Lithuanian - Swedish Wood Fuel Development Project
Financed by The Swedish Energy Agency
Phase II

INTEGRATION OF FOREST FUEL HANDLING IN THE ORDINARY FORESTRY

Studies on Forestry, Technology and Economy of Forest Fuel Production in Lithuania

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Preface

The increased importance of the local and renewable resources when meeting the international commitments of the country, decreasing the environmental pollution as well as the country dependence on the imported fuel, makes us to look for the optimal solutions.

In the Government programme of 2001-2004 it is planned to expand the use of local and renewable resources and to assure that in the year 2010 these resources would make up about 12% of the country fuel balance .

While carrying out the Government programme as well as the plan of the implementation of the strategic means of National energy, since the year 2000 the Forest Department under the Ministry of Environment as well as Swedish national forest board has been carrying out their bilateral project "Wood fuel development in Lithuania", financed by Swedish energy agency.

Lithuania has comparatively little local energy resources, however their use in the total primary energy balance since 1990 increased annually. The main part of them includes wood and solid fuel, the use of which in the year 2001met about 9% of country fuel requirements.

Technological, organisational as well as financial wood fuel production aspects were analysed during the project. The specific research and work has been carried out as well as the factors that influence the wood fuel production and transportation were analysed. With the common efforts the demonstration objects were established in Rokiskis forest enterprise. The project was interesting not only to the people working in forestry, energy sectors and municipalities but it also attracted the attention of the politicians.

The results presented in this report allow us to assume, that the wood fuel production technologies will soon become an integral part of the Lithuanian forestry system.

I want to thank everyone who contributed to the implementation of this project, especially Swedish energy agency, that managed to find additional finance for the purchase of the wood chipper.

A. Vasiliauskas
Vice minister
Ministry of Environment
Of the Republic of Lithuania

Abstract

During the year 2000, The Swedish Forest Administration and Forest Department, Ministry of Environment in Lithuania, started a bilateral co-operation project, named: "Swedish Lithuanian Wood Fuel Development Project", financed by the Swedish Energy Agency. The project was divided into 2 phases. The first phase objectives were to make a feasibility study in the eastern part of Lithuania and to identify the present conditions for the utilization of wood fuel within seven state forest enterprises and to define a demonstration and experimental area for the phase 2. The purpose of this work was to find solutions for creating horizontal and vertical integration in the handling of forest fuels in ordinary forestry and supply systems. The aim would be to give specific recommendations on which methods are the most suitable and profitable and on what type of equipment to use for various conditions and by the means of demonstrations to show how to integrate the positive results into the ordinary forestry activities. Different kinds of activities have been carried out to ensure capacity building and development on other levels within the system. 3 activity groups were established and have been working side by side with the appointed team leaders for each activity group from the institutions leading in the specific area within the forest sector in Lithuania. Swedish specialists from the Swedish Forest Administration were involved into the project and the activity groups as well. Lithuanian Forest Research Institute was involved into the project with research support. Additional to the project a mobile drum wood chipper was purchased from Sweden. 3 separate investigations have been conducted, one by Kaunas University of Technology on the analysis and estimation of material balance in Lithuania sawmilling industry, another by Forest Economy Centre on wood fuel produced in industry in Lithuania and the third one by Lithuanian Energy Institute and ÅF international on Bio fuel usage experience from the EAES program.

The report of phase II is divided in different chapters presenting information and results from the project. Discussion and conclusions from all chapters are collected under the chapter 17. Discussions and conclusions.

3. Introduction

During the year 2000, The Swedish Forest Administration and Forest Department, Ministry of Environment in Lithuania, started a bilateral co-operation project, named: *"Swedish Lithuanian Wood Fuel Development Project"*, financed by the Swedish Energy Agency. The aim of this project is to contribute and to lay the basis for the sustainable development projects going on in Lithuania with financing from the Baltic Billion Fund under the assignment to the Swedish Energy Agency directed towards the conversion of oil and coal fired boilers in the district heating system to the use of biofuel. The project was divided into 2 phases. The first phase objectives were to make a feasibility study in the eastern part of Lithuania and to identify the present conditions for the utilisation of wood fuel within seven state forest enterprises and to define a demonstration- and experimental area for the phase 2. The establishment of the demonstration- and experimental area during the phase two was made within Rokiskis state forest enterprise. Phase two has been supported by the advanced knowledge about forest fuel handling in Sweden. In the process, there has been co-operation between authorities and interest groups. Different kinds of activities have been carried out to ensure capacity building and development on other levels within the system.

3.1 Creation of the project phase 2

In the first phase of the project the following general main methodological approaches were applied: Definition of present forestry and economic aspects of round wood supply -demand situation in the area of interest, in general, and wood fuel, in particular. Calculation of future scenarios of wood fuel potential in the years 2011-2020, 2021-2030. Creation of a method for choosing territories with the best options for the establishment of demonstration- and experimental area, on the basis of collected versatile information. Evaluation and comparison of options for the establishment of a demonstration- and experimental area was carried out basing on the characteristics of forest sector and industry infrastructure within seven state forest enterprises.

In a two-day workshop in January of 2001 results from the phase one in order to anticipate necessary works in the project phase two were discussed. The workshop was carried out with a logical framework approach (LFA) method and the following Institutions from Lithuania were represented: **Ministry of Environment, Forest Department. General Forest Enterprise. 7 State Forest Enterprises. Forest Owners Association. Centre of Forest Economics. Lithuanian Forest Research Institute. Lithuanian University of Agriculture, Faculty of Forestry. Forest Inventory and Management Institute. Kaunas University of Technology. Lithuanian Energy Institute. Energy Agency. Lithuanian Association of Municipalities.** From Swedish side: **National Board of Forestry. Energy Agency. ÅF-International. I&W AB.**

The second day in the workshop was focused on the creation of activities. The project organization structure divided the activities described and specified different activity groups. Each activity group had to include several objectives or tasks. Each activity group had to have one appointed team leader from the institution leading in the specific research and development area within the forest sector in Lithuania. The appointed team leader was responsible for the effective work, results and participating in writing final report. Available research results and experience processed in Lithuania had to be connected with the information provided from Sweden in order to elaborate detail programs and methods, necessary for performing the specific activity. Within the demonstration and experiment area different activities have been carried out in order to find answers to different alternative solutions on how to handle forest fuels in a more rational way and to show by demonstrations how to integrate the positive results into the ordinary forestry activities. Within the project a mobile drum wood chipper was purchased from Sweden, financed by Swedish Energy Agency. Two study tours for Lithuanian participants to Sweden with focus on integrated forest fuel handling have been conducted through the project. Three established activity groups have been working in parallel. Swedish specialists from the Swedish Forest Administration were involved in the activity groups as well. Lithuanian Forest Research Institute (LFRI) was involved into the project under the activity group A with research support, financed by the Swedish Energy Agency.

3.2. Main tasks for the activity groups

Activity Group A. Silviculture and technologies. In general, the main tasks for group A.

- Estimation of wood fuel resources potential to be used for heating plant in Rokiskis.
- Creation of computer program for money expenditure calculation.
- Technologies of pre-commercial, commercial and final cuttings
- Estimation of work and financial expenditure on biofuel production outtake and transportation to heating plant.
- Evaluation of ash handling methods.

Activity Group B. Business development. In general, the main task for group B.

- Driving forces for wood fuel business identification.
- Socio-economic analysis on the impact of wood fuel extraction .
- Wood fuel business scenarios

Activity Group C. National institutional work. In general, the main task for group C.

- Determination of legislation barriers and suggestions for improvement.
- Standardization basis for wood fuel.
- Identification of Target groups.
- Collection and dissemination of EU directives and perspectives

3.3. Institutions and persons involved in the project

The team-leader for the activity groups and also co- authors for the final report have been: group A, Dr. **Jonas Saladis** from LFRI. group B, **Arvydas Lebedys,** Director, Centre of Forest Economics. group C, **Vilija Augutaviciene,** Chief specialist, Ministry of Environment, Forest Department.

People who participated in the research support conducted by LFRI were. Dr. **J. Saladis** [general leading, report writing and preparation]. Dr. **S.Mizaras** [methodical leading, data analysis, report writing]. Dr. **V. Miksys** [methodical leading, data analysis, report writing]. Dr. **K.Armolaitis** [methodical leading, data analysis, report writing]. habil. Dr. **A. Kuliesis** [methodical leading, data analysis, report writing]. Dr. **A.Raguotis** [establishment of demonstration objects, data analysis report writing]. P.**Danuseviciene** [preparation of methodic, data collection and analysis, report writing]. Dr. **D.Mizaraite** [preparation of methodic, data collection and analysis, report writing]. **D.Kavoliűnienë** [data collection, report preparation]. **M.Aleinikovas** [data collection, report preparation]. **R. Budrys** [preparation of methodology, data collection, report writing]. **L.Sadauskienë** [preparation of methodic, data collection and analysis, report writing]. **R.Sadauskas** [establishment of demonstration objects; data analysis, preparation of description on intermediate thinnings]. **A.Gustainiene** [preparation of computer software]. **V.Miksiene** [establishment of demonstration objects; data collection and processing]. **V. Vaskyte** [establishment of demonstration objects; data collection and processing]. **J. Zenkovaite** [analysis of literature, data analysis, report writing].

People participating in the project from Rokiskis Forest Enterprise: Director, **Rimantas Kapusinskas.** Deputy director, **Vidmantas Jasinevicius**. District director, **Gintaras Cypas**. Chipper operators, **Saulius Lapienis** and **Virgilijus Lapienis**.

The participant from Lithuanian Energy Institute **Nerijius Pedisius** made an investigation and wrote chapter 6 on heating plants together with **Ulf Lindgren** AF International.

Kaunas University of Technology (KTU), Department of Mechanical Wood Technology, participated in the project and made an analysis and estimation of material balance in Lithuanian saw-milling industry. Authors for the report: Dr. **Vilija Pranckeviciene** and Dr. **Anatnas Baltrusaitis** who was also a project co-ordinator during the year 2001.

The project Internet homepage: **http://miskai.gamta.lt/kuras/** was created by **Gerimantas Gaigalas** from Ministry of Environment, Forest Department. The correction of English grammar spelling for the report was made by **Ausra Budriene**.

The participants from The Swedish Forest Administration were **Bengt Carlson** and **Hans Wikström. Anders Gillgren** was involved in the creation of the demonstration- and experimental area and acted as a co-author for the final report. Dr. **Bert Åke Näslund** made comments on the data and report. The front page and layout for the final report was made by **Janne Bergström**.

Project co-ordinator for the year 2002 and also the co-author for the final report was **Renatas Budrys** from LFRI.

The project has been supported and monitored by an international project steering committee led by the Chairman: Dr. **Albertas Vasiliauskas**, Vice-minister, Ministry of Environment Lithuania. Members: **Vytautas Krusinskas**, Head of Atmosphere Section, Department of Environment Quality, Ministry of Environment. Dr. **Valdas Vaiciunas**, Director of Forest Department, Ministry of Environment. **Benjaminas Sakalauskas**, General Director, General Forest Enterprise. **Tomas Vaitkevicius**, Senior Specialist, Administration of Association of Municipalities. **Romualdas Jarmokas**, Director of Energy Saving Program, Energy agency, Ministry of Economy. **Gudrun Knutsson**, Head of Section, Swedish Energy Agency. Dr. **Bert-Åke Näslund**, Head of International Contractual Service, Swedish National Board of Forestry.

To all these mentioned and the others who participated and made comments on the data and report, I am most grateful. Finally, I would like to thank the director of The Forest Department at The Ministry of Environment Dr. **Valdas Vaiciunas** for his support and co-operation during this project.

Vilnius, December 2002
Lars Andersson
Project Manager

4 Background

4.1. The Swedish forest administration role for increased extraction of forest fuel

The Swedish forest administration has historically played an important role in bringing up to argument and legitimising norms within the forestry. Until recently the forest administration at district level has taken a passive role in the integration of the forest fuels handling. In the Forestry Act, extraction of forest fuel and compensatory fertilising is regulated by Regulations and General Advice, Section 30 (Respect for Nature), Section 14 (Notification of Forest Fuel Extraction) and with regard to storage Section 29 (Forest Protection).

Some years ago the Swedish Forest Administration decided to take an active part in the development. As the development continues and some incitements are still needed, the National Board of Forestry made recent recommendations for the extraction of forest fuel and compensatory fertilising instead of new legislation with laws and regulations that could be an obstacle for the development (see appendix 1.). In this text, the National Board of Forestry presents its view on how the extraction and the reintroduction of ash should be conducted in order to conform to present forest policy goals regarding sustainable forest management and the preservation of biological diversity. The National Board of Forestry is positive towards the use of forest fuels, provided that the new recommendations are followed.

4.1.1. Local integration of forest fuel on the district level

When a new structure within the local forestry is developed, for example the integration of handling of forest fuels, it is important to create dynamics. There has to be driving forces for the integrated extraction of forest fuels, not only on the higher level within the system, but also at local level. Experiences and studies show that forest owners are nowadays brought up against increasingly complex and elusive situations for decisions. At the same time as a fine-meshed net of new service - companies has expanded within the forest sector. Study from Törnqvist (1992) shows that 77% of the forest owners have long term contacts with at least one professional forester, for example forest officers from the forest authorities, inspectors from forest owner associations, etc. Figures from the Swedish Forest Administration evaluation of the Swedish Forest Policy conducted in 1999 (SUS2001) showed that 48% of the forest owners who lived less than 30 km away from their estate had long - term contact only with the local forest authorities.

The conclusions are that the forest officers is a key group in establishing and motivating the increased extraction of forest fuels. The importance of them as a key group can be explained through their knowledge of forestry, local competence and establishment. They are in position helping to co-ordinate and develop the extraction of forest fuel locally as they also have links to the forest owners and their advises to the forest owners are essential. As a first step in 1998 National Board of Forestry made a computer model for estimations of local resources of logging residues from clear-cutting sites for the use of the local forest authorities at district level. The Swedish Forest Administration has recently started sending their forest officers to special education courses on “forest bio-energy”.

4.1.2. Initial incitement.

The possibility of making alteration in the forestry sector locally is unfortunately low, one reason can be conservative thinking among foresters in connection with their locally strong position. It has, therefore, shown that locally initial external incitements are needed and it has been very important to pass the first stage, to make them see the possibilities! When people have been convinced in the possibilities, the extraction of forest fuels has been further developed and has been carried out with high enthusiasm.

4.2. Production of wood fuel in Sweden

Production of wood fuels for sale has earlier been concentrated to the southern parts of Sweden but now it is more spread all over the country. Wood chips and crushed wood waste is the largest product with about 50 % of the total production. Methods for taking out logging residues have been changed compared to the beginning of the 1980´s, when 60 % of the logging residues was chipped out at the clear cutting site. Today the figure is only 20-25 %.

The new strategy is to split the wood as near the consumer as possible, to receive the cheapest costs for decomposition (chipping or crushing) and at the same time to have better control of storage, quality and the raw material flow. Energy crop production (Salix) is produced on about 14.300 ha. Production of pellets and briquettes from industrial wood waste is about 4.1 TWh and is steadily increasing.

In general, it can be stated that bio-energy creates employment locally. The work is not concentrated to large urban areas or to specific regions in Sweden. Instead, it rises where fuel is available or where heating plants or incinerating facilities are located. As a rule, the fuel is harvested within a 100 - 150 kilometre radius of the consumption site. Therefore, an investment in forest fuels benefits the local labour market and also generates a larger number of job opportunities per TWh, about 190 annual day work. The supply of raw material like wooden chips, solid wood and pellets to the energy sector, has become a third assortment for Swedish forestry, besides pulpwood and saw logs. This has had an essential effect on the possibility of profits as well as on the amount of investments being made in the forestry sector.

4.2.1. Present consumption

Of the total energy supply in the year 2000 of 585 TWh, was 16.1 % from biofuel (94.4 TWh excluding peat, 2.4 TWh), from which wood fuels accounted for 49.2 % (46.3 TWh) or 8 % of the total energy supply. The use of wood fuel was divided in different sectors:

- Sawmill- and pulp-industry (by- products and reject) 42.8% (19.8 TWh)
- District-heating sector 32.4% (15 TWh)
- electricity production 2.1% (1 TWh)
- Dwellings 22.7% (10.5 TWh)

(source: Swedish Energy Agency)

The use of wood fuel for district heating has more than quadrupled since 1990.

4.2.2. Import of wood fuel

There is no official statistics of the import of wood fuel, which makes the quantities difficult to estimate. However, quantities have increased in recent years, and in 1997 were estimated as amounting to about 7-9 TWh corresponding to 3.3 – 4.3 Mill m^3s. Imports in that year accounted for 35-40 % of the supply for the district heating plants, and nowadays constitute an important source of this kind of fuel.

4.2.3. Potential consumption in Sweden in the future

The potential supply of wood fuel is very large in Sweden. Without taking ecological, technical and economic aspects into consideration, the supply could be about 125 TWh per year. However, the size of this amount depends upon the future need for industrial wood, among other things. How much gross volume of biomass fuels will be available in various time perspectives is unclear. Today about 10 TWh is collected as waste from clear cuttings and thinning. With the annual felling of to day and with compensation fertilising, as well as more effective technology, etc. the potential of dry matter (about 40 TWh or about 8 million tons), compared to energy forest production (Salix) with today's production capacity on 14.300 ha can only give 20 – 25 thousand tons of dry matter corresponding to 0.1 TWh.

4.2.4. Ash recycling

Nowadays, branches and tops of trees from logging operations are used for energy purposes to a larger extent than before. The extraction of branches, tops and needles can lead to an even more reduced nutrition level in the ground. In order to extract forest fuel in a sustainable way at the same time maintaining a long-term nutritional balance, the needles should generally be left at the site. If not, some sort of compensation should be made for the loss of nutritious matter, preferably by adding ash originating from bio-mass back to the forest land. A stabilised and slowly soluble ash is suitable for this purpose (see appendix 1.) .

4.2.5. Preserving the biological diversity

It is important that an extraction of forest fuels and a possible compensation with manure is carried out in a way that won't have any negative environmental effects on the biological diversity or on the water quality in streams, lakes and ground water. It is also important to make sure that no heavy metals leak out into the ground (see appendix 1.).

4.2.6. New technology in Sweden

As an effect of the rapid market growth, an imbalance between different regions may occur when the demand for wood fuels is high in some parts of the country and weak in others. Large combined heat and power stations have been built near large urban areas. They require heavy, reliable supplies of bio-energy fuel, which means that it has become increasingly important to transport large volumes of fuel in a cost-efficient manner.

The company Bala Press AB has developed an interesting technology for making bales of wood fuel throughout the whole chain from cut over to final consumer. Most of the savings that can be made through rationalising are of course made when the bio-mass is extracted with a forwarder, using road haulage and rail transport. Apparently the most cost-effective option is to use inter-modal transport systems including both road and rail haulage, rather than using road haulage alone. Although the machine for making bales has been developed continuously, its productivity appears to be fairly stable at approximately 15 bales an hour. The compacting technology opens the door to new ideas and can lead to a rationalisation of systems that are based on long distance haulage.

Examples of new technology

- Multitree-handling (MTH) felling heads for cost-effective felling in small wood stands
- New types of forwarders for heavier payloads
- Methods for making bales and logs of logging residue, e.g. to cut haulage costs and to increase the efficiency of chipping
- Heavy-duty chippers that can meet the need for efficient, large-scale chipping at the terminal or mill/consumer plant
- Forwarder equipped for making combined operations
- Smaller mobile chip-harvesters with containers and manipulator for chipping in thinning stands.

It is clear that technology and systems for forest fuel are developing at a good pace. Given the current market predictions, we are likely to see even more interesting solutions that will help forest fuel systems account for a significant share of the total energy resources used in Sweden in the future.

4.3. Why development projects are needed in Lithuania

In general Lithuania has relatively limited knowledge and experience in production and use of wood fuel, even if the interest in the use of local energy increased significantly after Lithuanian retained its independence. Extraction and processing of logging residues , round wood or small trees for fuel production can technically be carried out in many different ways. Most of the supply of fuel depends on the size of the felling operations, future mechanisation and how forestry otherwise develops. Consideration must also be paid to future industrial expansion, etc. However, further analyses and tests are required to screen the most cost-efficient methods and most suitable equipment for Lithuanian conditions to find and create horizontal and vertical integration in the handling of forest fuels in ordinary forestry and supply systems. As a domestic resource, the use of biofuels creates employment for farmers, forest workers, entrepreneurs', and for workers at boiler plants.

The importance for the rural development and for living conditions at the countryside is substantial. Employment is also created in the equipment manufacturing industry. The harvesting of forest fuels can be a driving force in forest management in the future, by that the economy of forestry measures can improve, and will favour the outcomes of different industrial assortments due to many stands that would not normally have been managed will be so thanks to the possibility of extracting forest fuels.

Today, energy development authorities on the national and regional level do not have enough knowledge and information on how to outline the strategy and tactics of wood fuel procurement. Opinions about the methods of evaluation of forest energy possibilities on the municipality level are very different and sometimes diametrically opposite. It is important that co-operation and co-ordination are made between the forest and energy sectors to ensure the development at the same time when the integration of forest fuel handling must be implemented.

5. General overview of the Lithuanian forests

Forests cover 30.9 % of the whole territory of Lithuanian. Forestland makes up 2 020.300 ha. Growing stock totals 371,7million m^3. The forest area and growing stock per capita is 0.57 ha and 106 m^3 respectively (2001). Over the recent years the felling accounts for about 5 million m^3 annually. According to experts the potential annual cut of 6.2 million m^3 could be maintained for coming ten years. The structure of ownership of forests has been considerably changed after the restoration of independence in Lithuania in 1991. Since the beginning of the land reform the ownership rights were restored to more than 165 thousand forest owners and the share of private forests in 2001 was approximately 458 thousand ha or 23 % of the total forest area. However, the process of restitution is still going on and after the completion of the land reform, it is estimated that private forests will occupy about 40 - 45% of the total forest area. The average area of a private forest holding is 3,4 hectares.

5.1. Lithuanian Forest Authority

The forest authorities in Lithuania have recently been reconstructed. The Institution who is responsible for the Forest act, formulation of strategies, recommendation and guidelines is Ministry of Environment, Forest Department. Regional Forest Control Units under the State Environmental Inspection subordinated to Ministry of Environment are responsible for implementation and extension service, including control of the forest owners following the legal act, both private and state.

5.2. State forest

Another institution that has big influence on the forests belonging to the state is General Forest Enterprise. The institution is subordinated to Ministry of Environment. Their task is to co-ordinate and manage 42 State Forest Enterprises on commercial level. Forest Enterprise is the basic forest management unit responsible for the implementation of forest management plans in the state forests. State Forest Enterprises are responsible for all forestry activities related to regeneration, tending and protection of forests within state forests, forest utilisation including harvesting operations, construction and rehabilitation of production facilities and building, road construction and maintenance of land drainage systems, recreation and equipment as well as other forest-related activities.

5.3. Private forest

Some of the private forest owners are members of the Forest Owners Association of Lithuania (FOAL) which is the only public organisation in Lithuania that represents and unites private forest owners. FOAL was established in 1993 and now has 37 local branches with more than 1600 active members. The main services that FOAL is providing for its members are information and consultancies; education in silviculture and forest management; representation of private forest owners. There are still quite many private forests under restitution for privatisation and these forests are not managed during the restitution time.

5.4. Intensity in forest management

The low intensity of forest management in Lithuania has resulted in forest stands growing relatively dense. Consequently, the felling generally yield larger volumes of firewood with a limited market, but as it is most often handled in the same way as e.g. pulpwood, the costs incurred from this practice are considerable. This is reducing profitability of forest management and increasing pressure to reduce the area of thinning, which may in the long term have a negative effect on the country economy. Management of private forestland is a new phenomenon in Lithuania. The new coming forest owners, living under economical constrains, also need to carry out most of the forestry measures.

The need for forestry measures such as pre-commercial or ordinary - thinning is enormous at the same time, as the volumes from clear cutting seem to increase. In 2001 there was theoretical possible outlet from final cutting - 3.8 mill m^3, sanitary cutting – 0.9 mill m^3 and in thinning forests – 1.0 mill m^3, (total 5.7 million m^3). Lithuania has enough wood resources and favourable age structure of stands to increase the wood supply up to 6.5 mill m^3 at the nearest future. Or even more, if forest management practice will change by shortening rotation ages and by using more intensive pre- and commercial thinning methods. The structure of wood consumption is also changing. Consumption of wood fuel increased more than twice after 1990´s and can be up to 30-50 % of total wood consumption in the future. Conversion of boilers supports this tendency.

Abandoned agricultural land has for a long time been naturally afforested, mostly with non-industrial species. Economical use of these areas is needed, for example for the production of wood fuel and later on for industrial wood.

5.5. Present situation regarding wood fuel

Wood energy is also a relatively "clean" domestic energy source, and it could potentially replace some of the imported fuels. Today wood fuel plays an important role despite the fact, that utilisation is not supported by taxes and subsides. A shift towards utilisation of wood-based energy would also require modifications in the present objectives and instrument (e.g. taxes and/or subsidies) of energy policy. Today relatively little research has been conducted on identifying potential policy options and instruments and assessing their fiscal and economic implications. Wood fuel has a positive effect on the CO_2-balance. Taxes on fossil fuel in the Nordic countries are related to the emission of CO_2.

The local fuel and hydro-energy comprise 9 % in the energetic balance of the country. Local and renewable energy sources could make 12 - 14 % of all the used primary energy resources according to the estimation of the local specialists and foreign experts. Information about wood fuel production in Lithuanian in 2001 (Statistic Department) shows 3.3 Mm^3, i.e., fire wood 2 Mm^3 (0.9 Mm^3 of firewood is produced in state forests and 1.1 Mm^3 in private forests), wood waste from sawmilling industry compromises 1.3 Mm^3. The information given by Energy Agency 2002 shows that the amount of produced energy from wood fuels in the year 2001 was 7.33 TWh (about 3.665 thou. m^3s if using the factor given in Sweden, 1 TWh correspond to about 500 thou. m^3s from forest fuel chips) and further additional potential is only 2.47 TWh (about 1.235 thou. m^3s).

The available forest fuel resources depend on the increment of the biomass of forest in Lithuania. In addition to that the use of bio-mass for heat production depends on the price of fuel, the complexity of the burning equipment and the burning price. The consumption is influenced by the price level, which depends on several factors – available forest resources and level of cutting, forestry operations as commercial- and pre-commercial thinning, situation in the wood market, harvesting-technologies and cost of the labour power, tax system, consumption of wood by sawmills and other enterprises of forest industry, export of forest products, location of enterprises and ports, road network, logistics etc.

6. Bio fuel usage experience from the EAES program.

** this chapter was written by Ulf Lindgren ÅF International and Nerijus Pedisius LEI*

6.1. Development of the use of biofuel in Lithuania

By comparing the conditions for the Lithuanian and Swedish markets in this sector some assumptions can be done. There are a number of similarities, the most significant difference is that Sweden has some more years of experience in using biofuel as a resource for district heating and co-generation, production of electricity. Swedish authorities have also used steering instruments as taxes and subsidiaries to develop the market with local fuel. During the last years Lithuania has started to use this resource for district heating systems and has built up a local market for production of equipment and know-how in this field. What can also be seen today is a need for the development of an infrastructure for fuel handling.

Today fuel mostly comes from the waste of sawmills and the forestry sector has so far been a smaller biofuel producer. This is also similar to the way it was in Sweden when the use of wood fuel increased. There are reasons to believe in a development of fuel production in Lithuania in the same way as we have seen in Sweden.

Steering instruments

Different political instruments are used to steer towards environmental and economic goals. The means are: Taxes and fees financial support and economic incentives laws, rules, and limit values research and development of education and extension. Lithuania is today very rapidly harmonizing with European union in all sectors also when it comes to use of sustainable renewable energy recourses, this will be beneficial for the development of the bio-energy sector in Lithuania.

6.2. Development of biofuel price.

It is difficult to describe the price development for biofuel in the Lithuanian market because of the following reasons:

- There exist no statistic for bio fuel that includes the price development.
- The fuel price is a not a public figure since both the buyer and company that are selling fuel work on a market with competition.
- The buyer is using more than one supplier and also different mixture of fuels.
- There are the differences depending on local conditions as an excess of waste or the opposite an increase in consumption will create a lack of fuel locally.
- The fuel is in most cases contracted in m^3 what will make it difficult to compare price levels from different contractors.

Within the program, financed by Swedish Energy Agency, a number of boilers have been converted into use of wood fuel, in most cases from mazut but also from gas firing. Data has been collected over the years and we have below described some typical figures. It should be observed that we have used a limited number of boiler houses. We have also converted it into average figures. There are differences in size and the yearly consumption vitiates from different plants 10-30 000 MWh . Figures should therefore not be seen as absolute values. It is more interesting to see the trend. From this experience we can notice that the price development has been quite stable; this is also the case when we are looking at single units. If we compare the mazut price with bio fuel it is clear that over the last five years there has been much bigger fluctuation for mazut. Price levels have been more stable over the years, this is a very natural development since the infrastructure is better and better developed.

Figure. 6.2.1.Price level for different fuel during the years

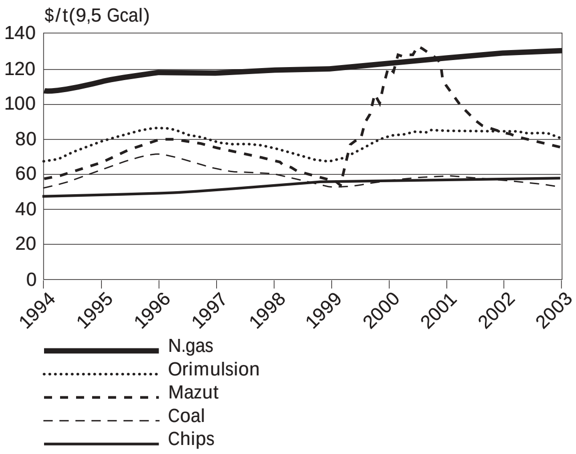


Table . 6.2.1. Overage wood fuel prices in some heating plants

Typical figures	1994	1995	1996	1997	1998	1999	2000	2001
Chips, Lt/m³ (without transportation)					14,71	17,29	17,30	17,32
Chips price, Lt/m³ (with transportation)				10,96	15,89	18,62	18,86	19,90
Chips price, Lt/MWh , alternative1				13,48	19,55	22,92	23,21	24,49
Chips price, Lt/MWh, alternative 2				16,23	23,53	27,59	27,94	29,47
Sawdust price, Lt/m³ (without transportation)				3,13	3,20	3,39	3,46	3,47
Sawdust price, Lt/m³ (with transportation)				4,94	4,13	6,47	5,12	4,36
Sawdust price, Lt/MWh, alternative 1				7,90	6,61	10,34	8,19	6,98
Sawdust price, Lt/MWh, alternative 2				9,75	8,16	12,77	10,11	8,61

Volume in example loose m³ . 1 solid m³ can be calculated to approx. as 2,5 m³ chips.

Alternative 1	
Assume sawdust 250 kg 45%	0,625
Assume chips 325 kg 45 %	0,813
Assume 19,2 MJ / kg dry substance	
Give approx. 2,5 MWh / ton	
Alternative 2	
Assume sawdust 225 kg 50%	0,506
Assume chips 300 kg 50 %	0,675
Assume 19,2 MJ / kg dry substance	
Give approx. 2,25 MWh / ton	

Looking at the typical figures above another source of difficulties to compare wood fuel from different suppliers can be detected. Fuel is often contracted in cubic meters, it can be in the form of chips or solid wood. The wood it self has a relative constant calorific value if we are looking at the type of trees that are used, referring to a report from one of Sweden's bigger forest companies a typical value can be 19,2 MJ / kg of dry substance. The problem is that since we are measuring in volume and not in mass there is accuracy problem. The same is with moisture content where it differs very much in routines how and if it will be analysed.

There is an ongoing work aiming to develop standards for bio fuel and Lithuania is participating in the work to harmonize to European norms. It is, of course, good that norms will be developed and that Lithuania is participating. If it solves the problems with measurement of wet fuel such as chips containing 30-55% of moisture it is difficult to say. The development of biofuel standards is focusing on more developed fuel such as pellets and briquettes where it is necessary to use the same norms to compete with an international market. For biofuel such as chips it is in the interest from both the buyer and the supplier to develop a system where the fuel will be measured in a way that it is possible to compare different suppliers as well as different mixtures of fuel. With the present situation it is impossible to compare two different suppliers, in a situation where we have a competition and prices is given in solid cubic meters the differences in price is less than the uncertainty in what quality we are comparing.

In times of high load such as winter period it is not only the price per MWh that is important but also the possibility to reach design capacity for the boiler, for this reason it can be more effective to use a higher quality fuel.

6.3. Limits for using biofuel

Consumption , installed capacity covers the existing load and there can be over-capacity installed.

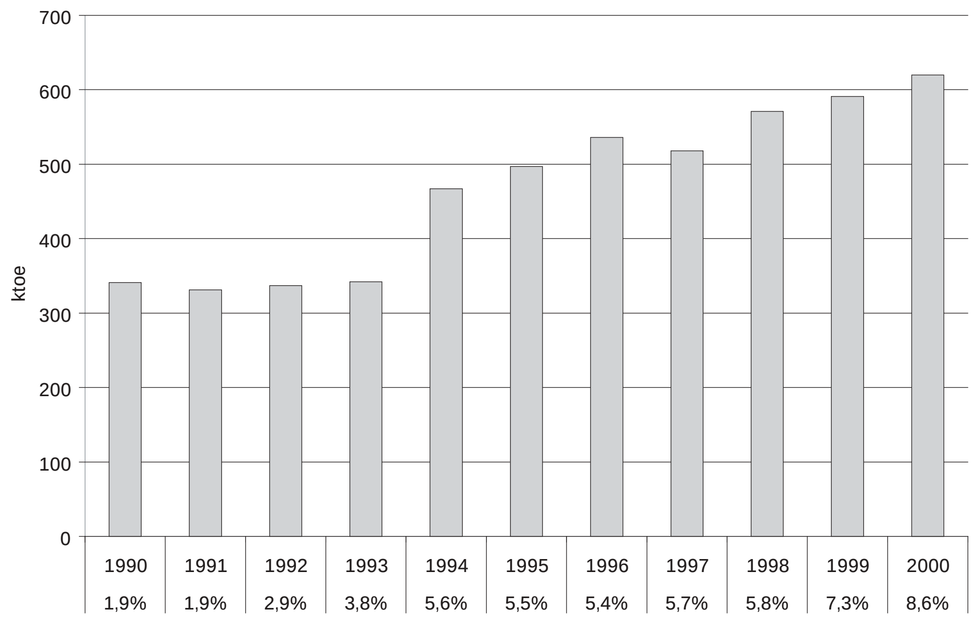
Price, the cost for DH production on biofuel can not compete with other alternatives, the fuel price needs to be on a level where the margin between bio fuel and the alternative will cover the normally higher investment in biofuel production units. It is not possible to define exactly how big this margin need to be since the variation is significant between different projects. As an example: with an Investment of 2 MLTL, a capital cost of 14% (interest plus amortisation) and a production of 28 000 MWh need minimum 10 LTL difference in price per MWh in fact will be higher since a risk assessment for fuel price movements etc. has to be done and a higher operation cost has to be calculated. So in this example the realistic difference has to be 15-20 LTL / MWh before someone start a project.

Independence, the customers feel a security to have an alternative that they can control by themselves, here is the biggest risk if district-heating networks will not be able to compete on the market.

Limited resources.

There is an upper limit for use of biofuel. Therefore it is important to investigate the future situation as far as possible. Municipalities and ministries need to have a resource plan for the different regions.

Figure. 6.3.1. The estimated amount of biomass used for energy production including wood fuel used in small private houses.



The diagram includes firewood for small family houses as well as district heating boilers. Until 1994 the consumption was only for smaller units, from 1994 district heating companies started to use bio mass. According to Energy in Lithuania 2000 statistic 70 ktoe were used to heat only boilers. This should give us approx. 455 000 solid m^3 used for district heating.

To convert ktoe to many more understandable units we could assume that wood in this case has a heat value of 2,25 MWh /ton and a solid m^3 to 0,8 ton then we in this example will have 1,8 MWh per solid m^3

1 ktoe = 11682 MWh and it will be approx 6500 m^3 solid wood

Alternative use of biofuel resources.

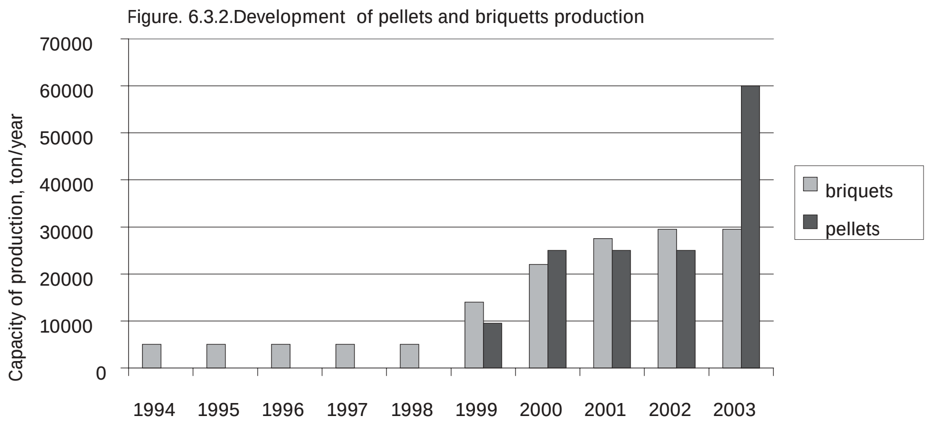
The resources from forestry should of course be used in the most optimum way and production that can be used as timber etc. should not be used as fuel.

Experience from Sweden shows that there is no conflict of interests - with the development of the wood industry there will be a possibility to find waste that can be used as fuel.

The situation for Lithuania today shows that in some cases fuel is processed from qualities that in future will be used for other purposes. Fuel export is also an alternative for both in the form of logs and more developed fuel as pellets and briquettes, 75% of briquettes produced by local companies are exported to Germany, Denmark, Sweden and Norway. The remaining part 25% is sold on a local market. The price of briquettes depends on season: it was about 250-280 Lt/t in summer 2002 and it rose up to 350 Lt/t respectively in winter 2001. The stable increase of the average price for briquettes was observed from 1994 to 2001: 150 Lt/t - on 1994 and 330 Lt/t - 2001. The price for briquettes slightly decreased up to 280 Lt/t in 2002 due to increase in the export from Poland and Czech Republic.

The price of pellets in local market is about 55 EUR/t in 2002 but for export the price could reach 95-105 EUR/t. The price of the raw material (saw dust) increased from 0 to 15 Lt/t (without transportation) in the period 1994-2002.

Figure. 6.3.2.Development of pellets and briquetts production



6.4. How can the development of the biofuel use look like.

In the nearest future the resources from wood fuels produced directly in the forest from trees or logging residues will be used. Other resources will also be used but the part with fuel from the forest does not need any special combustion technique and there are no problems with pollution. We believe that it is necessary to support the development of the infrastructure for the biofuel sector. Most important it will be to establish a co-operation between the forest industry and the wood processing industry. The forest industry has a possibility to develop a new branch on their production ”tree”.

7. Analytical estimation of material balance in lithuanian sawmilling industry

**this chapter is a reduced version of the origin chapter written by © A. Baltrusaitis, V. Pranckevicienë from KTU.*

7.1. Situation, problems, objectives and background of investigation

Total forest area in Lithuania exceeds 2000 thou. ha and covers 31 % of the country's territory. Estimations on annual potential of wood fuel resources from the forests and wood working industry still remain different according to the various information sources. Generalization of such figures gives annual resources consisting of 1.4 Mm3 of logging residuals in the forest, 0.6 Mm3 of wood processing waste, and over 1 Mm3 of firewood [1,2,3]. Total amount of different wood waste suitable for combustion in boiler houses is as large as 2.70 Mm3 per year or 3.8 mill. MWh of potential heat energy [2]. Reportedly real wood processing waste volume reaches about 1,5 Mm3. Annual consumption of wood waste is not yet clear but can be estimated as much as 1 Mm3 [3]. It is obvious that the figures related to the wood processing waste, mentioned above, that still repeatedly appear in serious reports from time to time need considerable revision and correction.

Wood processing industry annually processes around 3 Mm3 of round timber. About half of it is converted into slabs, edgings, trim blocks, sawdust or chips. The main part of it (about 40 %) is accumulated in the sawmill sector. This wood waste possesses high moisture content (45-55 %) and a lot of bark because many sawmills do not use the debarking machines yet. Another part of wood waste is accumulated when producing value-added products: furniture, particle board, veneer, etc. In this case the wood waste is dry (about 8-14 %) and without any bark. This kind of sawdust, shavings or chips makes excellent raw material for direct combustion or conversion into wood pellets and briquettes. The latter amount of wood waste depends on how much of sawn timber is left in the country and subsequently converted into ready wooden garments. Having such figures indicate that processing residuals could reach up to 50 % of the total volume of processed sawn timber.

Official statistics of 1998 stated that about 100 thou. m3 of wood waste was used for production, about 50 thou. m3 has been taken to the deposits and about 120 thou. m3 is used for combustion as a wood fuel. At the same time the real volume of deposited wood waste was estimated as much as 200 thou. m3 [3]. Such situation is not acceptable from both environmental and economical point of view. Moreover, figures are not statistically resumptive and reliable.

According to the data of Forest Department total wood fuel consumption in Lithuania is 2,75 Mm3. 43 % or 1,2 Mm3 make firewood produced in state forests, 0.6 Mm3 or 22 % make firewood produced in private forests and 0.95 Mm3 or 35 % make wood waste from sawmills [4]. Wood waste from sawmills was used in this way: 46 % as wood fuel for residential houses, 17 % for boiler houses, 17 % used for the sawmill needs and 13 % sold for pulp and board industries.

It is difficult to evaluate or trust all the figures related to the total wood waste potential and the share of individual items in various production stages. Even more complicated is technical and economical availability for collection and transportation to the boiler house or densified wood fuel production plant. More and more sawmills and other woodworking enterprises use wood waste in their boiler houses. One part of chips is exported, another part is directed to the internal paper and board industry.

Situation in wood processing industry concerning wood waste suitable for wood fuel is favorable to calculate and forecast analytically using specific methods. Research data and models of optimization of log and cant sawing carried out at the Department of Mechanical Wood Technology (Kaunas University of Technology) could be applied for such calculations of amount of wood residuals in the Lithuanian sawmill sector [5,6].

7.2. Annual consumption of round timber

Initial data for the calculation of the wood waste accumulated in the Lithuanian sawmill sector was provided by the Forest Economy Center (MEC). Annual consumption of sawlogs in 2001 was estimated as follows (Table 7.2.1.).

Table 7.2.1. Annual domestic processing of round timber

Softwood logs	
Total production of round timber: – sawlogs – pallets logs (small size logs). Processed in local sawmill sector: – sawlogs – pallets logs (small size logs).	1800 thou. m^3, – 1100-1200 thou. m^3, – 600-700 thou. m^3, 1600 thou. m^3, – 900-1000 thou. m^3, – 600-700 thou. m^3,
Hardwood logs	
Total production of round timber; Processed in Lithuania, total: – for veneer production – in sawmill sector: – sawlogs – pallets logs (small size logs).	1100 thou. m^3, 1100 thou. m^3, –200 thou. m^3, –900 thou. m^3, – 400-500 thou. m^3, – 400-500 thou. m^3,

7.3. Material balance in sawlog processing

The formulas and models created and derived by the authors of this chapter as well as available information on the methods used in different countries made the basis for analytical calculation and estimation. Various authors [7,8,9,10,11] provide different information about material balance when processing sawlogs. The share of each item such as balance like percentage of sawn timber, drying shrinkage, sawdust, slabs, edgings, trim blocks, etc. differs according to the technology and equipment used. Therefore typical sawing patterns, sawing kerfs, standard sizes of boards and other factors specific for Lithuanian conditions were necessary to take into account. Even more important was to have a distribution of certain type sawlogs into top-end diameter classes which would be typical for Lithuania in order to have total volume of round timber in each class. Only then correct sawing pattern was possible to be used for calculating the material balance when sawing each of provisory logs of each diameter class. Different standard sizes of boards have to be applied for sawing coniferous and hardwood sawlogs and totally different for sawing pallet logs. Moreover, different equipment and technology has to be considered in each case. Thus the data available on the distribution of round timber into diameter classes from different countries (Scandinavia, Russia, North America [8, 9,10]) naturally was not applicable for accurate calculations. However this data was still used for comparison and verification of the analytically obtained results.

Sawing patterns for each respective sawlog diameter class (16-36 cm, with 2 cm increment) have been selected using standard sizes of boards. The chosen width of longitudinal sawing kerfs (those lying alongside sawlog) for log and cant sawing as well as crosscut kerfs for shortened side boards was 5 mm. or rather minimally possible. Sawing kerfs for edging of side board falling out of primary and secondary breakdown were also 5 mm. Sawn timber volume shrinkage has been selected as 7 %. Maximum 30% of sideboard wane was also allowed. For each diameter class real taper was calculated instead of commonly used 1 cm/m. Calculations were made for average sawlog length 5 m.

Material balance in percents (sawn timber volume yield, sawdust, edgings, slabs and trim blocks) has been calculated using special program CAS 3.75 A for block sawing pattern. Program CAS allows virtual modeling of sawmill using real dimensions of logs, changing kerfs, board sizes, etc. Amount of sawdust was calculated according to the real sawing kerf height, width and length. Sawdust from cross cutting and edging operations was also included.

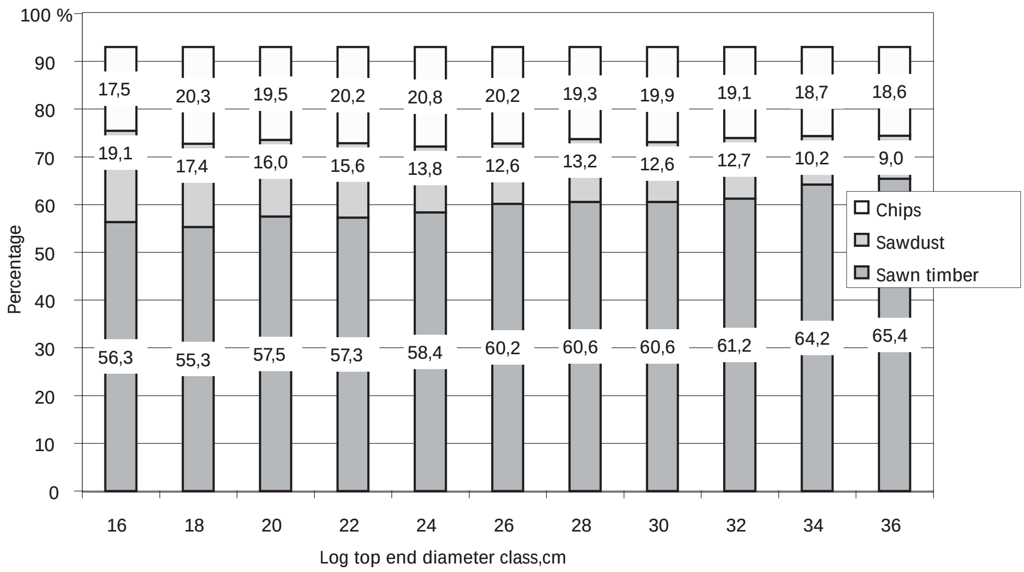
For each diameter class sawing pattern represents the optimal sawn timber recovery. It means that amount of sawdust and chips from slabs, edgings and trim blocks for every respective diameter class is the minimum that could be achieved. Naturally such advanced technologies are targeted for every sawmill and even in good sawing practice quite often real wood waste volumes could be 5-8 % larger.

Symmetrical sawing pattern, optimal cant height and optimal number of center yield boards and side yield boards of standard sizes mean minimum number of kerfs and thus minimum sawdust amount.

Volume yield consistently increases with the growth of top end diameter from 56.34 % for D=16 cm, up to 61.23 % for D=36 cm. It means that wood waste amount decreases in the selected diameter range respectively by approximately 5-6 % when processing sawlogs in larger diameter classes. Still total volumes of wood waste depend on the volume of logs processed in each diameter class. Calculations were made according to the correlation formulas [11]. It is clear that correlation formulas give wrong (in some cases up to 5-6 % different) results and thus are totally unacceptable for the estimation of sawdust volumes when sawing small size logs. Differences starting from the diameter over 24 cm are minor. Results obtained from the correlation formulas [10] and precise data received from sawing simulation methods (sawdust and chips) describe very well that existing data based on formulas and correlation for sawing conditions with ideal sawing conditions (e.g. with the kerfs of 3.2-3.4 mm) give considerable deviation in comparison with the realistic production-as-usual.

Data presented in Figures 7.3.1. was summarized as a material balance for sawing of sawlogs in each top end diameter class.

Fig.7.3.1. Total material balance for sawlogs (sawn timber, sawdust and chips)



Each column in every single diameter class plus 7 % of shrinkage makes 100 % of respective sawlog volume.

Percentage of sawdust and chips received by calculation allows calculating each top end diameter class amount of these sub-products when knowing volumes of round timber processed annually in each respective diameter class. But for realistic and adequate application real distribution of sawlogs according to the diameter classes in Lithuania is needed. During the last 5-6 years wide research on such distribution has been carried out by the authors in a number of sawmills, state forest enterprises all across the country. Thousands of logs were measured (top end diameter, length, taper, sweep) and existing data banks of logs processed in sawmills and produced from logging operations in forests were used. Measuring and testing was carried out in different districts of Lithuania: Kaunas, Alytus, Varëna, Birțai, Klaipëda. The data on the sawlog produced in the state forest enterprises was complemented by the measurement results in the sawmills of SFE's. Other well known sawmills of high productivity like JSC "Pajűrio mediena", G.Kaminskas PE, JSC "Skirmeda", JSC "Klijuota mediena" were among those field-tested. Such sawmills receive round timber from different SFE's as well as private forests. Moreover, field-testing was carried-out during several years and only for round timber from Lithuanian forests. Therefore large number of sawlogs from different forests in different districts, different tree species have been represented.

Then the information collected in our data bank was processed in order to receive softwood and hardwood sawlog distribution by volume according to the top end diameter classes in the range of 16-42 cm (increment 2 cm). The same procedure was applied for the pallet logs and similar distribution was calculated in diameter range of 14-26 cm with the increment of 2 cm. Received distribution were later on applied for the calculation of the material balance of total volumes of round timber processed in Lithuanian sawmills per year. Since total volume of such sawlogs according to MEC estimation was 900-1000 thou.m^3/year each column in the graph represents the share calculated in this range.

The Largest volumes (68.7 %) from annual consumption of sawlogs were processed in the diameter classes of 16-24 cm. Since different volume yield is naturally received from small sawlogs here we can also expect higher amount of sawdust from sawing kerfs.

Totally different distribution represents broadleaf sawlogs. Most of the processed sawlogs (80 %) are in the diameter range of 24-36 cm, thus we can expect more optimal sawing and higher volume yields and consequently lower wood waste volumes. The distribution of volumes for broadleaf sawlogs by the top end diameter classes. Total volume – 400-500 thou.m^3

Final material balances for softwood and broadleaf sawlogs for each diameter class are presented in Fig. 7.3.2 and 7.3.3. respectively.

Fig.7.3.2. Material balance for coniferous sawlogs (Total volume 916,7 thou.m^3, from which: 529,27 thou. m^3 sawn timber, 143,87 thou.m^3 sawdust, 179,8 thou.m^3 chips)

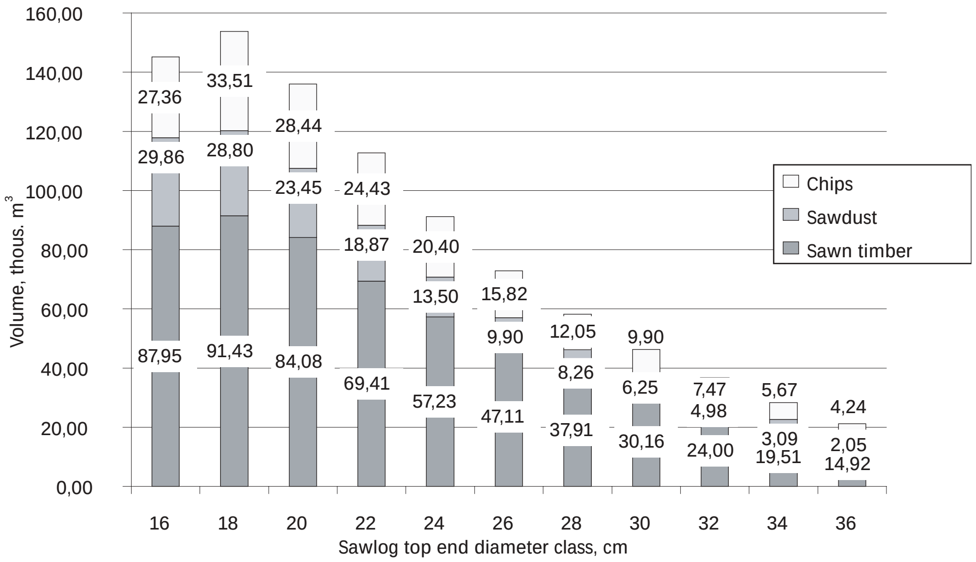
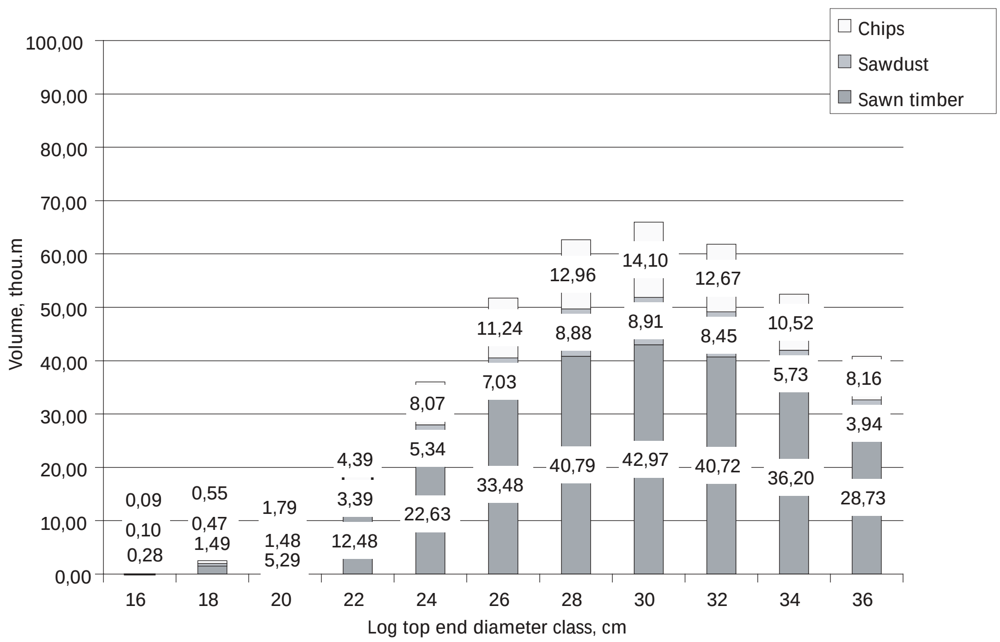


Fig.7.3.3. Material balance of broadleaf sawlogs (Total volume 433.7 thou.m^3, from which: 265.06 thou. m^3 sawn timber, 53.73 thou.m^3 sawdust, 84.55 thou.m^3 chips)



7.4. Material balance in small size pallet logs

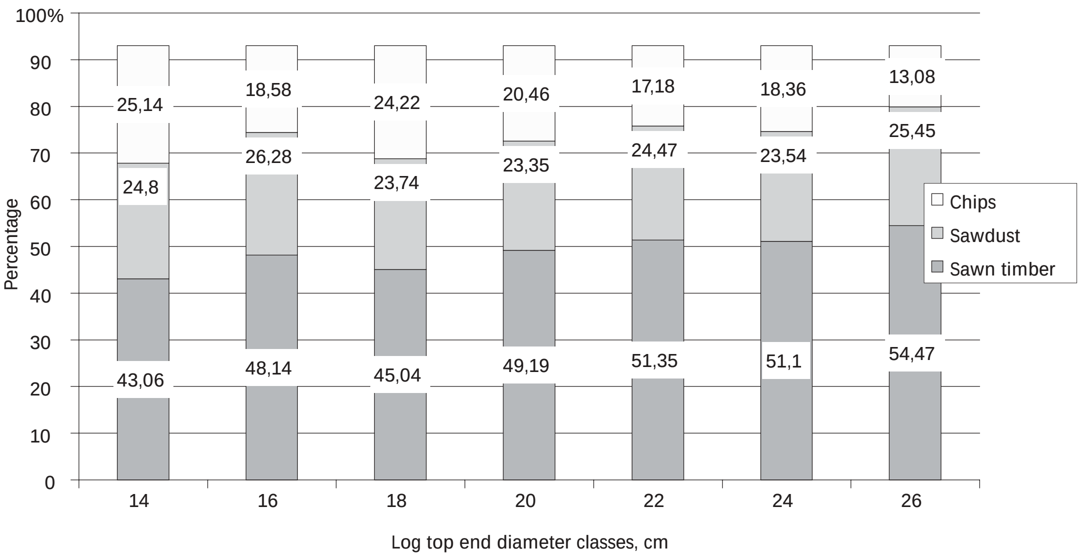
Sawing patterns for each respective pallet log diameter class (14-26 cm, with 2 cm increment) have been selected using nominal sizes of pallet boards. The tendency in comparison with sawlogs sawing is similar but figures differ especially when sawing smaller size logs.

When simulating and modeling pallet logs sawing process sawing patterns were selected according to real nominal sizes of pallet boards: thickness 17,19,22 mm, width 78, 98, 118, 113 and 143 mm. Average length of pallet logs was 2.4 m. Methodical approach was the same like in the case of sawlog processing: the sawing simulation using different board sizes was applied for each diameter class until the highest volume yield was achieved. Volume sawn timber, sawdust and chips are presented in figures 7.4.2.

Volume yield range for small size sawlogs in different diameter classes is 43.06-54.47 %. Obviously it is not possible to estimate volumes of wood waste on the average figures especially taking into account the division of logs into different diameter classes.

If amount of sawdust remains considerably stable in each single diameter class totally different picture is seen for chips. Here we use range of 13.08-25. 14 % when comparing diameters of 14 cm and 26 cm. Any calculation on "average" figures here is totally unacceptable.

Fig. 7.4.1. Total material balance for small size logs (sawn timber, sawdust and chips) by percentage



Final material balances based on above presented data for coniferous and broadleaf small size logs processed into pallet boards are presented in figures 7.4.2 and 7.4.3.

Fig.7.4.2. Material balance of coniferous small size logs. Total 600 thou.m^3, from which 289,7 thou. m^3 sawn timber, 146,35 t kst.m^3 sawdust, 121,84 thou.m^3 chips

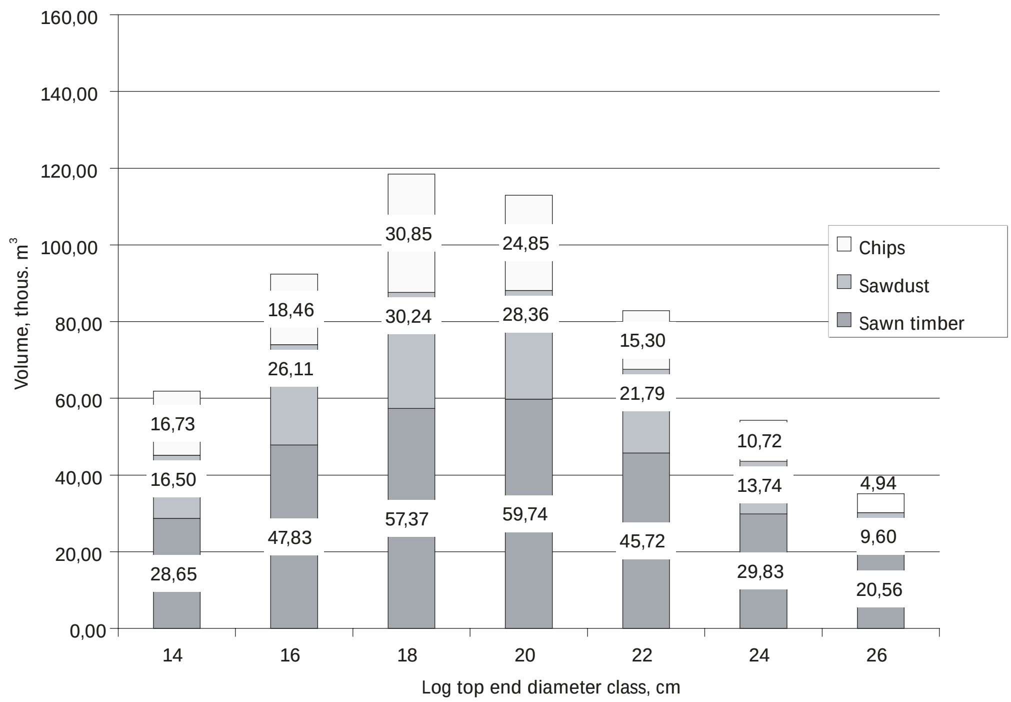
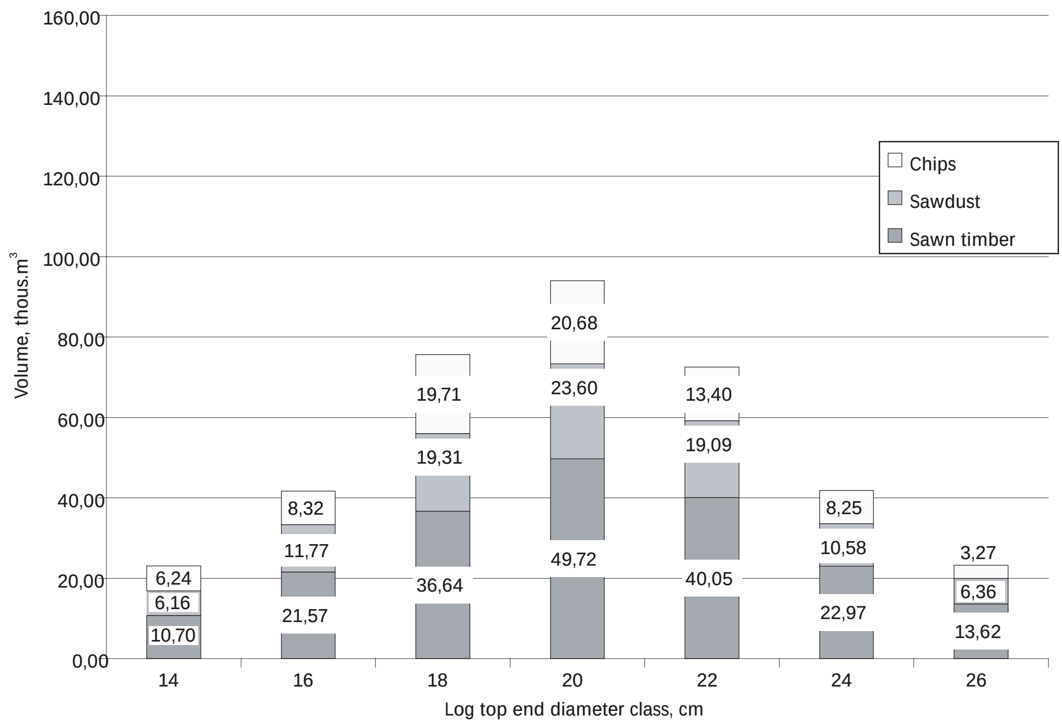


Fig.7.4.3. Material balance of broadleaf small size logs. Total 400 thou.m^3, from which 195,27 thou. m^3 sawn timber, 96,88 thou.m^3 sawdust, 79,88 thou.m^3 chips



Annual material balance for coniferous and broadleaf sawlogs and pallet logs processed in Lithuania on realistic sawing patterns is presented in table 7.4.1. As far as sawlog calculation was based on diameter range of 16-36 cm, what included 96.99 % of total annual volume, the material balance was recalculated for the whole 1000 thou.m^3. The same procedure was then repeated for broadleaf sawlogs. The latter final figures are in bold in brackets.

Table 7.4.1. Annual outcome of processing of round timber

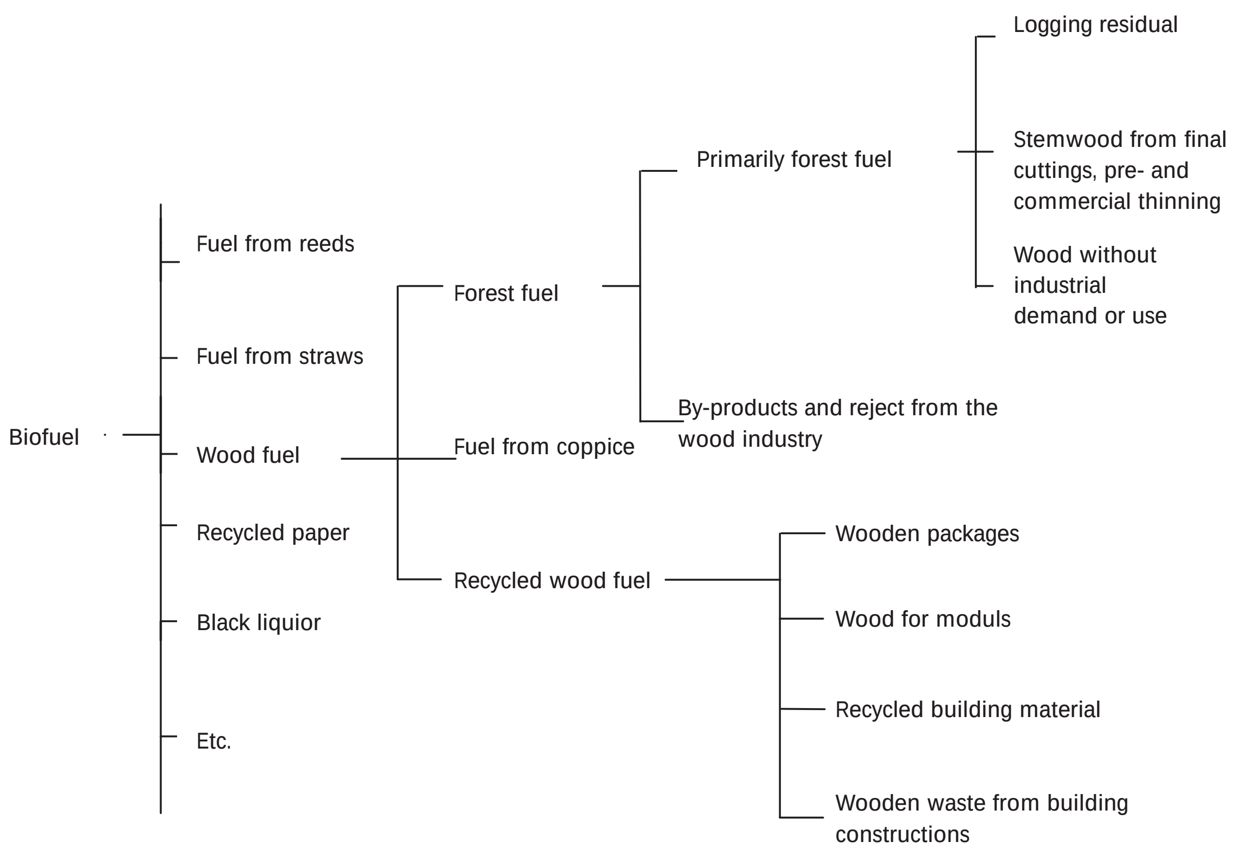
Species	**Sawn timber**	**Sawdust**	**Chips**
Coniferous: Sawlogs (16-36 cm) (969.9 thou.m^3/year) Pallet logs (14-26 cm) (600 thou.m^3/year)	563.7 **(581.19)** **289.7**	149.01 **(153.63)** **146.35**	189.29 **(195.16)** **121.84**
Broadleaves: Sawlogs (16-36 cm) (433.7 thou.m^3/year) Pallet logs (14-26 cm) (400 thou.m^3/year)	265.06 **(305.58)** **195.27**	53.73 **(61.94)** **96.88**	84.55 **(97.48)** **79.88**
Total (thou.m^3/year)	1313.73 **(1371.74)**	445.97 **(458.80)**	475.56 **(494.36)**

8. Forest fuel production, technique and requirements

8.1. Definition of forest fuel

Wood fuels are defined as biofuel originating from trees and consisting of wood, bark, needles or leaves. Normally wood fuels are divided into forest fuels. When integrating the extraction of forest fuels in the ordinary forestry activities we nowadays define the part of the forest fuels that comes directly from the forest (e.g. fire wood, logging residues etc.) as primarily forest fuels, not including by-products and reject from the wood processing industry. By-products and reject from the wood industry also consist of wood origin from the forest and are defined as forest fuels (industrial wood waste).

Fig.8.1.1. Division of biofuel, wood- and forest fuels into sub-groups by origin of raw material and integration of flow.



8.2. Forest fuel production technique

There are several alternatives of the equipment for the extraction of primary forest fuel on the European market. Chipping can be performed in the forest, at roadside landing or at terminal. When extracting tops and branches special chipping equipment is designed and produced with high capacity and accessibility.

8.2.1. Forest fuel from pre-commercial thinning

The most common method is felling the trees with manual tools (such as sward) or motor chain saw with felling handle. The whole trees are collected and piled near the technical corridors. One way is then to transport the piles out to the roadside landing or chip in technical corridors. Machines with multi tree handling system have been developed in Sweden and are nowadays used in this kind of stands.

8.2.2. Forest fuel from commercial thinning

In thinning there are more methods possible to use than in pre commercial thinning as the outcome of thinning also consists of industrial wood such as pulpwood and even the pulpwood can be handled in different ways. The 2 most used systems are the chipping conducted in technical corridor or at roadside landing.

8.2.3. Tree section

Outtake of **tree section** means that the trees still have the branches still sitting on the stem and are cut into suitable length for the hauling.

8.2.4. Forest fuel from clear cutting

Top and branches can be extracted in 2 different ways either by chipping at the clear-cutting area or extracted to roadside landing and stored. The forest fuel can also be extracted in different time e.g. directly in concession with the logging operation or after it have been stored in piles in the clear-cutting area.

8.2.5. Chipping in forest, terminal or roadside landing

It is often more suitable to chip at roadside landing than in the forest. You then have a possibility to use large chipping units with high capacity at the same time as smaller machines without damaging the ground can perform the hauling. Chipping at terminal can be conducted with stationary units with high capacity and accessibility. Possibilities to store unprocessed material are big. You are therefore less dependent on time of the year and weather. Transportation to terminal can be done when conditions are most suitable concerning transport capacity and the road accessibility. This requires suitable vehicle for transportation of material from forest to terminal. If chipping at terminal you should consider having a mobile chipping unit instead of stationary chipping unit. The mobile chipper can, in parallel with the work at the terminal, be used at roadside landing and also in the forest.

8.3. Difference between disc-and drum chippers

Disc chippers consist of a rotating, heavy, balanced disc with radial mounted knives. Disc chippers are most suitable for chipping roundwood (firewood) without branches or in some cases whole trees from pre-commercial thinning. Usually these machines are manually fed and only tops and branches are not possible to decompose with accepted chip sizes in this kind of chipper. Weak tops with branches usually make problems when chipping whole trees or bushes, making stop in the chip-blowpipe or twirling around the disc when the weak parts of the tress are not decomposed in right chip length. If it doesn't cause an immediate stop in the chip production the problem occurs later at the consumer when the delivered chips contain long weak pieces of tops or branches. This can cause serious problems in the feeding system for the boiler, twirling around the screw and or conveyor system. Output capacity from a mobile disc chipper is limited to 5-15 m^3/h.

Drum chippers consist of a rotating drum with longitudinal knives. The drum has high speed. Horizontal feeding usually with feeder roll or a feed intake conveyor with chains which makes chipping of tops and branches possible at the same time as the capacity is much higher. Mobile drum chippers are also suitable to feed by crane and the chipper can chip down whole trees, tops and branches and roundwood and also all in one mixture at the same time. When feed by crane output is capacity 40-90 m^3loose volume chips/h.

8.4. Transportation

The main haul is often one of the problems that are most difficult to solve when dealing with wood fuels. The principal reasons for this are the texture of the assortment range and the relatively low solid volume in combination with a low cost ceiling. The problem is further complicated by the fact that the drain areas are large with relatively small available volumes per unit. Through development of special chip transport vehicles the cost has been reduced to level per m^3 just over the cost for round wood transportation on longer distances. The technique for loading and unloading has been developed by container systems, but nowadays self loading trucks with manipulator crane have also been developed. (More about transportation in Lithuania can be read in chapter 12 and 17).

8.5. Storage

Normally the demand and supply of forest chips depend on the seasons in year. For this reason storage of forest fuel is needed. There is also a need to store due to the reasons of security of supply and the storage can increase the energy content by natural drying which reduces the material moisture content. The cost for storage per MWh consists of two parts: 1) how big capital has been invested in the stored material (buying material, transportation, decomposition, etc.) and 2) changes in energy content while storing.

To minimise the capital cost normal principals of storing are required. As small volumes as possible should be stored for as short time as possible. The material should be stored in the cheapest form, as little decomposed and transported as possible. Storage of not decomposed material in connection with roadside landing is the most suitable. Storage during winter season should be done in connection to roads, which are kept opened due to other reasons than the forest fuel extraction. Storage should be at the roads, which will not be closed due to heavy frost.
What happens with wood fuel during the storage?

The energy changes, which occur while storaging are complicated. The changing in energy content occur due to very complicated factors. The important ones are the chemical origin of the material, moisture content, texture, the length of storage period, weather, storage place exposition, etc. Regarding research on storage conducted in Sweden the following factors should be considered:

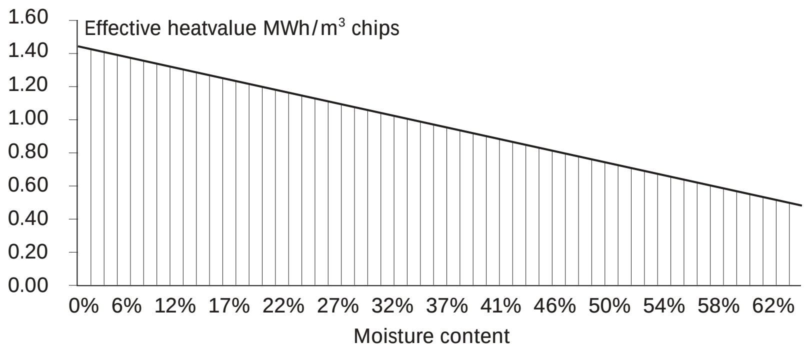
- Storage during summer of not decomposed material can give an increased energy content due to the drying of the material. Chipping of naturally dried material gives protection against picking up moisture, even if the chips are stored outside.
- When storing decomposed material the changes in energy are less dependent on the weather. More important is the chemical origin of the materials and the moisture content at the time of the decomposition (chipping).
- When storing a decomposed material, energy losses can occur due to microbial activity. If it is a mixture of big part of bark and other materials microbial activity increases. If the material is dry, in large pieces and consisting of wood the energy losses are less.

With today's knowledge it is recommended to store not decomposed material and decompose (chip) when there is a demand.

8.6. Measurement and price of forest fuel

The new assortment makes a problem regarding the price and measurements. Traditional assortments have been measured and evaluated with respect to volume, etc. regarding easy measured criteria. The buyer of forest fuel is less interested in the volume. His interest is in the amount of energy in the forest fuel and it can not be measured without a relatively complicated method and sampling. The factors, which are the most important for the effective energy content in a decided volume of wood fuel, are the amount of dry matter per volume unit and the material moisture content.

Fig.8.6.1. Effective heat value in 1 m^3 (Chips, loose volume) as a function of the forest fuel moisture content



Factors that should be considered are:

- assortment
- amount of dry matter/volume unit
- dry matter content

The easiest way is to weight the load (truck) before and after unloading the chips and then take samples for the analysis.

The calculations of delivered energy in MWh /ton fuel (raw weight) are carried out in the following way:

$$\text{MWh/ton} = \left[19{,}2 * \frac{100-A}{100}\left(1-\frac{M}{100}\right) - 2{,}44\frac{M}{100}\right] * \frac{1}{3{,}6}$$

19,2 = effective heat value in ash- free dry matter in MJ/kg

M= Moisture content in percentage by weight

A= Ash content in percentage by weight of dry substance

2,44= Heat of evaporation at +25 degree Celsius

The following ash content used if analysis of ash is not conducted:

Fuel from stem wood	1%
Fuel from logging residues	3%
Fuel only from bark	3%

When delivering from small objects (cutting places) and smaller suppliers these measurements can be unpractical and not cost effective. Instead of that the assessment of raw weight of the load should be conducted with a subjective dry matter content in classes. Random samples to check the dry matter content in order to control the subjective assessments should be conducted regularly.

8.7. Energy content in forest fuel chips

1 m^3 solid volume forest fuel corresponds to approximately 2.5 m^3l (loose volume) forest fuel chips, or the opposite 1 m^3l forest fuel chips corresponds to 0.37 m^3s (solid volume) forest fuel. 1 m^3l weights about 340 kg when the moisture content is 45 %. 1 m^3l normally has energy content between 0.85-0.95 MWh. The moisture content for forest fuel chips normally varies between 35-50 percent. 1 m^3s of forest fuel chips contains approximately 2.19 MWh. 1 MWh corresponds to approximately 1.19 m^3l or 0.53 m^3s.

8.8. Forest fuel chip quality

The transport problem is often related to big pieces, sometimes the load of wood chips contains iron bars, stones etc, which can create different stops in conveyors or screws in the heating plant. Long pieces of bark can also be a problem. Wintertime ice and snow can create problems. Therefore there is in some way a relation between the quality of the transport system and the possibility to use a wider range of fuel. The burning process is the other critical point as it is easier to handle a quality that does not differ from time to time, the adjustment of air and other parameters will in that case be stable and easy to control. Handling of very fine fraction like sawdust is also complicated.

Examples of the requirements for the wood chips:

1) Requirements from boilers produced by Kazlu Ruda in Lithuania: Maximum pieces 50 x 50 x 50 mm. Moisture content 30-55%.
2) Normal requirements from boiler houses in Lithuania using Swedish technology: The mixture of wood chips and sawdust (50% X 50%). Wood pieces 15 x 40 mm, separate pieces up to 70mm.
3) Swedish standard, SS 18 17 06. Wood chips are divided in fine wood chips 5-15 mm, and thick wood chips 15-50 mm.

9. Wood Chipping Aspects in Lithuania

**this chapter was written by dr. Antanas Baltrusaitis from Kaunas University of Technology, Department of Mechanical Wood Technology.*

9.1. Historical review of wood chipping development in Lithuania

Stationary wood chipping devices of different design have been started to be used in Lithuania in sawmills for converting slabs, edgings, trim blocks and other sawing residuals into chips for board industry. Production of chipboards was first launched in 19?? First in Kazlu Ruda particleboard factory (capacity approximately 100 000 m^3) and in 19?? in Klaipėda particleboard factory (capacity 80 000m^3). Most of that time state owned sawmills including some bigger sawmills in the State Forest Enterprises (SFE) as an obligation had to supply these factories with technological chips. Enterprises with screening facilities were able to shift high quality chips and screen-left was in some cases used for fuel. At that time such usage was not economically cost-efficient due to extremely low gas and oil prices. Nevertheless even then directives of fuel chips production existed under the popular slogan of these times which was "complete and complex raw material utilization". Up to 30% of chips consumed in mentioned above chipboard factories has an origin from different sawmills throughout all the country.

In early eighties first mobile disk chippers were started to be used in SFEs and soon most of them were equipped with such machines. Most of mobile chippers were produced by Swedish company "Bruks" with feeding-works including lower conveyor and upper feed roll. The best quality chips were produced from stems but to some extent machines were applicable for chipping logging residuals. Prevailing logging technology at that time was based on extracting and transporting of the whole tree stems with manual delimbing. Logging residuals were simply scattered on the site thus eliminating collection of logging residuals. On the other hand no equipment existed for such collection and partly because of common opinion and rules of leaving them in the forest for soil fertilization. Attempts to use these machines for chipping firewood were not cost-effective and soon stopped. For some period of time mobile chippers were used at the roundwood terminals and sometimes even for chipping of sawmill residuals and then finally disappeared from the market and production. Since that time some negative rumor exists between foresters about possibilities of chipping in the woods.

Notwithstanding to the unsuccessful attempts and experience in mobile chipper application R&D activities were carried out on designing of new type mobile chippers for small size trees and technology for their application. Conical screw mobile chipper for precommercial thinning was built and tested at Lithuanian Forest Research Institute during 1982-1986. Machine was specially designed for chipping small size trees from precommercial thinning to the fuel chips with average length 35-55 mm. Main technical specifications of the chipper MPC-5 when 3-point mounted on agricultural tractor MTZ-82, power 70 kW:

Chipping conical screw velocity, rpm	1 250
Technical feed speed, m/min	70
Intake opening, mm	150 x 150
Output, m^3/h loose volume	
(average tree diameter 7cm)	10-15
Energy consumption, kWh/m^3	0,9-1,0
Length, m	1,20
Width, m	0,80
Height, m	0,55
Weight, kg	115

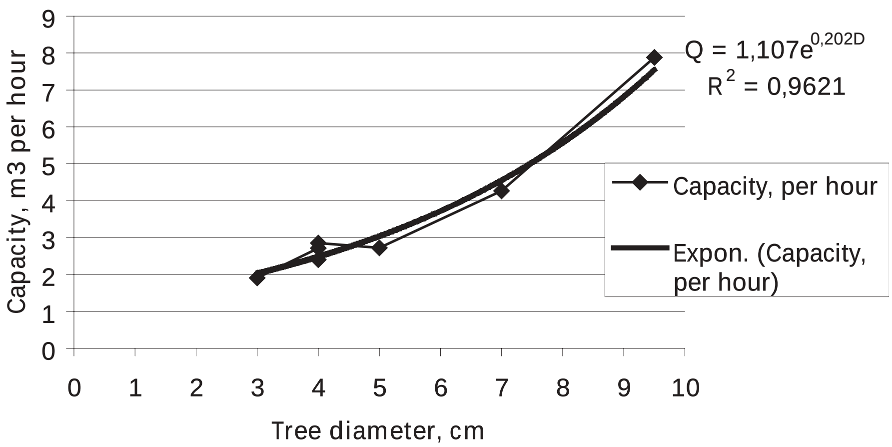
The results of field-testing of machine are presented in the Table 9.1.1. and Figure 9.1.1.. Feeding of undelimbed whole trees into machine was manual and conducted by two workers.

Table 9.1.1. Capacity indicators of whole tree chipping with MPC-5

Parameters of small size trees			Chipping time per tree, s	Effectiveness factor of machine	Average feed rate, m/s	Feed rate effectiveness factor	Chipping capacity, m³ loose volume	
Diameter, cm	Height, m	Volume, m³					Per hour	Per shift
3,0	3,0	0,0019	3,60	0,61	0,83	0,64	1,91	12,4
4,0	5,0	0,0040	5,31	0,56	0,94	0,72	2,71	17,6
4,0	4,0	0,0036	5,40	0,45	0,74	0,57	2,40	15,6
4,0	3,0	0,0034	4,30	0,72	0,70	0,54	2,85	18,5
5,0	5,0	0,0063	6,93	0,73	0,72	0,56	2,72	24,1
7,0	6,0	0,0137	11,55	0,71	0,52	0,40	4,27	27,7
9,5	8,0	0,0312	14,25	0,95	0,56	0,43	7,88	51,1

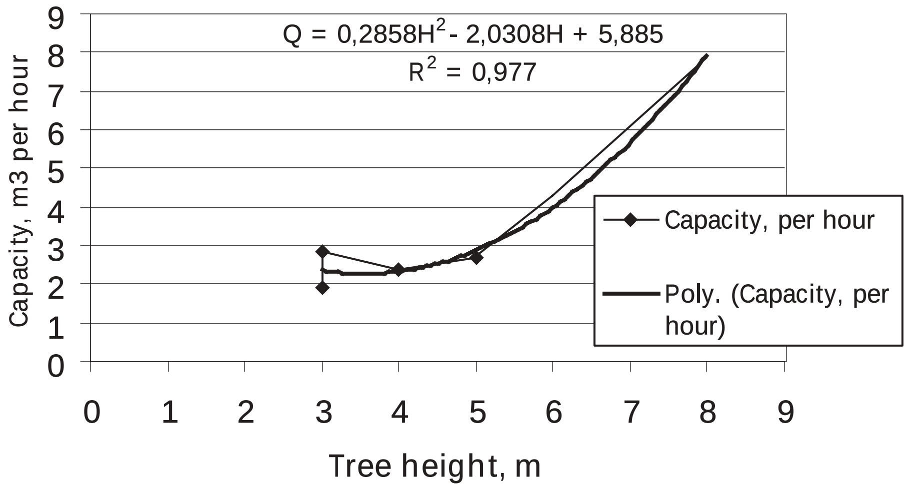
Machine effectiveness or "loading" factor shows chipping time versus idle running of machine. When loading manually continuous chipping was achieved from tree DBH about 10cm. Average feed rate was always considerably lower than theoretical feed speed of feedworks. Chipping capacity per hour represents a non stop production while capacity per shift shows reduced effectiveness figures due to normative time loses. Average calculated feed rate ranged from 0,52 to 0,94 m/s, or considerably lower than technically available from feed-works. The reason was typical for all chipping machines - diminished feed effectiveness due to tree "slipping" in the feed-works. Dependence of chipping capacity on tree DBH is provided in Fig.9.1.1.

Fig. 9.1.1. The graph and model disclosing influence of tree diameter on chipping capacity



Looking at data on average diameter of removed trees from certain thinning conditions it is possible to make preliminary prognosis on expected chipping capacities when feeding manually. Average diameter of, e.g. 9 cm corresponds to possible thinning in 30-40 years stand. It is obvious that expected output of 8-9 m^3/h is unacceptable. Even less efficiency applies to lower range of diameters, e.g. when conducting pre-commercial thinning. Thus, manual loading restricts usage of this type of machines purely to the small-scale production, as for private forest owners, farmers, etc. In Lithuania average private forest property is only 3-4 ha, thus the market for such machines among private owners is very limited. Therefore the supply of wood chips produced by such machines in private forest is not likely to be expected and they are totally not applicable for large-scale production in SFE's.

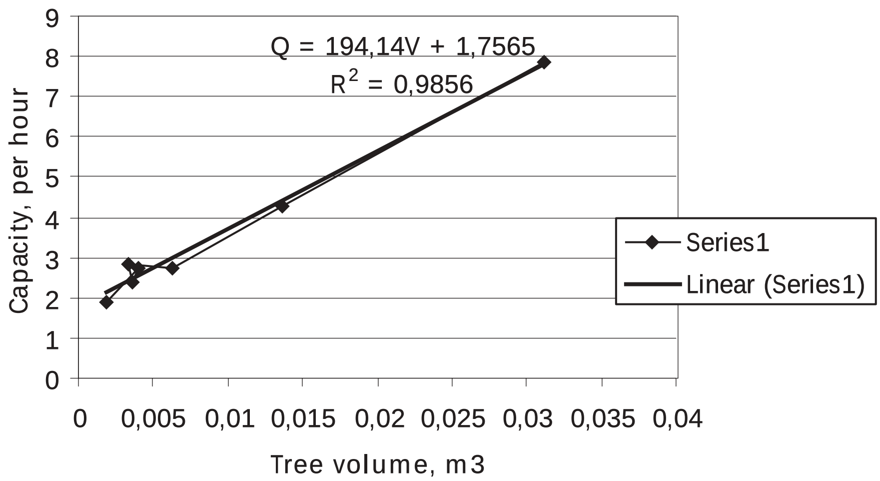
Fig. 9.1.2. Present dependence of chipping output on tree height.



Without any doubt the tree height correlates with the diameter but there are also some specific peculiarities when chipping the same diameter but different height trees, and visa-versa. Mostly it is connected with the difficulties to load successive tree until crown of preceding one is totally chipped-down.

Resumptive factor for the tree diameter and height is volume. Fig.9.1.3. reflects dependence of whole tree volume on chipping capacity.

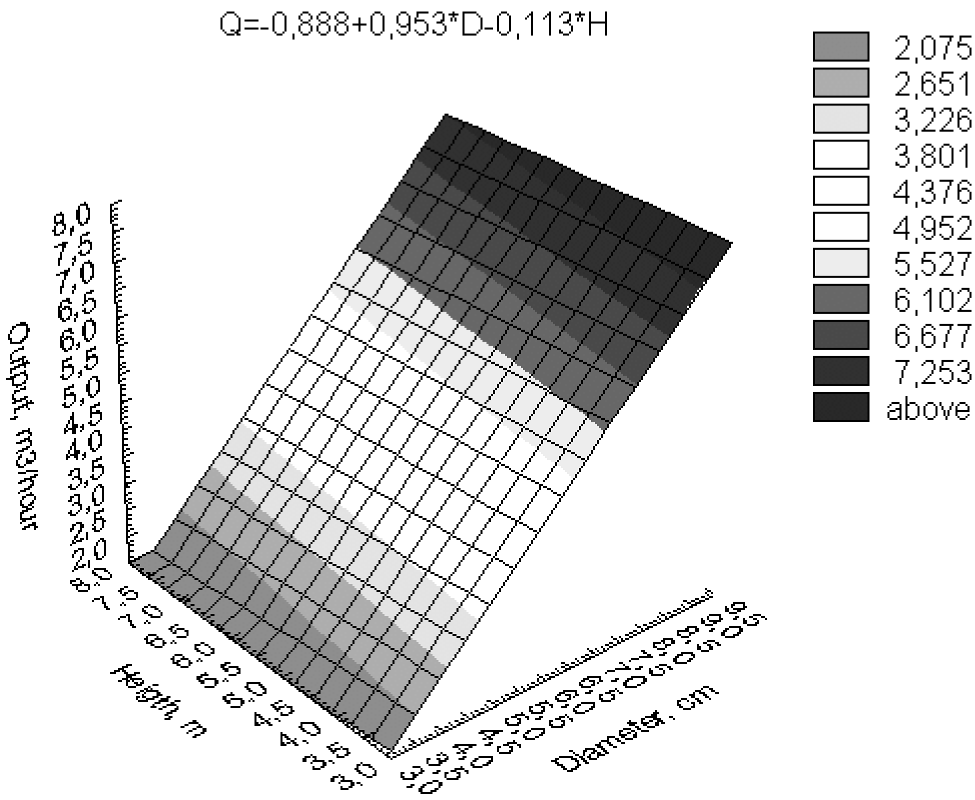
Fig. 9.1.3. Graph and model of tree volume on chipping capacity



Dependence is purely linear thus facilitating its application for simple output forecasting. It is worth to note that the model was received from the field-testing data when chipping whole trees by manual feeding them into machine.

The interrelation between the tree diameter and height as factors contradictory influencing chipping output is also interesting. 3D graph of chipping capacity dependence on tree DBH and height as well as two-factorial linear model discloses some phenomena of application of manually fed chipping machines (Fig. 9.1.4.).

Fig. 9.1.4. 3-D graph and model of interrelation of tree diameter and height on chipping capacity (R=0,9655; R2=0,9322; adjusted R2=0,8983)



When feeding whole trees, loading of the next tree was possible only after complete disappearing of the crown of the preceding tree. On the other hand two workers were not able to feed tree successively before preceding one was chipped-down because of extremely heavy working conditions when working with whole small size trees. Model equation discloses positive influence of tree diameter on chipping output, while tree height reflects minor diminishing effect. Such complexity when estimating influence of several factors enables to obtain more overall picture and real numerical influence of certain factors. There is noticeable difference in judging abilities when using 3-D graph and model comparing with that in Fig. 9.1.2. The last one at first glance declares great influence of tree height, but in fact diameter is dominant! But the necessity of treetop trimming is nevertheless obviously suggested by the model thus enabling to increase machine capacity by facilitating manual loading.

9.2. Wood chipping machine: demand and implementation

Arguments and conclusions on the productivity of manually fed wood chippers described in Chapter 9.1 of this study eliminated such machines in large-scale production. Such production is typical for SFE's and serious wood fuel suppliers. The problem is what type, composition and capacity chipping machine was optimal for the Lithuanian conditions and where to purchase them. Preliminary inquiry showed that in Lithuania and neighboring Eastern European countries where lower prices could be expected no heavy-duty crane-loaded machine was produced. Technical specifications of machines produced in Lithuania and Byelorussia presented below (reportedly no chipping machines are produced in Latvia, Estonia, Kaliningrad district or Poland):

Tractor mounted disc chipper 25 DH is produced in JSC Umega, Metalo str. 5, LT-4910, Utena, Lithuania and is suitable for round-wood and brush chipping. No data on testing on tops and branches is available. Drum chipper Bebras-1 was made as a test sample and after that no production reported. Application – chipping of branches and sawmills edgings. Producer – JSC Rokiškio Mašinu Gamykla, Respublikos str. 113, LT-4820, Rokiškis, Lithuania. Tractor mounted disc chipper MPH-1 was designed for processing of logging residuals and sawmill waste. Producer – Mozyrskij Mashinostroitelnyj Zavod, Portovaja str.17, 247760, Mozyr, Byelorussia.

10. Studies on forestry, technology and economy of forest fuel production in Rokiškis forest enterprise

**This chapter is a reduced version of the Lithuanian forest research institute reports "Assessment of forest fuel production technological and economical aspects in pre-commercial thininngs" and "Studies on forestry, technology and economy of forest fuel production in Rokiskis forest enterprise".*

Note: There are still some mistakes in the final version of LFRI research reports and it should be corrected before the reports will be official published. The parts used in chapter 10 have been reviewed and corrected by : Renatas Budrys, Lars Andersson, and Anders Gillgren.

10.1. Objectives and tasks

This research is Lithuanian Forest Research Institute input to the joint Swedish-Lithuanian Wood fuel development project Phase II. It is designed to prepare forest fuel production demonstration objects for pre-commercial, commercial thinnings, final cutting and ash utilization in the Rokiskis forest enterprise, using Swedish experience. One part of this work is the estimation of work expenditure as well cost in traditional and forest fuel production technologies and estimation of wood fuel resources.

The main tasks in this research:

1) establishment of demonstration objects in pre-commercial, commercial thinnings, final cuttings and ash utilization areas of Rokiskis forest enterprise;
2) assessment of technological and economical aspects of forest fuel production in different types of cuttings;
3) estimation of wood fuel resources potential to be used for boiler houses in RFE
4) evaluation of ash handling methods.

Research object – assessment of work expenditure and cost of forest fuel production and comparison of these expenditure and costs to the work expenditure in traditional forestry technologies, changes in vegetation in ash fertilization objects and potential forest fuel resources.

In Selyne and Kamajai districts of Rokiskis forest enterprise 10 demonstration areas were established. These areas were designed for demonstration of forest fuel production technologies in pre-commercial (2 plots –1U, 2U), commercial (4 plots – 1E, 2E, 3E, 4E) thinnings, final cuttings (3 plots – 2P-1, 2P-2, 3P) and ash utilisation (1 plot). Main stand parameters of these plots are present in appendix 2.

For every pre-commercial and commercial thinning demonstration area as big as possible area of forest stand homogenous according to density and species composition was singled out. In the final cutting demonstration areas all trees were measured.

Objects for pre-commercial and commercial thinning demonstration areas were chosen in the forest stands typical for Rokiskis forest enterprise according to species (birch, spruce and pine), normally irrigated, less and medium fertile sites. The chosen stands were homogenous according to species composition, stocking level, in sanitary cuttings – according to the amount and distribution of trees to be felled. The intensity of pre-planned thinning in demonstration areas was compared to other commercial thinning areas in Rokiskis forest enterprise.

10.2. Methodology

10.2.1. Methods for estimation of wood fuel resources

Stem-wood resources were assessed by using data of stand-wise forest inventory. The amount of wood in final cutting areas was assessed according to the area of mature stands. The area of mature stands for the next two decades was forecasted using the model of forest resource dynamics "Kupolis" (more about model Kupolis in chapter 15 and 17). The amount and structure of non-merchantable wood was separately assessed in final cuttings, commercial and pre-commercial thinning.

For the calculation of volume removable wood, bark and branches from final cutting and commercial thinning areas merchantable volume and assortment tables were used. For this assessment average tree diameters in stand and adequate distribution of removable timber by tree species and percentage of branch volume were ascertained. According to the data the share of non-merchantable wood from stem volume was estimated. In final cuttings it comprises 13% and in commercial thinning 17%.

The area of pre-commercial thinnings increases with increasing area of young stands and management intensity. It was assumed, that after reforestation of cut areas, new young stands up to 20 years of age would be cleaned 3 times. It means that over the period of 10 years every young stand will be cleaned 1-2 times. In some very fertile forest sites cleaning will be necessary every 3-5 years, while in poor sites with pure pine or birch stands such a silvicultural measure will not be necessary at all. It was determined that 10 year-old and younger stands during one cleaning could be removed 4 m^3/ha of wood and 11-20 year old stands - 12 m^3/ha of small stems and 2.4 m^3/ha of branches. Another important source of forest fuel is bark from industrial assortment. Forest enterprises sell some assortments, like pulpwood, sawlogs with bark. It was estimated, that 60% of industrial assortments from final cuttings and 40% from commercial thinnings could be debarked and this bark could be used as forest fuel in Lithuania.

10.2.2. Methods of economical investigation

Methods of time expenditure assessment. All the time of a workday was divided into the work time and break time. Work time is used to do work and can be divided into beginning-finishing time, operational time and time for the service of workplace. The measured time expenditure was compared to standard time expenditure. "Quotas and appraisement for wood harvesting output" assessed standard time for beginning and finishing work, service of workplace and breaks.

All expenditure of a workday was assessed by the method of work time photography. The structure of a workday, current expenditure for work and breaks can be assessed by the work time photography (WTP). Using these figures we can rationally plan the work. By doing the individual WTP we observed one worker. Observation was divided into four steps: 1) preparation, 2) observation, 3) calculation of data, 4) analysis and conclusion.

The collected information was recorded on special observation blanks. During observation the observer had to measure time expenditure (in minutes) for all operations and write them in the documents. If some operations took less than 1 minute, they were not observed separately. When calculating the observation data, all categories of expenditure were marked, summarized and the current balance of work time expenditure as well as the absolute and percentage for every time expenditure category was calculated.

Analysing the observation data the objective is to assess the irrational and not productive expenditure under current work organization schedule. The mean current balance of work time expenditures is calculated as an arithmetical mean from all the observations. Using these data we can calculate current work time balance, analyse how productively the working time is used, how big the losses of work time are and project the standard work time balance.

When investigating time expenditure used to produce 1 unit of production the photo timekeeping was used. It is a combined method of observation containing the elements of photography and timekeeping. In the process of WTP, some categories of time expenditures were observed separately from others, it means that for some elements of work operations timekeeping is done. If the results of observation are sufficiently accurate, they can be used for further calculations. To achieve the necessary number of observation, the tables of Sarkisoff V. and Shelechoff V. were used. The data of photo timekeeping usually starts from building the row of variation and from the assessment of row permanence coefficient. Such statistical parameters as average time expenditure, standard deviation, coefficient of variation, standard error of mean and accuracy were calculated as well.

Methods for the assessment of monetary expenditure. For the preparation of wood fuel several types of monetary expenditure are used. This is the expenditure for producing it in thinning plot, extraction to road, chipping and delivering of chips into boiler house.

According to the categories the expenditure is divided into expenditure for work, materials and service of mechanisms. The monetary expenditure is calculated according to the formula :

$$S = \sum\left[(t_j * d_j)\right] + \sum(m_{ij} * k_i) + \sum(n_{ej} * z_e), \qquad (1)$$

where S –expenditure to produce wood fuel raw material, Lt / m^3; t_j – time expenditure necessary to do the work *j*; d_j – labour cost per time unit (hour), including additional taxes and social insurance, in Lt; m_{ij} – amount of material *i* used for work *j* ; k_i – cost of material *i* in the market; n_{ej} – time expenditure of mechanism *e* to do work *j* ; z_e – cost per working hour of mechanism *e.*

Calculation of mechanism exploitation cost. The cost per working hour for mechanisms and other tools used for a long time was calculated according to formula 2. The cost of working hour for every mechanism was calculated for every mechanism in predefined technologies.

$$z_e = (V_p - V_l) / E + R / E + \sum(D_{ed} * k_d) + I, \qquad (2)$$

where z_e – cost per working hour of mechanism *e* ; V_p – market price of mechanism; V_l – the price for the mechanism after its life cycle, up to 10% of market price ; E – duration of mechanism exploitation, according to the regulations of the Lithuanian Republic Government ; R – expenses for current repair and technical maintenance in percentage from market cost. These expenses were assessed for the whole duration of exploitation; D_{ed}– expenses for fuel and lubricants per one working hour of mechanism *e* ; k_d – cost of fuel and lubricants for one unit, in Lt ; I – other different expenses, 10% of exploitation expenditures.

Monetary evaluation of work time. Work price depends on work complexity and difficulty and cannot be less than the minimal rate certified by the Government of the Lithuanian Republic. Currently the minimal rate is 2.53 Lt/hour. The actual rate of working hour was assessed considering payment rates in Rokiskis forest enterprise. For initial calculation the following rates were used: for manual work – 3.53 Lt/hour, work with mechanisms (chainsaw, brush-cutter) – 5.29 Lt/hour. After changing rates it will be possible to change the current rates. Additionally 12% of rate (for holidays, safety instructions, etc.) and 31% for social insurance were added to the tariff.

Monetary evaluation of materials and other tangibles. In the calculation of expenditures only the cost fuel and lubricants were added. Expenditure was assessed according to the quotas for producing 1 cubic meter of output in Rokiškis forest enterprise and costs of these materials. The costs of spare parts were added into the cost of mechanism exploitation per working hour.

Assessment of profitability of wood fuel production. According to the methodology given before chapter 2 only direct production expenses to produce 1 solid cubic meter of wood fuel were assessed. At this moment any expenditure related to wood fuel chipping and transportation to boiler house is not assessed. To the direct expense of 1 solid cubic meter it is necessary to add the expenditure related to transportation of machinery to the thinning or cutting plot. These expenditure can be calculated according to formula 3:

$$s = \frac{\sum T_i}{V} \qquad (3)$$

where T_i - monetary expenditure for transportation of *i* machinery to the thinning or cutting plot, in Lt ; V – volume of produced wood fuel.

Wood fuel production expenditure is calculated according to specifications, and then a decision will be made, under what conditions the production of wood fuel is worthwhile. Disposable income (before tollage) will be calculated according to formula 4:

R=I-S-S (4)

were *R* – disposable income for sold wood fuel ships, Lt / m^3 ; *I* – income for sold wood fuel chips, Lt / m^3 ; *S* – expenses to produce wood fuel ships, Lt / m^3 ; *s* – expenses to transport mechanisms to thinning or cutting area, Lt / m^3.

10.2.3. Methods of ash utilisation

Demonstration objects of fertilisation with wood ash established in plot where 90-year-old pine stand with spruce in the 2nd storey (Appendix grows.).

For fertilisation the ash from Rokiskis town heating plant was applied, the quality of which in most cases meets the criteria accepted in Sweden. Prior to studies the ash was kept for 2 months in an open place spread by a 20-40 cm deep layer, thus, under the influence of rain it has hardened (stabilised). Fertilisation was conducted manually at two doses:

- 2,5 ha-1 (amount recommended in Sweden)
- 5,0 t ha –1 .
- An adjacent unfertilised part of the stand is considered to be the control.

Studying the influence of ash applied in demonstration objects on forest soil and vegetation after 6 months since application, it was evaluated.

Forest soil chemical properties. In each plot 12 samples of joint forest litter and mineral soil (0-5; 5-10 and 10-20 cm depths) from 20 systematically chosen places were taken. In the laboratories of the Lithuanian Forest Research Institute and the Centre of Agrochemical Studies of Lithuanian Agricultural Institute the following parameters were ascertained: pH_{CaCl2} ir pH_{KCl} – by potentiometer; Corg. – with Heraeus apparatus; total P – colorimetrically with molybdate; total K – with flame photometer; total Ca – with atomic absorption spectrometer; total Mg – with atomic absorption spectrometer; Heavy metals (Cr, Cd, Pb, Ni, Cu, Zn, Mn and Fe) – ISO/DIS 11047-93, with atomic absorption spectrometer Analist 800.

Forest soil microflora and bioactivity. The micro flora of forest litter and upper mineral soil layer (0-10 cm) was studied by sowing soil suspensions diluted to a various degree on nutriculture media of different groups of micro organisms. The studies of micro organisms were conducted with three replications. All in all 162 analyses were done. Some indices of soil biological activity were ascertained in the forest. The intensity of CO_2 isolation from the surface of the earth with 5 replications was defined by the absorption method (Shtatnov, 1952), while the intensity of cellulose decomposition, also with 5 replications, was determined by accepted in Finland methods provided in the program of integrated monitoring (UN/ECE, 1993). The activity of soil ferments catalysis and saccharase was ascertained in the laboratory with three replications according to the methodology described by S.Klupt (1962). A total of 36 analysis were done. Diversity of the live soil cover can be described as species composition and coverage of mosses, lichen and grasses. It was assessed by means of inventory in 12,56 m^2 (radius 2 m) circular plots with 3 replications, a total of 9 observation plots.

10.3. Results

The data necessary for the calculation and comparison made in this work was gathered in the forests of Rokiskis forest enterprise. The Cost was estimated for traditional technologies and forest fuel integrated in pre-commercial, commercial thinnings and clear cuttings using all necessary figures from Rokiskis forest enterprise.

Computer software "SĄNAUDOS" is designed for calculation forest fuel direct costs. This software is created in Lithuania forest research institute during the participation in the project for calculating cost of different forestry technologies and their conditions. To run the program following hardware is recommended: personal computer (with processor at least 486 Mhz); computer software "Foxpro 2.6 (or higher version) for Windows and printer.

From the main screen the following cost calculations for precommercial, commercial thinnings and clear cuttings can be started. Also results can be corrected and parameters of mashinery, costs, salary etc can be revised. After calculation by program all necessary data results were used for analysis.

10.3.1. Theoretical studies on forest fuel resources assessment

Volume of firewood as well as logging residues was assessed for 2 decades – 2001-2010 and 2011-2020 for all stands of Rokiskis f.e. in industrial and protective forest stands growing on normally irrigated or temporarily wet sites. The same parameters were assessed for the state forests of Rokiskis f.e.

At present firewood is used as a forest fuel. The most important additional resource is logging residues. Logging residues in all forests will comprise 60 thou. solid m^3 (Table 10.3.1.1). More than a half of this amount (31.3 thou. solid m^3) can be extracted from final cutting areas (Table 10.3.1.1). In 2011-2020 it was predicted to increase the amount of logging residues up to 71.5 thou. solid m^3. Possible to take out logging residues in all forests from all cuttings will comprise 19.6 thou. solid m^3 (Table 10.3.1.2). It makes 33 % from the total amount of logging residues. Logging residues in final cutting will comprise 13.8 thou. m^3 or 40 % of the whole amount of logging residues in final cuttings. The amount of firewood in all cuttings is almost the same as the amount of logging residues (Table 10.3.1.1). In final cuttings the amount of firewood comprises 11.5 thou. solid m^3.

Table 10.3.1.1. Distribution of logging residues in 2001-2010 and 2011-2020 from industrial and protective forests of Rokiskis f.e. on normally irrigated and temporarily wet sites by cutting and user categories.

The amount of logging residues in 2001-2010 from all state forest cuttings will comprise 21.7 thou. solid m^3 (Table 10.3.1.1). 12.5 thou m^3 of this wood can be extracted from final cutting areas. The amount of possible to take out logging residues will be less - 7.8 thou. m^3 . In final cutting areas 4.3

Object	**Cut-tings**	**Volume, in thous. solid m³**							
		Logging residues							**Total logging resi-dues**
		Stem residues				**Branches**			
		Small stems	**Stumps**	**Bark**	**Total stem resi-dues**	**Mer-chan-table bran-ches**	**Non-mer-chan-table bran-ches**	**Total bran-ches**	
2001-2010									
In state forests	All	3,52	1,25	7,98	12,75	0,50	8,47	8,97	21,71
	final	0,23	0,82	5,05	6,10	0,50	5,90	6,40	12,50
In all forests	All	10,51	3,28	21,05	34,84	1,40	23,73	25,13	59,97
	final	0,56	1,97	12,17	14,70	1,40	15,20	16,60	31,30
2001-2010									
In state forests	All	4,11	1,57	10,02	15,70	0,70	11,61	12,31	28,02
	final	0,30	1,07	6,62	8,00	0,70	7,10	7,80	15,80
In all forests	All	10,44	3,84	24,49	39,14	1,60	31,24	32,76	71,53
	final	0,73	2,56	15,81	19,10	1,60	20,00	21,60	40,70

thou m^3 could be extracted (Table 10.3.1.2). The biggest amount of possible to take out logging residues (1.4-1.5 thou. m^3) can be extracted in Juodupe and Rokiskis districts, and 1.1 thou m^3 in Vyzuona district.

Logging residues of spruce trees comprise the biggest amount of logging residues - 21.5 thou. m^3 - from all forests of Rokiskis f.e. Birch logging residues will comprise 17.1 thou m^3 and 10.7 thou. m^3 pine logging residues. Comparing the amount of possible to take out logging residues we have a slightly different situation. The amount of logging residues from spruce and birch trees will be very close - 6.4 and 6.2 thou. m^3 . Pine logging residues comprise 3.3 thou m^3. Logging residues of these tree species comprise 81% of all possible to take out logging residues.

Table 10.3.1.2. Amount of firewood and possible to take out logging residues in 2001-2010 from Rokiskis f.e. industrial and protective forests (III-IV gr.) on normally irrigated and temporarily wet sites

	Cuttings	Volume in thou. m³ per year					
		2001-2010			2011-2020		
		Logging residues	Fire-wood	Total	Logging residues	Fire-wood	Total
In all forests	All	19,57	20,00	39,57	23,93	25,60	49,53
	final	13,82	11,50	25,32	17,81	15,70	33,51
In state forests	All	7,38	7,80	15,18	9,53	8,90	18,43
	final	5,53	4,30	9,83	7,11	4,90	12,01

Table 10.3.1.3. Distribution of firewood and logging residues by tree species in 2001-2010 and 2011-2020 planned cuttings from Rokiskis f.e. industrial and protective forests (III-IV gr.) on normally irrigated and temporarily wet sites.

Tree species	Volume in thou. m³ per year					
	2001-2010			2011-2020		
	Logging residues	Fire-wood	Total	Logging residues	Fire-wood	Total
Pine	1,60	1,30	2,90	1,49	1,00	2,49
Spruce	2,78	1,70	4,48	4,31	2,40	6,71
Oak	0,05	0,00	0,05	0,02	0,00	0,02
Ash	0,05	0,00	0,05	0,17	0,10	0,27
Birch	1,96	2,40	4,36	2,24	2,70	4,94
Black alder	0,19	0,10	0,29	0,14	0,20	0,34
Aspen	0,42	2,00	2,42	0,60	2,00	2,60
Grey alder	0,27	0,20	0,47	0,42	0,50	0,92
Other	0,05	0,10	0,15	0,12	0,00	0,12

In state forests the biggest amounts of spruce logging residues comprising 9.2 thou m³ can be found, while birch and pine logging residues are almost the same (5.3 in 4.7 thou. m³). More than a half of possible to take out amount in state forest comprise stem bark and 1/3 - non-merchantable branches. They will make up 4.2 and 22 thou m³. The volume of merchantable branches and small stems is not so high. It will make from 6 to 7% of the whole amount of possible to take out logging residues for every of these categories.

In 2001-2010 the amount of logging residues from coniferous trees and black alder is higher than the amount of firewood, while that from birch and aspen is lower. The amount of pine logging residues will comprise 123% from pine firewood, spruce logging residues - 164%, black alder logging residues 190%, birch logging residues - 82%, and aspen logging residues - only 21% of the amount of aspen firewood. In 2011-2020 the amount of possible to take out logging residues will be by 29% higher. It is caused by an increase of spruce logging residues by 55% (Table 10.3.1.3).

Currently heat producers in foreign countries pay not for the amount of forest fuel but for energy content. The energy content of forest fuel depends on tree species, density of wood, but mostly on wood humidity. In Lithuania most buyers of wood chips pay average prices. The only condition is that the humidity of woodchips must be not higher than 50%. We have calculated the amount of energy that could be produced in Rokiskis f.e. The humidity of logging residues can be easily reduced from 50 to 35% while drying in paper covered piles for 6-12 months. This decrease of humidity will raise the energy content by almost 23%. It shows that the estimation of wood fuel resources is highly dependent on the technology used and other conditions.

10.3.2. Forest fuel production influence on pre-commercial thinnings costs

The data on work time usage both in the technologies of pre-commercial thinnings, and forest fuel production was collected in the 14 lots of the block 74, as well as in the l plot of the block 80 of the forest district. In the birch stand (bl. 36 plot 21) pre-commercial thinnings were carried out. It was aimed to improve the tree increment in the stand and increase the volume of forest fuel in subsequent cuttings.

In every demonstration area two variants of forest stand handling were designed: traditional handling, based on Lithuanian thinning standards (traditional variant) and handling according to Swedish pre-commercial thinning and forest fuel outtake recommendations (Forest fuel variant). In every demonstration area at least four sample plots were singled out. For every variant two neighbouring sample plots were chosen. One of these plots was cut using manual instruments, two other– using a brush-cutter as the traditional variant and a motor-saw with felling handle "Apuri".

When using manual tools and spreading brushwood in cutting place the following works are done: worker gets work task, studies it, cuts brush, spreads cut brushwood, walks from one brush to other, sharpens tool.

When using brush-cutter and spreading brushwood in cutting place worker has additional work. He must prepare brush cutter for work, fill it with fuel, and sharpen cutting disk, to do daily maintenance of brush cutter.

For pre-commercial thinning technologies created with help of Swedish consultants were used. These technologies are more complex. Cutting of brushwood, piling, extraction of brushwood, chipping and transportation of chips to boiler house must be done.

When using machinery for forest fuel production the technology involves studying work task, preparation of motor saw to work, brush cutting, crosscutting, piling, walking from one brush to another, filling the fuel, chain sharpening, doing daily maintenance of motor saw. For this technology motor saw "Jonsered 2054" with felling handle "Apuri" was used.

Individual work time photography was made for all four researched technologies for traditional pre-commercial thinning cuttings using manual tools and machinery, as well as for the thinning with forest fuel production using manual tools as well as machinery.

10.3.2.1. Evaluation of work time expenditure using manual tools and brush cutter

After the work time photograph was made the balance of work time expenditure is drawn. Following this balance in the pre-commercial thinnings using sabre, it was identified that work time is used not rationally in comparison to the normative time (Table 10.3.2.1.1).

The coefficient of the work time usage in the pre-commercial thinnings using sabre is 0.98. Preparatory - finishing time, operational time and workplace servicing time are close to the normative ones. The breaks resulting from the violation of work ethics (being late to the work after the lunch) make up 1.7%. If these breaks were eliminated the work productivity would increase by 2%.

Table 10.3.2.1.1. Actual and normative work time expenditure balance in pre-commercial thinnings using the sabre

Index	Time expenditure category	Actual expenditures		Normative expenditures		Time expendi-tures to be re-
		min.	in %	min.	in %	moved (min.)
t_{pb}	Preparatory – finishing time	5	1,0	4	0,8	1
t_{op}	Operational time	413	86,0	425	88,5	
t_{a}	Work place servicing time	10	2,1	10	2,1	
t_{prd}	Breaks of the violation of work ethics	8	1,7	-	-	8
t_{po}	Time for rest and personal needs	44	9,2	41	8,6	3
	Total:	480	100,0	480	100,0	16

After eliminating the wastage of work time and after decreasing is irrational expenditure (less time allocated for the rest), the duration of operational time will increase by 16 minutes and will make up to 88.5% of workday duration.

The work time photography in the pre-commercial thinnings using brush cutter shows, that after eliminating the wastage of work time and after decreasing its irrational expenditure the duration of operational time will increase by 44 minutes (Table 10.3.2.1.2). The prolonged operational work time would make up 76.2% of the workday duration.

Table 10.3.2.1.2. Actual and normative work time expenditure balance in pre-commercial thinnings using the brush cutter

Index	Time expenditure category	Actual expenditures		Normative expenditures		Time expendi-tures to be re-
		min.	in %	min.	in %	moved (min.)
t_{pb}	Preparatory – finishing time	22	4,6	27	5,6	
t_{op}	Operational time	327	68,1	366	76,2	
t_a	Work place servicing time	33	6,9	30	6,3	3
t_{pt}	Breaks because of technical reasons	19	4,0	-	-	19
t_{prd}	Breaks because of the violation of work ethics	10	2,1	-	-	10
t_{po}	Time for the rest and personal needs	69	14,4	57	11,9	12
	Total :	480	100,0	480	100,0	44

The coefficient of the work time usage in the pre-commercial thinnings using brush cutter is 0.94. Preparatory - finishing time, operational time and workplace servicing time are close to the normative ones. The breaks resulting from the violation of work ethics (being late to work in the morning) made up 2.1%, breaks caused by technical reasons such as failure of the brush cutter engine - 4.0%. Elimination of these breaks will increase the work productivity by 8.9%.

10.3.2.2. Evaluation of work time expenditures in pre-commercial thinnings and forest fuel production using manual tools and machinery

During the process of work time photography making, for forest fuel production, we accepted that, normative work time expenditure would be the same as for traditional pre-commercial thinning technologies.

After making the work time photography for the thinning and forest fuel production by using the sabre, it was identified that the workday time is almost the same as the normative. After reducing the expenditure of the irrational work time, which makes up to 4 minutes, the duration of the operational work time may be increased up to 88.5% of the workday duration (Table 10.3.2.2.1). The coefficient of the work time usage is 1.0.

After making the work time photography for the forest fuel production using machinery it was identified, that the coefficient of the work time usage is only - 0.89 (Table 10.3.2.2.2). The time close to the normative is only for the preparatory - finishing and workplace servicing works. The breaks resulting from the violation of work ethics (being late to the work after the lunch) make up 1.7%. The biggest influence on the work productivity was made by the breaks caused by technical reasons. This happened due to the work with new machinery, to which the worker was not accustomed. After eliminating these breaks the productivity of work would increase by 18%. After the elimination of work time wastage and the decrease in its irrational expenditure, it is possible to increase the duration of operational time up to 78 minutes, which would make 76.2% of workday duration.

Table10.3.2.2.1. Actual and normative work time expenditure balance of forest fuel production using the sabre

Index	Time expenditure category	Actual expenditures		Normative expenditures		Time expendi-tures to be
		min.	in %	min.	in %	removed (min.)
t_{pb}	Preparatory – finishing time	6	1,3	4	0,8	2
t_{op}	Operational time	421	87,6	425	88,5	
t_a	Work place servicing time	10	2,1	10	2,1	
t_{po}	Time for rest and personal needs	43	9,0	41	8,6	2
	Total :	480	100,0	480	100,0	4

Table 10.3.2.2.2. Actual and normative work time expenditure balance of forest fuel production using the machinery

Index	Time expenditure category	Actual expenditures		Normative expenditures		Time expenditures to be removed (min.)
		min.	in %	min.	in %	
t_{pb}	Preparatory – finishing time	28	5,8	27	5,6	1
t_{op}	Operational time	288	60,0	366	76,2	
t_a	Work place servicing time	34	7,1	30	6,3	4
t_{pt}	Breaks caused by technical reasons	44	9,2	-	-	44
t_{prd}	Breaks caused by the violation of work ethics	8	1,7	-	-	8
t_{po}	Time for rest and personal needs	78	16,3	57	11,9	21
	Total :	480	100,0	480	100,0	78

10.3.2.3. The cost evaluation of the forest fuel produced in the pre-commercial thinnings

In the pre-commercial thinnings using machinery in Selyne forest district of Rokiskis forestry enterprise brush cutter "Husqvarna 252 RX" was used for thinning. For manual thinning the sabre was used. For forest fuel production in the young stands using machinery motor-saw "Jonsered 2054" with handle "Apuri" was used, while for manual forest fuel production the sabre was used.

The work hour costs for two mechanisms calculated according to the methodology of the identification of work hour cost:

- brush-cutter "Husqvarna 252 RX" - 2.89 Lt/hour.;
- motor-saw "Jonsered 2054" with handle "Apuri" - 4.63 Lt/hour.

The work hour cost for the sabre was not calculated, because it is not considered to be the tool for long term use. Its value is divided in proportion to the wood quantity produced during its work time and it makes up 0,06 Lt/ m^3. The work time during the workday of the brush cutter and motor saw with handle "Apuri" is equal to operational work time during workday.

For forest fuel cost evaluation in the pre-commercial thinnings it is necessary to know not only the work hour cost of machinery, worker's salary but also time expenditure for one production unit (in our case for loose m^3). The salary of the worker in pre-commercial thinnings depends on the category of the work. The manual thinning is done by the worker of III category, whose salary - 5,18 Lt/hour., machinery thinning – by VI category - 7,76 Lt/hour.

Using normative calculated time expenditure as well as machinery costs it was estimated, that the price for 1 m^3 of forest fuel produced using handle tools is - 2,84 Lt, while the one of the pre-commercial thinnings using machinery - 3,73 Lt (Table 10.3.2.3.1). The difference in cost of forest fuel production with different technologies is 0,89 Lt/l.m^3.

The calculation of salary showed, that in manual thinnings the salary is higher, than in machinery thinnings by 10%, or 0.26 Lt/hour. This is influenced by higher time expenditure in slasher thinning. Additional cost on machinery that makes up 1.16 Lt/l.m^3, higher cost of forest fuel production using machinery.

Table 10.3.2.3.1. Normative expenditure of forest fuel production in pre-commercial thinnings

	Worker salary			Machinery cost			Total
Technology	Time expenditure,	salary,	Lt*/ 1	Time expenditure,	cost ,	Lt*/ 1	Lt/l. m^3
	hour/ l.m^3	Lt*/hour	l.m^3	hour/ l.m^3	Lt*/ hour	l.m^3	
With sabre	0,546	5,18	2,83			0,012	2,84
With brush cutter	0,331	7,76	2,57	0,251	4,63	1,16	3,73

*1 Lt = 3.5 EUR

10.3.2.4. The influence of forest fuel production on the cost of pre-commercial thinnings

The calculations mentioned above show that the actual cost of 1 ha pre-commercial thinning when cut 280 loose m³ from ha, is from 330 Litas in manual thinning to 523 Litas in machinery thinning . This difference in costs is determined by the cost of the machinery used as well as higher salary of the worker.

The cost of forest fuel when 280 loose m³ per ha are felled, would be from 818 Litas in manual thinning to 1176 Litas in machinery thinning. However for this wood to reach the boiler house some additional operations are necessary: to take the brushwood to the roadside, to chip it with the mobile chipper, to load chips on the trailer and to transport them to the boiler houses.

Preliminary calculations show that cost from 2.80 to 5.03 Lt/l. m³ depends on the extraction distance, slasher productivity, the transportation distance to the boiler house. Thus the additional cost when cutting 280 m³/ha, would be from 1120 to 1680 Litas.

According to the data of Rokiskis forest enterprise from 280 loose m³ of brushwood it is possible to produce about 56 solid m³ of chips. At the moment, when the price for 1 m³ of chips in the boiler house is 38 Litas, the income received for the sold forest fuel will make up to 2128 Lt.

Therefore, producing forest fuel may considerably reduce the costs of pre-commercial thinnings. Depending on the stand conditions as well as the productivity of machinery used and cost of pre-commercial thinnings may give some profit. Of course, in pre-commercial thinnings it is first of all aimed to improve the conditions for the tree growth, therefore the result would be considered as good even when the chip price covered their production costs.

10.3.3. Forest fuel logging labour time input

Pre-commercial thinning

In the traditional pre-commercial thinning technology the cut stems are spread in the cutting place, while in the forest fuel production - they are piled. Time expenditure research was carried out in two trials of Rokiskis forest enterpise forest using hand tools and machinery. Time expenditure in both trials using the same technologies differs insignificantly. Research results of time expenditure of cutting and spreading according to the traditional technology as well as cutting and piling forest fuel production technology are presented in table 10.3.3.1.

Table 10.3.3.1. Work expenditure on pre-commercial thinning areas

Stand characteristics, thinning intensity and technology		**Work expenditures, In hour/m³**
Tradi-tional thin-ning	Spruce stand with broad-leaved trees admixture; hand tools; Thinning intensity – more than 181 loose m³/ha, height of trees more than 4 m	1.10
	Spruce stand with broad-leaved trees admixture; brush-cutter "Husqvarna 250 R"; thinning intensity – more than 181 loose m³/ha, height of trees more than 4 m	0.74
Forest fuel produc-tion	Spruce stand with broad-leave trees admixture; hand tools; Thinning intensity – more than 181 loose m³/ha, height of trees more than 4 m	2.76
	Spruce stand with broad-leaved trees admixture; motorsaw "Jonsered 2150 Turbo" with felling handle "Apuri"; thinning intensity – more than 181 loose m³/ha, height of trees more than 4 m.	1.70

Commercial and final cuttings

In commercial and final cuttings all standard procedures of cutting were done: felling of trees, pruning etc. The tops for the forest fuel were left without pruning. These tops and thick branches were stacked into piles near technical corridors. The size of these piles should be not less than necessary for single manipulators pickup when taking out forest fuel. Some amount of branches from trees felled directly on technical corridors were left there to preserve the soil.

After piling of tops and other cutting residues the amount of forest fuel was accounted according to volume tables. The cutting residues meant for forest fuel will be left in the piles for drying when the leaves and needles fall down. The forest fuel transportation was done using a tractor with a trailer or a forwarder. During thinning and transportation time measurement for all operations was made – felling of trees, pruning, piling of tops and branches, loading into a trailer, driving with and without load, unloading of forest fuel. Time is divided into the time for the assortment logging, forest fuel logging as well as cutting area preparation and clearing-out.

Trials 1E and 2E were established in 65-years-old pine stand with birch admixture and the second storey of spruce, growing in normally irrigated site. The cutting intensity in trial 1E was low – just 10%. In this stand all birches , suppressed pines and some damaged spruces were felled . In traditional commercial thinnings, like the above-mentioned trial, the production of wood fuel is not perspective. In trial 2E birches, suppressed pines and damaged spruces were felled, but intensity of cutting was much higher – 33%. Cutting of mature birches led to higher cutting intensity. Wood fuel amount in this stand was much higher.

Trial 3E was established in 65-year-old highly stocked pine stand. In this stand suppressed pines, mature soft broadleaves and also some damaged and/or suppressed spruces were cut. In this stand a big amount of low quality wood was cut. This stand has an average dense understorey, which was cut only in technical corridors and other places where it was necessary.

Trial 4E was established in a mixed pine-spruce-birch stand with the second spruce storey. The 2nd storey was intensively damaged by dears. In this stand technical corridors were made and during cutting additionally 28 m^3/ha were felled. In this stand damaged spruces, mature birches and suppressed pines were felled. Higher amount of wood fuel was also due to a bigger felled volume.

For trials in clear cutting areas 3 stands were selected. Trials 2P-1, 2P-2 was established in a stand, where spruce trees dominated. The understorey in this trial was sparse. In this trial low-experienced workers were employed. Most felled trees were spruces with a big amount of small-sized branches. This caused the situation that the workers left a big amount of branches on the technical corridor, especially from trees felled directly on it.

Trial 3P was established in soft-broadleaved tree stand. In this trial there was a dense and big-sized understorey, mostly hazelnut. This understorey was very dense in the less-stocked part of the stand. This understorey and a big amount of firewood, especially big-sized hazelnut bushes, have led to a high amount of forest fuel.

Compared to the traditional technology, when all the branches and tops are used for technical corridors, the technology with integrated wood fuel production is very promising. This is caused by a situation, when work expenditure for forest fuel production replace work expenditure for putting logging residues into technical corridors. Additional work expenditure for forest fuel production in intermediate cuttings is low, while in clear-cuttings is equal or even less than work expenditure for the traditional handling of branches. This is caused by a reduced distance of handling branches and eliminated work expenditures for firewood pruning.

The extraction of wood assortment and forest fuel to the roadside.

The forest fuel extraction was done by using 2 mechanisms – a forwarder "Valmet-840" and a self loading trailer "Weimer WE-8" with an agricultural tractor MTZ-82.

Average load was assessed after measuring produced forest fuel piles, calculating amount of the forest fuel and counting loads. Table 10.3.3.2 shows the main parameters on forest fuel extraction expenditure using a self loading trailer "Weimer WE-8" in intermediate and final cutting areas. In this case the average load volume is much less – about 1,8 m^3. Work expenditure for one load transportation is almost the same as using a forwarder. Thus, work cost for extraction is higher.

Forest fuel extraction was done by ordinary workers having no special experience. In the work of forwarder "Valmet-840" no problems were observed. More problematic was the work of a self loading trailer – loading and unloading were much slower and the piles were less regular.

Table 10.3.3.2. Work expenditure in transportation of forest fuel and traditional assortment, using forwarder “Valmet 840” and self loading trailer “Weimer WE-8”

Parameter	Traditional assortment	Forest fuel transportation
	Walmet 840	
Driving speed, m/min	65	134
Loading duration, min.	27	13
Extraction speed, m/min	69	85
Unloading time, min.	11	6
Volume of load, m^3	8	4
	Weimer WE-8	
Driving speed, m/min	106	80
Loading duration, min.	10	12
Extraction speed, m/min	105	97
Unloading time, min.	6	3
Volume of load, m^3	2	2

Fuel wood chipping and taking to the boiler-house.

The wood is chipped using the drum chipper “BRUKS 604 CT”, with agricultural tractor “K-700”.

The chipped forest fuel was transported to the boiler-houses by the tractor T – 150 with a trailer (load volume - 25.3m^3). The transportation time was calculated according to the average tractor speed 30 km/hour. For longer distances wood fuel may be transported by vehicles with larger trailers, such as vehicle “MAZ 5516” and 45 m^3 trailer.

Exploitation costs of the machinery used in wood logging.

Calculation of shift machinery value is given in the table 10.3.3.3.

Table 10.3.3.3. Work cost of different mechanisms and machinery in intermediate and final cuttings.

Mechanism or machinery	Work cost, Lt/hour
Motor-saw ”Jonsered 2150 Turbo” with ”Apuri”	4,07
Motor-saw ”Husquarna 254XP”	3,57
Brush-cutter ”Husquarna 250 R”	2,75
Forwarder ”Valmet 840Y”	60,76
Tractor ”MTZ-82” with „Weimer WE-8”	42,02
Tractor ”T-150”	49,84
Tractor ”K-700”	72,12
Manipulator ”LOGLIFT F 70 L”	36,28
Chipper ”BRUKS 604 CT”	72,20
Lorry ”MAZ 5516”	60,44
Trailer	7,89

The efficiency of forest fuel logging

For every trial the main parameters, such as work expenditure, work and total cost were calculated. The data is presented in the appendix 2. The economical calculation of forest fuel production efficiency is presented in table 10.3.3.4.

Table 10.3.3.4. Economical effectiveness of forest fuel production, Lt/ha

Cutting category (Trial No)	With forest fuel production			Traditional technology			Effectiveness of forest fuel production
	Income	Cost	Profit	Income	Cost	Profit	
Pre-commercial thinning (R)	2184	2442	-258	-	319	-319	61
Pre-commercial thinning (M)	2184	2860	-676	-	476	-476	-200
Commercial thinning (1E)	1972	766	1206	1790	699	1091	115
Commercial thinning (2E)	6907	2531	4376	6072	2382	3690	686
Commercial thinning (3E)	7129	2681	4448	6074	1961	4113	335
Sanitary cutting (4E)	7664	2412	5252	7310	2243	5067	185
Clear-cutting (2P-1)	22287	5639	16648	20399	4639	15760	888
Clear-cutting (2P-2)	22162	5200	16962	19992	3882	16110	852
Clear-cutting (3P)	22640	7426	15214	18810	4978	13832	1382

Note: R-using manual tools; M-using motor saw with felling handle.

The most cost ineffective is forest fuel production in pre-commercial thinning areas. In manually cut areas the effectiveness of forest fuel production was 61 Lt/ha, while using machinery the effectiveness was negative – -200 Lt/ha. Such a low effectiveness of thinning was caused by a low experience of workers and supposedly by incorrect stand.

Clear-cutting trials were mostly cost effective . In trial 3P the effectiveness of forest fuel production was 1382 Lt/ha, while in other two cases it was lower – 852-888 Lt/ha. Commercial thinnings and sanitary cuttings are medium effective. In these trials the effectiveness of forest fuel production was 115-335 Lt/ha.

10.3.4. The influence of factors on the input of forest fuel logging

Therefore, producing forest fuel may considerably reduce the costs of pre-commercial thinnings. Depending on the stand conditions as well as the productivity of machinery used and cost pre-commercial thinnings may give some profit. Of course, pre-commercial thinnings are first of all aimed to improve the conditions for the tree growth, therefore the result would be considered as good even then, when the chip price would cover their production costs.

The main factors influencing the cost of forest fuel production for boiler-houses include worker skills, the method of felling, intensity, extraction distance, actual productivity of the wood chipper and transportation distance to boiler-houses.

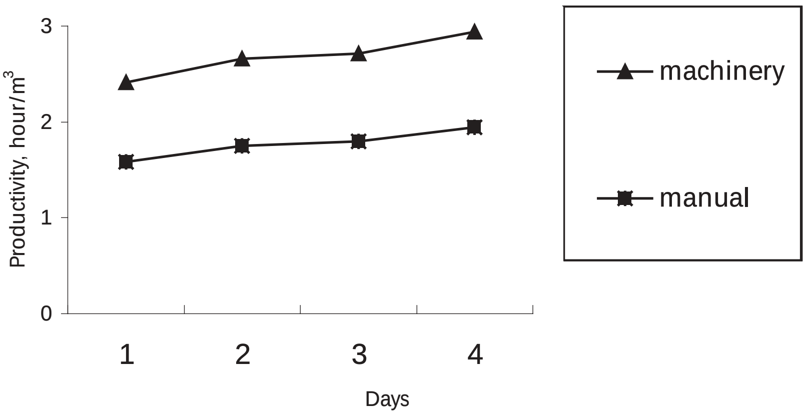
Forest fuel logging cost in young stands depends on the intensity of cuttings. The lower is the felled volume per 1 ha, the higher is the work time expenditure. Besides, the cost increases when the brushwood height decreases. Forest fuel logging costs in young stands were 37-42 Lt/m^3.

Forest fuel production in pre-commercial thinnings is a novelty for foresters and workers. The forest workers have no sufficient knowledge in working according to the new technological requirements yet. Comparing the efficiency of work it was noticed, that work efficiency in forest fuel production when using machinery during the four work days increased by 30%, while in manual work only by - 20% (Figure 10.3.4.1.). Forest fuel production using handle tools is the technology, similar to pre-commercial thinnings using handle tools. It has two additional operations - cross cutting and piling of brushwood. The worker can increase his work productivity by performing tree cutting and stowage operations in a rational way.

When producing the forest fuel with machinery good working skills of motosawer are essential, as the motor saw with the attached handle "Apuri" was used for this work. Better results may be achieved by developing working skills. Besides the new machinery this technology contains some additional operations. After cutting the tree the worker has to take it down in a right way, to make it easier for a piling. At the time depending on the tree size the saw may be put on the ground or kept in hand, which requires good skills.

Workers psychological attitude towards the work with machinery is also very important. Bigger dissatisfaction was caused by the motor saw with handle "Apuri" usage for cutting, because of the fact that after cutting the tree should be pilled. It is possible to say that the productivity of work increased only when the worker psychologically got used to the new technique, i.e. after 2 workdays. The data mentioned above shows, that factual work productivity may be easily brought closer to the normative. That is why for the further calculations of productivity the normative work time was used.

Fig. 10.3.4.1. Work productivity dynamics in forest fuel production.



During forest fuel production piling takes more time in young stands than in commercial or final cuttings because the extraction distance to technical corridors is longer and a dense remaining forest disturbs the process. In commercial or final cuttings most of the trees are felled near technical corridors, thus extraction distance is considerably shorter. The cost of forest fuel extraction in young stands is higher, because loading onto the trailer takes more time, due to remaining dense trees.

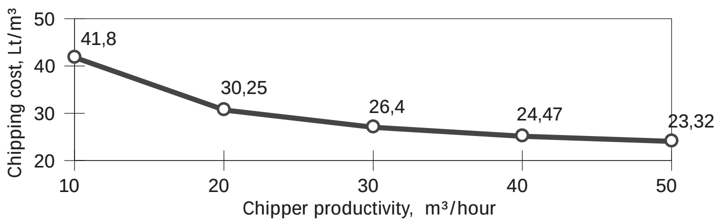
The cost of forest fuel extraction depends on many factors, first of all, on the type of cuttings. The cost is the lowest in final cuttings, the highest in pre-commercial cuttings. Other important factors include machinery exploitation costs and its productivity as well as extraction distance. The dependence of fuel wood logging cost on the extraction distance is shown in table 10.3.4.1.

Table 10.3.4.1. The dependence of forest fuel cost on raw-material extraction distance

Distance, m	Cost of forest fuel, Lt/ loose m³
< 200	30,3
201-500	32,2
501-1000	35,2
>1000	39.0

The cost of raw material chipping mostly depends on the actual productivity of the chipper. When the productivity of the chipper is increased from 10 to 50 m^3/hour, the fuel wood cost may be decreased about 1,5 times (Fig. 10.3.4.2).

Fig. 10.3.4.2. Dependence of wood fuel cost on productivity of the chipper.



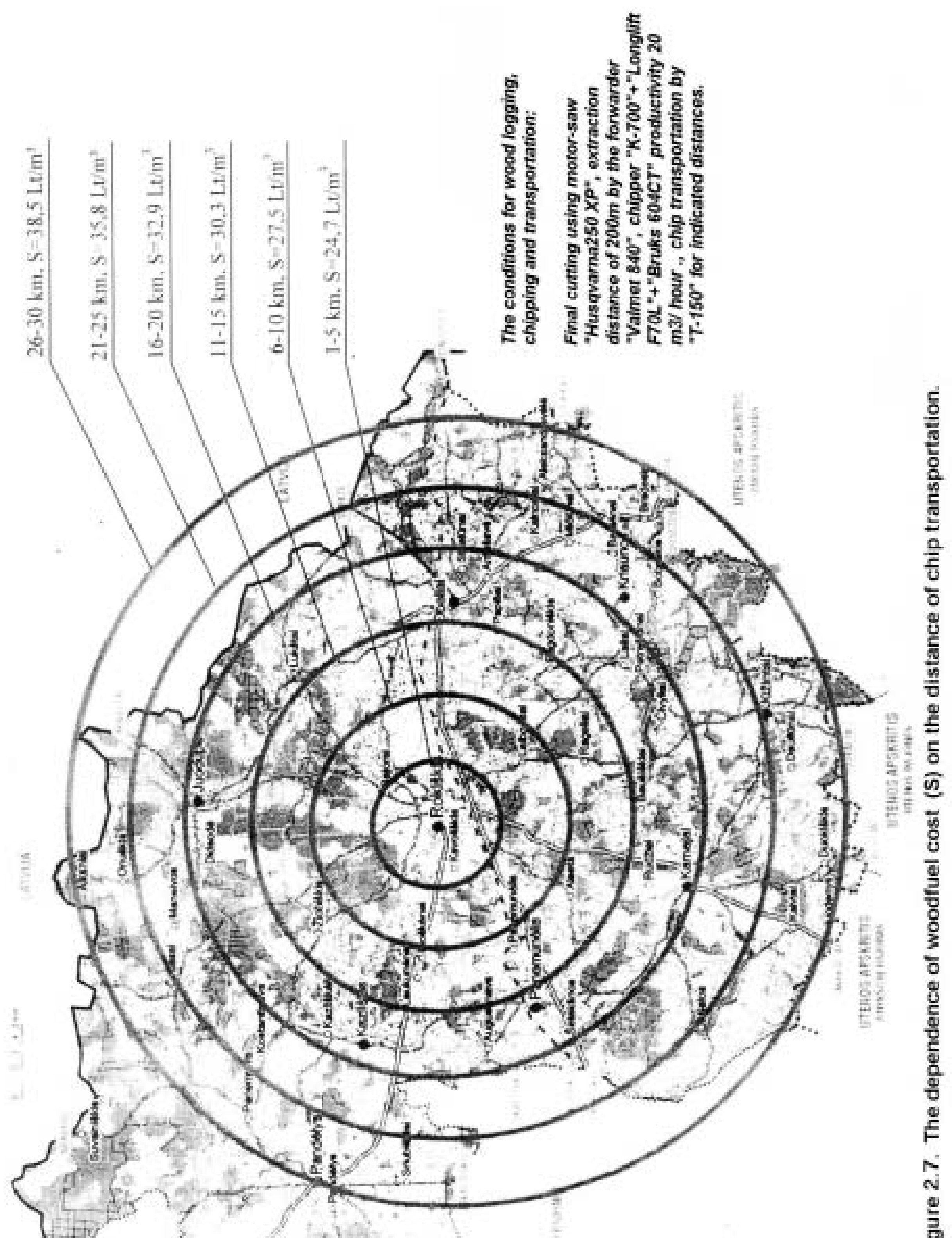
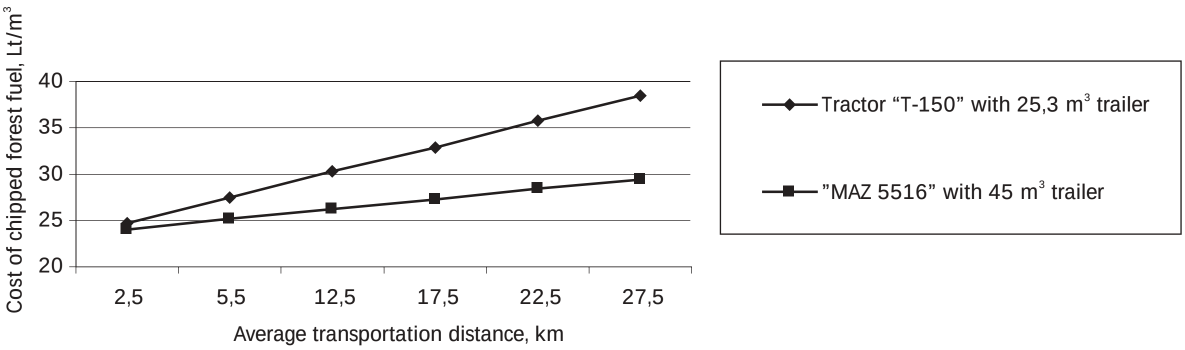


Fig.10.3.4.3. The dependence of wood fuel cost (S) on the distance of chip transportation

The influence of forest fuel transportation distance to the boiler-house on forest fuel cost is shown in figure 10.3.4.3. With increased transportation distance from 5 km to 30 km, the cost increases from 24.7 Lt/m³ to 38.5 Lt/m³.

Forest fuel transportation cost is greatly influenced by the machinery used as well as the capacity of the trailer. When transporting by MAZ 5516 with the trailer of 45 m³ for 30 km, forest fuel cost decreases by 25 % in comparison with transportation by the tractor T-150 with a trailer the capacity of which is 25.3 m³. (Fig. 10.3.4.4).

Fig. 10.3.4.4. The dependence of wood fuel cost on the machinery distance of chip transportation.



The structure of forest fuel cost was analysed following its logging operations and cost economical elements (figures 10.3.4.5, 10.3.4.6). Chipping (38.7%) makes up the biggest part of forest fuel cost in final cuttings according to logging operations. Transportation and extraction make up about 23-24% of the cost. According to economical elements the biggest part of costs is given to the machinery - even 77.5% while fuel makes 17.6%. Increasing the intensity of their usage may decrease the machinery costs. It can be done by increasing work time per day and/or the productivity of machinery, the number of work hours per day (or the number of shifts) and workdays per year as well as the time of useful usage during the whole period of machinery exploitation. For example, when using the tractor “K-700” for 800 hours per year its hourly exploitation costs comprise 131.50 Lt, while using it for 1000 work hours – 111,06 Lt. In the second case hourly costs decrease by 15, 54%

Fig. 10.3.4.5. The structure of fuel wood produce cost (30,20 Lt/m³) according to operations.

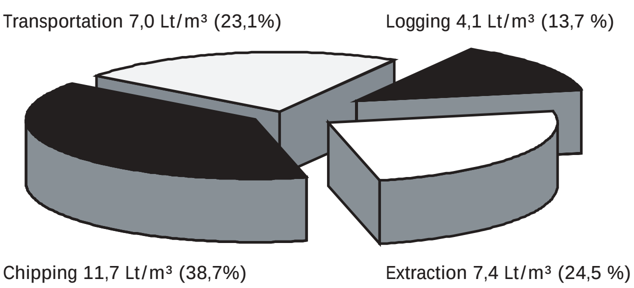
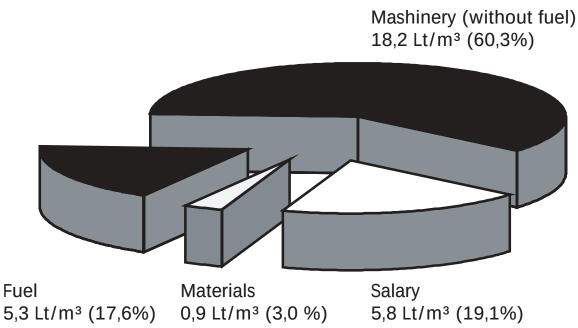


Fig. 10.3.4.6. The structure of fuel wood produce cost (30,20 Lt/m³) according to input elements.



10.3.5. Studies on ash utilisation

Changes in soil chemical properties

In each plot 12 samples of joint forest litter and mineral soil (0-5; 5-10 and 10-20 cm depths) from 20 systematically chosen places were taken. In the laboratories of the Lithuanian Forest Research Institute and the Center of Agrochemical Studies of Lithuanian Agricultural Institute the following parameters were ascertained: pH_{CaCl2} and pH_{KCl} – by potentiometer; Corg. – with Heraeus apparatus; total P – calorimetrically with molybdate; total K – with flame photometer; total Ca – with atomic absorption spectrometer; total Mg – with atomic absorption spectrometer; Heavy metals (Cr, Cd, Pb, Ni, Cu, Zn, Mn and Fe) – ISO/DIS 11047-93, with atomic absorption spectrometer Analist 800. A total of 96 chemical analyses were done (Table 10.3.5.1)

Table 10.3.5.1. The composition of wood ashes from Rokiskis town heating plant used in forest fertilisation demonstration objects

Chemical parameter	Amount	Recommended minimal and maximal amounts of complex ash substances (Skogsstyrelsen, 2001)
Corg., %	1,32	10-15 (maximally)
Total P, g kg-1	7,2	10 (minimal)
Total K, g kg-1	24,6	30 (minimal)
Total Ca, g kg-1	255	125 (minimal)
Total Mg, g kg-1	34,4	20 (maximal)
Boron, mg kg-1	225	500 (maximal)
Vanadium, mg kg-1	109	70 (maximal)
Chromium, mg kg-1	44	100 (maximal)
Cadmium, mg kg-1	9,6	30 (maximal)
Lead, mg kg-1	40	300 (maximal)
Copper, mg kg-1	80	400 (maximal)
Zinc, mg kg-1	820	1000-7000
Mercury, mg kg-1	0,015	3 (maximal)
Arsenic, mg kg-1	0,65	30 (maximal)
137Cesium, Bq kg-1	<5,0	5 (maximal)
Benzapyrene, µg kg-1	0,0	2 (maximal)

By spreading wood ash forest soil may become more alkaline and enriched by all main nutrients, except nitrogen (P, K, Ca and Mg) as well as organic. C required by plants. Ash may be contaminated by heavy metals. Therefore, data on saturation of Haplic Luvisols with the both groups of elements are analysed separately.

Theoretically calculated, the greatest amounts of Ca in demonstration objects (in 2,5 t ha^{-1} of ash - 63,8 and in 5,0 t ha^{-1} – 127,6 g m^{-2}) were spread together with ash, while the amounts of other macro elements were from 7-10 (Mg, K) to 20-35 times (organic C and P) less.

Although great amounts of Ca were applied, after 6 months the reaction (pH_{CaCl2} and pH_{KCl}) of forest litter and upper 20 cm deep mineral soil layer has not changed essentially. The saturation of forest litter and upper mineral soil layer with org. C, Ca, Mg, P and K has not changed as well.

It was found, that among heavy metals the greatest amounts of Zn were spread (205-410 mg^{-2}), while the amounts of Pb and Cr were 20 times, Cu – 10 times and Cd even 85 times less. Although the amounts of Zn were the greatest in ash, its amount after 6 months in forest litter and upper 20 cm deep mineral soil layer has not changed essentially . Concerning other studied heavy metals (Cr, Cd, Pb, Ni, Cu, Mn and Fe) in forest litter and upper 5 cm deep mineral soil layer of fertilised by ash areas was ascertained an insignificant increment of Pb (on an average increased by 14-35% and 39-41%, respectively), while only in the litter – Zn (14-32%) concentrations. Besides, only in the variant where 2,5 t ha^{-1} of ash were applied, the amount of Cr in the forest litter increased by about 30%. However, it must be admitted, that even these concentrations are from 4-7 times (Cu, Cr) to

11-13 times (Pb, Cd and Zn) less than acknowledged in Sweden critical concentrations in forest litter (Tyler, 1992).

As with macro elements, accumulations of heavy metals were calculated in forest litters of different mass (Table 10.3.5.2). The assumption that ash application could insignificantly increase Pb and Fe, while applying 2,5 t ha^{-1} ash doze also Cr amount, has been confirmed. The data shows, that after 6 months since wood ash application chemical composition of forest litter and upper 20 cm deep mineral soil has not changed essentially. It leads to the assumption, that ash is still "hanging" on abundant soil cover, especially mosses.

Table 10.3.5.2. Accumulation of some heavy metals in the forest litter (mg m-2) of fertilized with wood ash demonstration objects after 6 months since application (2002).

Amount of ashes	Forest litter mass, kg m^{-2}	Cr	Cd	Pb	Ni	Cu	Zn	Mn	Fe
0,0 t ha^{-1} (control)	5,5	26,4	2,8	184,2	30,2	29,2	213,4	2750	15125
2,5 t ha^{-1}	7,9	49,8	2,4	302,6	47,4	35,6	203,8	2133	28638
5,0 t ha^{-1}	9,3	37,2	4,6	421,3	46,5	32,6	241,8	2446	29062

Biological soil properties

The number of micro organisms and their activity in the soil shows its ecological stability. Our experiments with forest fertilisation using wood ash have revealed, that wood ash impact on soil micro flora is rather insignificant. An observable increment in the number (by 25%) of ammonifiers in forest litter occurs only in the variant with 5 t ha^{-1} ash doze (Table 10.3.5.3). In this variant number of amonifiers increased by 25%.

Table 10.3.5.3. The influence of wood ash on soil ammonifying micro organisms

Dose of ashes, t ha^{-1}	Total amount of microorga-nisms	Bacteria	Actinomyces	Micromyces	Bacteria	Actinomyces	Micro-myces
	thou. g^{-1} of dry matter.				%		
Forest litter							
0 (control)	6256	4982	1034	240	79,6	16,5	3,9
2,5	6085	4740	1053	292	77,9	17,3	4,8
5,0	7823	6573	967	283	84,0	12,4	3,6
Upper mineral soil horizon							
0 (control)	385	317	29	39	82,3	7,6	10,1
2,5	346	247	58	41	71,4	16,8	11,8
5,0	446	386	29	31	86,6	6,5	6,9

Oigonitrophilous micro organisms are characterised as having more favourable reaction to ashes . They were singled out on nitrogen-free eshbi agar medium (EA). The number of these micro organisms under 5,0 t ha^{-1} ash doze in forest litters increases even by 120%, while in soils by 70%. Other groups of micro organisms in forest litters and soils are rather scarce, though their role in forest ecosystems is very important. Only having applied 5,0 t ha^{-1} of ash the amount of nitrifying bacteria in forest litter has reached an appreciable size – almost 2 thousands. Cells per 1 g of dry matter. The amount of denitrifies in forest litters is by far greater. However, the impact of ashes on the activity of denitrifies was not determined. After ash application the number of denitrifies in forest litters and mineral soil horizon remained unchanged, while in the variant with 2,5 t ha^{-1} ash doze their amount has even decreased. Anaerobic joiner of atmospheric nitrogen *Clostridium pasteurianum* reacts positively to ashes. In the variant with 5,0 t ha^{-1} the number of these bacteria in forest litter has augmented even by 4 times (Table 10.3.5.3).

Biological soil activity resembles the activity of its micro organisms, the intensity of this activity. One of soil biological activity parameters is the intensity of CO_2 isolation from the soil. In all study variants CO_2 differed quite insignificantly – hardly 1 kg/ha per hour (Table 10.3.5.4) and was independent of ash application or their dosage. The intensity of cellulose decomposition also failed to show differences between separate variants. More than 1,5 months have decomposed 9-13% of cellulose buried in the soil. The activity of catalysis and saccharase in forest litters of our demonstration objects is rather high. The effect of wood ashes on them was negative. Having applied 5,0 t ha^{-1} of wood ashes the activity of saccharase in the forest litter has decreased twice. In the mineral soil no impact of ashes on the activity of ferments was ascertained.

Table 10.3.5.4. The influence of wood ash on soil bioactivity

Dose of ashes, t ha^{-1}	Intensity of CO_2 isolation, kg/ha per hour	Cellulose decomposition over 1,5 month, %	Activity of catalase, O_2 ml g^{-1} 5 $min.^{-1}$	Activity of saccharase, sugar mg g^{-1} 24 h^{-1}
Forest litter				
0 (control)	0,98	-	40,9	198,3
2,5	0,96	-	35,9	108,5
5,0	1,02	-	30,7	89,4
Upper mineral soil horizon				
0 (control)	-	11,2	3,0	9,4
2,5	-	13,0	3,8	11,0
5,0	-	8,6	3,7	9,4

Response of soil vegetative cover

The mean total projection coverage of all plants (except bushes and trees) in the control and fertilised with ash objects is 80-89%. In semi-bushes coverage bilberries make up 7-14%, grasses 6-18% and mosses 57-70%.

The obtained results show, that wood ash doze of 5,0 t ha^{-1} over 6 months since their application have caused no negative effect on the cover of mosses. *Hylocomium splendens* and *Pleurozium schreberi* prevailed among mosses. Coverage by mosses in all study variants made up >5%. The ascertained pH_{KCl} in the litter 10 cm deep mineral soil layer fluctuated from 3,02 to 3,87. This demonstrates, that the soil land remains highly acidic and has not changed under the impact of ash.

Projection coverage by red bilberries in separate variants decreases with increasing doze of wood ashes. In the same way the projection coverage of grassy vegetation changes It decreases from 17,9% in the control variant to 6,9% in the variant with 5,0 t ha^{-1} of ash application.

Having summarised the study results it may be stated, that the soil of established demonstration objects for fertilisation with wood ash is covered by dense (80-85% projection coverage) vegetative cover, where coverage by mosses comprises 58-70%. After 6 months since ash application no negative effect on the species composition of vegetation and the abundance of individual species was ascertained. However, the first signs of withering of mosses favoured by acid environment – whitening and turning grey – have been observed, although they might have as well been caused by a prolonged drought.

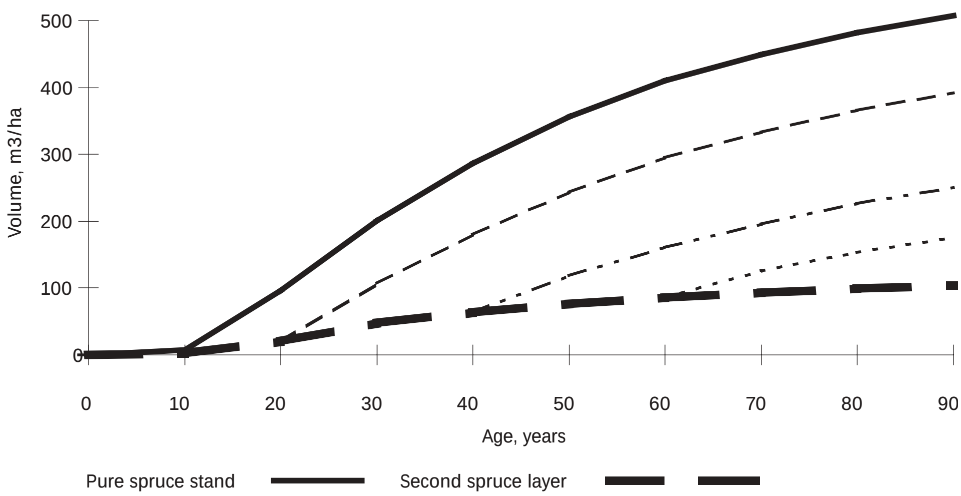
10.4. Possible changes in silvicultural systems with the purpose to use wood as a fuel for heating plants

Lithuanian stand thinning models are made so that the maximum stand productivity would be guaranteed (Kairiukstis, Juodvalkis, 1985). Despite this, some possibilities for modifications of thinning systems still remain. This refers not to the intensity of cutting, but to the aspects of stand species composition regulation. Fast growth is characteristic to young soft deciduous trees such as birch, asp, alder. Comparing of the same age hard deciduous or conifer trees, soft deciduous trees produce higher volume wood. However, an admixture of soft deciduous trees reduces the productivity of conifers. Therefore, it is advisable to try to harmonise the fast growth of young soft deciduous trees with a sufficient productivity of purposeful conifer stands.

In order to solve this problem we used earlier created mathematical models, designed to reflect the influence of soft deciduous trees on the productivity of spruce storey and general stand productivity (Miksys, 1997). We used data of earlier investigations (Kairiukstis, 1959, Kairiukstis, 1969, Kairiukstis, Juodvalkis, 1985) on the dependence of crown density on the stand age, dependence of light amount in deciduous storey on crown density and data on spruce growth dependence on lighting. Tables of spruce growth process were also used.

Using the models when deciduous trees are felled at different ages, calculations of general stand productivity were made. We assume that until felling of deciduous trees spruce trees grow dependently on the light amount they get while after cutting – according to the consistent patterns of growth process of one-storey spruce stand. Principal scheme of these calculations is presented in figure 10.4.1.

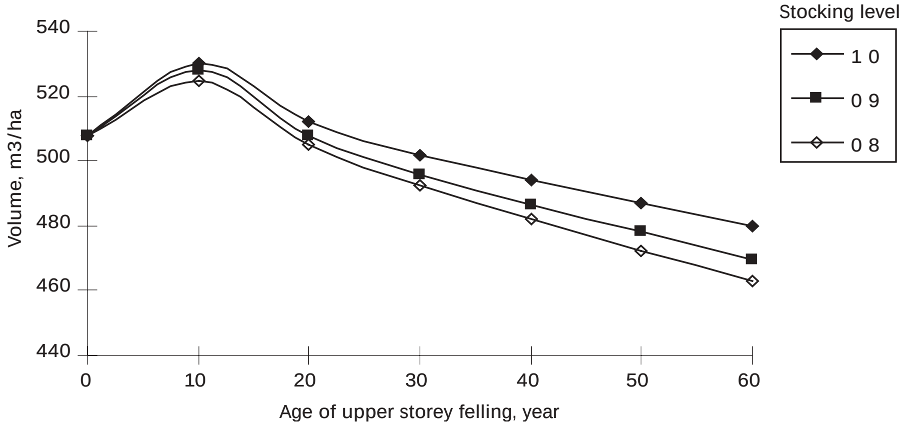
Fig. 10.4.1. Modelling scheme of spruce storey growth under different felling age of deciduous trees



Values of growth process rates are pure (one-storey) spruce stands or the second storey of spruce which all the time grows under birch and asp cover.

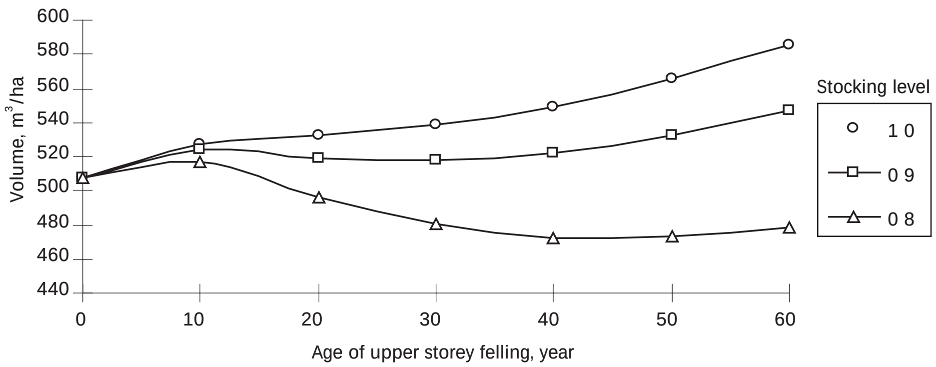
Analysis of the general stand productivity, when the storey of deciduous trees is felled in different age, shows, that in the most common of habitats birch and spruce we can get up to 530 m^3/ha when birches are felled being 10-15 year old. If all the birches are felled during the early thinning, the general stand productivity is about 20 m^3/ha less. When birches are felled in older age, the general stand productivity gradually decreases (Fig. 10.4.2). Birch stand produces more wood, but it doesn't cover the mass loss caused by a slow growth of spruce.

Fig. 10.4.2. Change of the total wood volume received during a turnover period in birch-spruce stands with different stocking level when birch storey is felled at different age



In aspen stand we see almost an identical situation. However, the light amount under the aspen cover, comparing to the birch stand, is slightly higher. Thus, the productivity of aspen-spruce stand is higher. Analysing the general growing stock per hectare, when aspen storey is felled at different age, the variation of this parameter is more complex (Fig. 10.4.3).

Fig. 10.4.3. Change of the total wood volume received during a turnover period in unthinned aspen-spruce stands when aspen storey is felled at different age



When aspen storey is felled in the age of 10-15 years, the general productivity increases comparing to pure spruce stand. If aspen trees are felled even older, the general amount of wood depends more on the stand stocking level of the aspen storey. If the aspen stand's stocking level is 1.0, the general volume increases. The volume is almost the same or even decreases if the stocking level is less than 1.0. However, because of small commercial volume of older aspen stands, the timber volume is distinctly smaller comparing to the receivable amount of that wood when aspen trees are felled in young age and pure spruce stand is planted after that.

The productivity of spruce storey depends on two factors: growth conditions of the spruce stand under the cover of deciduous trees and on the duration of growth under deciduous cover. Data on the productivity of spruce stand, which grows under soft deciduous cover, is presented in table 10.4.3.1. The longer spruce storey grows under the highly stocked first storey the smaller is the productivity of such a stand. However, a 10-15-year long period under deciduous trees decreases the productivity of spruce storey.

According to the above-presented data we can state, that it's not necessary to cut all the soft deciduous trees till 10-15 years of age. It is recommended to reduce the density of deciduous trees in order to make their smothering for spruces minimal. In this case the loss of productivity of spruce storey is minimal. The biggest part of soft deciduous trees should be felled until 15 years of age. In this case it is possible to get from the deciduous storey a significant amount of wood suitable for heating plant fuel and have a productive spruce stand in the future.

Table 10.4.1. Relative productivity (in % from spruce stand) of spruce stands formed from the second storey covered by soft deciduous trees during deciduous felling

First storey stocking	**Volume in 90 years-age, in % from pure spruce stand**						
	Felling age of the 1st soft deciduous storey						
Level	**1**	**10**	**20**	**30**	**40**	**50**	**60**
Birch stands							
1.0	100.0	96.3	77.2	61.0	49.2	40.7	34.4
0.9	100.0	96.5	78.3	63.0	51.8	43.5	37.6
0.8	100.0	96.5	79.7	65.4	54.7	46.9	40.9
0.7	100.0	96.7	81.1	67.9	58.1	50.6	45.1
0.6	100.0	96.7	82.9	70.9	61.8	55.1	49.8
Aspen stands							
1.0	100.0	96.3	79.3	64.8	54.1	46.3	40.6
0.9	100.0	96.7	80.9	67.5	57.5	50.2	44.7
0.8	100.0	97.0	82.7	70.5	61.4	54.5	49.6
0.7	100.0	97.2	84.6	74.0	65.7	59.6	55.1
0.6	100.0	97.6	87.0	77.8	70.9	65.7	61.6

Today the delay of pre-commercial thinning is quite o ften. If the necessary cuttings are delayed, it is very difficult to form a desirable species composition in the stand. On the other hand, we may think that the problem of delayed young stand cutting can more successfully be solved by forest fuel production. That is because one of the main reasons for a delayed young stand cutting is high costs of pre-commercial thinning which can be reduced by the production of forest fuel.

11. Changes in Silviculture (Pre-commercial thinning)

**this chapter was written by Anders Gillgren from Swedish Forest Administration*

11.1. Introduction

In Swedish Lithuanian Wood Fuel Development Project, SLWFDP, phase 2 one of the issues was to show how treatments in forest can be changed in order to give possibilities for forest fuel outtake in young stands. These changes are in some aspects more radical and of more importance than those in thinning because of their effects on the stand development in the future. Pre-commercial thinning has been a subject of many studies and re-searches in Sweden for the last two decades. Thanks to that there are a lot of experience both from practical studies and theoretical calculations you can also use in Lithuania.

11.2. Summary

The young stands in Lithuania forests are in big need for treatment. In order to show different treatments and effects from these, some plots were chosen in Rokiskis FE, Seleny district. To be able to make a comparison between traditional precommercial thinning and precommercial thinning combined with forest fuel outtake four different methods were used.

1. Traditional with brush cutting knife
2. Traditional with motor-manual brush cutter[1]
3. Forest fuel outtake using knife.
4. Forest fuel outtake using Apuri[2].

In spite of skilfulness' and education of the workers the result still shows that there is a great amount of forest fuel available in young stands as well. In this particular case an 18-year-old stand, pre-commercial thinned twice, still gave 56 m^3s (100 MWh) per ha. If one third of the stands younger than 30 years had this amount of volume it would be possible for the next 10 years to make an annual outtake of 0,56 million m^3s (1 000 000 MWh). An analysis of the figures in Lithuanian Statistical Yearbook of Forestry 2000 and 2001, even with very hard reduction of available areas, gives almost the same volume of available forest fuel, 0,6 million m^3s/year from young stands. Swedish reports from researches and analysis of possible outtake in young stands have results that shows similar amounts that could be taken from young stands, 40 m3s/ha

11.3. History of silviculture in general and pre-commercial thinning in particular

Silviculture has occupied man for some hundred years. Of course different methods have been used during different periods. Due to social and technical development the treatments have changed from very simple ones like burning all forest to give place for agriculture to high technical equipment used for felling/transporting logs. The forests that we harvest today in final cuttings have been treated in one or another way. Pre-commercial thinning, the way it is carried out today, is a "new" treatment in forest. In general pre-commercial thinning was done by taking useful woods from forest. Like fire wood, woods for fences, woods for haystacks etc. There are three main changes that have taken place that had considerable impact on forest development:

1. The technical development in agriculture has decreased the use of woods.
2. The final cuttings of forest have changed from small scaled areas cut by many men to bigger units cut by machines
3. People who used to work halftime in forest and halftime as farmers are not available in the same extent as 30 years ago.

How will forest be treated properly and who will carry it out?
This diverging development leads to the fact that there will be very hard to find people for pre-commercial thinning. Lithuanian forestry is still not so mechanised and there are quite many people working manually in cuttings. This fact is a good condition for young stands to be precommercial thinned. -

11.4. Good - necessary combination

Silviculture has turned out to be a science not always connected to e.g. economy. Many different ways have been claimed to be the right way to good forest and *high quality forest.* High quality forest is also a matter of personal opinions. It depends on who is stating it and at what time. Of course there are some fundamental abilities in wood that are useful in most cases, e.g. resistance against rottening but at this moment it turns out to be very hard to claim any more ability that is generally so essential. Talking about timber it depends on what kind of boards you will make and what quality you need. Then you have pulpwood that demands other qualities. For future it is more or less impossible to predict what species will be asked for. To be well prepared however it is important to make different species grow as good as possible by breeding them on sites, which are best for them. This is where silviculture and forestry will be combined.

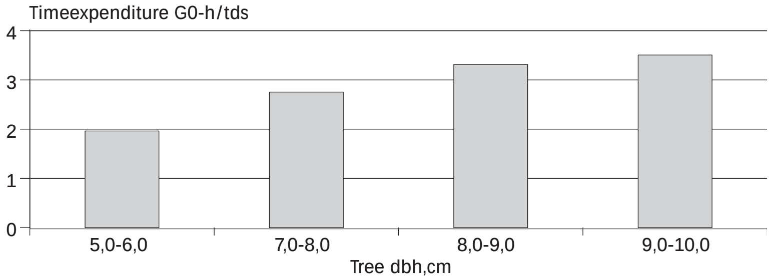
11.5. Swedish experience

Since the end of the 1970th there have been many trials to make out the extraction of forest fuel as profitable as possible. Most of the efforts have been put to young stands that are untreated after reforestation. So called conflict stands. Due to this lack of treatment these stands did not give enough profit so there was not established any business with forest fuel from young stands. Instead some machines were constructed for pre-commercial thinning, but not even that worked properly. In the end of 1970th and beginning of 1980th pre-commercial thinning was carried out by motor brush cutters. The way pre-commercial thinning was made, next thinning was supposed to be made according to pulpwood and timber, it never gave possibility to make any forest fuel outtake.

In the mid 90th it became so obvious that non pre-commercially thinned young stands had to be dealt with the greatest concern. Great numbers of activities were started and the main result from these was that pre-commercial thinning became a subject at every meeting with foresters. In forest, however, not so much has happened yet. In one of the pre-commercial thinning projects a machine was developed and used for forest fuel outtake, "Enhar" which is short for –energy harvester. See p.11.5.1. At the beginning "Enhar" was called "the pre-commercial thinning machine". The biggest novelty in it was the multiple tree handling. The machine did not have to cut and put each tree on the ground and could instead cut several trees, (3-6), and collect them in the felling head and by that diminish the movements of crane. A lot of studies were carried out[3]. One study was conducted and the main issue was to see how multiple tree handling influenced the effectiveness of outtake of biomass in young stands (figure.11.5.1.). One essential conclusion can be made. More time has to be spent on small trees to get the same amount of m^3 than on bigger ones. This experience points at the conclusion that you cannot exclude precommercial thinning as a method in forest treatment. Not only because of technical reasons but most of all because of economical ones.

Picture 11. 5. 1. Energy harvester in young stand

Figure. 11.5.1. How tree diameter influenced on effectiveness in outtake of biomass in young stands



11.6. The economical value of pre-commercial thinning

There are numerous studies that show how important precommercial thinning is for good development of a stand. But very few put economical figures to it. In a web designed model for calculation of pre-commercial thinning [4], see table 11.6.1., you can simulate a pre-commercial thinning and compare the economical results from pre-commercially thinned stands with the ones of not pre-commercially thinned. The pre-commercially not thinned stand gave a negative economical result and as this simulation is based on thinning with machines, the main reason for that is the stem volume. There were many trees but they were very thin and as one thin tree takes almost the same time to treat, as a thick one, the cost per m^3 is much higher for the thin tree. On the opposite first thinning in the pre-commercially thinned stand gave a positive economical result thanks to thick and well-developed trees. The total difference is 4 620 SKr (1.700 Lt) which is the amount of money you could pay for pre-commercial thinning and still be on the right side of the economical borderline. Calculations like this only consider what is taken out and not what is left and its increasing value in better stem volume and thanks to that lower cost next time and so on.

Table 11.6.1. From an analytic model in www.skogforsk.se

Thinning at the age of 30 y and 13,9 m height.

		Stand A (pct at age of 15 y)	Stand B (no pct)
Outtake	m^3sub/ha	**62**	**63**
Pulpwood	%	**86**	**98**
Timber	%	**14**	**2**
Income	SKr/ha	**16340**	**15979**
Harvest cost	SKr/ha	**-9694**	**-18880**
Et	SKr/ha	**6646**	**-2901**
Yield by pre Commercial thinning	SKr/ha	**9547**	
Cost for pre Commercial thinning	SKr/ha	**1199**	
Today's value of Pre-commercial thinning With 2% interest	SKr/ha	**4620**	

11.7. Standing volume in young stands

The results from demonstration plots in Rokiskis show that there can be a much bigger volume available in young stands than has been expected so far. It all depends on the treatments. Of course you have to choose the right treatment according to the conditions given in forest. Which means in this case you choose places for forest fuel outtake according to possible outtake volume, stem volume, distance to roadside, distance to market (boiler houses) and price of chips. Possible outtake depends, among other things, on site index, stand age, and former treatments. Former treatment means in this case, pre-commercial thinning. If site index is high the stand will be possible to thin with forest fuel outtake at an earlier age than if the index is low. One basic condition for that is there should have been made a pre-commercial thinning before. Stem volume has, as mentioned above, a decisive importance on economy of harvesting. It depends of course on the site index and age but without any treatment the volume, which is produced in a stand, will be spread on too many stems to be possible to take hold on. The figure that usually is mentioned as a limit for tree dimensions in economical calculations on forest harvesting is 10-cm dbh. At this size the tree volume is enough to allow machines, in both technical and most of all economical aspects, to make a good work. The distance to roadside is of greater importance. The smaller the object is and the less volume the stand keeps. You have also to take under consideration what ground conditions are. If outtake has to be made in winter or if you can do it at any time of the year.

A Swedish study made by SLU[5] estimation on volume, possible outtake and costs was done. The main issue for this study was to find, like above, the time expenditure in handling small trees with a specially made machine, Enhar. However, very detailed measurements of the stands were made. They all showed that there are quite big volumes even in young stands that could be taken as forest fuel. The biggest figure of outtake in this research is from pine plots, 49.8 m^3s/ha. But the range is not so wide. The lowest figure, 29.2 m^3s/ha, is from the Birch plot with the highest density. All others are over 33.1 m^3s/ha. Another study by SLU[6] was dealing with energy content and its costs of extraction from forest. This was made in order to see the difference between the treatments of young stands. It was carried out in 5 types of pre-commercial thinning and thinning on four different sites. The thinning was done only for forest fuel outtake and put in time at stand age of 20-30 years. The analysis shows that 29-46 tDS could be taken which corresponds to about 100 m^3s/ha. Table 11.7.1. The third research[7] and its results are from a stand which was pre-commercially thinned 9 years ago, data was collected from stem dimensions and stand volume. Table 11.7.2.

Table 11.7.1. Biomass outtake, TDS per ha

From "Alternativ för biomassauttag i ungskog", 1998, Eriksson

Stand height 8 m

Site index (SI)	Pre-commercially thinned at 2 m height and age of 10 to 12 y	m^3s	Age of stand
T 20	**29,1**	73	30
T 24	**26,4**	66	20
G24	**45,9**	115	28
G28	**43,4**	109	23

In this calculation 1 tds is supposed to correspond to 6,25 m^3l (chipped m^3) and 1 m^3s (solid) corresponds to 2,5 m^3l

Table 11.7.2. Data from pre-commercial thinned stand, 1999, Gillgren

Stand data from 1999						
Clear cut	1972					
Planted	1975					
Pre-commercial thinned	1990	Everything smaller than 5 cm at stump height, was pre-commercial thinned.				
Plot areas,m²	100					
Plot no.	Number of **Coniferous**	Medium diameter,cm	Medium Height,m	Number of **Broad leaves**	Medium diameter,cm	Medium height,m
1	27	5	1,5	32	9	9
2	8	3	1,2	37	10	12
3	10	7	1,9	24	8	7
4	14	5	1,8	32	10	11
5	14	4	1,5	34	11	11
Sum of stems	73			159		
Stems/plot	14,6	5	1,6	31,8	10	10,2
St/ha	**1460**	**5**	**1,6**	**3180**	**10**	**10,2**
m^3s/st		0,001		**0,03**		
" /ha		1,4		**95,4**		
Possible outtake, m³s/ha				**60**		

11.8. Forest fuel in young stands in Lithuania

How big volume from young stands can forest in Lithuania provide then? Of course this volume will not necessarily be used for forest fuel. But as this project is dealing with the integration of forest fuel outtake, and the volumes today are not used at all it may give guidance for the future if you know what volumes are available. In order to get some kind of estimation you have to know the distribution of young stands. Below follows a comparison between two different tables from Lithuanian Statistical Yearbook of Forestry, one from 2000 and the other from 2001. Table 11.8.1.

Table 11. 8. 1. Distribution of forest stands in Lithuania by dominant tree species at the age of 20 y and 30 y.

From Lithuanian statistical Yearbook of forestry 2000

Age class	**2**			**3**		
	Area,ha	**Volume,m³**	**m³/ha**	**Area,ha**	**Volume,m³**	**m³/ha**
Dom. Spec.						
Pine	36388	1704100	47	50843	5572300	110
Spruce	54941	2273000	41	33958	3965500	117
Birch	22051	960400	44	42125	3833100	91
Aspen	2705	191000	71	4978	634400	127
Alder	44990	3121300	69	53178	5685600	107
Oak+Ash	5295	245300	46	6652	597100	90
Other	1067	45300	42	2024	178800	88
Total	**167437**	8540400	**51**	**193758**	20466800	**106**

From Lithuanian statistical Yearbook of forestry 2001

Age class	**2**			**3**		
	Area,ha	**Volume,m³**	**m³/ha**	**Area,ha**	**Volume,m³**	**m³/ha**
Dom. Spec.						
Pine	23067	648100	28	41018	4702300	115
Spruce	54665	2217000	41	37670	4240500	113
Birch	18818	771200	41	26590	2370600	89
Aspen	2724	203000	75	2493	329800	132
Alder	26390	1799000	68	48433	5209100	108
Oak+Ash	4298	199400	46	4937	418400	85
Other	751	29900	40	1304	104900	80
Total	**130713**	5867600	**45**	**162445**	17375600	**107**

The young stands that are considered here are those up to 30 years of age. According to the restrictions on cutting in some forests you have to reduce the area by 15-20 %. The statistics is just showing a tendency what could happen in reality. Therefore you have to be very careful when dealing with these figures. In stands at the age of 20 years, there are those, which have a very low stock volume, and those, which are very dense. The figures for this class are 130 000 –167 000 ha. Because of some reason the area has diminished by 22 % from 2000 to 2001. The biggest areas consist of spruce and alder. If you make the reduction for restricted areas by 20 % you will have an area of about 100 000 ha with an average growing volume of 45 m³s/ha which makes 4 500 000 m³s. As these stands are growing very fast and most of them are in big need for pre-commercial thinning you can assume that at least half of this volume is to be pre-commercially thinned. That makes a considerable volume more than 2 million m³s available as forest fuel. If this is done over a 10-year period **0,2 million m³s** could be an annual outtake from very young forests. Today this volume is spread on to many small stems to be economically available. But in the future, when the stands are treated properly, according to the recommendations in this project, the volume will be concentrated in a less number of trees, which is more economically to handle. Then there are even bigger areas in the 3rd class, 30 years of age. Like the younger stands the area has also decreased from 193758 ha to 162445 ha. With the same reduction for restrictions because of environmental reasons there will be a bit more than 120000 ha with the average growing volume of 12-15 Mill m³s. This volume is probably in stands, which ought to be thinned. If the thinning is carried out in the way that 30 % of the volume is taken out it will reach an amount of 4-5 million m³s. Over the same period as above, 10 years., the annual outtake could be at least **0,4 million m³s.** Altogether the young stands seem to be able to give a contribution of quite a good amount of sustainable bio energy. The results from the demonstration areas in Rokiskis gave as high volume as **56 m³s/ha**[8]. If that were the outcome from just half of the areas mentioned above (100 000+120 000)/2=110 000 ha, it would give almost the same, **0,61 million m³s** annual in 10 years.

Footnotes

[1] Husqvarna

[2] Finnish equipment in combination with motor chain saw.

[3] Arbetsdokument NR 8,1999, Liss

[4] www.skogforsk.se

[5] Arbetsdokument nr 2,1997, Gullberg, Johansson och Liss

[6] Alternativ för biomassauttag i ungskog, 1998, Eriksson

[7] Data from precommercial thinned stand, 1999, Gillgren

[8] LFRI-report 2002

12. Business Development

**this chapter was written by Arvydas Lebedys from Center of Forest Economics*

12.1. Wood fuel from industry

Wood residues from forest industries is the main source of woodfuel in Lithuania.

There is no reliable data on sawmilling residues (chips, particles, slabs, sawdust) in Lithuania. According to the estimates annual sawnwood production remained stable. During the last 4-5 years it was about 1,0-1,2 million m^3. Sawmill sector is very fragmented and there are only 10-15 big sawmills with the production of over 10,000 m^3/yr. These biggest sawmills account for 20-30% of total sawnwood production, the rest is produced by more than 600 hundred very small (as compared to Nordic countries) sawmills. No reliable data exists about the small-scale sawmills.

Taking into account the estimated annual sawnwood production level, it could be estimated that every year about 1,0-1,5 million of wood residues are sawn in Lithuanian sawmills.

Data presented in energy balance[1] for the years 2000 and 2001 show the annual consumption of 3,2-3,3 million m^3s of wood fuel, both firewood and woodwaste from industries. 2,5 mill m^3s of it are consumed in the households, and mainly it should consist of firewood because the usage of chips and briquettes is not common in residential sector in Lithuania so far. According to the data from the state sawmills[2], individuals purchased about 10-20,000 m^3s of slabwood, and perhaps most of it was used as a fuelwood in households. As state-owned sawmill produces less than 10% of total sawnwood in Lithuania, it could be estimated that in 2001 about 0,2 mill m^3s of slabwood was burned in households. Following this the remaining 0,7-0,8 mill m^3s should be mainly wood residues from the industries, 0,4 mill m^3s of which are consumed by the industry heating plants and the remaining 0,4 mill m^3s are consumed in other sectors (industry, services, agriculture sectors).

However the data collected by the Ministry of Environment[3] shows, the following balance of woodwaste in 2001:

0,3 mill m^3[4] (127,000 t) – production

0,3 mill m^3 (118,000 t) – conversion

Only 7,000 tons, or 6% of converted volume were delivered to dumping places, the rest went for energy or processing.

It should be mentioned that this data is clearly underestimated because several major sawmills are not presented in the list of companies. However one statement can be made – today Lithuanian sawmill sector converts (sell or consume inside the company) practically all residues.

Based on the data from energy balance, foreign trade and interviews with board producers and other sources, sawmill residues (chips, slabwood, sawdust) consumption in 2001 can be estimated as following:

Consumption:

0,1 mill m^3s export (chips for pulp)

0,2 mill m^3s for particleboard, fibreboard

0,4 mill m^3s heating plants

0,4 mill m^3s within the industry and other sectors (sawmills, etc.)

0,2 mill m^3s burned in households (individuals)

0,1 mill m^3s – for production of briquettes, pellets

Total consumption– 1,4 million m^3s
Remains unused (5-10%) – about 0,1-0,2 mill m^3s

The figures in the table present the estimated consumption, not the production of sawmilling residues in 2001. Quite significant part of residues that were consumed by heating plants in 2000-2001, were accumulated in late 1990s, and the real market for previously problematic sawmill by-products appeared only in 2000. There were thousands of cubic meters of residues (chips, sawdust) accumulated in the yards of the major sawmills which were visited by the author in 2000. However in winter of 2001/2002 most of these sawmills confirmed that they solved this "headache" recently and now they can find the market or consume all by-products practically themselves.

12.2. Wood fuel from forestry operations

As mentioned above, the annual consumption of wood fuel in households in both 2000 and 2001in presented official data in the energy balance is 2,5 mill m^3s. Mainly firewood is used in the households in Lithuania so far, and other wood fuel such as briquettes, chips are not common in Lithuania. As it was mentioned in the previous chapter, about 0,2mill m^3/yr of slabwood from sawmills is used in the households which is replacing round firewood.

Comparing to the official data on forest fellings (5,7 mill m^3s in 2001), the firewood consumption figure 2,3 mill m^3s of firewood seems to be overestimated. It is hard to believe that firewood accounts for 40% of total roundwood removals in Lithuania. The volume of 2 mill m^3s would be closer to reality.

Until 2001 wood fuel from forest practically consisted only of round firewood. There were some trial supplies of forest chips in mid-1990s, in connection to boiler conversion projects (e.g. conversion of Moletai boiler). But all these attempts to supply forest chips in 1990s were not based economically as in that time there was an oversupply of wood waste from forest industry (sawmills).
In 1990s the demand and supply for forest fuels (firewood) could be described as following:

- there was no real demand for forest fuel from energy sector;
- converted boilers enjoyed an oversupply situation with residues from sawmill sector;
- Prices for firewood were going down due to insufficient demand (1996-2000).
- No chips were produced in forest, as they could not compete in cost with chips from sawmills.

However taking pace in the restructuring of energy sector (conversion of boilers in wood using) led to growing demand for wood fuel in last years. Also wood-based panel producers (particleboard, fibreboard) increased the usage of sawmill residues (replacing roundwood) in the last years. Therefore, board industry and particularly heating plants during the last 2-3 years consumed the piles of slabs, chips and sawdust, which were accumulated in sawmill' yards during almost 10 years. Last winter (2001/2002) has changed the patterns of wood supply for energy in Lithuania. Rapid conversion of boilers to the usage of wood created additional demand for wood, and availability of residues from sawmill industry the production of which stabilised over the last years, is not in parallel with the growing demand for wood fuel.

No reliable statistics is available on the whole firewood market in Lithuania. Statements bellow are based on the statistics from the state forests, which now account for about 2/3 of total roundwood supply in Lithuania.

Last winter was the first time since Lithuania regained its independence when demands for "low-grade" wood (firewood, wood for board industry) exceeded the supply. Inventories of unsold wood in state forests decreased by 30-50% since 2000, and now the monthly supply (production + inventory at the end of the month) is at the same level as monthly sales (figure 10.2.1). Due to the growing demand prices for firewood in state forests increased from 22 LTL/m^3sob to 25 LTL/m^3sob. Price for board wood followed this trend (figure 12.2.2).

Figure 12.2.1. Aggregated supply and demand of firewood and roundwood for board industry in state forests, 1999-2002

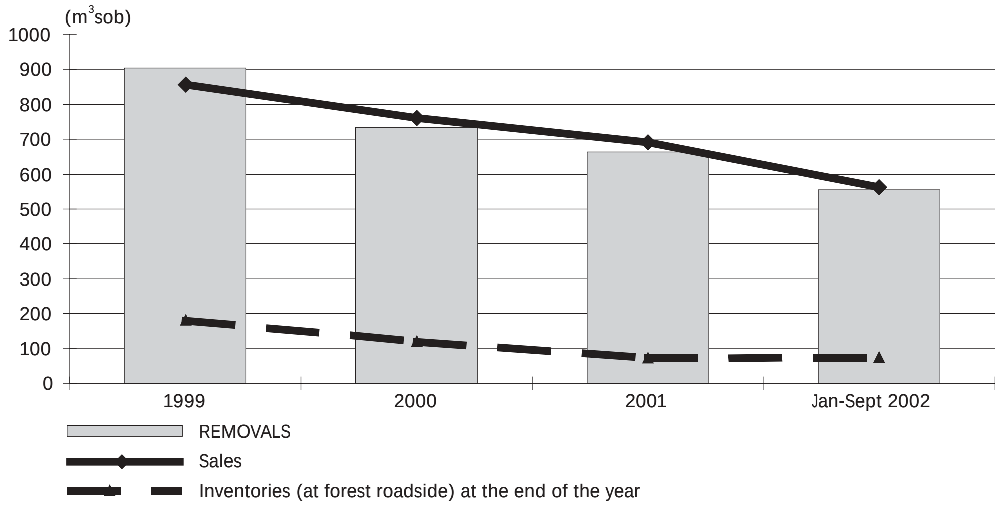
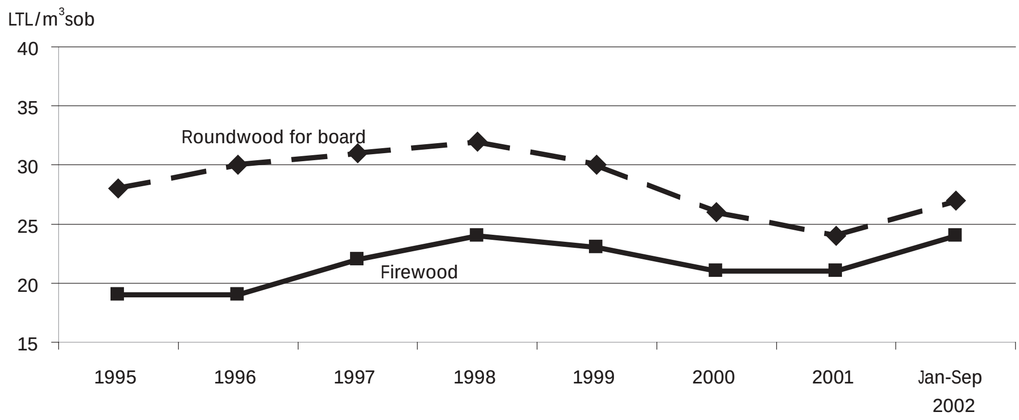


Figure 12.2.2. Prices for firewood and roundwood for board industry in state forests, 1995-2002



Additionally to the growing demand from energy sector and board factories, in some regions the new producers of charcoal demanded firewood, pellets. Demand for firewood in residential sector is not decreasing, and additionally the demand from small boilers (e.g. schools) fuelled with firewood increased significantly (figure 12.2.3).

Firewood demand and supply situation is very different in different regions of Lithuania. In the Northwest of Lithuania where most of boilers conversion was taking place in recent years, supply of roundwood for particleboard and fibreboard (also aspen pulpwood) practically stopped this year. This happened due to the high transportation cost to the board producers, which are located at a distance of about 150 km from the region. Average price (at forest roadside) for firewood became 10% higher than for board roundwood in the region this year. Sales of firewood during 10 months of this year have already exceeded the level of the whole year 2001 in the state forest enterprises of the North West of Lithuania (figure 12.2.4). Private logging companies acting in private forests of the region also proved that demand and prices for firewood increased in the region.

Figure 12.2.3. North Eastern Lithuania: Supply and demand of firewood and roundwood for board industry in state forests, 1999-2002

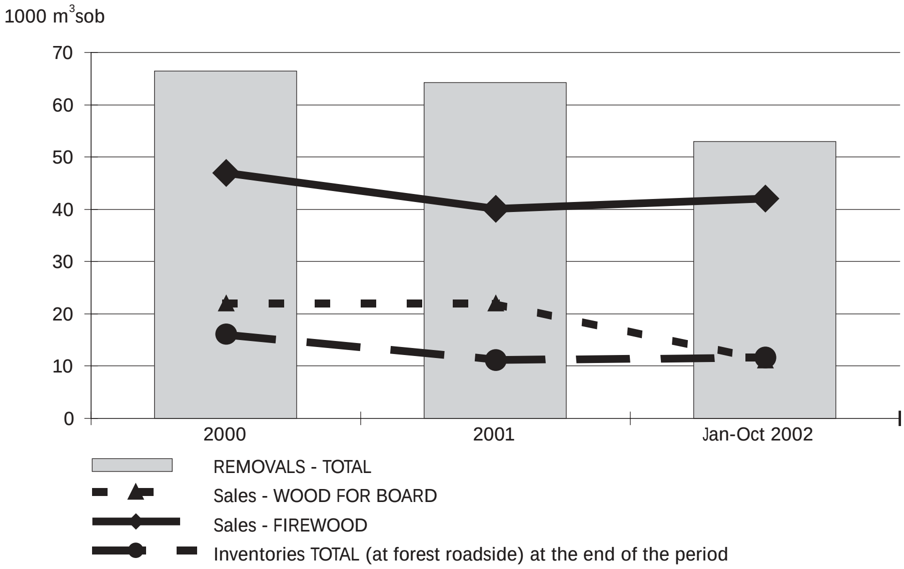
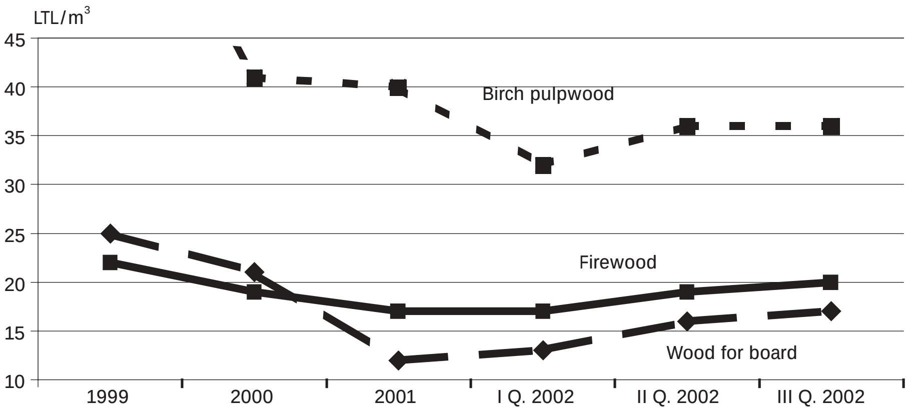


Figure 12.2.4. North Eastern Lithuania: Prices for selected roundwood assortments in state forests. For firewood and roundwood for board industry the prices are given per m^3 solid with bark. For birch pulpwood the price is given per m^3 under bark (without bark)



Even the production of birch pulpwood in the region can be a question for future in the North Eastern Lithuania. Today the real price for birch pulpwood is already the same or even slightly lower than the price for birch firewood. Pulpwood is measured and the price is paid for the solid cubic meter of bark, while for firewood – for m^3 of bark, thus taking into account this difference, the competition for birch is possible in the region.

Additional demand and shortage of residue supply from sawmills created possibilities to start supply of forest chips produced by mobile drum chippers. This is completely new, market driven development, which was only started in May 2002. Until this year, only small volumes of chips produced from round firewood were coming from forest.

The real possibilities to increase supply is the integration of forest fuel handling which is possible only by using drum chippers which increase the volume of forest chips adding the chips from tops and branches[5]. If the waste from logging operations is not integrated widely, i.e. we rely on chipping round firewood from traditional logging, to boiler plants, it is obvious that prices of round firewood for private household will go up further in near future.

12.3. Future scenarios of wood fuel business

International projects on forest fuel supply in Lithuania started almost ten years ago, but the real market driven supply started only in the last years. In recent years wood has become the competitive resource for energy generation practically without any legal (tax) incentives.

The forest fuel chips handling is the new development in Lithuanian forestry. The demonstration project in Rokiskis was on time, and the demonstrations that were carried out proved that it is not easy to convince people and change their traditional thinking, especially in forestry.

Nordic countries have long traditions, compared to the Baltic States, but conditions are not the same in these countries. Therefore not all the driving forces, which are actual in e.g. Sweden, are of the same importance in Lithuania. But the main advantages with wood fuels are the same:

- Domestic and renewable energy source
- No carbon-dioxide emissions
- New jobs

In addition to the general advantages above mentioned, wood fuel development creates the new economic possibilities for forestry sector. The main driving forces for wood fuel development are the following:

- New additional income possibilities to forest owners
- Lower cost for silvicultural works:
  - additional income allows to carry out pre-commercial thinnings in larger area for the same cost
  - easier soil scarification after the removal of felling residues
- Reduced risk for insect damages (felling residues removed from forest)
- Better conditions for recreational forest areas

However besides the positive sides of introduction of integrated forest fuel handling into forestry, the risk of increased negative factors, such as removal of nutrients, strip roads and more damages to the soil and trees has to be reduced. These questions need some research and analysis to be done in Lithuania in the future.

Speaking about the economical side of forest fuel business, simplified comparison of cases in Sweden[6] and Lithuania is presented bellow.

• Sweden:

(-) [7]Cost for logging and chipping:
- appr. harvesting/forwarding 19 SEK/m^3l (110 SEK/t)
- appr. chipping 22 SEK/m^3l (125 SEK/t)

(-) [8]Transportation to the boiler (avg. 60 - 70 km) – 40 SEK/m^3l = **appr. 37 LTL/m^3s**
(+) [9]Price delivered to the boiler – 120 SEK/m^3l = **appr. 110 LTL/m^3s**
Net value : 40 SEK/m^3l (238 SEK/t),
i.e. 40 SEK / 0,40 (conv. coef) x 0,37 (exchange rate) = **appr. 37 LTL/m^3s**

• Lithuania

(-)[10]Cost for logging and chipping:
30 - 43 LTL/m^3s
(-) [11]Transportation to the boiler (avg. 60 - 70 km) –**3 - 7 LTL/m^3s**
(+) [12]Price delivered to the boiler **37-48 LTL/m^3s**
Net value : **from -13 to +15 LTL/m^3s, i.e. on average +1 LTL/m^3s**

The figures presented for Lithuania show that the direct net profit in forest fuel chips business is hardly possible. In Lithuania, it possible to gain about 15 LTL/m^3s only when fuel chips are produced from clear cuttings, while in Swedish case it is possible to get almost triple net income at the same conditions. When looking at Lithuanian “loss scenario” (pre-commercial thinning), the loss (price minus direct cost) of about 13 LTL/m^3s is the final result.

In addition to this “pessimistic” forest fuel chips cost/price situation, the following issues affecting forest fuel chips business development must be considered:

- **The practice of short-term (annual) contracts between heating plants and suppliers.** It is practically impossible to invest into high-priced machinery (drum-chipper, etc.) when the expected profit margin is close to zero.
- **Payment for chips based on cubic meter, not energetic value, which strongly depends on moisture contents, tree species.** Moreover, different companies are setting different coefficients for

conversion from loose m^3 to solid m^3 of chips (from 0.36 to 0.40, i.e. 10% difference).

- **Large-scale investments.** It is practically impossible to invest into high-priced machinery (drum-chipper, etc.) when the expected profit margin (from direct cost and sales price) is close to zero. Based on the comparison, the net income in Sweden is considerably higher than in Lithuania, and this corresponds to the payback of investments into machinery (drum chipper, etc.). High machinery cost will definitely influence the pace of development of investments into forest fuel chips production in Lithuania. There are no very large logging companies (including state forest enterprises) in Lithuania. The biggest logging companies harvest up to 100-150,000 m^3 of roundwood annually, and they prefer to put investments into machinery with clearly better payback (e.g. forwarders) than drum chippers.
- **Market intelligence, information systems.** Reliable information is an essential tool for planning. In the report a lot of information was based on the estimates, and many authors emphasized the need for it. Even industry wood residue volumes and breakdown was interpreted differently using different sources, because real price statistics does not exist in Lithuania. More difficulties arise when we speak about the potential of wood fuel from forest.
- **Legislation.** There no any real legal instruments (tax incentives) that would create competitive advantages for wood against other raw materials used for fuel in Lithuania today. And it is clear, that wood will be able to compete with other materials as far as its price is competitive . This is the way it is today. But in the future, rising demand and competition may lead to the increase in prices for wood fuel (such tendency is noticeable already now) and makes it too expensive comparing to other fuels. Legal instruments would foster the expansion of wood as fuel.
- **Change of traditional thinking.** This issue is very important, and the demonstrations within the project in Rokiskis proved how difficult it is to convince to start new things. It is not easy to convince forestry people to change their traditional thinking. And today it is obvious that perhaps foresters could benefit mostly through the both direct and indirect advantages (e.g. costs reduction, stand improvement) from integration of forest fuel handling into practice in long term.
- **Know-how from Nordic and other countries.** It is always useful to get the advice from more experienced counterparts. Nordic countries have relatively long traditions of wood fuel business and their know-how should be used in order to evolve from the current stage. From the business point of view, assistance to suppliers with drawing contracts (m^3/mW), measurements, training are the main issues for future.

Conclusion - integration and cooperation between stakeholders is essential to explore for future wood fuel development in Lithuania.

12.4. Socio-economic effects of forest fuel development

As the forest fuel chips production is a very new development in Lithuania, it is not easy to say what real effect on employment and economic development in the region as well as the whole country it will have in the future when wood fuel consumption rises dramatically. Therefore the synthesis from various sources, mainly from Nordic countries, is presented bellow and these factors should be considered and estimated in the future.

Regional economical effect is a common name for the sum of changes in a regional economy, which are the results of an action. The relations between the sum of effects and the origin of action are measured with a multiplier factor, a number over 1.
Economical effects often used in analyses are:

- Regional consumption;
- Regional employment;
- Public tax incomes;
- Public consumption.

The 2 most common multiplier factors are income multiplier and employment multiplier. There are 3 types of effects, which explain the phenomena multiplier.

- **Direct effects.** Corresponding to the origin of changes i.e. the increased production.

- **Indirect effects.** Corresponding to the effect on all suppliers to the company in question. Export companies buying a part of the achievement in the region are they are located. Subcontractors buying from other regions, etc.
- **Consequence effects.** All changes above give employment within the region. Increased incomes results in higher consuming within the region. The new higher consuming gives other consequent effects.

Example from Sweden[13] total increased employment is 1,3-1,5 annual work places per GWh.

In Finland[14], if in heat generation 15 MW oil plant is replaced by wood heating plant, the annual local employment increases by 9 man per year. Calculated by small-sized 3/9 MW co-generation station which in heat generation replaces oil heating plants and in power generation replaces coal condensation power, the annual local employment effect is 12 man per year with wood fuel.

There is a general assumption made both by the Lithuanian Ministry of Economy and the foreign experts that installed 1 MW of biofuel capacity employs 2 extra people[15]. Considering 6 MW installed in Ignalina boiler house, it should have created 12 extra labour places in the area. It is complicated to evaluate the exact number of created new jobs. The fuel production (chipping) chain is considered to be the most labour intensive . In Ignalina, in 1998-2000 6MW woodfuel boiler made the following economic effects:

- Heat production cost was down from 115,87 to 95,38 LTL/MWh, i.e. by 18%
- 0,9 mill LTL "stayed" within the municipality due to ceased imports into the area of municipality (from 2,04 to 1,35 mill LTL)

According to the recently announced estimates by Swedish experts, in order to produce wood fuel sufficient for 1 MW production during one year three people are required[16]. For the CHP plant, which uses 290 GWh/year of bio fuel, about 99 people would be needed. Together with the staff of 24 people in the new plant, 123 jobs would be created.

The above mentioned figures prove that the use of wood fuel creates additional jobs. As the usage of wood fuel in Lithuania is the new development and due to the cheap labour cost the automation level (especially in forestry) is lower than in Nordic countries, it is obvious that not the least level of additional employment has to be taken into consideration. E.g. in Rokiskis it was observed, that in the heating plant the additional job was created for the driver of bulldozer which is feeding the boiler with wood residues pulling them to the conveyor. It is clear that more jobs in forestry operations in Lithuania than in Nordic countries will be also created at least in the initial stages of forest fuel integration. In further stages investments into optimization, productivity of wood fuel supply chain will take place, and it is possible to decrease the number of people employed per unit.

Footnotes

1 "Energy balance 2001" Statistics department

2 MEC data

3 data about wood waste accumulation and conversion collected by Joint Research Centre

4 for conversion coefficient was used 1 m^3 (solid) =0,42 t

5 More information about additional volumes produced by using new technology is given in other chapters of the report

6 Data obtained during the Study Tour to Sweden in April 2002

7 Jan-Erik Liss, Tomas Gullberg, Högskolan Dalarna, Study Tour to Sweden in April 2002

8 Falun CHP plant (20MW), Study Tour to Sweden in April 2002

9 Falun CHP plant (20MW), Study Tour to Sweden in April 2002

10 LFRI report (Jonas Saladis, Activity group A)

11 Transportation by truck figures from the chapter 14

12 MEC database

13 GDE-NET, Sweden 2002.

14 Juha Turkki, Espoo, Finland 1999

15 Abaravicius J., "Bio-fuel Based District Heating in Lithuania", LUMES, Lund University, 2001

16 Olov Stenbäck "Prefeasibility study regarding bio fuel fired combined heat and power plant or district heating-plant at Visaginas, Lithuania", SwedPower, 2002.

13. Institutional and Legal Aspects Regulating Wood Energy Activities in Lithuania

**this chapter was written by Vilija Augutaviciene from Ministry of Environment, Forest Department in Lithuania.*

13.1. Policy, strategy and programs

During the last decade after the restoration of Lithuanian independence, the importance of indigenous and renewable energy sources came increasingly appreciable for decreasing dependency on imported fuels, dealing with the social problems (opening job opportunities) especially in rural areas and decreasing environmental pollution.

The Lithuanian renewable energy policy is based on the following legal acts regulating country energy sector:

- National Energy Strategy (10 October 2002, No. IX-1130)
- Law on Energy (16 May 2002, No. IX-884)
- Law on Electricity (20 July 2000, No. VIII –1881)
- Law on Biofuels (18 July 2000, No. VIII-1875)

All these documents put an emphasis on energy efficiency improvement extending the use of renewable energy and promotion of both producers and consumers to the effective use of local and renewable as well as secondary energy resources.

13.1.1. National Energy Strategy

The new national energy strategy adopted by Lithuanian Parliament in September 2002 underlines that Lithuania will seek to use about 2 mill. toe (tone of oil equivalent) of indigenous, renewable and waste energy sources per year. Seeking to use local energy resources as much as possible, as well as to create new working places and to improve environmental condition:

1) local energy recourse programs will be drafted and revised;
2) the use of local energy recourses will be stimulated by organizational, economical and legal measures; support will be provided for enterprises and expansion of production of equipment for preparation and use of local energy resources and organization of implementation.

Energy Strategy emphases that Lithuania will seek that energy generated by renewable resources will amount to 12 percent until 2010 and fulfill the requirements of EU directives.

With the regard to environment, the strategy claims that Lithuania will follow the requirements of international environmental conventions, the Lithuanian Environmental Strategy, the Strategy for Approximation in the Environment Sector and the requirements of the National Implementation Strategy of the United Nations Framework Convention on Climate Change and the requirements of EU environmental directives.

13.1.2. Law on Electricity

The law on electricity promotes the consumption of electricity produced from local, renewable and waste energy resources and article 11 claims that "*the State shall encourage customers to purchase electricity produced from local, renewable and waste energy resources*".

13.1.3. Law on Biofuels

Seeking to develop and promote the biofuels production and consumption the Parliament of the Republic of Lithuania passed the law on biofuels in 2000. The purpose of this law is "*by implementing the National Energy Strategy and Law on Energy to establish the legal basis for biofuels production and* *consumption*".

The goals of the law are set in an the Article 2:

1) *to regulate biofuels production and consumption;*

2) *to promote the usage of indigenous, renewable and alternative energy resources instead of imported fuels;*

3) *to promote biofuels production and consumption;*

4) *to stimulate the growing of agricultural plants suitable for energy purpose;*

5) *to apply the directives of European Union concerning alternative energetic and the undertaking of Kyoto protocol to decrease the green gas effect;*

6) *to establish legal basis for biomass extraction and making into biofuels, usage of biofuels and investment to biofuels industry;*

7) *to create new job places for biomass extraction and conversion to energy purposes, as well as for producing equipment for express purpose.*

The Article 4 declares that "*biofuels production from Lithuanian origin raw material and its consumption is the State priority*". Besides, this article sets that tax concessions, perquisite and guarantee that established in others legal acts are applied for biofuels producers, users and investors to biofuels industry.

The Article 5 appoints the responsibility of state institutions:

"The Government of the Republic of Lithuania":

1) *defines and carries on the promotion policy of biofuels production and usage;*

2) *appoints the institution responsible for implementation of this law;*

3) *prepares and confirms the programs of biofuels production and usage; designs objective assignations for implementation these programs from state budget while drafting budget;*

4) *supports investment projects funded from EU funds and other financial institutions;*

The Ministry of Economy:

1) *prepares and confirms legal acts on biofuels production and usage, essential requirements for biofuels;*

2) *supervises on prosecution of those requirements;*

Responsible institution appointed by the Government:

1) *contributes towards development of biofuels industry, promotion of biofuels production, usage and regulation to Government and others institutions, to producers and consumers of biofuels;*

2) *estimate the programs of biofuels producers affording to Government and its institutions for seeking support;"*

The responsibility of local self-governmental institutions is set in the Article 6:

1) *The Councils of Municipalities promote fuel users located in their territory to use biofuels, within the competence frame of the favourable economical conditions for production of biofuels and investments to bio-fues production;*

2) *The Councils of Municipalities approving the municipality economy development plans:*

- measure the demand and potential to produce and use biofuels;

- set the trends of the development of biofuel production and usage."

13.1.4. Government Programme

The measures for implementation of the Government programme of the Republic of Lithuania for 2001-2004 have scheduled "to expand the use of local and renewable energy resource; following EU recommendations to seek that energy generated by renewable resources will amount to 12 percent until 2010" and have planed "to develop the measures to promote the use of local and renewable energy resources".

In 2001 Government adopted Resolution No 1121 "On the Resume of the revised and Updated National Energy Efficiency Program and Core directions for Implementation of the Programme in 2001-2005". While executing paragraph 3 of the Resolution Minister of Economy approved the revised and updated National Energy Efficiency Programme and Key measures for the implementation of the revised and updated National Energy Efficiency Programme in 2001 through 2005. And the Ministry of Environment was indicated as the institution responsible for "*Developing methods and schemes for collecting wood residue for fuel, evaluating and implementing the methods and schemes*". As well as the same measure has to be fulfilled while implementing Nation Energy Strategy.

13.2. The role of different institutions and organisations

Once integrated wood energy strategies, programmes and projects have been shaped, activities can be implemented by assigning specific responsibilities to different agencies such as forestry services, energy units, rural development and financial agencies, NGOs, the private sector, research and development organizations and community groups (Wood energy for future: FAO's perspective).

A number of public and private actors is involved or could have an interest in participating in the development, implementation or monitoring of the policies and projects concerning wood energy in Lithuania.

13.2.1. Governmental Organizations involved

Which institutions are responsible for what in Lithuania? What roles do government ministries, agencies, research organisations and associations play to accomplish these goals?

Ministry of Economy

The Ministry of Economy has a key role to play in using political strategies and actions in mobilizing investments, selecting projects, allocating investment funding to wood based energy development and supporting those who supply wood for fuels. According to the Government Resolution (19 January 2001, Resolution No 53) Ministry of Economy is the national authority responsible for implementation of the Law on Biofuels concerning development (production and usage) of fuels from forests and wood residuals, such as straw, peat etc.

Ministry of Economy, Energy Agency

The Ministry of Economy is the founder of Energy Agency, which deals with the programs of local, renewable and waste energy resources, organizes their implementation, updating and revision.

Ministry of Environment

The Ministry of Environment is the main managing authority of the Government of the Republic of Lithuania, which forms the environmental policy, forestry, utilization of natural resources as well as co-ordinates its implementation.

Ministry of Environment, Forest Department

The Forest Department of the Ministry of Environment is responsible for normative and regulatory functions such as forestry policy and legislation.

General Forest Enterprise

The General Forest Enterprise has responsibility for State forests management and commercial activities as well as co-ordination of the activities of all 42 State Forest Enterprises. Forest Enterprise is the basic forest management unit responsible for round wood harvesting, production and sales. Forest enterprises have an interest in using a small sized and low quality wood.

13.2.2. Research Organisations involved

Lithuanian Energy Institute

Lithuanian Energy Institute has a potential to carry out the research activities related to consumption and production of wood based energy.

Lithuanian Forest Research Institute

The main research activities are focused on biological diversity and sustainability of forest ecosystems; forest productivity, protection, utilization and economics; forest genetic resources and their conservation, enrichment and utilization. It also conducts research focusing on the usage of wood fuels.

13.2.3. Non Governmental Organisations involved

Forest Owner's Association

Forest Owner's Association, which promotes co-operation between private forests owners, is interested in finding markets for all kind of wood from private forests in order to reach sustainable and economically efficient forest management in private forestry.

Association of Bio-energetic and Energy Saving

Association of Bio-energetic and Energy Saving is non-profit organisation that promotes the use of biomass for energy production.

Association "Lietuvos mediena"

All major companies producing wood products belong to the Association, which represents their interests in Lithuania and abroad. The Association publishes and disseminates information on the productions and commercial activities of its members. Members of the Association may have an interest in using and selling the waste from wood industry.

Lithuanian Green Movement

Lithuanian Green Movement has had various interests in activities related to forest management and planning and environmental protection.

13.2.4. Technical Agencies involved

Private companies dealing with the implementation of heating plants fired with wood-fuel – "**Kazlu Rudos Metalas**", "**Singaras**", "**Germeta**", "**Ardynas**" **etc.**

13.2.5. Communication and co-ordination

Various communication activities were organized in the frame of "Wood fuel development in Lithuania" project such as meetings, workshops, presentations of project results, press editions and web site. The Ministry of Environment together with the project team conducted project presentation and discussion "The role of different institutions and organizations and partnership in wood fuel development in Lithuania" on 12 September 2002. The most important officers of the state that is Prime Minister of the Republic of Lithuania Mr. A.Brazauskas, Minister of Environment Mr. A. Kundrotas, Vice-minister of Environment Mr. A. Vasiliauskas, General Director of General Forest Enterprise Mr. B. Sakalauskas and leaders from all above mentioned organizations attended the meeting and became acquainted with project results. The meeting was opened by Mr. A.Kundrotas (the Minister of Environment) who welcomed participants and underlined the importance of the project for addressing the challenges facing the forestry sector by implementing Programme of the Government of the Republic of Lithuania for 2001-2004, international agreements and recent decisions of the World Summit on Sustainable Development in Johannesburg (Aug./Sep. 2002).

In the discussions the participants exchanged experiences and views on the promotion of wood based energy. The participants put emphasis on the lack of co-operations and strategic co-ordination from the institutions in charge.

13.3. Legal aspects

13.3.1. Regulations

Lithuanian policy and programs concerning biomass have been designed and set by decision-makers. But there are no clearly defined ways and means to implement them through the mechanisms such as regulation, taxation, grants, subsidies etc.

While implementing shaped policy some (shot term) procedures for promoting biofuels were approved.

13.3.1.1. Law on Value Added Tax

Law on Value Added Tax (VAT) (8 May, 2001, No. IX-311) foresaw 9 percent tax (standard 18 percent) on heat furnished to households and biofuels produced while using local bio-mass. Unfortunately, this tax concession was abolished in March 2002 when the Parliament of the Republic of Lithuania passed the new Law on VAT (No. IX-751).

13.3.1.2. The Law on Excise Taxes

The Law on Excise Taxes (18 July 2000, No. VIII –1876) indicated that electric power generated while using biofuel is not subject to the excise tax (*since 2002.07.01 new Law on Excise Tax force).*

13.3.1.3. State Commission of Prices and Energy Control

In order to promote purchasing of energy generated using renewable energy resources the State Commission of Prices and Energy Control established the tariffs and their application conditions. Currently valid power purchase price for plans using biofuels is 20 cents/kWh (it is an attractive price for power producers).

13.3.1.4. Energy Saving Fund

According previous Law on Energy "Energy Saving Fund" was set up for financing energy saving and efficient consumption programmes, for the introduction, operation and development of measures for the use of indigenous, renewable and secondary energy resources. But practically the fund did not function because of insufficient financial support from the state. According to the new National Energy Strategy the Special Program for the Implementation of Energy Saving Means will support the implementation of renewable energy projects.

13.3.1.5. Lithuanian Law on Environmental Pollution Taxes

Lithuanian Law on Environmental Pollution Taxes and other environmental legal acts do not provide the concessions for biofuel users. The introduction of Carbon Tax and the implementation of Polluter Pays Principle would probably be the most favorable solution of the economical success of wood fuel projects.

13.3.1.6. Financial regulations

Obviously bio-mass from forest residuals has a great potential in Lithuania. But there are some obstacles for successful development of fuels from forest (harvesting) residuals. First of all it is not competitive compared to fossil fuels. Secondly, the way of forest residual to its final utilisation is very complex; it includes many phases starting from the preparation of raw materials (harvesting, extracting, transportation etc), chipping and distribution to the consumers. Such complex system needs not only clarity at all levels but also considerable investments. Therefore Lithuanian authorities should enforce some financial regulations in order to stimulate investments in preparation and usage of fuels from forest residuals.

13.3.1.7. Lithuanian rules of forest cutting

The first tests to collect forest cutting residuals in Rokiškis forest enterprise have showed that Lithuanian rules of forest cutting in force are almost identical to Swedish where such practice is widely used. There are no obstacles for forest fuels extraction in legislation of forestry.

To facilitate an extracting of forest fuels one proposal was made during the presentations of project results in Rokiškis. Regulations for Final Forest Felling (approved by the order No. 73 of the Minister of Environment in 1999) claim that "while felling cutting sites, the transport movement off skidding path is not allowed". The proposal was to not to apply this requirement when extracting of harvesting residuals from clear cuttings.

The use of forest residuals for fuel as well as their supply is influenced by natural and economical conditions. The traditions and attitude toward forestry activities are also important.

13.4. Standardisation of wood fuels

In order to ensure the sustainable production, conversion, marketing and use of wood fuel it is necessary to have standards. A buyer of the fuel need to know how much heat the fuel will give, the moisture, the chemical content, to be sure his boiler will not be damaged. He also might need to know the origin due to rules concerning greenhouse gases. Unfortunately Lithuanian Wood fuel standards do not exist. This creates uncertainty about quality of the products as well as misunderstanding when applying tax privileges (for example 50 % VAT tax).

Analysis of existing wood fuel standards in other countries shows that they differ largely from one country to another and there are no common understanding concerning terminology, sampling and sampling methods.

For the year 2010 the European Union has a goal to increase the share of renewable energy ware to 12%. A prerequisite to reach this will be to increase the utilisation of solid biofuels. This leads to a need for extended trade. To manage and get a smooth businesses and common understanding there need to be firm and streamlined standardised ways in place all over Europe.

A very important work of standardizing solid biofuels was started by European Committee for Standardization (CEN). One reason for this is to stimulate good competition situation for companies in different countries and thus enhancing more effective work and cheaper energy. Nineteen countries are participating in CEN, e.g. the Nordic countries, Germany, France, United Kingdom, Italy, Spain, Austria. The standardization project follows a mandate given by the European Union, and the mandate gives the frames within which this specific TC is to work.

The standardization is going on in five Working Groups, WG. They are:

- WG 1 "*Terminology, definitions, and description*", secretariat in Germany, chair is Martin Kaltschmitt, Institute for Energy and Environment
- WG 2 "*Fuel specification, classes, and quality assurance*", secretariat in Finland, chair is Jan-Erik Levlin, KCL
- WG 3 "*Sampling, and sampling preparation*", secretariat in United Kingdom, chair is Andy limbtick, Greenland Reclamation Ldt
- WG 4 "*Physical, and mechanical test methods*", secretariat in Sweden, chair is Nina Haglund, NAH Consulting AB
- WG 5 "*Chemical test methods*", secretariat the Netherlands, chair is Herman van der Staak, KEMA Power Generation

Within each WG there are one or several Work Items (WI) and each WI shall at the end result in a standard. WG 1, WG 2 and WG 3 have in total just 5WI, but WG 4 and WG 5 have as many as 16 WI. Usually a country nominates two experts.

Examples of WI are:

- Terminology, definitions, and description (WG 1)
- Fuel specification, and classes (WG 2)
- Methods of sampling (WG 3)
- Methods for the determination of moisture content (WG 4)
- Methods for the determination of ash content (WG 4)
- Methods for the determination of ash melting behaviour (WG 4)
- Methods for the determination of durability of pellets and briquettes (WG 4)
- Methods for the determination of carbon, hydrogen and nitrogen content (WG 5)
- Methods for the determination of chlorine content (WG 5)
- Methods for the determination of the content of major elements (WG 5)

"Terminology, definitions and descriptions" and "Fuel specification and classes" are ready for comments. Other working groups will continue their work at least until the end of the year 2003.

It is not necessary for Lithuania to create its own standards. Taking into consideration that EU standards are under preparation that the best plan for Lithuania would be to approve and apply the standards prepared by CEN. Of course all formalities take some time to agree on CEN prepared standards, but on the other hand Lithuania has no work that has been started in this field. The quickest path is to start discussions on "Terminology, definitions and descriptions" (CEN Final Draft) and if it is needed to prepare "Wood Fuels-Terminology, definitions and descriptions" LST (Lithuanian standard or enterprise standard) based on above-mentioned Final draft of CEN.

13.5. International conventions and EU directives

There is a continuous worldwide concern over the "global warming" and widespread discussions about the need to reduce the production of the so-called greenhouse gases (GHG).

13.5.1. United Nations' Framework Convention on Climate Change

The United Nations' Framework Convention on Climate Change (UN FCCC) was signed by over 150 states in June 1992. It forms the bases for international work on climate issues, with progress being reported to the regular Conference of Parties. Lithuania signed the UN FCCC in 1992 and ratified it in 1995.

13.5.2. Kyoto protocol

The third Conference in Kyoto in 1997 drew up a protocol as an appendix to the main UN FCCC, under which the parties agreed on levels of emission reductions to be effected over the period 2008-2012. In 1998 Lithuania signed Kyoto protocol, committing itself to a reduction in GHG emissions of 8 % by 2008-2012 from the base of 1990 (Energy Chapter Secretariat, 2000).

13.5.3. European Union

In 1995 Lithuania signed Treaty of Associate Membership to the European Union and after the transfer period expires it will become full and equal member of the EU. One of the preconditions for the membership is the conformity of environmental policy and relevant laws to the legal forms in use of EU documentation.

The Treaties on European Union make no provision for a comprehensive common forestry policy. The management, conservation and sustainable development of forests are nevertheless vital concerns of existing common policies like the CAP and the rural development, environment, trade, internal market, research, industry, development, co-operation and energy policies.

13.5.3.1. Communication from the Commission to the Council and the European Parliament on a forestry strategy for the European Union

"Communication from the Commission to the Council and the European Parliament on a forestry strategy for the European Union" (COM (1998) 649, 03/11/1998) is the basic document concerning EU forestry strategy and notes that "this strategy should be considered within the scope of the principles and commitments adopted at international level and in particular within the framework of the UN Conference on Environment and Development (e.g. the Kyoto Protocol on Climate Change)…". Among others the chapter "Wood as a source of energy" is included:

13.5.3.2. An Energy Policy for the European Union

*"The **White Paper** for a Community strategy and action plan entitled **"An Energy Policy for the European Union"** (COM (95) 682 final of 13 December 1995) predicts that the percentage of energy produced from renewable sources will amount to 12% of total energy by the year 2010 (the current level is less than 6%), and thereby anticipates a substantial increase in the use of biomass for energy purposes in addition to extensive use of hydropower, wind and solar energy. The potential that forests can play as a source of energy, either by short rotation plantations or by the use of forest residues and available low quality wood should be favored.*

When exploring the possibilities of increasing the potential of energy crops from forestry, the following considerations must be taken into account:

- the potential of wood-based biomass as a source of energy should not be overstated on the basis of general theoretical data about the availability of forest resources, because these resources vary in distribution and type, which partly explains the difficulty in evaluating their real potential for energy use at EU level;

- at present wood is in most cases a more expensive raw material for energy production than competing products. One way to address this could involve adjusting taxes. Any change in tax systems in the Member States or at EU level should take due to account of demand for wood products and the requirements of industry for sustainable wood products;

- although short rotation forestry for energy production can contribute to a slowing of the rise in atmospheric carbon dioxide concentrations, care should be taken to ensure that this does not have adverse effects on the environment.

The issue of Community support for the use of wood as a source of energy is currently being discussed within the framework of the Commission proposal on Rural Development."

13.5.3.3. Council Decision of 28 January 2002 on the principles, priorities, intermediate objectives and conditions contained in the Accession Partnership with Lithuania.

The Council Decision of 28 January 2002 on the principles, priorities, intermediate objectives and conditions contained in the Accession Partnership with Lithuania sets priorities and objectives to Lithuania concerning preparation for membership. Some of them could be related to wood fuels development in Lithuania - "set up improvement of energy efficiency and the use of renewable energy sources and strengthen the relevant institutions in this area" and continue implementation of the *acquits*, in particular in relation to sulphur content in liquid fuels and waste management.

Therefore Lithuania has to implement the requirements of Council Directive 1999/32/EC of

26 April 1999 relating to a reduction in the sulphur content of certain liquid fuels. According to the order approved by the Ministers' of Environment, Economy and Communication from 1 January 2004 it will forbid using the liquid fuels having more that 1 % of sulphur.

The implementation of Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market will make an influence on the use of wood fuels as well.

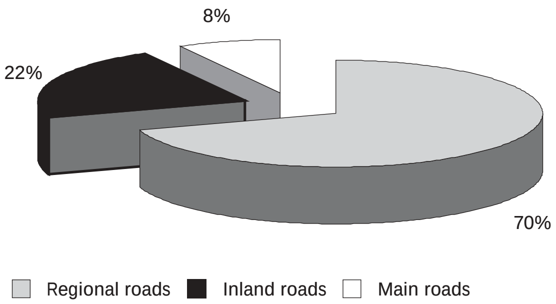
Wood ash recycling would be in accordance with the Green Paper "Towards a European strategy for the security of energy supply" (COM (2000)769), European Council Directive of 15 July 1975 on waste (75/442/EEC), waste directive 91/156/EEG and The Sixth Environment Action Programme Environment 2010: Our future, Our choice' - COM/2001/0031.

14. The system of transport in Lithuania

14.1. General data on Lithuanian Roads

Total length of the State road network is 21 312 km (2002-01-01). The main part in this network is occupied by regional roads – 14 724 km (figure 14.1). Inland and main roads length respectively 4 864 and 1 724 kilometres.

Fig. 14.1.1. Structure of the State road network



During the transport ministers of European countries conference in Crete in 1994 two Trans European Network (TEN) corridors crossing Lithuania were identified:

- North-South direction: I corridor (freeway VIA BALTICA and railway RAIL BALTICA), connecting Tallinn - Riga - Salociai - Panevezys - Kaunas - Kalvarija - Warsaw, and its branch - I A corridor (Tallinn - Riga - Siauliai - Taurage - Kaliningrad)
- East-West direction: IX corridor, the branch IX B corridor (Kiev-Minsk-Vilnius-Klaipeda) and IX D corridor (Kaunas-Kaliningrad)

6 European main roads cross Lithuania:

- E67 VIA BALTICA (Helsinki - Tallinn – Riga – Panevezys - Kaunas – Warsaw - Vroclav - Prague)
- E28 (Berlyn - Gdansk - Karaliaucius (Kaliningrad) - Marijampolë - Prienai - Vilnius - Minsk)
- E77 (Pskov - Ryga - Siauliai - Karaliaucius (Kaliningrad) - Warsaw - Krakow - Budapest)
- E85 (Klaipeda - Kaunas - Vilnius - Lyda - Cernovcai - Bukarestas - Aleksandropolis)
- E262 (Kaunas - Utena - Daugpilis - Rezekne - Ostrav)
- E272 (Vilnius - Panevezys - Siauliai - Palanga - Klaipeda).

14.2. Road transport management

The State management of road transport is carried out by the ministry of Communication and municipalities. According to its competence the Ministry of Communication prepares obligatory legal deeds that regulate the activity of the road traffic as well as passenger and cargo traffic for the municipalities, natural and legal; people. The policy of roiad transport is formed by the department of Roads and Road.

The implementation of road transport policy directly involves Lithuanian road traffic direction under the Ministry of Communication, the duties of which is the maintainance of the state roads, analysis of the traffic intensity growth dynamics, the realization of traffic safety measures, the implementation of

the investment projects, and road funds administration. For the maintainance, repair works and extension of the State roads network, 500-600 mln. Lt will be used every year.

The State road transport inspection under the Ministry of Communication regulates, supervises and controls the activity of road traffic businessmen and transporters on a state level. One of the goals of the inspection is to ensure equal competition conditions for all individuals involved in the road transport business. The inspection also defends the interests of transport users, thus ensuring the observance of all the laws and other normative deeds that regulate the road traffic activity.

In the past few years the Lithuanian road transport system experienced considerable changes, that provided conditions for penetrating the European Community market as well as for achieving its main aims: free movement of people and goods. At the moment Lithuanian goods traffic is privatized. The activity of road transport sector is regulated by more than 30 legal deeds of Lithuanian Respublic, which correspond to the legal deeds of the European Community. The main of these are the following: The Law on the fundamentals of Transport activity, Road transport Code; Road Law; Road Fund Law. The main valid legislative deeds are the following: Road transport licensing rules, Passenger and luggage road traffic rules, International passenger road traffic rules, Inner Cargo road traffic rules, Intenationalr Cargo road traffic rules, The rules of state MOT inspection; Road traffic rules, etc.

By the January, 1, 2001 the licences of cargo and passenger traffic business in Lithuania were possessed by 3569 transporters, 497 – for driving passengers on international routes, 164 – for driving passengers long on distance routes. 3175 transporters had the licences to transport the cargos on the international routes. 13064 vehicles were licenced for the transportation of cargo (11014) and passengers (2050).

In the congress of October 4, 1991 84 country transporters established Lithuanian national transporters association "Linava". At the moment "Linava" unites almost 2000 transporters. The number of the members of the Association rapidly increased until 1999, later it considerably decreased and now there are 1500 members. The departments of "Linava" were established in the largest cities of Lithuania Vilnius Kaunas, Klaipeda, Šiauliai, Panevežys, Alytus. The number of ecologically clean, "green", "greener and more secure" as well as "Euro3 secure" vehicles has been rapidly incresing recently. Lithuanian transporters own more than 5 000 of such vehicles.

14.3. Measurements of vehicles

By passing the order of February 18, 2002 the minister of Communication of the Lithuanian Respublic identified the maximum allowed vehicle mesurements (tables 14.3.1., 14.3.2.).

Table 14.3.1. Maximum allowed vehicle mesurements (in meters*).

1. Lenght:	
1.1.single vehicle	- 12,00 m.
1.2.trailer	- 12,00 m.
1.3.connected vehicle (vehicle with semi-trailer)	- 16,50 m.
1.4.autotrain (vehicle with trailer)	- 18,75 m.
2. Width:	
2.1.all road vehicles	- 2,55 m;
2.2.refrigerator with insulated walls	- 2,60 m.
3. Height:	
all road vehicles	- 4,00 m.

* Special permission is required for vehicles exeeding these limits

Table 14.3.2. Maximum allowed vehicle general weight (in tons*).

1. Autotrain trailers:	
Biaxial	- 18 t;
Triaxial	- 24 t.
2. Combined vehicles:	
2.1. pentaxial or hexaxial autotrain, consisting of:	
a) biaxial vehicle, connected to triaxial tailer	- 40 t.
b) biaxial vehicle, connected to biaxial or triaxial tailer	- 40 t.
2.2. pentaxial or hexaxial connected vehicles, consisting of	
a) biaxial vehicle with triaxial semitrailer	- 40 t ;
b) triaxial vehicle with diaxial or triaxial semitrailer	- 40 t ;
3. Single vehicles:	
3.1. diaxial	- 18 t ;
3.2. triaxial	- 25 t;

* Special permission is required for vehicles exeeding these limits

14.4 Transport costs

Nowadays, for wood chip transport, tractor with trailer is used . From the research work made by LFRI in the demonstration and experimental area the following figures on transport costs using traditional vehicles were shown:

The cost of using tractor T-150 with 25.3 m^3 trailer was: 2.3 Lt/km, corresponding to a transport **cost per m^3 solid volume of 0.23 Lt/km**

The cost of using lorry MAZ 5516 with 45 m^3 trailer was 1.8 Lt/km, corresponding to a transport **cost per m^3 solid volume of 0.10 Lt/km**

The large chip transportation companies are now starting to use vehicles with semi-trailer. Semi trailers are made in Russia and upgraded to 4 m. height. The dimensions of this upgrade trailer are the following:

- height - 2,7m.;
- weight – 2,5m.;
- length – 12,6/13,6 m.

The load volume is from 85 to 92 loose m^3. Cost per 1 km is 1,5 Lt, using vehicles made in Europe countries. There are some problems with unloading chips, because the semi-trailers don't have hydraulic system for unload. This would correspond to a transport **cost per solid m^3 of 0.044 Lt/km** if using the load capacaty of 85 loose m^3 . If using load of 92 loose m^3 it would corespond to a transport **cost per solid m^3 of 0.040 Lt/km.**

Fire wood is trasported by connected vehicle (vehicle with semi-trailer) or auto train (vehicle with trailer). Main vehicles are made in Russia. You can rent this kind of vehicles from 1,5 to 2 Lt/km, plus additional services: laoding and unloading – 5 Lt/m^3. The capacity of transport volume depends on the length of fire wood and coefficient, e.g. at the same coefficient 2 m. length fire wood load has about 38 m^3; 2,4 m. – 32 m^3; 3m. – 40 m^3. Time consumption for loading and unloading increases for about 30 % for 2 m. logs compaed to3 m logs.

One alternative for transportation of forest fuel is railway system (figure 14.4.1.). You can transport large amounts there. There are ongoing ideas in Lithuania to develop a net and with to implement the system of loading and unloading chips by railway. Transport capacity of about 50 m^3 volume of chips in each wagon is estimated, but at the same time other problems occur. It is necessary to have terminals for chips in railway stations, what requires additional investments.

Fig. 14.4.1. Railway net in Lithuania

15. International Experiences in Simulation of Wood Fuel Resources

** this chapter has been rewritten from the project report "Assessments of policy options for encouraging utilization of wood energy in Estonia (phase 1)", carried out in 1998 by Estonian National Board of Forestry and Swedish National Board of Forestry with funding from the Swedish Energy Agency. The Co-authors in the original version were Lars Andersson from Swedish National Board of Forestry and Peeter Muiste from the Estonian Agricultural University, Faculty of Forestry.*

15.1. Studies of biofuel in the energy balance

Due to great importance of biofuels in the energy-balance of Nordic countries, several profound studies have been carried out during the last years. Leading countries in this field are Sweden and Finland, but interesting analysis has also been carried out in Czech Republic, UK, the USA (Louisiana) and other countries. The following overview gives a short description of the models and programmes for simulation of wood and wood fuel resources.

15.1.1. A. Rummukainen, H. Alanne, E. Mikkonen Wood procurement in the pressure of change – Resource eveluation model till year 2010

Linear optimization model was used to calculate seven wood procurement scenarios for the years 1990, 2000 and 2010. Productivity and cost functions for seven cutting, five terrain transport three long distance transport and various work supervision and scaling methods were calculated. All methods were based on Nordic cut to length system. Finland was devided in three parts for description of harvesting conditions. Twenty imaginary wood processing points and their wood procurement areas were created for these areas. The procurement systems, which consisted of the harvesting conditions and work productivity functions, were described as a simulation model. In the model the wood procurement system had to fulfill the volume and wood assortment requirements for processing points by minimizing the procurement cost. The model consisted of 862 variables and 560 restrictions.

Commentary: Though this model was orientated to timber procurement scenarios and the issues concerning wood fuel were not discussed, the report contains valuable data about productivity and cost analysis of different forest and haulage technologies. As only imaginary wood processing points were selected for analysis, no GIS-programs were used.

15.1.2. T. Saksa Large-scale production of wood chips from forest for energy

The project belonged to the National Bioenergy Research Programme of Finland and was aimed to start a large-scale use of wood chips from forest for energy production in the Mikkeli region in Central Finland. The possibilities to use wood chips in energy production were studied from the point of view of local raw material resources, economy of wood chip production and everyday logistics in wood chip delivery. The economic effects of the use of wood chip in energy production on the whole Mikkeli region's economy were also estimated. The local raw material resources were estimated to be large enough in the area nearer than 40 km from the heating plant to maintain a sustainable large-scale wood chip production for decades. The economic calculations showed that the wood chips production from logging residuals was economically possible in large-scale use in Finnish conditions and that subsidies are needed for wood chips production from young thinning stands.

Commentary: The report analyses the wood chips supply in one region, having the consumpion concentrated in the middle of the region, and presents interesting economic calculations about different technologies. But this model is not suitable for modelling in larger areas with distributed supply and demand.

15.1.3. Tapio Ranta Cost analysis model for the whole woodfuel delivery chain

The computer based model for calculating the production costs of wood fuel in Finland was ready in 1996 . Now the cost analysis model is under updating for special purposes in wood fuel production and delivery chain. The cost analysis model is built on Windows-based software, SQLWindows, using different sources of data (ODBC). With the model it is possible to manage these SQLBase databases with SQL-queries. The data included in the databases origins from various energy wood sources (local communities or part of them, forestry boards planning areas or even stands ready for cutting). By knowing the planned share of first thinnings, final cuttings and other harvesting operations it is possible to estimate the potential amount of wood fuel from each area. The databases from energy wood users, forest and transportation machinery and distances are also available in the system. Using the information it is possible to find out the fuel demand of power and heating plants in each moment (e.g., amount and quality), costs of various machines (harvesters, forwarders, trucks) as well as distances between energy wood sources and users.

With the use of calculation software of energy wood it is aimed to make regional plans concerning the increased use of energy wood and analyzing different alternatives to increase energy wood use and their effects. The increased use should be viewed and analyzed from both the current users and their potential and possible new users. With this software it is possible to analyse in what conditions there are potential to make business in a profitable way and what it means when calculating the amount of raw materials and production equipment. In order to calculate the production cost the long distance transport both to the energy wood from forest standings and energy wood as a by product from mechanical forest industry (bark, chip, dust, shavings) should be defined . When defining the long transport distance from some regional area, geographical central point of this area, which is described as the average distance from this area to the energy wood user had to be used. In this phase there will be great help of the GIS-software with the real digital road network. In order to make it possible to utilise them the co-ordinates of the users and sources ready in databases have to exist or if they don't then the distances have to be given manually. The whole cost calculation program environment has been built around a Windows based program, and by the aid of it all databases are processed. When processing the results, other programs such as Excel-spreadsheet to analyse the results more in detail and visualise them in graphical way will be used. There are also some options for future enlargement needs, like visualising the results with GIS-software by maps and distance calculations with road network by maps and linear optimization with LP-package integrated in spreadsheet program.

Commentary: According to the available information, this model is probably the best one to take as an example for creating supply-demand model of wood fuel resources. But it was created for research and consultation purposes for the conditions of Finland and one of the authorsTapio Ranta has informed, that "this program is not for sale and they use it for cost analysis of their Finnish customers". So, no additional information about it is available.

15.1.4. M. Laihanen, H. Malinen, I. Nousiainen A model for wood-fuel supply and production costs in the forest industry

The computer model was developed to evaluate the supply and production costs of wood-fuel. Principles of new integrated wood-fuel production methods, which use the above ground biomass more effectively, were examined. Total costs resulting from integrated production were devided into wood raw material and wood fuel. In a case- study the model was applied to the fuel and raw material acquisition of a pulp and paper mill. The main aim was to study the effects of the new methods on raw material balances, fuel supply, fuel costs and mill energy balance.

Commentary: The model was aimed to give an areal supply potential of biomass and evaluation of production costs of wood-fuel and it is not suitable for modelling the supply-demand balance in bigger areas.

15.1.5. J. Malinen Estimation of energy wood resources with the MELA system

MELA system was designed in the 1970s in Finland (in the Finnish Forest Research Institute) for regional and national timber production analysis based on the data of the National Forest Inventory. Currently, it is also being widely used in stand level forest management planning. The system has been used since 1994 in Lithuania and since 1995 in Estonia. MELA is a forestry model and an operational decision support system for the estimation of production potentials of forests and solving problems of management of stands in order to achieve the overall goals for forestry. It integrates forest level production planning and stand management optimization into a hierarchial multiple objective optimization problem. Forest management regimes are derived from the goals for forestry in each particular decision situation on a basis of actual forest resources and their predicted management and development potentials. During the last years the development work to link energy wood planning to the system has been made. In addition to the industrial roundwood harvesting energy wood harvesting alternatives are also simulated now. This required, that new models concerning energy wood harvesting were linked to the system and new output variables (amount of energy wood, energy wood harvesting costs etc.) were defined. The best mangement schedule for each stand is selected with linear optimization from the simulated alternatives. Management scedules containing energy wood harvesting can be selected to the optimal solution and energy wood resources of the study area can be estimated.

Commentary: As the system is designed for forest level production planning and stand management optimization, it can be used for the estimation of energy wood resources, but it is less suitable for analysing supply-demand balance of wood fuel.

15.1.6. M. Parikka Biosims – A Method for the Estimation of Woody Biomass for Fuel in Sweden

The method was developed for the analysis of stand level and regional raw material base for woody biomass and wood fuel, taking ecological restrictions into consideration. The method uses stand data or sample plot data from the National Forest Survey data. Traditional forest inventory is focused on volumes of industrial wood and models are used for estimation of stem volume and growth. This information is not sufficient for forestry planning, if the wood for energy purposes should be considered. Biosims method calculates the total forest resources by using oven dry weight as a standard measurement unit, which gives advantage in conversion of volumes to energy equivalents and definition of ecological restrictions for removal of woody biomass. The biomass is measured as oven dry weight per unit area. The program is built up in modules, which makes it possible to enlarge the model by adding new modules. Two methods for calculation of woody biomass were used:

1) The biomass functions for main tree species. Woody biomass inventory or utilization level is based on regression functions. Diameter and height distribution are used for calculation.

2) The ratio method, i.e. a woody biomass inventory based on trditional forest inventories and conversion factors or functions between stand variables.

Both methods can be used to calculate the biomass at stand level and at regional level. The volume of marketable timber is calculated by using traditional volume and yield functions, woody biomass in kilograms or tonnes of dry matter per unit area. The Biosims method has been used for several applications at stand level, in the Dalarna region (Sweden) and for estimation of wood fuel potential in Sweden up to year 2020. In the last case the complete version of method was used for two scenarios relating to the development in the Swedish forest industry.

Commentary: Woody biomass only from forest land was calculated. A brief presentation of factors that influence the wood fuel supply systems, e.g. energy and environmental taxes, forestry etc. has been made, but it is not sufficient to analyse the supply-demand balance of wood fuel market. Logistics and production costs have not taken into account.

15.1.7. G. Lönner et al. Kostnader och tillgänglighet för trädbränslen på medellång sikt

The aim of this work was to estimate technically and economically available quantities of wood fuel in a medium time horizon, approximately 10 years taking into account ecological considerations. In this study earlier developed model has been applied using the sample plot data from the National Forest Survey and the cutting level of 87 Mm^3 in the period 1998-2008. Estimates of the cost influencing factors (terrain class, wood fuel concentration, location in the relation to the nearest road etc.) have been done for the same sample plots. Calculations have been done for four regions. All types of wood fuel are included, i.e. logging residues, direct fuel cuttings, wood without industrial use, industrial by-products and recycled wood. Costs have been calculated on the basis of best available logging techniques and include direct logging and transport costs, direct administration costs and stumpage for the forest owner. The distance for truck transport is set to 70 km to the energy plant, to railway station, or to the harbour. That distance is judged to be representative as a typical value for the country as a whole. Different types of tree for the reduction of the gross quantities have been used – ecological, technical and economical. For the ecological reductions recommendations of the Swedish Board of Forestry have been applied, resulting in a 10% reduction. Technical reductions are judged for each of the defined logging methods, on the basis of practical experiences. Economic reductions are based on the defined cost influencing factors. The supply has been expressed as a function of the future price of the fuel.

Commentary: The study estimates technically and economically available quantities of wood fuel in Sweden. The calculations are not linked with geographical data – digital road networks, location of consumers and forest resources.

15.1.8. The HUGIN system

The Hugin system was started in the end of the 1970s and it was aimed to be used for the strategic planning of forestry both at the regional and national level. Later on, it has been further developed and is at present capable of forecasting e.g. future volumes of biomass, distribution of logged trees into assortments, costs and revenues from silviculture and logging and effects of nature conservation to forestry. The basic feature of the system is a deterministic simulation model with some stochastic components built in. The forecasts are based on the data from the Swedish National Inventory (NFI) and specific assumptions on future silviculture and cutting. The HUGIN system can be divided into three parts:

1. Selection of data from the Swedish National Inventory - A program is used to generate the initial state of forest based on data from NFI sample plots of a selected area before a long-term forecast.
2. Forecasting - The individual sample plots are used as the units for the decision-making on different measures and the individual tree in each plot is used as the unit for the growth prognosis. Different methods are used for the predictions of stand development for new and young stands and established stands. It is possible to study the effects of different management programme . Treatments included and controllable in the management program are soil scarification, planting, sowing, natural regeneration cleaning, thinning, final felling, draining of wet forest land and fertilisation. The system is also able to consider costs related to regeneration, logging and other work and revenues from logged trees optimally divided into assortments.
3. Presentation of results - The main results, i.e. the development of the state of forest, growth, and potential cut are edited and printed by an output program.

Commentary: The system was worked out for strategic planning of forestry for the estimation of the development of the forest state , growth, and potential cut. It was not aimed to analyse supply-demand balance of the resources.

15.1.9. Yield and Calc - Windows programs for yield calculation and system analysis

The **Yield** program is used to calculate the yield of sawlogs, pulpwood and forest-energy wood. The user can influence the distribution and accuracy of the assortments, e.g. by choosing different bucking breaks and empirical exploitation percentages. The program offers eight units of measurement and allows the user to define certain stand data and basic conversion factors.

The **Calc** program is used to calculate the cost per hour and per unit output from different machines, and to combine the machine costs in system chains from forest to mill. Functions that enable productivity calculations to be made for all common makes of forest machinery are included. A choice of nine units of measurement is available, based on certain conversion factors derived, for instance from the stand types used in the Yield program. Both costs and revenue for the machine systems can be computed.

Commentary: **Yield** program can be used as a sub-program for modelling the Estonian wood fuel resources. For using **Calc** program the variables in the program need adaptation for other conditions.

15.1.10. J. Sourie et al. Integration of the Decision Support Tool “Biomass Toolkit” Using a New Economic Model

The model for the microeconomic analysis of biomass systems. The economic model is divided into three sub-models concerning agriculture, industry and the microeconomic criterion for sharing of the co-property between partners respectively. The approach can be linked to game theory. For the modification of biomass systems both technical and economic aspects have taken into account.

Commentary: The model is mainly aimed at agricultural biomass calculations.

15.1.11. S. Hemstock, F. Rosillo-Calle, N. Barth BEFAT (Biomass Energy Flow Analysis Tool): A multi-dimensional model for analysing the benefits of biomass energy

BEFAT model incorporates both socio-economic and environmental benefits of biomass energy into an overall cost analysis. Biomass production chain from supply throughout to the end use in agriculture and forestry operations is calculated.

Commentary: The model is aimed for smaller regional biomass calculations.

15.1.12. B.C. Biomass estimation model (Turner & Standish, 1986)

It is a model for simulation concerning assessment of logging residue in British Columbia (BC). The model is using data for stands (stand volume, age etc) but it can also handle other calculation-units when it's needed. The model is using a menu system and the result can be present in tabular form for different tree-components (stem, stem bark, branches and fine fractions incl. needle). The model is constructed by modules.

15.1.13. Ifchipss (Industrial Fuel Chip Supply Simulator)

Ifchipss-model (Young et al., 1991) is based on the GIS –System (Geographic Information System). It estimates the average of the total cots for production of "whole tree chips" for energy production. The calculation-part of the model consists of the following (parts of models): (1) Accessibility model (2) Harvest cost model (3) Model for calculation of forestry operation net income (4) Transport cost model. Ifchipss is at the moment limited for production of whole tree chips and no other systems are defined. The model cannot make consideration regarding policy questions and (not market regulated factors). The advantage with Ifchipss is that the information can be published in the form of a map (map –sheet).

15.1.14. Forplan (Forest Planning Model)

Forplan (Johnson et al., 1986) is a model for long-term forest planning of state forests (national forests) in the USA. It is characterized as a general asset (resource) model that can consider different utilities (usefulness) (Multi-resource model) because in the calculations it takes into consideration even the ground, water, animals etc. The main principal of the model is concentrated on the production of industrial wood. Biomass calculations are not used.

15.1.15. TimberRam – model (Navo, 1997) and Muscy – model (Johnson & Jones, 1976)

They have been used as the base for Forplan. The importance of the different utilities (usefulness) depends on to whatextent it can express the connections between production of wood and other utilities and also on how to price the other utilities. The model is using optimization technology.

15.1.16. Musyc (Multiple – Used Sustainable – Yield Resource Scheduling Calculation).

Musyc model (Johnson & Jones 1979) has better opportunities to modify silviculture strategies considering other utilities than the Timber – Ram model. Even Musyc-model uses optimization technology.

15.1.17. Dynast (Dynamically Analytic Silvicultural Technique – Multiple Benefit)

Dynast (Boyce, 1977) has been used for planning of silviculture measurement for the production of industrial wood, planning of landscape "picture" and other utilities for instance hunting, berries, mushrooms and other nature resources. Dynast can be characterised as a multiple access model. It's a dynamic system model with one "built in" feedbacksystem for analysing effects off different silviculture measurements. This means that the model strives to attain one condition, where all utilities are accessible on one stable and persistent level. It tries to optimise a continuos supply of raw materials for the industry and other utilities with preserved yield related to invested capital. The model is built on the simulation language Dynamo.

15.1.18. Forecyte (Kimmins & Scoullar, 1980)

Forecyte (Forest Cycling and Yield Trend Evaluator) is an interactive simulation model for the study of the long term effects of each stands on nutrient input, nutrient balances, production with different silviculture intensity measurements. For example you may study the effects of increased take out of green biomass when taking out the whole tree. The Forecyte – model has often been used to analyse the dynamic connection in the ecosystem. The model is the hybrid of a process - model and an empirical - model. Different variants have been tested in Sweden.

15.1.19. Matrismodel (Sallnäs & Eriksson, 1998)

It has been developed for cutting calculations and forest consequence analysis. It is an arealmatris model and it is built on linear – programming - technique. The model is not so comprehensive concerning silviculture strategies etc as Hugin. The basic data is the same as for hugin, but it demands some treatment before it can be used in the model. The advantage with the model is that you quickly change the assumption and even make long - time - analysis. It suits best for the analysis of larger connected areas, Example County's and other balance- areas. The model has given good results when used for example, for forest – sector – analysis..The disadvantage of the model is that there isonly one alternative for the intensity in the silviculture (maximum production). In the model there are not any calculation routines for the woodbiomass (treebiomass).

15.1.20. Nimras model (Ashton et al., 1980)

It is used as the means for the assistance for the evaluation of alternative national strategies for forest - and pastureland considering certain restrictions. It consists of 4 different parts that consist of models.

15.1.21. Samm (Fight et al., 1990)

Samm-model (Southeast Alaska Multiresourse Model) is an integrated, wood-planning model for several utilities. It consists of 4 parts of models (1) industrial wood (2) water (3) fishing (4) deer animals. The model described the dynamic procedure in nature and the connection between those.

15.1.22. Lithuanian Forest Resources in the XXI Century. Model KUPOLIS (Kuliesis & Petrauskas, 2000).

The aim of this work was to calculate and make analyses by simulations of the forest use in 2001-2030 and in the general situation of 2001-2100 using model KUPOLIS. Forecast calculations were made only for those forests that have undergone stand wise inventory. Forecasting forest use, only stand area expansion due to forestland reforestation was considered. Data on the use of non-forestland area, naturally or artificially afforested, is not included in the calculations. Forest use scenarios presented in this work are simulated according to an expert forest plantation establishment, natural regeneration and stand -tending scenario. Apart from the expert scenario of reforestation, two other scenarios were investigated. It is the scenario, when current forest regeneration situation was transferred for a century, as well as the scenario imitating forest regeneration according to currently accepted standards. These scenarios are based on the differences in final use intensity, though all of them attempt to distribution level of stand area of separate species by age classes and to guarantee sustainable forest and also constantly increasing sue of wood. Simulation of stand management was carried out following currently used formation regime of standard stands (L.Kairiukstis, A.Juodvalkis, 1985), however, other management alternatives are possible as well. Distribution of wood by assortment structure was done according to the assortment tables (A.Tebera et al., 1999). Salvage cuttings were evaluated according to the use of growing stock increment loss in over 40-year-old stands. The volume of salvage cuttings was calculated by the portion of mortality and increment loss (A. Kuliesis, 1993). Improvement cuttings were calculated basing on existing stand tending standards. The size of final cuttings was calculated for the whole Lithuanian territory.

During the year 2000 one assessment was made concerning resources of forest fuel (SLWDP, report Phase 1). Cutting residues were calculated according to forecasted cutting budget for different tree species and different cutting types. The simulation covered only commercial and protective forests (III and IV group) where clear final cuttings are allowed. There were three possible sources of the wood that can be considered as a fuel-wood. First source was small size timber (top diameter under bark 5.6-13.5 cm). The use of such timber for forest fuel will be decided by the market (meantime the biggest part of such timber is supposed to be used as a pulpwood and as a pallet wood. Even aspen or grey alder trees are processed to pallet boards and exported). The second source of fuel-wood was traditional firewood. The main and permanent source of forest fuel was cutting residues (tops and branches). Practically such wood had no demand in the Lithuanian market. Due to increased final use in a private sector (privatization should be finished and all forests will be involved into normal use, now use in forests reserved for privatization is stopped.) the amount of cutting residues as well as small size timber and firewood is expected to increase.

Conclusions: All these models described in this chapter are worked out for specific conditions and needs of different countries. The forestry data, forest technologies, tax systems, technical level of forest industry enterprises etc. are different in different countries and these models can not be transferred directly to the conditions of other countries. The adaptation of programmes is usually possible and they are available (on sale), but in some cases they were prepared only for local needs and are not on sale.

16. Demonstration in the experimental area in Rokiskis Forest Enterprise

16.1 Purpose of the work in the demonstration- and experimental area

Within the demonstration- and experimental area different activities have been carried out in order to find different alternative solutions on how to handle forest fuel in a more rational way and to show by demonstrations how to integrate the positive results into the ordinary forestry activities. Within the demonstration- and experimental area 9 main plots were established for tests and demonstrations. In these plots two ways of forest stand handling were designed: traditional handling technology, based on Lithuanian cutting variant and one with integrated forest fuel handling according to the Swedish variant. Pre- and commercial thinning and final cutting represented the stands chosen for the plots. The results from the studies on forestry, technology and economy of forest fuel production in the demonstration- and experimental area are presented in chapter 10.

Picture 16.1.1. Teamleader, Dr. Jonas Saladis from LFRI presenting results from one pre-commercial thinning plot during one demonstration in Rokiskis 2002.

16.2 Results and dissemination from the demonstration- and experimental area

From the total amount of 9 plots 3 plots were chosen for the demonstrations representing pre-commercial -, commercial thinning and final cutting. One additional demonstration site showing the purchased wood drum chipper from Sweden in action was established. The last demonstration site was showing the heating plant in Rokiskis.

7 separate demonstrations with a combined seminar after the demonstration for different target groups were conducted. About 115 participants from Lithuania. (table 16.2.1.). participated in the demonstrations. Additionally 12 articles in 7 different newspapers and newsletters in Lithuania with information on the project have been published. The project has also been presented in different international meetings (workshops, seminars and conferences) in Lithuania, Sweden, Norway, Denmark, Finland, Estonia, Ukraine and Russia. During the workshop for the creation of the second phase of the project in January 2001, a short reportage about the project was shown in the evening news on the national Lithuanian television.

Table 16.2.1. Invited target groups and number of participants during the 7 demonstrations:

Invited sectors	Invited	Participants
Forest		
General forest enterprise	1	1
Centre of forest economics	3	3
State forest enterprises	42	27
Private forest owners association	9	4
Private forest owners co-operatives	9	4
Contractors	16	9
Forest industry (board factories)	5	1
Pulpwood export companies	4 **tot: 89**	4 **tot: 53**
Education and Research Institutions		
Lithuanian Forest Research Institute	5	3
Forest Management Institute	5	3
Agricultural University, Faculty of Forestry	5	3
Kaunas Forestry College	5	3
Kaunas University of Technology	5	2
Lithuanian Energy Institute	6 **tot: 31**	6 **tot: 20**
Municipals		
Municipalities	18	9
Heating plants	18 t**ot: 36**	7 **tot: 16**
Office of Government		
Prime minister / A.M. Brazauskas	1	1
Parliament of Lithuania	10	2
Ministry of Economy	3	1
Ministry of Environment	4	4
Minister of Environment	1	1
Vice Minister of Environment	1 **tot: 20**	1 **tot: 10**
Associations		
Lithuanian green movement	1	1
Lietuvos mediena	1	1
Association of bio-energy	1	1
Association of municipalities	1 **tot: 4**	1 **tot: 4**
Heating plant/energy company		
Panevezio energija	3 **tot: 3**	3 tot: 3
Journalists	11 **tot: 11**	9 **tot: 9**
Total:	**194**	**115**

16.3. Map of the forest enterprises location in Lithuania

Rokiskis Forest Enterprise is located in the North-east of Lithuania near the border to Latvia.

17. Discussion and conclusions

** All authors, with exception for the authors in chapter 6, have contributed to this chapter with some of the text.*

17.1. Chapter 4.1. Forest Authority role

The authorities of the forest sector in Lithuania have an important task to fulfil and should continue taking an active part in the development of the integration of the handling of forest fuels. Education and courses for the forest officers and extension service personnel in "forest bioenergy" should be developed.

17.2. Chapter 5. Lithuanian Forest sector

To achieve the sustainability in the supply of wood fuels and especially in connection to the conversion of oil and coal fired boilers in the district heating system to the use of biofuel some of the wood fuels have to be supplied directly from the forest.

It is also possible to use recycled wood fuel. However, this fuel is regarded as a waste. The boilers must then fulfil the EU directive 2000/76/EG Incineration of waste, which will make the boiler more expensive. At the moment there are no large amounts of recycled wood fuel available in Lithuania.

The future development depends on the wish of the government and parliament to support the renewable fuels. Studies on wood fuels can give the necessary information for making decisions on the higher level. The magnitude of the problems in forest management in Lithuania, calls for further studies to verify the potential for profitability in utilization of forest fuels. It is important to continue to provide information, advice and education to verify the potential of outcomes from forestry measures including safeguarding against negative environmental impacts.

The Lithuanian forest owners' association is young. At present there are no more than 1% of the private forest owners associated. In general, private forest owners are reluctant to join the forest owners' association or other organizations because they cannot see any benefit. It was also explained that associations based on co-operative ideas in particular have difficulties in recruiting members. We should not forget to support all the private forest owners not belonging to any association.

Conclusion:

The authorities of the forest sector in Lithuania should create national guidelines and recommendations for the extraction of forest fuel and compensatory fertilising .

The state forest is an important player on the market now and will remain in the future. Due to an increased use in the private sector the amount of forest fuel will probably increase within this sector and an umbrella organisation/association should be established to provide information on possibilities to integrate forest fuel from all commercial forest and also help with information and links between consumers-suppliers-forest owners.

A national energy strategy should be based on the data collected by forest and energy specialists on the county and regional level. Further modelling of the supply-demand balance of wood fuel should be conducted. Environmental and social effects should be analysed relating to the increased utilization of wood fuel.

17.3. Chapter 6. Biofuel usage experience from The EAES program

In Lithuania, the contract is made between the heating company and the suppliers per solid m^3 and not per the amount of delivered energy. The amount delivered wood chips is estimated by loose m^3, but paid for solid volume. Many of the heating companies have their own definitions and often use the formula where 1 m^3 of solid volume contains 50% of moisture and the energy content is 1.8 MWh. It is also stated that 1 solid m^3 gives 2.5 m^3 of chips, loose volume. In chapter 12 it was mentioned that different companies are setting different coefficients for conversion from loose m^3 to solid m^3 of chips (from 0.36 to 0.40, i.e. difference is 10%).

It is obvious that the questions on how and what units to measure and what coefficients to use - for calculations haven't been focused on seriously by the heating -energy and forest sectors. There is also a need for standards and definitions. If comparing with figures concerning forest fuel energy content given in chapter 8 we will find some differences. If using forest fuel in an integrated way the moisture content usually decreases to approximately 35-45% while storing at roadside landing etc.. In general, when talking about forest fuel in Sweden the average moisture content is 45% with energy content per m^3l of 0.85 MWh or 2.1 MWh per m^3s.

What could be interesting to see is the average price level for the wood chips in 2001 and converted to Lt/solid m^3 (m^3s) and MWh from the table shown in chapter 6. (If using the figures given in this chapter 2.5 m^3l = 1m^3s = 1.8 MWh).

Chips without transportation: 43.00 Lt/m^3s correspond to 23.88 Lt/MWh

Chips including transportation: 49.75 Lt/m^3s correspond to 27.64 Lt/MWh

Below there are figures provided from one of the largest energy companies in Lithuania that show how much the heating plants in Lithuania pay for mazut per MWh.

42.5 Lt when using mazut 400 Lt/t

47.5 Lt when using mazut 450 Lt/t

52.5 Lt when using mazut 500 Lt/t

The price they are paying today for 1 m^3s of wood chips is about 40 Lt. (40Lt /1.8 MWh) = 22 Lt/MWh! When calculating to estimate the benefit for conversion of boiler from mazut, into biofuel the price of mazut 500 LT/t is used. Difference in cost for 1 MWh when using wood fuels is if compering the prices more than 50% lower. To make normally higher investment in biofuel production units and including higher operation cost it is needed to have a reduced fuel price of 10-20%/MWh and then the price for produced energy is about equal if compared to mazut price. This will give us an upper limit of alternative fuel price of 42.00 - 47.25 Lt/MWh -corresponding to a price per m^3s between **75.60 - 85.05 Lt/m^3s**! (if 1m^3s gives 1.8 MWh as in example in chapter 6) The price for gas in Lithuania depend what kind of consumer you are:

Consumer use m^3 per year	**Price for 1000 m^3/ LT (without VAT 18%)**
20 thousand to 0.1 mln m^3	488
0.1 mln to 0.4 mln m^3	478.72
0.4 mln to 1 mln m^3	470.51
1 mln to 5 mln m^3	452.95
5 mln to 15 mln m^3	434.85

1 000 m^3 of gas = 8 MWh (source: www.ekostrategija)

For the comparison: according to one spreadsheet www.ekostrategija1 tone of mazut generates 9 MWh.. If 1 tone of mazut costs 500 Lt, the fuel price per 1 MWh will be 45 Lt. Comparing the mazut price with the prices on gas shows the price per MWh for gas is higher than mazut (price for gas 54-56 Lt/MWh).

In chapter 6 it is mentioned that the price for fuel must be 15-20 Lt/MWh lower than other fuels before taking the decision about investment. That would give us the price possible to pay for wood fuel if comparing with mazut of 37.5 - 42.5 Lt/MWh corresponding to the price per m^3s of **67.5 - 76.5 Lt** (if 1m^3s gives 1.8 MWh in example in chapter 6)! If using 2.1 MWh per m^3s the possible price per m^3s would be even higher!

As we don't have any data or examples from at least one heating plant about the share between used cheap sawdust and wood chips it is impossible to see the average price they are paying today as we don't know how big the share percentage is. We can assume that the amount of forest fuel chips used in the boiler plants is still very small part of the total woodfuel amount used. In any case, the figures above show good profitability for the heating companies using wood fuel! That means that the price given in chapter 6 will not reflect the real situation or even potential average prices which could be paid in Lithuania for forest fuel chips and still have enough low fuel price to benefit conversion from oil to biomass. To take another example we can compare the heating plant in Rokiskis that pays 39 Lt per m^3s. If the heating plants use high amounts of cheap sawdust they are able to pay more for the share of the wood chips used and vice versa. If compering figures above and the mazut prices it's obvious that level of payment could be much higher.

Therefore, we can only say that with the data we have today the average price must be at least 10-20 percent lower than the price for other competitive fuels. Example of prices we have above also show that the heating companies in Lithuania are making real good business. In that case looking at the figures above there is no immediate need to introduce new taxes as support to increase the share of biofuels in Lithuania.

Total capacity of heating boilers in Lithuania in the year 2002 is 270 MW (source: Energy Agency in Lithuania). If we estimate that they are running in average about 5.000 hours we will get 1.350 thousand MWh. If we use the formula (as in chapter 6.) 1.80 MWh per m^3s we will have the consumption of 750 thousand m^3s. (When using the formula used in Sweden 2.1 MWh/m^3s we will have the consumption of 643 thousand m^3s). This will not reflect the share in district heating as the total amount also includes other kind of boilers/heating system.

Figures below including all energy produced from wood in Lithuania:

Year	2000	2001
Energy produced from renewable resources (wood)	7.28 TWh	7.33 TWh
Future potential for renewable resources (wood)	2.52 TWh	2.47 TWh

(source: Energy Agency in Lithuania)

Conclusions:

There is a need to clarify problems mentioned above with the measurements, units, coefficients and prices. There is also a need to clarify what exceeds the limits the heating plants can pay for forest fuel chips and it should be in the interest of both suppliers and consumers. Contracts should also be stipulated for several years. 3-5 with index regulations as no suppliers can make the decision and take large investments in equipment with the only one- year contract in their hand.

Official figures given, even sometimes from the same source, make confusion as the figures given as official varies depending from where the data was collected and who presented it.

17. 4. Chapter 7. Analytical estimation of material balance in Lithuanian saw milling industry

This special investigation was needed to carry out, using different statistics. If to speak about saw milling industry, the situation in Lithuania is much clearer. The important fact is that real volume and realistic sawing pattern was estimated. Material balance for typical Lithuanian practice of sawing saw logs (1.5 Mm^3) and small size pallet logs (1.0 Mm^3) is totally different. It is not good enough to use only "average" figures. Even if the result is similar to the result from chapter 13 Wood Fuel From Industry, we can then say that statistics or preliminary "rough" judgement is correct and can be finally accepted. If trusting the following data (0.95 Mm^3 or 35% wood waste from sawmills [4] the Wood waste from sawmills was used in a such way: 46% as wood fuel for residential houses, 17% for boiler houses, 17% used for own sawmill needs and 13% sold for pulp and board industries then this statistic seems to be confirmed as totally correct. Every slab, edging if not chipped is sold as firewood.

The important factor is the calculated volume 2.5 Mm^3 of the round timber out of domestic logging. There is some amount of sawn timber imported from Russia which is only planned in sawmills or processed in other places in Lithuania and some amount of the imported and locally processed round timber. Then the waste volume can reach 1.2 Mm^3 mentioned in chapter 13. Even if there will be some growth of sawn timber production (even more than 20%) it will be made by modern sawmills with higher recoveries. Efficiency of processing in existing sawmills will also grow due to modernization and production concentration, material balance will be close to figures calculated.

Conclusion:

1. There are many speculations and figures about the resources of wood waste from saw logs processed in Lithuanian sawmill sector. Still no reliable data is available. Figures about wood processing waste appear repeatedly from time to time in different reports need considerable revision and correction.

2. Analytical calculation of sawmill residuals suitable for wood fuel based on realistic technologies and production scales is one of the possibilities for such estimation and also verification of available and future statistical data from the industry.
3. Sawing patterns typical for Lithuania have been applied for calculations in different log diameter classes. Great differences in material balances between every single class revealed totally unacceptable calculation on so called "average" yields of the sawn timber, sawdust, slabs, edgings, etc.
4. Reliable distribution of logs processed in sawmills allowed the estimation of material balances separately in each class. Volumes of potential of sawdust and chips received using this method could be established and declared as unavoidably accumulating in the sawmill sector. Still such volumes for the production-as-usually- could be increased by some 5-8 % in order to evaluate fluctuations in sawing skillfulness and efficiency.
5. **Minimum annual volume of wood waste suitable for wood fuel accumulated in Lithuanian sawmills is as large as 460 thou.m^3 of sawdust and 495 thou.m^3 chips.**
6. Wood waste from the sawn timber left in Lithuania and subsequently manufactured into final wood factories (furniture, windows, doors, etc.), could be estimated as 50% of the total volume of domestically processed sawn timber.
7. **Waste distribution among the consumption within processing industry, the competition among the producers of densified fuels, etc. make you to draw the conclusion that there is no space for optimism of extra resources of forest fuel for heating plants from this sector.**

17. 5. Chapter 8. Forest fuel production, technique and requirement

Silviculture is an essential issue in the discussion of take out of forest fuels. The future management and environmental influence on forest-land must guide how, when and what type of forest fuels should be used for energy purposes. The main idea of forest production is based on the utilisation natural, long-term production capacity of the wooded grounds. The availability of forest fuel depends on the intensity of the forestry. Future demands will determine what tree species and what kind of silvicultural methods should be used. The utilisation of the out-turn from forestry activity, e.g. low quality wood from clear-cutting, pre- and commercial thinning, can be refined to forest fuels. By that the economy of forestry measures can improve.

In an initial phase existing cutting technology should be used as far as possible. Tailor-made solutions should be used as much as possible to avoid big investments in specially designed machines. The potential to reduce costs is big when it concerns forest fuel integration. First of all there must be a good co-operation and co-ordination between the logging and extracting operations. It must be clear before the cutting operation starts whether forest fuel will be integrated and extracted. The cutting can then be adapted to the total operation and will give a better profit even on the industrial assortment. Many forest owners or logging companies can be sceptical to the extraction of forest fuel. In many cases it only depends on limited knowledge and they are not aware of the fact that the assortment in demand is not traditional assortment requested by the forest industry.

Conclusion:

The price of wood fuel is rather small, if compared with the prices of other kinds of fuels, thus the demand for wood fuel is constantly increasing, it is crucial to think carefully before further expansion is carried out. There is otherwise a considerable risk of major setbacks for the solid-fuel plants if we are to recognise that the raw material cannot be produced and supplied in certain regions. Pilot studies are needed in specific areas where conversion projects are in an initial phase.

17. 6. Chapter 9. Wood chipping aspects in Lithuania

1. Machine with manual feeding even with the high feed rate 1,24 m/s cannot reach high capacity. Even when chipping trees with average DBH of 8-9cm hourly capacity is only 7-8 m^3 of chips loose volume when loading by two workers.
2. Effective chipping of different size stems and logging residuals can be achieved only by using machines equipped with feeding cranes.
3. Machines with manual feeding are applicable only for small-scale production and have absolutely

no sense to be used within SFE's.

4. Fuel chip suppliers have also to base production on heavy-duty machinery to become important players on the market.

Figures given in chapter 11, table 11.7.2. (m^3/stem) confirm the figures given in this chapter in table 9.1.1.

Technical data and capacity of these machines once more confirm that local and neighboring markets cannot offer equipment suitable for large scale production. Mobil forwarder or special chassis mounted chippers with cranes and containers for chips are at present expensive for Lithuanian conditions. During Elmia Wood 2001 technical data and prices of different chipping machines from manufacturers in many countries were examined to find the optimal one for Lithuanian conditions and also for testing it in a way suitable to obtain experimental results of fuel chips production valuable in longer perspective. One of the reasonable options is smaller mobile drum chipper produced in the Scandinavian countries such as Sweden and Finland. The capacity is 40-90 m^3/h. The demand of such machines throughout the country could be approximately 25, or practically rounding-up one for each SFE or administrative district in the country.

Conclusion:

There are some options for using mobile drum chippers connected and driven by suitable tractors possible to find in Lithuania. Sweden and Finland and other countries are producing suitable mobile drum chippers. Due to high production prices in these countries the best option would be to start production of suitable mobile drum chippers in Lithuania or some other Eastern European neighbor country. The demand will increase in all Eastern Europe countries if the use of forest fuel in this region increases. The structure of forestry sector of these countries is similar to Lithuania.

17.7. Chapter 10. Studies on forestry, technology and economy of forest fuel production in Rokiskis Forest Enterprise.

17.7.1. In wood fuel resource assessment

1. The amount of possible to take out logging residues in 2001-2010 from all forests of Rokiskis f.e. comprises 19,6 thous. m^3. In 2011 – 2020 the amount of possible to take out logging residues will increase by 22 %.

2. The highest concentration of possible to take out logging residues was calculated in the forests of Juodupe, Rokiskis, Vyzuonai and Kamajai forest districts. The biggest amount of possible to take out logging residues will be taken out from spruce, birch and pine forest stands.

3. In 2001 – 2020 the possible to take out logging residues will comprise 34 % of all logging residues in the forest enterprise or 9 – 12 % of the whole extracted volume.

4. The biggest amount in possible to take out logging residues comprises bark (56 – 57 %) and non-merchantable branches (30 – 31 %). Small stems as well as merchantable branches comprise 6 – 7 %. The amount of possible to take out logging residues in final cuttings comprises 70%, while in intermediate cuttings it makes only 30 %.

5. In the future the methods and software for easier forest fuel resources assessment using stand wise inventory data as well as NFI and GIS must be developed.

(More discussion on the assessments and the used model KUPOLIS can be read in Chapter 17. 12).

17.7.2. Chapter 10.3.2. Forest fuel production influence for pre- commercial thinning cost.

During the last decade in Lithuania about 13 thous ha of young stands were thinned by applying different young stands pre-commercial thinning technologies every year. The largest areas of young stands were thinned in 1997 (14149 ha), and the smallest – in 1993 (10173 ha). In the last three years young stands thinning areas have been decreasing, first of all because of unprofitability. Young stand thinning is planned only in the stands of high density where thinning is essential. A young stand thinning as one time farming task is unprofitable, that is why the Forest funds are established for these thinning. In the last few years the forest fund spends about 3,5 mln. Lt per year for the young stands thinning (Table 17.7.2.1.). The expenditure of the forest fund on the young stands thinning was about 1% of the total expenditure. Since 1997 when the expenditure on the young stands thinning was more than 4 mln. Lt, the expenditure has still been decreasing and in the year 2000 it was just about 3,3 mln. Lt.

Table 17.7.2.1. The dynamics of the expenditure of the forest fund.

	Forest fund	For pre-commercial thinnings		Area of thin
Year	Expense, thous. Lt.	Thous. Lt.	% of FF expense	young stands, ha
1995	285 066	2 536	0,9	12290
1996	336 036	3 472	1,0	12500
1997	338 535	4 116	1,2	14149
1998	325 237	3 795	1,2	13796
1999	295 703	3 766	1,3	13357
2000	290 990	3 290	1,1	11977

Average cost for 1 ha of the young stands thinning during the last 6 years was from 206 to 290 Lt, and the volume of felling in_1ha fluctuated from 14 to 18 m^3. As a rule this production is left in the forest, that's why no income is received from this farming activity. One of the means for decreasing the cost of the young stand thinning might be the production of the raw materials for the boiler house fuel.

Following the data of the State Forest Inventory and Management institute the 1-20 year old stands, where the pre-commercial thinning of the young stands is carried out, in Rokiskis forestry enterprise occupies the area of 7654,2 ha. Spruce, gray alder and birch predominate in the young stands. The stands of these species occupy about 87 % of the total stand area (Table 15).

State forest makes up 50%, private forests 13%, reserved for the privatization forests make up 37% of the total 1-20 year old stands area. State forests contain 74% of the total area of spruce stands, 10% of the total area take the birch stands and 7% of the total area take the black alder stands.

Table 17.7.2.2. 1-20 year old stand area according to predominating tree species.

Tree Species	State Forest, ha	Private forest, ha	Forest reserved for the privatization, ha	Total
Spruce	2792,9	407,7	888,0	4088,6
Gray alder	94,7	320,4	963,6	1378,7
Birch	390,6	134,3	638,7	1163,6
Black alder	251,1	56,0	176,0	483,1
Pine	57,2	28,6	101,4	187,2
Aspen	84,3	20,5	58,5	163,3
Ash	98,3	11,2	37,1	146,6
Other	30.3	5.2	7.6	43.1
TOTAL	3799,4	983,9	2870,9	7654,2

In the private forests spruce stands make up 41% of the total area of the 1-2 year old stands, the gray alder occupies 32% of the area. Birch and the black alder make up respectively 13% and 6%. The areas of the other tree species do not exceed 3% of the total area. In the forests reserved for the privatization 1 and 2 age class stands are dominated by white alder - 34%, spruce makes up 31%, birch stands - 22%, black alders - 6%. The area of the other tree species does not exceed 5.5%.

During the last ten years in Rokiskis forest enterprise pre-commercial thinning was carried out in the area of 325 ha, 15 m^3 of wood were felled from 1 ha. In the year 2000 comparing to the data of 1999 the area of the thinned young stands decreased up to 202 ha, i.e. more than 38%.

Looking at the foreign countries the biggest experience in the young stands thinning is possessed by the Scandinavian countries, especially by Sweden. Up to the middle of the eighteenth century, young stands thinning was carried out by using manual mechanisms (brush cutters, axes, etc.), however later thinning machines were started to be used (Hellstrom C., 1992). Mechanization in Swedish forestry expanded, what enabled to increase the effectiveness of the work.

In 1997 – 1999 in Sweden the biofuel program was started. This program helped to identify the possible development trends of this activity. Felling residues was used for the biofuel. Usually there are final cutting residues, i.e. branches, tops and so on. This kind of fuel was not widely spread in the beginning, because the research, on what impact on the fertility of the soil may the residues taken from the cut area have was not yet carried out. In the future it is anticipated, that the preparation of such logging residue packets will occupy an important place in the tree cutting works. High importance is given to the forest fuel production in the pre-commercial thinnings because the income from the softwood young stands for production covers part, and (in some cases) all costs of the young stands thinning (SkogForsk, 2000).

The research data confirmed that forest fuel production in the young stands is possible in Lithuania as well. First of all, the selection of the optimal technology as well as usage of proper machinery determined it. In comparison to traditional pre-commercial thinning, only several additional operations have occurred: tree piling and, if necessary, cross cutting. Handle "Apuri" allows controlling the saw with one hand. This allowed to pull the tree down optimally at the same time following all necessary safety measures. The structure of the workday in working with this machinery was different from the normative ones only because of different technical obstacles. After the removal of these problems such mechanism could be available and widely used in pre-commercial thinning.

It was planned that the thinning cost with integrated forest fuel production would be higher than the ones of traditional thinning. However, we found out, that the income from the wood fuel produced may not only decrease the costs of young stands thinning, but even give some profit. That would allow carrying out additional thinning in the younger stands, as well as would increase the volume of the felled wood in the older stands, as well as the resources of forest fuel. The latter fact is especially important for the businessmen who carry out the reconstruction of the boiler houses, and who wish to have a constant supply of the forest fuel.

1. The work time expenditure for the production by using handle tools is 0,546 hour/per loose m^3, while by motor saw "Jonsered 2054" with handle "Apuri" - 0,331 hour/per loose m^3. Big importance in using the machinery is given to the workers skills.
2. The costs of forest fuel production, when 280 loose m^3/ha is felled in the stand using handle tools makes 2,84 Lt/m^3l, while using the motor saw "Jonsered" 2054 with handle "Apuri" - 3,73 Lt/m^3l.
3. A general cost of traditional pre-commercial thinning where 280 loose m^3 of brushwood is felled makes 330 Lt/ha when using handle tools and 523 Lt/ha when using machinery. The costs of forest fuel production during the thinning increased from 1635 to 2453 Lt/ha, depending on the thinning tool, the distance of wood extraction to the roadside, efficiency of the chipper and the distance of the chip transportation.

Conclusions:

The structure of the workday of traditional pre-commercial thinning does not differ from the workday structure with integrated forest fuel production. The differences present can be easily removed by improving the machinery and workers' qualifications, that's why it is useful to apply the normative input in calculating work time expenditure. At the moment the cheapest method of fuel wood preparation in pre – commercial thinning is manual thinning using sabre.

For the composition of Technological cards it is necessary to carry out further study on young stands thinning with integrated forest fuel production in the areas of different composition of tree species as well as different density.

17.7.3. In forestry and technology research

The results show that it is clear that the amount of produced forest fuel increases with integrated forest fuel handling technology. Comparing traditional and integrated technology by using data from Appendix 2 we can see the difference in m^3s. table 17.7.3.1.

Table 17.7.3.1. Difference in m³ solid volume/ha of produced forest fuel, comparison between traditional and integrated technology in commercial and final cutting.

Cutting category	Traditional technology				Integrated technology				Increased forest fuel with factor
	Industrial wood, m³/ha		Fire wood	Total volume	Industrial wood, m³/ha		Forest fuel	Total volume	
	Long	Short	m³/ha	m³/ha	long	short	m³/ha	m³/ha	
Commercial thinning (1E)	2	23	**0.5**	25.5	2	23	**5**	30	**10**
Commercial thinning (2E)	19	57	**1.4**	77.4	19	57	**21**	97	**15**
Commercial thinning (3E)	30	32	**6**	68	30	32	**31**	93	**5**
Sanitary cutting (4E)	32	48	**6**	86	32	48	**12**	92	**2**
Clear-cutting (2P-1)	75	160	**17**	252	75	160	**58**	293	**3**
Clear-cutting (2P-2)	114	79	**9**	202	114	79	**61**	254	**7**
Clear-cutting (3P)	80	122	25	227	80	122	112	314	4

The smallest amount of forest fuel was produced in typical commercial thinning where technical corridors were made in the previous cutting. The biggest amount of forest fuel was produced in aspen stand with dense under storey with a big part of firewood while smaller amount was produced in spruce and pine stands. Amount of forest fuels increases by extraction from pre commercial thinning stands, the average figure of extracted forest fuel from the pre commercial thinning stands was 56 m³ solid volume/ha.

For forest fuel production the traditional technology with added operations for logging residues and unprunned firewood piling near technical corridors can be used. In forest fuel production the productivity of work increases with the increasing amount of logging and firewood as well skillfulness of workers.

1. The amount of produced forest fuel in intermediate cutting trials was 5-31 solid m³. The smallest amount was produced in typical commercial thinnings where technical corridors were made in previous cuttings. The highest amount was produced in a stand with a big part of firewood.
2. The amount of produced forest fuel in clear cutting areas was 58-112 solid m³/ha. The biggest amount of forest fuel was produced in aspen stand with a dense understorey. A smaller amount was produced in spruce and pine stands.
3. The amount of forest fuel is mostly dependent on the felled volume and its structure, especially the amount of firewood and branches. Most promising for forest fuel production are the stands of soft broadleaves, such as birch, aspen, alder with a dense understorey.
4. Work expenditure for loading and unloading in the extraction of forest fuel are 2 times lower as compared to the traditional assortment, e.g. sawlogs and pulpwood.
5. The following advantages were observed in cuttings with integrated forest fuel production:

- in final cuttings for technical corridors less amount of branches was used, and it allowed to avoid the so called "widening" of technical corridors;
- firewood production allows cuttings in traditionally less profitable forest stands, thus increasing the yield and the quality of those stands;

6. In conflict stands of spruce with broadleaves some amount of broadleaves can be left until 15 years of age. Therefore, we can get an additional amount of wood and keep the productivity of stand on the same level.

17.7.4. In economical research

Due to more rational handling some cost for the handling of the traditional industrial assortment turns over to the forest fuel assortment or disappears at the same time as the productivity increases. All calculated costs are real costs i.e. overhead cost which is varying between different companies are not included and are also influenced by business effectiveness within the company. If comparing data and also using data in appendix 2 we can see that the production cost for traditional industrial assortments decreases with integrated forest fuel handling, table 17.7.4.1.

Table 17.7.4.1. Difference in direct costs Lt/solid m³ for wood produced and extracted to roadside, in comparison with traditional and integrated technology in commercial and final cutting.

	Traditional technology	Integrated technology		Reduce cost
Cutting category	Industrial wood incl. fire wood	Industrial wood	Forest fuel	for industrial
(Trial No)	Lt/m³	Lt/m³	Lt/m³	wood, %/m³
Commercial thinning (1E)	27	23	15	**15**
Commercial thinning (2E)	28	24	15	**14**
Commercial thinning (3E)	29	27	14	**7**
Sanitary cutting (4E)	26	25	14	**4**
Clear-cutting (2P-1)	18	17	11	**6**
Clear-cutting (2P-2)	19	17	11	**11**
Clear-cutting (3P)	22	20	10	**9**

Note: 3.5 Lt corresponds to 1 US$

The cost for forest fuel extraction depends on many factors, first of all – on the type of cuttings. The cost is the lowest in the final cuttings. Other important factors include the machinery exploitation costs and its productivity as well as extraction distance.

During the cutting in pre commercial stands more time is used for handling the felled trees than in the commercial- or final cuttings. One reason is small dbh and high number of stems, another is that the distances to technical corridor are longer and more complicated to collect the outcome from the operation due to the remaining stand. Forest fuel production in pre-commercial thinning using hand tools diminishes the losses by 61 Lt/ha as the income for the forest fuel will covers some of the traditional cost for these forestry measures. Motor chainsaw with felling handle tools should only be used in pre commercial thinning stand where silvicultural measures have been carried out before or in conflict stands where dbh is no less than 5 cm.

The biggest influence on profitability has the forest fuel concentration in clear cutting areas. On the other hand the most reduced cost for the industrial assortment per m³ when using integrated forest fuel handling is in commercial thinning. Comparing with traditional technology, when all branches and tops are used for technical corridors the technology with integrated forest fuel production is very promising, however it requires a new way of thinking about silviculture. When integrating the forest fuel handling mobile drum wood chipper is needed for acceptable decomposition of the forest fuel. With more knowledge of methodology and more skilled personnel the results from the integrated forest fuel handling methods will improve.

1. Work expenditure for forest fuel preparation comprised 2-3 hours per solid m³ in thinning, 0.6-0.8 in commercial thinning and 0.6-0.7 hours per solid m³ in final clear cuttings. Work expenditure in the cutting area comprised 90% in pre-commercial thinning and about 75% in other cuttings.

2. The forest fuel direct cost in pre-commercial thinning reduced by the direct cost of traditional pre-commercial thinning was 38-43 Lt / solid m³. The total forest fuel direct cost in intermediate cuttings is 34-35 Lt / solid m³, while in clear cutting - 30 Lt / solid m³.

3. Forest fuel production in pre-commercial thinning using hand tools diminishes the losses by 61 Lt/ha. The use of mechanism in pre-commercial thinning is not profitable due to low skills of workers and improper stands. In commercial and final cuttings forest fuel production is more profitable as compared to the traditional technology. In commercial thinnings it gives additionally 115-686 Lt/ha, in final cutting - 852-1382 Lt/ha. The biggest influence on profitability is done by forest fuel concentration in cutting areas.

4. Influence of different factors on the direct cost of forest fuel.

- The increase of intensity reduces the cost of forest fuel in pre-commercial thinning. The increase of cut volume from 35 to 260 loose m³/ha reduces the cost of forest fuel from 48 to 43 Lt/ha by using motor-saw with felling handle in stands higher than 4 m.

- The cost of forest fuel increases with increasing extraction distance. In clear cutting forest fuel cost increases from 30 to 35 Lt/solid m³ with increasing extraction distance from 200 m to 1000 m.

- Forest fuel cost decreases with increasing chipper productivity. If the chipper produces 20 solid m^3/hour, then forest fuel cost is 30 Lt/ m^3. With increasing productivity up to 40 solid m^3/hour, the forest fuel cost decreases down to 25 Lt/ m^3.

5. Forest fuel cost increases with increasing transportation distance. With distance increase from 5 to 30 km using T-150 with 25 m^3 trailer the cost of forest fuel increases from 25 to 39 Lt/ m^3. Using MAZ 5516 (45 m^3) the increase of cost in the same conditions would be lower - from 24 to 29 Lt/ m^3.

6. The biggest part of forest fuel cost in clear cutting takes chipping (39%), extraction and transportation - 24%. Machinery is very expensive. It takes 78% of the cost, including 18% of fuel cost.

17.7.5. In research on ash utilisation

The aim of ash fertilisation is to compensate the nutrients removed with the harvested timber, balance nutrient status of the tree stand, counteract soil acidification and improve tree growth. Wood ash contains all elements, which are needed for tree growth except for nitrogen and it presumably will not leach very easily. Thus it can be considered to be an ecologically sound fertiliser. However, there are still several questions that should be answered before ash fertilisation can be recommended in the use in practical forestry scale in Lithuania. Project should be started to give results to these questions and further develop ash recycling. There is also a need to develop guidelines and recommendations for the heating plants in Lithuania on how to handle the ash after combustion.

Conclusion from the research on ash:

1. Six months after ash spreading at 2.5 and 5.0 tones/ha in Haplic Luvisols no changes of organic carbon and macroelements, such asCa, Mg, P, K were found. An insignificant increase of Pb, Fe and Cr was ascertained.

2. A positive effect of ashes for the litter microflora was found while spreading 5.0 tones/ha of ashes. The amount of ammonifying bacteria increases by 25%, bacilas - 100%, oligotrofic microorganisms - 120%. An increased role of nitrificators, Clostridium pasteurianum and cellulose-decomposing bacteria was ascertained. The influence on microorganisms in the soil was not found.

3. Species composition of the vegetation layer after spreading of ashes did not change. The first signs of mosses drying were observed - they became white or grey.

4. Currently it is worthwhile to use forest fuel ashes for spreading according to Swedish recommendations (Skogsstyrelsen, 2001. Swedish recommendations for the extraction of forest fuel and compensatory fertilizing in Sweden). It could not cause any negative effect, because the buffer effect of soil in Lithuania as compared to Sweden is higher.

5. Lithuanian recommendations for the extraction of forest fuel and compensatory fertilising should be developed.

At present one EU-Life project between Sweden and Finland is under construction. From the results of the conducted research on recycling of wood ash (ash from fuels originate from forests) in Sweden and Finland, the project aims to create conditions for a regular recycling of wood ash to forestland in both small and large scale and by demonstration and spreading of knowledge, showing how regular recycling of wood ash is organised with respect to environmental, technical, economical, logistic and administrative aspects. Different handbooks will be produced and translated into English language. One solution could be that participants from Lithuania would take part in the separate demonstrations and seminars and also the produced handbooks would be translated into Lithuanian language. Lithuania is not a member of the EU-Life programme and can therefore not be the counterpart in such project, including receiving finances from the EU-Life programme for participation in demonstrations and seminars or translation of produced handbooks into Lithuanian language.

17.8. Chapter 11. Changes in Silviculture

In traditional silviculture in Lithuania at least two pre-commercial thinnings are made and mostly without outtake of any volume from forest. Of course some pre-commercial thinnings are combined with outtake of firewood but not as business. This project aims to show how you can change the relation between pre-commercial thinning and thinning in order to get more profit from forest. There are some basic statements you have to agree on first.

1. The shorter time between investment and harvest the better economy.

2. The bigger volume handled each time the less cost per unit.

3. The more skilled and motivated worker the better result.

The first statement refers to the time from pre-commercial thinning to the first economically positive action, thinning. If you can shorten that time from i.e. 20 to 10 years you will diminish the cost of interest with ¼ at a rate of 3%. The second statement is very obvious because even if a big tree is heavier than a little that fact does not affect the time you handle the tree at least not essentially. So if you can double the volume of a tree you diminish the time per m^3 to half and that is the same as half the cost for that tree! The third statement you may call an understatement, but nevertheless, some people think you can put anyone to forest and he will do the job accurate. As mentioned above, prospects for having skilled people working in forest in Sweden in the future are quite bad. Harvesting of mature forest will be carried out even more by machines but yet there are no machines that can do the first pre-commercial thinning. All calculations referred to in this report are pointing at the same direction. You have to prepare a stand in some way to be able to make further treatments more profitable. There are great volumes available in young stands. You just have to decide what to do with them.

All dense regeneration, where no pre-commercial thinning (cleaning) has been conducted, will be formed into "conflict stand" independent from the tree spices. Cleaning- thinning in this type of stands is obstructed by the fact that some of the stems with the best quality are often restrained or damaged. Furthermore raised tree-crowns and thin stems make high risk for snow-brake in the nearest years after the cleaning-thinning operation have been carried out. Delayed cleaning-thinning makes you therefore to leave dominated stems with -reasonably developed tree-crowns even if they have not so good stem quality. The high risk for snow-brake requires leaving more stems than in "normal" developed and managed stand on a first stage. The measures of transferring the "conflict stand" into "good normal stand" sometimes require several operations of cleaning-thinning before the stand can be considered as stable. In "conflict stands" with very delayed cleaning-thinning, i.e. stands with an middle height over 6 m and several thousand more stems/ha than recommended, leaves 2 options.

1. To make a delayed cleaning-thinning and leave more stems/ha than would be in normally managed stand. In some cases a new cleaning-thinning is required after some years before the stand is considered to be stable and can be left until more commercial thinning.

2. To do nothing and try to manage the stand later on in the first commercial thinning.

Both these alternatives have the following factors in common: the cost for this treatment will be considerably higher than in normal cases. It's therefore only a matter of question to choose the less bad alternative. If extraction of forest fuel can be integrated in these operations the cost for treatment of these stands will be heavily reduced.

Conclusion:

Figures, given in chapter 9, table 9.1.1. (m^3/stem) confirm the figures given in this chapter in table 11.7.2.

In spite of skilfulness and education of the workers the result still shows that there is a great amount of forest fuel available in young stands as well. In this particular case an 18-year-old stand, pre-commercially thinned twice, still gave **56 m^3s (100 MWh)** per ha. If one third of the stands younger than 30 years had this amount of volume it would be possible for the next 10 years to make an annual outtake of **0,56 million m^3s (1 000 000 MWh)**. An analysis of the figures in Lithuanian Statistical Yearbook of Forestry 2000 and 2001, even with very hard reduction of available areas, gives almost the same volume of available forest fuel, **0,6 million m^3s/year** from young stands. Swedish reports from researches and analysis of possible outtake in young stands contain the results that show similar amounts that could be taken from young stands, **40 m^3s/ha**

17. 9. Chapter 12. Business development

Wood fuel from Industry: From the estimate presented in the table and the statement in previous paragraph it is clear that there is no space for additional volume of sawmilling residues to be used for fuel at the current sawnwood production level.

In the nearest 3-5 years, together with restructuring sawmill sector and increasing fellings, which will lead to the increased availability of logs, sawnwood production is expected to grow by 10-20%.

However it is most probable that in the future more of chips will go for exports to pulp producers which offer very competitive prices, therefore competition for chips in the energy sector, board factories and pulp producers is expected to tighten. And it is clear that new, alternative sources (wood fuel from forest) must be evaluated carefully.

Figures below confirms the estimation done in chapter 12 and also the figurers given in chapter 7 on material balance in Lithuanian sawmilling industry.

Raw materials in 2001, published by The Statistics Department:

1. Wood waste formation: total 1,4 mill m^3
   - industry - 1,2 mill m^3
   - agriculture, forestry - 0,2 mill m^3
2. Processed or used in industrial production:
   total - 0,3 mill m^3
3. Destroyed or transported to the dump:
   total - 0,2 mill.m^3

The balance from 1-3 lines: 1,4 mill m^3 - 0,3 - 0,2 = 0,9 mill m^3
Conclusion: “these 0,9 mill m^3 were either burned, or sold to individual houses or simply remained unused”.

Wood fuel from forestry operations: At this time 2 mobile drum chippers are operating in Lithuania, and there is no doubt, that the number of chippers will increase in nearest years. Still the investment is too high as this kind of chippers is produced in the countries where the price level is much higher and adapted to their conditions. This emphasises the need to investigate possibilities for production, of these kind of chippers in some other country, maybe through some joint-venture company.

Future scenarios of wood fuel business: Promotion of the forest fuel development should not only be concentrated on raw material aspects, but also issues on directly related to energy sector. It is therefore recommended to strengthen the communication within and between the representatives of forest sector, energy sector, governmental institutions, municipalities and other involved organisations, perhaps by creating the necessary institutional framework and structures with the human and financial resources able to pay attention to the needs of involved parties.

Socio-economic effects of forest fuel development: The detailed analysis of socioeconomic effects, based on Lithuanian conditions and Nordic know-how is needed in the near future. It would help political decision makers to plan the future development, both in the regions and the whole country. Every new created workplace has essential importance for the rural development in Lithuania.

17. 10. Chapter 13. Institutional and legal aspects regulating wood energy activities in Lithuania

All those organizations mentioned in chapter 13. can influence the policy orientation concerning wood fuels. However, there is a lack of cooperation and communication between the forestry sector and the energy sector as well as between governmental institutions and NGOs. It should be significantly improved.

Energy Agency dealing with biomass programmes should play more active normative (particularly in standardization) and proponent role because they are the interface between policy makers and research organizations. The effectiveness of any programme or project has to be monitored and continuously assessed so that policy and planning inputs to new programmes and projects can be modified in the light of experience.

Associations and private sector should join forces in the promotion and future development of wood energy systems. They should participate more actively in preparation of regulations, adaptation standards for biofuel. The Lithuanian Association of Bio-Energetic and Energy Saving is almost invisible in Lithuania and should operate more actively performing co-operation and dissemination of information in Lithuania and abroad, bringing together partners who are directly involved in all biomass aspects and promoting fiscal incentives and administrative support. To get an efficient platform to exchange experiences between countries, association should be more active on international level (e.g. AEBIOM - European Association for biomass).

Other option would be to establish an association dealing exclusively with wood fuels and having task to provide support to companies producing and marketing domestic wood fuels.

Last but not the least, more holistic approach shared in common by specialist governmental organizations, NGOs and private sector must replace scattered field activities undertaken by different organizations without strategic coordination.

17.11. Chapter 14. The system of transportation in Lithuania

Forest fuel is a new assortment in Lithuanian industry and the transport of this production is only developing. Suppliers or transportation companies should invest more in logistic system. Only big suppliers do this at the moment. The others transporting chips using vehicles which are not cost effective and efficient (agricultural tractors with trailers or low volume lorries). According to economical elements from chapter 10 , transportation cost make big share of the total forest fuel cost also when including the relatively high cost for chipping, when using such expensive drum wood chippers as in this case. Using unsuitable transport vehicles such as are used today limits the transport distances down to about 30 km. If other transport vehicles like the semi trailer mentioned in chapter 10, with capacity of 85-92 m^3 loose volume and a transport cost of 1.5 Lt/km were used: you can transport wood chips to heating plant at 100 km distance (total cost will then be 200 km * 1.5 Lt divided into amount transported wood chips, would give a total price per m^3 solid of 8.00-8.80 Lt for transporting wood chips 100 km), at lower cost than transporting 25.3 – 45 m^3 loose volume for 30 km with the agricultural tractors with trailers or low volume lorries!

It is also not efficient to use such small lorries when using drum chippers producing between 40-90 m^3 loose volume chips per hour. Then chipper probably has to stay waiting for lorries during the day.

Even attempt to increase the length of firewood production (e.g. if not using drum chipper, which even can chip branches and top still sitting on the stem) from today's 2 m up to 3 m would decrease the cost more than 10 % for handling the firewood in the forest and including hauling to roadside. The time consumption for loading and unloading during transportation increases by about 30 % for 2 m. logs comparing with 3 m logs. One main reason mentioned in some forest enterprises for using 2 m. logs of fierwood instead of 3 m. was that it would make a mixture of the differenty assortments of roundwood which has thesame lenght (3 m) and it would then be difficult to sellect the right assortsment when hauling the logs to raodside landing. If this is the main reason, it could easily be solved.

With the help of various sources of information, it is possible to calculate the cost ceiling for the withdrawal of different energy assortment ranges for various main haul distances, the cost ceiling for the chipping of energy wood at depot or terminal, etc. In addition, it is possible to estimate how the size of drain area (available volume) is influenced by different measures adopted to reduce transport cost and what the cost ceiling is for these measures. This is a question of great interest for the future.

Conclusion:

The sensitivity to transport of the assortment range means that local shortages can arise. Attempts must be made to find solutions and systems that allow to improve transport economy. By improving transport economy, transport distances can be prolonged at the same time as the risk of shortages is minimized. Information and spreading of knowledge as well as the change in conservative thinking about transportation of forest fuel are important. If integrating the forest fuel handling, transport distance can increase comparing with traditional methods, i.e. traditional handling in forest such as roundwood (firewood) – hauling to roadside- transportation to terminal- chipping - transportation of wood chips to heating plant. When integrating forest fuel handling and using drum chipper, the forest fuel is extracted to roadside landing- chipped and transported to the consumer.

17.12. Chapter 15. International experiences in simulation of wood fuel resources

The model KUPOLIS was worked out for strategic planning of forestry for the estimation of the development of th e state of forest, growth, and potential cut. It was not aimed to analyse supply-demand balance of resources. The real amount of wood that can be used for fuel depends on a market situation. Simulation cannot substitute forestry strategy. In the best case simulation is only a mean to check the facts of strategic importance, to reveal errors and to define their causes. For two thirds of the Lithuanian territory the forest survey material is 10 years old and even older. It is also stated by the authors *"without any doubt, that, having done forest inventory on the whole territory of the* *country, forest use volume in this part, as compared to forecast calculations, should increase. Comparing the use of 2001-2030 and 2001-2100, two moments should be taken into consideration. Firstly, mean gross annual increment accumulation over the whole 2001-2100 period is more intensive in private and other forests. It is foreseen, that their mean volumes over 100 years will increase by 68 m/ha, while in state importance forests - by 36 m/ha. It is also very important to note, that in mature stands is foreseen a much more intensive accumulation than on average in all stands. This would be the result off ending young stands growing*".

In the new assessment of forest fuel made during the year 2000, for the Lithuanian Swedish Wood Fuel Development Project phase 1, it was assumed to reject the debarking of logs. Small stems and branches in the stands until 20 years of age were not estimated due to the mean from ecological and economical point of view. It was also estimated that only about 50% of branches was purposeful to collect in a final cuttings and from the total amount of cutting residues per Lithuania during the first decade (2001-2010) which reached 2,4mill m^3 per year, only 1/3 of it was assumed to be extractable. Even less percentage of collected branches (30%) in thinning in the stands was over 20 years old. Presently there are no restrictions to take branches out of the forest.

Another important constraint - Land reform in the country - is the not finished. It complicates the estimation of feasible biofuel resources. Contribution of the forest energy to the national energy balance is also difficult to evaluate using only figures disclosing the resources of the whole country.

All available models of supply-demand balance of wood fuel are worked out for specific conditions and needs of different countries. These models cannot be transferred directly to Lithuanian conditions and they should be adopted.

In the assessment of supply- demand balance of wood fuel the following data should be collected:

a) available forest resources considering ecological restrictions
b) level of thinning and cutting
c) non-forest lands
d) average prices in wood market
e) harvesting technologies and breakdown of the costs
f) cost of the labour power
g) tax system
h) consumption of wood by sawmills and other enterprises of forest industry
i) available quantities of waste wood from forest industry enterprises
j) consumption of wood fuel by boilerhouses and location of the boilerhouses
k) consumption of wood fuel by farms and dwellings
l) export of forest products
m) location of enterprises and ports
n) road network and logistics
o) prices of different fuels and prognosis for the coming years

Analysis of- annual increment inventory data in Lithuanian forests (A.Kuliesis, 2000) shows that the increment is underestimated. Mean gross annual increment by direct measurements is 7-15% higher. Preliminary figures from the National Forest Inventory 2001 (Lietuvos Misku Statistika, Nacionaline misku inventorizacija, 2001) shows underestimation of annual increment up to 22 %, from the average of the today's official annual increment per ha and year of 6.2 m^3 to 8 m^3 (table 17.12.1.). With respect to the real situation this, as compared to the forecasted one using too low increment function in the model, also shows much higher standing volume per ha.

Table. 17.12.1. Comparison on forest data between statistic yearbook and National forest inventory, 2001.

	Statistic yearbook 2001	**National forest inventory**
During year:	(1998-200)	(1998-2001)
Forest covered area in ha:	1.927.700	2.006.300
Standing volume m^3:	371.707.000	451.600.000
Increment m^3/ha/year:	6.1- 6.2	8
Overage standing volume /ha:	193	225

Site index (index for productivity directly related to the increment) is also often used as a quite heavy variable in all increment prognoses and thinning programs and will influence the choice of the right silvicultural methods that could influence the future growth of the forests in Lithuania. If the site index used is too low, comparing with reality, we will not use the forest lands natural productivity in an efficient way.

It's is also obvious that higher increment gives more growth and standing volume per ha than forecasted prognoses and forest management shows and in reality there is also more cut volume per ha than forecasted in prognoses e.g. forest management plans.

The results from the plots in the demonstration- and experimental area including experiences from Sweden, show in reality that changes in silviculture and integrated forest fuel handling comparing with traditional technology, increase the volume of extracted forest fuel at the same time as the economic effectiveness of integrated forest fuel production decreases the cost for the silvicultural measures or direct cost of the industrial assortment and increases the total economical effectiveness per ha comparing with traditional technology. New assessments should be carried out with different scenarios using technical- and or economical-, ecological considerations as different variants for showing the real potential for forest fuel harvest.

Conclusion:

The most reasonable solution is to work out a model, which fits to the forestry databases and tasks of modelling using stand wise inventory data as well as national forest inventory and GIS. At the same time contribution from other available programmes in the field of modelling of wood fuel supply should be used.

The final goal could also be to work out suggestions for changing tax system and legislation for improving the competitive position of wood energy among the other sources of energy. Experiences in modelling could later be used in other previous Soviet countries (Estonia, Latvia, Russia etc.) as the structure of forestry sector of these countries has been similar to Lithuania.

17.13. Chapter 16. Demonstration in the experimental area in Rokiskis Forest Enterprise.

The distance to the demonstration- and experimental area could be one explanation for the lower number of participants from some of the invited sectors, located far from the area. It's therefore a need to continue spread information as an campaign to verify the potential forest fuel when integrating forest fuel handling in ordinary forestry, especially among those who still doubt and also with respect to what have been mentioned in other chapters about "conservative thinking among many foresters".

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Appendix 1

Swedish recommendations for the extraction of forest fuel and compensation fertilising

Skogsstyrelsen
NATIONAL BOARD OF FORESTRY

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Recommendations for the extraction of forest fuel and compensation fertilising

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Introduction

The forest has a significant role to play in Sweden as a renewable energy resource in a sustainable society.

The recommendations below outline how the National Board of Forestry, Sweden considers the extraction of forest fuels[1] and compensation fertilising[2] should be conducted in order to avoid any undesirable effects on the nutritional balance in the soil, on the biological diversity and the water quality in lakes, watercourses and water tables, and also to avoid any net flow of noxious substances (e.g. heavy metals) into the soil.

The National Board of Forestry is positive towards the use of forest fuels, provided that the recommendations below are followed. The fuels from Swedish forests are renewable, of domestic origin, and contribute minimally to the greenhouse effect and related climatic effects. Extraction, transport and processing of forest fuels create new employment opportunities. Moreover, the utilisation of fuels from Swedish forests reduces dependency on energy supplies from abroad.

[1] This refers to so-called *primary forest fuel*, i.e. the part of forest fuel that comes directly from the forest, such as forest residue (branches and tops that are left after the extraction of stemwood) and a range of fuels from final felling, thinning, cleaning and other timber operations.
[2] Compensation fertilising refers to the introduction of nutrients with the aim of compensating for the removal of mineral nutrients that occurs in connection with the extraction of primary forest fuel. Mineral nutrients refers to all nutrients with the exception of nitrogen.

Preserve the nutritive balance in forestry land

The National Board of Forestry is of the opinion that:

- compensation fertilising should take place when forest fuels have been extracted and most of the needles are left in situ, with some effort being made to spread them out.

  One extraction per rotation, however, can be carried out without compensation fertilising, provided that most of the needles are left and spread out.

  Compensation fertilising ought to be carried out:
  → When extracting from highly acidified forestry land.
  → When extracting from peat land.
  → When extracting the greater part of the needles in connection with regeneration felling.

  The needles may be taken out:
  → Once during the rotation in connection with light thinning or clearing.
  → From areas with a high degree of nitrogen impact, provided that compensation fertilising takes place.

The predominant part of the nutrient content of a tree is retrieved from the needles, branches and tops. Depending on the nutrient, the removal of nutrients with logging residues (i.e. branches and tops) increases by 1.5 – 5 times compared with harvesting only stemwood. Ordinarily, in the extraction of forest fuel, the removal of mineral nutrients cannot be fully compensated by weathering and deposition. Consequently, the supply of mineral nutrients available to plants diminishes. By leaving most of the needles, the extraction of nutrients is limited considerably. In this way, the need for compensation fertilising is also reduced. If the needles are left and compensation fertilising takes place, then the loss of mineral nutrients is prevented.

By spreading out the needles as evenly as possible, the risk of nutrient leakage is reduced as the vegetation is then given a greater opportunity to avail itself of the nutrients that are released from the needles at the same time as the composting effect in piles of slash and needles is counteracted. Today, logging residues are often left in smaller piles, spread over the cutting area to dry and to allow the needles to fall off. A successive improvement in spreading out needles, employing technical means, should be an ambition within the development sector. One alternative to allowing the needles to fall off is to leave behind more sprigs, branches and tops so that their nutrient content corresponds to the amount in the needles. Compensation fertilising should always be carried out when extracting forest fuel in connection with final felling, which comprises removal of all biomass above the stump, including the needles.

One logging residue extraction per rotation can take place without compensation fertilising. To avoid the need for compensation occurring after extraction that is associated with regeneration felling most of the needles should be left and spread more or less evenly. The risk for a rapid change in soil conditions is small even if compensation is not carried out for the occasional extraction. A great deal of nutritious fractions remains during practical handling. There should, however, be an ambition to successively develop and introduce new technology for compensation fertilising.

In highly acidified forest land[3] in south-west Sweden, significant sections of the volume of the nutrients available to plants is lost due to leaching. In order not to make the situation worse, such areas ought to undergo compensation fertilising following the extraction of forest fuel.

In forest ecosystems in peat land, the availability of certain mineral nutrients is limited. A large amount of the nutrients is confined to the trees. If logging residue extraction occurs in peat land, it is therefore especially important to leave the needles behind and also carry out compensation fertilising.

When extraction takes place during thinning out and clearing operations, which may even include the needles, no compensation fertilising is necessary. The reason for this is that the extraction and the distribution of compensation fertiliser involves more transport and thereby an increased risk for damage to the soil and trees. Moreover, the removal of nutrients resulting from a logging residue extraction in thinning out or clearing operations is relatively moderate. It should, however, be an ambition to successively develop technology to enable the careful removal of needles and nutrient compensation.

The extraction of forest fuel results in a significant amount of nitrogen being removed. In nitrogen-rich forest land with a high nitrogen load[4], logging residue extractions including needles can be positive. They counteract the accumulation of nitrogen that can lead to an increase in nitrogen leaching, soil acidification and changes in vegetation. Compensation fertilising should be conducted following such extractions provided that the fertiliser and application rate do not lead to nitrification and nitrogen leaching.

The removal of nitrogen through the extraction of forest fuel may, in certain cases, lead to a relatively large decrease in the total available nitrogen supply (above all in northern Sweden), with temporary reductions in growth increment as a consequence. In certain areas, even the provision of ashes may result in temporary growth reductions. Leaving the needles behind can counteract these

[3] Highly acidified forest land refers here to forest land within areas with a relatively high deposition of acidifying substances (primarily in Blekinge, Skåne, Halland, Bohuslän and adjacent parts of Småland, Västergötland, Dalsland and south-western Värmland) provided that it is located within catchment areas for i) acidified lakes or watercourses in which surface water alkalinity is less than 0.05 mequiv/litre (measured during a stable period), or for ii) lakes that have been liimed to counteract acidification and which the county administrative board has judged as being in need of liming. Bog, and other naturally acidified lakes are *not* regarded as being acidified.

[4] Forest land with a high nitrogen impact primarily refers to coastal locations in south-western Sweden where a risk for nitrogen saturation may exist. Even within other areas in Götaland and parts of Svealand, where nitrogen fallout is high and the soil fertile, the extraction of forest fuel that includes the needles may be positive from the perspective of reducing the nitrogen load.

effects. Alternatively, it might be appropriate to apply nitrogen. Guidelines regarding nitrogen application are to be found in the National Board of Forestry's General Recommendations, SKSFS 1991:2. (A revised issue of this publication is planned for 2002.)

Forest fuel extraction in lichen-rich areas in northern Sweden may result in regeneration difficulties and should therefore be avoided.

Preserve biological diversity

The National Board of Forestry is of the opinion that:

- It is important that trees and bushes that have previously been left untouched in consideration of the natural and cultural environments are not damaged.
- Wet forest land and other forests with a high natural values should be exempt from extraction operations if their natural values are affected negatively.
- Extraction should not include species of trees that are less common. This applies to a particular stand as well as in the landscape.
- When extracting forest fuel, a certain proportion of tops should be left behind. It is especially important to leave dead wood as well as tops and large-dimension branches from deciduous trees.

The extraction of forest fuel means a more intensive utilisation of forests and forest land. It is therefore especially important that trees and bushes, both standing and lying, that have been left untouched during previous forestry operations due to ecological and cultural considerations are not damaged. Special attention should be paid to grazing land, the edges of woods near fields and meadows, burnt forest land and deciduous trees bordering lakes and watercourses when extracting forest fuel. One-sided extraction of deciduous trees in mixed forests should be avoided. Regulations regarding the consideration of the interests of nature conservation and cultural environment conservation (paragraph 30 in the Silvicultural Act) also apply to the extraction of forest fuel.

Dead wood, especially large-dimension dead wood from both coniferous and deciduous trees, has a significant bearing on the flora and fauna. Consequently, wood like this should be left when extracting forest fuel. The most significant contribution to biological diversity is wood from pine and deciduous trees, especially large-dimension wood from [5]selected broad-leaf tree species.

During the summer, certain species of rare insect use wood from selected broad-leaf tree species as host trees. The extraction of wood from selected broad-leaf tree species should therefore be carried out immediately after felling or by 15th May if felling took place during the period 1st September to 15th May. If this is not possible, then all twigs, branches and tops from at least every fifth tree, or equivalent, should be left and, preferably, exposed. These measures are most urgent in southeastern Sweden.

[5] In the present context, the term "selected broad-leaf tree species" refers to beech, oak, ash, elm, lime, maple, hornbeam and wild cherry.

Nutrient compensation

The National Board of Forestry is of the opinion that:

- Compensation fertilising should, primarily, be carried out through the provision of ashes. However, other products that contain mineral nutrients can also be used. Ashes and mineral products may also be combined.
- Most of the ashes used in products to be spread about in the forest should originate from the combustion of forest fuel. However, mixing in a certain amount of ashes from other fuels is not a problem. It is the quality of the ashes that determines its suitability.
- The ashes should to be stabilised and slow to dissolve.
- In compensation fertilising, the dose per hectare and rotation should be based on the loss of liming effect and the total removal of base cations (i.e. Ca^{2+}, Mg^{2+}, K^{+}) in branches, tops and needles during the rotation. The extraction of stemwood should be taken into consideration when judging the level of compensation.
- In order to avoid short-term negative effects, a maximum of 3 tonnes of DM (dry matter) in ashes should be returned per hectare and 10-year period if the total compensation requirement is greater than 3 tonnes DM per hectare.
- In compensation fertilising, the total input of heavy metals and other undesirable substances per rotation should not be greater than the amount removed with the total biomass.
- During the extraction of forest fuel it may be necessary to compensate for removed nitrogen and thereby counteract a reduction in growth increment. Guidelines for nitrogen input can be found in SKSFS 1991:2. (A revised issue of this publication is planned for 2002.)
- In compensation fertilising, nitrogen leaching and loss of input nutrients ought to be prevented by the choice of the work method, product and the point of time for the measures to be taken.

Guidelines with regard to the rate of application of ashes, appropriate nutrient composition, the highest permitted input of heavy metals, as well as the degree of stabilisation of the ashes are given in “Recommended application rates of ashes and desired quality in compensation fertilising”, Appendix 1.

The National Radiation Protection Institute (SSI) has, in its “Policy for biofuel”, Reg. No. 822/504/99, drawn up guidelines for the highest permitted caesium content in ashes that are to be returned to forestry land. At the moment, the SSI is preparing regulations regarding the handling of biofuel ashes that contain Cs^{137}.

Heavy metals may disturb the biological processes in the soil and affect the quality of surface and ground water. The content of heavy metals in ashes must not be so high that biological processes in the soil are impaired or the input of ashes exceeds the total removal of heavy metals per rotation, see Appendix 1.

Compensation should take place to compensate for the diminishing effect of lime as well as the complete removal of base cations (Ca^{2+}, Mg^{2+}, K^{+}), caused by the increased removal of biomass during the rotation. Compensation for the removal of individual nutrients may lead to unacceptably high supply of ashes with regard to environmental effects and availability of ashes. Desired quality and recommended doses of ashes are presented in Appendix 1. However, the need for compensation in peat soil should be calculated based on the removal of phosphorus and potassium. Ashes included in compensation fertilisers should, with regard to the rotation, originate mainly from combustion of forest fuels.

It may be necessary to store ashes in intermediate storage facilities or storage places pending being spread in the forest. Ashes or products made out of ashes should be stored in such a way as to prevent leaching as much as possible. Potassium is the nutrient most susceptible to leaching. The storage place should be dry and be situated relatively high in the terrain. Permanent intermediate storage facilities ought to have hardened surfaces and/or roofs. From the perspective of Swedish law, ashes are considered to be refuse. A permit is normally required for the transport, handling, processing, intermediate storage and stockpiling of refuse or, alternatively, there is an obligation to report such operations to the authorities. Further details on test levels, etc. can be found in the National Environment Protection Agency – General Recommendations 99:1.

Poorly stabilised ashes may be injurious to flora and fauna and also increase nutrient leaching. Only stabilised (chemical/physical) ashes and those that dissolve slowly should therefore be used. Negative environmental effects grow with increasing application rates of ashes. However, the negative environmental effects of application rates of up to 3 tonnes (DM) per hectare are judged to be very small.

Compensation fertilising must not take place during periods of snow-cover, ground frost or severe run-off if there is a risk that nutrients will subsequently end up in a watercourse. Consequently, they will be of no benefit to the soil or to the flora. Compensation fertilising should be conducted so that: 1) the fertiliser is spread evenly in the stand, 2) mechanical damage to the soil is limited and 3) damage to trees is limited.

Due to the risk of leaching on recently clear-felled areas, compensation fertilising ought not to take place prior to the re-establishment of ground vegetation. In practice, spreading should be avoided over a period that extends from five years before to approximately five years after regeneration felling with ashes that are not particularly stabile or dissolve slowly. If products containing ashes are developed that do not give rise to any particular leaching during the felling phase, then they can be spread in connection with regeneration felling.

Limit damage caused by vehicles and prevent damage caused by insects

The National Board of Forestry is of the opinion that:

- It is important that the technique and point in time for forest fuel extraction and compensation fertilising are chosen so that the risk of damage to the ground and to remaining trees is limited.
- Large-dimension, fresh coniferous wood should be handled separately when extracting forest fuel.
- Stacks with forest fuel should not be stored immediately adjacent to the edge of a stand comprising the same species of tree as that stored in the stacks.

The extraction of forest fuel and compensation fertilising requires increased transport in the forests while, at the same time, the ground-protecting effect of the slash is lost. This increases the risk of damage to the soil and to growing trees caused by vehicles and to trees that have been left standing or lying for reasons of environmental consideration. Special care should be taken in areas with poor carrying capacity.

The spreading of ashes in stands may result in blasting damage to trees closest to access tracks when spreading from the ground, especially during the period when the sap rises. It is therefore vital that both spreading techniques and the products used are designed so that such damage does not occur.

If large-dimension, fresh, coniferous wood is left unbarked in the forest during the spring and early summer, it will easily become nest material for insect pests. Such wood should therefore be handled separately. Regulations concerning the limitation of insect pests (§ 29 of the Silvicultural Act) apply in connection with the extraction of forest fuel.

If logging residues from coniferous trees are stored immediately next to the stand, this may result in attacks of pests on living, adjacent trees. Stacks of slash should be positioned at least 50 metres from the edge of the forest. This only applies if the species of tree is the same in the edge of the stand as the one stored in the piles.

Documentation, regulations and contacts with authorities

Documentation

The National Board of Forestry is of the opinion that:

- The extraction of forest fuel and completed compensation fertilising should be documented.

Many years may pass between the extraction of forest fuel and compensation fertilising. Completed measures should therefore be documented. Documentation is best done in a forest management plan or similar document. It should contain details of the extraction/extracted species of tree, time of extraction, if the needles were removed or left behind, and also details of probable compensation fertilising (time, amount and chemical composition).

Regulations and contacts with authorities

In the Silvicultural Act, extraction of forest fuel and compensation fertilising is regulated in Regulations and General Recommendations to § 30 (Consideration to Nature), § 14 (Notification of Forest Fuel Extraction) and with regard to storage § 29 (Forest Protection). The consideration that must be shown to the environment in all activities is presented in Chapter 2 of the Environmental Code. Activities or measures that may significantly alter the natural environment shall, in accordance with Chapter 12, § 6 of the Environmental Code (1998:808), be reported for consultation.

In those cases in which it is considered that forest fuel extraction or compensation fertilising will significantly alter the natural environment, applications for consultation are to be submitted to the National Board of Forestry. The person reporting the extraction of forest fuel, in accordance with § 14 of the Silvicultural Act, is also considered as having completed an application for consultation in this respect. If there is a risk of surface water or ground water pollution, compensation fertilising is also included in the regulations regarding activities harmful to the environment in the Environmental Code, Ch. 9.

Further guidelines regarding the handling of ashes can be found in, for instance, the Environmental Code, Ch. 15 and the Public Cleansing Ordinance (1998:902). There are guidelines in these sections that concern the storage of ash in intermediate storage facilities or storage places, which could be appropriate pending its spreading in forests. Ashes are considered to be refuse under Swedish law. A permit is normally required for the transport, handling, processing, intermediate storage and stockpiling of refuse or, alternatively, there is an obligation to report such operations to the authorities. Further details on test levels, etc. can be found in the National Environment Protection Agency – General Recommendations 99:1[6].

[6] Reading suggestions regarding activities harmful to the environment. General Recommendations 99:1. The National Environment Protection Agency, 1998. For later amendments, see www.environ.se ”Lagar och rättesnören” (i.e. *Laws and Guiding Principles)*.

Recommended application rates and desired quality of ashes in compensation fertilising

Ash dosage

Compensation should take place following the extraction of branches and tops (i.e. logging residues). Compensation can be done for stemwood extraction, as a separate measure or in connection with compensation for extraction of logging residues. Stemwood compensation is especially important in the highly acidified areas of southern Sweden. The guiding values for the suitable dose in nutrient compensation are, for practical reasons, somewhat standard.

The application rate of ashes can be decided by one of two methods; a simpler (standardised method) or a more detailed (nutritional balance method).

Standardised method

This method is employed when details of previous logging residue extractions are lacking or if compensation is to take place for stemwood during the current rotation. Ashes used must fulfil quality requirements in accordance with Table 5 and also SSI guidelines for caesium. The peak values for heavy metals given in Tables 6 and 7 do not need to be taken into consideration when the standardised method is employed. Compensation normally occurs once per rotation.

Table 1. Recommended application rates when the standardised method is employed

Species of tree	Tonnes of ashes DM/hectare and rotation (poor soil – fertile soil)
Spruce	1 – 2
Pine	0.7 – 1.5
Birch/other deciduous trees	1 – 2

The upper part of the interval is regarded as fertile soil/southern Sweden and the lower part as soil/northern Sweden. For mixed stands, the application rate can be decided upon by weighting the values based on the distribution of tree species.

Nutritional balance method

In compensation for the extraction of logging residue, the ash dosage that is to be introduced into the stands is decided, primarily, by the species of tree, the extent of the logging residue extraction, which parts of the trees are removed and the chemical composition of the ashes.

Normally, the return of the ashes is done on one occasion per rotation; however, the dosage may be divided into several treatment operations.

Tables 2-4 can serve as a guide when estimating the size of the application rate for compensation during one rotation in different stands and in different extractions. The application rate can be decided upon by weighting the values based on the distribution of tree species.

The table values assume that the ashes spread fulfil the quality requirements given in Table 5 and SSI guidelines regarding caesium. The total input of heavy metals during the rotation should not exceed the maximum values given in Tables 6 and 7.

The data given in Tables 2-4 is calculated using the programme, *"Snurran 1.0"*, which was developed by SkogForsk (Forest Research Institute of Sweden). The values given are based upon the content of 4 % potassium, 15 % calcium and 3 % magnesium. The values are not claimed to be exact for extractions from particular stands. The dosage may be adjusted if the contents are substantially higher. In peat land on the other hand, the compensation requirements should be governed by the extraction of phosphorus and potassium, but the guidelines below can also be followed for such areas. In order to avoid short-term negative effects, the total amount of dry matter (DM) in ashes returned per hectare over a 10-year period ought not to exceed 3 tonnes.

When introducing nutrient-enriched ashes, the portion should be adapted so that the equivalent amount of base cations[7] and effects of calcium will be the same as when using pure ashes. The amount of easily dissolvable salts should be limited.

[7] The equivalent sum total of base cations = amount of calcium introduced / 20.0 (equivalent value for Ca) + amount of magnesium introduced / 12.2 (equivalent value for Mg) + amount of potassium introduced / 39.1 (equivalent value for K). If the amount introduced is given in kilograms then the equivalent sum total of the particular sort is given in kilogram equivalents, if the weight is expressed in tonnes then tonne equivalents are given, etc.

Table 2. Spruce stand – the standard values in nutrient compensation, tonnes of dry matter (DM) in ashes per hectare and rotation

Extraction		**Habitat index**, compensation dosage, tonnes of DM in ashes/hectare and rotation		
		G18	G26	G34
All stemwood during rotation		1.5	2.0	2.5
Final felling	Logging residue without the greater part being needles *	0.7	0.8	0.9
	Logging residue with the greater part being needles **	1.1	1.3	1.4
Cleaning -thinning	Delayed cleaning***	0.4	0.5	0.6
	All thinning: logging residue without the greater part being needles ****	0.3	0.6	0.8
	All thinning: logging residue with the greater part being needles *****	0.6	1.0	1.3

* In the extraction of logging residue without the greater part being needles in the final felling, the application rate of ashes is based on 75 % of the logging residue and 25 % of the needles being removed.
** In the extraction of logging residue with the greater part being needles in the final felling, the application rate of ashes is based on 75 % of the logging residue and 75 % of the needles being removed.
*** In the compensation for the extraction of logging residue and stemwood in delayed cleaning, it is assumed that 75 % of the logging residue, 75 % of the needles and all stemwood are removed. The extraction is estimated to be between 25 m^3tvb (i.e. total volume over bark) and 50 m^3tvb per hectare. The arithmetic mean diameter is estimated to be between 6 cm and 10 cm.
**** In the extraction of logging residue without the greater part being needles in all thinning that is normally conducted during one rotation, it is assumed that 75 % of the logging residue and 25 % of the needles are removed.
***** In the extraction of logging residue with the greater part being needles in all thinning that is normally conducted during one rotation, it is assumed that 75 % of the logging residue and 75 % of the needles are removed.

Table 3. Pine stand - the standard values in nutrient compensation, tonnes of DM in ashes/hectare and rotation

Extraction		**Habitat index**, compensation dosage, tonnes of DM in ashes/hectare and rotation	
		T18	T26
All stemwood during rotation		0.8	1.2
Final felling	Logging residue without the greater part being needles *	0.2	0.3
	Logging residue with the greater part being needles **	0.3	0.4
Cleaning -thinning	Delayed cleaning***	0.2	0.3
	All thinning: logging residue without the greater part being needles ****	0.1	0.2
	All thinning: logging residue with the greater part being needles *****	0.2	0.3

*, **, ***, **** and *****, see Table 2.

Table 4. Birch stand/other deciduous trees - the standard values in nutrient compensation, tonnes of DM in ashes/hectare and rotation

Extraction		**Soil fertility**, compensation dosage, tonnes of DM in ashes/hectare and rotation	
		B18	B26
All stemwood during rotation		1.4	2.1
Final felling	Logging residue without leaves[0]	0.4	0.5
Cleaning -thinning	Delayed cleaning[00]	0.3	0.6
	All thinning: logging residue without leaves[0]	0.2	0.3

[0] In the extraction of logging residue without leaves in the final felling or all thinning that is normally conducted during one rotation, the application rate of ashes is based on 75 % of the logging residue being removed.
[00] In the compensation for the extraction of logging residue and stemwood in delayed cleaning, it is assumed that 75 % of logging residue and all the stemwood is removed. The extraction is estimated to be between 25 m^3tvb and 50 m^3tvb per hectare. The arithmetic mean diameter is estimated to be between 6 cm and 10 cm.

Table 3. Pine stand - the standard values in nutrient compensation, tonnes of DM in ashes/hectare and rotation

Extraction		**Habitat index**, compensation dosage, tonnes of DM in ashes/hectare and rotation	
		T18	T26
All stemwood during rotation		0.8	1.2
Final felling	Logging residue without the greater part being needles *	0.2	0.3
	Logging residue with the greater part being needles **	0.3	0.4
Cleaning -thinning	Delayed cleaning***	0.2	0.3
	All thinning: logging residue without the greater part being needles ****	0.1	0.2
	All thinning: logging residue with the greater part being needles *****	0.2	0.3

*, **, ***, **** and *****, see Table 2.

Table 4. Birch stand/other deciduous trees - the standard values in nutrient compensation, tonnes of DM in ashes/hectare and rotation

Extraction		**Soil fertility**, compensation dosage, tonnes of DM in ashes/hectare and rotation	
		B18	B26
All stemwood during rotation		1.4	2.1
Final felling	Logging residue without leaves[0]	0.4	0.5
Cleaning -thinning	Delayed cleaning[00]	0.3	0.6
	All thinning: logging residue without leaves[0]	0.2	0.3

[0] In the extraction of logging residue without leaves in the final felling or all thinning that is normally conducted during one rotation, the application rate of ashes is based on 75 % of the logging residue being removed.
[00] In the compensation for the extraction of logging residue and stemwood in delayed cleaning, it is assumed that 75 % of logging residue and all the stemwood is removed. The extraction is estimated to be between 25 m^3tvb and 50 m^3tvb per hectare. The arithmetic mean diameter is estimated to be between 6 cm and 10 cm.

Desired quality of ashes

Starting points

The quality requirements given below proceed from the following:

- Regulations and General Recommendations (SKSFS 1993:2) of § 30 of the Silvicultural Act.
- The joint policy publication ”Biofuel Ash in Rotations” of the National Board of Forestry and the Swedish National Environment Protection Agency. 1994.
- The documentation report ”Quality requirements for ashes that are to be returned to forest land” of the National Board of Forestry and the Swedish National Environment Protection Agency.

Origin of the ashes

Most of the ashes that are to be spread in the forest probably originate from the combustion of forest fuel. However, a certain admixture of ashes from other fuels would not result in problems. The quality of the ashes is what determines its suitability for being spread on forest land. The guidelines provided do not refer to any other residual products than ashes.

Treatment prior to spreading

Ashes to be spread in the forest must be treated so that:

- Acute damage to the soil and vegetation, such as mechanical damage to trees, is avoided.
- Even spreading is made possible.
- The ashes dissolve gradually.

The ashes are hardened by adding water and also by mechanical processing to produce particles of suitable size and hardness. Ashes can be treated by rolling to form granules or by compacting into pellets. Another possible technique is self-hardening with subsequent crushing and screening. The addition of plant nutrients and a bonding agent may also occur.

Standard values for chemical composition

Recommendations with respect to the chemical composition products made out of ashes are summarised in Table 5. The maximum content of micronutrients and heavy metals is set so that the maximum heavy metal input *for spruce forests* in southern Sweden is not exceeded when the application rate of ashes is in the order of 3 tonnes of dry matter/hectare.

The values given in the table refer to primary contents of the ashes that are spread in the forest, i.e. after any addition of plant nutrients and bonding agents, but without water. If the ashes contain a lot of inert material or a bonding agent, the contents in the ashes will be lower and can then be given per unit of weight of active ingredient. The chosen application should then be based on the active ingredient.

The main principle is that all substances are to fulfil the standard values. Minor deviations for individual elements are, however, acceptable. If the minimum contents given are not reached, then the possibility of introducing such nutrients to the ashes should be considered.

Table 5. Recommended minimum and maximum contents of elements in ashes intended for spreading in forest land. The value for the total polyaromatic hydrocarbons (iPAH) is preliminary.

Elements	Standard values	
	Lowest	Highest
Macronutrients, g/kg DM		
Calcium	125	
Magnesium	20	
Potassium	30	
Phosphorus	10	
Trace elements, mg/kg DM		
Boron		500
Copper		400
Zinc	1 000	7 000
Arsenic		30
Lead		300
Cadmium		30
Chromium		100
Mercury		3
Nickel		70
Vanadium		70
Organic environmental toxins, mg/kg DM		
Total PAH		2

Maximum heavy metal input with ashes

If the introduction of ashes entails a considerable increase in heavy metal content in forest land then negative ecological effects may result in both the short and long term. The risk of unwanted and acute effects in the soil is negligible if the ashes have been stabilised so as to give a slow rate of dissolving. In order for unwanted long-term effects to be avoided, the input of heavy metals must be limited and the maximum values given below should not be exceeded.

The guiding principle is that the quantity of heavy metals returned during a rotation must not exceed the quantity removed during the same period. A certain degree of standardisation and practical adaptation has been carried out in compiling the values given below. They are based on extraction in timber-rich stands and also with regard being taken to any local variation in biomass content. They are thus to be considered as maximum values that are not normally reached.

The highest acceptable input of heavy metals with ashes during a forest generation is given in Table 6 and Table 7. The differences between spruce and pine depend partly on the biomass being lower in the pine stand than in the spruce stand and partly on the contents differing between the species of tree.

Supporting documentation for providing maximum values for deciduous trees is not available and, instead, the maximum values for spruce can be used.

Table 6. Maximum values, i.e. maximum input of heavy metals with ashes or other compensation fertilisers to forest land with SPRUCE (or deciduous trees) during a forest generation

Heavy metal	Southern Sweden*	Central Sweden**	Northern Sweden***
	grams/hectare		
Arsenic	90	90	90
Cadmium	100	50	25
Chromium	300	200	150
Copper	1 200	600	500
Mercury	10	10	10
Nickel	200	200	200
Lead	1000	500	250
Zinc	20 000	15 000	10 000
Vanadium	200	100	100

* = south of 60 degrees of latitude
** = between 60 and 64 degrees of latitude
*** = north of 64 degrees of latitude

Table 7. Maximum values, i.e. maximum input of heavy metals with ashes or other compensation fertilisers to forest land with PINE during a forest generation

Heavy metal	Southern Sweden*	Central Sweden**	Northern Sweden***
	grams/hectare		
Arsenic	30	30	30
Cadmium	100	50	25
Chromium	300	200	200
Copper	800	800	500
Mercury	5	5	5
Nickel	200	200	200
Lead	400	200	100
Zinc	10 000	7 000	5 000
Vanadium	100	50	50

* = south of 60 degrees of latitude
** = between 60 and 64 degrees of latitude
*** = north of 64 degrees of latitude

Caesium

The National Radiation Protection Institute (SSI) has, in its "Policy for biofuel" (Reg. No. 822/504/99), specified, inter alia, that biofuel ashes that have a ^{137}Cs content of 5 kBq/kg or more should be put in depositories and not spread in the forest. At the moment, the SSI is preparing regulations regarding the handling of biofuel ashes that contain ^{137}Cs.

Stability of the ashes

Only stabilised (chemically or physically) ashes and ashes that take a long time to dissolve are to be used. Stabilised ashes considered to be ashes that are granulated, in pellet form or self-hardened/crushed ashes. The target is that the ashes or products made out of ashes shall dissolve over a period of 5 to 25 years in the field. Moreover, the initial speed of dissolution should be so slow that no acute, unwanted effects occur after spreading.

At present, reliable methods to characterise ashes with regard to the speed of dissolution in the field are not available. One way of estimating the stability of products made out of ashes is to measure the conductivity in water extracts in accordance with the reactivity analysis method described below. This gives a total measurement of the dissolution of salts from the ashes and indicates the risk of acute damage to vegetation, especially mosses and lichens. If the guiding values, given in Table 8, are exceeded for a product made out of ashes, the effects on ground vegetation should be examined more stringently before the product is spread on a greater scale.

Table 8. Preliminary target values in assessing products made out of ashes

Dosage	Conductivity
1 tonne/hectare	14 mS/cm
2 tonnes/hectare	12 mS/cm
3 tonnes/hectare	10 mS/cm

Another way of judging the characteristics of a product in the field is to use a method for leaching wood ashes (Larsson and Westling, 1999[8]).

This method demonstrates a conceivable process in the field with regard to the acid-neutralising ability of ashes and the release of nutrients. The method may be useful when comparing various products and working out routines for the production of compensation fertilisers. The method is based on the repeated leaching of ashes in a laboratory environment and indirectly describes the long-term leaching process under natural conditions. The leachate corresponds to several decades of precipitation in the field.

[8] Larsson, P.-E. and Westling, O. 1999. Leaching of wood ashes – a laboratory study. Report B 1325, 1999. IVL.

Quality control and chemical analytical methods

Sampling

The finished product is to be sampled but samples should also be taken of the ashes before processing. Sampling should be carried out in accordance with the guidelines given in the Nordtest Method NT ENVIR 004 for the sampling of solid waste particles, or SS 18 71 13 for biofuel and peat. Generally, sampling for analysis should take place for amounts of 250 - 500 tonnes of ashes or products made out of ashes, or at least once during the period (i.e. autumn to spring) when forest fuel is burnt. In larger combustion plants and plants that use pure forest fuel, sampling can be carried out less frequently than in plants using a greater variety of fuels and with different operational conditions.

Sampling should be carried out by using at least 15 sub-samples, each of which comprising 1 litre so that they represent the finished product as closely as possible. The sub-samples are to be carefully mixed to form a general sample. The number of sub-samples and their size will depend upon the homogeneity of the ashes. Additional sub-samples may be required if the ashes are evidently not homogeneous.

Sub-samples should preferably be taken from a conveyor belt or as the material is falling into a pile or hopper, etc. When taking samples from piles, the sub-samples must be obtained from various heights and depths in the piles.

Reference samples, from every general sample taken from the finished product, should be saved for at least three years together with its analytical value. It must be noted that hardening during the time in storage may impair the reactivity of the reference samples.

Chemical analyses

Accredited laboratories should conduct chemical analyses. The following analytical methods are recommended:

Total contents of macronutrients and trace elements

The target values for contents of macronutrients and trace elements given in Table 5 refer to total contents.

The following standard methods are recommended:

A. Digestion in lithium methaborate; analysis ICP-AES (ASTM 3682).

B. Digestion in HNO_3 + HCl + HF; analysis ICP-AAS, ICP-QMS (ASTM 3683)

The analyses can be used for practically all metals and P. Boron cannot be analysed using Method A. Volatile substances are analysed after decomposition in sealed containers.

Total contents comprise both easily dissolvable as well as slowly soluble fractions. The methods may, therefore, overestimate the value of the ashes as a source of potassium if it contains a lot of sintered material or inert material. Moreover, the accessibility of certain heavy metals is lower than the total analyses indicate.

Content of extractable macronutrients and trace elements

At present, research and development is underway into methods of characterising ashes with regard to availability of plant nutrient and toxic metals. As an approximate measure of the elements that may be released during a forest generation, an analysis of the fraction that is soluble in nitric acid is recommended. This method can be employed as a complement to total analyses, especially for ground ashes or other ashes suspected of containing inert material.

The method entails extraction in hot, concentrated (65 %) nitric acid on a plate or in sealed teflon containers in microwave ovens and following ICP-AAS (Haraldsson 2000[9]). It can be used for analyses of Ca, Mg, K, B, P, Cu, Zn, Mo, Co, Pb, Cd, As, Cr, Ni, and V. Extraction in sealed containers is required for the analysis of Hg.

Total polyaromatic hydrocarbons (PAH)

Analysis using HPLC or GC-MS after extraction in acetone/hexane or the equivalent. The total PAH is counted as the sum of 16 compounds (EPA 16).

Reactivity

Measurement of conductivity in water extracts

50 grams of ashes is mixed with 200 ml of deionised water (weight ratio 1:4) and shaken for one hour. After sedimentation in a sealed vessel for 15 – 30 minutes, the conductivity and pH are measured in the clear solution.

Leaching of wood ashes

The leaching of ashes using a leaching liquid comprising deionised water adjusted to pH 4.0 (mixture ratio 1:2000): the leaching liquid is decanted after 24 hours and new liquid is added. The decanted liquid is analysed. This procedure of replacing liquids is continued for 30 days (Larsson and Westling, 1999[10]).

[9] Haraldsson 2000. See the National Board of Forestry web page (www.svo.se)
[10] Larsson, P.-E. and Westling, O. 1999. Leaching of wood ashes – a laboratory study. Report B 1325, 1999. IVL.

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Forests have a significant role in Swedish energy supplies. The predominant part of the energy from forests originates from stemwood but the extraction of branches and tops for energy purposes has also become common in many places. There is a considerable increase in the removal of nutrients when not only stemwood but also branches and tops are harvested. It is essential that these activities do not imply a threat to biodiversity in the forest, that the nutrient conditions in forest soil are maintained and that conditions in subsoil water, lakes, watercourses or seas are not impaired.

In this publication, the National Board of Forestry presents its view on how the extraction of branches and tops and the return of ashes should be conducted in order to conform to present forest policy regarding sustainable production and the preservation of biodiversity.

In the long term, an increase in the removal of nutrients requires that compensation for the lost elements must be carried out. This is important but has not yet begun to be implemented on any particular scale. One section of this text deals with compensation fertilising, in which guidelines are given regarding the quality of ashes, application rates and quality control.

Appendix 2.

Stand parameters and monetary expenditures of forest fuel production in the pre-commercial, commercial thinning, final cutting and ash handling plots

Pre-commercial thinnings

Plots 1-2 (manual thinning)
The assessment of forest stand parameters was done before thinning in one 100 m^2 temporary sample plot per one sample plot of demonstration area. In temporary sample plots the dbh of every tree thicker than 2 cm and the height of every 7^{th} tree for every tree species were measured.

Production from 1 ha :

	Traditional technology	Integrated technology
Industrial timber	-	-
Firewood	-	-
Forest fuel	-	56
Total, m^3	0	56

Technology:
During the forest fuel logging young spruce stands were thinned using the sabre, brush was cut and piled up near technical corridors. The extraction was carried out by the tractor "MTZ – 82" with the trailer "Weimer WE-8" up to 200 m. The chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood is transported for 15 km by the tractor " T-150" with the 25.3 m^3 trailer. Thinning intensity - 56m^3/ha. In the traditional method pre-commercial thinning was done using the sabre and then spread in the cutting area.

Calculation of forest fuel cost in pre-commercial thinnings (using hand tools)

Work	Precommercial thinning with forest fuel production			Traditional technology		
	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³
Bush cutting and piling	2.760	5.18	14.30	1.100	5.18	5.70
Extraction	0.205	50.75	10.40			
At roadside	2.97		24.70			
Chipping	0.06	192.54	11.55			
Transportation to boilerhouse	0.103	66.46	6.85			
Material cost			0.51			
Total cost 1 m³	3.13		43.61	1.100		5.70

Pre-commercial thinnings

Plots 1-2 (machinery thinning)

The assessment of forest stand parameters was done before thinning in one 100 m^2 temporary sample plot per one sample plot of demonstration area. In temporary sample plots the dbh of every tree thicker than 2 cm and the height of every 7^{th} tree for every tree species were measured.

Production from 1 ha :

	Traditional technology	Integrated technology
Industrial timber	-	-
Firewood	-	-
Forest fuel	-	56
Total, m^3	0	56

Technology:

During forest fuel logging young spruce stands are thinned using the motor-saw"Jonsered 2150 Turbo" as well as felling handle "Apuri". Brushwood after cutting was piled near the technical corridors. Extraction was done by the tractor "MTZ – 82" with the trailer "Weimer WE-8" up to 200 m. Chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood was transported for 15 km by the tractor " T-150" with the 25.3 m^3 trailer. 56m^3 of forest fuel was produced from one ha. In the traditional method of pre-commercial thinnings brushwood was cut using the brush-cutter "Husquarna 250R" and then spread in the cutting area.

Calculation of forest fuel cost in pre-commercial thinnings (using motor-saw "Jonsered 2150 Turbo" with felling handle "Apuri")

Work	Pre-commercial thinning with forest fuel production			Traditional technology		
	Work expenditures, hour/m^3	Work cost, Lt/ hour	Total cost, Lt/m^3	Work expenditures, hour/m^3	Work cost, Lt/ hour	Total cost, Lt/m^3
Bush cutting and piling	1.70	12.80	21.76	0.740	11.48	8.50
Extraction	0.205	50.75	10.40			
At roadside	**1.91**		**32.16**			
Chipping	0.06	192.54	11.55			
Transportation to boilerhouse	0.103	66.46	6.85			
Material cost			0.51			
Total cost 1 m^3	**2.07**		**51.07**	**0,740**		**8.50**

Commercial thinning

Plot 1E (0.18 ha)
For the measurement of stand parameters in every demonstration area 4-6 temporary sample plots of 400 m² each were measured. In a sample plot the dbh of every tree and 3 or more tree heights for the main element in each storey and 1 or more tree heights for each other element were measured.

Rokiškis FE, Kamajai forest district, block 136, plot 16

Site	Storey	Species	Age,	Productivity	Height,	Dbh,	Stocking	Volume
		composition	years	class	m	cm	level	m3/ha
Ncl	I	90P 8S 2B	65	II	23	28	0.9	264
	II	100S	40		12	12	0.3	42

Production from plot (average stem volume is 0.378 m³):

	Traditional technology	Integrated technology
Industrial timber	4.6	4.6
Firewood	0.1	-
Forest fuel	-	0.9
Total, m3	4.7	5.5

Technology:
During forest fuel production the motor-saw " Husqvarna 254X" was used, a team consisting of 2 people was working. Firewood was prepared only from the butt part of stems. Forest fuel (top and branches) was piled near technical corridors. In the traditional forest logging industrial assortments as well as firewood were pulled to technical corridors. Forest fuel and industrial assortments were extracted by the forwarder "Valmet 840Y" for 250 m. Chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood was transported for 15 km by the tractor "T-150" with a trailer.

Calculation of forest fuel cost in commercial thinning trial 1E.

Work	With forest fuel production			Traditional technology		
	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³
Trad. assortment						
production	0.976	10.77	10.51	1.557	9.05	14.09
extraction	0.157	72.92	11.45	0.157	72.92	11.45
Material cost			1.24			1.24
Total at roadside	**1.133**		**23.20**	**1.714**		**26.78**
Forest fuel						
cross-cutting	0.017	12.35	0.21			
piling	0.45	6.04	2.72			
Total in cutting area	0.47		2.93			
extraction	0.172	72.92	12.54			
Total at roadside	*0.64*		*15.47*			
chipping	0.06	192.54	11.55			
transportation	0.103	66.46	6.85			
materials			0.95			
Total forest fuel cost			**34.82**			

Commercial thinning

Plot 2E (0.18 ha)

For the measurement of stand parameters in every demonstration area 4-6 temporary sample plots of 400 m^2 each were measured. In a sample plot the dbh of every tree and 3 or more tree heights for the main element in each storey and 1 or more tree heights for each other element were measured.

Rokiškis FE, Kamajai forest district, block 136, plot 16

Site	Storey	Species composition	Age, years	Productivity class	Height, m	Dbh, cm	Stocking level	Volume m3/ha
Ncl	I	72P 16S 12B	65	II	21	22	0.9	249
	II	100S+P	40		12	12	0.3	38

Production from plot (average stem volume is 0.345 m^3):

	Traditional technology	Integrated technology
Industrial timber	5.3	5.3
Firewood	0.1	-
Forest fuel	-	1.5
Total, m^3	5.4	6.8

Technology:

During forest fuel production the motor-saw " Husqvarna 254X" was used, a team consisting of 2 people was working. Firewood was prepared only from the butt part of the stem. The forest fuel (top and branches) was piled up near the technical corridors. In the traditional forest logging industrial assortments as well as firewood were pulled to the technical corridors. Forest fuel and industrial assortments were extracted by the forwarder "Valmet 840Y" for 250 m. Chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood was transported for 15 km by the tractor "T-150" with a trailer.

Calculation of forest fuel cost in commercial thinning trial 2E.

Work	With forest fuel production			Traditional technology		
	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³
Trad. assortment						
production	1.012		11.03	1.641		15.16
extraction	0.157	72.92	11.45	0.157	72.92	11.45
Material cost			1.24			1.24
Total at roadside	**1.169**		**23.72**	**1.798**		**27.85**
Forest fuel						
cross-cutting	0.017	12.35	0.21			
piling	0.38	6.04	2.30			
Total in cutting area	*0.40*		*2.51*			
extraction	0.172	72.92	12.54			
Total at roadside	*0.6*		*15.05*			
chipping	0.06	192.54	11.55			
transportation	0.103	66.46	6.85			
materials			0.95			
Total forest fuel cost			**34.40**			

Commercial thinning

Plot 3E (0.49 ha)

For the measurement of stand parameters in every demonstration area 4-6 temporary sample plots of 400 m^2 each were measured. In a sample plot the dbh of every tree and 3 or more tree heights for the main element in each storey and 1 or more tree heights for each other element were measured.

Rokiškis FE, Sėlynės forest district, block 58, plot 18.

Site	Storey	Species	Age,	Productivity	Height,	Dbh,	Stocking	Volume
		composition	years	class	m	cm	level	m3/ha
Ncl	I	74P 15S 10B	65	Ia	26	27	0.7	344
	II	92S 8AL	45		14	13	0.3	78

Production from plot (average stem volume is 0.251 m^3):

	Traditional technology	Integrated technology
Industrial timber	30.3	30.3
Firewood	3.1	-
Forest fuel	-	15
Total, m^3	33.4	45.3

Technology:

During forest fuel production the motor-saw " Husqvarna 254X" was used, the team consisting of 2 people was working. The firewood was prepared only from the butt part of the stem. Forest fuel (top and branches) was piled up near the technical corridors. In the traditional forest logging industrial assortments as well as firewood were pulled to technical corridors. Forest fuel and industrial assortments were extracted by the forwarder "Valmet 840Y" for 250 m. Chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood was transported for 15 km by the tractor "T-150" with a trailer.

Calculation of forest fuel cost in commercial thinning trial 3E.

Work	With forest fuel production			Traditional technology		
	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³
Trad. assortment						
production	1.206	11.56	13.94	1.489	10.82	16.10
extraction	0.157	72.92	11.45	0.157	72.92	11.45
Material cost			1.24			1.24
Total at roadside	**1.169**		**26.63**	**1.646**		**28.79**
Forest fuel						
cross-cutting	0.017	12.35	0.21			
piling	0.309	6.04	1.87			
Total in cutting area	*0.326*		*2.08*			
extraction	0.172	72.92	12.40			
Total at roadside	*0.498*		*14.48*			
chipping	0.06	192.54	11.55			
transportation	0.103	66.46	6.85			
materials			0.95			
Total forest fuel cost			**33.83**			

Commercial thinning

Plot 1S (0.34 ha)

For the measurement of stand parameters in every demonstration area 4-6 temporary sample plots of 400 m² each were measured. In a sample plot the dbh of every tree and 3 or more tree heights for the main element in each storey and 1 or more tree heights for each other element were measured.

Rokiškis FE, Sėlynės forest district, block 54, plot 11

Site	Storey	Species	Age,	Productivity	Height,	Dbh,	Stocking	Volume
		composition	years	class	m	cm	level	m3/ha
Ncl	I	45P 33S 22B	75	II	23	30	0.8	285
	II	100S	40		10	10	0.3	30

Production from plot (average stem volume is 0.374 m³):

	Traditional technology	Integrated technology
Industrial timber	27.0	27.0
Firewood	2.0	-
Forest fuel	-	4.2
Total, m3	29.0	31.2

Technology.

During forest fuel production the motor-saw " Husqvarna 254X" was used, a team consisting of 2 people was working. Firewood was prepared only from the butt part of the stem. Forest fuel (top and branches) was piled up near the technical corridors. In the traditional forest logging industrial assortments as well as firewood were pulled to technical corridors. Forest fuel and industrial assortments were extracted by the forwarder "Valmet 840Y" for 250 m. Chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood was transported for 15 km by the tractor "T-150" with a trailer.

Calculation of forest fuel cost in sanitary cutting trial 1S.

Work	With forest fuel production			Traditional technology		
	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³
Trad. assortment						
production	1.131		12.43	1.234		12.97
extraction	0.157	72.70	11.41	0.157	72.7	11.41
Material cost			1.24			1.24
Total at roadside	**1.288**		**25.08**	**1.275**		**25.62**
Forest fuel						
cross-cutting	0.017	12.30	0.21			
piling	0.294	6.04	1.78			
Total in cutting area	*0.311*		*1.99*			
extraction	0.172	72.70	12.50			
Total at roadside	**0.483**		**14.49**			
chipping	0.06	192.54	11.55			
transportation	0.103	66.46	6.85			
materials			0.95			
Total forest fuel cost			**33.84**			

Final cuttings

Plot 3P (0.22 ha)

For the measurement of stand parameters in every demonstration area 4-6 temporary sample plots of 400 m^2 each were measured. In a sample plot the dbh of every tree and 3 or more tree heights for the main element in each storey and 1 or more tree heights for each other element were measured.

Rokiškis FE, Sėlynės forest district, block 62, plot 12, 13

Site	Storey	Species	Age,	Productivity	Height,	Dbh,	Stocking
		composition	years	class	m	cm	level
Ncl	I	4B 3S 3As	65	I	26.4	31.7	0.8

Production from plot (average stem volume is 0.252 m^3):

	Traditional technology	Integrated technology
Industrial timber	44.5	44.5
Firewood	5.5	-
Forest fuel	-	24.7
Total, m3	50.0	69.2

Technology.

During forest fuel logging the motor-saw " Husqvarna 254X" was used, a team consisting of 2 people was working. Firewood was prepared only from the butt part of the stem. Forest fuel for boiler-house (top and branches and understorey brushwood) was piled up near technical corridors. In the traditional forest logging industrial assortments as well as firewood were pulled to technical corridors. Forest fuel and industrial assortments were extracted by the forwarder"Valmet 840Y" for 200 m. Chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood was transported by the tractor "T-150" with the trailer of 25.3 m$^{3.}$

Calculation of forest fuel cost in clear-cutting trial 3P.

Work	With forest fuel production			Traditional technology		
	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³
Trad. assortment						
production	0.977	11.18	10.92	1.242	10.26	12.74
extraction	0.109	72.92	7.95	0.109	72.92	7.95
Material cost			1.24			1.24
Total at roadside			**20.11**	**1.351**		21.93
Forest fuel						
cross-cutting	0.102	12.35	1.26			
piling	0.274	6.04	1.65			
Total in cutting area	*0.376*		*2.91*			
extraction	0.104	72.92	7.58			
Total at roadside	*0.480*		*10.49*			
chipping	0.06	192.54	11.55			
transportation	0.104	66.46	6.91			
materials			0.95			
Total forest fuel cost			**29.90**			

Final cuttings

Plot 2P-1 (0.19 ha)

For the measurement of stand parameters in every demonstration area 4-6 temporary sample plots of 400 m² each were measured. In a sample plot the dbh of every tree and 3 or more tree heights for the main element in each storey and 1 or more tree heights for each other element were measured.

Rokiškis FE, Sėlynės forest district, block 62, plot 7, 11

Site	Storey	Species	Age,	Productivity	Height,	Dbh,	Stocking
		composition	years	class	m	cm	level
Ncl	I	6S 2B 1P	85	II	20.9	23.1	

Production from plot (average stem volume is 0.327 m³):

	Traditional technology	Integrated technology
Industrial timber	44.7	44.7
Firewood	3.2	-
Forest fuel	-	11.0
Total, m3	47.9	55.7

Technology.

During the forest fuel logging the motor-saw " Husqvarna 254X" was used, a team consisting of 2 people was working. Firewood was prepared only from the butt part of the stem. Forest fuel for boiler-house (top and branches and understorey brushwood) was piled up near technical corridors. In the traditional forest logging industrial assortments as well as firewood were pulled to technical corridors. Forest fuel and industrial assortments were extracted by the forwarder"Valmet 840Y" for 200 m. Chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood was transported by the tractor "T-150" with the trailer of 25.3 m³.

Calculation of forest fuel cost in clear-cutting trial 2P-1.

Work	With forest fuel production			Traditional technology		
	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³
Trad. assortment						
production	0.774	9.44	7.31	0.932	9.91	9.24
extraction	0.109	72.92	7.95	0.109	72.92	7.95
Material cost			1.24			1.24
Total at roadside			**16.50**	**1.041**		**18.43**
Forest fuel						
cross-cutting	0.107	12.35	1.32			
piling	0.348	6.04	2.10			
Total in cutting area	*0.455*		*3.42*			
extraction	0.104	72.92	7.58			
Total at roadside	*0.559*		*11.00*			
chipping	0.060	192.54	11.55			
transportation	0.103	66.46	6.85			
materials			0.95			
Total forest fuel cost			**30.35**			

Final cuttings

Plot 2P-2 (0.17 ha)

For the measurement of stand parameters in every demonstration area 4-6 temporary sample plots of 400 m² each were measured. In a sample plot the dbh of every tree and 3 or more tree heights for the main element in each storey and 1 or more tree heights for each other element were measured.

Rokiškis FE, Sėlynės forest district, block 62, plot 7, 11

Site	Storey	Species	Age,	Productivity	Height,	Dbh,	Stocking
		composition	years	class	m	cm	level
Ncl	I	6S 2B 1P	85	II	20.9	23.1	

Production from plot (average stem volume is 0.489 m³):

	Traditional technology	Integrated technology
Industrial timber	32.7	32.7
Firewood	1.5	-
Forest fuel	-	10.3
Total, m³	34.2	43.0

Technology.

During forest fuel logging the motor-saw " Husqvarna 254X" was used, a team consisting of 2 people was working. Firewood was prepared only from the butt part of the stem. Forest fuel for boiler-house (top and branches and understorey brushwood) was piled up near technical corridors. In the traditional forest logging industrial assortments as well as firewood were pulled to technical corridors. Forest fuel and industrial assortments were extracted by the forwarder"Valmet 840Y" for 200 m. Chipping was carried out using the chipper "BRUKS-604 CT" attached to the tractor "K-700". The chipped wood was transported by the tractor "T-150" with the trailer of 25.3 m³.

Calculation of forest fuel cost in clear-cutting trial 2P-2.

Work	With forest fuel production			Traditional technology		
	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³	Work expenditures, hour/m³	Work cost, Lt/ hour	Total cost, Lt/m³
Trad. assortment						
production	0.863	9.54	8.23	1.071	9.47	10.14
extraction	0.109	72.92	7.95	0.109	72.92	7.95
Material cost			1.24			1.24
Total at roadside			**17.42**			**19.33**
Forest fuel						
cross-cutting	0.121	12.35	1.49			
piling	0.350	6.04	2.11			
Total in cutting area	*0.471*		*3.60*			
extraction	0.104	72.92	7.58			
Total at roadside	*0.575*		*11.18*			
chipping	0.060	192.54	11.55			
transportation	0.103	66.46	6.85			
materials			0.95			
Total forest fuel cost			**30.53**			