% of the total domestic consumption of electricity[6]. The theoretical potential for biofuels is sufficient to meet the entire demand for electricity in Lithuania. However, the technical potential exists only through the beneficial use of heat, i.e. connecting biofuel power plants to existing district heating (DH) systems. The technical potential is about 350 MW[9].

1.2.3. *Potential for New Energy Generation Plants*

There are not many wood-based energy generation plants under planning or construction. A new biofuel plant (48 MW) near Vilnius was opened in 2019. It is an example of private equity-funded infrastructure that aims to mitigate climate change.

However in Lithuania, there are a lot of plants under reconstruction (gas boilers are being converted to wood fuel boilers etc.) using EU funds. For example, AB Panevėžio energija rebuilt one of the city's boiler houses. The installation of a new 8 MW biofuel boiler combined with a 1.8 MW condensing economiser has replaced the operation of the previously used natural gas fired boiler. The new boiler started operation in July 2019. Furthermore, AB Panevėžio energija will be reconstructing another boiler in 2020.

1.2.4. Available Forest Biomass resources

In 2017 the total forest land area in Lithuania was 2,189,600 ha, covering 33.5% of the country's territory. Since the 1st January 2003, the forest land area has increased by 144,300 ha corresponding to 2.2% of the total forest cover. During the same period, forest stands expanded by 107,400 ha to 2,058,400 ha.

Scots pine accounts for the largest share of Lithuanian forests, covering 713,200 ha. Compared to 2003, the area of pine expanded by 1,700 ha. Norway spruce stands cover 429,500 ha of the country, with a reduction of 15,800 ha. Birch stands cover the largest area among deciduous trees. Since 2003, this area increased by 64,400 ha and reached 456,600 ha by the 1st of January in 2017. The area of black alder increased by 36,600 ha to 156,100 ha. The area of grey alder decreased by 400 ha reaching 121,600 ha. The area of aspen stands expanded by 36,500 to 93,800 ha.

Changes in the felling rates in state forests were insignificant over the last five years. The volume from final fellings in state forests came to 2.7 million m^3. The share of the final felling constituted 70% of the total harvest (72% in 2015). The volume from intermediate felling increased by 4% to 1.2 million m^3. The volume of wood processed in commercial thinning operations decreased by 1% to 587,000 m^3 and constituted 15% of the total harvests. The felling rates in private forests increased from 2.9. million m^3 to 3.1 million m^3.

The average harvestable wood fuel volume has been estimated to be 5.8 million m^3 annually[11]. Firewood amount to 1.8 million m^3 annually of this amount. This quantity corresponds to 21% of the volume of the round wood being processed. The theoretical volume for forest chips is 4 million m^3. There is potential to make wood chips from 0.85 million m^3 of roundwood logging residues, 0.3 million m^3 of forest stumps, 0.3 million m^3 of biomass from young stand treatments, 0.25 million m^3 of biomass from short rotation coppices, 0.6 million m^3 of biomass from low-value stand reconstruction, 0.2 million m^3 of biomass from park and landscape treatment per year. Theoretically, the felling of low-values stands at this intensity (0.6 million m^3 per year) would be possible for many years, but to plan more intensive use of low-value stands is difficult, because most of them belong to private forest owners. The owners need to be financially interested and currently only 15-20% of logging waste is collected and used for biofuel. According to scientists, about 50% could be used without violating eco-sustainability requirements[1].

The supply of wood fuel (excluding imports and exports, industrial wood residues, and firewood) nowadays in Lithuania is approximately three million m^3. In the future, the harvesting of low-value stands dominated by grey alder and poplar for wood fuel seems inevitable. At the moment only one third is used for fuel.

Biofuel processors are still preparing a lot of raw materials from abandoned fields and ditches, which farmers often give away free of charge. For this reason biofuel processors are not willing to pay even a few extra euros for logging residuals. Small-scale private plants could engage in biofuel production by themselves in that way. Central heating system (CHS) companies need to buy fuel from the Baltpool Energy Exchange. The demand for biofuel still exceeds the supply level, thus raising the annual price of logging residues in the biofuel auction of the first half-year in 2018 by 39% (compiled only from data on the state's forestry sector). The trend towards mounting prices will remain in the future as well, yet not so drastically. Human resources are lacking in the field for making biofuel because of low salaries.

From May 2018 solid biofuel quality requirements will apply to all producers, importers, traders or users of solid biofuels in Lithuania[5]. Over the last ten years, Lithuania has made significant progress in converting its heat sector from fossil fuels to renewable biofuels, and biofuels today account for two-thirds of total combustion in district heating and the share of biofuels in households is even higher. It is necessary to control the solid biofuel quality to reduce environmental pollution.

1.2.5. Current District Heating Systems and Investment Needs in Lithuania

The district heating (DH) sector in Lithuania accounts for more than 50% of the country's total heating sector. The rest of the sector includes individual heating consumers, mainly using gas or solid fuel boilers. More than 40 independent heat producers were operating in the DH production market. 31.3% of the energy used in DH was produced by independent heat producers. In 2017, 49 licensed heat supply companies were operating in the DH sector with annual sales of heat exceeding 10 GWh.

The main consumers of district heating are residents living in apartment buildings (Fig. 2). In 2017, they sold about 73% (5,554 GWh) of the total amount of thermal energy sold. This was a 0.3% growth in heat users. Only 0.05% of customers terminated their contracts with DH companies in 2017. In 2012–2017, the average heating price decreased by as much as 38% and currently stands at 4.75 cent/kWh excluding VAT.

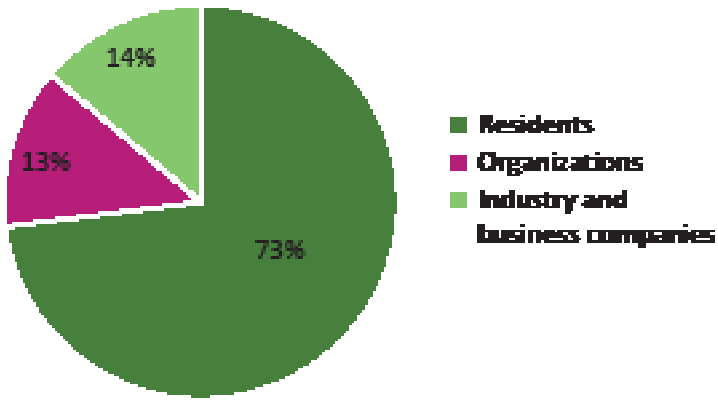


Figure 2. Structure of heat energy consumers in percentages.[12]

The total length of the Lithuanian DH sector, including sections operated by non-heat suppliers, is approximately 2,846 km. Over the period 2007-2013, using EU structural funds, has been updated about 12% the total length of DH lines. Piping replacement is a slow payback investment. Heat transfer losses in the pipeline system reach 15.5% or 1.38 TWh[14].

1.3. Policy Instruments with Key Elements Promoting the Forest Bioenergy Business

There are currently no promotional programmes for using logging residues or stumps for biofuel. Stumps can be used from non-forestry land, which has grown vegetation over a period of 25 years and returned to agricultural land. It is possible to harvest stumps only from clear cutting, but not from all stands. Stumps cannot be taken from protected areas[11]. The use of logging residues and stumps in areas with poor vegetation is not allowed. Plantation forestry or plantations of fast growing tree are not a national priority. State forest companies do not cultivate such plantations. Only private companies and farmers tend to cultivate fast growing trees in plantations. Until 2013 EU support for plantation production was allocated. Now there is no real support.

There are some ongoing discussions on how to promote using logging residues for biofuel in state forests. At the moment only 2% of all the biofuel on the Baltpool Energy Exchange is provided by the State Forest Company. Due to technical issues the State Forest Company gains only a very small profit from using logging residues for biofuel. At the same time there are some intentions to ban the use of chips for energy from logs larger than a certain diameter, because they could be used by furniture industry companies. This could lead to a more intensive use of logging residues and reduce competition between biofuel producers and industry. Lithuania has an annual limit on the amount of wood that can be cut. Increasing the harvesting rate or more efficient use of raw materials could provide raw materials for both the industry and the energy sector.

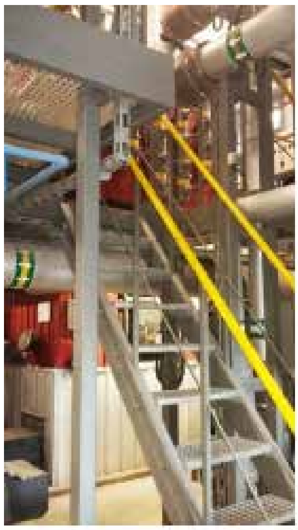
A large part of the waste from the large wood industry is used in the production of pellets, because it prepares clean sawdust and chips without bark; a lot of waste is consumed by wood-based panels (Ikea Industry Lithuania, Klaipeda Wood and Grigeo). Of these companies, bark and other wood waste is mainly used for energy production.

2. CONCLUSIONS ON THE BEST PRACTICES IN THE COUNTRY-SPECIFIC CONDITIONS

2.1. Best Practices in Lithuania

<table>
<tr><td colspan="2">A. Juškos ūkis Bioenergy Plant</td></tr>
<tr><td colspan="2">Before 2015 the plant owner’s greenhouses were heated by natural gas fuelled boilers and additional small biofuel boilers (totalling 2 MW). Due to shortages and the high price of heat energy, the owner decided to build new and more powerful biofuel plant. Nowadays a Kalvis K-4000MK 4 MW is installed as the main boiler. A substitute Kalvis K-2000MK 2 MW boiler is also installed, but this is used only as an emergency option or during the summertime, when a lower amount of energy is required.

The plant uses woodchips, which are stored near the plant in a warehouse. The owner of the plant produces biofuel himself from his own land and from the land of neighbouring farmers. The plant produces 33,000 MWh of heat energy annually on average. The annual raw material use amounts to approximately 37,000 m³ of wood chips (SM2 standard, 35% moisture content).

The produced heat is used by the owner’s farm only.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Picture 1. Woodchips before entering the bunker. (Photo: Vidmantas Verbyla)</td><td>Picture 2. Boiler. (Photo: Vidmantas Verbyla)</td></tr>
</table>

UAB Kietaviškių gausa Bioenergy Plant

Before 2017, UAB Kietaviškių gausa was supplied with heat from the nearby Elektrėnai power plant fuelled by natural gas, which is presently the largest electricity provider in Lithuania. Since 2017 the company has had its own bioenergy plant. The plant consists of one 5 MW VHG-5000 boiler in addition to a 1,500 m^3 accumulation tank. The annual raw material use is 10,200 metric tonnes or approximately 9,000 solid m^3. The annual energy production of heat is approximately 20,000 MW.

The heat power plant is fuelled by wood chips. The fuel is acquired from several local suppliers, most notably from a BOEN owned sawmill and largely consists from very high-quality chips made from oak and ash timber. This fuel type was selected during the planning of the power plant due to local availability, price and opportunity to mix it with coconut splint, which is in abundance as a production residual in UAB Kietaviškių gausa.

UAB Kietaviškių gausa is the only user of the produced energy. The plant is fully automated and requires just two operators at a time. The UAB Kietaviškių gausa power plant is a good regional example of how to facilitate the growth of small or medium sized businesses involving state-of-the-art wood-fuelled energy technologies. In the countryside of Lithuania, heat produced by plants burning wood fuels are often the only available option due to the lack of other heat energy sources.

Picture 3. *UAB Kietaviškių gausa bioenergy plant. (Photo: Vidmantas Verbyla)*

UAB Jurbarko komunalininkas

This heating plant in Skirsnemunė is owned by Jurbarkas district municipality and operated by UAB Jurbarko komunalininkas.

Two Grandex 100 boilers, comprising 200 KW combined, are installed. One boiler is used as an emergency backup. The annual raw material use totals 70-80 tons of wood pellets (30 tons of oil equivalent). The plant produces 227 MWh of heat energy annually on average. The plant storage can accommodate up to 40 tons of fuel. Pellets from storage to the boiler are transferred by pneumo-transporter. Technology-wise, it is a modern fully automated installation, requiring one person during the heating season to operate part-time. Plant is fully automated.

The heat power plant is fuelled using granulated sawdust. During the planning of this plant, wood pellets were selected as the preferred fuel type due to the relatively low power of the installation, as well as the lower price of instalment and simplicity of pellet-powered boilers maintenance, requiring only one employee to operate and thus reducing operation costs.

Heating energy is supplied to the local school, cultural center and a kindergarten, or to 2,962 m² combined.

Picture 4. Pellets storage. (Photo: Valda Gudynaitė-Franckevičienė)

Picture 5. Boiler. (Photo: Valda Gudynaitė-Franckevičienė)

2.2. Issues Faced by the Stakeholders

Energy independence is being discussed, however imports of Belarussian chip have increased by 50% and account for about 1/3 of the biofuel market. Although Lithuania has great potential for biofuels cheaper Belarussian biofuels are traded on the Baltpool Energy Exchange, which increases the energy dependency of Lithuania on this resource. Indigenous biofuel production has declined due to additional income from other forestry activities.

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Appendix 5

BASICS OF THE FOREST ENERGY ATLAS (FEA) AS A PROJECT PRODUCT OF WORK PACKAGE WP4

The Forest Energy Atlas is an open access Internet map service showing the energy wood procurement potential on a regional basis in Estonia, Finland, Latvia, Lithuania and Sweden.

The following organizations have contributed to the development of the application:
Estonia: Estonian University of Life Sciences & Foundation Private Forest Centre
Finland: Natural Resources Institute Finland
Latvia: Latvia University of Life Sciences and Technologies & Latvian Rural Advisory and Training Centre
Lithuania: Kaunas Forestry and Environmental Engineering University of Applied Sciences & State Forest Enterprise
Sweden: Swedish University of Agricultural Sciences

The use of the Forest Energy Atlas (GIS platform and database) is supported by a user guide and the materials have been produced in close cooperation with key stakeholders to present spatially explicit estimates of the forest biomass potential. The application is available at: http://test-forest-energy-atlas.luke.fi/ with the username "featester" and password "Forest2018Proto". Feedback can be sent to the address: fea@luke.fi

What Materials are Included in the Database of the Forest Energy Atlas?

The energy wood potential is estimated for the forest land available for wood supply based on the current guidelines for harvesting concerning all the included countries. The results are expressed as cubic metres, except in Sweden as dry tons. The assessment methods are described in the metadata in the Forest Energy Atlas.

The assortments included in the database for each country are as follows:

Estonia:

- Logging residues from final fellings, pine
- Logging residues from final fellings, spruce
- Logging residues from final fellings, broadleaved
- Stumps from final fellings, pine
- Stumps from final fellings, spruce
- Firewood from thinnings (trees smaller than pulpwood-size and low quality)
- Firewood from final fellings (trees smaller than pulpwood-size and low quality)
- Pulpwood from thinnings, pine
- Pulpwood from thinnings, spruce
- Pulpwood from thinnings, birch
- Pulpwood from thinnings, aspen
- Pulpwood from final fellings, pine
- Pulpwood from final fellings, spruce
- Pulpwood from final fellings, birch
- Pulpwood from final fellings, aspen
- Sawlogs from thinnings, pine
- Sawlogs from thinnings, spruce
- Sawlogs from thinnings, birch
- Sawlogs from thinnings, aspen
- Sawlogs from thinnings, black alder
- Sawlogs from thinnings, other species
- Sawlogs from final fellings, pine
- Sawlogs from final fellings, spruce
- Sawlogs from final fellings, birch
- Sawlogs from final fellings, aspen
- Sawlogs from final fellings, black alder
- Sawlogs from final fellings, other species
- Bark from pulpwood and sawlogs, all species
- Logging residues from thinnings, pine
- Logging residues from thinnings, spruce
- Logging residues from thinnings, broadleaved

Finland:

- Stemwood for energy from 1st thinnings
- Stemwood for energy from 1st thinnings (smaller than pulpwood-sized trees)
- Logging residues from clear fellings, pine
- Logging residues from clear fellings, spruce
- Logging residues from clear fellings, deciduous
- Stumps from clear fellings, pine
- Stumps from clear fellings, spruce.

Latvia:

- Small diameter trees from pre-commercial thinnings, biomass in solid m^3
- Logging residues from commercial thinnings and selective final fellings, biomass in solid m^3
- Firewood from commercial thinnings and selective final fellings, assortment in solid m^3
- Logging residues from clear fellings, assortment in solid m^3
- Firewood from clear fellings, assortment in solid m^3

Lithuania:

- Small-diameter trees in stands dominated by coniferous tree species
- Small-diameter trees in stands dominated by broadleaved tree species
- Firewood in stands dominated by coniferous tree species
- Firewood in stands dominated by broadleaved tree species
- Logging residues in stands dominated by coniferous tree species
- Logging residues in stands dominated by broadleaved tree species
- Stemwood in grey alder stands
- Stumps in stands dominated by coniferous tree species
- Stumps in stands dominated by broadleaved tree species

Sweden:

- Branches – logging residues (pine, spruce and birch together)
- Stumps (pine and spruce together)
- Sawlogs (pine and spruce together)
- Pulpwood (pine, spruce and birch together)
- Bark (pine, spruce and birch together)

Practical Tips for the Use of Forest Energy Atlas

The map layers menu is the entry page to the biomass database that the user has access to in the Forest Energy Atlas. It includes biomass data from all the organizations that have contributed with the biomass potential. All the data are presented at 1 km x 1 km spatial resolution. The user has the possibility to use the search function to retrieve information on a specific map layer or data provider.

The user can select a region of interest in three ways:

a) Freely outlining a polygon;
b) Defining a center point and a radius of a circle;
c) Selecting from predefined regions (e.g. administrative boundaries)

General Conclusions

Energy wood related investments should not be made based only on the estimates that the Forest Energy Atlas provides. Market factors play an important role and this includes aspects such as the willingness of forest owners to sell the material in question and what price the purchasers are ready to pay for it. The general economic situation in the forest industry has a strong effect on the supply and demand of energy wood. Environmental regulations also influence decisions on whether to sell or not to sell. There are also differences between the countries in terms of what kind of forest resource information is available and how the used terminology has been defined for the subsections of the energy wood material.

Appendix 6

BUSINESS MODELS AND GOVERNANCE STRUCTURES FOR SMALL-SCALE FOREST BIOHEAT PRODUCTION WITH A SPECIAL FOCUS ON FOREST ENERGY CO-OPERATIVES

1. Introduction

This supplementary article to the Handbook WP 2 "Cost-effective and sustainable harvest methods" contributes to the outcomes of the Interreg Baltic Sea Region Program Baltic Forbio project, which offers a comprehensive range of views on business modelling as a driver for forest bioenergy use in the Baltic Sea Region.

The article highlights the economics and organizational aspects of small-scale local forest bioheat supply schemes set up as a market-driven business by their owners for earning them a profit and, apart from private self-interests, for promoting the social claims of their stakeholders. The article intends to provide insights into its readers about small-scale co-operative forest-based bioheat business models and governance structures as viewed against the background of the Finnish experience. Co-operatives have been demonstrated to be a convenient participatory model of organizing forest owners' joint business activities.

The intention of the article is to contribute to a basic understanding about the main characteristics of basic types of business models and of contractual and organizational structures and how they are affecting transaction costs. Transaction costs denote the indirect costs of production, that are caused by setting up, managing and monitoring (governing) the internal and external transaction relationships of a firm (corporation).

A business model is a tool largely applied in the field of strategic business management. A business model provides a shorthand description of a production system in terms of the economic value it creates, and the benefits thereby created to customers, owners, investors and other stakeholders. Further, it describes the set of activities and resources putting its value proposition into practice, and the way these activities are organized, and the resources are used to achieve on cost efficiency. Such a description offers a way to explore and report distinctive types of business behaviour. A business model may serve as a guide to setting up a new business along the lines being already tested and verified. In the sense of an ideal type, a business model may illustrate "best-practice" behaviour.

The intention is further to feature the co-operative model as a special form of corporate governance structure. The representation draws upon the concepts and theories of institutional economics, which constitutes an explanatory framework for the role of social institutions in shaping economic behaviour. This approach moves the conceptual perception of the firm as a set of technological relations between the inputs and outputs of production towards a definition as a social institution and a set of contractual relations.

Before a conceptual project design is ready to be proposed to a third party, decisions are to be made with respect to the technical feasibility, financial viability, the financing model of the project, as well as the contractual and the organizational setup of its activities and trade relations. A governance structure shapes the economic behaviour of individuals with the intention to reduce uncertainty, provide proper incentives and to ensure the operational efficiency of transactions.

2. The Concept of a Business Model

Whenever a business enterprise or a single business within is established, it either explicitly or implicitly employs a business model that describes the design or architecture of the value creation, delivery, and capture mechanisms it employs. A business model is delineated, first, by the value it creates to customers. A value proposition can usually be broken down into single value contributions related to discrete business activities. The second element is the net revenues it generates to its owners, which, on its part, depends on the ability to generate and capture willingness to pay, and on the operational efficiency of the discrete activities, which contribute to the value delivered to and to be paid for by the user. The third strategic element is its value architecture, comprising technologies, resources and competencies, and how well their use is organized and managed for the expected outcome to be achieved.

A successful business model is determined by its ability to achieve an attractive return on investment to its owners. Therefore, it must ensure that a sufficient portion of the value it creates is appropriated by its owners themselves rather than by external chain members. A successful business model requires that customers are willing to pay a price for the product or service it creates that exceeds the cost of producing it. For energy production, the architecture of value creation is tantamount to a production system spanning an upstream supply chain, which is designed and operated cost efficiently. For a business model to be socially and environmentally sustainable it must create value to the users of its products, to its stakeholders and the environment.

A business model for operating a local forest bioheat supply system creates value by deploying local forest feedstock resources. Its core technology is composed of a production system, where thermal energy is generated from the incineration of forest-based wood fuels. Its core activities comprise procuring primary energy inputs from forest feedstock resources and operating the heat production facility, possibly including heat distribution. Solid wood fuels, as the main primary energy source, are provided from local forest resources owned either by the heat supplier itself or purchased from other feedstock sources in its vicinity. The production of wood fuel may be either controlled by the forest owner or organized by a contract agent.

Important for the performance of a business model in terms of its ability to create and capture value to its stakeholders besides the functioning and integration of technical processes are governance structures and social mechanisms of coordination. The description of a business model may be appropriate to confine on a single business entity as the unit of analysis, if the activities and the linkages between them, which are of strategic importance for the model's performance, reside within its boundaries. For a business model in local small-scale forest bioheat production, where dependencies between independent network partners prevail, a broader system perspective is more appropriate. Applying a broader perspective allows considering the arrangements governing the contributions of independent business partners that are responsible for activities, which are the major components of the business model.

3. Forest Bioheat Contracting

Two different kinds of heating schemes can be identified in terms of the architecture and scale of the business operations (business model). These are a single property - single client heating schemes and multi property - multi client heating schemes. The former is commonly denoted as a community heating scheme. Business models employing one or the other of these heating schemes due to the difference in size vary as to their main stakeholders.

A single property - single client heating scheme may comprise multiple buildings all connected to the same on-site boiler plant. A community heating setup differs mainly with respect to the scale of operations, including the responsibilities to maintain a more extended heat distribution network and, as a result, the enhanced capital investments needed, and the business risks involved. There is an enhanced demand risk of a declining customer base due to the different terms of contract.

An on-site single property set up may comprise a public school, a college building, a boarding school, parish houses, a care home or a greenhouse farm. A community varies in size and constitution. A community usually comprises a township or neighbourhood, where setting-up a bio-heating system may be linked to area regeneration.

In the case of a single-client single-property scheme, a single private or non-profit organisation is the host of the scheme and its main off-taker. The host is usually not the sponsor (equity provider) of the scheme. The main stakeholder of the business model is usually a micro business under ownership of a single individual in the legal form of a sole proprietor, or in its variety as a multi-plant multi-client venture a jointly owned corporate business entity (partnership). The micro business may be in the role of either the investor and asset owner or act merely as a contractual operation and maintenance service provider. Accordingly, using asset ownership as a distinctive feature, two varieties can be separated, the full contracting model and operation contracting model, respectively.

In Finland, for a large share, these forest-heat contracting schemes are being operated as private ventures, in the corporate form of a joint stock company or as a co-operative company under the ownership and the governance of local forest owners.

The privatization of a heat supply may have been initiated by a policy aiming at incorporating public services. In Finland, privatization has been triggered by the policy of municipal councils aiming at incorporating their public services. The incorporation of a public service is essentially the definition of a new governance model to be performed by a private contracting agent.

4. Financial Performance of Forest Bioheat Contracting

A follow up of the financial performance of Finnish heat service contractors, mainly small forest-bioheat enterprises, for 2010-2012 showed that typical performance had been 7.5% as indicated by net profit margin, and 10%, as indicated by ROI. Comparing business units of different size, multi-site multi-plant business units with a total boiler capacity between 2-5 MW are most profitable, yielding a profit margin of 15% and an equal return on investment. The revenues a typical business unit generates in average per year amounts to 370,000 €. The heat capacity of the local heat-only boiler stations being used for forest-bioheat contracting range between 0.5-5 MW, being typically 0.5-1 MW.

Forest heat contracting: Financial performance	
Median unit sales	370,000 €
Median net profit margin	7.5%
Median return on investment	10.0%
Return on investment, 2-5 MW units	15.0%

Woodchip Fired Bioheat Boiler Plant, 1,000 kW – Investment and costing	
Financing terms	
Interest rate, %	6.00
Payback period, years	
Technical equipment	15.00
Fixed structures	30.00
State aid	0.00
Technical performance	
Annual offtake, MWh/year	3,000.00
Peak heating load, hours/year	3,000.00
Boiler efficiency, %, average/year	80.00
Electric power consumption, €/MWh	0.32
Woodfuel	
Woodfuel costs, €/MWh (fuel energy content)	17.80
Woodfuel procurement, €/MWh	21.80
Stumpage, €/MWh	4.00
Upfront investments	
Purchasing costs, boiler plant, €	400,000.00
Purchasing costs, fixed structures, €	51,000.00
Other expenses, €	1,500.00
Plant operation	
Amount of work, hours/year	800.00
Labour costs incl. additional charges, €/hour	30.00
Annual costs	
Capital costs	
Technical equipment, €/year	41,000.00
Fixed structures, €/year	3,700.00
Total, €/year	44,700.00
Operation and maintenance costs	
Labour costs incl. additional charges, €/year	24,000.00
Maintenance and repair costs, €/ year	4,000.00
Total, €/year	28,000.00
Variable costs	
Fuel, €/MWh	27.30
Electric power etc., €/MWh	2.90
Total, €/MWh	30.10
Total, €/year	60,200.00
Total costs	
Total heat energy costs, €/year	133,100.00
Total heat energy costs, €/MWh	66.60

5. Offtake Agreement

A special variation of a renewable energy contracting model well established on the market, are arrangements, where the output of a production scheme is being sold on a long-term basis under the terms of a purchase power arrangement (PPA). In the case of a service contract, asset ownership may also be retained by the outsourcing party, whereby the subject of the agreement between the purchaser and the third-party is limited to plant operation and maintenance services. Under a long-term PPA, a purchaser may be obligated to make fixed payments for available capacity or take-or-pay energy payments over multiple years. An offtake agreement secures the long-term revenue stream of a project and mitigates the cash flow risk and price volatility related to short-term or spot market sales. Without such an agreement, it could be difficult for a project to attract private capital. Contracting-out of services to private third-party providers often antedates a tendering or bidding process.

6. Forms of Incorporation for Co-operatives

Co-operatives may take the form of companies limited by shares or by guarantee, partnerships or unincorporated associations. There are specific forms of incorporation for co-operatives in some countries, e.g. Finland

7. Governance Structure and Legal Forms

In conjunction with the set-up of business operations, decisions related to the governance structure have to be made. Legal forms set forth by commercial codes are collections of legal provisions regarding corporate governance for corporate business entities. Legal forms variate as to their regulations for corporate governance structure, whereby the goals, responsibilities and respective tasks for running an organisation are defined and assigned to its individual members and bodies (called CEO, executive managers, board of directors, board of management, management committee, or board of trustees). They differ essentially also by the terms of corporate accountability of the organisation's executives towards its owners and shareholders. These basic structures (governance structures) may be developed in many ways to suit organisation's needs.

8. Incompleteness and Enforceability of Contracts

The enforceability by lawful means of a contract may neither be satisfactory nor even intended by the contracting parties. It is rare in practice that all the important commitments of a contractual agreement are governed by law or third-party arbitration. Parties may be unable to write an enforceable contract, because their commitments may not be easily verified. In case the contract deals with a long-term commitment, it may be impossible to anticipate, describe and provide for all future contingencies that might affect the contract. A contract that accounts for all possible contingencies is complex. For a contract to be enforceable it must be written in a way a court or any other third party can understand. Also, to formulate a contract, let alone filing a suit to enforce a claim by legal action may be excessively expensive. Therefore, real world contracts are incomplete.

Any real-world contract is incomplete. A contract may be incomplete because parties decline to condition performance on non-observable future states, because it cannot be verified or otherwise may be excessively complex. A contract that is intended partly enforceable by legal means or by arbitration of a third party, must rely on self-enforcement by some means. Important elements of self-enforcement are informal mechanisms. These are based on values, informal rules and trust in different forms related to expected social conduct. A contract which in some important aspects of performance is enforced by relational mechanisms is called a relational contract. A relational contract, per se, is an informal agreement governed by a set of unwritten codes of conduct that affect the behaviour of individuals within firms or between firms.

Relational enforcement which relies on informal personal relationships of trust alone might be powerful in some specific circumstances. Relational contracts function very well in environments, where between the contracting parties there is trust due to reputation. Trust develops under the condition of repeated interaction. Trust may be a property of the relationships between the members of a small local community.

Under the conditions of environmental change und uncertainty relational contracts tend to be less effective as the conditions under which the relationship is formed might become obsolete quickly. Also, as the commitments of partners increase, a governance model that rely on relational contracts alone becomes insufficient, either.

9. Contracts Governing Supply Chain (Inter-organizational) Transactions (Economic Exchange)

For a supply chain in primary production, the assignment and the control of responsibilities of raw material and commodity suppliers or production service providers, is put into practice by contractual agreements, whether written or verbal, either in the form of purchase orders covering single business transactions or long-term contractual arrangements.

A supply chain governance structure consists of contractual agreements that describe the commitments of the supply chain partners, including the final output user, who in the case of forest energy production, is the off taker of the final energy product. The concerns a contractual agreement (supply contract) resolves are related to the transfer pricing of accomplishments and the respective volumes, timelines and quality standards. It further stipulates the liabilities of a party following a failure to comply with its commitment and the penalty (enforcing accountability) payable for early termination or breach of contract.

In the case of purchase orders covering single, limited and generally standardized business transactions, standard form contracts based on general terms and conditions, usually apply. Long-term comprehensive partnership commitments, which are customized and tailored to individual specifications, in contrast, are the outcome of negotiations between the contracting parties. These trade relationships always rely besides on legal means also on relational self-enforcement.

Feedstock supply is a critical factor for the viability of a forest energy production investment and safeguards are needed to minimize the risk of supply chain interruption. While some less important aspects of performance can be governed by relational incentives, securing a supply commitment should be legally enforceable. Relying on self-enforcement alone is insufficient.

10. Governing the Risk of Supply Chain Interruption

The performance of a forest energy production system, such as a woodchip-fired heat boiler plants, is most vulnerable to discontinuities in wood fuel supply. Discontinuities may unfold with respect to moisture content, uniformity (particle size), energy content and contamination (debris). Feedstock sourcing, processing and delivery cause an enormous part of the overall costs of production. Because of this, safeguarding the non-interrupted functioning of the feedstock supply chain at affordable costs and hedging against the financial risks involved, is a managerial concern.

Risk mitigation starts with pre-emptive measures to enhance the operating capacity of the supply chain to resist disruptions. Preventive measures are equally advised for dealing with the financial impacts of an interruption. A financial risk may be transferred or shared based on a release and indemnification clause to be included in contractual agreements. After all contractual obligations are accounted for, the downstream energy supplier is ultimately liable for the financial loss incurred to the buyer of the energy produced. The respective liability is defined within the scope of the offtake agreement. Risk exposure should be evaluated and covered by a share of the surplus to be retained as a financial reserve and not to be paid out as a dividend to owners. If a feedstock supply chain fails, a feedstock user must seek alternative inputs to remain operational, either on the spot market, or by permanently switching to a new supplier. Both ways impact on its cost structure and compromise its capacity to generate profits.

11. Technology Risk Mitigation

Solid forest-based energy conversion technologies are in a state of high commercial readiness, which is widely confirmed by demonstrations in their actual operational environment. In order to avoid unnecessary risk, it is advisable not do embark on "unrealistic" non-commercial technologies (as the project developer may suggest). Vendor selection should rest on convincing evidence of the credibility of both, the technology (track record) and the vendor's service and support. Lenders are reluctant to finance non-legacy technology. Successful technology sourcing requires enabling capabilities for tendering and comparing possible technologies and vendors as to their technical and commercial terms of supply.

12. Integrating Transaction Relationships into a Corporate Governance Structure

Agreements concerning the extensive commitments of the contracting parties in terms of long-term financial contributions, extended stakeholder commitments and risk exposure, must be enforced by integrating transaction relationships into a corporate governance structure of joint ownership, internal control and incentive mechanisms. This general rule applies also for contractual arrangements between the stakeholders of a small-sized forest energy production set-up.

Corporate governance covers the internal structure and rules that govern a business corporation. Corporate governance is concerned with both the shareholders and the internal aspects of a corporation, such as internal control, and the external aspects, such as the relationship with its shareholders and other stakeholders. Governance structure should ensure effective supervision and control by the corporate's owners and promote cohesion and a shared vision among its major stakeholders as well as reducing conflict. An effective management control by its owners calls for formal contractual agreements (contractual governance).

13. The Costs and Benefits of a Governance Structure

A governance structure is to be considered as a source of transaction costs, which add to the operational costs and overall cost performance of economic transactions related to operating a production system. A governance structure may be characterized as a contractual or organizational arrangement. Corporate governance refers to the internal structures and processes of an organizational set up, how these elements are designed to ensure accountability and responsiveness. In the case transactions are improper and inefficient to arrange within a contractual relationship between independent party, an option would be to conduct the transaction within a formal organizational structure. A governance structure may be appropriate for organizing economic transactions under certain circumstances. The appropriateness of a governance structure can be assessed in terms of its contractual or organisational costs, the enforceability of contractual agreements, its ability to maintain a high intensity of incentives and to provide safeguards against opportunistic behaviour.

Contracting costs consist of the cost of searching for information, the cost of bargaining and composing the contract, and the cost of enforcing the contract. These costs may be incurred either in terms of extra expenses or extra time to be used. Costs may also include a provision for the risk of fault and breach of contract.

Organizational costs are administrative costs and efficiency losses caused by organizing transactions through administrative fiat. On the other hand, if a transaction is internalized or dealt with within an organizational entity, instead of being governed by a contractual relationship between independent parties, the behaviour of the trading parties can be controlled by the authority of a single proprietor.

Internalization by vertical integration may be advisable because of the risk of strategic supplier dependency due to a transaction-specific investment. The risk may materialize as a hold-up cost imposed by the rent-earning pricing behaviour of a supplier as the owner of a resource, which is needed in the productive process – for instance of a downstream bioenergy producer - but which is locally in short supply. Although a resource may not be in short supply, bargaining power may be high, because of high switching costs.

A transaction-specific investment arises when one party requires an unusual or idiosyncratic resource. Consequently, alternative sources of supply are unlikely to be readily available. Investment in specific assets expose an investment to opportunistic rent appropriation. Rent appropriation is a circumstance, which is depressing the financial performance of an investment. Incompleteness and verifiability may foreclose a contract's legal enforceability. When the frequency of repeated transactions is high, there are likely to be efficiency gains in making long term arrangements, if one party needs a specific resource.

For an organizational setup, transaction costs include the costs of organizing the business activity over time, planning the future and limiting as well as allocating risks, which may materialize in the future. It therefore includes the elements of uncertainty and opportunism, which are both pivotal aspects of corporate governance.

Corporate governance is the collection of rules, mechanisms, processes and relations by which a corporation is controlled and operated. Corporate governance includes the processes through which corporations' objectives are set and pursued. The governance framework defines the procedures by which the stakeholders interact and by which their interests are aligned. A governance framework determines the organisational efficiency, with which an organisation meets its goals. A government framework should be evaluated by its efficiency.

Incorporation does not come without a cost. This may be caused by the deficiencies of collective decision-making being not in the best interest of corporate owners. Inefficiency may relate to managerial opportunism and decreased incentives compared to competitive markets. The cost of incorporating transactions may be prohibitively high for a party, which perceives joint ownership to conflict with its preference as an independent business entity to preserve its control rights and bargaining power.

14. Relational Aspects of Corporate Governance

Corporate governance structures all rely on regulatory measures to enforce liability claims. But informal social rules are also an important ingredient of corporate governance structures. Informal social norms by their impact on social cohesion, are of substantial importance for group (corporate) performance because they are fundamental for building cohesion and a shared vision and for reducing conflicts among stakeholders (relational governance). Strong group cohesion creates motivation, safeguards commitment to collective tasks and counteracts against opportunism. Means for strengthening social cohesion include preclusive and preventive measures, such as decisions related to the organizational form (investor-owned or patron-owned), membership criteria, participation, transparency and reward policy.

15. Joint Ownership as a Safeguard against Rent Appropriation due to Asset Specificity

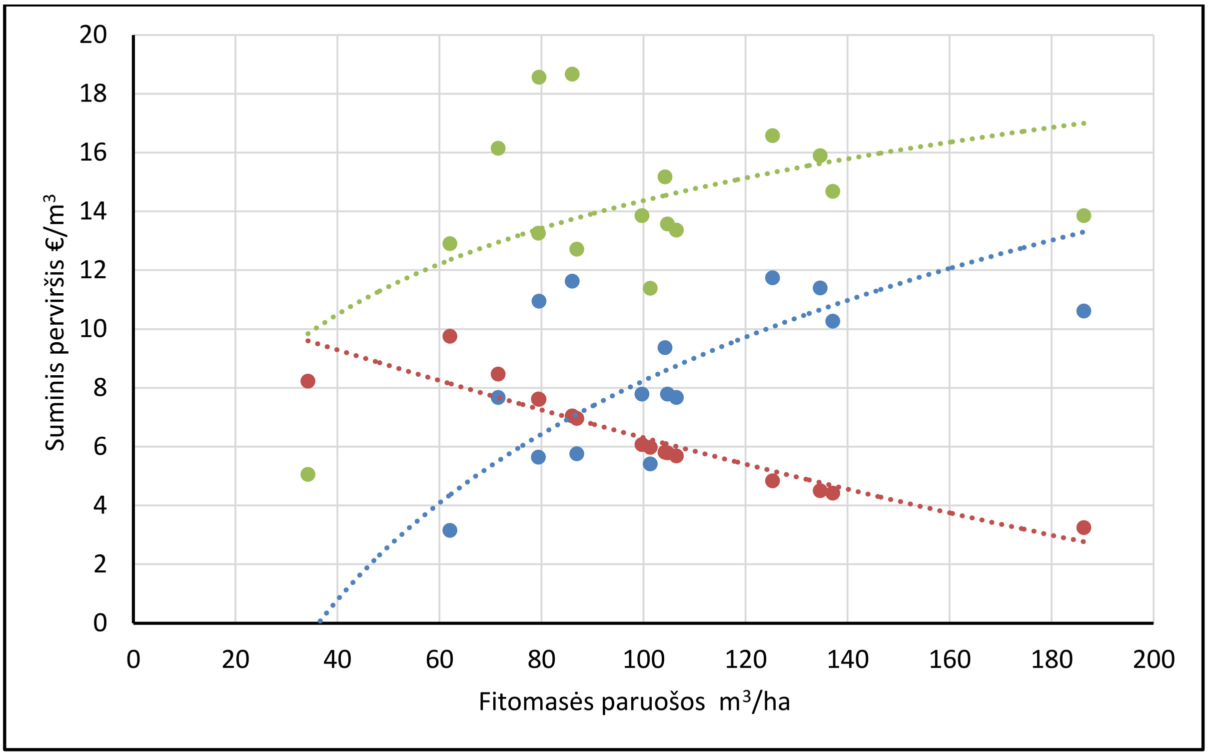
Business activities requires investments in physical assets, which in the case of forest energy production, comprise equipment for feedstock harvesting, processing and transport and a boiler plant. These physical assets are usually owned by a separate legal entity, which is jointly owned and controlled by its shareholders. Usually the physical assets needed to set up production to some degree are specific investments. Specific investments are tailored to specific transactions vertically along the supply chain. The specificity of production assets provides an explanation for the existence of such corporate ownership structures.

Investments in specific production assets (tangible or intangible) are necessary due to site specificity or the technical requirements that can be met only with specialized equipment. An investment into a specific asset or a group of assets generate value more efficiently than a non-specific investment. But by the very same reason putting money into relationship specific assets increases the risk of loss in the value of the investment in case the operations they support are discontinued. In terms of economics, the risk of financial loss is related to the contracting party's tendency to exploit the bargaining disadvantage of the owner of a relationship-specific asset after the investment is made. A contracting party due to its bargaining power is able to appropriate the net earnings (gross operating surplus) of an investment by increasing the price for production inputs, in the case of seller, or by decreasing it, in the case of a buyer, as long as the price paid covers the operating costs and the salvage value of the investment. Up to this point, an investor still makes a better deal by continuing the transaction relationship instead of terminating it.

In the case of an investment into a forest energy production set-up such as a woodchip heat boiler plant, a feedstock supplier is able to appropriate the ex-ante gross operating surplus (quasi rent) of the investment by increasing the selling price of its production input as long as the residual earnings of the investment (its gross operating surplus) is at least equal to its earnings in its next best use.

This risk of losing money because of the loss in value of a relationship-specific investment may lead supply chain partners to refrain from their investments. The risk caused by this hold-up problem is mitigated by integrating a supply chain relationship into an appropriate organizational set-up.

For a for a heat supply chain (1,000 kW boiler plant), which earns 65 €/MWh, not considering spatial costs, a forest stand selected for wood fuel harvesting, should provide an aggregate surplus over the immediate operating expenses of supply chain agents (quasi rent, conversion surplus), which is equal or above the aggregate surplus earned by their fixed investment in its next best use (supply chain agent's opportunity cost). A subsidy of 430 €/ha to be paid to producers causes harvesting to shift towards lower-yielding stands. How the surplus is distributed between supply chain participants depends on their bargaining power.



Annotation: The surplus after allowing for total supply chain costs including bioenergy production is the difference between unit revenues over the total unit cost of bioenergy production. The costs of woodfuel produced from whole-tree biomass are calculated for a sample of 16 juvenile forest stands; state aid payable in 2002 for biomass recovered. Bioenergy production accounts for an average share of 58% of total value created. Trendlines of best fit added to the scatter plot. Literature: 1) Tanttu, V., Ahtikoski, A. & Sirén, M. 2004. Korjuuvaihtoehtojen kannattavuus metsänomistajalle nuoren metsän harvennuksessa hankintakaupalla. / Financial performance of alternative feedstock harvesting methods. Metsätieteen aikakauskirja 4/2004: 509-525. 2) Nummelin, T. Petäjistö, L. Rummukainen, A. & Kautto, K., 2015 Metsähakkeen toimitus energiantuotantolaitokselle – toimintatavat ja arvon syntyminen. / Wood chip supply for energy production – operating models and and value creation. Luonnonvara- ja biotalouden tutkimus / Natural resource and bioeconomy research 54/2015.

16. A Co-operative as a Hybrid Governance Structure

A co-operative enterprise is a horizontal or vertical alliance of independent economic agents, with the common interest to capitalize on collaboration as a strategy of value capture by forward integration, as a means to achieve production cost efficiency due to scale economies, but also to achieve bargaining power and transaction cost economies.

The cost of incorporating transactions may be prohibitively high for a party, which perceives that delegating ownership rights to an agent comes along with threats arising from conflicting interests. As a governance structure, a patron-owned co-operative lowers the threshold of collaboration in terms of collective ownership and governance. First, because a co-operative as an organizational form is not fully integrated, as compared to a hierarchy. Second, a co-operative firm as a legal entity is democratically controlled by its members. Each member is usually entitled to one vote regardless of their financial contribution. Third, the basic structure of a co-operative is rather simple. The patron-members are the owners of the co-operative firm. Members also often have a close association with their enterprise.

17. Co-operative Corporate Governance

An organization's code of conduct is a tool of corporate governance (Arrigo 2006). The code of conduct is administered in the formal rules put down in the co-operative statutes. Concerning a member of a co-operative, the code of conduct regulates its individual entitlements and obligations, as well as the membership requirements. Membership is acquired by signing a formal contract and on payment of a membership fee and on purchase of a share of voting stock. A member has the right to resign from the co-operative. A member may be expelled from the co-operative, if the member has neglected a duty ensuing from membership.

The payment for joining a co-operative consists of a membership fee and an equity contribution. An owner's equity capital contribution can be paid either as an upfront contribution when joining the co-operative or as the share of the surplus retained at the end of each year. While owners have equity investments in the corporative, residual income is distributed based not on equity investment, but on their patronage, that is, their business dealings or transactions with the jointly owned business entity.

Renumeration to patrons is typically tied to their transactions with the co-operative and consists of a prefixed price to be paid for goods and services delivered as a first instalment and a pro rata bonus or "patronage refund", which is a cash payment to the patrons taken out from the co-operative's annual surplus earnings. Although members are entitled to a share of the co-operative's surplus, membership does not fix renumeration as a legally enforceable claim. Applying this kind of mechanism, a co-operative is classified as a mixed governance form consisting of semi-high-powered and low-powered incentives.

The difference between a co-operative and a non-profit corporation may not always be recognized. Both corporative structures can be used to build democratic organizations. They are each designed to limit profit maximization as a dominating motive and to create social benefit. One primary difference is that a non-profit organization cannot distribute surplus earnings to their members, while a co-operative corporation generally distributes profits based on members' patronage.

Ownership and governing rights of traditional co-operative societies is limited to patron-members. There exists no individual ownership to the co-operative's equity and therefore no market for members to trade their shares at a price that reflects true co-operative value. Therefore, a traditional co-operative with their capital stock confined to voting stock do not attract investors aiming at a return to their investment. This may be a hinderance for start-up capitalization or an additional increase of equity capital. Voting stock is generally redeemed at par value by the co-operative, when a member resigns form membership e.g. due to retirement. In such a case, investors may want to issue other nonvoting classes of stock with different par values and different redemption policies. Non-voting stock may be issued in exchange for these additional equity payments. Co-operatives with mixed classes of stock is characterized as a distinct co-operative model from the traditional co-operative model.

A co-operative – an easy way to organize a small business

Formation

- There is no legal minimum capital required.
- A co-operative can be incorporated by at least three persons.
- Natural or legal persons are eligible for membership; there is only a single legal representative required.

Decision-making

- Decision-making is simply composed of CEO, board of directors and general meeting.
- Each member has equal ownership rights regardless of capital contribution; as well equal voting rights in matters put to the vote in at the general meeting.

Resignation

- Members are entitled to resign on notice of resignation.

Liabilities

- Members' financial responsibility is limited to their shares; they are not personally liable for the co-operative's debts.
- Members are not liable beyond the share price paid in case of capital loss, liquidation or bankruptcy.

Capital contribution

- The price of share capital is payable in cash or in kind.
- There is an option to subscribe additional share capital.

Capital refunding

- Capital contribution is repaid in case of dissolution and on resignation.
- Surplus is paid to members in proportion to their use of co-operative services.

Taxation

- Income is taxed due to a special tax framework.
- Co-operatives and members are separately liable as taxpayers.

18. Income Taxation Treatment of Co-operatives

As to the net earnings distributed to owners, a co-operative may provide a legitimate way to reduce taxable income and to avoid double taxation. In some situations, government tax treatment may provide a co-operative with a considerable advantage as compared to other legal forms regarding the reduction and the balancing out of annual fluctuation in taxable income.

Co-operatives calculate taxable income and use income tax rates like other corporations, but with one principal difference. This difference consists in the way a co-operative distributes surplus earnings to its patrons based on patronage transaction, rather than to investors based on investment.

The general principle for the financial transactions between a co-operative and its members is, that all the co-operative's expenses and revenues should enter the income statement of its members leaving no margin (surplus or deficit) to be retained as profit by the co-operative. Therefore, if a corporation reports a margin in its financial statement, it should be taxed only once when it is paid to the co-operative patrons as its final recipients. If the co-operative's operations result in a profit margin that according to the statutory regulations is income retained from patron-members and recognized as a patronage refund, it is deducted from the co-operative's taxable income and added to the taxable income of the its patron members. Apart from patronage refund, the pay-out of a dividend, which is distributed to the membership according to the share of the capital stock and other nonpatronage earnings, is not eligible for a tax deduction.

19. Forest Bioheat Co-operatives

A co-operatively governed local micro-sized forest bioheat production setup can be characterized as a processing co-operative. In this specific case, patronage consists of forest feedstock suppliers and wood fuel processing and logistical services provided by the co-operative's owners to their jointly owned wood fuel processing unit(s) (one or several bioheat boiler plants). A processing corporative is a form of vertical integration of subsequent technical steps of value production as well as of horizontal co-operation between suppliers otherwise organized as independent business entities. The members of the co-operative pool their resources and provide risk capital to invest in downstream processing assets, and to gain access to the capital market. The commodity offtake (heat energy) is produced and delivered and billed to the buyer by the co-operative.

A processing co-operative is a hybrid structure, because compared to an integrated governance structure, the assets used by suppliers to provide raw materials or services as a patronage, in contrast to the jointly owned processing unit, are owned individually and not under a single entity with unified ownership. Specifically, in the case that forest asset owners are the patrons of a processing co-operative, these remain independent economic agents. Their transactions with the co-operative are still subject to the high-powered incentives of the market. A co-operative governance arrangement is not pure vertical integration (hierarchy), because forest assets and processing assets are not under a single entity with unified ownership. The arrangement may besides forest assets include also other types of production asset ownerships.

In Finland, the patrons of forest-based bioheat production co-operatives comprise the following groups:
- private forest owners that use their woodlots to gain income from wood sales as the main or a supplementary source of personal income
- contractors providing wood harvesting, wood chipping or transportation services either as a sole trader or as a separate legal entity
- forest-owning farmers that use their woodlands as a supplementary source of income and self-employment.

20. Forest Owners as Members of a Forest Bioheat Co-operative

A co-operatively governed micro-sized forest bioenergy production setup is typically initiated by local stakeholders, mainly feedstock producers, with the aim to invest as a joint venture into downstream processing assets and thereby to add value to their feedstock sales and whereby to add value to their forest property.

Considering the transactions between forest asset owners and the co-operative owner of the processing assets, each forest owner delivers its supply directly to the processor and receives a uniform, bargained price. Instead of pricing purchases at production costs a market-based transfer pricing mechanism is applied to provide an incentive, i.e. motivation to seek efficiency gains. The price paid to feedstock sellers is exposed to market prices as far as the contract price of heat sales is regularly adjusted by a price index comprising a basket of fuels (e.g. woodchips, peat and light fuel oil) traded in the market at competitive prices. Therefore, forest owners still compete with another and are therefore subject to the high-powered incentives of the market.

Though, the energy conversion facility is jointly owned by the owner-members of the co-operative, as by statutory provisions, shared ownership of production assets does not extend to the patrons' forest assets. The same provisions apply also to the other types of ownership of properties and assets. Their owners remain economically independent and do not merge their business activities or assets into one large firm.

In sum, a feedstock buying and processing bioheat producer can be described as a co-operative hybrid that combines dimensions that are market-like, i.e. separate ownership, no authority relationships, strong incentive intensity, and autonomous adaptation, with hierarchy-like features, i.e. information sharing, coordinated adaptation, formal horizontal agreements, and common staff.

21. Group Cohesion as Safeguard for Continuity of a Co-operative Venture

The co-operative firm is facing an increasing risk of breaking up when the initial enthusiasm vanishes. Membership turnover may go along with a decline of members' similarity. Financial motives, prevailing among joining members, may give rise to free riding. This may deteriorate social behaviour. The leaving of high ability members may further weaken the co-operative's performance, which impacts motivation and performance as a reinforcing cycle. Strengthening group cohesion, getting visible as a strong experience of togetherness, counteracts behaviour motivated by egoism or selfishness, and thereby contributes to safeguarding continuity.

Cohesion among group members may arise from a mixture of underlying phenomena, such as interpersonal attraction, group identity, a sense of interdependence and responsibility. A number of factors, such as members' similarity, group size, and membership turnover, all easily observed and measured, offer means for conscious cohesion building. These factors should be reflected, for instance, in a co-operative's member recruitment policy, the rules of membership admission, and voting rights.

Preclusive measures in the forefront of group formation should tackle the main factors impacting group cohesiveness, mainly members' similarity and group size. Small group size, for instance, is more susceptible to social pressure and makes complicated incentive and monitoring schemes dispensable. Preventive mechanisms, such as exclusion, offer means to enforce co-operative behaviour after the organization has been set up. Often, the factors underlying cohesion work through enhancing the identification of individual members with the group they belong to, as well as their beliefs of how the group can fulfil their personal needs.

22. Legitimacy

When asking about the fit between an organization's behavioural attributes and the interests, claims and attitudes of its stakeholders, the question is about the legitimacy of the organization from the viewpoint of its stakeholders. Legitimacy, besides judicial legitimacy, means the state of acceptance of an entity's behavioural attributes, or the normative status it enjoys among its stakeholders. Legitimacy is rooted in norms, beliefs and culture. Thinking about the success factors of co-operatives, one must reach beyond pure economics and give due consideration to these aspects making up a background setting as well. Therefore, these aspects should be addressed then thinking about how far legitimacy or lack of it contributes to the popularity of a co-operative governance model in a specific context.

Co-operatives capitalize on its pragmatic legitimacy for stakeholders, primarily users either consumers, producers, suppliers or workers, depending on the type of co-operative, who enjoy a privileged use of its services. Other stakeholders may give credit to co-operatives indirectly, for instance the local community who may enjoy economic and social benefits from the activities of the co-operative.

Most people probably have a positive opinion of co-operatives due to its democratic governance and its community involvement, although less so as a for-profit corporate structure. Nonetheless, legitimacy has been a problem in some parts of Europe, where co-operatives are perceived as socialist-minded models inherited from the past. A sincere problem for co-operatives in many countries is poor knowledge. Co-operatives are not well recognized as a discrete organizational model but associated as a hybrid structure mixing up commercial and societal logics. This appears as a serious barrier to entry because many stakeholders are likely to be reluctant to support an organizational form that they do not know or understand. Such barrier may disable co-operatives from transforming their potential advantages into concrete opportunities.

23. Good Practice Example – Eno Forest Bioheat Co-operative

The Eno energy co-operative has been established in 1999. Today, it is one of about 300 local wood heat enterprises in Finland, of which the first ones have been established already in 1992. The co-operative is located in Eno settlement in North Karelia, Finland. The co-operative was launched, after the first boiler station was financed and put into operation under the authority of the local administration. The co-operative expanded heating production successively, investing in a second and third boiler station during the following years. Total annual capacity in 2004 amounted to 4.8 MW.

Picture 1. Yläkylä Heating plant

Owner and Operator: Eno Energy Co-operative, North Karelia, Finland
Size: 0.8 MW
Output: 2,800 MWh (2015)
Forest chips: 6,200 loose m^3 (2015)
Photo: Urpo Hassinen
Annual Report 2016

The co-operative, as co-operative governance models in general, is a coalition of independent and self-interested participants. As a horizontal and vertical alliance of supply chain actors, the intention of the joint venture is to capitalize on collaboration as a source of competitive advantage. Founded by twelve forest landowners, the co-operative comprises private forest holdings and wood chip contractors as their members. There is no professional management hired, instead, management is being assigned to member representatives.

The co-operative owns and operates the heating plants. Heat energy production is sold directly to consumers, public authorities, local industries and private housing owners, based on long-term delivery contracts that ensure the continuity of operations. The co-operative manages and supervises the whole supply chain from the forest site downstream to the point of consumption, including heat transfer to the customer's heating site.

The co-operative buys the fuels for heat generation from private forest owners who are typically the energy co-operative members and also from energy wood harvesting contractors.

Picture 2. The Eno Energy Co-operative's wood fuel supply is contracted to Forest Service Turunen Inc. The total annual volume delivered to clients is amounted up to 28,000 loose cubic meters. Photo: Arto Soininen

The co-operative entrusts harvesting, chipping and transport operations to autonomous contracting service vendors. Annual wood chip deliveries amount to 30,000 loose cubic meters. Forest owners may also do themselves the on-site fellings, and the collecting, processing and roadside delivery of wood fuel. A chipping contractor usually provides machine services but may also execute purchasing functions. In this case, the chipping contractor is authorized to buy wood fuel for the account of the co-operative.

Picture 3. After thorough considerations local authorities and forest owners decided to go for wood chips heating.
Photo: Urpo Hassinen

The co-operative aims at providing affordable heating for the local community based on local energy sources. As to the self-interest motive of participation, operations are to be organized cost efficiently, so that the co-operative's revenues cover all its liabilities and members earn a profit. Locality is crucial for the co-operative's business operations not only in terms of membership but also in terms of sourcing local fuel and production services.

The co-operative provides an additional source of income and employment for local forest owners and the local economy and supports environmental goals by substituting non-renewable by local renewable energy sources. Its activities contribute to the viability of the local community by providing opportunities and future perspectives for young people.

Picture 4. Using local wood chips curbs fuel oil carbon dioxide emissions by 5,000 tons each year. Eno Co-operative activists are pleased of being recognized with the 'Hinku' - environmental award for their supporting a carbon neutral community.
Photo: Taru Tykkyläinen

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Visits to seminars and meetings

North-Karelia Forest Heat Entrepreneurs' Day
Date: 6.4.2018
Place: Kontiolahti, Kotiseutukeskus
Host: North-Karelia Forest Centre

Finnish Machine Contractors' Energy Day
Date: 8.3.2019
Place: Helsinki
Host: Koneyrittäjien liitto (Finnish Machine Contractors' Association)

North-Karelia Forest Heat Entrepreneurs' Day
Date: 29.3.2019
Place: Kiihtelysvaara, suojeluskuntatalo (Suojapirtti)
Host: North-Karelia Forest Centre

Regular meeting of project managers under the Renewable Energy and Climate Programme
Date: 3.4.2019
Place: Joensuu
Host: North Karelia Regional Council

National Heat Entrepreneurs' Day
Date: 25.-26.4.2019
Place: Tampere, Varala Sports Institute
Host: The Finnish Bioenergy Producers' Association

Expert interviews

Dr. Lasse Okkonen
Lector, Expert on Renewable Energies
Karelia University of Applied Science
Date: 13.2.2019
Place: Joensuu
Host: The Natural Resources Research Institute Finland (Luke)

Mr. Urpo Hassinen
Senior Expert Advisor Forestry and Renewable Energy
North-Karelia Forest Centre
Date: 5.3.2019
Place: *Joensuu*
Host: F*innish Forest Centre*

Mr. Esa Kinnunen
Senior Expert Adviser Bioenergy, Senior Project Manager
North-Karelia Forest Centre
Date: 5.3.2019
Place: *Joensuu*
Host: F*innish Forest Centre*

Expert consultations

Dr. Jukka Korri
Renewable Energy Expert, Project Manager
Työtehoseura TTS - Association for Vocational Education, Training, Research and Development

Mr. Hannes Tuohiniitty
Bioenergia ry - Association of Finnish Bioenergy Producers
Executive director, Sector manager
Chair Heat Entrepreneurship Network (Lämpöyrittäjyysverkosto)

Mr. Jaanus Aun
Managing Director
Estonian Private Forest Centre (PFC)
Date: 11.2.2020
Place: Tallinn
Host: Baltic ForBio WP2 Working Group Meeting

Mr. Jim Antturi
Forestry Expert
Työtehoseura TTS - Association for Vocational Education, Training, Research and Development

Mr. Kim Blomqvist
Senior Expert Renewable Energy Technologies, Project Leader
Karelia University of Applied Science

Mr. Mikko Tilvis
Senior Expert Advisor Forestry and Renewable Energy
Pirkanmaa Forest Centre

Mr. Simo Jaakkola
Executive Manager
Association of Finnish Machine Contractors

Mr. Tage Fredriksson
Bioenergia ry - The Bioenergy Association of Finland
Sector manager
Chair Woody Biomass Energy Council (Puuenergiavaliokunta)

Mr. Timo Turunen
Supervisory Board Chairman
Eno Energy Cooperative

Mrs. Aino Heikura
Senior Project Manager Renewable Energy and Climate Programme
North Karelia Regional Council

On-site visits and interviews of forest bioenergy entrepreneurs

Mr. Ilkka Lukkarinen
CEO Biowin Karelia Oy
Vaskela Heat Boiler Station
Date: 6.4.2018
Place: Kontiolahti

Mr. Pasi Kakkinen
CEO Metsäpasi
Date: 5.4.2019
Place: Lieksa

Mrs. Laura Hämäläinen
CEO Itä-Savon Lähienergia Oy
Date: 23.4.2019
Place: Kerimäki

Mr. Mikko Jauhiainen
CEO Ruutana Heating Oy
Date: 25.4.2019
Place: Kiuruvesi

Interreg Baltic Sea Region Programme Baltic ForBio Project 2017-2020

Accelerating the Production of Forest Bioenergy in the Baltic Sea Region (BSR)

Forest biomass is a very important source of renewable energy in the Baltic Sea Region. Over 80% of the renewable energy consumed in Estonia, Finland, Germany, Latvia, Lithuania, and Sweden is produced from forest biomass. At present, a major part of the forest biomass used for energy purposes comes from by-products of the wood-based industry, recycled wood, and firewood used by households. Forest harvests produce huge amounts of residues, of which a large share could be used for energy purposes but are currently left in forests due to economic and ecological reasons. There is a large potential in tackling the increasing demand for forest bioenergy by increasing the harvest of logging residues and small trees in pre-commercial thinning.

The project aims to increase the production of renewable energy in the BSR by improving the capacity of public authorities, forest and energy agencies, organisations of forest owners and entrepreneurs, and forest advisory organisations to promote the harvest and use of logging residues and small trees cut in early thinning. Based on available technologies and research results, the project has produced this handbook describing cost-effective and sustainable harvest methods including technological, economic, and environmental aspects in the different phases of forest growth. Training programmes for the harvest of logging residues and small trees and demonstration sites for biomass recovery in pre-commercial thinning are presented in the handbook. The handbook enables the establishment of sustainable business and to increase local capacity for bioenergy production.

About the project

Baltic ForBio is a trans-European research collaboration about sustainable green energy with 13 partners in 6 countries and 4 additional associated organizations

Timeframe and funding

Duration: Oct. 2017 – March 2021
Total budget: EUR 2.55 million
European Regional Development Fund: EUR 2.00 million

www.slu.se/balticforbio/