POTENTIAL AND COMPETITIVENESS OF BIOMASS AS ENERGY SOURCE IN CENTRAL BALTIC SEA REGION

RESULTS AND FINDINGS OF THE PURE BIOMASS PROJECT 2012–2013

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Tuomas Alijoki (ed.)

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INTRODUCTION

Efficient use and production of energy is a relevant factor for a sustainable economy and has significant effects on the development and preservation of the Central Baltic Sea Region environment in the next decades and centuries. Diverse use of biomass in energy production is important for increasing the energy supply to meet our growing demands.

The use of renewable energy sources (RES) is one of the most essential planning components of national and global environmental policy, connected to solving local, regional and global environmental problems, such as air pollution and climate change. Only some renewable energy sources – solar, wind and water – are practically inexhaustible. Biomass from farming and forestry are renewable, but not inexhaustible energy sources, which must be taken into account when intensifying their use.

A regional bioenergy strategy can serve not only as an answer to environmental problem issues topical in the region, but also to gain international context by promoting the transfer of technologies and knowledge and positioning the region as a significant international player in the development of bioenergy. Sustainable development criteria, as well as the structure and problems in the energy sector, can be most effectively assessed at the regional level. Due to the significance of renewable energy in national development plans, a regional bioenergy strategy can offer us an answer to the essential environmental issues in the Central Baltic region.

In the Pure Biomass project, criteria for sustainable development have been stressed, which allows us to assess the structure and problems of the energy sector most effectively at the regional level. The development scenario for project areas is related to increasing energy efficiency, obtaining and using renewable energy sources as well as developing modern technologies.

This publication offers the main results of the multinational Pure Biomass project in the form of articles written by experts in their own fields. The publication consists of studies conducted during the project and reveals the experiences gained within and also outside the project network.

The Pure Biomass project was started 1st of January 2012 as a consortium of five project partners from Latvia and Finland:

- Kurzeme Planning Region (Lead partner)
- Ventspils University College – ERI Ventspils International Radio Astronomy Center
- Ventspils City Council
- Turku University of Applied Sciences
- Valonia – Service Centre for Sustainable Development and Energy of Southwest Finland.

The subtitle of the Pure Biomass project is "Potential and competiveness of biomass as an energy source in the Central Baltic Sea region". The project was co-financed by Central Baltic INTERREG IV A 2007–2013 programme.

OBJECTIVES AND ACTIVITIES OF THE PURE BIOMASS PROJECT

The objective of the Pure Biomass project was to build public understanding about the benefits of using biomass for energy production. Project work was based on studies of biomass availability, technical-economic aspects and environmental protection. The results can be used to promote the technical and economic benefits of the use of different types of biomass feedstock in energy production in the project focus areas.

In order to achieve the project aims, the following tasks were completed:

- resource assessment analysis and mapping of regionally available biomasses
- assessment of forest biomass potential using remote sensing methods
- determining environmental aspects of biomass use
- testing and monitoring of regionally available biomass to determine the technical-economic parameters (including pilot project biomass plantations)
- evaluation of the technical-economic feasibility of using biomass for specific areas and financial analysis of the implementation of the results
- detailed guidelines for the financial-economic calculations and business plan development
- baseline information produced for the energy producers, local authorities and the public about biomass as a technically, economically and environmentally friendly energy source.

Studies on regional biomass resources show the availability and potential of different biomass types. Using satellite images and existing databases enables mapping of the resources remotely. Biomass resource management plans include the quantity and quality of the potential biomass and also the technical-economic feasibility of the resources. The biomass resource management plans also help local municipalities and businesses to start using biomass as an energy source.

The information obtained during the research is provided for further use – to regional and local municipality institutions with proposals for the optimisation of energy production and consumption. The results are also disseminated to the general public. Utilisation of renewable energy sources can have significant impacts on regional and local economic development and sustainability.

The lead partner in the project was the Kurzeme planning region, which is a subordinated public entity under the supervision of the Ministry of Environment Protection and Regional Development in Latvia. The Kurzeme Planning Region Administration ensures the planning and coordination of the development of the Kurzeme planning region, carries out the function of public administration in the area of public transportation in compliance with its competence and ensures cooperation among municipalities and state administration institutions. One of main functions of the Kurzeme Planning Region Administration is the identification of projects of regional importance, preparation of projects for financing from various financial sources and participation in the implementation process of projects.

PROJECT FOCUS AREAS

Kurzeme region – one of the five regions in Latvia - is located in the northern part of Latvia, along the coast of the Baltic Sea. The coast line of the Kurzeme region is more than 350 kilometres long. The Kurzeme region has total area of 13,600 km^2 , of which 51.9 percent is forested. The region consists of 18 districts and two big cities – Liepāja and Ventspils. The total population of the region is 299,000 and the population density is 22 people per km^2.

The Kurzeme region has a rich cultural heritage and traditions – fishing villages, small historical towns and cultural events. The region offers a wide range of nature protected areas, such as Natura 2000 areas, a national park, nature parks and reserves.

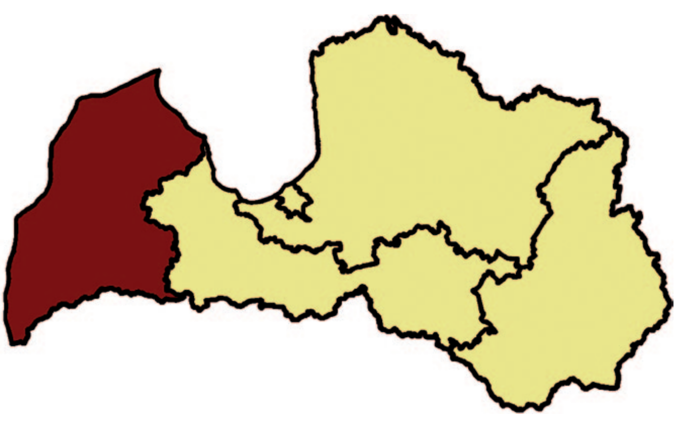

Figure 1. Location of Kurzeme in Latvia.

Southwest Finland is one of the 19 regions in Finland. With its beautiful archipelago and a long coastline it is closely connected to the endangered Baltic Sea. Southwest Finland is mostly lowland and is sometimes described as the granary of Finland. The total area of Southwest Finland is about 20,500 km^2. The total population of Southwest Finland is 470,000 persons and the population density is 44 people per km^2.

The region is made up of 28 municipalities of which 11 are towns. Turku, established in the 13th century, is the biggest and the most significant city of the region – it is also the oldest city and a former capital of Finland. Turku offers major traffic connections to the rest of the country to the north and to the west, and connects Finland with Sweden with ferries travelling across the archipelago.

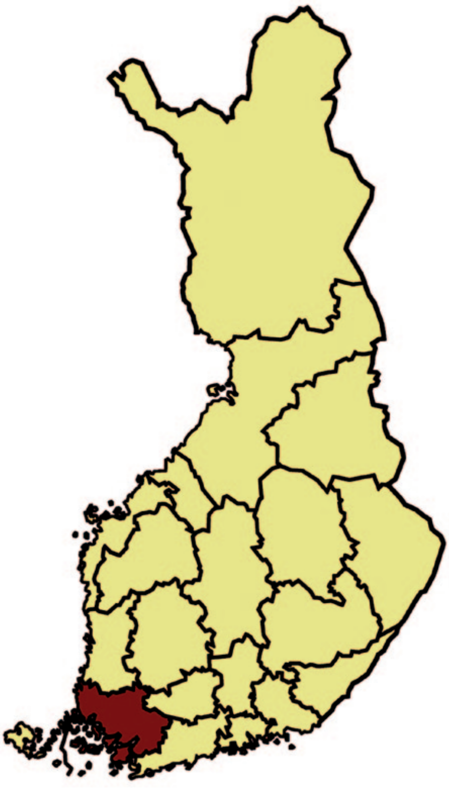

Figure 2. Location of Southwest Finland.

Edvins Drigins
Project manager
Kurzeme Planning Region Administration
www.purebiomass.eu

RENEWABLE ENERGY STRATEGIES – INTERNATIONAL, NATIONAL AND REGIONAL ASPECTS

Sanna Paloposki
Project coordinator
Turku University of Applied Sciences

Several EU-level, national and regional strategies are connected to the use of renewable energy sources and affect decision-making also in Southwest Finland. The main objectives are to significantly cut down greenhouse gas emissions and to reach carbon neutrality by the year 2030.

The European Commission required the Member States of the European Union to submit their national renewable energy Action Plans in 2010. The plans describe in detail the means by which each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption. The national renewable energy action plans describe the targets, the technology to be used, the trajectory to be followed as well as the measures and reforms to be undertaken to overcome the barriers to developing renewable energy. The national renewable energy action plans are based on Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources.

NATIONAL ACTION PLAN FOR FINLAND

The Finnish Ministry of Employment and the Economy's Energy Department submitted Finland's national action plan for promoting energy from renewable sources to the European Commission on June 30, 2010.

According to the action plan, the main outlines of Finland's approach to increasing the use of renewable energy are set out in the long-term Climate and Energy Strategy submitted as a report to the Finnish Parliament in November 2008 (VNS 6/2008 vp). The long-term Climate and Energy Strategy was updated in March 2013, when it was published as the National Energy and Climate Strategy, Government Report to Parliament.

According to the Finnish National Energy and Climate Strategy, Finland aims to reduce greenhouse gas emissions by 20 percent by the year 2020 in comparison to the levels in 1990, which is the EU-level target. In addition, the share of renewable energy sources in final energy consumption is targeted at 38 percent and the share of biofuel in transport fuels 20 percent, which both exceed the obligations set by the EU. It is assumed that Finland will reach the set targets in terms of both greenhouse gas emissions and the share of renewable energy sources in energy consumption. During the entire period of 2010–2019 Finland will already exceed the annual minimum targets for renewable energy set by the EU.

Finland will especially focus on increasing the use of wood biomass as a renewable energy source, as it is the most cost-effective way to increase renewable energy sources in heat and power production. Wood biomass will also be used to replace peat and coal. The aim is to replace coal by the year 2025. In addition to wood biomass, the use of field biomasses and manure as well as by-products and waste from the food industry as energy sources will be supported in Finland. The development of biogas production will be encouraged. Total biogas production in Finland is targeted to reach 0.7 TWh by the year 2020. Thus, biogas production is financially supported in Finland.

In addition to the financial support for biogas plants and other renewable energy forms, research and development of new technologies is a key issue in Finland, as well as education, guidance and communication.

REGIONAL OBJECTIVES

At the regional level, the utilisation of renewable energy sources is described in the Energy Strategy of Southwest Finland 2020, which was published by The Centre for Economic Development, Transport and the Environment for Southwest Finland (ELY Centre for Southwest Finland) in 2010.

At the moment, energy production in Southwest Finland is highly dependent on nonrenewable energy sources, which cover about 90 percent of the total primary energy production of 16,000 GWh in the area. Coal and oil consumption is exceptionally high in Southwest Finland compared to the rest of the country. The goal set in the Energy Strategy of Southwest Finland is that by the year 2020 the international and national climate and energy targets will have been reached in the region and the region will be on its way towards carbon neutrality. The strategy also emphasises the positive impact of new technologies on economic life in the region.

Because the use of energy sources of agricultural origin is at the moment rather insignificant, even a drastic proportional increase will not result in large amounts of energy produced. In addition to the potential of biomasses, technical, economical and societal matters will also affect the amount of energy produced using renewable energy sources. Thus, the decisions made locally by individual landowners and producers are significant. By the means of different financial support systems, the attractiveness of local heat and power production at small scale plants can be increased.

The Energy Strategy of Southwest Finland names carbon neutrality as one of the three main targets in the region's energy production. Even if it might not be possible to reach carbon neutrality by the year 2020, energy production should be developed so that carbon neutrality is possible by 2030. At the same time, greenhouse gas emissions should decrease by at least 50 percent by 2020 from the 2007 level.

Even if total energy production remains at its present level, the share of renewable energy sources should reach 40 percent of the region's own energy production, 50 percent of the district heat production, 33 percent of electricity production and 20 percent of traffic fuel. Most of these goals exceed the national and international targets (Fig. 1). As far as possible, energy production should utilise local energy sources. This will be encouraged by, for example, supporting local energy investments and innovations.

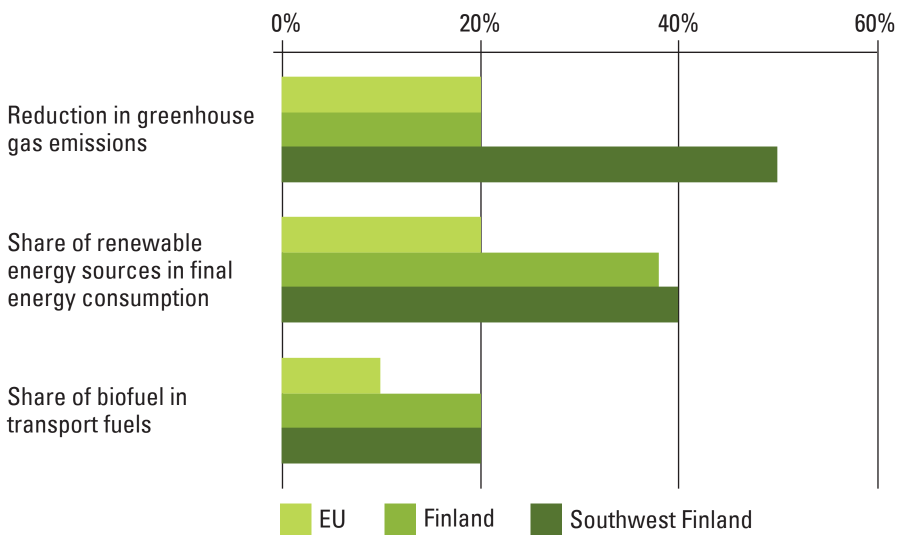

Figure 1. EU, national and regional targets for the reduction of greenhouse gas emissions and the share of renewable energy sources and biofuels. The targets are set for the year 2020 compared to the levels in 1990.

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ENVIRONMENTAL IMPACTS OF USING BIOMASS

Tuomas Alijoki
Project assistant
Turku University of Applied Sciences

Katariina Hirvonen
Student assistant
Turku University of Applied Sciences

Sanna Paloposki
Project coordinator
Turku University of Applied Sciences

Assessing the environmental impacts of bioenergy production is a challenge, because both direct and indirect emissions arise from every phase of production. Long-term planning and wise land use can ensure that the impacts on the environment will not become ecologically unbearable.

This article is an abridgement of the original study conducted by a student on the degree programme of sustainable development at Turku University of Applied Sciences in the summer of 2013. The object of the study was to collect information about the various environmental impacts of the use of biomasses in Southwest Finland on a general level. The research was conducted by investigating existing research material as well as conducting interviews with experts in the field.

THE MAIN INDICATORS FOR ENVIRONMENTAL IMPACTS

The use of biomasses in energy production can be justified by the benefits in the fight against climate change. The combustion of biomass releases carbon, but it will be ultimately an essential building block for growing biomasses. In comparison, the use of fossil fuels releases carbon which has been out of the cycle hidden in Earth's crust for long periods of time. In the year 2008, 87 percent of energy produced in Southwest Finland was based on fossil fuels – oil, natural gas and coal. There is room to improve the use of renewable energy sources. Using biomasses in energy production is an efficient way of reducing greenhouse gas emissions by recycling carbon.

Even though greenhouse gas emissions are the focus of most life cycle analyses on bioenergy, there are also other environmental impacts which have to be taken into consideration: acidification, particulate matter emissions, impacts on the ozone layer, eutrophication, toxicity, impacts on biodiversity and soil erosion were also analysed in this study. These factors are important when creating an overall picture of the use of biomass as energy.

It is challenging to estimate the environmental impacts of the use of bioenergy production. The utilisation of biomass causes both direct and indirect emissions. These emissions arise from every phase of production: cultivation, harvesting, refinement, transportation, energy use and disposal. It is also a challenge to compare the benefits and impacts of different biomasses with one another. One is most suitable for use in energy combustion and the other one can be used when refined as biodiesel. Rough estimates can be made using the main indicators for environmental impacts. The environmental impacts of bioenergy production are relative to the used biomass source and refining process.

SUMMARY OF THE RESULTS

Most of SO_2 emissions in Southwest Finland come from large scale power plants which use fossil fuels. The use of renewable biomasses in energy production has only a minor or no contribution to acidification. Results have shown that a high moisture content of the biomass combusted in CHP plants decreases the thermal value and lowers the combustion temperature and thus increases the amount of combustion gases and particulate matter emissions in the process. The environmental impacts of combustion can be controlled by drying the matter properly before the actual energy use. The combustion of wood and crops is advantageous compared to coal – it will most likely produce less SO_2 and NO_x emissions. Nitrogen oxides affect negatively the formation of ozone in the lower parts of the atmosphere. Thus, lower emission levels in the energy use of wood and other biomasses do not have a significant negative impact on the ozone layer.

Particulate matter emissions from power plants are similar, regardless of what type of fuel is used. This is because efficient particle filters are necessary in larger scale plants. To minimise particulate matter emissions, it is necessary to use highly refined fuels such as pellets. By using biodiesel instead of ordinary fossil diesel, particulate matter emissions can be cut to 20–39 percent. Combustion of wood on a household scale with basic equipment is a source of particulate matter. However, because this kind of energy production takes place in sparsely populated areas of Finland, it does not seem to significantly contribute to negative health effects.

The cultivation of crops and field biomass causes nutrient loads which contribute to the eutrophication of water systems. The amount of the load is relative to many factors such as the cultivated plant as well as cultivation practices, location and area. With perennial plants, the vegetation is long-term and nutrient loads can be cut by even 20–25 percent. With annual plants the impacts can be just the opposite. Soil without a vegetation cover is vulnerable to erosion and landslides, which both contribute to eutrophication in the form of increased nutrient loads. Harvesting of the non-cultivated plant Common reed (Phragmites australis) for energy production is a potential way to remove nutrients from water systems. In some areas this is problematic, because vast reed bed areas can work as a buffer zone and protect against coastal erosion.

Biodiversity can be assessed by studying the amount of different live organisms as well as the number of extinct or degraded species in the given area. The most significant negative impacts on biodiversity are caused in the early stages of bioenergy production in agricultural, coastal or forest environments. Production, transport and refinement may cause the decline of habitats of species. Thus, the living conditions of organisms might be reduced in areas where biomass energy sources are produced.

CONCLUSIONS

When the environmental impacts of different energy sources are assessed, some important points have to be taken into consideration. Firstly, is the supply of the used biomass executed so that it is sustainable and will not affect the productivity of, for example, soil or coastal areas? It must be guaranteed that the ecological impacts will not become unbearable. Secondly, will the impacts of bioenergy production be greater than the use of some alternative way of producing energy? These possible differences and reasons for them must be studied. The exact comparison of impacts of different biomasses with each other is not worthwhile in this case, because finding the best biomass alternative in every sense is not possible by using only theoretical data.

The justification of using biomass as a source of energy must be stressed. Some sources can be utilised in an alternative manner – building material, fertiliser, etc. – adding up the economic value of the biomass and avoiding the negative environmental impacts of energy use. In some cases, the right way to utilise biomass depends on the preferences of the person in question.

Even so, bioenergy production can be economically feasible and environmentally friendly if local solutions are applied. It is not cost-effective to transport biomass from the other side of the globe or even the country – at the moment, biomass must be produced, processed and consumed locally. Negative environmental impacts can be addressed and controlled with long-term planning and wise land use. The energy potential of biomasses in Finland is relatively small compared to overall energy consumption. Thus, the use of biomass in energy production can only be a partial solution in controlling greenhouse gas emissions and climate change. Saving energy and the efficient use of already utilised resources play a great role in this global challenge.

SOURCES

Hirvonen, Katariina 2013. Environmental impacts of the use of biomass in Southwest Finland. Report in Finnish. Available at www.purebiomass.eu > Materials.

MAPPING BIOMASS AND ASSESSING POTENTIAL USING REMOTE SENSING DATA

Agris Traskovs
Project scientific officer
Ventspils University College

Linda Gulbe
Project scientific officer
Ventspils University College

Remote sensing provides information about land cover and can be used for the assessment of biomass potential in vast areas. Satellite images were used to study the current and upcoming situation in the Kurzeme planning region.

Ventspils University College carried out the estimation and mapping of above ground biomass, bioenergy and forest inventory parameters for the Kurzeme planning region using automatic remote sensing data processing methods and assessment of biomass potential. The objective of this study was to research ways to evaluate, map and predict forest stand parameters.

As a result, thematic maps containing biomass-related information, technical specifications about the application of remote sensing data processing and data requirements were produced. Biomass-related information consists of a forest area map, tree species map, forest standing volume and biomass map, forest bioenergy map as well as maps of other forest inventory parameters.

Performed studies are focused on forest areas, since forests in the Kurzeme region are the largest biomass container compared to other biomass resources. However, local forest conditions are quite complex for automatic processing, because Latvia is situated on the border between two different forest types: northern coniferous trees and deciduous trees of a temperate climate zone. For this reason, diversity in the forest structure is very high – there are variations in stand age, density and volume, and there are mixed stands with different tree species combinations and different fertility conditions.

Figure 1. Forests in the Kurzeme planning region.

JUSTIFICATIONS FOR THE USE OF REMOTE SENSING

Previously the forest inventory was performed using on-site measurements, which is a comparatively expensive and slow process. A remote sensing approach can overcome most of these problems by allowing comparatively cheap production of wall-to-wall thematic maps containing information about forest inventory parameters.

Satellite images provide regular information about land cover in vast areas. However, the quality of these images is often affected by atmospheric conditions, such as haze or clouds, and medium spatial resolution which characterises how large the smallest object observable is in the image. Meanwhile, airborne data can be acquired in beneficial weather conditions with higher spatial resolution, but the financial expenses are significantly higher. Since each data source has both advantages and limitations, different remote sensing data sets were used in the Pure Biomass project.

1. Multispectral satellite images of Landsat TM/ETM+ and SPOT HRVIR1/2

These sensors record reflected sunlight from the Earth's surface features. Information is obtained in visible light and also in the parts of the electromagnetic spectrum which is invisible to the human eye (e.g. infrared).

Both summer and winter season images are employed in the project to explore the seasonal effects on biomass mapping as well. However, the most significant challenges in data processing were related to spatial resolution. One pixel (smallest element of the image) in a Landsat TM image corresponds to a 30x30 m area on the Earth's surface and it is common that this area can contain more than one land cover type.

Figure 2. Landsat TM summer satellite image (true color).

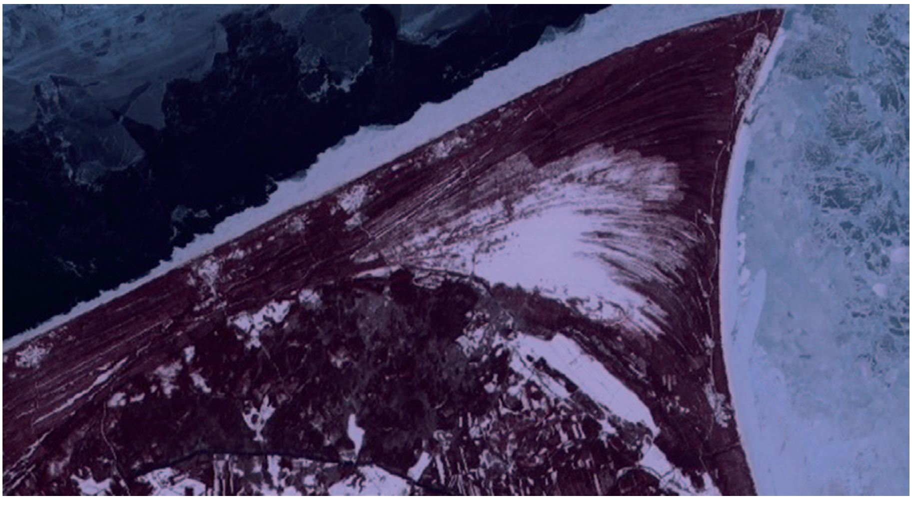

Figure 3. SPOT HRVIR1 winter satellite image (false color).

2. ALOS PALSAR SAR satellite data

SAR (Synthetic Aperture Radar) systems employ their own microwave radiation instead of sunlight to illuminate features on the Earth's surface. SAR data can be obtained at any time of the day and in any weather conditions since microwaves are capable of penetrating through all atmospheric conditions.

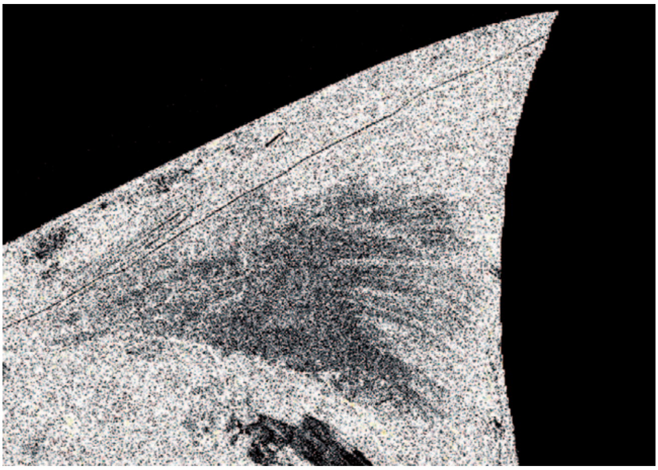

Figure 4. ALOS PALSAR SAR image.

3. LIDAR airborne data

LIDAR (Light Detection and Ranging) technology transmits pulses of laser light toward the Earth's surface and measures the time of the pulse's return. Time information is processed to calculate distances between an airplane sensor and different features on the ground. LIDAR data gives information about the three dimensional structures of forests.

4. MODIS NPP

NPP is designed to monitor global ecological conditions, such as large-scale climate shifts, deforestation, desertification, pollution damage, crop conditions, glacial retreats, flooding, wildfires and urbanisation. It is updated daily by NASA.

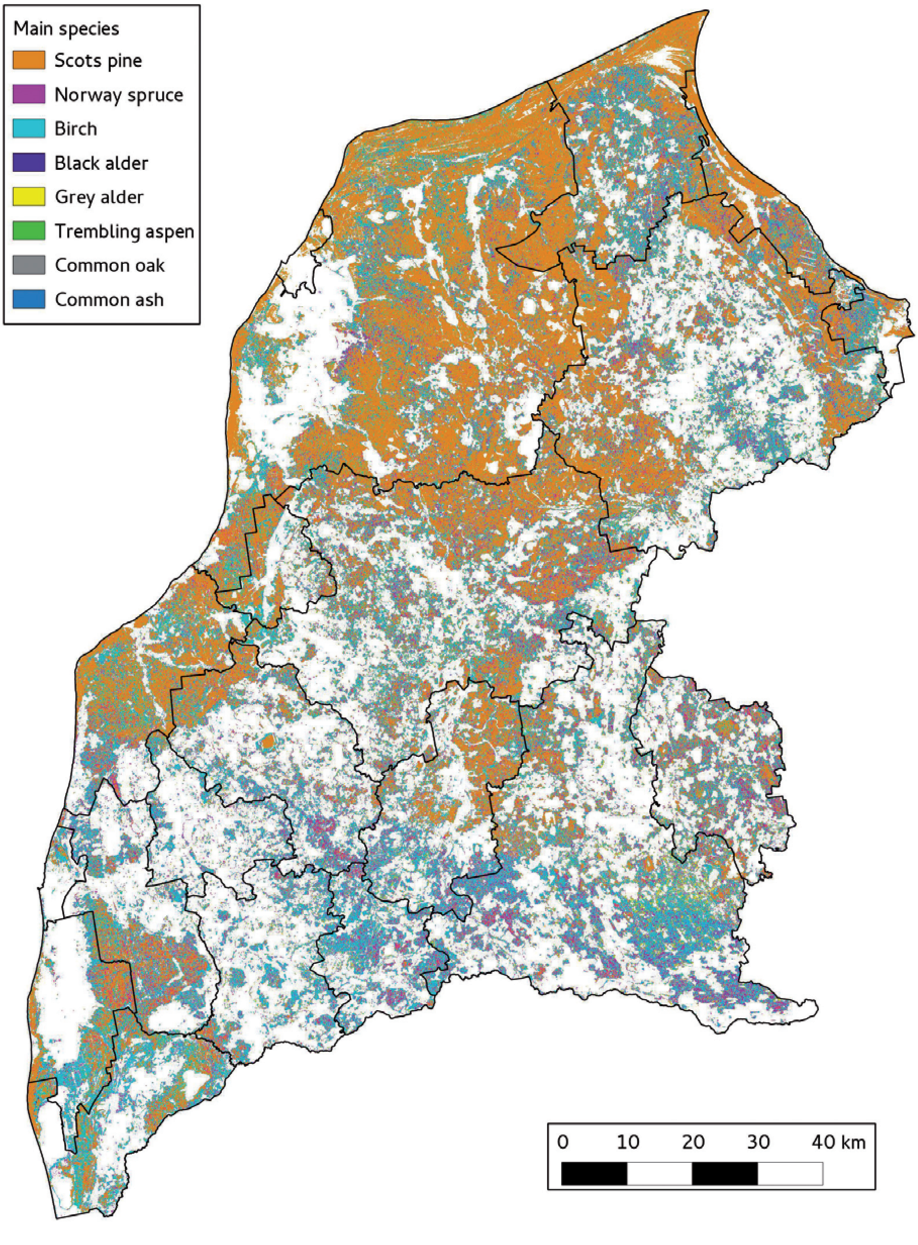

Figure 5. Example of MODIS NPP data.

BIOMASS MAPPING PROCESS

Thematic maps about forest biomass and other forest parameters are automatically prepared using special types of methods called supervised classification. A classification task is to examine each pixel in a satellite image and estimate all forest inventory parameters of the area on the ground corresponding to this pixel. The whole supervised classification procedure can be divided into three steps: preparation of training data, classification and validation of the results.

1. PREPARATION OF TRAINING (SAMPLE) DATA

During this stage the analyst needs to select sample data, which are used to teach the classification algorithm how to perform mapping (how different land cover types, such as forest, agricultural land, looks in the remote sensing data), and develop a numerical description of the variables the mapping needs to be focused. A sample data set contains remote sensing data values and corresponding forest inventory values obtained from field measurements. This is the most important and also most challenging part, because classification accuracy depends a lot on how qualitative sample data are selected. Quality generally means how well different tree species can be distinguished in the satellite image and if there are good relationships between the biomass values and the values of the satellite image pixels.

The following steps were performed to prepare training data:

a) **Ground truth data set –** A forest inventory data base was checked for faulty records. Visually it is impossible to distinguish even different tree species in a satellite image, so accurate information about forest stands is crucial.
b) **Calculation of biomass using a Shvidenko model.** The forest inventory data base does not include information about biomass, so modelling to estimate the total above ground biomass and biomass of different parts of the tree (such as stem, branches and leaves) was employed and added to the forest inventory data base.
c) **Automatic selection of sample stands in satellite images** using forest inventory database (Fig. 6).
d) **Sample data quality check.** Stands with high variations, such as different ages or volumes were taken out of the sample data set as well as mixed pixels and outliers.

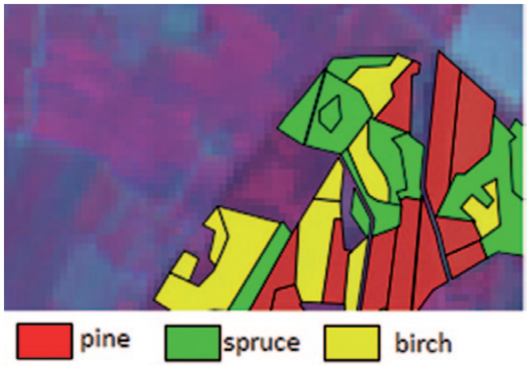

Figure 6. Selected sample stands in the satellite image for the three most frequent tree species.

2. CLASSIFICATION

Several classification algorithms were tested and evaluated for biomass mapping: k-nearest neighbours, regression trees, and neural networks. Classification is performed by comparing each satellite image pixel with sample data pixels, and the algorithm looks for the most similar sample pixels to the unknown satellite image pixel that has to be classified. Forest inventory parameters for the unknown pixel are estimated using forest inventory parameter values for the most similar sample pixels. Details on how to perform the comparison are unique to each classification algorithm.

Since the most valuable information can be obtained using different sensor data, data fusion was also studied during this project. Data fusion means the combined processing of different sensor data to improve the accuracy of the mapping. However, even in the case of data fusion, the challenging tasks to be overcome remained the weak relationships between forest inventory variables and remote sensing data values, mixed pixels containing more than one land cover and the fact that the pixel digital value is affected by many parameters at once, such as both tree species and stand density (Fig. 7).

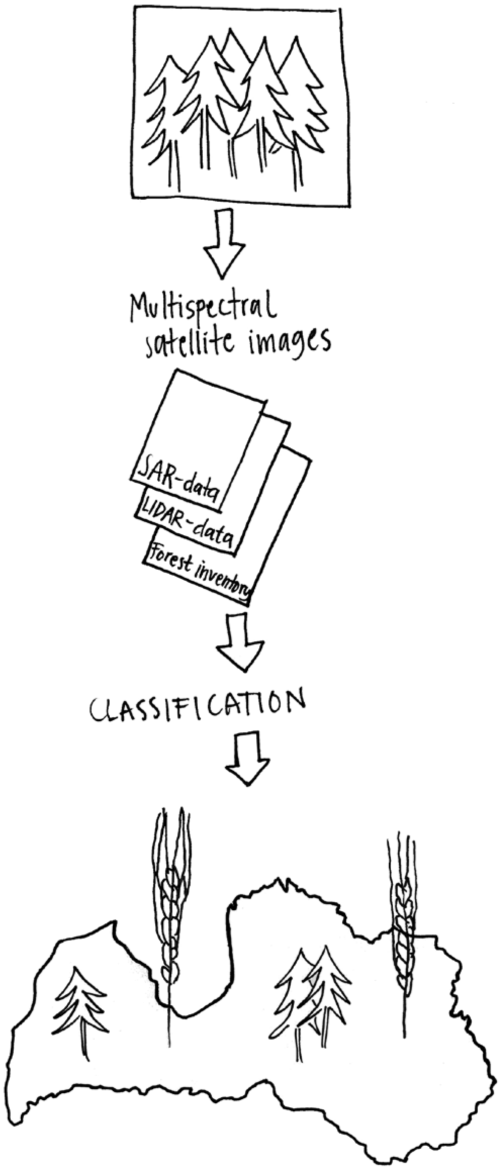

Figure 7. Data fusion means an integrated approach to different sensor data processing to prepare thematic maps (Drawing: Anna Hallvar).

3. VALIDATION OF THE MAPPING

The final step is the assessment of accuracy for thematic maps to check the validity of the results. Basically, this means the reliability of these maps. There are plenty of methods on how to assess the accuracy based on mathematical statistics, but the most popular is performing a classification on data for which forest inventory parameters are already known and comparing the results. In this study, intensive efforts were put to validation to show the possibilities and limitations of remote sensing data classification.

MAPPING RESULTS

The results of the mapping are thematic maps, which are in the form of geocoded images (GeoTiff). This means that the user can easily load these maps in GIS and process them together with other data. The prepared maps show forest areas and forest cover, aboveground biomass and bioenergy, biomass estimates for different parts of the trees and the most important forest inventory parameters, including standing volume separately for deciduous trees.

Figure 8. Location of the thematic maps' fragment.

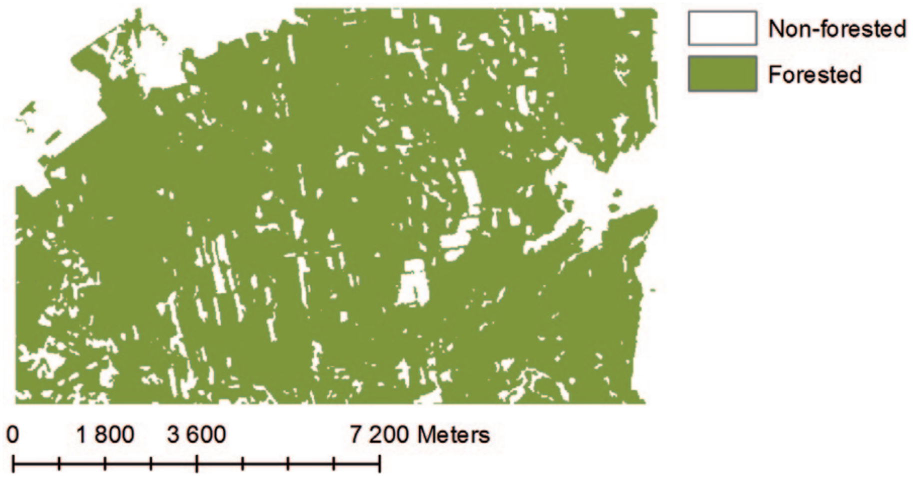

Figure 9. Forest area map.

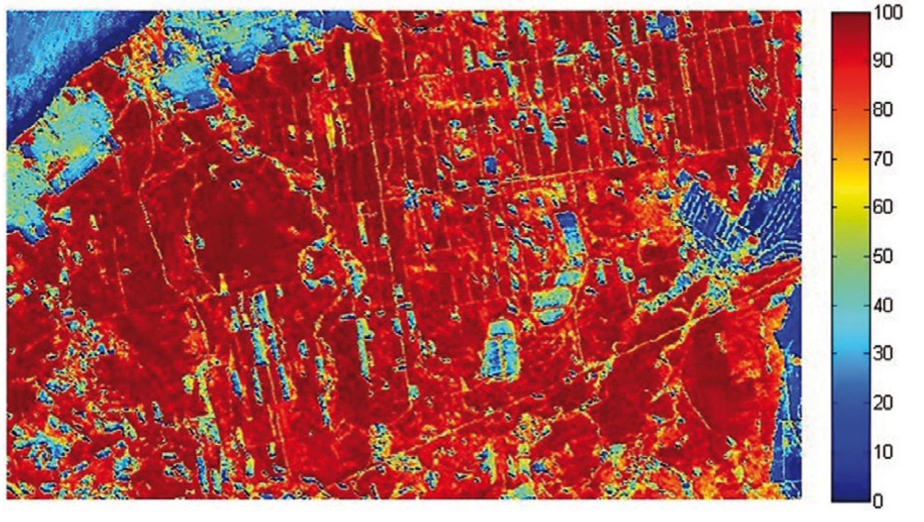

Figure 10. Forest cover map showing percentage of forest cover within each pixel.

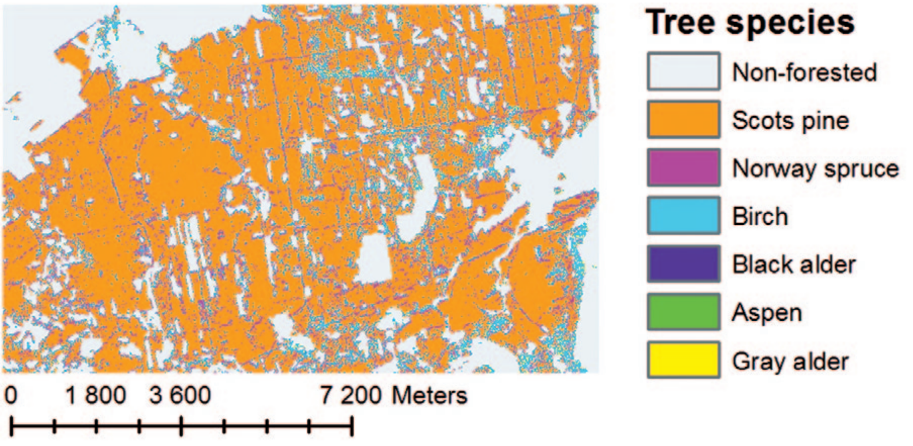

Figure 11. Tree species map.

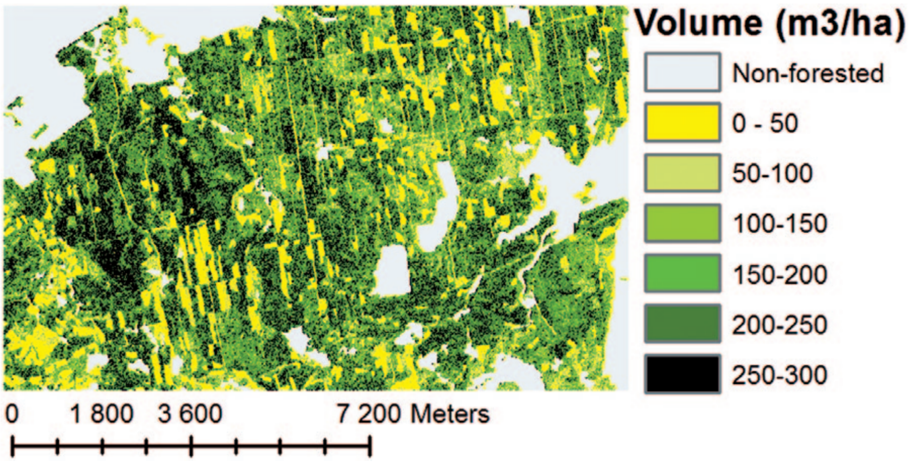

Figure 12. Standing volume map.

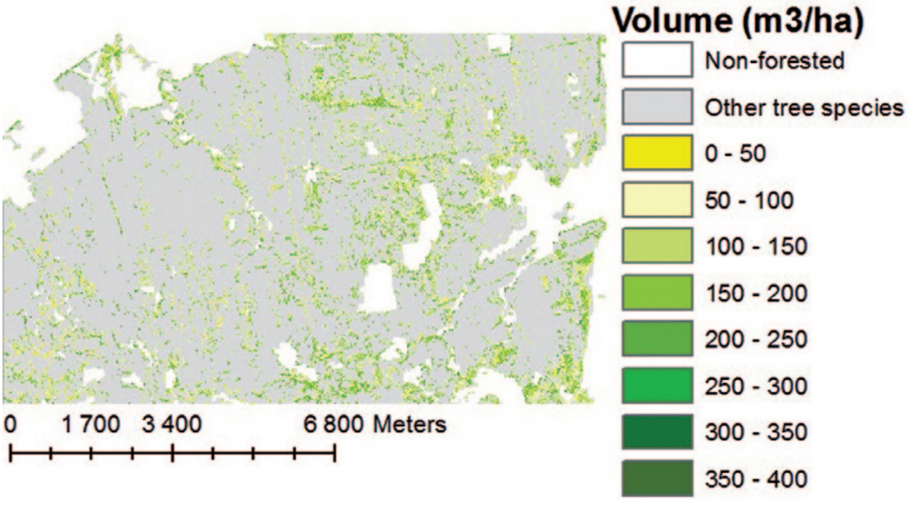

Figure 13. Above ground biomass map.

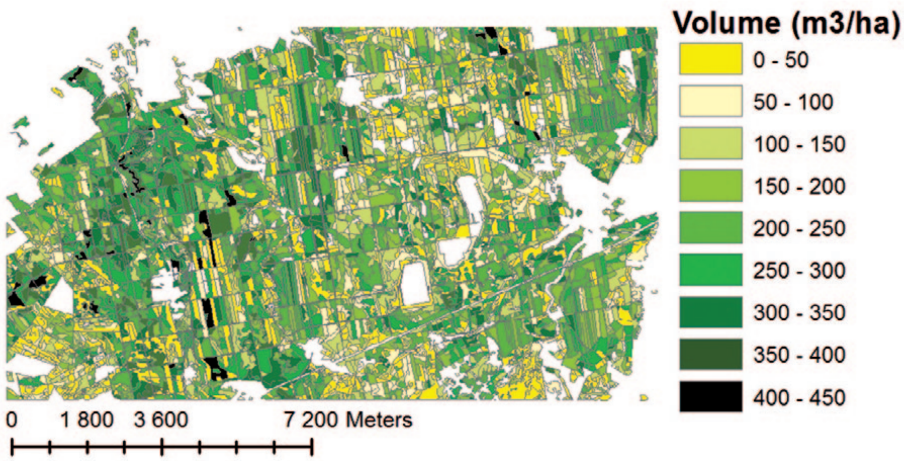

Figure 14. Standing volume map for deciduous trees.

ASSESSMENT OF BIOMASS POTENTIAL

Estimates of the amount of biomass in future can be very useful as they allow some foresight for the possible problems or future possibilities in the field. Such predictions can also be used to decide on the economic possibilities of biomass usage for different uses. However, caution should be maintained, especially in cases when long-term predictions are made. As the long-term future is unpredictable, these predictions should be seen more as a possible outcome if no major events influence the situation. No such event can be included in the prediction, so the predictions are more or less the best case statistical assessments, since events such as major storms, floods or droughts are bound to occur at some point.

An Estonian differential forest growth model was used as a basis for these predictions. Taking into account the geographical vicinity, the assumption was made that it would work without problems also in the Kurzeme region. Some changes were made, because the model itself was created for a maturing forest. The newly seeded stands were not included in the original model, so the age range had to be assessed using a regression analysis. When the young forest stands were assessed with the calculated linear formula, the data was given to the base forest growth model.

The predictions themselves include the growth prediction of different forest parameters such as forest stand age, height, diameter and volume – parameters that can be only assessed as statistical values. The parameters differ depending on the stand fertility and tree species that grow there, making the model as dynamic as it can be. The model also includes the thinning of stands as they grow. Most forest owners perform this as it benefits the stand and its growth.

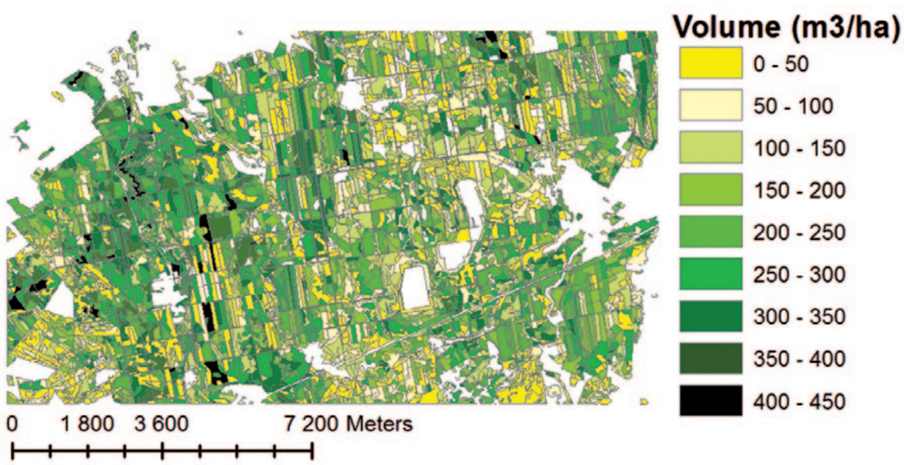

Figure 15. Forest standing volume for 2015.

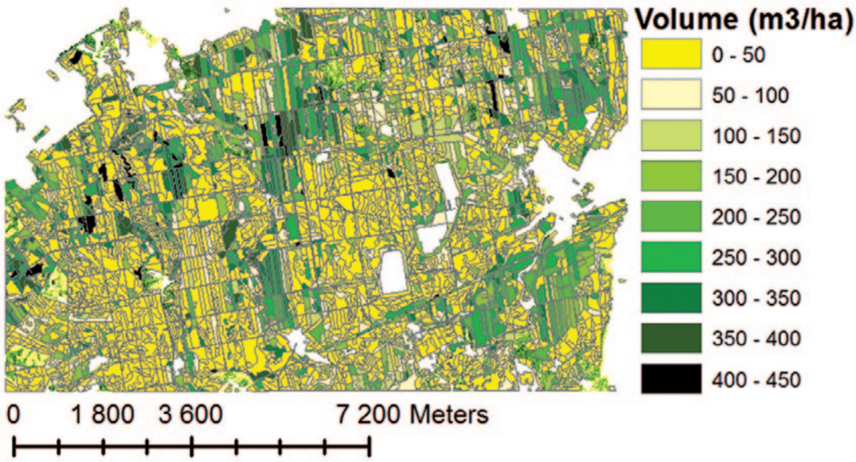

Figure 16. Forest standing volume for 2025.

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BIOMASS POTENTIAL IN SOUTHWEST FINLAND

Tuomas Alijoki
Project assistant
Turku University of Applied Sciences

Sanna Paloposki
Project coordinator
Turku University of Applied Sciences

Southwest Finland holds a vast biomass potential that is only marginally utilised. Even though the majority of the total biomass potential consists of wood biomasses, there are various other unused renewable sources of energy which must be taken into consideration when meeting the national and international energy objectives.

The utilisation of biomasses in energy production is strongly supported by the need to restrain climate change, cut down greenhouse gas emissions, secure energy supply and increase the local employment rate. In Finland, wood biomasses are already highly utilised. The availability of wood has led to a situation where the demand for other biomasses has not yet existed. Also, the technology suitable for the processing and utilisation of different types of biomasses is not yet widely available or is underdeveloped. Financial support for the use of alternative biomasses is insufficient. For comparison, in Denmark, where there is a continuing deficiency of wood biomass, energy usage of straw is strongly supported.

In the near future, the European Commission will control and minimise the use of food plants as a source of bioenergy. Crops suitable for food production are not legitimate for financial support intended for energy plants cultivation after 2020. Thus, upcoming financial support will determine which biomasses can be utilised in energy production. These new alignments may create a new demand for the utilisation of, for example, common reed, hemp, biowaste and algae. Such a market shift will surely generate new practical solutions, which are needed in order to increase wider scale energy utilisation of biomasses. By developing innovative technologies it is possible to alter the structures of energy production and decentralise it.

To meet future demands and needs, the current situation of the location and amounts of available renewable biomasses must be assessed. These calculations can later be used as support for policymakers and other planners as well as a tool for raising awareness among citizens. The results of this biomass potential assessment in Southwest Finland are presented in the study ”Biomass potential in Southwest Finland”, which was conducted in a research hatchery by three students – Solja Helle, Jani Aarnio and Juho Kanerva from Turku University of Applied Sciences – in the autumn of 2012 (Alijoki & Paloposki 2013).

FOCUS OF THE STUDY

Southwest Finland holds a vast biomass potential that is only marginally utilised. As mentioned before, the majority of the total biomass potential consists of wood biomasses. Data about the biomasses was gathered from various reliable literature sources and local research organisations.

In order to have a clear view of the total amount of available biomasses in Southwest Finland, the study focused on:

- wood biomasses
- industrial and communal waste such as biowaste and landfill gases
- manure
- low-value fish from the sea and inland water fishing as well as waste from fish farming
- field biomass and uncultivated biomass such as grain and oilplants, hemp, reed canary grass, common reed and grass plants.

RESULTS

According to the calculations, the maximum potential of renewable biomass resources in Southwest Finland is 1,525 GWh (Table 1).

Table 1. Biomass potential in Southwest Finland.

Biomass	Quantity/a	Maximal potential (MWh/a)	Realistic potential (MWh/a)	Percentage % of maximum
Wood	636 990 ha	3 323 500	873 000	26
Biowaste	39 000 t *	49 000	- **	>50
Manure	2 037 700 t	285 000	200 000	70
Devalued fish	17 800 t	26 500	8 000	30
Field biomass	52 000 ha ***	2 084 000	354 000	17
Common Reed	17 100 ha	359 000	90 000	25
Total		6 127 000	1 525 000	

* Presumed comsumption
** Most of the potential is utilised in combustion together with other householdwaste
*** Surplus area from food production (Kola & Simola 2010)

According to the target set in the Energy Strategy 2020 in Southwest Finland, 40 percent of all energy production should be produced from renewable sources by 2020. If energy consumption remains at the level of 2010, renewable fuels should produce 7,400 GWh in 2020. (Centre for Economic Development, Transport and the Environment 2010)

Utilisation of biomasses will most likely increase in Southwest Finland due to the shown high potential as well as the urge to meet the national and international energy strategies. Success in fulfilling the demand of the strategies requires the adoption of the newest technologies and the use of other renewable energy sources, such as wind and solar energy besides biomasses, as well as a supporting the governmental system. Development in the demand and supply of biomasses is essential. This requires national level control and possible development support. A lack of knowledge, economic profitability, unsuitable technology and prejudice may set limits on biomass-based energy production.

Waste and industrial effluents are not included in this estimation. In reality, the technically and economically feasible biomass potential is lower than the estimate. Notable is also that peat is considered as a slowly replenishing natural resource and is excluded from the calculations. The maximum biomass potential was mainly reviewed in this study. Nevertheless, the social aspects, technical and economical viewpoints as well as environmental issues must also be taken into consideration when the total feasible and available volume of bioenergy is studied in the future.

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MONITORING BIOMASS THROUGH PILOT PLANTATIONS

Ivo Lemss
Project manager
Ventspils City Council

Pilot biomass plantations were established to cultivate and study the possible energy crops of the future. Monitoring was carried out with measurements of annual biomass growth, agro-technical characteristics and harvest peculiarities.

The most suitable energetic biomass cultures for biomass production purposes in Northern Kurzeme were determined during the project. This was achieved by setting up pilot biomass plantations near the city of Ventspils in Latvia.

Figure 1. Growth measurement of hemps (Photo: Ventspils City Council Development Department archive).

The Latvian State Forest Research Institute "Silava" developed an agro-technical plan for establishing and cultivating energy crop pilot plantations within the framework of the project. Energy crop plantations were established on the basis of this agro-technical plan. Biomass growth measurements were carried out each month in real time field research. (Fig. 1 & 2).

Figure 2. Growth measurement of Reed canary grass (Photo: Ventspils City Council Development Department archive).

Some of the energy crops were cut down in October 2012 and 2013 in order to measure the heat output and other characteristics of the biomasses. The measurements of annual biomass growth, agro-technical characteristics and harvest peculiarities were carried out in a laboratory.

BIOMASS MONITORING

One of the main characters of the biomass monitoring and assessment of the whole biomass volume which can be produced in a certain place and in a certain period of time period is the height (cm) measurements of different biomass species (reed canary grass, hemps, silver grass, willow) (Table 1).

Table 1. Biomass height measures (cm) July–October 2012.

Biomass height measures (cm) July – October 2012						
			Month			
No.	Species	Unit	July	Aug.	Sept.	Oct.
1.	Reed canary grass	Average, cm	30,7	56,1	56,9	No data
2.	Hemps – 25	Average, cm	122	168	151	153
3.	Hemps – 50	Average, cm	131	150	152	169
4.	Silver grass/ miscantus	Average, cm	24	40	56	57
5.	Willow/osier	Average, cm	31	78,4	92,6	96,5

During all periods of biomass monitoring from July 2012 until October 2013 different activities had been implemented. This included biomass species growth control, sample sites establishment and harvesting (ploughing, seeding, fertilisation, mowing) with sampling and visual assessment of biomass quality. (Fig. 3).

Figure 3. Biomass sampling (Photo: Forest institute "Silava").

Testing of biomass samples taken from the biomass fields contains also measurements of humidity, dry matter and ash content. These measurements were an important part of the whole biomass monitoring process in terms of achieving the project aim. (Table 2).

Table 2. Biomass humidity, dry matter, ash content measures July–October 2012 (Reports of the forest institute "Silava").

Biomass humidity, dry matter, ash content measures July–October 2012							
				Month			
No.	Species	Indicator	Unit	July	Aug.	Sept.	Oct.
1.	Reed canary grass	Humidity (average)	%	80,8	78,9	75	65,1
2.	Hemps		%				
3.			%	79,4	68,4	68,9	35
4.	Silver grass / miscantus		%	70,4	78	75,5	57,2
5.	Willow/osier		%	72,5	66	59,1	52,7
1.	Reed canary grass	Dry matter (average)	t/ha	0,3	2,3	2,4	2,3
2.	Hemps – 25		t/ha	3	6	5,1	3,4
3.	Hemps – 50		t/ha	2,8	5	5	5,3
4.	Silver grass / miscantus		t/ha	0,1	0,3	0,6	0,6
5.	Willow/osier		t/ha	0,4	1,5	1,4	1,3
1.	Reed canary grass	Ash (average)	%	13,1	9,2	8,4	7,4
2.	Hemps		%	11,1	7,6	8,3	3,5
3.	Silver grass / miscantus		%	12,4	8,4	8,9	8,4
4.	Willow leafs		%	7,2	7,9	8,1	7,9
5.	Willow / osier shoot		%	3,9	3,2	Wood – 1,2 Bark – 3,7	2,2

Heat efficiency assessment of the biomass enables calculation of heat output (MWh per ton dry matter) for one total average sample from each of the biomass species. Taking these results into account, the next step is to calculate MWh per tonne in natural humidity for each of biomass species. (Table 3 & 4).

Table 3. Biomass heat output measures for one total average sample (Reports of the forest institute "Silava").

Biomass heat output measures for one total average sample					
				Thermal output	
No.	Species	Indicator	Unit	Lowest	Highest
1.	Reed canary grass	Thermal output	MWh/t	5,197	4,871
2.	Silver grass / miscantus		MWh/t	5,229	4,88
3.	Willow/osier		MWh/t	5,506	5,157
4.	Hemps		MWh/t	5,219	4,877
5.	Hemps stubbles		MWh/t	5,217	4,874

Table 4. Biomass heat output measures August 2012 – February 2013 (Reports of the forest institute "Silava").

Biomass heat output measures August 2012–February 2013								
				Month				
				2012				2013
No.	Species	Indicator	Unit	Aug.	Sept.	Oct.	Nov.	Feb.
1.	Reed canary grass	Thermal output (average)	MWh/t*	0,49	0,7	1,25	0,64	No data
2.	Hemps		MWh/t*	1,07	1,04	2,92	1,87	3,614
3.	Silver grass / miscantus		MWh/t*	0,54	0,68	1,69	0,58	No data
4.	Willow/osier		MWh/t*	1,3	1,7	2,07	1,91	2,027
1.	Reed canary grass	Thermal output (average)	MWh/t**	4,85				
2.	Hemps		MWh/t**	4,86				
3.	Silver grass / miscantus		MWh/t**	4,86				
4.	Willow/osier		MWh/t**	5,14				

*Naturally humid.
**Dry matter.

RESULTS OF THE STUDY

It is clear that silver grass (*mischantus*) cannot be planted in so severe climatic conditions as they are in Latvia near the Baltic Sea. Other results so far can be evaluated by looking deeper into other studies' findings in Latvia and Europe.

Existing willow plantations in Europe show that the most productive clones are *Tora, Tordis, Torhild, Inger and Klara*. It is expected that productivity in industrial fields in three years will reach 25–30 tons per ha (dry hard biomass material). In Latvia, the average humidity value of freshly chipped willow is 49–55 percent, depending on the clone used and the harvesting time. Field experiments show that average heat combustion values are 18.9 MJ per kg or equivalent 5.25 kWh retrieved from three-year-old willow chips.

It is known that reed canary grass in Latvian conditions can give high biomass harvests with low humidity content and problems are related only to precipitation during harvesting time. There is no information available about silver grass harvesting experiences in large fields. In order to reach high productivity, silver grass requires a constant average temperature all through the year, which is usually common near Ventspils, but very cold winter conditions could be the big challenge if the air temperature drops very rapidly. So far, different silver grass species are successfully introduced in landscape gardens, where it has good growing conditions throughout the winter period. As a result, there is a high probability that fast growing, appropriate clone species for biofuels will survive our climate.

Figure 4. Newly planted aspen field in Kurzeme (Photo: Tuomas Alijoki).

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MARKET ANALYSIS OF BIOMASS UTILISATION

Ivo Lemss
Project manager
Ventspils City Council

Three energy use scenarios for 2025 were prepared for assessing possible future changes in the share of biomass usage. The analysis was based on international forecast data and existing fuel price fluctuations.

The objective of this study was to evaluate the current situation and future development until 2025 of the demand and supply of biomass in the existing and planned central heat supply systems of Northern Kurzeme. Municipal bodies and companies were also taken into account.

FOCUS OF THE STUDY

The study analysed biomass supply phases and processes, including processing, delivery, purchase and storage of biomass. The supply of biomass in each district of the Northern Kurzeme region is carried out in a different manner. Procurement procedures (e.g. in the Kuldiga district), open negotiating procedures (e.g. the Ventspils district and the city of Ventspils) as well as price surveys (e.g. in the Roja district) are used. There are also municipalities where firewood is stocked by workers of the municipality (e.g. in the Talsi district Ķūļciems civil parish).

The Northern Kurzeme region consists of the city of Ventspils and the following districts — Ventspils, Dundaga, Roja, Talsi, Kuldiga (*Kuldīga*), Alsunga and Mersrags (*Mērsrags*). According to the data of the Central Statistical Bureau of the Republic of Latvia, the total area of region is 7,211 km^2 and, at the beginning of 2012, the total number of residents was 116,500. The biggest populated areas of the region are Ventpils, Kuldiga and Talsi. Forestation in the Kurzeme region is at 55.3 percent.

Figure 1. North Kurzeme region covering 8 municipalities (Photo: Ltd. Ekodoma).

*Explanatory note. "Novads" in Latvian = "County" in English

The study analysed biomass supply chains and processes as a whole, including the preparation of biomass, supply, buying and storage. In each North Kurzeme region municipality the full supply chain of biomass differs.

FUTURE DEVELOPMENT OF FUEL PRICES

A price forecast for the types of fuel used in Northern Kurzeme until 2025 was prepared based on international forecasts and their trends and by analysing the previous fuel price dynamics in Latvia. An overview of energy sources in each municipality is given in Table 1.

Table 1. Total amount of energy production sources (CHP plants and sources owned by municipality) in eight North Kurzeme municipalities in 2012.

Total amount of energy production sources (CHP plants and sources owned by municipality) in 8 North Kurzeme municipalities in 2012				
No.	Municipality	Total number of energy production sources	Total input capacity, MWth	Fuels used
1.	Alsunga county	3	3,27	Firewood
2.	Dundaga county	9	3,8	Firewood, wood pellets
3.	Kuldiga county	38	26	Firewood, wood chips, wood pellets, diesel, natural gas
4.	Mersrags county	6	1	Firewood, liquefied gas, diesel
5.	Roja county	6	6	Firewood, wood chips
6.	Talsi county	58	55	Firewood, wood chips, wood pellets, coal
7.	Ventspils city	6	84	Wood chips, diesel, fuel oil, coal, wood pellets
8.	Ventspils county	29	17	Wood chips, diesel, liquefied gas, firewood

Based on international forecast data and tendencies, and by analysing existing heat fuel price fluctuations in Latvia (Fig. 2), a forecast of the development of heat fuel prices until 2025 was prepared for the North Kurzeme region (Fig. 3).

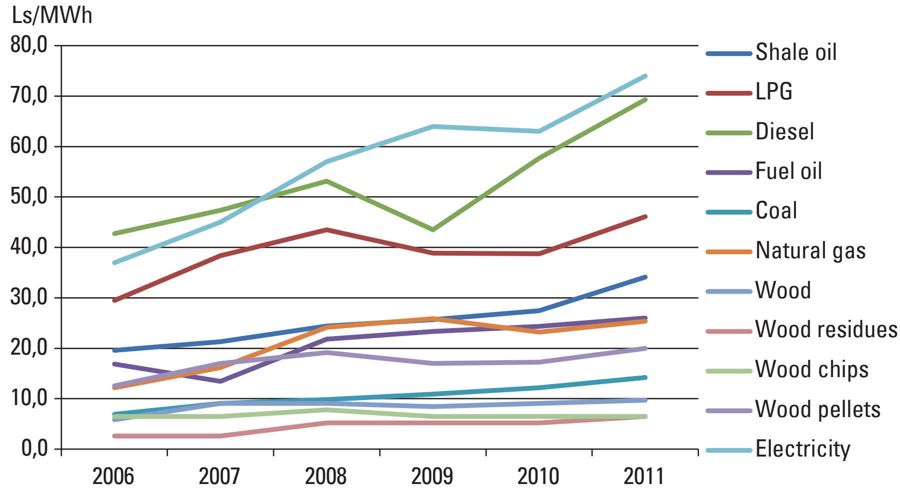

Figure 2. Average fuel costs in Latvia (Central statistical bureau of Latvia 2013).

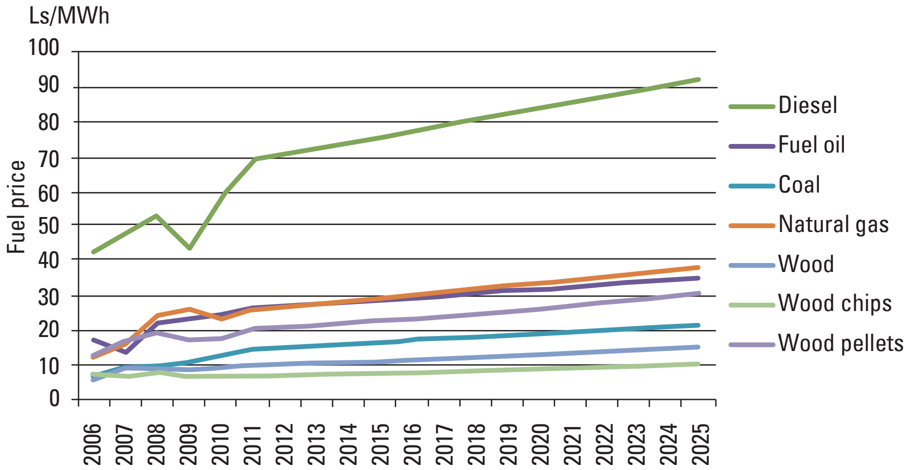

Figure 3. Biomass cost scenario until 2025 (European Commission 2009; Central statistical bureau of Latvia; Ekodoma Ltd. 2013).

From Figures 2 and 3 it can be seen that conventional energy sources are becoming more and more expensive in comparison with renewable energy sources both at the national level and international level cost scenarios. Although the price of coal is the third lowest of the energy sources, in the long-term perspective, coal as an energy source is exhaustible. Thus, biomass sources such as wood chips and wood pellets are a good option for combined heat and power production in different communities in the Central Baltic region or other European cities in the long term.

The fuel consumption structure in North Kurzeme 2012 is presented in Figure 4, which shows the current situation and the domination of wood biomass fuel.

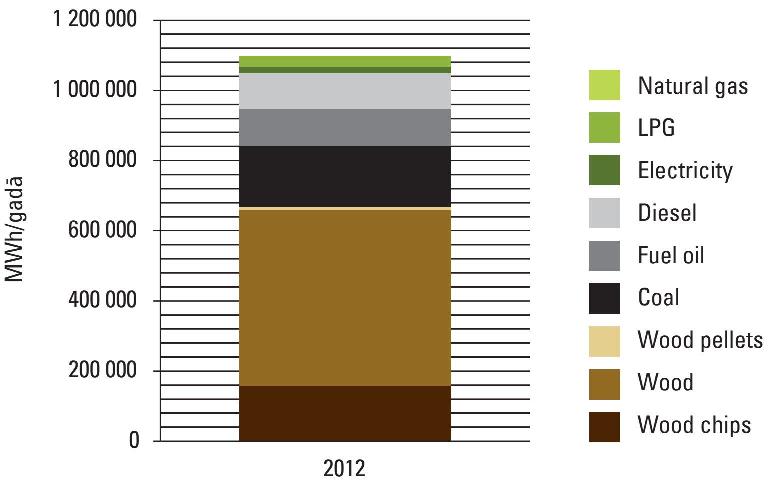

Figure 4. Fuel consumption structure in North Kurzeme 2012 (Ekodoma Ltd. 2013).

THREE ENERGY SCENARIOS FOR NORTH KURZEME

To assess the possible future changes in the share of biomass usage, three future scenarios were prepared – base scenario, RES scenario and sustainable development scenario. Depending on which scenario will be taken into account, changes in the biomass usage share differ (Fig. 5, 6 & 7).

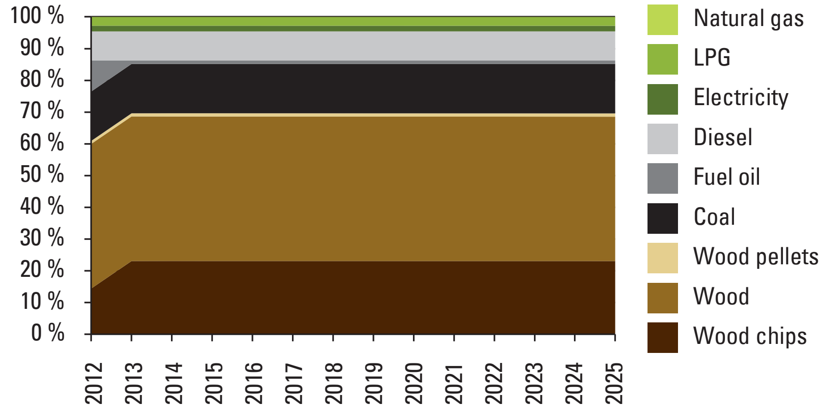

Figure 5. Base (0 alternative "business as usual") scenario – share of biomass % in North Kurzeme (Ekodoma Ltd. 2013).

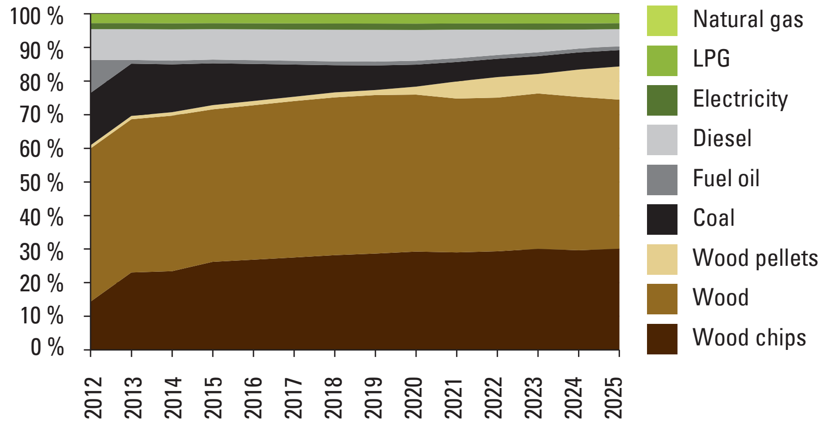

Figure 6. RES (totally "green") scenario – share of biomass % in North Kurzeme (Ekodoma Ltd. 2013).

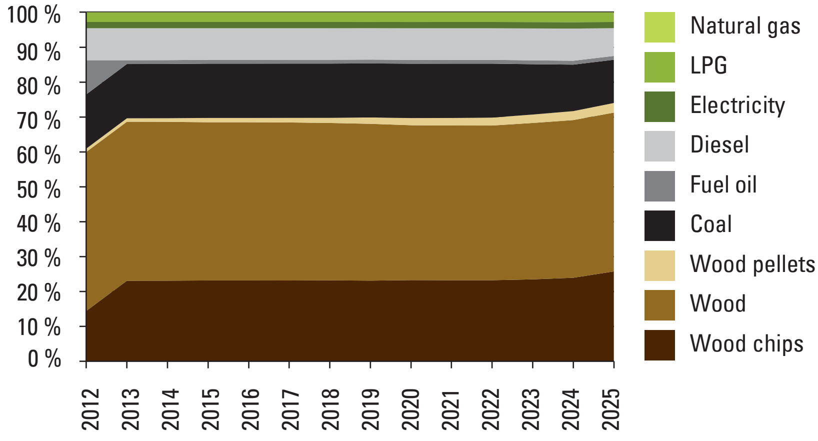

Figure 7. Sustainable development (investments in clean technologies in economically justified cases) scenario – share of biomass % in North Kurzeme (Ekodoma Ltd. 2013).

The base scenario shows that a continuing "do nothing" policy will keep the situation in a phase of "stagnation", consuming approximately the same amount of each energy source, while at the same time not achieving the "green" aims at the local, national or even European levels. The RES scenario shows that more and more investments in the development of green technologies (green production) are increasing the share of biomass quite fast during seven to eight years in comparison to the "do nothing" scenario, where nothing is changing. In this scenario, the share of biomass is approximately 65 percent in 2018 and approximately 80 percent in 2025. The sustainable scenario shows that a large share of biomass can be achieved in the long-term perspective (within 15 years).

SOURCES

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COST-BENEFIT ANALYSIS OF BIOMASS UTILISATION – FUTURE SCENARIOS IN THE KURZEME PLANNING REGION

Edvins Drigins
Project manager
Kurzeme planning region

A cost-benefit analysis allows the comparison of each type of biomass resource. On the basis of these calculations, it is possible to create future scenarios for determining the most efficient solution for the cultivation of biomass and to assess the technical indicators and costs of each type of biomass for the entire Kurzeme planning region.

The development scenario for the Kurzeme planning region, similar to Latvia in general, is connected with the increase of efficiency in energy use, obtaining and using new renewable energy sources as well as the development of technologies. The use of local energy resources and replacing imported fossil fuels is favourable for the development of Latvia and its citizens. Still, there is no societal consensus regarding the usefulness of renewable resources. Currently, the municipalities of the Kurzeme planning region have a unique opportunity to use this situation for the development of science and education, to increase the safety of energy supply and economic growth while simultaneously helping Latvia to maintain a reputation of an environmentally responsible country.

Data of the Central Statistics Bureau from 2011 show that the total area of forests in Latvia was 3,221 thousand hectares, of which 752.3 thousand hectares were in the Kurzeme planning region, and of which 401.2 thousand hectares were coniferous forests and 340.1 thousand hectares were deciduous forests. In separate regions, there is considerable mean stock volume per territorial hectare, but in other regions it could be increased. Regions with the largest proportional stock volume are the Ventspils, Alsunga, Grobina, Pavilosta, Roja and Mersrags regions, but with absolute stock volume they are Ventspils, Talsi, and Kuldiga.

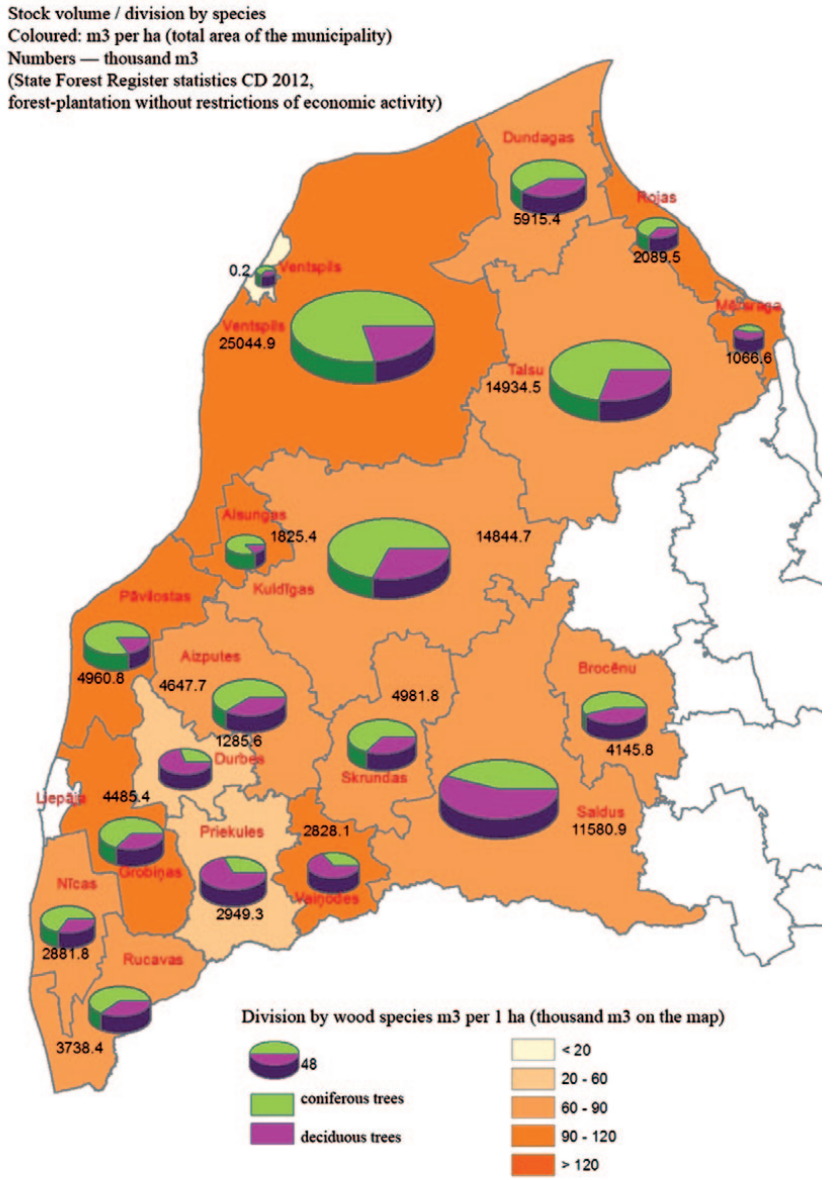

Figure 1. Stock volume and division by wood species, m^3 per ha / total area of the municipality.

It can be considered that there are more qualitative stands in the Kurzeme region as compared with the rest of Latvia. On average, forest coverage in the Kurzeme planning region is higher than elsewhere in Latvia. At the same time, relative demand for forest resources for deciduous trees in the entire Kurzeme region is sufficiently low. Deciduous trees could be a potential source for the production of energy wood, and this potential is not used sufficiently in Latvia.

Reserves of traditional energy wood product resources in Latvia after 2014 will be practically exhausted, which will cause a price increase in the segment of higher quality wood resources. However, the increase will not be uneven. A decrease in demand and low prices in the pulpwood market, together with the increasing local demand from energy sector allow Latvia to increase the resource base of fuel wood at the expense of lower quality wood products that were being exported up to now.

So that the municipalities of the Kurzeme planning region are able to predict price tendencies of fuel woodchips and economic stability of heat supply systems in the future, other possible types of alternative biomass resources must be assessed. This will help to ensure available raw materials for the consumption of residents and heat supply companies and guarantee a more stable price policy and heat supply rates in future in the entire Kurzeme planning region.

The uncultivated territories exceed the area currently used for growing energy cultures in the whole territory of the Kurzeme planning region, which means a significant potential for resources in the future (Fig. 2).

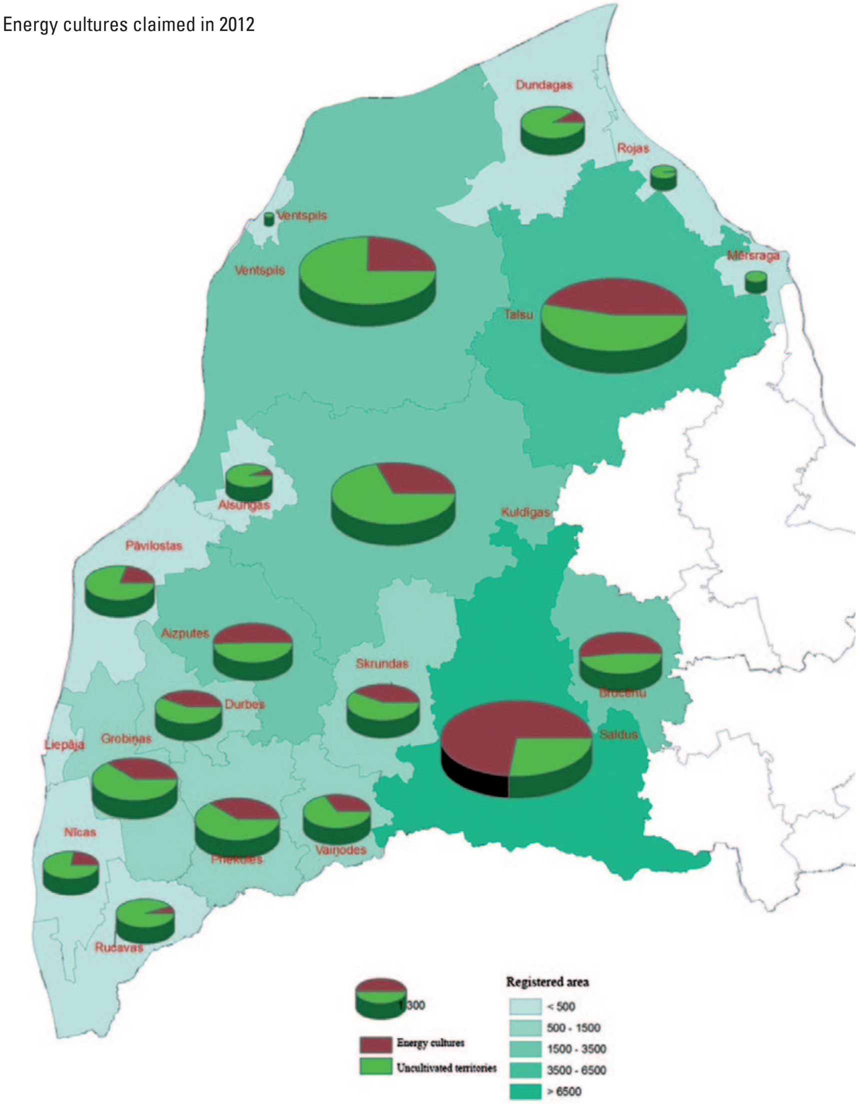

Figure 2. Areas of energy cultures registered with the Rural Support Service and their relationship to uncultivated territories.

LOCAL CONDITIONS FOR A COST-BENEFIT ANALYSIS

Analyses were conducted with the following types of biomass resources: quick-growing sallow, hybrid aspen trees, hemp, reed Canary-grass and elephant grass (or *Miscanthus*). For the purposes of preparing a cost-benefit analysis, several local conditions must be applied to all types of biomass resources and their production:

- total area is fixed at 50 hectares to ensure a sufficiently precise comparison with various biomass resources
- average evaluation period of 10 years is used, as some of the biomass resource cycles can last for 10 years, and some of them for a shorter period
- area of the land is part of the property where the project is implemented
- costs are evaluated according to the main types of costs per 1 hectare of the area
- discount value of the project has been established for all types equally and is based on the average financial profitability factor in the agricultural and forestry sectors in 2011, which is evaluated based on the data on how much profit a company has made per one unit of capital – according to the data of CSB about 2011, the financial profitability in agriculture, forestry and fishery after taxation was 13.241 percent
- for the purposes of a better comparison, the costs have generally been evaluated as a service provided by another company
- the produced end-result is expressed as the acquired volume of wood chip or pellets, which, if necessary, can be converted into units for measuring energy according to the values for each of the resources indicated above.

COST-BENEFIT ANALYSIS OF BIOMASS – CASE SALLOW

The following is an example of a cost-benefit analysis for quick-growing sallows. To plant one hectare of the territory with quick-growing sallows, approximately 12,000 sallow cuttings are necessary. The price of one cutting is LVL 0.03, which means that the purchasing costs on one hectare form a total of LVL 360. Sallows are sun-loving, shadow-intolerant plants which quickly react to the available nutrition in the soil. Therefore, when creating quick-growing sallow plantations, appropriate management such as preparation of soil and plants, mowing and fertilisation is required. With appropriate management of the plantation, the average amount of wood chip obtained from one hectare is 175 m^3. The first income should be expected in the third year of the cycle. The sales price of wood chip at the end of 2012 was approximately LVL 5.60 per m^3. Considering the inflation of the price of wood chip, the expected income in the third year of the cycle is LVL 50,980.

Table 1. Calculation of income and expenditure from sallow cultivation.

Calculation of income and expenditure, March 2013											
Year		1	2	3	4	5	6	7	8	9	10
Income											
Chip price, LVL/m³ of silage*	LVL/ m³ of silage	5,60	5,70	5,83	5,94	6,06	6,18	6,31	6,43	6,56	6,69
Sale of chips	LVL			50.980			54.100				58,56
*http://mezi.lv/lv/sludinajumi/?cfdsview=category&cfdscat=44											
Income	LVL	0	0	50,98	0	0	54,1	0	0	0	58,56
Expenditure											
Purchase of plants	LVL	0	0	0	19101.74	0	0	20270,92	0	0	0
Initial preparation of plantations	LVL	0	0	0	7072,42	0	0	7505.309	0	0	0
Mowing (2x in the year of the 1st cycle)	LVL	2,841	0	0	3,015	0	0	3,199	0	0	0
Mowing (in the year of the 2nd cycle)	LVL	0	1,449	0	0	1,538	0	0	1,632	0	0
Fertilization with sewage sludge (in the year of the 3rd cycle)	LVL	0	0	2,628	0	0	2,788	0	0	2,959	0
Chippings (every 3 years)*	LVL	0	0	16,386	0	0	17,389	0	0	0	18,823
Expenditure	LVL	2,841	1,449	19,014	3,015	1,538	20,178	3,199	1,632	2,959	18,823
Excess of income over expenditure	LVL	-2,841	-1,449	31,966	-3,015	-1,538	33,922	-3,199	-1,632	-2,959	39,737

Calculation of the discounted current values of the project is based on the average profitability (13.241 percent) of the agricultural sector, which is LVL 18,465, whereas the standard of internal profitability is 19.08 percent. This means that investing in sallow cultivation project would bring additional LVL 18,465 in today's values if compared to the average theoretical project in the agricultural sector.

Figure 3. Sallow chips to be used as energy in southern Sweden (Photo: Pekka Alho).

Table 2. Discounted current value of the sallow cultivation.

11. Discounted present value of the project March 2013										
Year	1	2	3	4	5	6	7	8	9	10
Cash flow of the basic activity										
Net profit	-3,581	-2,855	26,102	-4,125	-2,5	28,142	-3,865	-2,15	-3,329	33,588
+ Depreciation	0	0	0	0	0	0	0	0	0	0
Cash flow of the basic activity, total	-3,581	-2,855	26,102	-4,125	-2,5	28,142	-3,865	-2,15	-3,329	33,588
Cash flow from investments										
Investments	-24,665	0	0	0	0	0	0	0	0	0
Sale of fixed assets										
Cash flow from investments, total	-24,665	0	0	0	0	0	0	0	0	0
Cash flow from financing										
Loan	24,665	0	0	0	0	0	0	0	0	0
Loan repayment	0	-2,466	-2,466	-2,466	-2,466	-2,466	-2,466	-2,466	-2,466	0
Cash flow from financing, total	24,665	-2,466	-2,466	-2,466	-2,466	-2,466	-2,466	-2,466	-2,466	0
Cash flow for the year	-3,581	-5,321	23,635	-6,591	-4,966	25,676	-6,332	-4,616	-5,795	33,588
Amount of money at the beginning of the year		-3,581	-8,902	14,733	8,142	3,176	28,852	22,52	17,904	12,108
Amount of money at the end of the year	-3,581	-8,902	14,733	8,142	3,176	28,852	22,52	17,904	12,108	45,696
CF for IRR	-28,245	-2,855	26,102	-4,125	-2,5	28,142	3,865	-2,15	-3,329	33,588
Internal rate of return	19.08%									
Discounted Cash Flow										
Discount factor	0.8	1,8	2,8	3,8	4,8	5,8	6,8	7,8	8,8	9,8
Discount rate	13%									
Cash Flows	-3,262	-4,281	16,79	-4,135	-2,751	12,56	-2,735	-1,761	-1,952	9,992
Net present value	18,465									

Assessment of the results of cost-benefit analysis for each type of biomass resource allows us to compare each of them by various factors, initial and annual costs, as well as the produced volume of biomass on one hectare on average in 10 years' time. Based on these calculations, it is possible to assess the technical indicators and costs of each type of biomass – actually for the entire the Kurzeme planning region.

THREE FUTURE SCENARIOS FOR THE KURZEME PLANNING REGION

According to the evaluation of the cost-benefit analysis, each type of biomass allows production of a certain amount of woodfuel (wood chip) or pellets. The results of the previous calculations are reflected in Table 3.

Table 3. Average volume of resources acquired in the Kurzeme planning region from various woodfuel-producing plants.

	chips from 1 ha on average per year	pellets from 1 ha on average per year m^3 of silage	Resources of 1 ha		Resources of 50 ha	
			chips, m^3 of silage	pellets, m^3 of silage	chips, m^3 of silage	pellets, m^3 of silage
Elephant grass		10.38	0.00	10.38	0.00	519.23
Canary grass		10.38	0.00	10.38	0.00	519.23
Hemp		10.38	0.00	10.38	0.00	653.85
Hybrid aspen	38.90		38.90	0.00	1945.00	0.00
Quick-growing willows	58.33		58.33	0.00	2916.67	0.00
Total			97.23	33.85	4861.67	1692.31

To determine the most efficient solution for the cultivation of biomass in the territory of the Kurzeme region, various scenarios that differ with their proportion between several types of biomass being cultivated were assessed:

a) *basic scenario* that envisages cultivation of the abovementioned types of biomass resources in equal areas. Use of the total area in the amount of 25 thousand ha will create additional energy resources in the region in the amount of 486 thousand bulk m^3 of woodchip resources per year, as well as 171 thousand bulk m^3 in pellet resources. This scenario will create net current value of 8.341 thousand Latvian lats, and thus, over a 10-year period, the additional net current value of nearly 10 million Latvian lats will be created;

b) *scenario No. 1* – directed towards additional cultivation of plant cultures, with a smaller emphasis on the promotion of osier and hybrid aspen cultivation (this situation would be theoretically possible if these cultures received additional support for energy acquisition). Use of total area in the region in the amount of 25 thousand ha would create additional 97 thousand bulk m^3 of woodchip resources per year, as well as additional 261 thousand bulk m^3 in pellet resources, which is a 390 thousand bulk m^3 reduction in woodchip resources and a 90 thousand bulk m^3 increase in pellet resources. In this scenario, the net current value indicator would improve to 14 million Latvian lats over a 10-year period;

c) *scenario No. 2* – increased yield of woodchip resources – in which cultivation areas for osiers and aspens are increased, while the area of energy plants is reduced. Use of the total area in the amount of 25 thousand ha as compared with the basic scenario will create additional energy resources in the region in the amount of 875 thousand bulk m^3 in woodchip resources per year, as well as 80 thousand bulk m^3 in pellet resources, which is an increase of 389 thousand bulk m^3 in woodchip resources and a decrease of 81 thousand bulk m^3 in pellet resources. The net current value indicator as compared with the initial scenario has worsened – to 5.5 million Latvian lats over a 10-year period.

The analysis shows that any perspective type of biomass resources in the territory of the Kurzeme planning region has sufficient potential for its cultivation when critically evaluating their cost-benefit potential.

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BIOTERMINALS – SOLUTION IN BIOMASS LOGISTICS

Anna Hallvar
Project coordinator
Turku University of Applied Sciences

Transportation and storage of biomass includes many challenges. To meet the future energy requirements in Southwest Finland, it is necessary to find different kinds of cost-effective ways to carry out logistics functions in biomass logistics chains. Logistic bioterminal functions could be an option to reduce the costs of biomass supply chains.

Different kinds of logistics solutions define how high the increase in use of bioenergy could be in the future. Positive environmental impacts and other benefits of renewable energy must be seen in total costs of supply chain management and in the energy balance sheet.

This article is a part of the Planning and Directing Bioenergy Production in Southwest Finland project of Turku University of Applied Sciences. The project's objective is to increase the use potential of biomass for energy through geographic information software. The project has had cooperation from the Pure Biomass project in the collection of data about biomass potential in the region.

CHALLENGES IN THE BIOMASS SUPPLY CHAIN

Designing the logistics system for biomass-to-bioenergy industry is challenging. Unique features of solid biomass are low bulk density, seasonal availability of the resource, restrictions on harvesting season and frequency, content variation with time and conditions, weather effects, scattered distribution over a wide geographical area, and so on. If the power plant operates throughout the year, there is a need for storing very large amounts of biomass for a significant time period. Different biomass types require specific treatment. There is a need to include strategic decisions in the supply chain design, because the seasonality of supply increases the complexity of dimensioning and optimal operation of facilities.

Bioenergy logistics do not depart from other goods logistics. Biomass is a good example of functional products, the starting point of which has to be a cost-effective supply chain. Collection, transportation and storage are crucial factors when evaluating financial aspects of bioenergy production. The supply chain is effective when large volumes are supplied with minor input. It is typical in the energy sector that demand is intensely varying and additional input is needed when the demand and supply of products changes significantly. In Southwest Finland the variation is a result of seasonal weather conditions. The limited time frame for collecting a large amount of biomass leads also to significant seasonal needs of equipment and workforce.

Biomass has a high moisture content and low energy density, especially compared to fossil fuels. The low energy density increases the cost of collection, handling, transport and storage of the biomass. It is possible to increase the energy density by reducing the water content of biomass by chipping, baling, and bundling etc. By reducing the water content of biomass, it is possible to reduce transportation costs and improve the physical properties. In conclusion, the challenges to the biomass supply chain are low energy density, seasonal availability, scattered distribution over a wide geographical area and inadequate harvesting and handling equipment. The main solutions to these issues are:

1) the development of technologies and a need for technological innovations for producing energy from more a diverse range of feedstock
2) decentralising the supply chain and diversifying the types of feedstock used
3) optimisation of biomass logistics. (Fig. 1)

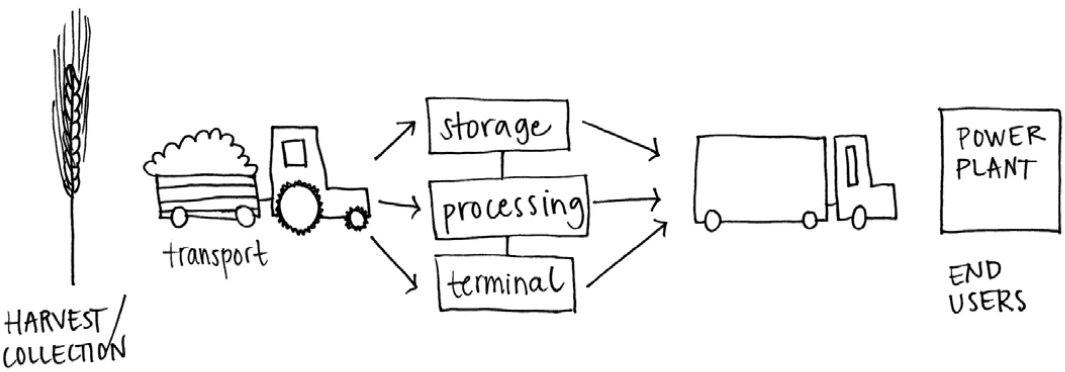

Figure 1. Supply chain of biomass (Drawing: Anna Hallvar).

BIOMASS LOGISTICS IN SOUTHWEST FINLAND

Transport distances between crop cultivators, biomass producers and end users are relatively long in Southwest Finland. Agricultural areas and sources of biomass are remote from the energy consumption points and thus moving the biomass to a plant near the energy consumers requires a well-organized transportation plan. Biomass terminals could be one answer to biomass logistics challenges in Southwest Finland, because the volume of available biomass is high but the potential is widely scattered around the area (Fig. 2).

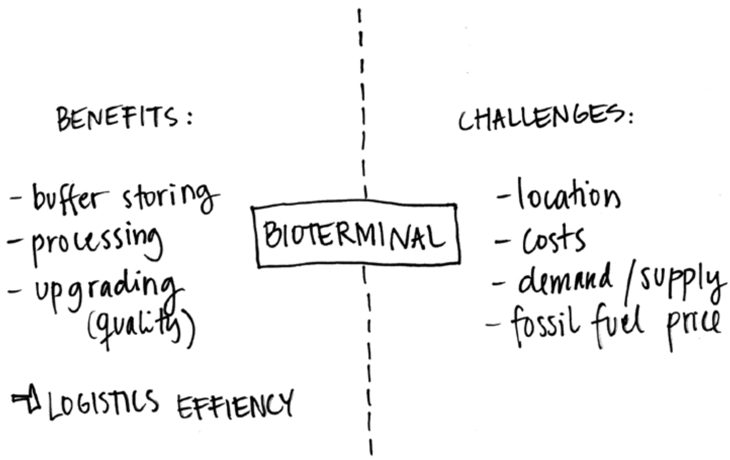

Figure 2. Costs can be reduced by adding a operational biomass terminal to the supply chain (Drawing: Anna Hallvar).

When there is a great diversity in the types bioenergy feedstock and several feedstock sources, transportation distances are shortened and costs are reduced. Bioenergy must become increasingly competitive with other energy sources to be economically feasible.

Biomass feedstock is transported by road in Southwest Finland. Depending on the distance travelled and mode of transportation, the cost of agricultural residues ranges from 20% to over 40% of total delivered cost. Railway transportation could be one solution for long transport distances in the future. However, due to the current sparse network of railways and low number of loading places, effective utilisation of railways in biomass logistics is not possible.

BIOTERMINAL CONCEPT

The role of terminals is growing and the question is, when does a bioterminal bring added value to the biomass supply chain?

Bioterminals can help to improve the reliability of deliveries to the power plants, if terminals are operating also as biomass storage facilities. Terminals could be feedstock processing places where small quantities of feedstock are gathered for larger flows. From small quantities of different kinds of biomass feedstock, it is possible to mix various biofuels for the needs of energy plants. The challenge in terminal operations is to find solutions to manage the biomass feedstock supply and demand. It is necessary to find a mechanism that is approved by biomass producers and power plants. With a growing demand there is need for larger storage facilities. Another challenge is to find a balance between transportation and storage.

One of the benefits of using terminals in the supply chain is the possibility to reduce the humidity of feedstock. It has direct impact to the energy content and weight of the material. It is more efficient to transport dry materials, because transport capacity is then optimised. Large transportation units are beneficial when quantities are large. Costs of bioenergy logistics can be decreased in long distance transport with the use of terminals and a well-designed supply chain.

To increase the reliability of deliveries, it is advisable to gather as many biomass producers and crop cultivators as possible to be part of the terminal´s functions. A bioterminal could be a more reliable biomass feedstock supplier than lots of minor suppliers. A bioterminal can also be an independent biofuel producer that supplies energy to different end users. By centralising all operations of a biomass supply chain with a bioterminal it is possible to decrease overall costs.

Bioterminals could have multiple tasks (Fig. 3). They could serve as a storage facility and buffer for biomass as well as part of the biomass production systems. If a terminal is intended to serve as a buffer storage facility for a power plant, it must be located near or attached to the plant. The location should also enable minor producers and suppliers to deliver biomass feedstock. If the terminal has been built to serve multiple end users, the location decisions are based on the volume of available biomass. Even though the availability of biomass is one of the most crucial factors in choosing the location, attention must also be paid to the customers. To enable profitable activity, the demand for biomass feedstock has to be sufficient in the terminal's operational area and the terminal should have good transport connections. It is essential to be able to serve as many bioenergy suppliers, producers and end users as possible. When considering the location of a terminal, one way to reduce investment costs is to use existing infrastructure. Terminals that are available for use should be taken into account when planning new energy projects. It is also possible to gain some synergy benefits from surrounding industry, for example in personnel and machinery costs.

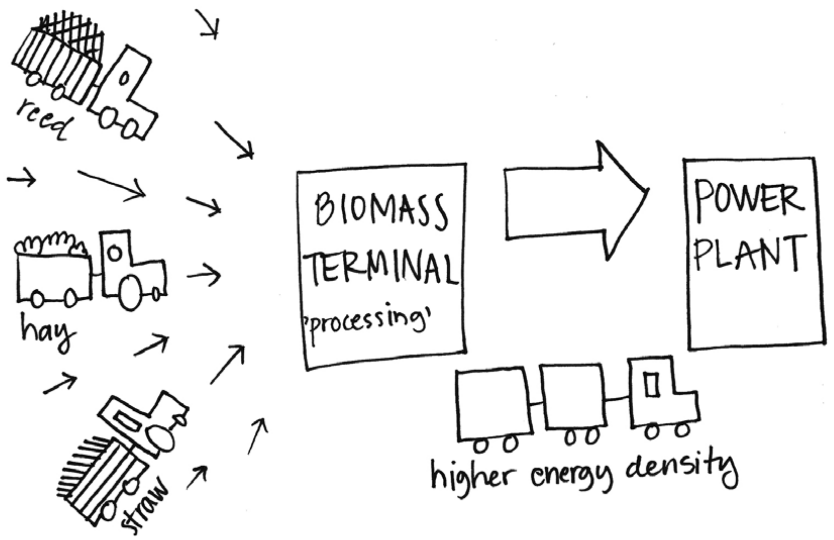

Figure 3. Bioterminal concept (Drawing: Anna Hallvar).

Small and multi-polar terminal functions could be an answer in rural areas. There is a possibility of creating many kinds of local functions to bioenergy terminals. Bioenergy terminals could serve local settlements and businesses. In small local terminals, there is a possibility to make woodchips for households or build a small heat centre. Small local terminals could increase the use of renewable energy and motivate small bioenergy producers. In the future, when planning new energy projects, it is necessary to take into account smaller and larger scale energy operators and pay attention to the supply chains. This way it is possible to increase the use of renewable energy in Southwest Finland.

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SUGAR BEET AS A SOURCE OF BIOETHANOL AND BIOGAS – COST-BENEFIT ANALYSIS

Edvins Drigins
Project manager
Kurzeme planning region

The cultivation and use of sugar beet shows good potential in Latvia. A cost-benefit analysis of the utilisation of sugar beet was conducted during the project. The study gathered the main planning documents and normative acts as well as technical-economic calculations on the use of sugar beet in the Kurzeme planning region.

Increasing of the use of renewable energy resources in the national energy balance is a challenge. The most efficient solutions for using local resources in energy production must be sought in order to increase the use of renewable energy resources. Taking into account the experience of other European countries, cultivating sugar beet is considered as one of the alternatives to replacing fossil energy resources due to their varied uses including energy production. The use of sugar beet could result in a revival of sugar beet cultivation in Latvia and lead to new opportunities for farmers.

BACKGROUND

Latvia's general target for the share of energy from renewable sources in the gross final consumption of energy is 40% in 2020. Moreover, each EU member state shall ensure that the share of energy from renewable sources used in transport in 2020 is at least 10% of the final consumption of energy in transport. In 2006, the Sugar Reform was launched in the European Union. As part of the reform, Latvia was refused sugar production quotas and, as a result, sugar production plants were closed by paying compensation to sugar beet farmers, sugar production plants and local governments.

During the period from 2002 to 2006 until the reform was launched, 14 thousand hectares on average were cultivated with sugar beet. Sugar beet productivity was 36–39 tonnes per hectare, with sugar content of 16–17% at the time of harvesting.

In Latvia, the regions most suitable for sugar beet cultivation are Southern Kurzeme and Zemgale, where the vegetation period is longer and a greater yield in production is possible. The quality and quantity of sugar beet production depends on various inter-connected factors such as soil fertility and cultivation techniques.

Sugar beet fits well in crop rotation, which is of particular importance to crop farmers. Sugar beet can be the subsequent crop after winter wheat, summer wheat, summer barley, legumes and cultivated clover, or the preceding crop before summer barley, maize and legumes. If cultivated in crop rotation, sugar beet increases soil fertility, improves the soil structure, reduces soil aciditys and picks up nitrogen and other nutrients, thus preventing the pollution of underground water. According to the database of the Central Statistical Bureau, the total area of agricultural land in the Kurzeme region is 348,585 hectares, of which 79% or 275,807 hectares (arable land and fallow) could be used for cultivating sugar beet.

Transport appears to be an important factor in the sugar beet industry. To reduce sugar beet transport costs and related emissions, production units are usually located near sugar beet cultivation sites. If it is not possible to process the beet immediately, it is necessary to ensure correct storage – this is an important factor to consider. Faster processing of beet ensures a higher percentage of sugar, and thus also better economic results and profit. Given the climatic conditions in Latvia, an acceptable solution is a 100-day processing season.

BIOETHANOL AND BIOGAS PRODUCTION

Producing bioethanol from sugar beet is similar to producing sugar – the sugar beet is shredded and the sugar is extracted by hot water within a counter current flow. After separation of the solids through pressing, the sugar suspension is pasteurised to prevent biological contamination. Then it can be fermented directly without any further treatment. After fermentation the ethanol is purified. The purification process generates the by-product known as vinasse, which contains unfermented hydrocarbons. Table 1 shows the main parameters for ethanol production and purification.

Table 1. General parameters for both ethanol production pathways from sugar beet.

Ethanol yield	76 kgEtOH/$t_{\text{sugar beets}}$
Electricity demand	0.13 kW h/kgEtOH
Heat demand	7.3 MJ/kgEtOH
Transport field – conversion plant	40 km

Sugar beet from the Kurzeme planning region gives the highest bioethanol yield – 6,250 litres per hectare. Bioethanol production from sugar beet is 1.7–3 times higher than from other raw materials such as maize (3,740 l/ha), wheat (2,760 l/ha), rye (2,030 l/ha), triticale (2,230 l/ha), and straw (2,310 l/ha).

The sugar reform matched the increase in production of biofuels, in several EU countries sugar beet processing plants were transformed into bioethanol production plants, the result of which was a sharp increase in the amount of bioethanol produced in recent years. In total, 30% of the bioethanol produced in Europe is acquired by processing sugar beet.

One of the by-products in sugar production is sugar beet pulp, which can be dried and used as supplementary food for animals. Sugar beet pulp, however, can also be used for producing biogas – it is worthy of note for its high biomethane yield from an area of 1 hectare.

Table 2. Generation of by-products of both investigated ethanol production pathways for ethanol from sugar beet.

Feed pellets from sugar beet pulp	
Pulp yield	53 $kg_{\text{pulp, dry/t sugarbeets}}$
Electricity demand for pressing and pelletising	0.16 kW h/$kg_{\text{pulp, dry}}$
Heat demand for drying	0.34 MJ/$kg_{\text{pulp, dry}}$
Biogas from sugar beet pulp and vinasse	
Biogas yield	0.43 Nm^3/kgEtOH
Methane content	70%
Electricity demand for biogas generation	0.187 kW h/Nm^3
Heat demand for anaerobic stillage* treatment	0.66 MJ/Nm^3
N/P/K — recovery	10.7/0.5 g/kgEtOH
Electrical efficiency CHP plant	20%
Thermal efficiency CHP plant	70%

* stillage — by-product of spirit production, which is acquired by processing molasses. Fresh stillage contains 90–95% of water.

Activities in Austria, France, Germany, Hungary, the Netherlands, Poland and Sweden show that sugar beet is suitable for biogas production thanks to its fast fermentation and high yield. It has been calculated that the amount of biogas produced from 1 ha of sugar beet could provide electricity for one household for 3 years.

The digestate from the pulp is used as fertiliser, which is relatively dry (approximately 20% dry matter); therefore no further dewatering is necessary. The digestate from vinasse is anaerobically treated and fed back to the extraction step. The biogas is burned in a CHP plant and used for heat and electricity generation.

COST-BENEFIT ANALYSIS FOR USING SUGAR BEET AS BIOMASS

The following conditions were applied in this analysis:

- the sugar beet field is 50 hectares and the field is to be owned by the project promoter
- a credit will be taken as an investment in the initial crop and for ensuring current assets during the initial period until first revenue
- interest rate is 6% and its term is 10 years
- main annual costs items for maintaining the sugar beet field are: purchase of seeds, fertilisation, spraying, ploughing, sowing, etc., as well as beet harvesting with a combine harvester
- revenue is drawn from selling sugar beet
- cost-benefit calculation has been performed for a cycle of 10 years.

The discounted current value calculation of the project is based on the average profitability of agricultural projects (16%), and its value is LVL 7,514, but the internal rate of return is 3.86%. Thus, by investing in the sugar beet cultivation project, an additional LVL 7,514 of current value would be gained in comparison to the average theoretical agricultural project.

This calculation is based on a clear cost-benefit analysis model, not taking into account risk factors regarding the possible loss of harvest quality, additional sales and marketing expenses or possible income from by-production activities. These factors have to be taken into account when estimating implementation provisions of a specific project in the territory of Kurzeme planning region.

POTENTIAL OF BIOETHANOL AND BIOGAS PRODUCTION

Table 3 provides a summary of theoretical calculations regarding costs of bioethanol production in Latvia if sugar beet is used as the raw material.

Table 3. Costs of bioethanol production (sugar beet).

Indicators	Sugar beet indicators
Raw material yield, t/ha, wet weight*	51.2
Production of bioethanol, l/ha	5,517
Biomass necessary for producing one litre of bioethanol, kg/1000 l	9,30
Price of raw material, LVL/kg	0.028
Cost of raw material, LVL/l bioethanol	0.25
Processing costs*, LVL/l	0.12
Total production costs, LVL/l	0.37
Income from realisation of by-products, LVL/l	0.10

* Lithuanian results according to a research done by Nordzucker AG.

According to the theoretical calculations summarised in Table 3, the cost of production for one litre of bioethanol is LVL 0.37 (for one tonne – LVL 469.90). Estimates of bioethanol production costs in the EU show that wheat and sugar beet-to-bioethanol production costs are broadly similar at around 0.42 LVL per litre (excluding taxes).

According to data by the Latvian Ministry of Economics, at the end of 2012 there were 27 biogas production plants operating in Latvia, and it is expected that their number will grow. The number of the decisions submitted exceeds one hundred.

Currently, the green mass imported from Lithuania is also used to produce biogas in Latvia; this green mass also contains sugar beet and is purchased at 20 LVL per tonne, but silage is purchased for 25 LVL per tonne. In addition to the cost of green mass and silage, costs for delivery of the substrate also have to be covered. The combination of various raw materials allows for the reduction in the costs of biogas production, but at the same time it requires close monitoring of fermentation processes when the substrate material is changed.

When studying the potential amount of substrate, the delivery schedule must be planned so that all available substrates ensure regular refilling and loading into fermenter. In addition, the use of various raw materials does not promote the emergence of monocultures.

SCENARIOS

The possible scenarios for using sugar beet as biomass are as follows.

Scenario No. 1: bioethanol + biogas

A precondition for the realisation of this scenario is support from the government for bioethanol production. Bioethanol is produced to cover the material share of the consumption of bioethanol in Latvia, and the bioethanol produce in addition is exported. Biogas is produced throughout whole year by using a mixture of sugar beet and other ingredients. During the sugar beet processing season, sugar beet pulp after production of bioethanol is used, but after this season sugar beet silage is used.

Scenario No. 2: bioethanol + supplementary food for animals

A precondition for realisation of this scenario is support from the government for bioethanol production. Bioethanol is produced so as to cover the material share of the consumption of bioethanol in Latvia, and bioethanol produced in addition is exported. Sugar beet pulp (wet or dried) after production of bioethanol is used as a supplementary food for animals.

Scenario No. 3: sugar + bioethanol + biogas

A precondition for realisation of this scenario is the cancellation of the EU sugar quotas and the construction of a new sugar production plant. This is a less likely situation, since unofficially it has been admitted that it is unlikely that sugar quotas will be cancelled in 2015. This scenario uses the sugar beet resource to its fullest. The production of sugar ensures at least a part of sugar consumption in Latvia. Bioethanol is produced so as to cover the material share of the consumption of bioethanol in Latvia, and the bioethanol produced in addition is exported. Biogas is produced throughout the whole year by making a mixture of sugar beet and other ingredients. During the sugar beet processing season, sugar beet pulp after production of bioethanol is used, but after this season sugar beet silage is used

Taking into account the current situation and profitability calculations, the most realistic scenario is scenario No. 1.

According to the experts' evaluation, the cultivation and use of sugar beet in the Kurzeme planning region shows good potential. However, it should be taken into account that the efficiency and profitability of using this resource is affected by the following factors: the purchase of new equipment for sugar beet farmers, a government support scheme for the production of bioethanol and the capacity of bioethanol production plants, the development of sugar production sector and, possibly, the construction of a sugar production plant.

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HIGH YIELDING HEMP CROP AS ENERGY PLANT

Noora Norokytö
Project manager
Turku University of Applied Sciences

Hemp is known to be a versatile plant that can be used in many purposes. Nevertheless, the hemp business sector is still in a state of development and despite the various environmental and economic advantages, the cultivation areas are small in Finland. Cultivation areas could be increased if the harvested hemp is used as energy.

Different kinds of hemp (*Cannabis Sativa L.*) varieties are crown for various purposes. Industrial hemp can be grown for oilseed or fibre. Fibre hemp is used for fibre production and it produces large volumes of biomass during one growth period. Fibre hemp consists of the woody core in the inner part of the stem and long fibres in the outer part of the hemp stem. Traditionally fibre has been the most valuable part of the plant and the main reason for its cultivation for thousands of years. Only 20–25% of the mass of the stem is fibre and 75–80% is shives – the woody core. Although the greater value is still in the fibre, it is economically and ecologically reasonable to obtain a market value from the shives as well. Shives can be used as building material, animal bedding or in energy production.

In Finland, fibre hemp can produce approximately 5 to 10 tons of dry matter per hectare. The cultivation areas of fibre hemp are still small in Finland only some tens or hundreds of hectares are cultivated annually. Hemp business sector is still developing. At this point it is needed to increase the cultivation areas and production volumes together with the utilisation. It could be possible to increase the cultivation area by using the harvest as energy.

Figure 1. Fibre hemp field in Southwest Finland (Photo: Mikko Neuvo).

ADVANTAGES OF HEMP CULTIVATION

If one looks the production of fibre hemp from the farmers point of view it shows different kinds of benefits. The cultivation of fibre hemp has positive effects on the soil. It increases the amount of organic matter in the soil, because a great volume of the leaf matter falls to the ground. Organic matter is also increased due to its powerful root system which also increases the amount of air pores in the soil. Hemp does not require pesticides as a result of vigorous growth. Hemp also captures a significant amount of carbon dioxide during its growth period.

For the farmer the most important thing is the economic viability of production. Hemp requires good farming land which means good nutrient levels and humic soil where moisture and aeration works well. Compacted soil should be avoided when growing hemp. Fibre hemp can be sowed in late June and harvested in early spring so it evens the peak in the farm work. For energy purposes, around 20 kilograms of seed should be sown per hectare.

Figure 2. Fibre hemp keeps the ground clear of the weeds. This is one quality that makes it good rotation crop (Picture: Noora Norokytö).

In Finland, the crop is left in the field over winter. This is called winter retting. Ice and frost will dry the crop, loosen the fibres and turn the crop a light natural white color. The soil stays covered through the winter. The biomass is harvested in the spring by cutting, swathing and bailing the crop. Dry bales need to be protected from moisture.

There are only two companies in Finland that have experience in cultivation contracts for fibre hemp. The prices paid to the farmer are somewhere in the region of 100–150 euros per ton of dry matter (Neuvo 2013). The prices follow European levels. When hemp is grown in good farming land and with high nutritional levels, it is possible to have biomass harvested around 5 000–10 000 kilos per hectare. The production can be economically reasonable for the farmer. But is it profitable to use the hemp harvest in energy production and can it compete with other plant material used in energy production with these farming costs and energy prices?

ENERGY USE OF HEMP

It is important to have a critical view on the cultivation of industrial hemp or any plant for energy. As in many considerations, one report of Regional Council of Southwest Finland (Tulevaisuustyöpaja 2012, 23) questions whether it is ethical to produce energy on farming fields. Is it even economically beneficial? The by-products of food production, for example straw, can be used as energy. Using cultivation areas which would be suitable for food production to produce energy crops is questionable. And in the case of hemp, the cultivation area would be used in energy production instead of the production of raw materials that can replace oil and chemicals used in high value products. According to Corianne Lepage of the European Parliament Committee of Environment, there is concern that fields in the EU are transformed from food production to produce energy crops – a similar development has happened already in USA, Brazil and even in Germany (Ympäristö 2013, 14). EU agricultural policy affects the farmers' interest when selecting the crops that are grown. Agricultural policy has an impact on the future of the hemp sector, and hemp could be a competitive plant from the farmer's point of view (Carus M., Karst S., Kauffmann A., Hobson J., Bertucelli S. 2012, 9).

If field crops are used as energy, it is necessary to look at all the suitable plants that could be the best for energy use. When hemp is compared to other high-yielding crops, like maize and reed canary grass, it seems to have potential for both methane and solid biofuel production. (Prade Thomas 2011, 53–57). Thomas Prade states in his doctoral thesis that the advantages of hemp over other energy crops are also found outside the energy balance, which means, for example, low pesticide requirements, good weed competition and suitability for crop rotations. Prade states that the future improvements in hemp biomass cultivation and energy yields may strengthen its competitive position against maize and sugar beet in biogas production and against perennial energy crops for solid biofuel production.

The largest amount of biomass in the hemp field is around September to October. It is not the best plan to use the green biomass in energy production, because there are still uncertainties in the harvesting. Most Finnish fields are too wet for big harvesters that time of the year. Dry crops harvested in the spring is the most efficient and reliable product for energy use. This is because it seems that the burning value will rise and the ash value will go down compared to green matter (Prade T. 2011, 3). If hemp is used as energy, it is most efficient to produce methane or burn the whole bails near the place of harvesting. If the stems are pelletised the long fibres need to be separated from the inner core, because the fibres will cause problems in the pelletiser equipment. In 2013, the price for pure shives was over 300 euros per ton in Europe (Carus Michael, European Industrial Hemp Association, 28.8.2013). Due to the need to separate the fibres one can calculate that pelletising would profitable.

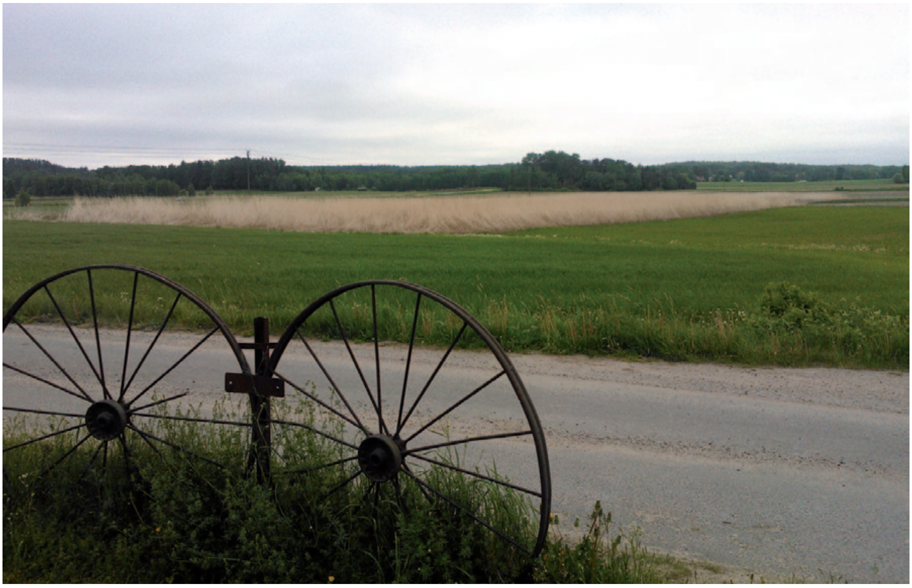

Figure 3. Dry hemp ready to be harvested (Photo: Noora Norokytö).

There are some arguments put forward by promoters of hemp that industrial hemp is the best plant to solve our energy problems. Both plant biomass and oil extracted from the seed can be used in different kinds of energy needs and they could replace fossil fuels. With critical thinking one can see that it is not quite so obvious. It is clear that the best way to utilise hemp is to process it for more valuable products than energy due to the price of the raw material, its valuable qualities in making various products and for sustainability.

PROJECTS FOR PROMOTING INDUSTRIAL HEMP

The production of industrial hemp from field to end products has been under review in project called Industrial hemp – new sustainable opportunities for business in rural areas of Finland. Project ran from beginning of 2011 to the end of 2013. It has been funded by Finland's Leader programme by Southwest Finland's Riverside Partners. One aim of the project is to increase know-how in the farming of oil and fibre hemp. Another aim is to make the image of industrial hemp more positive and better known to farmers, industries and the general public. There have been events with the aim of increasing knowledge about the use of hemp. Important networking in this new field has been done in Finland and abroad. The main objective of all these initiatives is to develop the rural areas in a sustainable way and increase employment and production of sustainable domestic raw materials. With oil hemp it is possible to increase domestic plant protein production. Oil hemp does not require quite so heavy processing compared to fibre hemp, and that is the reason it has had a more prominent position during the project. It could be possible to use the straw from the oil hemp for energy use since the seeds mature at the top of the plant. Prior to this, the cultivation areas must be increased in order to make it profitable.

The use of hemp crops as energy was assessed in project called Energy Hemp at Turku University of Applied Sciences during 2011. One spin-off company has launched since this project. The company, HempRefine Oy, is working to develop mobile decortication units for fibre hemp, and it has started to conclude cultivation contracts for the year 2014. HempRefine Oy may be a possible material supplier for energy companies in near future. (HempRefine Oy. 2013)

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ANALYSING FUTURE BIOMASS – COMMON REED *(PHRAGMITES AUSTRALIS)*

Pekka Alho
Project manager
Turku University of Applied Sciences

Hanna Hänninen
Lecturer
Turku University of Applied Sciences

Elina Lappalainen
Project assistant
Turku University of Applied Sciences

Jere Raita
Project assistant
Turku University of Applied Sciences

Assessing the possible boundaries and restrictions for the energy use of Common Reed enables the further development of the use of this potential renewable energy source. The utilisation of vast reed beds in Southwest Finland would have numerous positive impacts for the economy, nutrient cycles, biodiversity and recreational values of coastal areas.

In Southwest Finland, the growth of common reed beds has been aggressive and has even become a problem. Monotonic reed beds have decreased nature diversity. Former meadows and open shores have been turned into thickets and thus also restricted recreational values remarkably. However, common reed can also be seen as an opportunity. By harvesting the reed for energy purposes, it would be possible to increase local energy self-sufficiency and local activity in countryside, providing at least supplementary work for local farmers and entrepreneurs. Reed biomass could also be used for land improvement and fertiliser sources.

It is estimated by satellite imaging that approximately 30 000 hectares of reed is growing in Southern Finland (Pitkänen 2006). This indicates quite an enormous potential of unused biomass, growing practically on no man's land. All agricultural land will probably be needed to feed people and not for the purpose of producing biofuels. Not all reed beds can be used either, but certain carefully planned areas.

The summer reed is good raw material for biogas processing. The winter reed can be used in incineration processing in the district heat plants. Both these seasonal biomass sources have been tested in practice by Turku University of Applied Sciences and the local Centre for Economic Development, Transport and the Environment. The raw material has proved to work effectively. The main remaining question to be solved is the cost efficiency of the reed harvesting chain. This depends also on fossil fuel prices development and political guidance. On the other hand, it is difficult to evaluate the economic value of the positive impact of common reed harvesting on the conservation of nature and recreational values.

FOCUS OF THE STUDY

In the Pure Biomass project, common reed was analysed to assess the possible restrictions for its energy use. Samples of winter reed (previous summer growth) were collected on 30 May 2013 and fresh summer reed on 27 June in 2013 from Livonsaari and Mietoinen. Preliminarily planned large scale pilot harvesting sites were taken into account when choosing the sampling areas. Reed samples were taken both from water and land in which reed grows.

The main objective was to analyse the heavy metal and phosphorus content of reed. The reed samples were ground to a fine powder and dissolved in aqua regia. Metal and phosphorus contents were measured with a Microwave Plasma-Atomic Emission Spectrophotometer.

RESULTS

Potassium content in the reed varied depending on the area from which the samples were collected (water or land). The reed grown in water contained evidently more potassium than reed growing on land. However, the content of other metals and phosphorus did not depend on the growing site. The fundamental differences in the results came from the harvesting time (Table 1).

Table 1. Measured metals and phosphorus in reed samples (Turku University of Applied Sciences 2013) .

Unit: mg/kg	Copper	Lead	Potassium	Cadmium	Phosphorous	Arsenic
Mietoinen, winter, LAND 1	2,8 ± 0,2	7,9 ± 0,7	870 ± 21	< 1,4	210 ± 20	< 6,25
Mietoinen, summer, LAND 1	7,8±0,5	15,6±1,9	17280±780	< 1,4	1660±50	< 6,25
Mietoinen, winter, LAND 2	1,6 ± 0,03	4,5 ± 0,5	750 ± 10	< 1,4	170 ± 5	< 6,25
Mietoinen, summer, LAND 2	7,4±+0,2	16,4±0,7	18180±1350	< 1,4	1550±180	< 6,25
Mietoinen, winter, LAND 3	1,54 ± 0,05	4,5 ± 0,3	472 ± 4	< 1,4	190 ± 10	< 6,25
Mietoinen, summer, LAND 3	6,8±+0,3	9,2±0,4	17360±260	< 1,4	1490±30	< 6,25
Mietoinen, winter, WATER 1	1,5 ± 0,1	6,8 ± 0,8	940 ± 50	< 1,4	220 ± 30	< 6,25
Mietoinen, summer, WATER 1	7,9±+0,3	18,3±0,6	16090±340	< 1,4	1380±40	< 6,25
Mietoinen, winter, WATER 2	1,81 ± 0,08	5,2 ± 0,3	890 ± 20	< 1,4	212 ± 9	< 6,25
Mietoinen, summer, WATER 2	6,60±0,09	21,6±1,7	20100±100	< 1,4	1580±50	< 6,25
Mietoinen, winter, WATER 3	1,66 ± 0,08	5,5 ± 0,4	881 ± 9	< 1,4	270 ± 10	< 6,25
Mietoinen, summer, WATER 3	7,1±+0,3	11,5±0,7	17870±340	< 1,4	1440±20	< 6,25
Livonsaari, winter, LAND 1	1,56 ± 0,06	4,3 ± 0,2	470 ± 50	< 1,4	160 ± 10	< 6,25
Livonsaari, summer, LAND 1	4,2±0,1	7,2±0,4	15400±300	< 1,4	1410±50	< 6,25
Livonsaari, winter, LAND 2	1,77 ± 0,06	4,4 ± 0,6	440 ± 20	< 1,4	160 ± 3	< 6,25
Livonsaari, summer, LAND 2	4,4±0,1	7,6±0,4	16400±100	< 1,4	1310±10	< 6,25
Livonsaari, winter, LAND 3	1,9 ± 0,1	3,8 ± 0,1	440 ± 10	< 1,4	-	< 6,25
Livonsaari, summer, LAND 3	8,5±0,2	21,4±1,6	18440±460	< 1,4	1360±40	< 6,25
Livonsaari, winter, WATER 1	1,41 ± 0,03	4,9 ± 0,5	820 ± 9	< 1,4	160 ± 20	< 6,25
Livonsaari, summer, WATER 1	5,0±0,2	8,9±1,1	16350±250	< 1,4	1660±10	< 6,25
Livonsaari, winter, WATER 2	1,22 ± 0,04	4,4 ± 0,5	710 ± 20	< 1,4	110 ± 10	< 6,25
Livonsaari, summer, WATER 2	4,8±0,4	8,3±0,7	17500±900	< 1,4	1310±70	< 6,25
Livonsaari, winter, WATER 3	1,6 ± 0,1	4,4 ± 0,2	590 ± 6	< 1,4	170 ± 10	< 6,25
Livonsaari, summer, WATER 3	7,4±0,1	23±2	16810±570	< 1,4	1670±80	< 6,25
Limits	600	100		1,5		25

Figure 1. Reed bed in the bay of Karuna (Photo: Tuomas Alijoki).

Arsenic and cadmium content remained clearly under limits in all samples. The content was so small that the accurate figures gained are not published as reliable. Winter reed has a more wooden physical structure in comparison with summer reed and it contains less of all measured metals and, as expected, less phosphorus.

According to the measurements, it seems that no restrictions are needed for using reed as a fertiliser. If used as a fertiliser, certain nutrients (nitrogen, phosphorus and potassium) should be at a high enough level. The phosphorus and potassium content were higher reed harvested in summer. However, the total nitrogen content was not measured. Furthermore, according to the measurements, the heavy metal content of common reed will not limit further use. Decomposition residue from biogas processing is often used as a fertiliser in farming and may not contain heavy metals. Combustion of the reed produces more ash in comparison to combustion of wood. Also the melting point of ash and increased lignin content in winter reed straw may represent a technical challenge for burners made for wood fuel.

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BIOCHAR – AN ALTERNATIVE TO USING BIOMASS

Tomi Holstila
Student of sustainable development
Turku University of Applied Sciences

Carbon sequestration and soil improvement can be combined with the pyrolysis process – the production of biochar through the anaerobic heating of organic matter. The synthesis gas which is released in the pyrolysis process can also be burned to produce heat and electricity.

Everything that lives, including biomass, has carbon as its basic building block. In the natural carbon cycle plants photosynthesise carbon dioxide from the atmosphere to make carbohydrates, or sugars, the feedstock of their own growth. By burning biomasses, energy usable by humans is released as these compounds are again oxidised to carbon dioxide. By heating the biomasses in the absence of air, the volatile components are transformed to gases and we are left with a liquid fragment and a very stable, carbonaceous solid substance called biochar.

The production of biochar from different biomasses, or pyrolysis as oxygen-free heating of organic matter is called, has been the subject of research at the MTT Agrifood research institute in Jokioinen for several years. To study the potential of pyrolysis as a means of utilising the biomass in Southwest Finland, a student of Turku University of Applied Sciences participated in this research, conducting experiments with a mobile pyrolysis retort. In addition to the practical tests with different feedstocks, a literature review was conducted, later resulting in a thesis on the subject.

The synthesis gas which is released in the pyrolysis process can be burned to produce heat and electrical power and to maintain the process temperature. Part of the gases may be condensated to tar and other liquid distillates. These can be further refined to more valuable products such as biofuel or other chemicals. The pyrolysis process needs an external heat source to start, but after reaching a certain temperature it becomes exothermic, releasing more heat than it requires. In slow pyrolysis the process temperature is raised to around 450–550°C degrees. In this temperature range the yield and quality of the biochar product is optimal. The production process and physical properties of biochar are close to those of traditional charcoal, but the intended use is what distinguishes them from each other.

Figure 1. MTT demonstration scale mobile pyrolysis retort (Photo: Tomi Holstila).

Biochar has been known, for a long time, to be a good soil improver, and its use in agronomy was rather common until synthetic fertilisers and pesticides gained ground after the Second World War. A renewed interest in biochar started in the recent decades, when the Terra Preta grounds of the Amazon region gained publicity. Terra Preta, 'black soil', is known by locals to be a very fertile soil. Its secret is thought to be the biochar buried in soil for generations.

CARBON SEQUESTRATION AND SOIL IMPROVEMENT COMBINED IN ONE PRODUCT

Biochar is a friable material charred to a black colour, in which the binding agents that give biomass its physical form have evaporated. The behaviour of biochar in soil is explained in particular by its porosity: the nano-sized pores in the particles give them hundreds of square metres of surface per one gramme of material. These pores might be what explain the observed improvements of microbial activity and water retention capacity in biochar amended soils.

One of the important properties of biochar is its stability. Unlike most plant based masses, biochar is not mineralised over a short period of time to be utilised by plants and microbes, but stays in the soil for hundreds or thousands of years. That means that when biochar is used to improve soil quality, it also has a climate change mitigating effect as the carbon in biochar is removed from the atmospheric cycle. Scientists have not yet been able to define an accurate decomposition rate of biochar in soils, but an implication can be had of the fact that the biochar in Amazon soils dates back thousands of years.

For plants, an important factor is biochar's ability to retain nutrients in the soil in an available form for plants. This property is defined by cation exchange capacity: plants take the nutrients they need for growth from soil as positively charged cations. An inadequate supply of nutrients reduces plants' ability to grow. The options to artificially affect a soil's nutrient content besides fertilising are limited, but its cation exchange capacity may be altered by tillage and other soil management methods. Biochar is understood to have a good capability to retain nutrients in soil and thus have a positive effect on crop yields and a reduced need for fertiliser use, leading in turn to smaller environmental effects by preventing nutrient leaching etc.

UTILISING AGRICULTURAL WASTE STREAMS FOR BIOCHAR AND BIOENERGY

The production facility such as a farm may use its own and nearby residual streams in biochar production, which can then be reclaimed for different functions on the farm complex. During its life cycle biochar can be used several times, improving its financial feasibility: before application to soil it can be used as treatment to animal manure to reduce undesired odors and then the biochar-manure mixture works as a compost improver. As a farm complex often has large buildings that need heating, the heat released while burning the pyrolysis gas fraction can be utilised to reduce the energy consumption at the production site.

What makes biochar production interesting in a financial sense is its potential to turn waste management costs into a productive activity of added value. Different agricultural residues such as straw and manure are typically difficult to process in an environmentally sustainable manner. Pyrolysis has the potential to be a sensible way of processing different organic waste streams with no other beneficial application. Feedstock should not be excessively moist:

depending on the technology used, preferably less than 30% for the process to have a good energy balance. Usability of pyrolysis for waste streams such as horse manure and municipal waste sludge are currently being researched at MTT Agrifood. The optimal outcome would be that both their energy and nutrient content could be used with suitable technology.

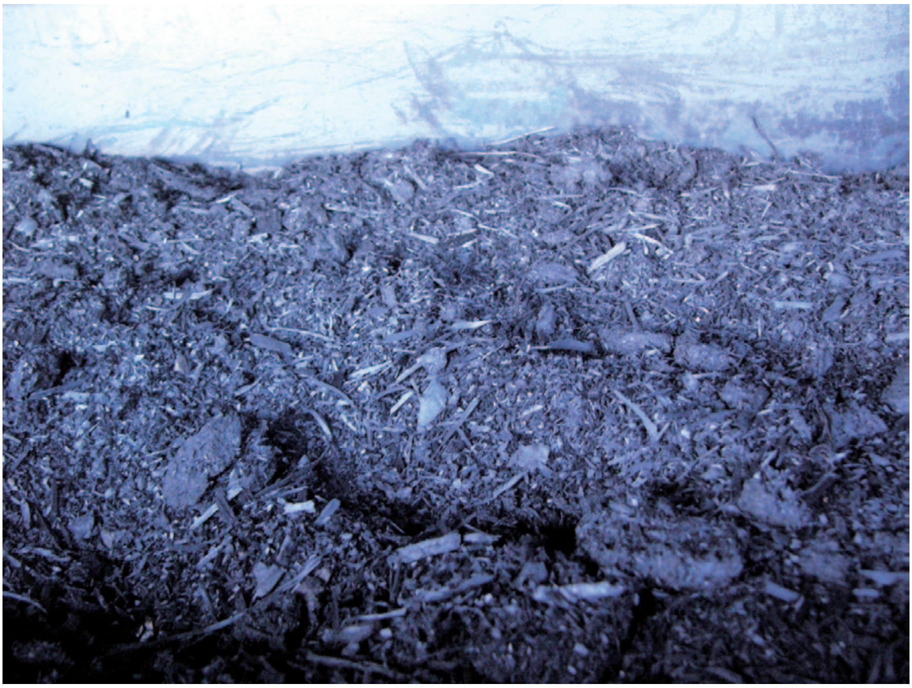

Figure 2. Biochar produced from horse manure in sawdust bedding (Photo: Tomi Holstila).

There are potential uses for biochar outside the field of agriculture as well. In Finland, the structural change in industrial activity and difficulties of paper and pulp industries have hastened the interest towards new ways of utilising forest biomass. Helsinki Energy is one of the companies examining the possibility of using carbonised wood to replace coal burning due to its good properties for burning and logistics.

DEFICIENCIES IN BIOCHAR SCIENCE

Biochar is a topic discussed to an increasing extent in the scientific world, which is constantly looking for answers to deal with climate warming, inadequate food production for the ever growing world population and depleting resources in fossil fuels and fertilisers. Biochar could be one way of solving this equation, but at the moment there still are many uncertainties involved.

The chemical and biological functioning mechanisms of biochar are not yet known in sufficient detail, as there are an abundance of factors affecting them. Biochar produced from different feedstocks differ from each other, and small changes in the production process can have significant effects on the product. One must also take into account the fact that biochar always reacts with its environment. Biochar applied to one field can have a completely different outcome to the neighboring one, as the management methods and therefore soil properties differ from each other.

There is also a contamination risk involved, as polycyclic aromatic hydrocarbon (PAH) compounds in particular are generated in thermal processing of organic matter. These compounds, hazardous to environment and human health, are mainly accumulated in the tars and gases, but the concentration in biochar can also be near harmful amounts.

POTENTIAL OF PYROLYSIS PROCESS IN SOUTHWEST FINLAND

Soil improvement is not necessarily a topical issue in farming in Southwest Finland as it is in for instance in semi-desert and other eroded areas. Therefore from Southwest Finland's point of view pyrolysis can be seen not only as a biochar production process, but as an alternative for the common waste management and energy supply for farm units or several nearby farms. Ongoing research at MTT and several other Finnish research institutes aims to develop our understanding of the benefits of biochar for farming and the potential for larger-scale, continuous pyrolysis plants for more practical end economical production. Field experiments are being done in vegetation zones comparable to Southwest Finland, and Turku University of Applied Sciences has also started planning future work on pyrolysis. If the entire process is employed, pyrolysis might be one among the future solutions for improved farming cost efficiency as well as mitigating the environmental impacts of food production.

MACROALGAE AS A POTENTIAL RENEWABLE ENERGY SOURCE IN FINLAND

Anne Hemmi
Project manager, Lecturer
Turku University of Applied Sciences

Eutrophication of the Baltic seas has led to a situation where the large amount of available nutrients enables the growth of various macroalgae. In some coastal locations, macroalgal biomasses may provide a significant energy potential.

Strategies at EU and national level focus on decreasing the dependence on fossil fuels to pave the way towards using an increasing number of renewable energy sources. Renewable sources are many and each has its own specific pros and cons related to energy potential, availability, usability and costs. Lots of interest has been shown in developing technologies and creating possibilities of finding new solutions to add to the collection of sustainable energy production. Macroalgal biomasses are among these, and they may provide a significant energy potential in some coastal locations. This has been tested in the Baltic in Trelleborg, southern Sweden (Tatarchenko 2011) where a group of Pure Biomass project personnel made an excursion in the spring of 2013.

Due to eutrophication, the amount of available nutrients (N, P) and consequently filamentous green and brown macroalgae, has been increasing for the last decades. This is a common phenomenon worldwide, but especially remarkable in the heavily polluted Baltic Sea. Human impact is also fostering the decrease or even disappearance of perennial leaf-like algae such as bladder wrack (*Fucus vesiculosus*) due to lack of hard substrata and competition in the eutrophicated littoral zones. Algal biomass may be used for a variety of purposes such as the production of biofuel, fertiliser or animal feed.

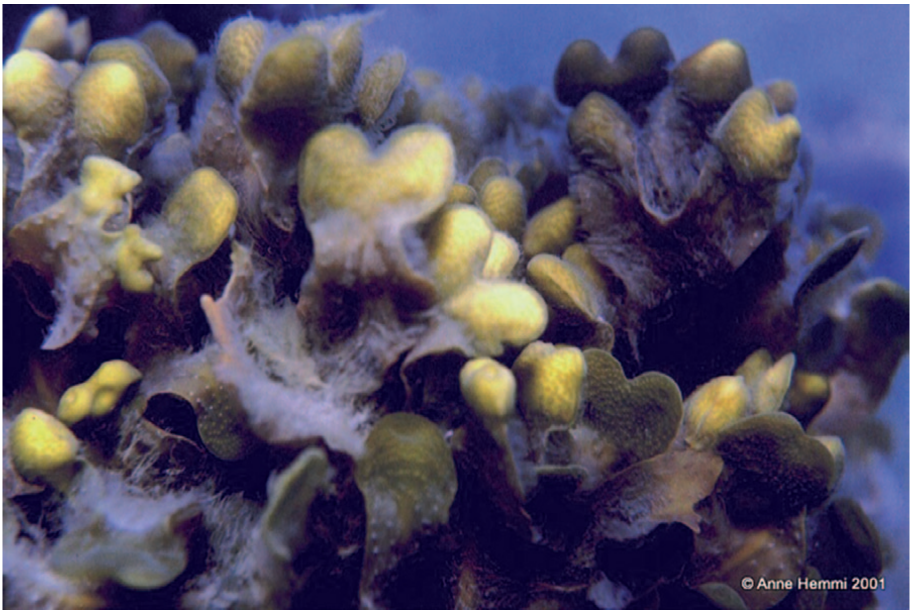

Figure 1. *Fucus vesiculosus* (Photo: Anne Hemmi).

MACROALGAE

Macroalgae is a common name for a diverse group of both annual and perennial species representing a wide range of growth forms and life-cycles.

The highest growth rates and biomasses are found in the exposed shores of temperate oceans, where frequent storms occasionally wipe the vegetation detached from the substrate and transfer the masses onto the beach. These beach casts formed by algae, seaweed and invertebrates are probably among the most promising way of collecting algal biomass for energy. Removing the banks increases the recreational values and takes away nutrients from the water column.

Tidal shores grow massive quantities of intertidal fucoid algae (Fucales, Phaeophyta), which are exposed to air on a regular basis. Fucoid algae are, however, often key species in the littoral ecosystems and thus maintain huge biodiversity. They host a number of invertebrates and fish, and provide feed, spawning sites and shelter for juveniles as well as adult sea life. The algae are also tightly attached to the substrate and difficult to harvest.

Bladder wrack (*Fucus vesiculosus*) declined drastically in the 70s from large areas of rocky bottoms in the Archipelago Sea. Slow recovery of Fucus vegetation has been observed during recent years, but still its amounts are far lower than before eutrophication.

Legal aspects have to be taken into account when operating in the vulnerable Baltic Sea region. Nature conservation sites like Natura 2000 and adjunct areas need careful planning and monitoring, if any of the existing resources should be utilised. Currently there is neither practice nor suggestions of how large a proportion of algal biomass can be taken without disturbing the conservation values of a particular ecosystem.

MACROALGAL CULTIVATION

It is possible to cultivate algae close to the shore in artificial net and polyethylene rope-based technology installations. Pilot installations have been built to filter the excess amounts of nutrients originating from land run-off, or in the proximity of a fish farm in order to catch some of the released nutrients from the system. Installations function as substrata mainly for annual filamentous algae from the genera *Cladophora* (Chlorophyta), *Ceramium* and *Polysiphonia* (Rhodophyta) and *Pilayella/Ectocarpus* (Phaeophyta). The yield of these species remains extremely low (only 5% of DW at its highest; SUBMARINER project 2013) compared with the animal biomass attached to the same ropes and nets. Therefore, cultivating macroalgae for energy is not feasible in the northern Baltic. In addition, winter conditions and occasional storms pose further challenges to the installations.

Figure 2. Filamentous algae (Photo: Anne Hemmi).

BIOGAS AND BIOFUEL FROM MACROALGAE

Macroalgae are suitable for local scale biogas production. They contain a lot of moisture and are suitable for anaerobic digestion or fermentation carried out by micro-organisms. Other possible technologies to produce energy include hydrothermal upgrading, combustion and gasification (SUBMARINER project 2013). Various energy products in addition to heat can be obtained depending on the technology used: conversion to bioethanol, anaerobic digestion to produce methane, the extraction of oils, and biorefinery to produce biofuels and other products. Following extraction, algal oils will need to be further refined (by hydrocracking and hydrogenation) to produce gasoline or jet fuels (European Biofuels Technology Platform).

The methane yield is only slightly lower than with terrestrial crops. Studies are still rather few, but they indicate that there is good potential which may be further developed.

MACROALGAE COMPOSITION IN SOUTHWEST FINLAND ALONG THE BALTIC SEA COAST

The coastal line in the Finnish Archipelago Sea is extremely fragmented. Coastal lines of thousands of islands form a suitable ground for macroalgal growth. The only perennial leaf-like brown species is the bladder wrack (*Fucus vesiculosus*), which is of great ecological importance and maintains high biodiversity. The Baltic Sea is heavily loaded with nutrient discharge from land and this has shifted the algal species composition towards filamentous, opportunistic species.

In the non-tidal and brackish northern Baltic Sea, seaweed grows close to the surface and produces far less annual biomass compared with the southern parts of the Baltic or even more so, compared with higher growth rates in oceanic conditions.

FUTURE PERSPECTIVES

Despite the interesting studies and many beneficial effects of harvesting algae for the ecosystems in the Baltic Sea, the conclusion is that macroalgal biomass does not seem a very promising source of energy in Finland in the near future. Potential in energy production at the moment is rather theoretical due to several reasons: low yield, lack of harvesting technology and relatively low price of other energy sources (fossil fuels and abundant renewables such as wood or agricultural by-products). These facts are against the vision of desired macroalgal energy production chains, where achieving a positive net energy value is a requirement.

SOURCES AND LITERATURE

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European Biofuels Technology Platform: http://www.biofuelstp.eu/algae.html

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EXPERIENCES OF OTHER PATHFINDERS – EXCURSION TO SOUTHERN SWEDEN 28–30 MAY 2013

Anne Ahtiainen
Director
Valonia

The Pure Biomass project group made a study visit to southern Sweden in order to investigate the possibilities regarding the use of algaes and salix (willow) in energy production. Good examples of the success of political coherence in the environmental work of municipalities were found during the excursion.

Växjö city has been working for a future free from fossil fuels for almost two decades. They have a wealth of experience on different initiatives against climate change and it is a place worth visiting. The project group was also very interested in salix cultivation, and the farm of SalixEnergi Ab was a perfect place to explore planting and harvesting methods of salix. Both project regions, Kurzeme and Southwest Finland, are situated in coastal areas and the problems with algae have provided an impetus to study whether it may represent a new resource for energy. In Trelleborg, we found pilot plants for not only macroalgae but also for microalgae.

VÄXJÖ – THE GREENEST CITY IN EUROPE

Växjö is situated in southern Sweden. Växjö municipality has 84,800 inhabitants and covers an area of 1,925 km^2.

In 1996, the city's politicians decided unanimously that Växjö would be a fossil fuel free city by 2030. The political unity and common decision has made it easier to carry out the actions required. The city created an environmental programme in 1995 and it was revised 2010. The targets are:

- The fossil CO_2 emissions shall be reduced by 55% per inhabitant between 1993 and 2015.
- The use of energy shall be reduced by 15% per inhabitant between 2008 and 2015.
- Electricity consumption shall be reduced by 20% per inhabitant between 1993 and 2015.

Municipalities are required to have an energy plan by law, which includes an action plan for the years 2012–2014. The energy plan will be used along with transport strategy tools in order to reach the fossil fuel free vision in the environmental programme. A distinction has been made so that the energy plan focuses on energy efficient and environmentally-friendly vehicles, whilst the transport strategy focuses on transport such as a sufficient public transport traffic, roads for walking and cycling as well as the behaviour of citizens. The energy plan will be followed up every year until an overview is carried out during the next mandatory period.

By 2012, Växjö had reduced the carbon dioxide emissions from fossil fuels by 41% per inhabitant since 1993. This success is not due just one or two key measures, but rather a combination of various ways and experiments.

The most important reduction in CO_2 emissions comes from district heating, where oil has been substituted with biomass, resulting in 80% of the heat coming from renewable energy sources. The transportation sector is a main source of emissions, and recently there has been reduction in emissions in this sector too, due to the increase of environmentally-friendly vehicles, such as hybrid and electric cars. Biogas is available for private cars, and public buses also run on biogas.

Figure 1. Sandvik 3 is under construction (Photo: Anne Ahtiainen).

Figure 2. Wood chips into Sandvik 2 (Photo: Anne Ahtiainen).

Our group visited Sandviksverket, the district heating power plant. The base load is covered by Sandvik 2 with 65 MW heat, and 35 MW electricity and also 25 MW heat from flue gas condensing, mainly operating on biomass. Sandvik 1 (50 MW heat and 20 MW electricity) is a standby plant operating on oil. In 2012, almost 80% of the fuel used was biomass. A new 100 MW biomass CHP power plant called Sandvik 3 will start operating in 2015. There will also be a new external handling station for biofuel including Sandvik 2 and 3.

Växjö is promoting solar energy – for example the city hall has solar panels on its roof. The city owns shares in a wind farm near Ockelbo.

Figure 3. Solar energy calculator on the wall of city hall (Photo: Anne Ahtiainen).

VISIT TO THE SALIX FARM IN SVALÖV

The excursion group visited a farm owned by the company SalixEnergi Europa AB, in Svalöv. The company provides Salix plants all over Europe and has dealerships in 17 European countries. The company also provides instructions for planting and harvesting, and act as a consultant in large plantation projects all over Europe. Additionally, they have also developed the "HSAB Fully Hydraulic" harvesting head that is easily fitted to John Deere, Krone or Claas forage harvesters.

Salix is a very fast growing biomass. It is planted directly into the ground in 20 cm long saplings, with 14,000 saplings to a hectare. In northern Europe the planting takes place in the spring time, through until the end of May. Normally there is no need to use fertilisers in the first year, but some weed control is required.

Figure 4. Salix field. Plantation is four years old and part of it was harvested two weeks earlier. The new growth is already about 30 cm long (Photo: Anne Ahtiainen).

Salix is usually ready to be harvested 4 years after planting. The best time for harvesting is in winter, from October to May, when Salix is fully dormant and the ground is still under frost. In the first harvest, the estimated yield is 20–25 tons of dry material per hectare. The following harvest can be carried out 3–4 years after the first harvest. The yield estimate is then 30–35 tons per hectare. According to some references, the energy content is 50–120 MWh per hectare.

USE OF ALGAES IN TRELLEBORG

Trelleborg is the southernmost town and municipality in Sweden, located in the coast of the Southern Baltic Sea. It has approximately 43,000 inhabitants and area of 340 km^2, with a coastline of 32 kilometers.

Macroalgae causes problems especially on public beaches and tourist areas. When algae decomposes, a large amount of greenhouse gases are produced. The Wetlands Algae Biomass (WAB) project tried to find solutions to not only this problem, but also to the nutrient leakage from farmland into the Baltic Sea. The removal of phosphorus and nitrogen can be carried out by collecting algae from the sea or the coastal areas. Algae is then used as a raw material in biogas production, after which the residue of the anaerobic process can be returned to the fields. However, the wetlands are very important nutrient buffer zones.

In Trelleborg, the algae is collected from the beaches and then taken to the Smyge pilot biogas plant. The plant uses hydrolysis to collect the main components from the algae and other materials, such as straw. The water which has passed through the raw material is collected and pumped into a balance tank, and is then fermented in the biogas reactor. The reactor has a capacity of 4 m^3 and is filled with fill cups to create a large solid space for the bacteria film to grow on. The bacteria converts the organic compounds of the slurry to methane, carbon dioxide and water.

Figure 5. This reactor shows light green from micro algae after two days (Photo: Anne Ahtiainen).

In Trelleborg, there is also a pilot plant for water purification using micro algae. The treated water from the waste water plant is led into the algae reactor. The reactor captures CO_2 from the air and biomass grows on the surfaces of the reactor. Biomass is then used in biogas production. During the process, the level of nitrogen and phosphates in the treated waste water is reduced by over 70%.

Trelleborg is also trying to prevent the eutrophication of the Baltic Sea through the restoration of old rivers and wetlands. The nutrients from the fields are captured in the wetlands before they reach the sea. Tulltorpså river restoration site was restored some years ago and has also a great value for leisure as well as a bird territory. Wetlands also help to prevent problems with floods.

Figure 6. Tulltorpså river restoration (Photo: Anne Ahtiainen).

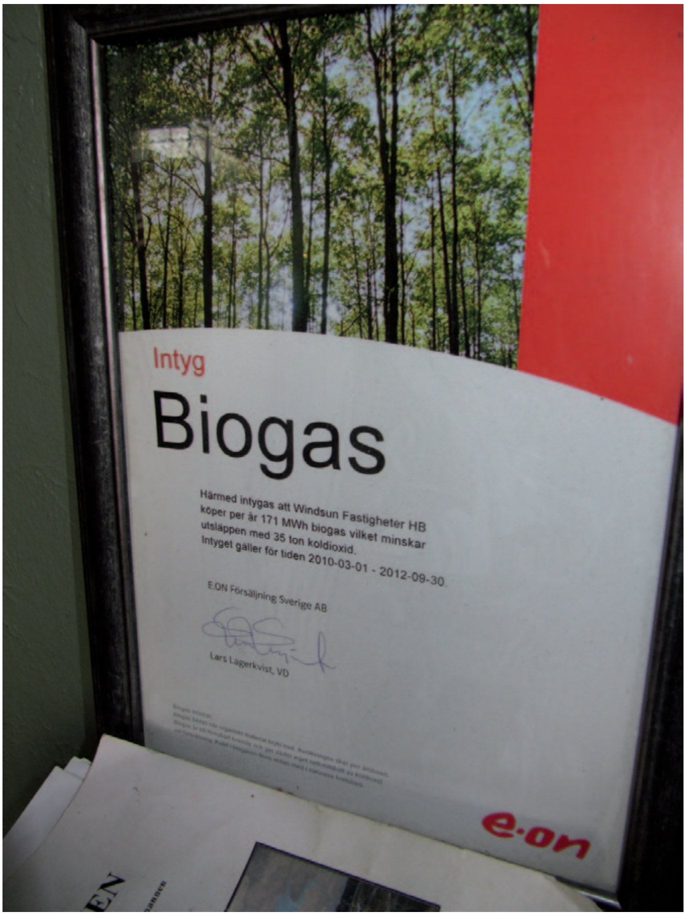

Figure 7. Anderslövs Gästgivaregård restaurant has a certificate which shows that they have been using biogas (Photo: Anne Ahtiainen).

CONCLUSIONS FROM THE STUDY VISIT

The study visit was very successful. It provided a lot of ideas what could be employed in the project regions in Kurzeme and Southwest Finland. It also showed the value of pilot projects, and being among the first, for publicity: over 100 delegations visit Växjö every year from all over the world. It was also useful to hear the good and bad experiences of successful projects. The visits to the cities also made clear the need for political will when implementing new techniques or practices.

LINKS

The city of Växjo	www.vaxjo.se
Salixenergi Europa AB	www.salixenergi.se
The municipality of Trelleborg	www.trelleborg.se
The Submariner project	www.submariner-project.eu
Tullstorpsån river restoration project	http://www.tullstorpsan.se/
Wetland Algae Biogas project	http://wabproject.pl/