

Bioenergy and Regional Development in the Nordic Countries

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Nordic co-operation

takes place among the countries of Denmark, Finland, Iceland, Norway and Sweden, as well as the autonomous territories of the Faroe Islands, Greenland and Åland.

The Nordic Council

is a forum for co-operation between the Nordic parliaments and governments. The Council consists of 87 parliamentarians from the Nordic countries. The Nordic Council takes policy initiatives and monitors Nordic co-operation. Founded in 1952.

The Nordic Council of Ministers

is a forum of co-operation between the Nordic governments. The Nordic Council of Ministers implements Nordic co-operation. The prime ministers have the overall responsibility. Its activities are co-ordinated by the Nordic ministers for co-operation, the Nordic Committee for co-operation and portfolio ministers. Founded in 1971.

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Summary

Over the last twenty years the Nordic regions have witnessed both the expansion of the bioenergy market and increasingly polarized economic development. Urban areas are rapidly growing while sparsely populated areas continue to face difficulties in finding new sources of income, and thus becoming ever more dependant on active national and EU support. Given the desire to find new ways to restore and improve regional economic structures and provide additional income for these areas, the expansion of the bioenergy market, in particular through first and second generation biofuels, is viewed as a potentially beneficial strategy towards the realisation of this ambition.

The aim of this study is to provide a preliminary overview of the potential inherent in the sustainable production of biomass and bioenergy, while, in addition, providing an analysis of their regional impacts in the Nordic countries. Which Nordic regions are more suitable for biomass- and bioenergy production? Which bioenergy alternatives are likely to be more sustainable, and what are the likely social and environmental consequences of an increase in bioenergy production? These are the central questions this study attempts to investigate.

Assessments presented in the study were undertaken on the basis of previous studies, as well as on data collected to provide an initial biomass potential assessment for the Nordic countries. The study does not however address the issues relating to specific market conditions or those relating to the economic incentives for bioenergy. Details of energy balances or the design, engineering and operation of biomass cultivation and bioenergy conversion technologies are not discussed.

In reviewing the content of this rapport it becomes clear that further research is needed to establish a better understanding of the role and potentials of bioenergy as a priority in Nordic regional development strategies. In this regard, studies on the socio-economic impacts of the exploitation of wood biomass for bioenergy purposes, the various approaches to bioenergy planning, the perception of energy crops and their impact on the landscape, and the pattern of innovation in renewable energy resource development remain among the most important themes here.

Bioenergy systems

Bioenergy systems rely on the essential elements of bioenergy production, namely sunlight, wind, rain, soil and human work. A closer look at bioenergy systems in practice reveals however that many other aspects should also be taken into consideration, including technical, social, economic, institutional and environmental concerns. In addition, it is clear that bioenergy systems can be intimately related to local, regional, national and trans-national socio-economic structures. Thus, the political choice to develop bioenergy alternatives is based on both bio-geophysical and socio-economic premises. In addition, the production, transformation, conversion, distribution and consumption of bioenergy involves several sectors including forestry, agriculture, transport and energy while also having direct implications for landscape planning, the interrelation between cities, peripheral and rural areas, and infrastructure systems, as well as the transport and daily lifestyle needs of people more generally.

Bioenergy feedstock and technologies

Feedstock

Among the available energy crops, most biomass per hectare is obtained from perennial energy crops such as willow and reed canary grass, while traditional food crops (grains and oilseeds, also characterized as annual crops) are less productive. When looking at the energy balance, which is the relation between the energy obtained from an energy crop, and the process energy consumed during the cultivation and harvesting, perennial crops are still significantly more advantageous. For annual crops, the most energy consuming activity is the use of machinery in connection with soil preparation, sowing, harvesting, and the use of fertilizers.

The obstacles to substituting traditional annual crops with perennial energy crops are however significant. The transition to perennial energy crops represents a change in traditional agricultural practice. Farmers can often be reluctant to cultivate perennial crops because they perceive them as entailing increased financial risks. A change towards perennial crops also demands significant investment in new machinery, resulting in short term high cultivation costs.

Biomass from forest residues has proved to be an excellent feedstock for bioenergy and has been used in the Nordic countries for district heating for several decades. This because of its easy availability, especially in Sweden and Finland, and the low process energy used to extract and transform it into pellets and briquettes and convert it into heat and electrical power.

Technologies

When comparing today's various technological alternatives for energy conversion from biomass; direct combustion, thermal gasification and biogas are the most energy-efficient. This is because they are well developed, have a high energy balance and have a larger, available and diversified feedstock in the Nordic climates.

Biogas appears to be the most environmentally friendly and resource-efficient alternative for the transport sector, and could be used during the transition towards second generation biofuels. Biogas production is based on well known techniques, has a low process energy demand as well as using a large and diversified feedstock originating in the main from agricultural residues and organic municipal waste. Compared to biogas, first generation bioethanol and biodiesel are easier for car owners to use but remain the less favourable option, due to the large amount of process energy consumed during the cultivation of the crops and refining processes, leading to increased carbon dioxide emissions.

In the long run second generation biofuels remain a better option for substituting conventional fuels mainly because they enable the use of a well-diversified feedstock which is readily available in the Nordic countries, especially in the northern regions. Technological developments currently point to the further development of bio-refineries able to simultaneously produce second generation biofuels, heat, electric power and other products while enabling the use of most of the energy content in biomass.

The bioenergy potential of first generation biofuels

The product lines presented in this study are bioethanol based on grain and straw, biodiesel based on rape, and biogas based on grain straw and liquid manure, projected for 2020. For bioethanol and biogas the highest bioenergy potential was found in

Denmark, followed by Sweden, Finland and Norway. For biodiesel based on rapeseed, Denmark and Sweden are the countries with higher potentials.

The main capacities for biomass production for renewable energies in the Nordic countries are consequently located in those regions with most favourable conditions. Not least the availability of fallow land provides an important basis for a considerable increase in bioenergy potential from agriculture. In terms of the geographical extent, winter wheat appears to be the dominant crop for bioethanol production in the southern regions of Denmark, Sweden and Norway. In Finland, however, the dominant crop is spring wheat. The projected development of yields of the main crops is relatively moderate except for rapeseed in Denmark which shows considerable yield increases.

Crop rotation methods change over time and currently offer innovative options for energy cropping. Changes have to be carefully handled to prevent environmental damage. In this way the potential for green biomass to produce silage for biogas fermentation could be extended. Changes in the extension of arable land for energy crop cultivation should be driven mainly by land availability and the availability of better adapted energy crops, but also by farmers' familiarity with the cultivation techniques for these crops. Also in relation to the question of the landscape consequences of increased bioenergy production, the inclusion of crop rotation as a part of the landscape planning strategy may help prevent the adverse effects of single crop dominance.

Environmental impacts

The cultivation of annual energy crops involves important environmental pressures but, where there is no expansion of arable land usage the environmental impact of a change from food to bioenergy production should be neutral. Under this condition, it is also believed that environmental benefits can be accumulated because cultivation methods for annual energy crops appear to be less nutrient and pesticide dependent. Where more land is used for the cultivation of annual energy crops it may involve several negative environmental impacts, mainly through higher levels of greenhouse gas emissions, nutrient leakage and reduced biodiversity. These factors become ever more severe if applied to the cultivation fallow land, and high value natural areas.

Compared to annual crops, perennial crops are, in general, significantly more environmentally friendly. The negative environmental impacts of perennial crop cultivation mainly relate to changes in the cultural landscape. The extent of the impact on the landscape will however be dependant on both the cultivation method used and the perception of local communities towards the large scale cultivation of perennial crops. Negative environmental impacts in perennial cultivation are also likely to occur in fallow land or high value natural areas, though to a lesser extent than with annual energy crops.

The environmental impacts of complementary felling or the extraction of forestry residues remain dependent on the management system used in forestry as well as the characteristics of the forest to be exploited. Due to the role of deadwood, stumps, branches, roots and tops in forested ecosystems acting as nutrient sources, preventing soil erosion, regulating water flows and as a refuge for flora and fauna, their extraction must be carried out without compromising these functions.

Bioenergy technologies vary in terms of their environmental impact. In general, the use of bioenergy for district heating or combined heat and power (CHP) is to be preferred to generation by liquid biofuels for the transport sector. This is mainly

because both the feedstock production and the refining process of biofuels demand large quantities of process energy and transport. Among biofuels used in the transport sector today, biogas remains the most environmentally friendly. This is because residual products, the main raw material for its production, can be transformed into biogas by using low quantities of process energy. The benefits from second generation biofuels in the Nordic countries rely on the utilization of woody biomass from forest, municipal waste and perennial energy crops, which are found in large quantities.

Labour market perspectives

In respect of labour market consequences, the primary production of bioenergy provides a substantial number of jobs in rural areas. In most cases, however, bioenergy production requires almost the same labour input as other agricultural field crops. Many so-called 'bioenergy crops' are basically those already produced by farms, so a change in final usage will not change farming activities that much.

A shift from annual to perennial crops may indeed even mean an overall reduction in the number of hours worked, though this would, in part, be compensated through peak activities in the planting and harvesting seasons. In a worst-case scenario this may entail an increase in the requirement for *temporary* labour, as perennial crops do not require continuous monitoring. Consequently, the primary production of bioenergy will only provide extra jobs to the extent that it will be possible to include areas which presently are kept outside agriculture. For most crops the technology and investment requirements will be the same as now, while a shift to perennial crops would require substantial initial investment.

In the current situation, where demand on the world market for food is rising bioenergy production will thus increasingly be competing with traditional food production for land and investment. As a consequence of this the creation of new jobs and the maintenance of current activities in rural areas will not see significant change in high yield regions, i.e. Denmark and southern Sweden. In less productive areas where food production is already marginalized, however, the option to produce bioenergy will enable farms to continue their activities beyond what may have been feasible given the development of production costs in relation to prices and subsidy levels over the last decade. In consequence, the long term perspective for the primary production of biofuels may enable a number of farms which are now in a marginal position to continue their activities. This applies to both low and high productive regions.

The most important labour market effects of bioenergy production appear when looking into the transformation and conversion of bioenergy and its related infrastructure development. In this context the choice of technology and scale of activity becomes an important issue.

The establishment and maintenance of small to medium scale district heating and combined heat and power plants will create around the same number of jobs in rural areas as those created in relation to primary bioenergy production. Besides providing new job opportunities, it also adds to the range of jobs available in rural and remote areas where opportunities are traditionally limited.

The alternative, establishing large scale centralized transformation or conversion facilities, facilitates almost the same level of job creation, so the net effects of bioenergy production will be almost the same, independent of the choice of technology. The transportation sector and the maintenance of an extensive district

heating system are among the activities potentially adding to the job creation total. But the impact will however be experienced predominantly in the urban areas, while the rural areas become primary production areas. The only exception to this general rule is biogas production, where the cost of transporting manure from farming areas to larger centralized processing units limits the profitability of the gas production.

The cost-effectiveness of the production of biodiesel and bioethanol are very different. While biodiesel production can be undertaken on a small scale, thus providing increasing development opportunities for a greater number of rural and remote regions, bio-ethanol requires production facilities of a medium to large scale which may be established outside the development centres, but will only provide jobs for a limited area. In general, the regional effects of bioenergy transformation and conversion are again – as with primary production - closely connected to primary production, leading to the direct effects becoming more obvious in Denmark and southern Sweden, while the options become more the further north we move.

Other socio-environmental impacts

Job creation numbers in connection with bioenergy production may turn out to be of a level to compensate for the general trend of job loss and out-migration, and thereby contribute to the maintenance of existing rural communities.

The landscape changes that would be the result of changes in land use may, however, have some negative impacts on the communities concerned. Conflicts between different regimes for perennial crops occur when business and landscape conservation values are considered. For example, small cultivation areas are believed to enrich the landscape, while large, square and homogenous areas are often seen as less appealing but more economically profitable. Moreover, as tourism in general and second home owners in particular have emerged as increasingly important contributors to local economies, the use of traditional annual agricultural energy crops on farmland is generally perceived as preferable although likely substantial changes may influence future activities. Large scale cultivation of bioenergy crops could also lead to conflicts in land-use in today's agricultural areas in the Nordic countries because these areas are also the most densely populated.

For northern peripheral areas with vast forest areas conflicts between the various regimes for the exploitation of these forestry resources will likely also appear. Moreover, increased deforestation for energy purposes, using traditional forestry management approaches, could lead to a loss in the recreational value of forest areas. One consequence of this could be labour source losses in the tourism industry while economic activities dependent on second homes will also be put at risk.

Innovation aspects

The development of technologies in connection with bioenergy production and conversion technologies has been characterized by a pattern of user-producer interaction. This is a pattern which resembles that in other parts of the renewable energy sector, where small scale producers in close cooperation with their customers have provided the basic options for the development of the sector.

This has led to the emergence of a de-centralized system of producers which may be argued is simply a consequence of the systems in the initial phases being low-tech. The pattern, however, seems to be robust despite the emergence of more technological demanding systems. As a consequence, the industries provide de-

centralized job opportunities characterized by a rather diverse profile, from unskilled to professionals and highly skilled specialists.

In addition to providing jobs and economic input to both rural and remote regions, the sector adds to the diversity of jobs available as well as requiring the increased availability of training and other educational facilities.

1 Introduction

Climate change mitigation and energy security have been two of the most important key policy objectives to have significantly contributed to the increasing share of renewable energy usage in the European Union. Bioenergy remains the largest renewable energy source while also having the potential to make a substantial contribution to securing energy supply and mitigating climate change in the future. As such, bioenergy is viewed as an important contributor to the solving of conflicts between energy consumption and environmental policy. (EEA, 2006)

Thanks to increasing fossil fuel prices, better cropping systems and increased area availability for bioenergy, farming bioenergy products from agriculture is progressively becoming more economically competitive in the EU. Notwithstanding this, for the Nordic countries in particular these trends are even more pertinent as the framework conditions for the growth of the bioenergy market are to a large extent tuned by EU energy policies (EEA, 2006)

A track record which has seen many years of biomass utilization for electrical power and district heating purposes has placed the Nordic countries in a strong position in the bioenergy technology market (ECON PÖYRY, 2008). While the expansion of the bioenergy market over the last twenty years has been considerable the broader picture of economic development across the Nordic regions has witnessed a progressive polarization. Urban areas are rapidly growing while peripheral areas face increasing difficulties in finding new sources of income, and in consequence are becoming ever more dependent on active national and EU support. As such then one of the most important challenges facing policy makers in the Nordic countries is the need to create a balance between different development trends across the Nordic region (Neubauer *et al*, 2007).

The expansion of the bioenergy market, in particular of first and second generation biofuels, is viewed as a potentially beneficial strategy which could help to restore regional economic structures and provide additional income for farmers and forestry workers. However, it is also acknowledged that the selection of bioenergy and the most suitable technology is strongly dependant on local conditions (Docman *et al*, 2008). Several factors, including the climate and soil characteristics, determine the spatial distribution of the environmentally compatible bioenergy potential and this in turn determines the economic benefits obtained from bioenergy production. At the same time, however, some regions may be more adaptable to the landscape consequences of biomass production while such crops may conflict with the perception of other landscapes as being pristine. Therefore, some regions will be more suitable than others to the establishment of large-scale biomass production from energy crops (Jørgensen *et al*, 2008).

1.1 Aim of the study

Against this background, the aim of the study is to provide a preliminary overview of the potential for the sustainable production of biomass and bioenergy, and an analysis of their possible regional impacts in the Nordic countries. Which Nordic regions are more suitable for biomass- and bioenergy production? Which bioenergy alternatives are likely to be more sustainable and what are the likely social and environmental consequences of the expansion of an increase in bioenergy production? These are the central questions this study will attempt to address.

This study was undertaken by means of two key activities; firstly a GIS-based overview of the distribution of the biomass potential of grain and oilseed crops in the Nordic Regions was carried out by the Faculty of Landscape Management and Nature Conservation at the University of Applied Sciences in Eberswalde, and this was followed by a social impact assessment based on previous studies of bioenergy in addition to assessments of the impact of similarly expanding agricultural and industrial activities in the Nordic regions.

The geographical extension in this study covers only Denmark, Finland, Norway and Sweden referred to here as “the Nordic countries”. Being also part of the Nordic region, Iceland and two of Nordic countries’ associated territories; the Faroe Islands and Greenland were not included due to time and resource limitations connected to the project. The study does not cover specific market conditions or the economic incentives for bioenergy. Instead, it focuses in the main on the regional social and environmental impacts of different bioenergy and feedstock production and on the various transformation and conversion technologies and production scale approaches.

Details of energy balances or the design, engineering and operation of biomass cultivation and bioenergy conversion technologies presented here are not discussed in detail. For in depth insight into the impacts of bioenergy production in the Nordic regions, the assumptions and the approaches used, require further complementary analysis and quantitative assessments on a regional and local scale.

1.2 Methodology for the analysis

1.2.1 The social impact assessment

According to Madlener (1994), socio-economic impact studies “are commonly used to evaluate the local, regional and/or national implication of implementing particular development decisions”. As such, traditionally socio-economic studies are measured in quantitative terms with a focus on economic indices such as employment and monetary gains. These aspects have been acknowledged as being dependent on other elements not always traceable to quantitative analysis, including social, cultural and environmental issues. In consequence, a general consensus exists on the need to transcend the socio-economic focus of direct economic impacts and include non-economic aspects such as cultural, demographic, social-psychological, and often political impacts on the components of the human environment where the impacts are likely to be felt, and on the steps that could be taken to enhance positive impacts and to mitigate negative ones (NOAA, 1994).

In order to assess the social and environmental impact of bioenergy feedstock production and conversion technologies, this study used a multidisciplinary analytical

approach in order to assess, in the main, the direct but also to a small degree the indirect impact of the introduction of large-scale bioenergy on societies in general and on the environment. In particular the assessments presented in this study are based mainly on the existing literature on the subject, in respect to both qualitative and quantitative analytical methods. In the schematic below the chosen structure and themes included in this assessment are laid out:

1. Economic
 - a. Competitiveness in terms of biomass potential
 - b. Infrastructure
 - i. Accessibility
 - ii. Distribution
 - c. Innovation
2. Environmental
 - a. Nutrient leakage
 - b. Greenhouse gas emissions
 - c. Biodiversity
 - d. Landscape
3. Social
 - a. Employment
 - b. Culture
 - c. Gender
 - d. Age structure

The interdependencies existing between the various aspects of bioenergy systems are also taken into account in the analysis.

1.2.2 Estimation of bioenergy potential

The methodology used in the estimation of the bioenergy potential of agricultural products has been developed by a working group at the University of Applied Sciences in Eberswalde. By using Geo Information System (GIS) and agricultural statistics the goal has been to assess and illustrate the potential for bioenergy application at NUTS 3 level in three specific scenarios:

- Scenario I “Status quo”
- Scenario II “Yield increase”
- Scenario III “Yield decrease”

Note: More detail on the proceeding and data analysis for the bioenergy potential estimations is provided in annex 1 or in the document entitled, “Estimation of bioenergy potential on the basis of agricultural statistics and spatial distribution for the Nordic countries” which is available from the University of Applied Sciences in Eberswalde.

Scenario I “Status quo”

In order to assess the current agricultural biomass potential, statistical data on agricultural crops and by-products was collected and used for the calculation of bioenergy amount. The results were represented in maps.

The complete scenario details the bioenergy amount based on agricultural statistics of the following activities:

- Compilation of agricultural statistics on the NUTS 3 level from 2000 - 2006
- Calculation of averages of statistical data from 2000 to 2006: Harvesting amounts of crops wheat, rye, triticale, barley, rape, maize and sunflower¹
- Calculation of yield amounts of by-products (grain straw): grain – straw index = 0,8
- Calculation of averages of statistical data on livestock units (cattle, pigs)
- Calculation of the liquid manure
- Compilation of energy contents of biomass to calculate potentials for Bioethanol (harvesting amount of grain), Biodiesel (harvesting amount of rape) and Biogas (biogas production based on grain straw and liquid manure)²
- Calculation of acreages of fallow land areas as an average of statistical data in 2000 to 2006

Scenario II “Yield increase”

Scenario II “Yield increase” aims to calculate the expected yield increases of the main crops and by-products in order to estimate their future biomass potentials for bioethanol, biogas and biodiesel in 2020. The yield for 2020 was calculated by means of a linear yield regression function.

This scenario consists of the following activities:

- Investigated crops: barley, rye, triticale, wheat and rape
- Calculation on national spatial level (NUTS 0 level)
- Investigation of yields per hectare for a 20-year period from 1987 to 2007 (FAOSTAT)
- Derivation of country and crop specific regression function
- Calculation of potential yield per hectare and country based on crop specific regression function for modelling year 2020
- Calculation of maximum acreages according to the agricultural statistics for the time period from 2000 to 2006
- Crop specific multiplication of maximum acreages (statistics 2000 to 2006) with potential yield per hectare and country of 2020

¹ Data of maize and sunflower are not sufficiently documented in the statistics (EUROSTAT, FAOSTAT, regional statistics of the respective Nordic Countries).

² Note regarding BTL: There is no crop specific data from the production line therefore the conversion of straw into bioethanol is used.

- Compilation of energy contents of biomass to calculate potentials for Bioethanol (potential amount of grain), Biodiesel (potential amount of rape) and Biogas (biogas production based on potential grain straw and liquid manure)

Scenario III “Yield decrease”

In contrast to scenario II above, scenario III has been used to show the potential of biomass in the case of a yield decrease. This scenario consists of the following activities:

- Investigated crops: barley, rye, triticale, wheat and rape
- Calculation on national spatial level (NUTS 0 level)
- Calculation of crop and national specific minimum yield per hectare based on agricultural statistics for time period from 2000 to 2006
- Calculation of crop specific averages of acreages according to the agricultural statistics for the time period from 2000 to 2006
- Crop specific multiplication of mean acreages (statistics 2000 to 2006) with potential yield (minimum statistics 2000 to 2006) per hectare and country
- Compilation of energy contents of biomass to calculate potentials for bioethanol (potential amount of grain), biodiesel (potential amount of rape) and biogas (biogas production based on potential grain straw and liquid manure)

The implications and limitations of the methodology

A number of the most important implications and limitations of using the current methodology for the assessments are listed below:

- The grain-straw-index used in this study is not validated to the Nordic cultivation conditions.
- Market Development: assessments do not imply the market development in terms of prices. Profits for farmers could be higher when cereals and oil seeds are sold on the global market.
- Supply of new feedstuff by the use of by-products from the bioenergy production, e.g. rape grist.
- Change of political regulation in the scope of renewable energy and nature conservation legislation would have significant consequences for the real availability of renewable raw material.
- Nature conservation: large-scale monoculture farming of biomass (e.g. maize and rape) could cause increased risk of plant diseases and pests followed by harvest losses, more applications of pesticides and a minimization of agro-biodiversity.
- Climate change can cause yield decreases which are not included in the calculated assessments.
- Climate change can result in an earlier start to the growing season (extension of the growing season).

- Dry weather conditions lead to a decrease in yield. More than one year in a row of dry weather conditions causes delivery problems in respect of renewable raw materials for the production process.
- The potential inherent in renewable raw materials significantly depends on parameters within the scope of agriculture, forestry and waste management - e.g.:
 - method of cultivation and management,
 - population development,
 - consumer behaviour,
 - competition between different utilizations,
 - socio-economic influences,
 - assumptions in respect of the food supply and of the increase in production within the scope of agriculture and forestry.
- These parameters can change in the coming years.

2 Identifying the main systems of bioenergy production

Throughout history biomass has been the main source of energy supporting most societal activities, from households, to large and small industries and transportation applications. Despite the use of fossil fuels and the development of new energy technologies, biomass is globally forecast to be among the principal energy sources in the foreseeable future. This is thanks to the development of new bioenergy technologies which are now reaching the market and successfully competing with fossil fuels. Bioenergy systems have a very complex nature due to their highly diversified raw material and technological options notwithstanding energy's central role in modern society. The following section will provide a brief description of bioenergy, its' interactions and the technologies involved, from both a technical and socio-economic point of view.

2.1 What is bioenergy?

Bioenergy is defined in this study as a renewable but limited energy source, made available originally from biological processes which use solar energy to synthesize atmospheric carbon dioxide (CO₂) and water into biomass. Biomass includes a wide range of products and by-products from forestry and agriculture as well as municipal and industrial waste streams. Specifically, biomass includes (Rosillo-Calle *et al* 2007):

- Trees
- Arable crops
- Algae
- Agricultural and forest residues
- Effluents
- Sewage sludge
- Manure
- Industrial by-products
- Organic fraction of municipal solid waste.

For energy purposes biomass is either burnt directly for heat or to generate electricity, or can be fermented into alcohol fuels, anaerobic digested to biogas, or gasified to produce high-energy gas (Figure 1). The way bioenergy is produced and consumed is determined by many factors including the demand for different energy sources, the specific chemical and physical characteristics of the biomass, its accessibility and the technology available for its' transformation and conversion.

For electricity and heat generation through direct combustion, any form of biomass can effectively be used. However, it is mainly woody biomass which is

transformed by combustion or gasification into heat or electricity. For transportation usages biomass is traditionally transformed, through refining processes, into liquid or gas, the so called biofuels (Rosillo-Calle *et al* 2007).

As illustrated in Figure 2 the connections and possible combinations along the bioenergy value chain, specifically between feedstock, transformation and conversion processes, and the application of bioenergy are many (ECON PÖYRY, 2008). The production and use of any form of bioenergy however also implies that energy is lost (see Figure 1), also termed process energy, which is the consequence of production, transport, transformation and conversion processes in bioenergy systems. Process energy is normally originated from other energy sources, often fossil fuels. Therefore, the less process energy used in bioenergy production the more net energy is available for consumers, while greenhouse gas emissions are prevented (Gustavsson, 2007).

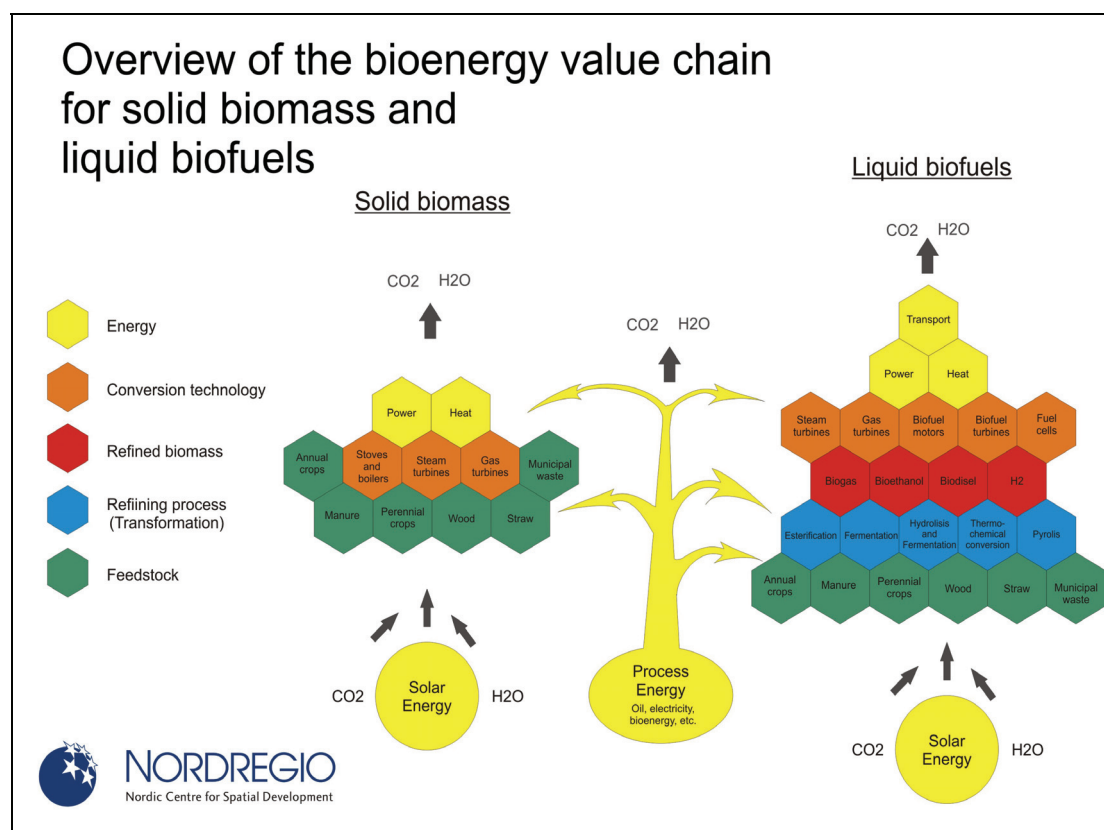


Figure 1 Overview of the bioenergy value chain for solid biomass and liquid biofuels

In general, liquid biofuels have a low net-energy value due to the fact that their transformation processes are very energy demanding while the direct combustion of solid biomass provides higher levels of net-energy, when the appropriate conversion technologies are used. On the contrary, refined bioenergy such as liquid biofuels has other benefits, in particular they are both easier to distribute and more suitable for conventional engines used in the transport sector. Thus, energy efficiency can be outweighed to a large extent by other factors, such as the technology available but also by resource availability, economic factors and not least, culture and lifestyle (Gustavsson, 2007). This is something that is discussed in the following chapters.

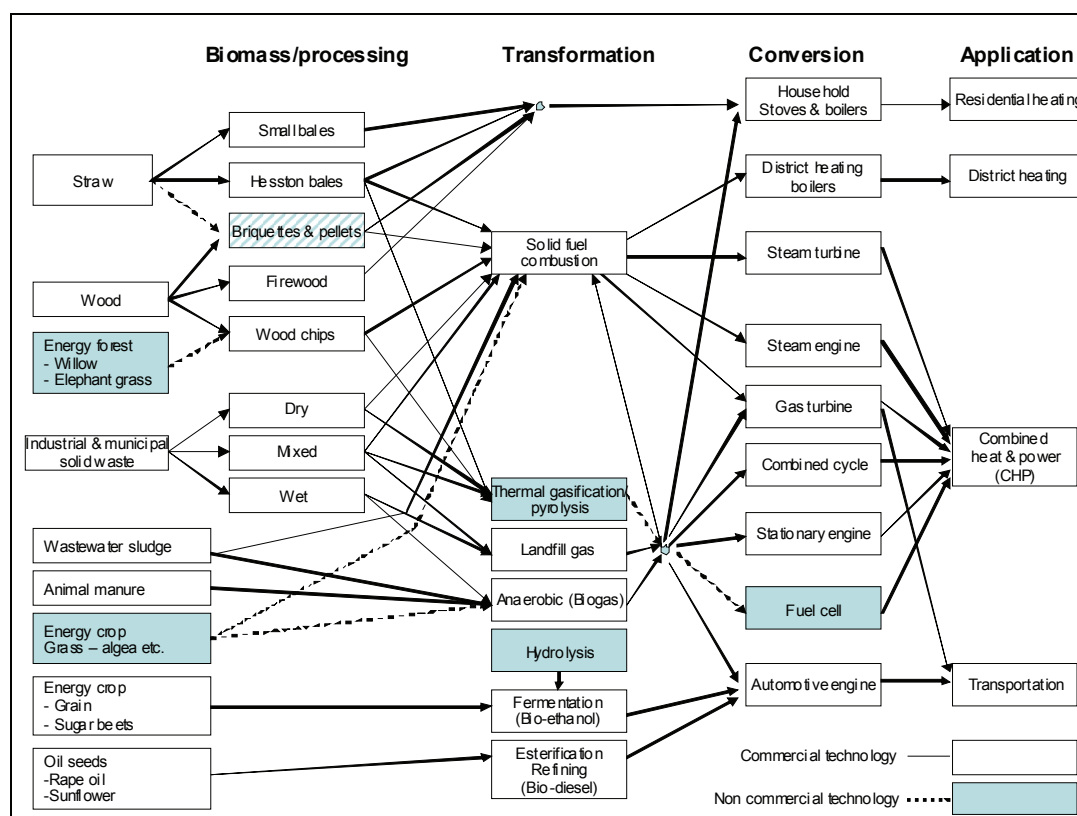


Figure 2 Detailed illustration of the bioenergy value chain (ECON PÖYRY, 2008)

2.2 Bioenergy systems and society

The baseline for bioenergy systems relies on the essential elements in bioenergy production namely sunlight, wind, rain, soil and human work. In order to reduce greenhouse gas emissions in addition to being able to compete and to successfully substitute for fossil fuels, bioenergy systems need to be efficient.

Sustainable bioenergy systems can be defined in different ways and many models have been developed. A traditional model for bioenergy systems comprises four aspects; resource, energy, environmental and cost efficiency (Börjesson, 2007). But bioenergy systems are, in a social and economic context, very complex subjects due to the nature and implications of the various technologies involved, but also due to their indispensable socio-economic

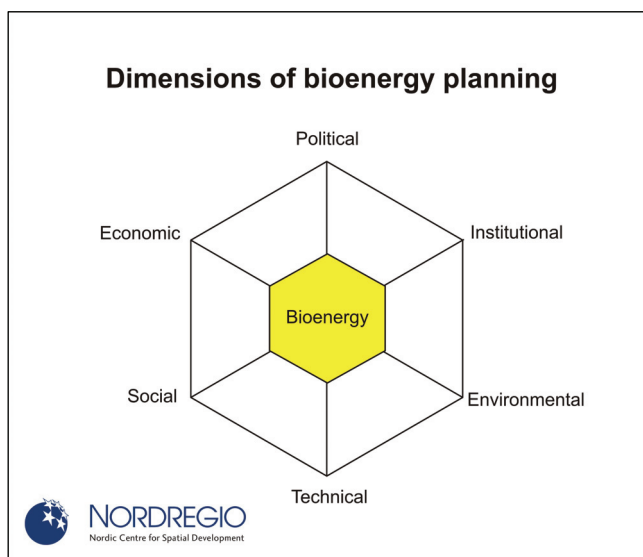


Figure 3 Illustration of bioenergy system and the dimensions of bioenergy planning

role (Domac *et al* 2005).

As illustrated in Figure 3, bioenergy systems are comprised of many individual aspects, including the technical, social, economic, and institutional and the environmental, and are intimately related to local, regional, national and trans-national socio-economic structures. All these aspects may play a central role in the planning stage, as well as in the implementation and operation of bioenergy projects. The political choice of bioenergy alternatives is thus made on both bio-geophysical and socio-economic premises. A closer look at bioenergy systems also reveals that the production, distribution and consumption of bioenergy involve several sectors including forestry, agriculture, transport and energy (Rosillo-Calle *et al* 2007). Additionally, energy systems have direct implications in landscape planning, the interrelation between cities, peripheral and rural areas, infrastructures, as well as the transport and people's daily lifestyle (Verwijst, 2007).

Table 1 Benefits associated with local bioenergy production (Domac et al 2005)

Dimension	Benefit
Social Aspects	• Increased Standard of Living – Environment – Health • Education • Social Cohesion and Stability – Migration effects (mitigating rural depopulation) – Regional development – Rural diversification
Macro Level	• Security of Supply / Risk Diversification Regional Growth Reduced Regional Trade Balance Export Potential
Supply Side	• Increased Productivity Enhanced Competitiveness Labour and Population Mobility (induced effects) Improved Infrastructure
Demand Side	• Employment Income and Wealth Creation • Induced Investment • Support of Related Industries

Bioenergy systems are dynamic since they are constantly changing over time in response to socio-economic and technological change and development, while also acting as a driving force for socio-economic change. The elements in energy systems are integrated with each other and interact accordantly in web-like interdependencies as illustrated in Figure 3. All elements are thus dependent on each other and must coexist in order to properly function in the long run. Which aspects appear more important or dominant, will change through time and with location, and will be determined by the balances or imbalances in the system occurring at a specific moment. A clear example of these dynamics is the development and the recent blooming of modern forms of biofuels for the transport sector.

The model presented by Domac J. *et al* (2005) (Table 1) illustrates the complexity of bioenergy systems by identifying the socio-economic benefits associated with local bioenergy production. The model is divided into four dimensions; social aspects, macro level, supply side and demand side.

Social aspects can be broken into two categories; those aspects relating to an increased standard of living, and those that contribute to increased social cohesion. Standard of living refers to households' income through better employment opportunities, as well as cultural values and health. Social cohesion and stability refers to migration effects, regional development and rural diversification (Domac *et al* 2005).

The Macroeconomic effects constitute the capacity to contribute to the main elements of regional development, such as economic growth through business expansion, employment, import substitution (direct and indirect economic effects on GDP and trade balance) and security of energy supply (Domac *et al* 2005).

The supply side effects are subjective and are likely to differ since they are the results of improvements in the competitive position of the region, including attractiveness to inward investment. These effects may result in the establishment of complementary economic activities, where local related industries often appear in response to increased bioenergy production (Domac *et al* 2005).

The demand side effects refer to the extent and direction of capital flow in employment and regional income. They can be categorised into direct, indirect, induced and displacement effects (Domac *et al* 2005).

2.3 Feedstock

2.3.1 Agriculture

Biomass from agriculture can be classified into energy crops and agricultural residual products.

Energy crops: are cultivated to produce solid, liquid or gaseous forms of energy. These are characterized by their fast growth rate, high biomass yield and durability. Energy crops can be further divided in two groups (ECON PÖYRY, 2008):

- Annual crops: include mainly grains, sugar beet and oilseeds.
- Perennial crops: include, among others, willow, elephant grass, reed canary grass and hemp.

In the Nordic countries, annual energy crops are usually transformed into first generation biofuels, mainly bioethanol and biodiesel. Wheat and rye are commonly used for bioethanol production while oil seeds, primarily rapeseed, are usually used in biodiesel production (ECON PÖYRY, 2008).

Perennial crops in the Nordic countries, such as willow, reed canary grass and elephant grass, are commonly used for bioenergy purposes. Perennial crops are characterized by needing several years to grow before they are harvested and often directly co-fired or transformed into densified biomass for electrical power and district heating generation. (ECON PÖYRY, 2008). As explained in the following section, it is possible to synthesize second generation bioethanol and biodiesel from perennial crops.

In terms of energy obtained per hectare, perennial crops are preferable as they are more productive than annual ones. On the other hand, annual energy crops demand less investment when switching from food crops, while providing faster financial return thanks to shorter rotation periods. Disadvantages related to annual crop cultivation mainly include the large areas required and significant use of energy, fertilizers and pesticides as explained below in section 6.1.1 (Blomqvist, 2007).

Agricultural residual products: include grain and rapeseed straw, stalks and pruning from food crops as well as wet manure from cows, pigs and hens, and dry manure from fattening hens. Straw, stalks and pruning are typically used for Combined Heat and Power (CHP) and district heating plants. Wet manure is usually used for the production of biogas, usually for heat and power generation, but also for transportation (VTI, 2006).

2.3.2 Forestry

Forestry biomass used for bioenergy often originates from residual products, mainly wood-processing waste, wood-based sawdust and black liquor from pulp and paper production. For bioenergy purposes black liquor, wood chips and densified biomass are the common resulting products from forestry (ECON PÖYRY, 2008).

Black liquor: is a liquid by-product of the pulp and paper production industry, resulting from the separation of the lignin from the wood used as a raw material. Today, black liquor is often used locally for internal heat and power generation at the paper and pulp plants (VTI, 2006).

Wood chips: include comminuted wood and longer twigs produced from immature stands from timber harvesting, and from over-mature and partly damaged forests (ECON PÖYRY, 2008).

Densified biomass (Wood briquettes and wood pellets): consist of dry fine comminuted wood, often from shavings and sawdust. Wood briquettes and pellets are used for both industrial and household heat production. Due to the densified biomass's homogeneity, its size, low moisture and ash content makes it easily manageable for machine usage, and it can also be burned in coal-firing boilers without slagging problems. Additionally, wood briquettes and pellets are easier and cheaper to pack, store and handle throughout the whole commodity chain (SOU, 2007).

2.3.3 Biowaste

Biowaste includes the residues and by-products of biological origin, arising from industrial and household activities. Biowaste may be in liquid, sludge or solid form and constitutes a significant proportion of the total waste generated. Many biowaste streams exist:

- Municipal solid waste: the biological component of municipal solid waste, often kitchen and garden waste, paper and cardboard.
- Construction/demolition wood- wood off-cuts from building construction and wood recovered from demolition.
- Secondary wood processing such as furniture manufacture.
- Packaging waste wood: from the packaging and pallets industries.
- Household waste wood: such as old furniture, fencing, etc.
- Sewage sludge: from communal sewage treatment plants.
- Food processing wastes: from the dairy and sugar industries and beer production.

2.3.4 Overview of feedstock alternatives

Among the various energy crops available most biomass per hectare is obtained from willow, while annual crops such as wheat are less productive (Table 2) (Johnsson, 2006). When looking at the energy balance, which is the relation between the energy, obtained from an energy crop, and the energy consumed during the cultivation and harvesting, perennial crops are still significantly more advantageous. Another advantage of using perennial energy crops is that they can be grown on marginally productive or degraded land unsuitable for food crop production.

Table 2 Area needed by energy crops to replace 1m³ of oil (for direct combustion). Modified from Johnsson B. (2006)

Biomass	Yield in tones/ha	1m ³ oil/tonnes product	Area ha/1m ³ oil
Oat	3.5	3.5	1
Straw	3.5	3.5	1
Wheat	5.5	3.5	0.64
Reed canary grass	6	3.5	0.58
Willow, 2nd harvest (4 years)	7	3.85	0.55
Aspen (25 years)	8.4	3.85	0.46
Spruce (25 years)	8.6	3.85	0.45

Fluctuations in energy balances for single energy crops occur due to the methods used in yield systems but also in relation to the soil quality and weather conditions. In respect of annual energy crops, the most energy consuming activity is the use of machinery in connection with soil preparation, sowing, harvesting, the spreading of fertilizers etc.

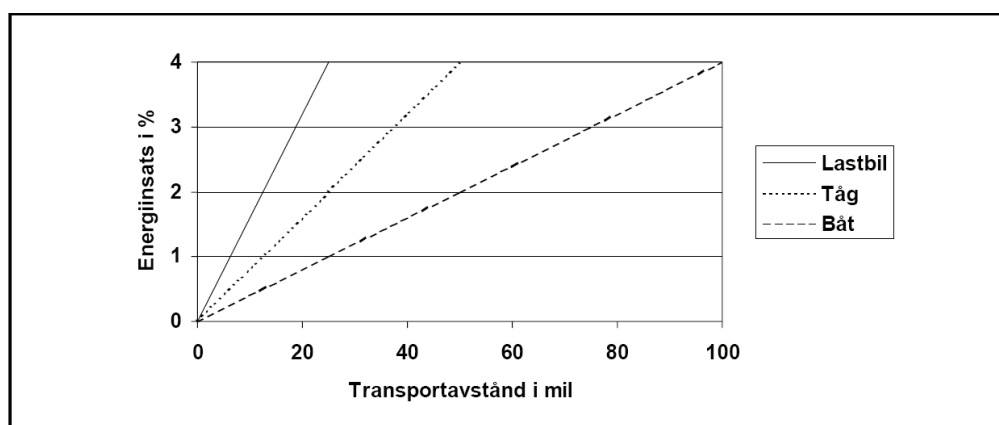


Figure 4 Energy consumption when transporting willow woodchips by truck, train and boat as % of the total energy content per Swedish mile (10 km). (Bioenergi & kretslopp, 2000)

Transport should also be included when assessing the energy balance of energy crops. However, as illustrated in Table 4 the total energy consumption when transporting biomass is usually low, being less than one percent of the total biomass energy value of e.g. willow, on routes under 50 kilometres (Bioenergi & kretslopp, 2000).

The obstacles related to the substitution of traditional annual crops with perennial energy crops are many. Perennial energy crop cultivation represents a change in traditional agriculture, and thus its acceptance among farmers is low. For traditional reasons farmers perceive increased financial risks in perennial crop cultivation. A change towards perennial crops demands significant investments in new machinery, resulting in short term high cultivation costs. Additionally, since perennial energy cultivation demands significantly less custody, it may lead to a reduction in the amount of labour required. The upshot of the summation of all these factors is a higher demand on yield profitability in connection to perennial energy crop cultivation (Rosenqvist, 2007).

Table 3 Examples of solid bioenergy. Modified from Susanne Kastberg (1995)

Biomass	Effective energy content MJ/kg¹	Moisture %	Ash content %	Sulphur %
Branches- roots-tops	9.5	45	1.5	0.05
Woodchips	16.6	12	0.8	0.03
Sawdust	8.4	50	1.5	0.03
Willow	7.9	50	1.5	0.02
Wood pellets	16.8	10	1.5	0.04
Wood briquettes	16.8	10	1.5	0.04
Wood	13.8	25	3.8	1
Straw	14.4	15	7	0.15
Reed canary grass	14.3	14	5.5	0.1
Mineral coal	27.2	12	10	0.6
Mineral oil (EO 1)	42.7	0.01	0.005	0.1
¹ (MJ/kg)/3,6 = MWh/ton. The presented values are approximations. Considerable deviations from these values exist depending on the origin, processing, and storing of the biomass, and due to seasonal fluctuations.				

2.4 Transformation and conversion technologies

2.4.1 *Direct combustion*

Household stoves and boilers

Small-scale use of biomass for heating of individual houses based on conventional stoves and boilers connected to a hydronic heat distribution system was the dominant technology before the introduction of district heating. Today, household stoves and boilers systems are more commonly found in sparsely populated areas, and in small towns and villages (Johansson *et al*, 2002).

District heating

District heating is a centralized system for large-scale heat generation and distribution for residential and commercial use. District heating uses local heat production plants to produce hot water, or in some systems, steam, which is transported by water pipes and used by customers for heating buildings and domestic hot water taps. Hot water is produced, transported to consumers in the supply network, cooled down by the consumers and transported back to the heat plant where it is heated anew (Aringhieri *et al*, 2003).

In most cases, the water is heated in plants using fossil fuels, biomass, biogas, geothermal reservoirs or a combination of all these energy sources. District heating is very energy efficient and flexible since it can be produced in centralized or decentralized plants outside cities (Aringhieri *et al*, 2003).

The only problem in this connection is heat loss in the heat transmission system, but highly efficient insulation materials keep heat loss down to a minimum, enabling distribution systems of 20-30 km to exist without decisive heat loss consequences. Therefore, district heating contributes to the decongestion of the often polluted air in the cities, and the potential to use heat from industrial processes (by-products). The most common types of district heating plants are cogeneration plants, so-called combined heat and power (CHP), or heat-only boilers (Aringhieri *et al*, 2003).

Combined heat and power generation (CHP)

Combined heat and power (CHP) generation is one of the most effective technologies when it comes to converting biomass into energy, having an efficiency rate of up to 90%. The principle behind CHP is to produce electric power while using the residual heat for district heating. Thus, one third of the total energy generated is converted into electrical power while two thirds is converted into district heat. (SOU, 2007:36)

Today, CHP often operates on either *fluid-based combustion* (FBC) or *Bubbling Fluidized Bed* (BFB). Both technologies allow the use of a larger range of biomasses and wastes including wood-based fuel and residues, sludge from paper and pulp industry and municipal waste. In fluidized-bed boilers, the fuel is fed into a solid bed where the biomass is burnt in a turbulent mix of gas and solids, created through the suspension of solid fuels upwards by blowing jets of air or gas through the plate. In a BFB boiler, fluidising air is blown at a lower velocity so the particles behave like a boiling fluid but stay in the bed (Alakangas *et al* 2000).

The most common CHP technology is the steam turbine, which often uses solid biomass from agriculture and forestry biomass. CHP is normally operated by large plants since the technology is too expensive for low scale energy generation. Biogas and gasified biomass are also used in CHP through gas turbines which are more suitable for low-level production, though still more expensive than steam turbine CHP (SOU, 2007:36).

2.4.2 Thermal gasification

Thermal gasification is the process in which fuel gases are extracted from solid biomass which can be used for power and heat generation. During the first part of the process, termed pyrolysis, the biomass is heated in the absence of oxygen, resulting in methane, hydrogen char and tar. During the following stage the char and tar obtained is exposed to high temperatures between 800-1200°C. The result of this process is a combustible gas whose primary components are hydrogen, carbon dioxide, carbon monoxide and methane. Raw materials used include wood biomass from agriculture and forestry, straw and solid household waste material (ECON PÖYRY, 2008).

2.4.3 Biogas

Biogas is produced through the anaerobic digestion of organic waste materials, often sewage, manure, animal fats, agriculture and slaughtering residues, and industrial and household organic waste into methane (60-70%) and carbon dioxide (30-40%). Biogas is mainly used for CHP and district heating but also in transportation after being refined and compressed (Jørgensen *et al*, 2008).

Biogas is currently produced in single farm units, centralized plants and landfill gas extraction systems. In a centralized biogas plant organic waste from food processing, agriculture and other industries is collected and fermented in large tanks. Other biomass sources which offer more decentralized alternatives to biogas production are waste water from treatment plants and organic fractions from household waste. Landfill gas is also possible to obtain from smaller decentralized plants. In the process biogas is extracted through a system of vertical and/or horizontal pipes and used for local electricity generation (ECON PÖYRY, 2008).

2.4.4 Liquid biofuels for transport

Biofuel takes different forms, including ethanol, methanol, Dimethyl Ether (DME), Fischer-Tropsch (FT) diesel and Rapeseed Methyl Ester (RME) biodiesel. At present, however, the predominant liquid biofuels in use are ethanol and biodiesel.

The processes behind biofuel production vary depending on the type of biomass used. Biofuels can be divided into three categories namely first, second and third generation biofuels, according to the current accessibility of the refining technology in the market (KVA, 2007).

First generation biofuels

First generation biofuels correspond to the current production of bioethanol, biodiesel and biogas from agricultural crops and organic waste streams.

Bioethanol

Ethanol can be produced from either sugars or, after hydrolysis, from starch. Sugars for ethanol production are obtained from either residue streams from the sugar industry or from sugar crops e.g. sugar beets. Starch is available either from residue streams from the food industry or from starch crops like wheat, rye and barley (KVA, 2007).

In the Nordic countries, bioethanol is mainly produced in a three step process from starch rich crops. The first step is called hydrolysis which breaks down starch into sugars by adding enzymes. In the second step yeast is added which breaks down the sugars, through anaerobic fermentation, into ethanol and carbon dioxide. Thereafter the resulting 10% ethanol solution is distilled to 96% ethanol concentration (Jørgensen *et al*, 2008).

Biodiesel

Biodiesel is predominantly produced by pressing oils from rapeseed and also, to a minor extent, from waste cooking oils and animal fat. The most common form of biodiesel is Rapeseed Methyl Ester (RME). Usually, the production of RME is undertaken in three steps; crushing, refining, and esterification. First the oils are mechanically removed from the seed by crushing or pressing. In the refining process the oils are prepared for esterification. In the last step, esterification, the oils are chemically modified by removing the glycerol by using alcohol, usually methanol, in the presence of a catalyst, usually potassium hydroxide (Booth *et al*, 2005).

Thanks to the removal of glycerol from the oil, the biodiesel can be used on all diesel engines involving minor or no modifications. Blending with conventional diesel is also possible (KVA, 2007).

Due to advanced technologies, decentralized low-scale biodiesel production is possible. In farm scale production, farmers convert their own yield into either unmodified vegetable oil or biodiesel for their own use. Group-scale production is also possible by groups of farmers combining their resources to produce biodiesel (Booth *et al*, 2005).

Second generation biofuels

Second generation biofuels are expected to be available to the market in about 10 years' time. These are liquid fuels, mainly ethanol, methanol and FT diesel, obtained from biomass containing lignocelluloses which consist of cellulose, hemicelluloses, lignin and carbohydrates (KVA, 2007).

Bioethanol

In the production of second generation bioethanol the projected biomass to be used is wood, straw and bagasse. The process behind bioethanol production from lignocelluloses follows the same principles as that for extracting ethanol from starch but it is far more complicated. This is because the ethanol production from lignocelluloses involves more chemical and bacterial reaction steps aiming to break down hemicelluloses, cellulose and lignin into sugars (VTT, 2006).

BtL: Biomass to Liquid (DME, FT-Diesel and methanol)

Dimethyl ether (DME), FT-Diesel and methanol can be obtained from syngas resulting from biomass gasification after being cleaned and transformed in catalytic processes (KVA, 2007).

Third generation Biofuels

Third generation biofuels are expected to be available in approximately 50 years. This group of technologies belongs mainly to the family of hydrogen from fuel cells (KVA, 2007).

Hydrogen

Hydrogen can be obtained from a large number of sources including the overproduction of electricity, refined biomass such as ethanol and methane, and biological processes using bacteria. Because pure hydrogen is difficult to store, ethanol, methane and dimethyl ether (DME) are three alternative hydrogen carriers that can be produced from thermal gasification and Fischer-Tropsch processes. When using hydrogen carriers, hydrogen can be separated through a hydrogen catalytic converter or directly by specific types of fuel cells (KVA, 2007).

In essence, a fuel cell works by catalysis, separating the component electrons and protons of the reactant fuel, and forcing the electrons to travel through a circuit, hence converting them to electrical power. Fuel cells are very versatile and can be used for transportation as well as for electricity generation both decentralized and centralized. Since fuel cells do not have moving parts and do not involve combustion, the theoretical electrical efficiency is high. It is currently however only possible to obtain 50% efficiency with this technology (Jørgensen *et al*, 2008).

2.4.5 Bio-refinery

A bio-refinery is a processing plant that combines biomass transformation and conversion processes. The idea behind bio-refineries is to maximise the value of all components, both energy and material, derived from the transformation process of biomass feedstock to produce biofuels, electricity and heat, as well as chemical products. Bio-refineries thus have the potential to become highly efficient processes with significantly reduced energy loss. In future, bio-refineries are expected to use woody feedstock and residual materials from agriculture and forestry to produce second generation biofuels (ECON PÖYRY, 2008).

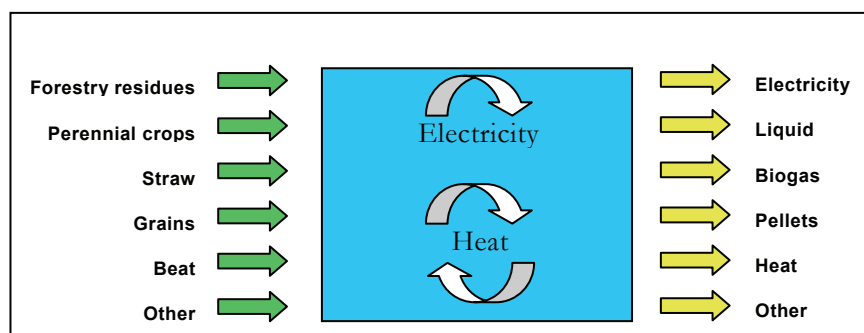


Figure 5 Schematic illustration of biorafinery operation. Modified from Börjesson (2007a)

2.4.6 Overview of transformation and conversion technologies

When comparing the different bioenergy alternatives previously described and according to Table 4 produced by Uffe Jørgensen *et al* (2008), direct combustion, thermal gasification and biogas are well developed technologies having a large and diversified feedstock, and high energy balance. Additionally these technologies are less expensive since they can be applied at a low scale.

Table 4 Overview of different bioenergy technologies. (Modified from Jørgensen *et al*, 2008)

Technology	Products	Status for technological development	Feedstock availability	Energy balance	Centralize /Decentralize production
Direct combustion	Heat, power	High	High	High	C/D
Gasification	Heat, power	Moderate	High	High	C/D
Hydrogen	Heat, power, transport	Low	High	-	C/D
Biogas	Heat, power, transport	High	High	Moderate	C/D
Biodiesel	Heat, power, transport	High	Limited	Low	C/D
Ethanol from starch	Transport	High	Moderate	Low	C
Ethanol from lignocelluloses	Heat, power, transport	Low	High	Moderate	C

The production of liquid biofuels for transport, excluding biodiesel, demands large centralized production facilities, thus implying significant investment. As described in the following chapter, the problem with biodiesel production relates to the large areas needed and the environmental consequences of the cultivation of oilseeds.

In general, the refining process of biomass is energy demanding leading inevitably to a lower energy balance. As illustrated in Table 4 and Table 5 for first generation biofuels, differences in terms of energy balance in the utilization of perennial and annual energy crops, become larger when annual crops are refined into liquid fuels for transport. Second generation biofuels have, on the contrary, a higher energy balance simply because most of the process energy consumed in crop cultivation is reduced.

Current technological developments favour the further development of bio-refineries. From an energy and resource efficiency point of view, the development of bio-energy refineries makes it possible to use wood biomass for biofuel production while using most of the residual energy for e.g. district heating and electric power generation.

Table 5 Energy balance of perennial and annual energy crops and their derivatives. (Modified from Jørgensen *et al*, 2008)

	Direct combustion		Refined bioenergy			
Energy crop	Willow	Elephant grass	Winter rape (RME+Straw)	Winter Rape (Oil+Straw)	Grass for biogas	Whole grain for ethanol
Exchange (tons/ha)	9	9	2.7 (Seed) 2.2 (Straw)	2.7 (Seed) 3.3 (Straw)	8	10
Moisture %	50	10	9 (Seed) 15 (Straw)	9 (Seed) 15 (Straw)	83	15
Energy exchange GJ/ha	147	161	RME: 31 Cake+glyc: 45 Straw: 38 Total: 114	Oil: 37 Cake: 39 Straw: 57 Total: 133	94 (Direct) 79 (Ensilage)	Ethanol: 80 Lignin: 29 Total: 109
Energy demand for cultivation harvesting and transportation	10	9	12	12	9 (Direct) 14 (Ensilage)	16
Energy use for refining	-	-	11	2	17 (Direct) 15 (Ensilage)	50
Total energy input (GJ/ha)	10	9	23	14	26 (Direct) 29 (Ensilage)	66
Net energy exchange GJ/ha	137	152	91	119	67 (Direct) 50 (Ensilage)	43
Energy balance (Energy exchange/energy input)	14	18	1.4 (RME) 3 (RME+Straw)	2.6 (RME) 7 (Oil+Straw)	4 (Direct) 3 (Ensilage)	1.7

3 Bioenergy in the Nordic countries

In the Nordic countries, especially in Denmark, Sweden and Finland, the share of bioenergy has significantly increased over the past 25 years. By 2004 the share of the total energy consumption originating from bioenergy was 20% in Finland, 17% in Sweden, 12.2% in Denmark and 4.2% in Norway. Thanks to the existence of a large forest industry and the extensive development of district heating systems since the 1980's, Sweden and Finland have a good organisational basis for further developing the bioenergy sector.

The dominant uses of bioenergy have been electricity production and heat generation. All forms of biomass currently used, include raw material from forestry and agriculture, as well as industrial and municipal solid waste and sewage sludge. The share of bioenergy used for electricity generation has increased over time. Finland is the leading Nordic country in this sector producing 12.6% of its total electricity in this way, followed by Denmark with 5.5% and Sweden with 3.7%. (ECON PÖYRY, 2008).

Biomass represents the main renewable resource for heating in Denmark, Finland, Norway and Sweden and provides 37% of gross heat production in the Nordic countries. The share of bioenergy gross heat production by 2002 was 48% in Sweden, 15% in Finland, 11% in Denmark and 7.6% in Norway. Sweden is leading in the use of biomass for heat generation, as 205 out of 290 municipalities are supplied with district heating generated from biomass. On the other hand, Finland shows the fastest growth in heat generation from bioenergy (ECON PÖYRY, 2008).

Sweden has a well functioning pellet production market comprising 80 factories and a large number of households with pellet boilers, pellet burners and stoves. Furthermore, Sweden has long experience of biomass production from energy crops, especially from willow, and is leading in the implementation of a commercial market for first generation biofuels, mainly based on bioethanol. In Denmark, biodiesel production based on rapeseed tripled between 2001 and 2006, the majority of which is being exported to, primarily, Germany and Sweden. Finland also boasts a modest level of biodiesel production based on vegetable oils and animal fat (ECON PÖYRY, 2008).

Denmark is the world leader in the development and commercial operation of the biomass combustion of, among other things, municipal waste and biogas produced from animal manure. Denmark is also a significant player in the development and future use of second generation biofuel technology. Finland holds a strong position in the commercialisation and use of biomass combustion, being specialized in fluidised bed combustion technology (ECON PÖYRY, 2008).

3.1 Policy instruments

Bioenergy targets across the Nordic countries vary considerably depending on historical accessibility to biomass and national traditions in environmental and energy policies. All Nordic countries have supported electricity and heat generation from renewable resources since during the early 1980's. The use of by-products from the forestry industry for energy purposes has also been prioritized in both Sweden and Finland, while in Denmark bioenergy policies have supported the use of straw for CHP (ECON PÖYRY, 2008).

Today's renewable energy targets in Denmark include a proposed increase in the share of renewable energy generation to 30% by 2025, where the Biomass Agreement for electricity production plays a significant role. In the Danish energy plan, the Government has also set a target of achieving 10% biofuel usage in the transport sector by 2020 (ECON PÖYRY, 2008).

In Finland, renewable energy targets stated in the Action Plan for Renewable Energy sources, aim at 25 % by 2015 and 40% by 2025. As bioenergy represents 95% of renewable energy in Finland, this target is primarily linked to the increase in the application of bioenergy in the energy system. Feed-in tariffs for peat in electricity generation and tax subsidies on renewables' support the use of bioenergy. Since 2003, an additional tax subsidy has been provided for large-scale electricity producers using bioenergy (>100 MWh) and from 2008 an expected subsidy for biogas in electricity production is planned. Biogas is expected to be based on agro-biomass, slaughter waste, manure and community waste. Finland does not operate with tax exemptions for biofuels in transport. A national target was set to reach 0.1% of biofuel usage in respect of total transport fuel consumption in 2005. Furthermore, the Finnish Government is implementing the EU Directive on biofuels by setting a target for biofuels of 5.75 % by 2010 (ECON PÖYRY, 2008).

In Norway, a proposed target for bioenergy has been set to increase usage by 14 TWh by 2020, which is close to a doubling from current use. There is also a medium-term target for 2012 which envisages the generation of 4 TWh of heat from bioenergy. A general target is 30 TWh more renewable energy and energy savings, as compared to 2001, by 2020. The intention here is to eliminate the main bottleneck for district heating through investment subsidies in the creation of district heating networks through investment support and support programmes. In the transportation sector a strategy to increase biofuel usage to 2% by 2008 and 5% by 2009 also exists. Biofuels in Norway are exempted from several taxes levied on fossil fuels. In addition, reductions in the Vehicle Import Duty on E85 cars have been in place since summer 2007 (ECON PÖYRY, 2008).

Sweden aims to break its dependency on oil by 2020 by increasing both the use of renewable energy and by pursuing energy efficiency programmes across its energy systems. The instruments deployed to raise bioenergy production and use include taxes, green certificates for the production of electricity with renewable energy and rural development programmes to support the production of domestic bioenergy. One of the main results of the energy tax system is the lower cost of biomass based district heating. For biofuels Sweden has set the European target of a 5.75 % share for total fuel consumption in the transport sector. Swedish efforts to increase the use of biofuels are primarily followed through the tax exemption regime. Other important drivers include a wide range of government initiatives (grants,

programmes, obligations) to 'kick-start' a clean transportation fuel value chain from production via car producers and fuel distribution to end-consumers. By 2006 the use of biofuels in Sweden was approximately 3% but most of the ethanol consumed by the transport sector is imported (ECON PÖYRY, 2008).

4 Identifying bioenergy potentials

The information in this chapter has been produced by a working group at the University of Applied Sciences in Eberswalde, formed by Hans-Peter Piorr, Sybille Brozio, Mirella Zeidler and Ivonne Berndt. The following maps and tables were obtained by using Geo Information System (GIS) and agricultural statistics to illustrate the potential for bioenergy application at NUTS 3 level for three product lines of biofuels, namely bioethanol based on grain and grain straw, biodiesel based on rapeseed, and biogas based on grain straw and liquid manure, projected for three specific scenarios;

- Scenario I “Status quo”: gives an estimation of the current biomass potential and is based on current harvesting amounts.
- Scenario II “Yield increase”: gives an estimation of the future biomass potential in 2020.
- Scenario III “Yield decrease”: gives an estimation of the minimum biomass potential.

Scenarios II and III contain estimations of yield levels of bioenergy crops and the potential cultivation areas of these crops.

4.1 Regional distribution

The assessments presented in this section show that each country has a unique regional distribution of bioenergy potential for each of the above-mentioned product lines. Cereals occupy the biggest section of the cropped farmland in the Nordic countries. Winter wheat appears to be the dominant crop in bioethanol production in Denmark, Sweden and Norway. In Finland the dominant crop is spring wheat.

The highest bioenergy potential for bioethanol and biogas is found in Denmark, followed by Sweden, Finland and Norway. For biodiesel based on rape, Denmark and Sweden are the countries with the highest values. The projected development of yields of the main crops is relatively moderate except for rape in Denmark which shows considerable yield increases primarily for biodiesel from rapeseed.

The results presented in this section reveal that if 20% of the today's preconditioned grain yields in the Nordic countries were used for bioethanol production an equivalent of 0.6 Mio t of gasoline could be produced. If 20% of the straw was processed another 0.29 Mio t of gasoline equivalents could be added to this figure. The total harvest of rapeseeds would result, on average, in 123,707 tons of biodiesel equivalents. For biogas based on manure more than 1,800 biogas plants, each with a 500 kW_{el} capacity could be fed. Using 20% of cereal straw as a co-substrate another 350 biogas plants of this size could be supplied. According to the calculations made for this study, based on the yield development of a 20-year period from 1987 to 2007, increases in the bioenergy potential projected for 2020 could be 13% for bioethanol from grain and grain straw, 13% for biogas from grain straw. In

addition, biodiesel production from rapeseed could be increased in Denmark and Sweden by about 50% and 73% respectively.

4.1.1 Bioethanol from grains and straw

For bioethanol from both grains and straw, most of the bioenergy potential is located in the southern and mid-regions of the Nordic countries, mainly in Denmark followed by Sweden, Finland and Norway (Figure 6 and Figure 7). In Denmark, no clear territorial patterns in respect of the bioenergy potential of bioethanol based on grain or grain straw are observable.

In Denmark the calculated increase by 2020 is around 18%; to approximately 598,000 tons of grain and 283,000 tons of grain straw. In Sweden, the bioenergy potential is highest in the southern regions located nearest to the coastline. The calculated increase in Sweden is approximately 3% to 282,000 tones for grain and 133,000 tons for grain straw. In Finland the major bioenergy potential is located along the Baltic Sea coastline. The calculated increase projected for 2020 is approximately 13% for grain and 11% for grain straw, to 162,000 tones and 78,000 tons respectively. In Norway, the highest potential is to be found in the south-east regions along the border with Sweden, primarily Hedmark, Akerhus and Østfold. The calculated increase projected for 2020 is approximately 24% to 67,000 tones of grain and 32,000 tons of grain straw.

Table 6 Bioethanol based on grain – use of grain = 20% (regional availability)

Country	Scenario	Annual bioethanol amount in 1,000 tons	Energy content in PJ	Equivalent of gasoline in 1,000 tons
Denmark	Status quo	505	13.3	311.9
	Yield increase	598	15.7	368.9
	Yield decrease	467	12.3	288.0
Norway	Status quo	54	1.4	33.4
	Yield increase	67	1.8	41.3
	Yield decrease	48	1.3	29.7
Sweden	Status quo	273	7.2	168.8
	Yield increase	282	7.4	174.2
	Yield decrease	232	6.1	143.0
Finland	Status quo	144	3.8	89.0
	Yield increase	162	4.3	100.1
	Yield decrease	132	3.5	81.6

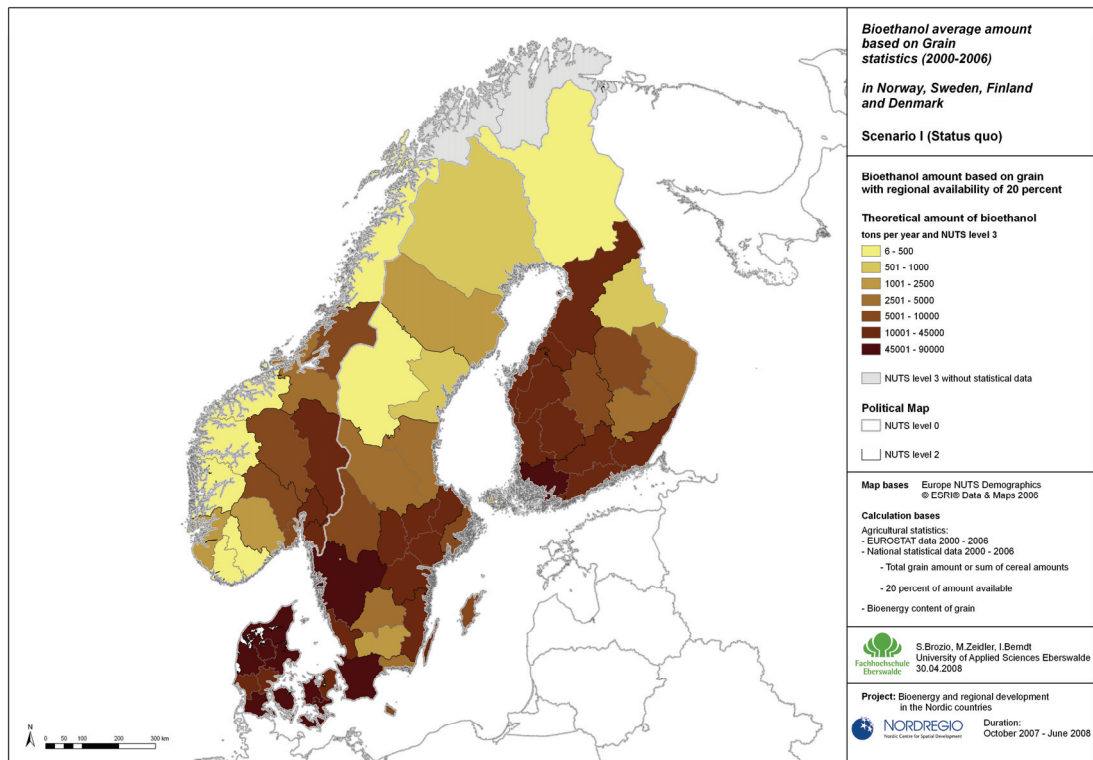


Figure 6 Scenario I: Bioethanol average amount of grain. Grain statistics (2000-2006)

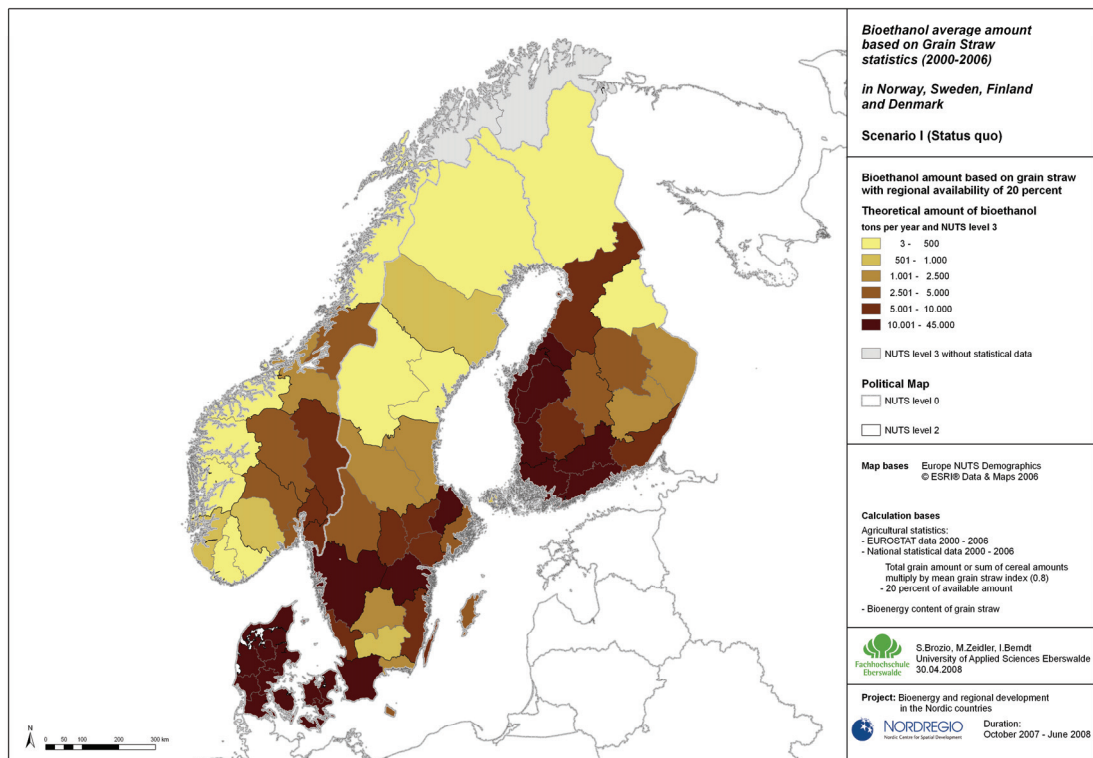


Figure 7 Scenario I: Bioethanol average amount of grain straw. Grain statistics (2000-2006)

Table 7 Bioethanol based on straw – use of straw = 20% (regional availability)

Country	Scenario	Annual bioethanol amount in 1,000 tons	Energy content in PJ	Equivalent of gasoline in 1.000 tons
Denmark	Status quo	239	6.3	147.6
	Yield increase	283	7.5	174.9
	Yield decrease	221	5.8	136.3
Norway	Status quo	26	0.7	16.1
	Yield increase	32	0.8	19.9
	Yield decrease	23	0.6	14.3
Sweden	Status quo	129	3.4	79.8
	Yield increase	133	3.5	82.1
	Yield decrease	109	2.9	67.5
Finland	Status quo	70	1.8	43.2
	Yield increase	78	2.1	48.3
	Yield decrease	64	1.7	39.6

4.1.2 Biodiesel from rapeseed

The highest potential for rapeseed biodiesel³ is found in the southern regions in the Nordic countries, mainly in Denmark followed by Sweden (Table 8). No yield has been reported for the most northerly regions, while the highest potentials are located in all Danish regions and a few regions in southern Sweden, mainly Skåne, Västra Götaland and Östergötland. For Finland most of the potential is shared by two regions located in the south, Varsinais-Suomi and Uusimaa. In Norway rapeseed production is very limited being mostly from oilseed yields overrepresented by turnip rape which is not included in this study. The prospects for an increase in rapeseed cultivation in Norway are not positive due to the cold conditions in the North and high winds and rainfall in the west as well as difficult accessibility to proper arable land for rapeseed (Andersen et al, 1998).

With regard to the estimations for bioenergy potential for rapeseed biodiesel projected for 2020, Denmark shows a potential increase of approximately 52% to 151,891 tons while in Sweden the increase is approximately 73% to 76,642 tons. When comparing Finland to Denmark and Sweden the current biodiesel potential from rapeseed alone appears to be very limited, only 1,313 tons biodiesel equivalent confined to a calculated harvested area of 3,000 ha. Estimations in the context of a yield increase scenario in Finland for 2020 are considerably enhanced, 2,803 tons biodiesel equivalent, about 113% in respect of the status quo scenario. This forecast increase is the consequence of trends pointing to the enlargement of acreage for rapeseed resulting e.g. in 11,000 ha for 2007. Due to considerable fluctuations in the rapeseed yield and uncertainties about climate conditions for rapeseed cultivation in Finland, the above figures may require more carefully calculations.

³ Turnip rapeseed not included in the estimations.

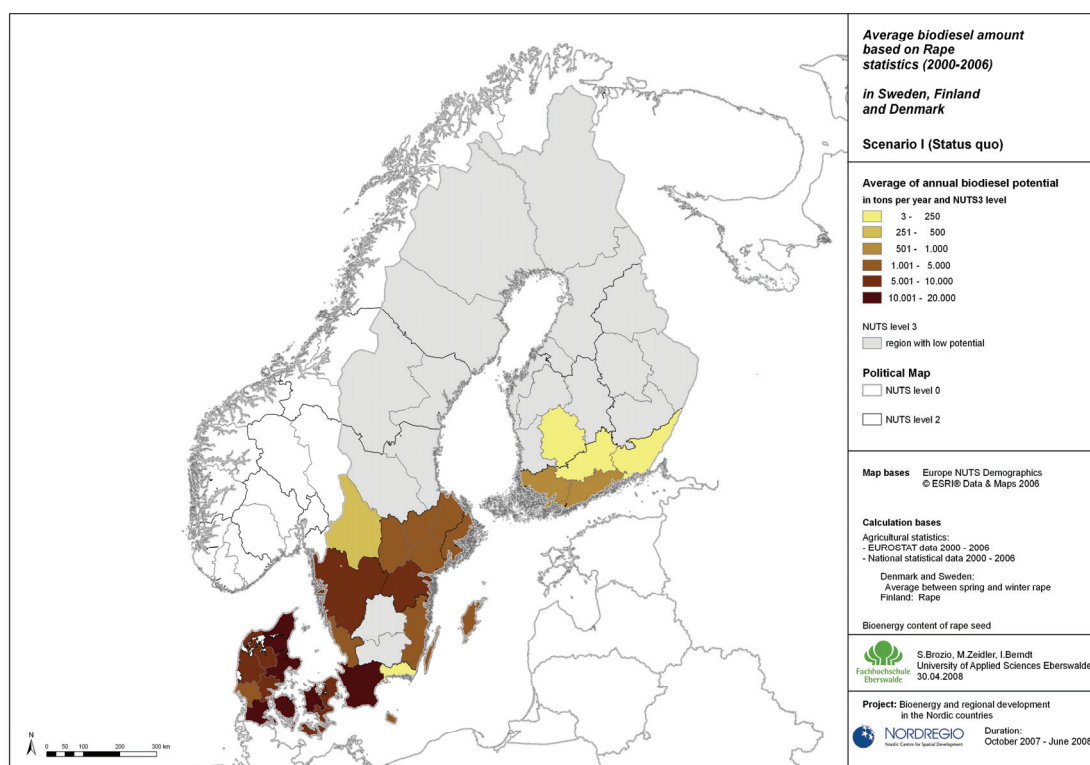


Figure 8 Scenario I: Average biodiesel amount based on rape. Statistics (2000-2006)

Table 8 Annual biodiesel amount and its energy content for three scenarios

Country	Scenario	Annual biodiesel amount in tons	Energy content in PJ	Equivalent of biodiesel in tons
Denmark	Status quo	100,251	3.66	85,008
	Yield increase	151,891	5.54	128,796
	Yield decrease	84,772	3.09	71,882
Sweden	Status quo	44,326	1.62	37,586
	Yield increase	76,642	2.80	64,989
	Yield decrease	40,019	1.46	33,934
Finland	Status quo	1,313	0.05	1,113
	Yield increase	2,803	0.10	2,377
	Yield decrease	912	0.03	773

4.1.3 Biogas from liquid manure and grain straw

For biogas from liquid manure and grain straw, the patterns also resemble those displayed by bioethanol from grains and grain straw, at least in the cases of Denmark, Sweden and Finland. The major difference to this pattern however exist in Norway where regions along the mid- and south-western coastline show significant potentials, the highest being found in Rogaland. This difference could be explained by the incidence of a high level of livestock farming. In terms of biogas from liquid manure the current bioenergy potential is greatest in Denmark (3,179 GWh), followed by Sweden (1,685 GWh), Finland (1,010 GWh) and Norway (932 GWh) (See Table 9).

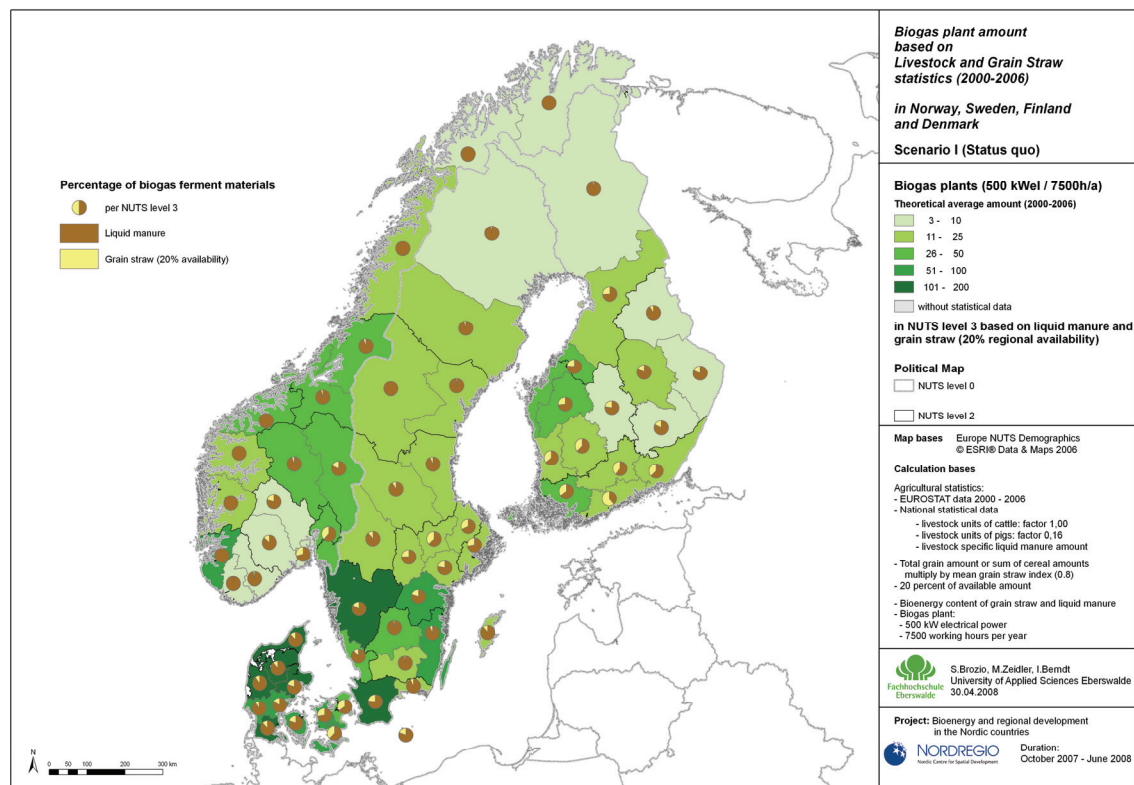


Figure 9 Scenario I: Potential amount of biogas plants based on liquid manure and grain straw. Statistics (2000-2006)

Table 9 Biogas based on liquid manure and grain straw as co-ferment

Country	Input material	Scenario	Energy content in mill. kWh _{el}	Biogas plants (7.500 h*a ⁻¹ and 500kW _{el})	Energy content In PJ
Denmark	Manure: 100%	Status quo	3,179	848	11.44
	Grain straw: 20%	Status quo	673	180	2.42
		Yield increase	927	274	3.34
		Yield decrease	723	193	2.60
Norway	Manure: 100%	Status quo	932	249	3.36
	Grain straw: 20%	Status quo	73	20	0.26
		Yield increase	105	28	0.38
		Yield decrease	76	20	1.29
Sweden	Manure: 100%	Status quo	1,685	449	6.06
	Grain straw: 20%	Status quo	364	97	1.31
		Yield increase	436	116	1.57
		Yield decrease	358	95	1.29
Finland	Manure: 100%	Status quo	1,010	269	3.63
	Grain straw: 20 %	Status quo	197	53	0.71
		Yield increase	256	68	0.92
		Yield decrease	210	56	0.75

4.2 Fallow land areas and yield development in the Nordic Countries

In the Nordic countries, the regional distribution of available biomass for bioenergy is determined mainly by the site's climatic, and geophysical conditions, but not least by the question of access to arable land which is higher in the southern regions. According to Figure 10, most arable land in the Nordic countries is located in Denmark, Southern Sweden and mid- and south-west Finland. Less favourable conditions for annual energy crop cultivation are found mainly in the northern peripheries, where the climate is too cold, as well as along the west coast of Norway where too much precipitation and high winds create difficult agricultural conditions throughout the year. This observation is also supported by historical trends in land use systems, production on fallow land and yield productivity.

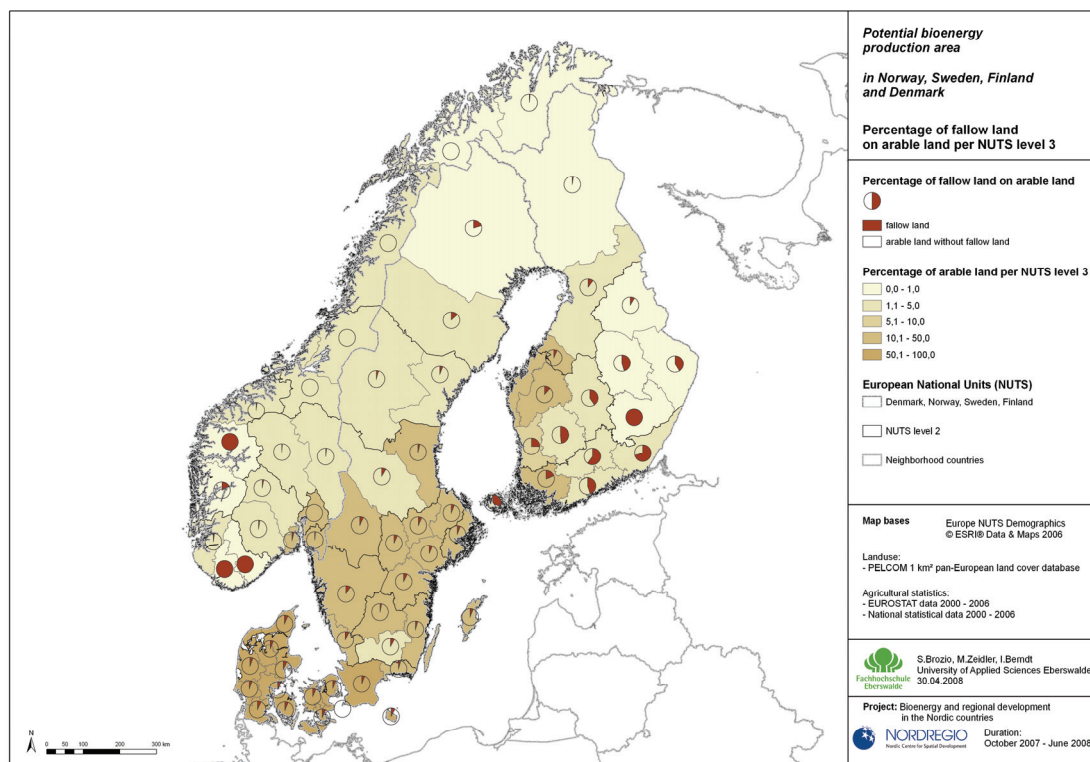


Figure 10 Potential bioenergy production areas for annual energy crop farming

Cereal cropping has predominated historically in the Nordic countries though the development of yields has been relatively modest in recent decades, except for rapeseed in Denmark, where considerable yield increases have been recorded. A change towards “energy crop rotation” with a higher output of biomass and better environmental performance is however also possible:

- Breeding and the introduction of highly productive and better adapted energy crops to the Nordic climate and geophysical conditions.
- Changes in the intensity of cultivation systems in terms of soil tillage (minimum tillage), pesticide and fertilizer input.

- Changes in cultivation methods by e.g. enhancing the production of by-products like straw.

Today more than 756,792 ha of fallow land exist in the Nordic countries, primarily situated in Sweden (335,764 ha) followed by Denmark (212,949 ha), Finland (195,329 ha) and Norway (12,750 ha). Perhaps the most limiting factor, in respect of the use of fallow land for energy cropping, is the particular crop's dependency on favourable soil, climate and geophysical conditions as well as easy accessibility to enable the use of heavy machinery and transport during harvesting.

It remains unclear however just how much of this fallow land actually boasts these optimal conditions for energy cropping. Assessments made thus far suggest that the majority of these areas are unsuitable for the cultivation of traditional food crops used for bioenergy production. Perennial crops on the contrary are more suitable because, compared to traditional food crops, they can be cultivated in less favourable conditions while demanding less soil preparation and monitoring.

Yield increases are predicted for the Nordic countries from several authors and even moderate assessments suggest increases of 10 to 25 % for the coming years. Changes in the acreage of crops are mainly driven by the extension of wheat and rapeseed areas but also by farmers' familiarity with and acceptance of the cultivation techniques relating to these crops in the context of crop rotation, nutrient supply and pest and disease control. Crop rotation methods have changed over time and innovative options for energy cropping are now available. In the future changes in rotation methods and the introduction of new varieties of energy crops will lead to higher yields. It will however remain important to carefully evaluate such changes to ensure that they do not result in negative environmental impacts.

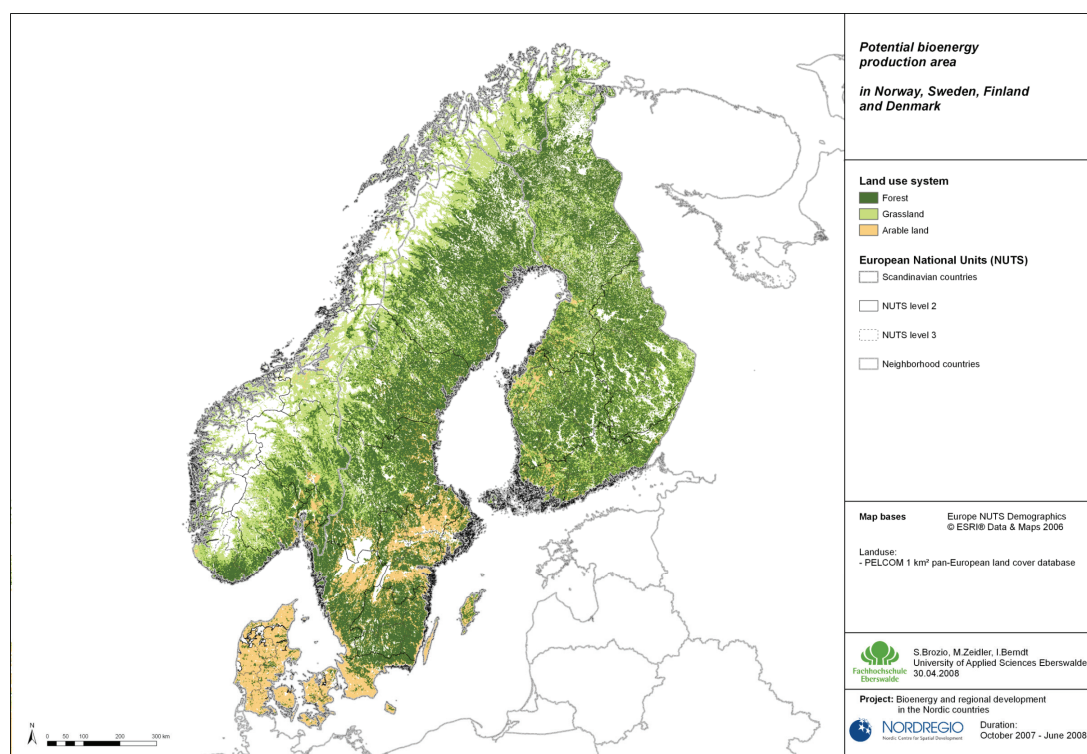


Figure 11 Potential bioenergy production areas in the Nordic countries -forest, grassland and arable land-

5 Identifying economic effects and labour market consequences

As already emphasized in the introduction to this report, it was beyond the scope of the analysis here to discuss the short and long term economic impacts of the various energy system approaches. As price structures and economic conditions differ in the Nordic countries this inevitably makes comparative analysis more problematic. Instead the focus here has been on the issue of job creation in relation to bioenergy production, transformation and conversion, as job creation is considered to be a relevant indicator of the economic consequences of bioenergy production.

The potentials outlined in the previous chapters have been converted into jobs, on the one hand in the primary sector, i.e. in connection with the crop production of bioenergy, and in the transformation, conversion and distribution sector on the other, where the energy crops are converted into energy. In connection with the latter, calculations have been made not only in terms of direct labour activities, but also in relation to the indirect effects in terms of the construction and material production activities involved.

5.1 Labour market effects

Evaluation of the direct labour market effects has been based on the number of man-hours spent on the different potential crops as shown in table 10 below. As indicated by the figures, differences exist not only in the labour market effect of different types of crops, marked differences actually occur depending on the scale of production. While for example maintaining willow in a growing year on 80 hectare plots only requires 1.82 hours per year per hectare, four times as much is needed when the plot size is down to 2 hectares. The level of yield also has some impact on labour demand, but does not influence the total labour market effects as much as area size and choice of crops.

Based on the calculations, four sets of maps have been generated (figure 12-15). The first two sets of maps show the labour market effects of the field crop production calculated in the previous chapter (figure 12), followed by the transformation and conversion of the crops to bioethanol and biodiesel (figure 13). The third set of maps (figure 14) show the labour market effects of biogas production, a summary of the total man-years needed for transformation and conversion of all types of biomass to bioenergy, and a regional overview of the relative labour market effects of production of biodiesel, bioethanol from grain and straw respectively, and biogas from manure and straw. The last set of maps (figure 15) show the production of willow for bioenergy as well as the effects of including fallow land to willow production. Details regarding calculations are available in annex 2.

The results of the maps in many ways display patterns similar to those indicating production potentials. Highly productive areas in Denmark and southern Sweden will benefit most, while less productive areas in northern Sweden, Norway and Finland will experience more limited results. It is moreover important to emphasize that the labour activities generated through production of first generation biofuels do not differ much from conventional production activities. The effects, therefore, are not to be found in this part of the production chain, but in connection with the transformation and conversion activities.

Table 10 Demanded labour force in conventional farming, hours/hectare

Crop	Yield level high			Production of/Use for:
	2 ha	20 ha	80ha	
Winter Rape	8.98	4.83	-	Biodiesel
Winter Wheat (grain)	13.5	6.47	-	Bioethanol
Winter Rye (grain and straw)	13.57	8.87	-	thermal usage
Winter Rye (grain)	9.14	4.6	-	thermal usage
Triticale (grain and straw)	14.18	9.15	-	thermal usage
Triticale (grain)	9.88	4.96	-	thermal usage
Willow, growing year	7.39	3.95	1.82	thermal usage
Willow, harvest year and storage	8.91	10.53	10.62	thermal usage
Crop	Yield level medium			Production of/Use for:
	2ha	20ha	80ha	
Winter Rape	8.79	4.67	-	Biodiesel
Winter Wheat (grain)	11.73	5.66	-	Bioethanol
Winter Rye (grain and straw)	12.2	7.62	-	thermal usage
Winter Rye (grain)	8.69	4.44	-	thermal usage
Triticale (grain and straw)	12.33	7.78	-	thermal usage
Triticale (grain)	8.96	4.6	-	thermal usage
Willow, growing year	7.38	3.95	1.82	thermal usage
Willow, harvest year and storage	5.86	8.18	7.56	thermal usage
Crop	Yield level low			Production of/Use for:
	2 ha	20ha	80ha	
Winter Rape	8.14	4.28	-	Biodiesel
Winter Wheat (grain)	10.13	5.00	-	Bioethanol
Winter Rye (grain and straw)	10.79	6.77	-	thermal usage
Winter Rye (grain)	8.11	4.12	-	thermal usage
Triticale (grain and straw)	11.49	7.32	-	thermal usage
Triticale (grain)	8.19	4.19	-	thermal usage
Willow, growing year	7.38	3.95	1.82	thermal usage
Willow, harvest year and storage	3.55	5.43	5.04	thermal usage

source: <http://daten.ktbl.de/energy/> (selected data)

Note : data calculated for Germany

The only exception here is the growing of willow, as this is not a common crop in any of the places studied. As indicated in the table below, a shift from annual to perennial crops may even entail, overall, a lower input of man-hours, though this will be partly compensated through peak activities in the planting and harvesting seasons. In this context, however, the land-layout chosen, i.e. the field size remains a decisive

factor. While willow production is comparable to other field crops when produced over small areas, the decrease in man-hours spent is substantial when it comes to large area coverage because maintenance labour input is very low.

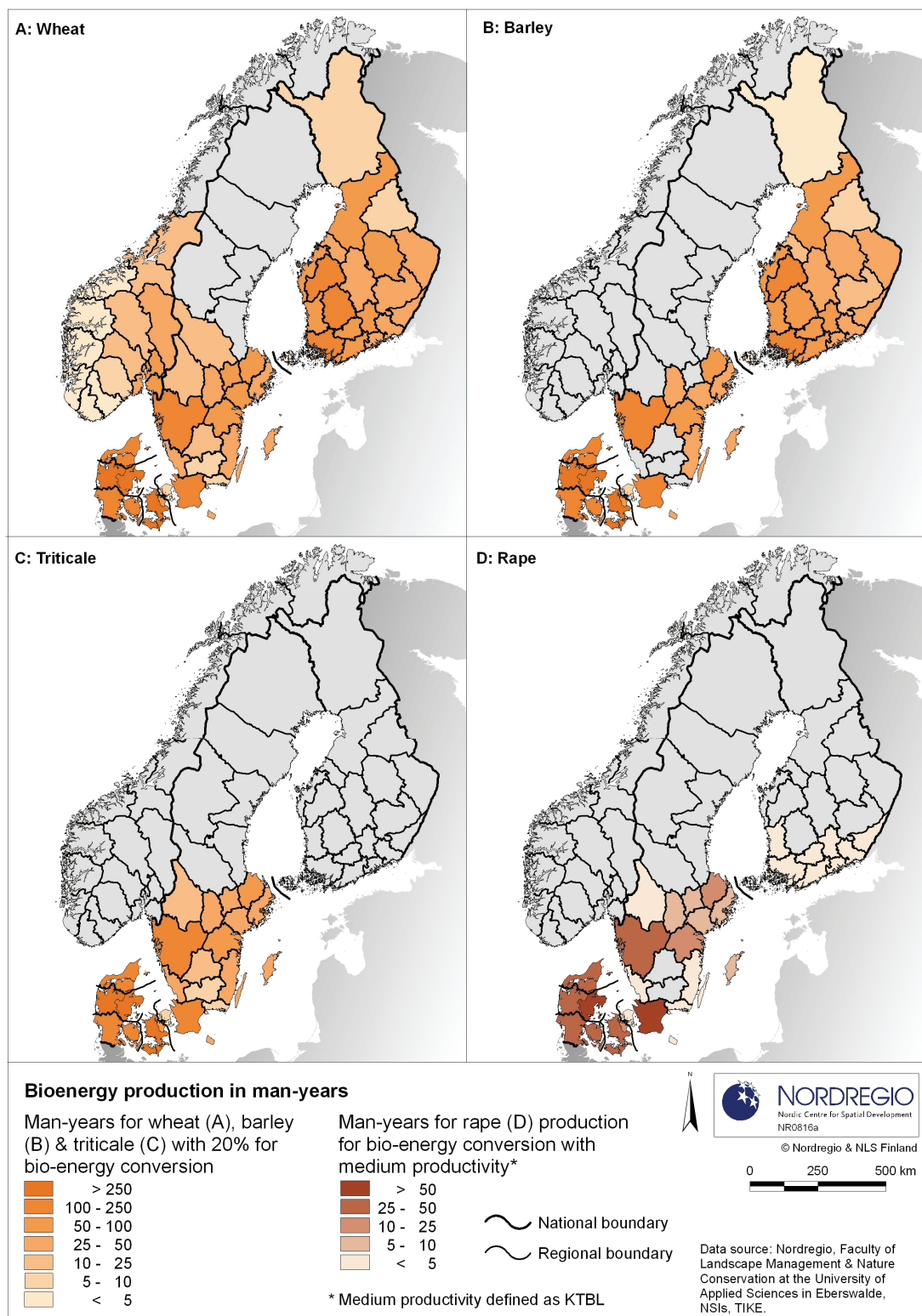


Figure 12 Labour market effect of energy crop cultivation – wheat, barley, triticale and rape -

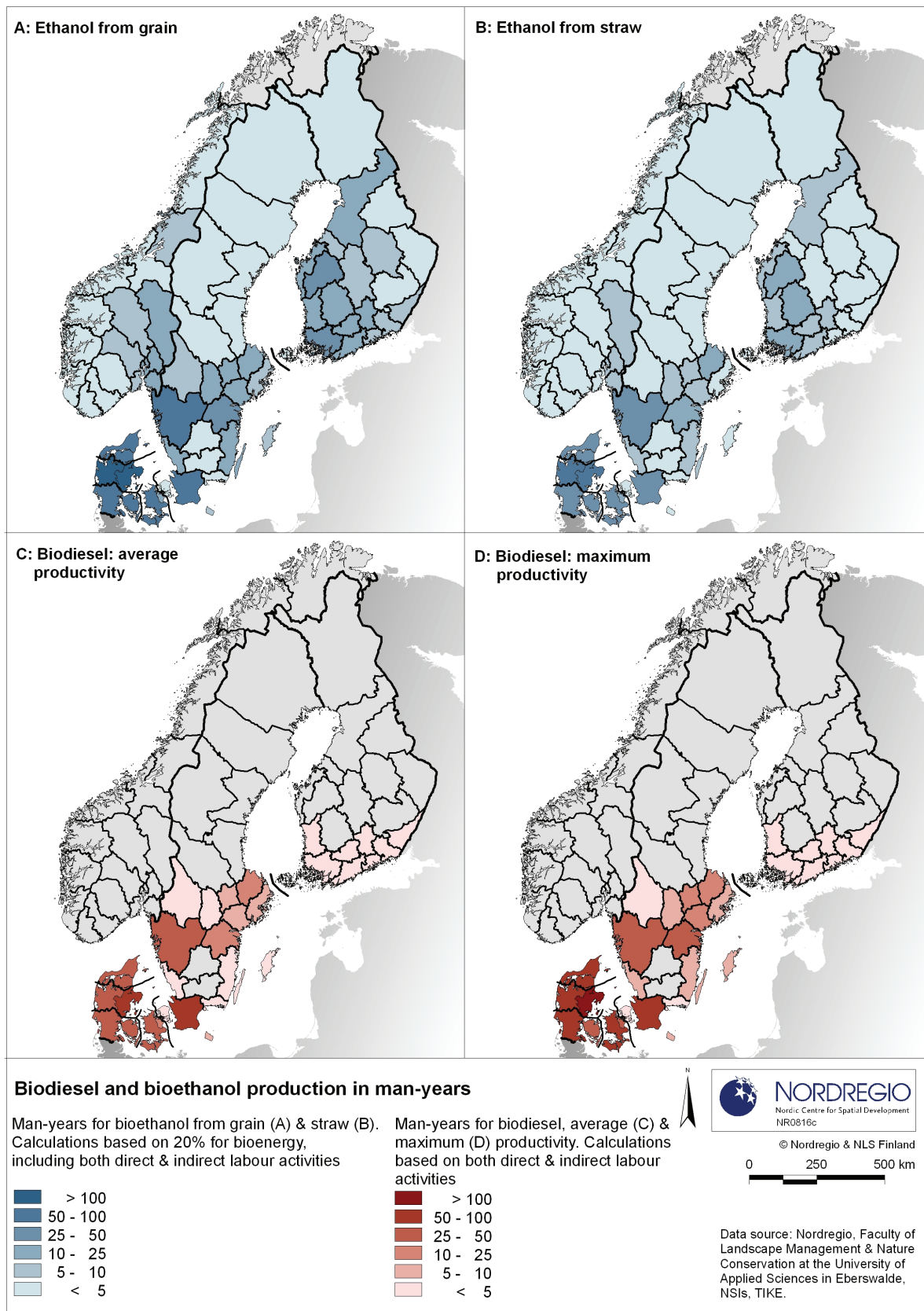


Figure 13 Labour market effects of biodiesel and bioethanol production

Consequently, the primary production of bioenergy will only provide extra jobs to the extent that it will be possible to include areas which are currently kept outside agricultural usage. For most crops the technological and investment requirements will be the same as now, while a shift to perennial crops would require substantial initial investment.

In the current situation where shortages exist in the world market for food bioenergy production will find itself in a competitive situation with traditional food production. As a consequence of this the creation of new jobs and the maintenance of current activities in rural areas will not change much in high yield regions, i.e. in Denmark and southern Sweden. In less productive areas where food production is already marginalized, however, the option of producing bioenergy will enable farms to continue their activities beyond what might be feasible when looking into the development of production costs over the last decade. The long term perspectives for the primary production of biofuels may, therefore, enable a number of farms which are now in marginal positions to continue their activities. This applies to both lowland highly productive regions.

As the inclusion of fallow land areas for bioenergy is the only real contribution to labour activities, the last two maps in Figure 15 (page 46) show the labour market effects of including these areas in production of willow. The result is very much a reflection of the maps showing the total fallow land areas, with especially Finland and parts of Norway benefiting from this opportunity, while the highly productive areas in general are already included in the production statistics.

Besides the production on fallow land, the most important labour market effects of bioenergy production appear when looking into the transformation and conversion of biomass and the related infrastructure development. In this context the choice of technology and the scale of activity becomes an important issue.

5.2 Effects of transformation, conversion, distribution and transportation

As discussed above, the primary production phase only provides jobs in excess of what already exists in agriculture to the extent that areas not currently part of the production process, such as set-aside/fallow land areas are included. The new job opportunities are found in connection with the transformation and conversion process and the infrastructure needed in order to make use of the bioenergy produced. In this context it is important to be aware both of the direct labour market consequences, i.e. how many persons are going to be involved in the district heating plants, the biodiesel or biogas production facilities etc., and also the jobs created in connection with the establishment and maintenance of these facilities.

As part of a report from *Vattenfall* on the labour market consequences of biofuels (*Biobränslenas sysselsättningseffekt*) from 1998, a calculation procedure regarding the indirect labour market effects has been outlined. The starting point is the investment in conversion facilities and infrastructure. Assuming three levels of secondary effects: fabrication and construction as the first level, manufacturing of materials as the second level, and the production of raw materials as third, the total effects of the investments would be jobs created at each level. (*“Biobränslenas sysselsättningseffekt”*, pp16). The original calculations were based on data from 1994, while the current analysis has updated the calculation to 2005, and taken into account the adjustments

in the statistical classifications which have been initiated in between 1994 and 2005. Consequently, the calculation includes the following categories:

Fabrication and construction:	
-	28 Industry for fabricated metal products, except machinery and equipment
-	29 Industry for machinery and equipment
-	30 Industry for office machinery and computers
-	31 Industry for electrical machinery and apparatus
-	32 Industry for radio, television and communication equipment and apparatus
-	33 Industry for medical, precision and optical instruments, watches and clocks
-	34 Industry for motor vehicles, trailers and semi-trailers
-	35 Industry for other transport equipment
Manufacturing of materials:	
-	20 Industry for wood and wood products
-	27 Industry for basic metals
-	45 Building industry
Production of raw materials:	
-	13+14 Metal ore mines and other mines and quarries
-	26 Industry for non-metallic mineral products

The results are shown in the table above. (All data from *Statistics Sweden*). An investment of 1 million SEK will generate 0.44 man-years in the fabrication and construction industries. In the industry 0.3 million SEK will be consumed by the industry itself (value-added value) while 0.7 millions will be used for covering costs from the next level, i.e. manufacturing of materials.

The manufacturing of materials will generate 0.54 man-years per million SEK, but only 0.7 million is available. Consequently, the net effect will be 0.38 man-years. As the value-added ratio of the manufacturing of materials is 0.31, only 69% of the 0.7 million, equal to 0.48 million, and will cover the costs of raw materials.

With a generation of 0.39 man-years for each million input to the production of raw materials, the net effect of 0.48 million SEK will result in a total of 0.19 man-years.

Table 11 Productivity and net labour generation in secondary industries in relation to the establishing of bioenergy production facilities

Activity	Labour generation Man-years per mill. Kr.	Ratio of value-added to sale value	Ratio of non-value- added to sale value	Net labour generation Man-years per mill kr.
Fabrication and construction	0.44	0.30	0.70	0.44
Manufacturing of materials	0.54	0.31	0.69	0.38
Production of raw materials	0.39	0.40	0.60	0.19
Total				1.01

In total, therefore, 1.01 man-years will be generated as a secondary effect of each invested million SEK. While the calculations from 1998 indicated a total secondary effect of 1.78 man-years, the present level is substantially lower, with a generation of 1.01 man years. The explanation is a reduced value added in each of the three steps described above, first of all due to an increase in efficiency and productivity due to a higher level of technology usage.

The maps in figure 13 and 14 show on a regional basis the outcome of different activities in relation to the transformation and conversion of raw materials into bioenergy. The maps show how many man-years can be generated through different types of energy production. There are many similarities between the maps, as the main characteristic of labour market effects is the transformation and conversion of area productivity.

Denmark and the southern parts of Sweden, as well as parts of Finland, are well represented in relation to bioethanol production, both based on grain (13:A) and on straw (13:B). The production area stretches quite far northwards in both Sweden and Finland.

Biodiesel (13:C&D) production is much more dependent on favourable natural conditions. Most of the regions in Denmark and several of the southern regions in Sweden are represented by high production values. Further north, however, the options for rapeseed production remain limited, leading to low or absent values.

A much more dispersed pattern is shown in connection with biogas production (Figure 14). The combination of different sources of biomass reduces the dependency on single environmental factors, and therefore enables a higher level of productivity in northern regions. Figure 14 also includes a map of the total number of man-years for conversion and transformation of biomass to bioenergy.

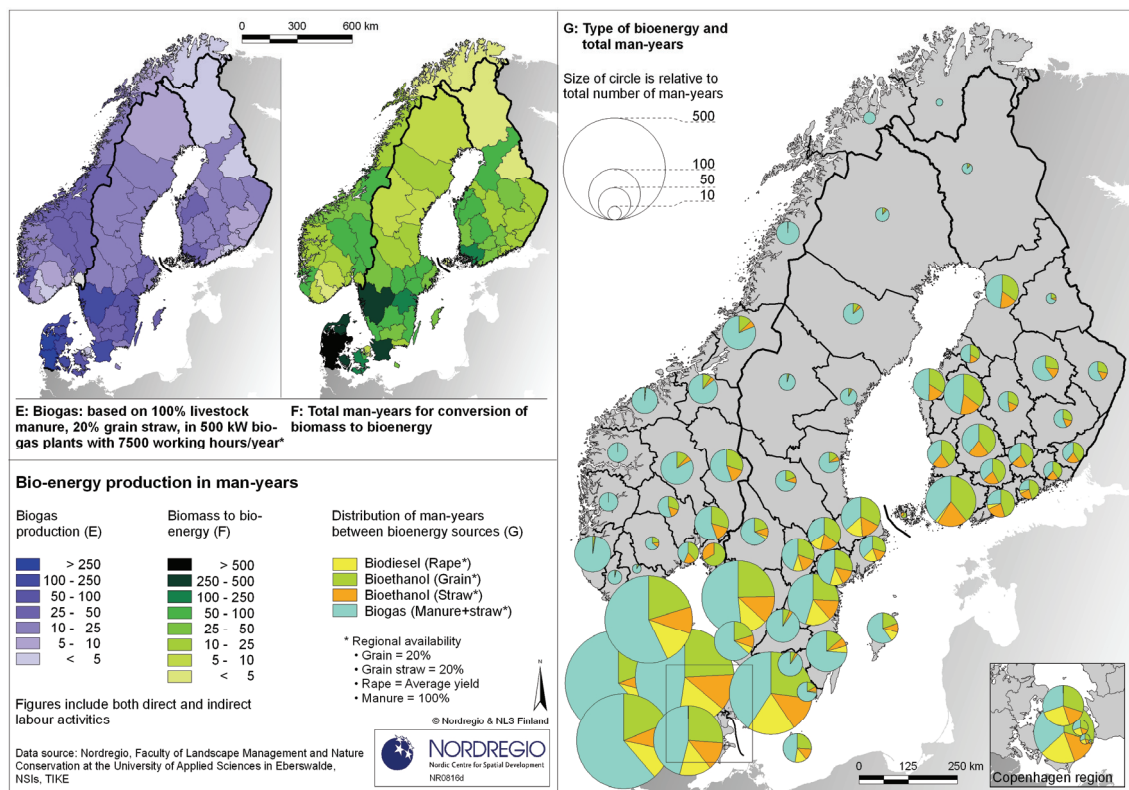


Figure 14 Labour market effects of bioenergy

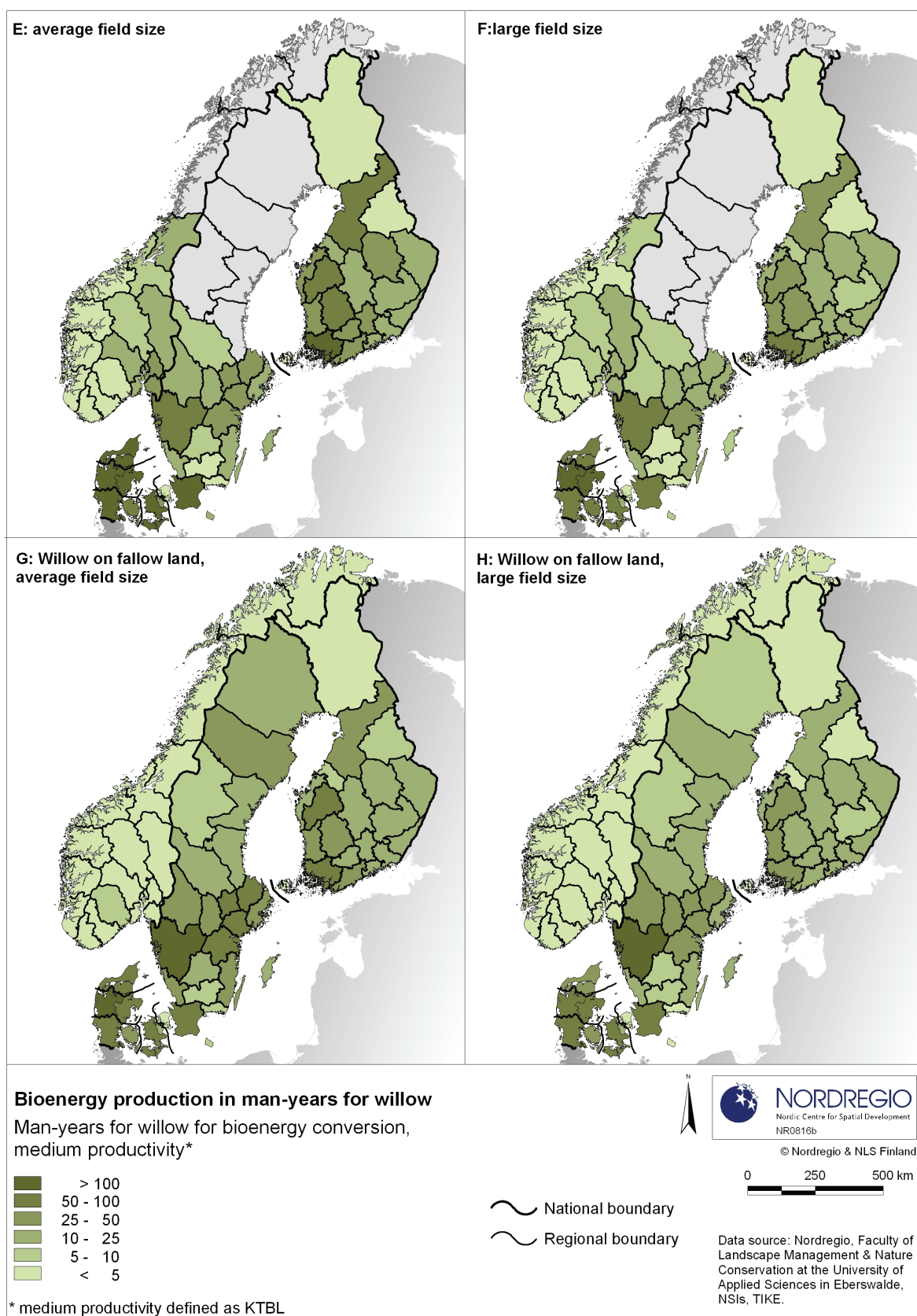


Figure 15 Labour market effect of willow

5.3 Labour market perspectives

Primary production of bio-energy provides a substantial number of jobs in rural areas. In most cases, however, the bioenergy biomass production requires almost the same labour input as other agricultural field crops. Many of the bioenergy crops are basically the same as those already produced, so 'conversion' will not change their activities that much.

A shift from annual to perennial crops may result in an overall lower input of man-hours, as the labour force needed to maintain the crop is low. This is partly compensated through relatively high rates of activity in the planting and harvesting seasons, but with a longer production period the overall level of man-hours will still remain low. Consequently, the primary production of bioenergy will only provide extra jobs to the extent that it will be possible to include areas which are currently kept outside agricultural usage. For most crops the technological and investment requirements will be the same as now, while a shift to perennial crops would require substantial initial investment.

While transforming food crops into fuel previously was considered to be acceptable – significant amounts of EU surplus food products were destroyed otherwise disposed of or, converted into alcohol during the 1980s and 1990s – while such practices remain controversial even to this day. In the current circumstances where the world market for food is experiencing shortages, bioenergy production will be competing with traditional food production, resulting in considerably higher food prices. If this is not to be a lasting situation, the option of transforming potential food crops into energy may again become available. In consequence, the creation of new jobs and the maintenance of current activities in the rural areas will not change significantly in high yield regions, i.e. Denmark and southern Sweden. In the less productive areas however where food production is already marginalized the option to produce bioenergy will enable farms to continue their activities beyond what may have been feasible when looking into the development of production costs over the last decade. In consequence, the long term perspective for the primary production of biofuels may enable a number of farms which are now in marginal positions to continue their activities where this otherwise would not have been the case. This applies to both low and highly productive regions.

The most important labour market effects of bioenergy production appear when looking into the transformation and conversion of bioenergy and its related infrastructure development. In this context the choice of technology and the scale of activity becomes an important issue.

Establishing and maintaining small to medium scale district heating and combined heat and power plants provide a number of jobs in rural areas which will be around the same number as those created in connection with primary bioenergy production. Besides providing job opportunities, it also adds to the diversity of the type of job available in rural and remote areas where opportunities are traditionally limited.

The alternative, establishing large scale centralized conversion facilities, creates almost the same number of jobs, so the net effects of bioenergy production will be almost the same, independent of the choice of technology. The transportation sector and the maintenance of an extensive district heating system are among the activities which will contribute. The impact will mostly be experienced in the urban areas, while rural areas will become, in the main, primary production areas. The only exception to

this is biogas production, where the costs of the transportation of manure from the farms to larger centralized units will limit profitability.

The cost-effectiveness of the production of biodiesel and bioethanol is very different. While biodiesel production can be undertaken on a small scale, and can thus provide opportunities for a larger number of rural and remote regions, bioethanol requires production facilities on a medium to large scale which are likely to be established outside the main centres. This will only provide jobs for a more limited area. In general, the regional effects of bioenergy transformation and conversion are – as with primary production – again closely inter-connected, leading to the direct effects becoming more obvious in Denmark and southern Sweden, while the options are more limited when moving further north.

5.4 Other socio-environmental impacts

Job creations in connection with bioenergy production may turn out to compensate for the general trend of job loss and out-migration, and thereby contribute to the maintenance of existing rural communities.

The landscape changes that would be the result of changes in land use may, however, have some negative effects on the communities concerned. Conflicts between different regimes for perennial crops occur when business and landscape conservation values are considered. For example, small cultivation areas are believed to enrich the landscape, while large, square and homogenous areas are often seen as less appealing but more economically profitable. And as tourism and second home owners have become increasingly important contributors to local economies while traditional annual agricultural energy crops are usually seen as preferable by these groups, substantial changes may influence their future activities.

For northern peripheral areas with vast forest areas conflicts between regimes for the exploitation of forestry resources will also appear. Increasing deforestation for energy purposes, using traditional forestry management approaches, could also lead to the loss of recreational values connected to such areas. The consequence of this could be labour source losses in the tourism industry as well as those connected with economic activities dependent on the servicing of second homes.

5.5 Innovation aspects

The development of bioenergy production, transformation and conversion technologies has long been characterized by a dispersed structure and a high level of user-producer interaction in the innovation process. For many decades alternatives to conventional oil-, nuclear- and hydropower resources have been considered low-tech approaches more characteristic of alternative lifestyles and thus not perceived as “real” alternatives.

This is a pattern which resembles other parts of the renewable energy sector, where small scale producers in close cooperation with their customers have provided the basic options for the development of the sector. Only during the last decade however has bioenergy become not only an accepted part of the discourse on future energy perspectives, but has also led to increased interest from high tech developers, for instance in the production of enzymes in second generation biofuel. In consequence these stakeholders are rapidly becoming important players in the game, which may change the development pattern.

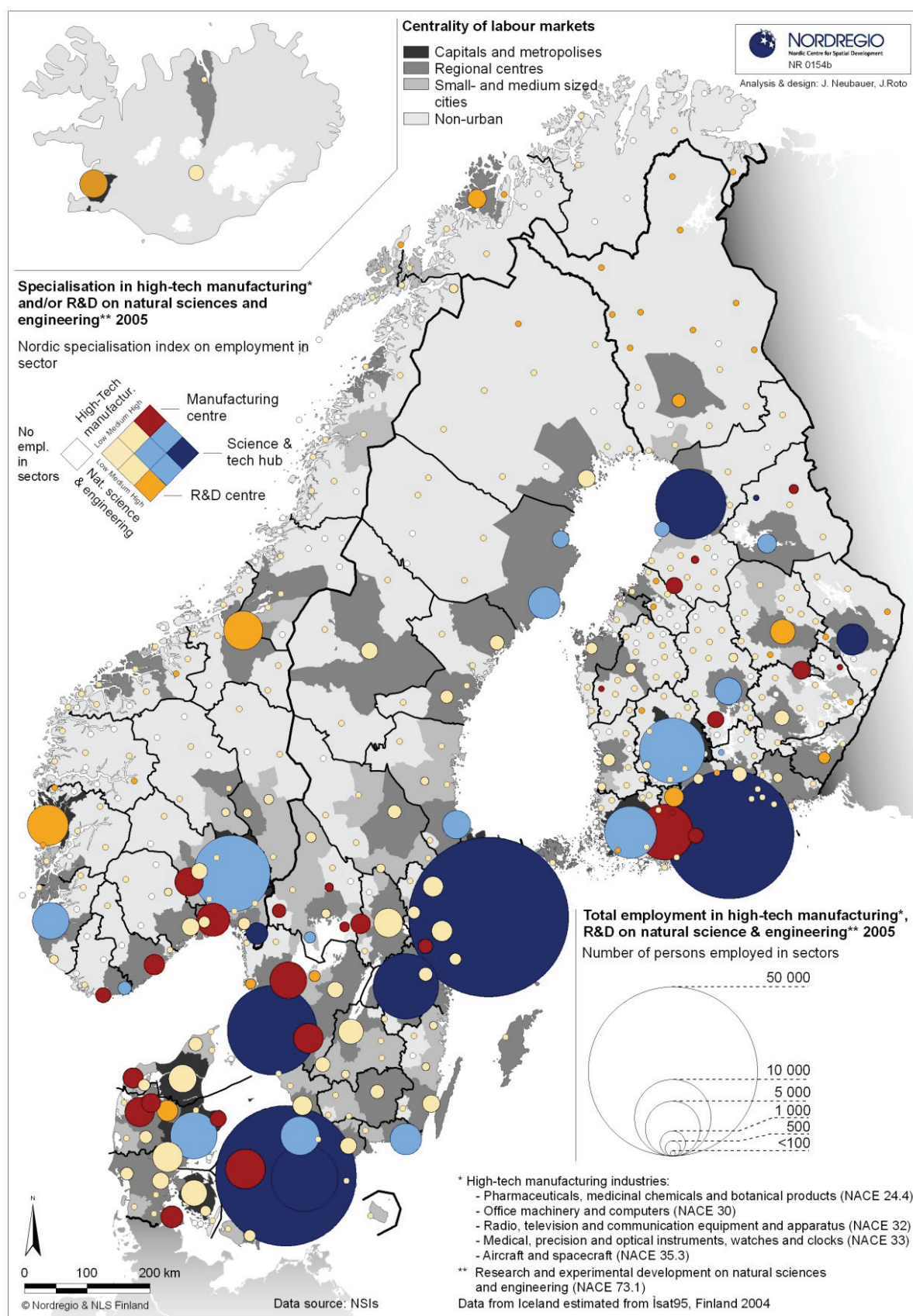


Figure 16 Total employment in high-tech manufacturing R&D on natural science & engineering 2005

The process thus far has however led to the creation of a de-centralized system of producers, and - as a consequence of the systems in its initial phases being low-tech - a continuing focus on small scale decentralized or distributed systems, based on local knowledge. This pattern seems to be quite durable, in spite of the emergence of still more technologically demanding systems requiring more in-depth research activities.

The latter, however, is very often provided by regional universities interested in contributing research-‘know-how’ to local and regional industries. The main limitation in this context is the tendency towards path-dependency, as the system is inherently limited by the boundaries of local-knowledge dependency.

The following map (Figure 16) illustrates some of the characteristics in respect of the innovation and research structure of the Nordic countries, with the capital regions characterized by the close connection between research institutions, higher education, and high-tech development. In regions with more dispersed settlement structure, including the more rural areas, however, the innovation pattern is characterized by the above-mentioned pattern, where artisans, producers, local technical centres, and consumers form an innovative network structure. The map indicates three types of innovation characteristics in these regions.

On the one we have hand small scale development activities, indicated on the map with low to medium high tech manufacturing and low to medium natural science and engineering. These centres are often based on local networks of artisans, engineers and users, focussing on small scale designs and development, aiming at solving energy problems on the individual or the community level, and characterized by incremental innovation processes. The first steps in the development of wind-energy and biogas are examples of this type of development.

On the other hand we have innovation connected to manufacturing centres situated in close proximity to users, taking advantage of the user-producer interaction as a key element in the innovation process. Current wind-energy and incinerator technologies are characterised by this type of development.

And thirdly we have centres of innovation based on R&D centres, usually the result of a longer history of incremental development with offset in former manufacturing centres.

In consequence, the industries provide decentralized job opportunities characterized by a rather diverse profile, from unskilled labour to professionals and to highly skilled specialists.

In addition to providing jobs and economic input to both rural and remote regions, the sector adds to the diversity of jobs available as well as demanding the greater availability of training and educational facilities.

6 Identifying environmental impacts

Large scale biomass production and the implementation of transformation and conversion bioenergy technologies could imply the emergence of environmental pressures and significant change in the agricultural landscape. This chapter thus aims to identify the environmental implications of some of the alternatives for bioenergy production previously reviewed in chapter 2.

6.1 Environmental impact

6.1.1 Feedstock

Cultivation of energy crops

The environmental consequences of the cultivation of energy crops depend on the following factors (Börjesson, 2007):

- The type of energy crop
- The cultivation system used
- The type of crop substituted
- The characteristics of the farmland used.

Theoretically, the cultivation of annual energy crops involves important environmental pressures but, generally speaking, where there is no expansion of arable land usage the environmental impact of a change from food to bioenergy production should be neutral (see Table 13) (Börjesson, 2007). In the context of proper cultivation methods, annual energy cropping involves less nutrient and pesticide usage and thus less environmental loading.

In cases where more land is used for the cultivation of annual energy crops in general, several negative environmental implications can be expected, including an increase in greenhouse gas emissions, nutrient leakage as well as reduced biodiversity. These consequences become more severe if applied to the cultivation of fallow land and highly valued natural areas (Börjesson, 2007). In particular, rapeseed cultivation implies increased environmental pressure since it requires larger quantities of fertilizers thus raising the levels of greenhouse gas emissions into the atmosphere and nutrient leakage into water streams causing eutrophication. Rapeseed have been shown, on the contrary, to provide some biodiversity benefits in the summer season, since cultivation provide habitats for a number of farmland specialist bird- and insect species, as compared to grains. (Booth et al, 2005).

Table 12 Global Warming Potentials (GWPs) (IPCC, 2007)

Greenhouse gas	GWP
CO ₂	1
CH ₄	21
N ₂ O	310

Besides being the major source of nutrient leakage into water streams, causing eutrophication, the use of mineral fertilizers has three other major environmental implications which explain part of the above-mentioned problems. First, important quantities of carbon dioxide emissions are released by machines when spreading fertilizers. Second, considerable amounts of nitrous oxide (N₂O) and methane gas (CH₄), both being the result of chemical processes in the soil, are released in the presence of fertilizers. These two gases are much stronger greenhouse gases than carbon dioxide (See also Table 12). In addition to this, the production of mineral fertilizers is highly energy demanding (Börjesson et al, 2002).

Table 13 Overview on the environmental consequences of increased bioenergy production from agriculture. (Modified from Börjesson, 2007)

Alternatives	Nutrient leakage	Biodiversity	Greenhouse gas emissions ¹
Substitution of annual crops by perennial crops on productive flat farmland.	++	+	+
Perennial crop cultivation on grass and set-aside areas in woodland.	-	-	+++
Perennial crop cultivation on grass and set-aside areas in flat farmland	-	+	+++
Perennial crop cultivation on infertile and high natural valued land.	-	---	+++
Substitution of conventional food crops with annual energy crops.	0	0	0
Annual energy crop cultivation on grass cultivation and set-aside areas in woodland.	--	+	++
Annual energy crop cultivation on infertile and high natural valued land.	--	----	++
(+) = positive effects (-) = negative effects (0) = no change reported ¹ Includes both carbon sequestration in soils and reduced emissions through substitution of fossil fuel utilization.			

Compared to annual crops, the cultivation of perennial ones is generally better for the environment because cropping methods imply less soil preparation and significantly less quantities of fertilizer and pesticide. Also in favour of perennial energy crop cultivation, these crops also benefit from self-nutrient recirculation, a process which prevents the formation and release of nitrous oxide and methane gas (Börjesson et al, 2002).

Through optimising the location and correct management of perennial energy, other positive environmental effects can be obtained including:

- Reduced risk for water and wind erosion
- Improved soil structure through increased humus content.
- Greater potential to use sludge and sewage as fertilizers.
- Possibilities to extract cadmium from the soil by cultivating specific willow variants.
- Increased biodiversity in the cultivated farmland. (Börjesson, 2007).

Perennial crops such as willow are thus, multifunctional since they can be used for among other things, soil remediation by reducing the presence of heavy metals in the soil and purification of municipal wastewater and sludge (Aronsson *et al*, 2007). From a regional perspective the multi-functionality of perennial energy crops make them suitable for densely populated areas suffering from water and soil problems related to the presence of toxic substances and eutrophication (Börjesson, 2007).

Negative environmental effects from the cultivation of perennial crops appear mainly when cultivation takes place in grass- or fallow land with extensive wild vegetation. In this case cultivation can lead to nutrient leakage and reduced biodiversity (Börjesson *et al*, 2002).

Residual products

From an environmental point of view, residues including sewage sludge, manure, straw, industrial by-products and the organic fraction of municipal waste represent the best feedstock for bioenergy production since low levels of process energy are required to obtain and convert them into heat and power. The use of residues can however also involve serious environmental risks. Therefore appropriate technologies must be carefully developed, evaluated and applied.

In terms of greenhouse gas emissions, biogas production from manure is beneficial since it prevents methane and nitrous oxide being released. With regard to the use of straw for energy production, no major environmental problems will occur as long as the majority of the yield remains on the farmland after harvesting. Straw helps to conserve the humus contained in soils, which is an element that preserves fertility and reduces the risks for nutrient leakage. This is particularly important in soils rich in clay or with a poor basic structure (Börjesson, 2007 and Jørgensen *et al* 2008).

Forestry

Dead wood, branches, roots and tops have several key functions in forest ecosystems, among others serving as a source of nutrients, regulating water flows, helping to prevent soil erosion and serving as a habitat for fauna and flora. The increased extraction of forest residues and complementary felling for bioenergy production is therefore likely to have an impact on the natural environment. However, these impacts will vary depending on the forestry management regime in use and the location for wood extraction (EEA, 2006).

The different parts of a tree contain differing amounts of nutrients, the highest amounts generally being present in the tops while the lowest are to be found in the stem wood. The nutrients trapped in dead wood, branches, root and tops are

progressively returned back into the soil as the wood decomposes. This also implies that biomass removal from forests, especially from branches and tops, always results in the export of nutrients, which can cause severe negative impacts on the growth of the next tree crop, especially in nutrient-poor forest areas (EEA, 2006). However, unlike the harvest of branches and tops, stump-harvest has less negative impacts since the content in the coarse part of the stump is relatively low (Egnell *et al.*, 2007).

Forest residues prevent soil erosion by decreasing the direct exposure of the soil to rainwater, sunlight and wind. Since deadwood and residues capture and store significant amounts of water and reduce water run-off on slopes, they also regulate the water flow through the ecosystem and act as filters for water running into water bodies. In connection to large scale forestry, forest residues help also to prevent soil compaction and erosion resulting from the use of heavy machines. (EEA, 2006)

6.1.2 Conversion technologies

Direct combustion

As outlined in the previous section, the energy balance of the direct combustion of perennial crops, wood biomass and other lignocellulosic rich residues is high; consequently leading to reduced carbon emissions. In firewood heating systems it is important to prioritize clean technologies which prevent emissions of health-hazardous substances, such as tar and other hydrocarbons, as well as sanitary problems associated with soot emissions. For large CHP and district heating plants the use of devices for the reduction of NO_x emissions is necessary. Ash disposal is another problem related to direct combustion. The optimal use of waste ash is as fertilizer, but due to their high heavy metals content, especially in ash from large-scale heat and power generation, they must be disposed of in appropriated dump fields (Jørgensen *et al.*, 2008).

Thermal gasification

The thermal gasification of residual biomass or whole crops has a high energy balance and low carbon emissions. As in direct combustion, the process of producing heat and power has a low process energy demand (Jørgensen *et al.*, 2008).

Environmental risks related to thermal gasification are mainly emissions of NO_x which can be reduced by the use of appropriate combustion technologies or catalytic converters (Jørgensen *et al.*, 2008).

Biogas

Among the first generation biofuels available for transport use, biogas remains the most environmentally friendly. This is because residual products, from a large number of sources, can be transformed into biogas, through processes requiring less quantities of process-energy. The use of agricultural by-products for biogas production has other environmental advantages, including the reduction of both nitrous oxide and methane emissions, and nutrient leakage. Methane is instead produced from the biomass for later collection and conversion into electricity and heat, or used as biofuel for motor engines. Furthermore, the “cake” resulting from the biogas production process can be used as a fertilizer through environmentally friendly techniques that prevent nitrogen leakage (Börjesson, 2007).

The negative environmental impacts of biogas production are generally related to local “bad smell” problems. In addition, substantial amounts of carbon dioxide are

released in connection with the operation of large centralized production biogas plants because plenty of transportation is needed to move large volumes of wet manure from individual farms (Jørgensen *et al.*, 2008).

Bioethanol

Bioethanol production is energy demanding, mainly during the distillation process in which a large amount of steam is used. In order to make the process more environmentally efficient, bio-refineries will allow the use of the residual heat from ethanol production to generate electrical power and district heating (Bentsen *et al.*, 2006).

Biodiesel

As for bioethanol produced from grains, most of the energy used in the production of biodiesel is consumed during the growing of the crops rather than in synthesising biodiesel. In the production of RME-diesel, esterification accounts for a significant proportion of the total energy input for biodiesel production (Booth *et al.*, 2005).

Second generation biofuels

The benefits of second generation biofuels, as experienced in the Nordic countries, include a significant reduction in greenhouse gas emissions given the energy savings connected with the use of wood biomass. It is also to be borne in mind that, due to the large variety of processes, their continued development and not least the different approaches used in assessing bioenergy systems, it remains difficult to determine the actual differences in environmental performance between specific second generation biofuels.

6.2 Impact on the landscape

The impact of energy crop cultivation on the landscape depends on two factors; the crop itself and the location. In general, no serious conflicts occur as long as cultivation is located outside areas of high natural or cultural value. However, the assessment of the landscape impacts of energy crop cultivation is rather controversial since it can often entail significant changes to the cultural landscape (Weih, 2006).

The use of traditional annual agricultural energy crops on farmland is generally preferred (Johnsson, 2006). But a more positive approach on willow cultivation recognises its potential to increase aesthetic values by enriching the structure of homogenous landscapes (NUTEK, 1993).

Solutions to improving the landscape value of perennial energy crop cultivation include combining several species of perennial energy crops, combining areas of perennial energy and annual crops or combining perennial energy crop areas with edge zones areas populated by native flora. Whether or not these alternatives are economically viable they are however seldom put into practice (Weih, 2006). More in-depth landscape consequences will be discussed in the following chapters particularly in connection to the economic and social impacts of bioenergy production.

7 Identifying social impacts

In the Nordic countries rural communities are currently experiencing rapid demographic and social change. Fewer and fewer rural communities are able to maintain their traditional dependence upon extraction-based industries such as agriculture, forestry and mining. Instead, they display a variety of different development trajectories.

One of these development paths may very well include an increased focus on energy crops and renewable energy production as described in the previous chapters. In order to evaluate the potential social impacts such a development may have, it is necessary, however, to put the changes into a perspective which includes the other factors influencing contemporary rural social landscapes.

The following analysis is based on secondary sources, as the project has not undertaken in-depth analysis of the different components. The aim here is to emphasise the potential social impacts of different approaches to bioenergy and how these impacts may influence the decision patterns in relation to changes in energy approaches.

7.1 The emergence of 'new ruralities'?

The array of different local development trajectories means that what is perceived of as the 'rural way of life' is becoming increasingly heterogeneous. Traditional family based farming activities are disappearing, resulting in job loss and the decline of other activities associated with extractive activities, and ultimately in the substantial out-migration of youth, and especially younger women (Rauhut *et al.* 2008).

With less people involved in these traditional activities, other characteristics are now shaping the rural landscape. For amenity-rich rural areas, one of the most prevalent development paths has been a shift towards recreation-based economies and commercial tourism, founded upon what is still perceived as an abundance of local natural resources. During the last decade so-called 'second-home' tourism's economic, environmental and social impacts on host home communities has become increasingly important (Müller *et al.* 2004), and such considerations have become an integral part of contemporary tourism and mobility research.

An important aspect of this new amenity-based rural development strategy is the extensive development of a seasonal housing market. As the number and concentration of recreational dwellings/seasonal homes has increased over time concern over environmental protection, landscape characteristics, economic costs and benefits, issues of social and economic inequalities and confrontation between rural and urban lifestyles have become major concerns for local planners, regional authorities and local rural residents.

In this context new lifestyle choices may contribute to rural community interactions between various parts of the rural population where the choices provide for particular sets of gendered responses, and may contribute to explaining how local development strategies are negotiated in local networks of public and private actors. This is necessary in order to fully comprehend the possible consequences of an

increasing emphasis on bioenergy, because rural communities are themselves developing into much more complex entities than when farming was almost the sole activity.

The diversifying rural place may however encourage the emergence of several contradictions between local and urban residents. This blending of urban and rural lifestyles creates a set of new blurred urban-rural lifestyles. Different socio-cultural and individual frameworks open new possibilities in social, economic and cultural contexts and create possibilities for new, flexible lifestyles to emerge, which may be approached from two perspectives which emphasise different interpretative frameworks. On the one hand, new lifestyles may be interpreted in relation to society and, on the other, in relation to the level of individual choices (Kahila and Rinne-Koski 2005):

- First, new lifestyles are enabled through increasing amounts of leisure time and rising standards of living. Households have the assets, time and opportunity to support several dwelling places and to move freely between places.
- Second, households tailor their lifestyles according to choices, possibilities, resources and preferences. They choose the best elements of urban and rural lifestyles and assimilate them into individually tailored lifestyles.

New lifestyles lead to different implications and forms of activities, which in turn lead to different opportunities and demands in rural areas. They may create new possibilities for rural economies that in turn produce new social, economic and also political settings and activities. A characteristic of many second-home owners and tourists is an idea of renewable energy production being an indication of the “closer-to-nature” perspective they may be seeking in the rural environment. It may, on the other hand, also create obstacles to specific changes, such as local demands for new job and income opportunities, for instance through the expansion of the areas used for energy crops, which may be met with objections from second home owners and short term tourists. They may have quite different perceptions of what a rural landscape should look like. Tuulentie (2007) emphasizes how both second home owners and tourists seek a close relationship with one specific place or region, and want to “go steady” with that place or region. Thus, visitors may, over time, transcend their typical positions and make a place or a region their regular haunt or even “home”. In this process Rasmussen (forthcoming) emphasizes how access to personal relations and, especially, informal services are considered not only to be a part of rural life, but to provide authenticity and connectivity between tourists/second home owners and the regular population.

The dissolving of formal economic rationales - or perhaps just a growing recognition of a long enduring situation – emphasises how informal relations and lifestyle parameters are (becoming) decisive for the dynamics and economic competitiveness of local communities (Keldsen, 2005). And in this process second homes and tourism have turned out to have an important role, both in relation to structuring the landscapes, and in contributing to the rural economies and challenging traditional lifestyle characteristics (Ærø *et al*, 2006). Similar results from second homes not only confirm the pattern, but emphasise how interaction with the community becomes a crucial part of the experience of “belonging” (Tress 2002).

In consequence, the various actors (local residents, part-time residents, local public sector administrators, commercial interests) may have diverse interests and different perceptions of reality and preferred development strategies, depending on their

points of reference. Local host/second-home owner conflicts are not restricted to planning and taxation issues, but easily spill over into debates on political and resource use issues. Involvement in local political issues by highly educated, affluent and astute seasonal residents is not uncommon where commercial developments and use of local resources interferes with notions of countryside preservation or privileged access. This may very well have a marked impact on decisions in relation to alternative energy systems – both positively through promoting them, but also negatively by objecting to the possible adverse effects they may have on the traditional rural landscapes.

In such multi-actor situations, the interactions between the different actors are often caused by the need to negotiate shared purposes and exchange resources such as information and trust. The formal and informal relationships between local authorities, commercial interests and different groups of residents, and the extent to which these interactions are organised collectively or individually, may be of crucial importance to the formulation of local development strategies.

7.2 Demographic and social trends

The movement of people to urban areas and the subsequent rural population decline has been one of the main continuing social trends of the 21st century (Edvardsson *et al* 2007). The result – high concentrations of people in urban regions, and dispersed population in the rural areas – is characteristic of Europe in general, but is especially marked in the Nordic countries - as shown on the map below - where the net population growth in all five countries is concentrated in the major city regions of Oslo, Helsinki, Copenhagen, Stockholm and Reykjavik.

The pattern of increasing population concentration accelerated during the 1990s with an increase of 1.2 million persons, or around 5 percent, of the Nordic population relocating over a domestic municipal boundary, in 2005, and with a substantial share of this flow of inter-municipal migration taking place between peripheral areas and urban centres (Neubauer *et al* 2007).

The most important driving forces in respect of demographic change for the time being are the age and gender structures. According to European Commission estimates, rural areas in the European Union represent 92% of the territory and 56% of the population. Rural economies generate 45% of GVA and provide 53% of the employment, but tend to lag behind in respect of a number of socio-economic indicators as compared to non-rural areas. Even where opportunities for growth in new sectors exist – primarily tourism - their attractiveness as a place to live and work has diminished alongside in the light of globalisation.

Ongoing changes in rural areas have led to marked changes in the age structures and dependency characteristics of rural communities. As shown on the map above, development in the rural areas has been characterized by a marked increase in the old age group, as well as a reduction of persons in the productive age group. It is also these areas which have been characterized by a marked out-migration. There are many explanations for this process, some related to the individual preferences among different age and gender groups, and others related to general economic conditions in the rural areas.

Farming has evolved into a one-person business. Women in small villages in regions with higher unemployment are disadvantaged on the labour market. On one hand this relates to their family role and the limited availability of kindergartens and

leisure time institutions for children. To the extent that they remain in charge of caring for their children their labour market connection is often limited to part-time jobs in nearby towns and villages. Their ability to commute to potential jobs outside their hometowns is limited by the availability of the above-mentioned services. In some cases this may still be considered the norm, namely, that “nothing can be done about it” and that alternatives are not considered possible. In these cases, however, the social situation and living standards eventually deteriorate, as the younger generation usually does not subscribe to such approaches.

The intensification of, and increasing emphasis on, technology, has thus reduced the level of manual, including female, involvement in the labour market, as well as the opportunities for a new generations to enter it. These ongoing economic and social changes first and foremost affect the decisional structures for both women and adolescents, though they are modified somewhat in areas where counter-urbanisation and the opportunity to commute to larger urban centres have added to the job opportunities offered.

Consequently, life in the countryside is losing its appeal for young people, who leave for the cities, resulting in further deterioration in the fabric of countryside life. This process is accelerated by the situation where markedly more women than men are pursuing higher education (Rauhut *et. al*, 2008), and while this has implications on the national level such implications are intensely magnified in rural settings, with a catch-22 situation occurring showing a general deficit of women, but also a surplus of women with higher education, and limited offers for qualified 3rd sector job opportunities. Comparative research seems to indicate these patterns regarding affinity to rural community life as being consistent across Europe, and definitely so throughout the Nordic countries.

More females than males consider - and eventually tend, to - migrate permanently away from their home community and region, first of all to look for job opportunities which better fit their qualifications, and which provide opportunities outside those traditional economic activities in these communities (Hamilton and Seyfrit, 1994). As a consequence, women tend to experience negative short-term and long-term consequences in terms of careers, earnings and pensions, and this has severe consequences for migration patterns.

Indicators from the EU research reveal that the employment rates of both men and women are lower in rural areas, just as unemployment combined with a lack of diversification in employment is more common for women than for rural men (Klass, 2007). In consequence, rural areas experience marked demographic, social and cultural changes while the process of change in the dependency structures becomes still more evident throughout Europe. It also contributes to the deterioration of the social infrastructure institutions and to the decline of public interest services, eventually leading to a loss of population, and observable lower fertility rates thus endangering the medium to long-term development of these regions, as indeed was indicated on the map of population development in the Nordic countries reproduced above.

It has become ever more obvious moreover that development cannot be based on agriculture or other primary sector activities alone. Diversification both within and beyond the agricultural sector is indispensable in order to promote viable sustainable rural development, but the ability of many rural communities to adapt to these changes has been very limited. The relatively high number of women employed in the service sector has been argued to represent “an escape valve” away from the

traditional rural structure based on agriculture which has become highly mechanized and masculine, towards a new, more diversified socio-economic structure in which women participate and receive both a salary and social protection. Furthermore, it is stressed that women often initiate the diversification of the rural economic realm by creating businesses, thereby generating both income and jobs.

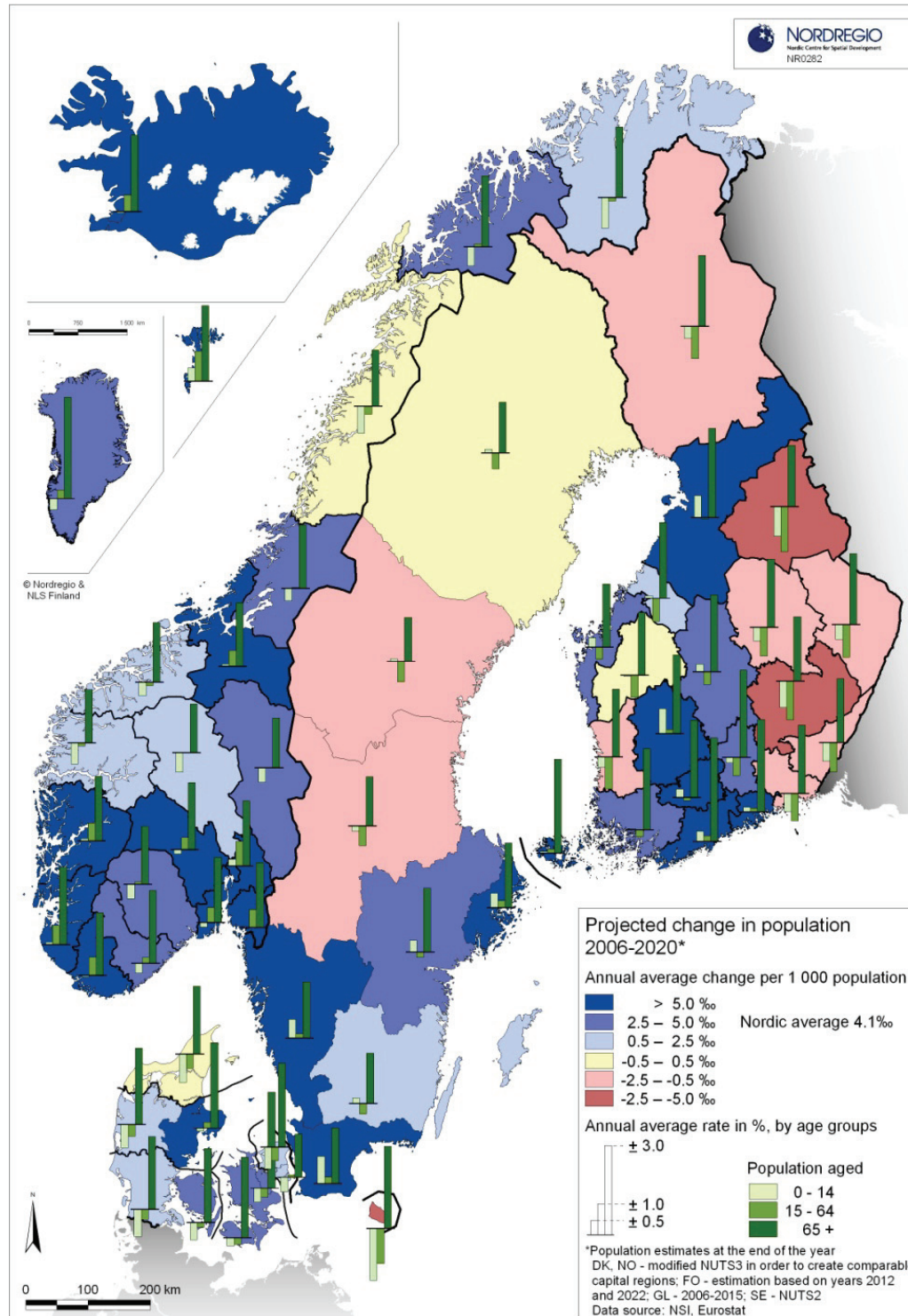


Figure 17 Projected change in population in the Nordic countries 2006-2020

It is sometime argued that second home demand adds to the process of out-migration from rural communities by displacing permanent residents, but research by Marjavaara in small island communities in Sweden (Marjavaara, 2007) shows that not only do migrating individuals experience improved conditions, but that second home activities add to the economic performance of the communities. A key question in this context then is the small business and the promotion of entrepreneurship on the grassroots level, ensuring that entrepreneurs are attracted to these rural areas. Studies among entrepreneurs in rural areas show that men mainly produce both goods and services, while women mostly start service enterprises. The exclusion of the service sector as eligible for grants to entrepreneurs in rural areas has excluded many women-led initiatives, but this has changed, and women are now prioritised for grants for entrepreneurial purposes. Consequently, the number of female entrepreneurs has increased considerably. In Norway, for instance, 24% of all self-employed persons are now women. (Spilling and Berg, 1998), and changes in State and Regional Development rules for grants resulted in an increase in women among grant receivers from 20 to 40 %.

7.3 Rural implications

As discussed in connection with the labour market consequences of the new emphasis on bioenergy, there are two aspects impacting the rural setting. On the one hand the direct effects caused by producing energy crops, and on the other hand the establishment of transformation and conversion facilities requiring some manual work, but in this context requiring various types of skills and knowledge which are not necessarily already available in these communities.

In relation to field crop production, bioenergy production requires almost the same labour input as other agricultural field crops, so as long as production takes place on land areas already under crop, the consequences may be limited. As discussed, a shift from annual to perennial crops may even mean an overall lower input of man-hours, though this would be partly compensated through the occurrence of peak activities during the planting and harvesting seasons. Consequently, the primary production of bioenergy will only provide extra jobs to the extent that it will be possible to include areas which presently are kept outside agricultural usage. A shift to bioenergy crops will therefore allow a continuation of current activities, but will not provide the basis for new activities to take place. A special situation may occur in cases where there is an increasing focus on perennial crops. As they are only labour intensive during the planting and harvesting periods, while the maintenance workload is limited, it may provide a basis for migrant work activities. With no requirements in respect of the daily control of farming activities, farmers may become urbanized, only going to the farm in connection with the intensive periods of planting and harvesting. Or bulk activities in these periods may be covered by temporary migrant workers, leading to a reduction in the permanent rural population. This may be “worst-case scenario”, but analogous situations from other parts of the world, where crops with short-term high intensive labour force requirements (cotton, sugarcane, tomatoes, citrus plantations etc.) are managed through considerable use of migrant labour, have led to an increase in the level of out-migration.

In relation to the conversion of bioenergy and the establishment of related infrastructures, the establishment and maintenance of small to medium scale district heating and combined heat and power plants provides a number of jobs in rural areas

which seem to be of a similar level to the jobs connected with primary bioenergy production. To the extent that these developments focus on decentralized activities it may provide important jobs while adding to the diversity of job types available in rural and remote areas. It may be job opportunities which may be attractive to younger men, thus compensating for the ongoing out-migration trend by contributing to keeping a few of them from leaving their communities. The types of jobs offered, however, are not those that currently seem attractive to women, so the impact on the out-migration pattern will likely remain limited.

As discussed previously the impact of the alternative, the establishment of large scale centralized transformation and conversion facilities, will mostly be experienced in the urban areas, while the rural areas become primary production areas.

When looking into the development perspectives of rural communities, the introduction of bioenergy does not in itself provide substantial new job opportunities, and thus a basis for maintaining the rural lifestyle. It is in its interaction with other ongoing changes in the rural setting that bioenergy crops and conversion activities may contribute positively. As noted above, the increasing importance of tourism and second homes may – in combination with existing farming activities - generate a potentially positive outcome. Both tourists and second home owners who seek a particular form of rural setting perceived this as being an important defining framework. They are not only seeking the company of other second-home owners or tourists, but are looking for interaction with the “original” rural landscape and its inhabitants by seeking a close relationship with one specific place or region where access to personal relations and informal services are considered to be not only a part of rural life, but to provide authenticity and connectivity between tourists/second home owners and the ‘indigenous’ population.

In this context it may, on the other hand, also create obstacles to specific changes, as the local demands for new job and income opportunities, for instance through the expansion of areas utilising energy crops, may be met with objections from second home owners and short term tourists. They may have quite different perceptions of what a rural landscape *should* look like, and this may have implications for the options available for expanding energy crop production and the establishment of energy transformation and conversion facilities. As emphasized in section 6, the use of “traditional crops”, and in relation to energy crops, of traditional annual energy crops is generally preferred (Johnsson, 2006). This may very well be a short term limitation, as a more positive approach towards perennial crops such as willow cultivation may appear when it is recognized that it has the potential to increase the aesthetical value of the landscape by enriching the structure of homogenous landscapes (NUTEK, 1993). More complex conflicts between different regimes for perennial crops may occur when farm economy, business development perspectives and landscape conservation values are considered. For example, small cultivation areas are believed to enrich the landscape, while large, square and homogenous areas are often seen as less appealing but more economically profitable (Weih, 2006).

In consequence, the various actors (local residents, part-time residents, local public sector administrators, commercial interests) clearly have diverse interests and different perceptions of reality and of preferred development strategies, depending on their points of reference. Local host/second-home owner conflicts are not restricted to planning and taxation issues, but easily spill over into debates on political and resource use issues. Involvement in local political issues by highly educated, affluent and astute seasonal residents is not uncommon where commercial

developments and the use of local resources interferes with notions of countryside preservation or privileged access.

Important questions regarding the social and cultural impacts of the increasing emphasis on bioenergy remain to be resolved. To what extent are people ready to accept changes in energy systems? The differences between acceptance of, for instance, bioethanol in petrol between Sweden and Denmark may illustrate that this may not be a voluntary process, even where the choice has been without cost for customers. And to what extent are people ready to accept changes in landscapes?

Landscapes with energy crops may in many cases differ from those with traditional food crops. Changes in landscapes could consequently also lead to changes in the perceptions of landscapes due to advantages or disadvantages related to energy crop cultivation. For instance, the farmer may skip crop rotation practices and instead maintain the same type of energy crop in consecutive years. Or monocultures of energy crops could be required in order to provide a workable economic basis for the primary producers, but may not be so attractive neither to the permanent nor the temporary residents. The farmers are used to the impacts of market demands on crop patterns, so a change from rotational practice or monoculture in food production to other types of monoculture for energy production might not generate much objection. But this may not be the case with second-home owners or tourists. It could be argued that they hold a very stereotypical view of agricultural landscapes, but whether or not this is a stereotype, their decisions regarding which areas to visit and where to acquire a second home will have a substantial impact on the future of the rural setting.

8 Institutional implications

The introduction of bioenergy on a larger scale will, without doubt, have an impact on the institutional framework needed for both development and implementation. While the production of conventional energy, i.e. hydropower, coal, oil etc., is very much dependent on large scale production from single sources with single line distribution networks to consumers – a typical one-to-many relationship – the production of bioenergy and related transformation and conversion depends on many suppliers, many technologies, and – of course – many consumers – a typical many-to-many relationship, with a common grid, but also including local distribution networks, individual producers and consumers. Instead of a rather simple – and well tested – institutional framework based on a system of top-down decision processes, the energy landscape becomes much more complex.

The complexity increases with the dissolving of the traditional Nordic approach to energy supply systems based on public service, and the increasing involvement of private actors, with the question of competition and market price setting becoming crucial for the decision processes.

A third component here is the role of governments in establishing a framework for the shift in systems from non-renewable to renewable resources. The approaches utilised here have however been somewhat heterogeneous across the Nordic countries, where policies in relation to direct support, CO₂ taxes, direct investment, research support etc., have been important components, and where new initiatives may be important if the Nordic countries are to be well positioned in the intensifying global market for renewable resource technology development.

In terms of the adoption of management approaches designed to optimize the output of biomass production while preserving the natural and recreational values of agricultural and forest areas, the approaches adopted thus far have been different, and related to several of the above-mentioned components. The future outcome is dependant on collaboration and cooperation between public and private institutions, researchers and the general public. For public authorities the challenge will be in the development of appropriate steering instruments. Another problem encountered by public authorities will be the need to harmonize overall goals in sectors such as energy, forestry, nature conservation, agriculture, etc. Thus, the key to sound bioenergy production will remain strong land-use steering instruments aiming at the preservation of natural and cultural values, while at the same time providing business incitements for private actors (Emanuelsson, 2007).

A case that exemplifies the importance of support from local political structures and private and public organizations in the introduction of bioenergy projects can be found in Växjö, in Sweden, during late 1970's. The discussion about using bioenergy for district heating gained forced in Växjö during the oil crisis of 1973. However, the use of bioenergy involved high investments costs, and uncertainty with regard to technology and fuel supply. In order to overcome these problems the company responsible for district heating VEAB opted to open discussions, and invited opinions from “laymen and specialists” in order to identify and realize the optimum level of socio-economic benefit. In turn, political support made it possible to apply

for financial grants for bioenergy projects. The result was, in the first place, a small retrofit heat plant for biofuel that became operational in 1983, followed thereafter by a number of activities, including the formation of the Bioenergy Group, a local Agenda 21 group, the Bioenergy centre at Växjö University and the building of a new CHP plant in 1994-96 (Bo, 2001).

One example of the institutional complexity of re-structuring a community from conventional to renewable energy system is the case of the island Samsø in Denmark (Hansen, 2007). The process began with a competition in 1996, arranged by the Danish governmental department of energy (*Energistyrelsen*). The idea was that a confined area within a period of 10 years should be able to transform its energy system to renewable energy forms, and the island Samsø, together with the company *PlanEnergi* in Århus won the competition.

The basic idea was to emphasise two main systems, windmills – a combination of smaller mills on land, and a park of larger off-shore mills - as the main supplier of electricity, and an extensive district heating system primarily based on a series of small scale incinerators fed with different types of biomass, but with supplemental inputs of heat from tanks of cooling water from the ferries connecting the island with Jylland and Sjælland. In addition biogas production from an old household waste dump was supposed to add to the total energy production of an estimated 285,2 TJ/year (PlanEnergi 2007).

A key element in the project was the substantial level of public involvement in the project, facilitated, on the one hand, by public acceptance of the changes in the landscape in respect of windmills and crops for biomass production, and on the other hand, because it was the original intention that participation should be voluntary. As a consequence of this policy, however, less than 40% of the 2000 households ended up being connected to the district heating system while the establishment of other parts of the system caused heated discussion and considerable conflict.

Even the initial step - the introduction of new windmills on land - caused trouble. Due to governmental support for power generated by windmills it was quite profitable to invest in the mills, so farmers with large land areas quickly became very interested in getting mills sited on their land. Their neighbours, however, with no such options strongly objected. The municipal planning authority had their own ideas about the positioning of the mills, but these plans contradicted the overall county planning ideas. So besides different interests among individuals, differences in interests between the administrative units concerned were also experienced (Hansen 2007).

In the original project plan the intention was to cover all types of energy generation with local products, but it soon became clear that the available technology did not allow for the production of petrol or diesel. Instead it was decided to establish an off-shore windmill park and “export” electricity in energy amounts comparable to the importing of energy for transportation.

The original idea of establishing a project with a very strong focus on public involvement slowly deteriorated. The most successful part of the project was the off-shore windmill park, as it contributed positively to the project without causing conflicts between different interest groups. The conflicts over the land based windmills illustrated how perceptions of the windmills depended on the profit motive. Similarly the question of district heating connections versus individual heating arrangements caused intense debate, and the ideas of promoting district

heating was by no means met with enthusiasm by the majority of the population. In addition, the question of promoting biomass production on former agricultural areas for heating purpose was met with antagonism by the hunter's association as well as by groups of nature conservationists.

As a consequence of the problems encountered the project authority slowly took over responsibility for project development while still maintaining a high level of public consultation and undertaking to regularly disseminate the results, but no longer relying on the public in relation to decision taking. A by-product of this has been the establishment of the "Energy Academy", a combined research unit, information centre and practical advisory unit, providing easy access to information and experience for others looking into the possibilities of embracing a renewable energy future.

Seen from one perspective the Samsø case has been a success. After a period of 10 years the community is more than 100% self sufficient with renewable energy, combining different renewable energy resources. So the project clearly demonstrates that such a goal is obtainable in a rural setting like that on Samsø.

From another perspective, however, there remain some obvious limitations to the project, at least as seen in the context of the original project outline. On the one hand the positive energy budget is heavily based on wind turbines covering not only local consumption but also geared for market-based energy export. At the same time the Island is still heavily dependent on the import of conventional petrol and diesel. On the other hand, the project initially aimed at encouraging extensive public involvement as the cornerstone of the institutional framework. Relying on public involvement and decentralized decisions as the main carrier of the project idea. This however proved to be a problematic, leading eventually to the adoption of a more centralized project management structure which became responsible for carrying through the project idea in its current form.

As indicated by the cases outlined above, increasing emphasis on different types of renewable energy poses the question of which kinds of institutions will be able to manage these new forms of energy policy. As noted previously, the introduction of bio-energy on a larger scale demands a very different institutional approach for both development and implementation as compared to the production of conventional energy. While the latter is very much dependent on large scale production from single sources with single line distribution networks to consumers, production of bioenergy and related conversion technologies depends on many suppliers, many conversion technologies, and consumers in both rural and urban settings. In addition, managing common grids such as local distribution networks, individual producers and individual consumers may require a new combination of 'top-down' as well as 'bottom up' institutions. Moreover, the complexity increases with the dissolving of the traditional Nordic approach to the provision of energy supply systems based on public service rationales, and with the increasing involvement of private actors, the question of competition and market price setting becomes crucial to the decision process.

9 Conclusions and outlook

9.1 Main findings

In the Nordic countries changing trends in land-use systems, in the availability of fallow land and in yield increases indicate that considerable amounts of bioenergy could be obtained from the agricultural sector. The dominance of cereals in crop rotation, primarily in the southern regions of the Nordic countries, speaks in favour of the production of bioethanol from grain and straw. Rapeseed production appears to be most successful in Denmark and southern Sweden though very limited in Finland and Norway.

The use of traditional food crops to produce first generation biofuels has important disadvantages partly due to the large amount of process energy, considerable use of fertilizers and pesticides, and extensive arable land demanded for the cultivation but also due to important land-use conflicts with food production. Perennial crops, on the other hand, are significantly more productive and environmentally friendly, and present a better option for biomass production than annual ones, especially in fallow land.

According to the literature reviewed in the course of this study, from an energy efficiency and environmental point of view the use of residual material from agriculture, forestry and municipal waste, as well as woody biomass from complementary felling and annual energy crops such as willow, appears to be the best available feedstock for bioenergy production in the Nordic countries.

When comparing the different (bioenergy) technological alternatives for energy conversion; direct combustion, thermal gasification, combined heat and power (CHP) and district heating, as well as the use of biogas, appear to be the most resource efficient and environmentally friendly.

Compared to the use of biogas in the transport sector, first generation bioethanol and RME biodiesel are easier to use in cars but remain a less favourable option, due to the large amount of process energy consumed during the cultivation of the crops and in the refining processes, leading so to increased levels of greenhouse gas emissions.

In the long run second generation biofuels are a better option for substituting conventional fuels mainly because they enable the use of a well diversified feedstock already available in the Nordic countries, especially in the northern regions. Current technological developments thus point to the further development of bio-refineries able to simultaneously produce second generation biofuels, heat, electrical power and, and other products while enabling use of most of the energy content in biomass.

The labour market consequences, primarily in relation to the production of bioenergy are often suggested to entail a substantial number of jobs being created in rural areas. The assessment made in this study however, predicts instead only modest changes in the labour market in connection to the expansion of bioenergy production in the Nordic countries. This is so because in most cases, bioenergy production requires almost the same labour input as in other agricultural field crops

which are basically the same types of crops that are already being produced by traditional agriculture. A shift from annual to perennial crops may even mean an overall lowering of man-hours, though this may, in part, be compensated through peak activity in the planting and harvesting seasons. In less productive areas where food production is already marginalized however the option to produce bioenergy will enable farms to continue their activities beyond what would have been possible if they were forced to compete with food producers situated in more favourable areas.

The most important labour market effects of bioenergy production emerge when looking into the transformation and conversion of bioenergy and its related infrastructure development. The alternative, establishing large scale centralized conversion facilities, entails almost the same level of job creation, so the net effects of bioenergy production will be almost the same, independent of the choice of technology. The transportation sector and the maintenance of an extensive district heating system are among the activities aiding job creation. The impact will be experienced predominantly in the urban areas; the exception to this is biogas, while the rural areas remain production enclaves. Bioenergy-related innovation also makes an important contribution here as will the potential to incorporate a skilled labour force in the near future.

Biogas production appears to have a major potential to generate jobs in relation to first generation biofuels, mainly because it can be produced on both a low and medium scale level, centralized as well as decentralized. While biodiesel production can also be undertaken on a small scale thus providing opportunities for a larger number of jobs in rural and remote regions, bioethanol production requires processing plants on a medium to large scale which may be established outside the population centres, but are likely only to provide jobs to a more confined area.

Bioenergy systems involve technical, political, social, economic, institutional and environmental aspects each of which are highly dependant on local, regional, national and trans-national socio-economic structures. In reviewing the content of this report it becomes clear that planning for bioenergy projects requires a multidisciplinary and multi-scale approach. As such, environmental and social impact assessment should reflect not only this, but also the interdependencies characterizing the bioenergy system.

9.2 Discussion

Whereas energy supply is changing and climate change has become a priority issue on the Nordic political agenda, the expansion of bioenergy usage aims at reducing greenhouse gas emissions and securing future energy supply. In the recently announced Nordic research initiative "*Från Norden till Jorden*", one of the research themes has its focus on the Nordic countries being CO₂-neutral, while another focuses on a sustainable bioenergy development. There seems then to be consensus on future energy policies which supports the implementation of bioenergy alternatives with the lowest greenhouse gas emissions while providing high levels of energy and a lower demand for process energy. At the same time, however, general agreement also exists on the realisation that due to the scarcity of available agricultural land, bioenergy should not compete against, but instead coexist with, the need to expand global food supply.

The availability of many bioenergy alternatives provides the possibility for both producers and users to choose the best adapted technique and feedstock available in

accordance with local geophysical, climate and socio-economic conditions. Differences in the dependency of specific forms of energy between industries, households and transport activities however make it difficult to determine the precise way in which bioenergy should be transformed and used. Precise policy recommendations will therefore be dependent on both the short and the long term goals of energy policy.

Since biogas appears to be a versatile, environmentally friendly and resource effective option, policy measures could enable the establishment of more biogas plants and see to expand the distribution infrastructure. According to this study biogas also appears to be a means of generating more employment in sparsely populated areas. In addition, policy measures in relation to the promotion of second generation biofuel production should also be prioritized in so far as the feedstock production does not compromise future access to natural resources and food production.

Increasing bioenergy production in the Nordic countries will demand changes in current institutional settings in order to effectively cope with the complexity of the systems which, for instance, include the increasing involvement of the private sector, market competition, changes in the regulatory framework and the various instruments needed to oversee the shift from non-renewable to renewable energy resources. Not least from a management point of view, the institutional framework in the Nordic countries could mediate conflicts both within and between sectors, especially with regard to the weighing of environmental, recreational and energy supply alternatives in respect of changes in land-use.

In the short term, first generation bioethanol and biodiesel proved to be good options in relation to stimulating the use of biofuels, though their production appears unsustainable in the Nordic countries – and perhaps even worldwide - in the long run, as large scale bioenergy production from food crops has shown to have led to food supply problems and higher food prices. Bioenergy use is thus not only a technological matter, but also requires policy measures which pay attention to important ethical issues which require the careful balancing of several factors, including the competition between food and energy security but not least other key social, economic and environmental goals.

9.3 Research themes

Based on the experiences uncovered in connection with this study, a number of issues have been identified which require further investigation. The following list is by no means complete, but instead focuses on future prerogatives.

- *Socio-economic impact assessment of the exploitation of wood biomass for bioenergy purposes in the Nordic countries:* Biomass from forestry residues and complementary felling appear to be promising feedstock options for future bioenergy supply in the Nordic countries. The development of second generation biofuels obtained from wood biomass will further the potential for regions in the northern peripheries of Sweden and Finland to engage in large-scale biofuel production, which in turn will bring socio-economic benefits, such as increases in employment levels and average incomes, to these regions.

- *Experiences with, and future perspectives of bioenergy planning in the Nordic countries:* As Sweden, Finland and Denmark each have more than twenty years of experience in bioenergy production, while an important share of the total energy consumption is bioenergy-based, important experiences have been gathered. It may be important then for future management approaches to utilise this long-held experience of the different management approaches and instruments used for energy planning not only in the Nordic region but also elsewhere.
- *The perception of energy crops:* Not only the potential economic outcome of energy crops, but also the perception of different energy crops being inclusive or intrusive in the rural landscape is important in relation to the acceptance of bioenergy as a future energy source. But, as yet, very little is known of the perceptions of energy crops in different population groups, and even less is known about how these perceptions influence different activities such as energy crop production, other production activities, second homes, tourism, leisure time activities etc. These are the key questions which need to be answered when planning for the future extension of bioenergy crop cultivation.
- *Mono-functional versus multi-functional landscape use:* Future planning and policies for landscape development should have a greater focus on the perspective of co-existence between different simultaneous landscape activities, for instance crop production, day-tourism, second-home activities, etc. A crucial question, however, remains what kinds of conflicts exist, how are different regions able to cope with these conflicts, and which institutional frameworks and policy measures are best able to take such conflicts into account.
- *Patterns of innovation in renewable energy resource development:* Innovation in the bioenergy sector appears to be a promising export industry which could generate a considerable amount of employment. Being part of the environmental technology sector, bioenergy innovation seems to be characterized by a pattern of user-producer interaction where small scale producers, in close cooperation with their customers, have provided the basic options for the development of the sector. It differs on the other hand it can be differentiated however by means of its decentralized system of producers which seems to be maintained in spite of the emergence of still more technologically demanding systems. The key question then is to what extent this pattern will continue, and what will be the likely regional consequences of an increased focus on system and knowledge export to, for instance, the developing world, where bioenergy and abundant excessive biomass may provide a cheap, important and abundant resource in the creation of sustainable energy systems development.

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Annex 1: Estimation of bioenergy potential

Statistical data basis

Hans-Peter Piorr, Sybille Brozio, Mirella Zeidler & Ivonne Berndt

Note: More detail on the proceeding and data analysis for the bioenergy potential estimations is provided in the document entitled, "Estimation of bioenergy potential on the basis of agricultural statistics and spatial distribution for the Nordic countries" which is available from the University of Applied Sciences in Eberswalde.

The estimations of bioenergy potential presented in this study are based on the use of publically available data on NUTS-0 and NUTS-3 levels obtained from FAOSTAT, EUROSTAT and the respective national statistical offices as presented in table 1. In order to properly define and select categories the statistical offices in the four countries were contacted (Ole Olsen and Torben Pedersen, Statistics Denmark; Anne Snellingen Bye, Statistics Norway; Rolf Selander, Statistics Sweden; Erja Mikkola, Ministry of Agriculture and Forestry (Tike) / Matilda).

The scrutinized crop categories were wheat, barley, rye, triticale, rapeseed, maize, sunflower, fallow land and livestock (cattle, pigs). The collected data was edited for the preparation of the GIS maps and the calculations presented in this report.

Table 1. National and regional data sources

Name	Country	NUTS-level	Source
National statistics			
FAOSTAT		0	http://faostat.fao.org/
EUROSTAT		2	http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136162,0_45572073&_dad=portal&_schema=PORTAL
Regional Statistics			
Statistics Denmark	Denmark	3	http://www.statbank.dk/statbank5a/default.asp?w=1280
Statistics Norway	Norway	3	http://www.ssb.no/jordbruk_en/
Statistics Sweden	Sweden	3	http://www.ssd.scb.se/databaser/makro/start.asp?lang=2
Ministry of Agriculture and Forestry (Tike) / Matilda	Finland	3	http://www.matilda.fi/servlet/page?_pageid=115,193&_dad=portal30&_schema=PORTAL30

Spatial data basis

The preparation of the GIS maps was undertaken on the basis of geographical and demographic data obtained from the four main sources presented in table 2. In addition some adjustments were needed in order to harmonize the agricultural with the geographical and demographic data.

Table 2. Geographical and demographic data sources

Subject	Name	Source
Land cover	Corine	http://dataservice.eea.europa.eu/dataservice/available.asp?type=search&search=corine+2000
Land use & Land cover	PELCOM	http://www.geo-informatie.nl/projects/pelcom/public/index.htm
NUTS-level regions	ESRI	Europe NUTS Demographics ArcGIS ESRI Data & Maps ©ESRI 2006
Precipitation	WorldClim	http://www.worldclim.org

Results: "Status quo"

Yield trends of agricultural crops in the Nordic countries

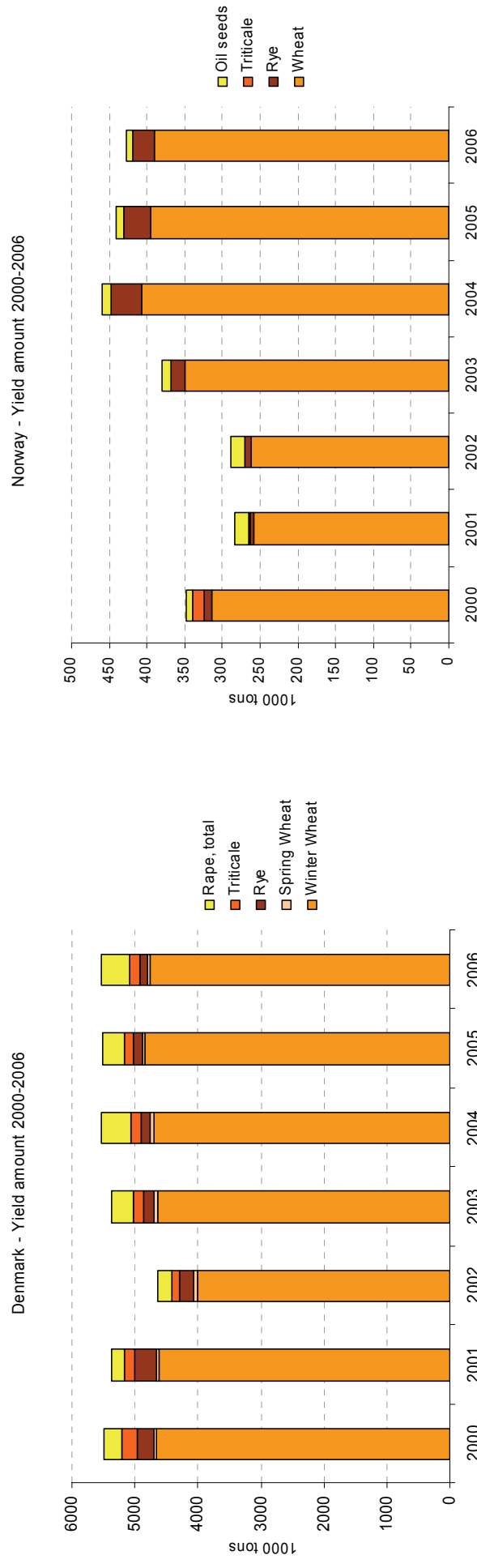


Figure 1. Denmark - Yield amount 2000-2006; Source: Statistics Denmark

Table 3. Denmark – Yield amount in 1000 tons

Crop	2000	2001	2002	2003	2004	2005	2006
Winter Wheat	4650.8	4624.5	4013	4646.5	4696.5	4834	4768.7
Spring Wheat	42.6	39.4	46.2	54.9	62	53.2	32.9
Rye	262.5	332.4	229.5	168.5	146.2	132	130
Triticale	244	169	121.6	145.8	159.5	151.6	156.3
Rape, total ⁴	291.7	211.6	217.8	354.2	468.1	342.2	434.7

⁴ Rape, total is the sum of winter and spring rape.

Figure 2. Norway - Yield amount 2000-2006; Source: Statistics Norway

Table 4. Norway – Yield amount in 1000 tons

Crop	2000	2001	2002	2003	2004	2005	2006
Wheat	313.4	259.1	261.5	349.5	406.8	395.4	389.7
Rye*	10.6	4.9	8.2	19.4	40.6	34.8	28.4
Triticale	15.0	1.0	0.9	0	0	0	0
Oil Seeds	9.1	19.3	17.8	11.3	12.3	11.2	9.5

* Winter Rye

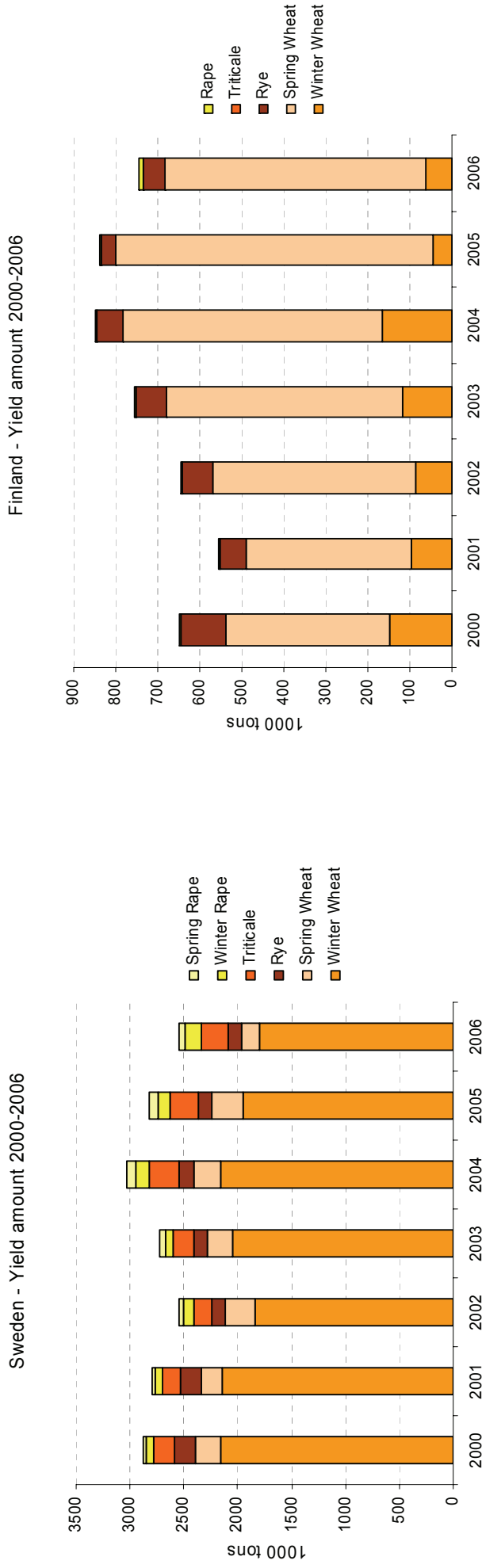


Figure 3. Sweden - Yield amount 2000-2006; Source: Statistics Sweden

Figure 4. Finland - Yield amount 2000-2006; Source: Eurostat

Table 5. Sweden - Yield amount in 1000 tons

Crop	2000	2001	2002	2003	2004	2005	2006
Winter Wheat	2154.5	2137.7	1844.6	2049.2	2159.4	1957	1795.2
Spring Wheat	245.4	207.1	268	233.5	252.9	289.8	172.2
Rye	187.3	180	128.2	118.1	133.4	112.3	115.4
Triticale	187.3	174.5	169.4	205.1	270.2	271.5	255.9
Winter Rape	80.9	61.7	90.9	66.7	128.6	113.1	151.7
Spring Rape	23.1	26.9	46.3	51.1	82.3	72.7	59.7

Table 6. Finland - Yield amount in 1000 tons

Crop	2000	2001	2002	2003	2004	2005	2006
Winter Wheat	147.5	97.1	85.0	117.7	165.0	44.8	62.7
Spring Wheat	390.8	391.8	484.0	561.3	617.3	756.4	621.4
Rye	108.2	64.1	73.0	72.8	62.4	32.4	50.9
Triticale	0	1.0	0.4	1.5	0	0	0
Rape	2.5	2.1	2.0	2.0	3.2	5.7	11.2

Acreage trends of agricultural crops in the Nordic countries

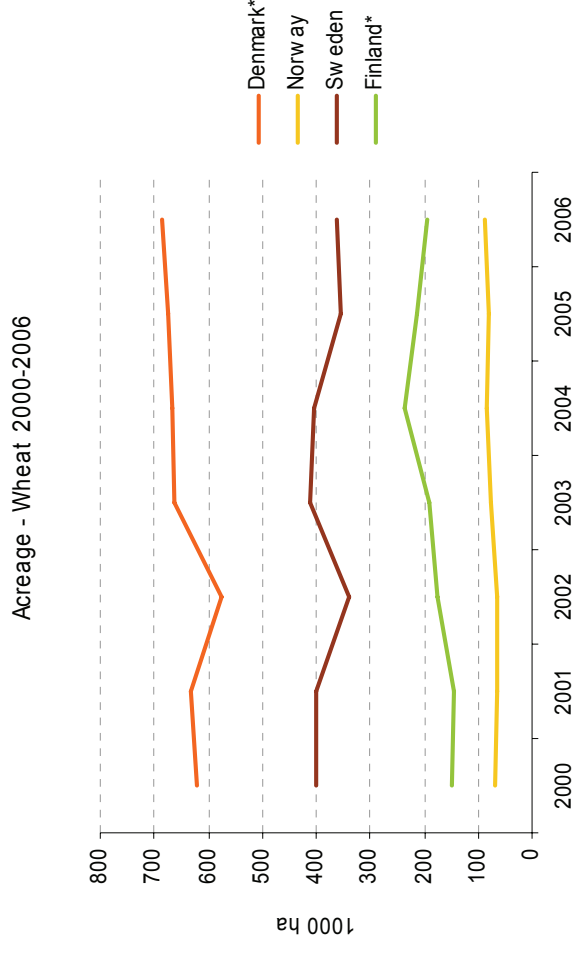


Figure 5. Acreage – Wheat 2000-2006; Source: Statistics Sweden, Statistics Norway, Eurostat*

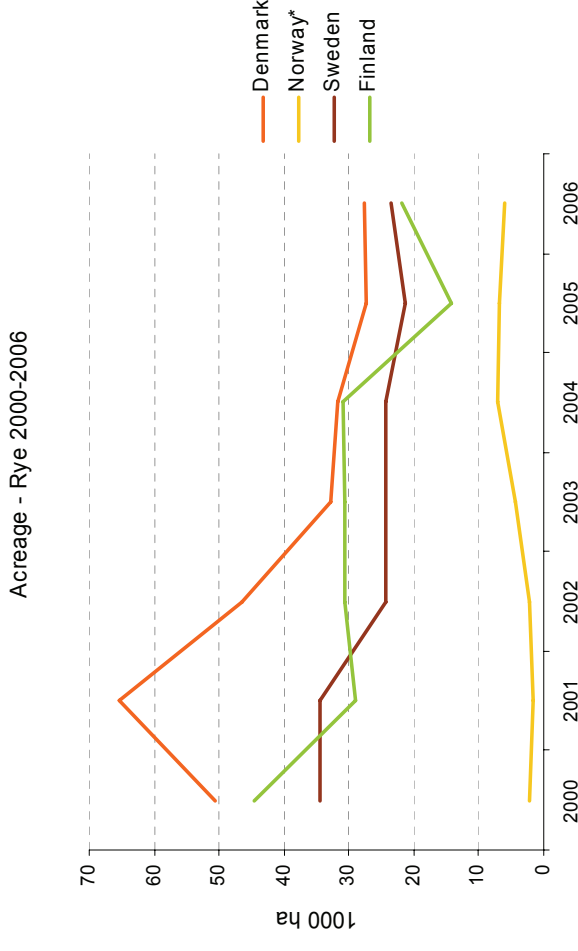


Figure 6. Acreage – Rye 2000-2006; Source: Statistics Denmark, Statistics Sweden, Tike/Matilda, Eurostat*

Table 7. Acreage – Wheat in ha

Country	2000	2001	2002	2003	2004	2005	2006
Denmark*	619200	634000	576600	664300	666400	675600	686300
Norway	68090	63600	63800	75760	85340	80820	85720
Sweden	401565	399165	339599	411348	403408	354755	360936
Finland*	149300	144600	174200	191600	235500	215100	192400

Table 8. Acreage – Rye in ha

Country	2000	2001	2002	2003	2004	2005	2006
Denmark	50500	65300	46400	32900	31600	27300	27500
Norway*	2300	1700	2200	4500	7100	6900	6000
Sweden	34533	34403	24395	24366	24402	21386	23454
Finland	44600	29000	30500	30700	31000	14300	21900

Annex 1: Estimation of bioenergy potential

Acreage - Triticale 2000-2006

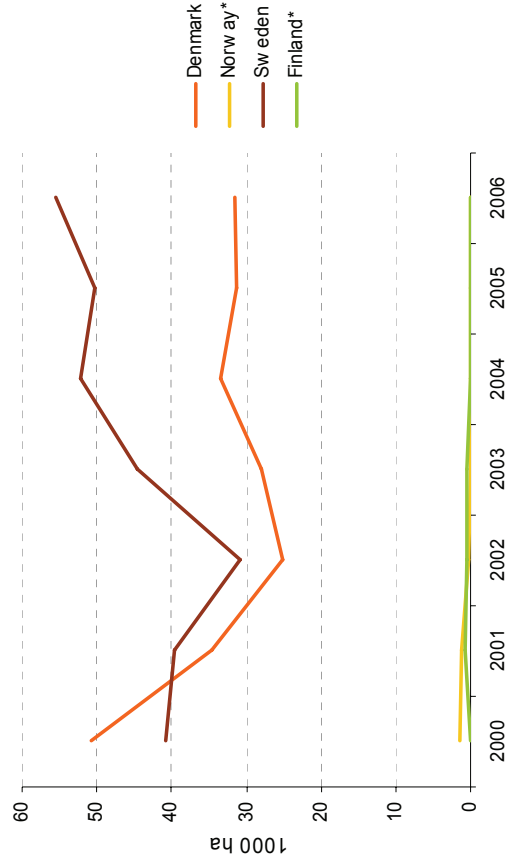


Figure 7. Acreage – Triticale 2000-2006; Source: Statistics Denmark, Statistics Sweden, Eurostat*

Table 9. Acreage – Triticale in ha

Country	2000	2001	2002	2003	2004	2005	2006
Denmark	50700	34700	25100	28000	33500	31300	31600
Norway*	1500	1100	200	0	0	0	0
Sweden	40728	39642	30809	44661	52195	50292	55406
Finland*	0	600	400	500	0	0	0

Acreage - Rape 2000-2006

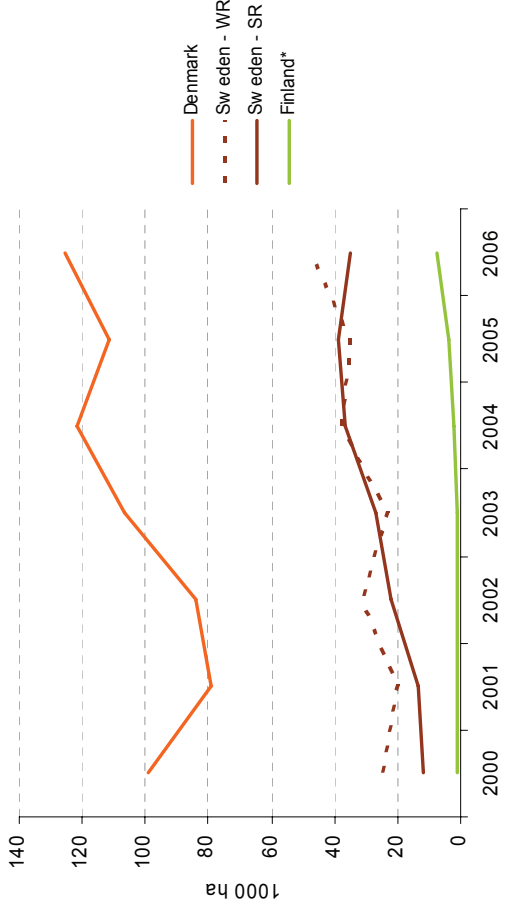


Figure 8. Acreage – Rape 2000-2006; Source: Statistics Denmark, Statistics Sweden, Eurostat*

Table 10. Acreage – Rape in ha

Country	2000	2001	2002	2003	2004	2005	2006
Denmark	99300	78900	84100	106600	121800	111700	125400
Sweden							
Winter							
Rape							
WR	24870	19900	31219	23352	37496	34997	47638
Sweden							
Spring							
Rape - SR	12112	13591	21943	26670	36715	38578	35148
Finland*	1200	1100	1300	1200	2300	3900	7300

Yield productivity of agricultural crops in the Nordic countries

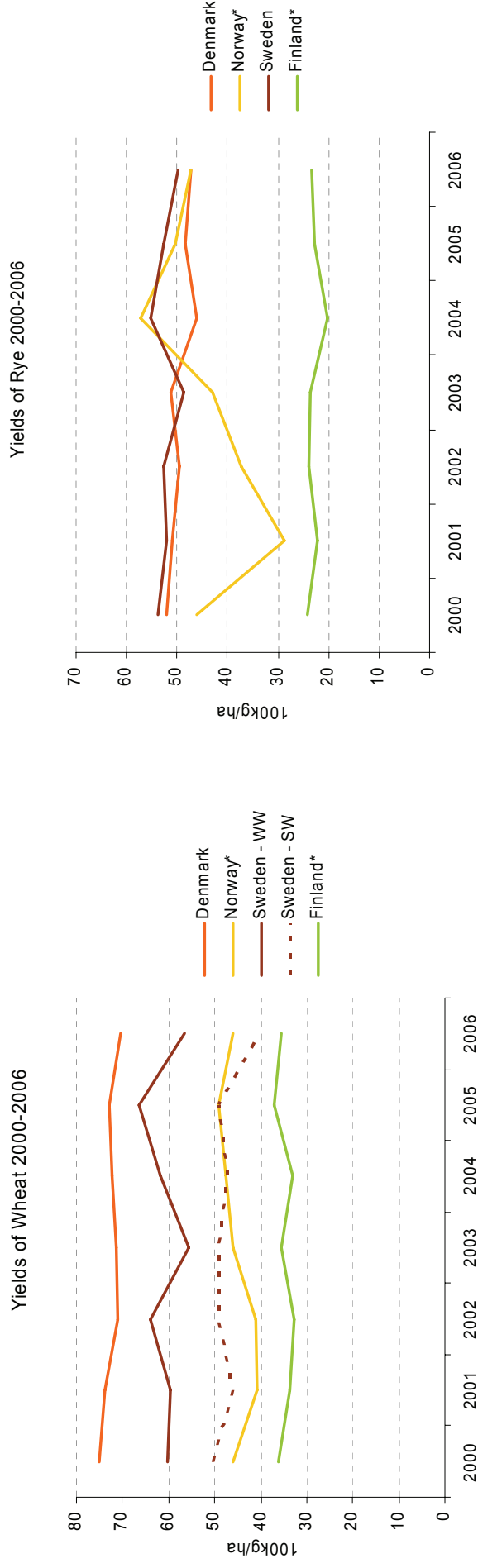


Figure 9. Yields of Wheat 2000-2006; Sources: Statistics Denmark, Statistics Sweden, Eurostat*

Table 11. Yields of Wheat in 100kg/ha

Country	2000	2001	2002	2003	2004	2005	2006
Denmark	75.1	73.9	70.9	71.3	72.2	72.8	70.4
Norway*	46.1	40.7	41	46.1	47.7	49.1	46
Sweden							
Winter							
Wheat							
WW	60.3	59.7	63.9	55.6	61.8	66.3	56.6
Sweden							
Spring							
Wheat - SW	50.4	46.0	49.0	49.0	47.4	49.1	40.3
Finland*	36.1	33.8	32.7	35.4	33.2	37.2	35.6

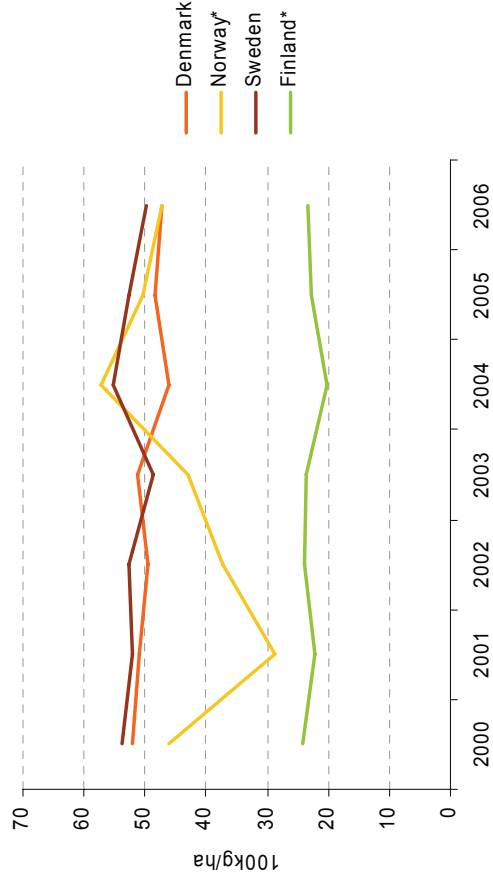


Figure 10. Yields of Rye 2000-2006; Source: Statistics Denmark, Statistics Sweden, Eurostat*

Table 12. Yields of Rye in 100kg/ha

Country	2000	2001	2002	2003	2004	2005	2006
Denmark	52	50.9	49.4	51.2	46.2	48.3	47.3
Norway*	46.1	28.8	37.3	43.1	57.2	50.4	47.3
Sweden	53.7	52.1	52.7	48.6	55.1	52.7	49.9
Finland*	24.3	22.1	23.9	23.7	20.1	22.7	23.2

Yields of Triticale 2000-2006

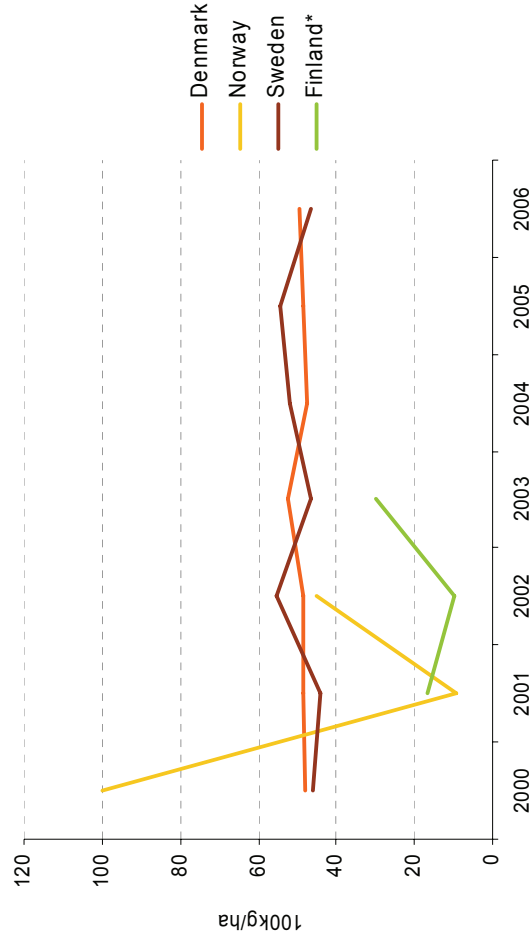


Figure 11. Yields of Triticale 2000-2006; Source: Statistics Denmark, Statistics Norway, Statistics Sweden, Eurostat*

Table 13. Yields of Triticale in 100kg/ ha

Country	2000	2001	2002	2003	2004	2005	2006
Denmark	48.1	48.6	48.4	52.2	47.6	48.5	49.5
Norway	100	9.1	45				
Sweden	45.5	43.6	54.8	45.8	52	54.2	46.7
Finland*		16.7	10	30			

Yields of Rape 2000-2006

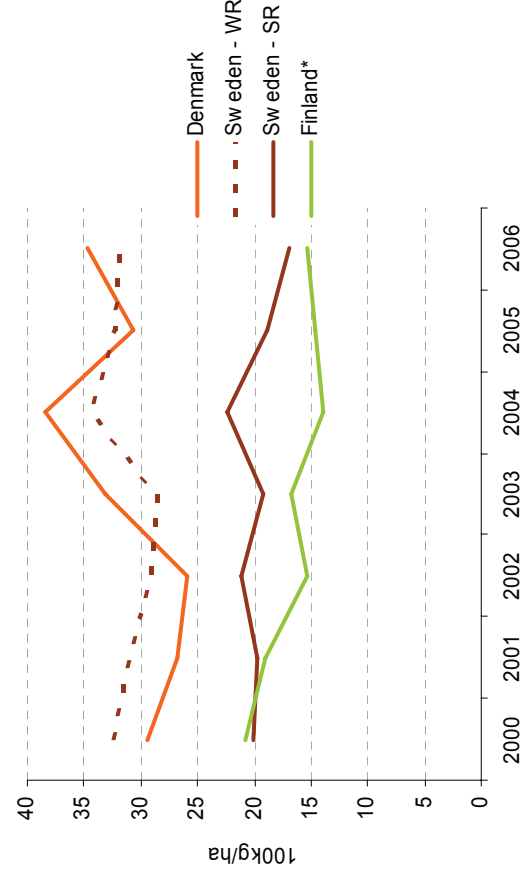


Figure 12. Yields of Rape 2000-2006; Source: Statistics Denmark, Statistics Norway, Statistics Sweden, Eurostat*

Table 14. Yields of Rape in 100kg/ ha

Country	2000	2001	2002	2003	2004	2005	2006
Denmark	29.4	26.8	25.9	33.2	38.4	30.6	34.7
Sweden							
Winter							
Rape - WR	32.5	31	29.1	28.6	34.3	32.3	31.9
Sweden							
Spring							
Rape - SR	20.1	19.8	21.1	19.2	22.4	18.9	17
Finland*	20.8	19.1	15.4	16.7	13.9	14.6	15.3

Bioenergy amount in the Nordic countries

Scenario: "Status quo"

Table 15. Biodiesel based on rape (Status quo)

Country	Scenario I "Status quo"	Annual biodiesel amount in tons	Energy content in PJ	Equivalent of biodiesel in tons
Denmark	Average ⁵	100251	3.66	85008
Sweden	Average	44326	1.62	37586
Finland	Average	1313	0.05	1113

Table 16. Bioethanol based on grain (Status quo)

Country	Grain in 1.000 tons	Use of grain	Annual bioethanol amount in 1.000 tons	Energy content in PJ	Equivalent of gasoline in 1.000 tons
Denmark	7569	100%	2527	66.5	1559
	3785	50%	1263	33.3	780
	1514	20%	505	13.3	312
	757	10%	253	6.7	156
	378	5%	126	3.3	78
Norway	824	100%	271	7.1	167
	412	50%	135	3.6	84
	165	20%	54	1.4	33
	82	10%	27	0.7	17
	41	5%	14	0.4	8
Sweden	4091	100%	1367	36.0	844
	2046	50%	684	18.0	422
	818	20%	273	7.2	169
	409	10%	137	3.6	84
	205	5%	68	1.8	42
Finland	2214	100%	721	19.0	445
	1107	50%	360	9.5	222
	443	20%	144	3.8	89
	221	10%	72	1.9	44
	111	5%	36	0.9	22

⁵ average of statistical amounts (2000 – 2006) of rape

Annex 1: Estimation of bioenergy potential

Table 17. Bioethanol based on grain straw (Status quo)

Country	Grain straw in 1.000 tons	Use of grain straw	Annual bioethanol amount in 1.000 tons	Energy content in PJ	Equivalent of gasoline in 1.000 tons
Denmark	7.041	100%	1196	31.5	738.0
		50%	598	15.7	369.0
		20%	239	6.3	147.6
		10%	120	3.1	73.8
		5%	60	1.6	36.9
Norway	767	100%	130	3.4	80.4
		50%	65	1.7	40.2
		20%	26	0.7	16.1
		10%	13	0.3	8.0
		5%	7	0.2	4.0
Sweden	3.806	100%	646	17.0	398.9
		50%	323	8.5	199.4
		20%	129	3.4	79.8
		10%	65	1.7	39.9
		5%	32	0.9	19.9
Finland	2.059	100%	350	9.2	215.9
		50%	175	4.6	107.9
		20%	70	1.8	43.2
		10%	35	0.9	21.6
		5%	17	0.5	10.8

Table 18. Biogas based on liquid manure and grain straw as co-ferment (Status quo)

Country	Input material	Use of input material	Energy content in mill. kWh _{el}	Biogas plants (7.500 h*a ⁻¹ and 500kW _{el})	Energy content in PJ
Denmark	manure	100%	3179	848	11.44
	grain straw	50%	1683	449	6.06
		20%	673	180	2.42
		10%	337	90	1.21
		5%	168	45	0.61
Norway	manure	100%	932	249	3.36
	grain straw	50%	183	49	0.66
		20%	73	20	0.26
		10%	37	10	0.13
		5%	18	5	0.07
Sweden	manure	100%	1685	449	6.06
	grain straw	50%	910	243	3.27
		20%	364	97	1.31
		10%	182	49	0.65
		5%	91	24	0.33
Finland	manure	100%	1010	269	3.63
	grain straw	50%	492	131	1.77
		20%	197	53	0.71
		10%	98	26	0.35
		5%	49	13	0.18

Regional availability of bioethanol, biodiesel and biogas based.

Scenario: "Status quo"

Table 19. Bioethanol based on grain: Regional Availability = 20 % in Denmark and Norway (Status quo)

Country	NUTS 3 level	Grain in tons (Availability=20%)	Annual bioethanol amount in tons
Denmark	DK002_003_004	89140	28394
	DK005	158629	50528
	DK006	212023	67535
	DK007	30637	9759
	DK008	185283	59018
	DK009	168949	53815
	DK00A	77423	24661
	DK00B	133137	42408
	DK00C	162983	51915
	DK00D	211891	67493
	DK00E	159969	50954
	DK00F	226286	72078
Norway	NO021	46602	14844
	NO022	17465	5563
	NO031	51223	16316
	NO032	19194	6114
	NO033	24494	7802
	NO034	6332	2017
	NO041	663	211
	NO042	653	208
	NO043	3524	1122
	NO051	18	6
	NO052	27	9
	NO053	1047	334
	NO061	11520	3669
	NO062	20494	6528
	NO071	113	36
	NO072	0	0
	NO073	0	0
	NO11_12	50462	16074

Annex 1: Estimation of bioenergy potential

Table 20. Bioethanol based on grain: Regional Availability = 20 % in Sweden and Finland (Status quo)

Country	NUTS 3 level	Grain in tons (Availability=20%)	Annual bioethanol amount in tons
Sweden	SE010	29815	9497
	SE021	73363	23368
	SE022	51523	16412
	SE023	98613	31411
	SE024	46930	14949
	SE025	57397	18282
	SE041	9200	2930
	SE044	273257	87040
	SE061	22499	7166
	SE062	12250	3902
	SE063	9223	2938
	SE071	2053	654
	SE072	1180	376
	SE081	5602	1784
	SE082	2293	730
	SE091	11090	3532
	SE092	6003	1912
	SE093	33813	10770
	SE094	27403	8729
	SE0A1	46710	14878
	SE0A2	191010	60842
Finland	FI131	14265	4544
	FI132	26025	8290
	FI133	15283	4868
	FI134	3120	994
	FI181_182	76770	24453
	FI183	144830	46132
	FI184_185	78355	24958
	FI186_187	46625	14851
	FI191	66370	21141
	FI192	47030	14980
	FI193	19285	6143
	FI194	82815	26379
	FI195_1A1	67625	21540
	FI1A2	55045	17533
	FI1A3	1245	397
	FI200	3340	1064

Table 21. Bioethanol based on grain straw: Regional Availability = 20 % in Denmark and Norway (Status quo)

Country	NUTS 3 level	Grain straw in tons (Availability=20%)	Annual bioethanol amount in tons
Denmark	DK002_003_004	71312	14084
	DK005	126903	25063
	DK006	169618	33500
	DK007	24510	4841
	DK008	148226	29275
	DK009	135159	26694
	DK00A	61938	12233
	DK00B	106510	21036
	DK00C	130386	25751
	DK00D	169513	33479
	DK00E	127975	25275
	DK00F	181029	35753
Norway	NO021	37282	7363
	NO022	13972	2759
	NO031	40978	8093
	NO032	15355	3033
	NO033	19595	3870
	NO034	5066	1000
	NO041	531	105
	NO042	522	103
	NO043	2819	557
	NO051	14	3
	NO052	22	4
	NO053	838	165
	NO061	9216	1820
	NO062	16395	3238
	NO071	90	18
	NO072	0	0
	NO073	0	0
	NO11_12	40370	7973

Annex 1: Estimation of bioenergy potential

Table 22. Bioethanol based on grain straw: Regional Availability = 20 % in Sweden and Finland (Status quo)

Country	NUTS 3 level	Grain straw in tons (Availability=20%)	Annual bioethanol amount in tons
Sweden	SE010	23852	4711
	SE021	58691	11591
	SE022	41219	8141
	SE023	78891	15581
	SE024	37544	7415
	SE025	45917	9069
	SE041	7360	1454
	SE044	218605	43175
	SE061	17999	3555
	SE062	9800	1936
	SE063	7379	1457
	SE071	1643	324
	SE072	944	186
	SE081	4482	885
	SE082	1835	362
	SE091	8872	1752
	SE092	4803	949
	SE093	27050	5342
	SE094	21922	4330
	SE0A1	37368	7380
	SE0A2	152808	30180
Finland	FI131	11412	2254
	FI132	20820	4112
	FI133	12227	2415
	FI134	2496	493
	FI181_182	61416	12130
	FI183	115864	22883
	FI184_185	62684	12380
	FI186_187	37300	7367
	FI191	53096	10486
	FI192	37624	7431
	FI193	15428	3047
	FI194	66252	13085
	FI195_1A1	54100	10685
	FI1A2	44036	8697
	FI1A3	996	197
	FI200	2672	528

Table 23. Annual amount of biodiesel in Sweden and Finland (Status quo)

Country	NUTS 3 level	Annual biodiesel amount in tons	
		Average	Maximum
Sweden	SE010	1853	2268
	SE021	3402	4694
	SE022	2326	3402
	SE023	6326	8789
	SE024	1517	2174
	SE025	1969	3245
	SE041	158	158
	SE044	19268	28256
	SE061	441	599
	SE062	0	0
	SE063	0	0
	SE071	0	0
	SE072	0	0
	SE081	0	0
	SE082	0	0
	SE091	0	0
	SE092	0	0
	SE093	1367	1764
	SE094	1481	1764
	SE0A1	1427	2111
	SE0A2	9266	14049
Finland	FI131	0	0
	FI132	0	0
	FI133	0	0
	FI134	0	0
	FI181_182	921	1859
	FI183	717	1418
	FI184_185	24	63
	FI186_187	47	63
	FI191	0	0
	FI192	21	63
	FI193	0	0
	FI194	0	0
	FI195_1A1	0	0
	FI1A2	0	0
	FI1A3	0	0
	FI200	0	0

Table 24. Annual amount of biodiesel in Denmark (Status quo)

Country	NUTS 3 level	Annual biodiesel amount in tons	
		Average	Maximum
Denmark	DK002_003_004	7479	10521
	DK005	10449	16002
	DK006	6701	10553
	DK007	1620	2300
	DK008	10809	14522
	DK009	11214	16758
	DK00A	2403	3119
	DK00B	7740	11183
	DK00C	5733	8757
	DK00D	15881	21011
	DK00E	9752	13073
	DK00F	14630	21641

Table 25. Biogas based on liquid manure (100%) and grain straw as co-ferment (20%) in Denmark and Norway (Status quo)

Country	NUTS 3 level	Annual biogas amount in MW _{el}		500 kW _{el} Biogas plants
		Livestock (100%)	Grain straw (20%)	(7500 working hours per year)
Denmark	DK002_003_004	62343	34087	26
	DK005	151983	60660	57
	DK006	133062	81078	57
	DK007	47542	11716	16
	DK008	280945	70852	94
	DK009	456894	64606	139
	DK00A	315335	29607	92
	DK00B	266947	50912	85
	DK00C	511253	62325	153
	DK00D	337495	81027	112
	DK00E	465470	61172	140
	DK00F	606137	86532	185
Norway	NO021	77547	17821	25
	NO022	131915	6679	37
	NO032	29373	7340	10
	NO033	22153	9366	8
	NO034	16128	2421	5
	NO041	11024	254	3
	NO042	28342	250	8
	NO043	202301	1348	54
	NO051	56465	7	15
	NO052	62185	10	17
	NO053	104937	400	28
	NO061	110056	4405	31
	NO062	134524	7837	38
	NO071	80755	43	22
	NO072	21458	0	6
	NO073	9337	0	2
	NO11_12_31	62486	38884	27

Annex 1: Estimation of bioenergy potential

Table 26. Biogas based on liquid manure (100%) and grain straw as co-ferment (20%) in Sweden and Finland (*Status quo*)

Country	NUTS 3 level	Annual biogas amount in MW _{el}		500 kW _{el} Biogas plants
		Livestock (100%)	Grain straw (20%)	(7500 working hours per year)
Sweden	SE010	31373	11401	11
	SE021	61391	28054	24
	SE022	70605	19703	24
	SE023	151096	37710	50
	SE024	55237	17946	20
	SE025	38918	21948	16
	SE041	42846	3518	12
	SE044	343283	104493	119
	SE061	68636	8603	21
	SE062	44875	4684	13
	SE063	50710	3527	14
	SE071	41421	785	11
	SE072	40167	451	11
	SE081	54256	2142	15
	SE082	26519	877	7
	SE091	157858	4241	43
	SE092	85134	2296	23
	SE093	182575	12930	52
	SE094	80713	10479	24
	SE0A1	139933	17862	42
	SE0A2	362167	73042	116
Finland	FI131	25459	5455	8
	FI132	52273	9952	17
	FI133	27028	5844	9
	FI134	10368	1193	3
	FI181_182	20109	29357	13
	FI183_FI200	101681	56660	42
	FI184_185	44034	29963	20
	FI186_187	30251	17829	13
	FI191	46752	25380	19
	FI192	31853	17984	13
	FI193	28084	7375	9
	FI194	87256	31668	32
	FI195_1A1	84212	25860	29
	FI1A2	61832	21049	22
	FI1A3	13754	476	4

Annex 2: Calculation basis for maps in figures 12-15

FIGURE 12:

- 12A – Man years for wheat production with 20% for bioenergy conversion. Area size of 20 ha and a medium yield level has been assumed = 8.97 hours/hectare.
- 12B – Man years for barley production with 20% for bioenergy conversion. Area size of 20 ha and a medium yield level has been assumed = 7.62 hours/hectare.
- 12C – Man years for triticale production with 20% for bioenergy conversion. Area size of 20 ha and a medium yield level has been assumed = 7.78 hours/hectare.
- 12D – Man years for rape production. Area size of 20 ha and a medium yield level has been assumed = 4.67 hours/hectare.

FIGURE 13:

- 13A – Man years for bioethanol production from grain – 20% for bioenergy, including labour activities of 100 Man years direct and 40 Man years indirect per TWh.
- 13B – Man years for bioethanol production from straw – 20% for bioenergy, including labour activities of 100 Man years direct and 40 Man years indirect per TWh.
- 13C – Man years for biodiesel – average productivity, including labour activities of 140 Man years direct and 142 Man years indirect per TWh.
- 13D – Man years for biodiesel – maximum productivity, including labour activities of 140 Man years direct and 142 Man years indirect per TWh.

FIGURE 14:

- 14A – Man-years for biogas production, based on 100% livestock manure, 20% grain straw, and production by means of 500kW biogas plants with 7500 working hours/year. Production includes labour activities of 200 Man years direct and 101 Man years indirect per TWh.
- 14B – Sum of man-years for all types of conversion and transformation of biomass to bioenergy.
- 14C – Regional absolute and relative labour market importance by type of bioenergy.

FIGURE 15:

- 15A – Man years for production of willow on an average field size (20 ha), with 3.95 hours/hectare in growing years, and 8.18 hours in harvest and storage years. With a 5 year production cycle this is leading to an average of 4.80 hours/hectare.
- 15B – Man years for production of willow on a large field size (80 ha and above), with 1.82 hours/hectare in growing years, and 7.65 hours/hectare in harvest and storage years. With a 5 year production cycle this is leading to an average of 2.97 hours/hectare.
- 15C – Man years for willow on fallow land, on an average field size (20 ha), with 3.95 hours/hectare in growing years, and 8.18 hours in harvest and storage years. With a 5 year production cycle this is leading to an average of 4.80 hours/hectare.
- 15D – Man years for willow on fallow land, on a large field size (80 ha and above), with 1.82 hours/hectare in growing years, and 7.65 hours/hectare in harvest and storage years. With a 5 year production cycle this is leading to an average of 2.97 hours/hectare.