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EMBASSY REPORT
NORDIC COUNTRIES

Bioenergies in the Nordic countries
Situation and Outlook in 2009

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Abstract

The Nordic countries have set very ambitious environmental targets in the energy sector compared with many other countries including other European member states. It is to a large extent due to the development of bioenergy use to reduce the fossil fuel dependency after the oil crisis in the 70s.

The word "bioenergies" includes a broad variety of biomass uses: from simple and traditional firewood to modern and high-tech process like fluidized bed, gasification or fermentation. In both cases, the Nordic countries, especially Sweden and Finland which have huge forest resources, are pioneers compared with others European countries. The biomass, mainly waste and by-products from forests, is collected and used as a valuable product for energy in a very efficient way in the Nordic countries. Combined heat and power systems, delivering heat to the district heating or to industries and producing electricity when the need of heat is lower, is one of the main strength of this bioenergy sector. The first part of the present report describes the actual use of biomass converted into energy. It also presents the incentives decided by the governments such as green taxes, like carbon tax introduced in the Nordic countries in the early 90s.

Beyond the environment and energy issues presented in the first part, the second part of the report is focussed on research activity in biofuels. The Nordic approach to first generation biofuels is presented before considering ongoing research to develop the second and third generations of biofuels which won't compete with food agriculture. The laboratories and industries conducting research for the biochemical or thermo chemical conversion paths as well as the projects for pilot plants are described and listed in an appendix. Although several new very innovative approaches have been noticed, the most promising improvement underway in the Nordic countries are not breakthrough technologies towards second generation biofuels but a better organisation between sectors such as forest industry, pulp and paper industry, oil or chemical companies in dynamic clusters. The current economic crisis affects the forest and pulp and paper industries and forces them to look for new market opportunities which accelerate the development of that new approach. These actors have indeed strong advantages when it comes to collect and handle huge volumes of biomass thanks to their experience of sustainable and environmentally friendly forest management. In the Nordic Countries, the potential bioenergy share in the energy mix, currently around 15%, is assessed to be about 25% which constitutes good possibilities for further progress.

Just before the coming climate conference in Copenhagen to be held in December and during the Swedish presidency of EU, this report gives an overview of the biomass contribution in the energy sector within Nordic countries.

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Summary

Introduction

Biomass, if used sustainably, belongs to the renewable energy sources which do not emit greenhouse gases (GHG) from fossil carbon. Biomass is both traditional, in using wood for heating, and also the subject of intense research to create second and third generation biofuels. These types of fuel will not compete with food resources as is the case with first generation fuels already used in our car tanks. We see that the bioenergy sector is actually very varied and is enriched each year with new opportunities.

Compared to other renewables, biomass has the advantage that it can produce heat and electricity as well as liquid or gaseous fuels. This means this energy source can be used in several consumer sectors like industrial and home heating, electricity generation and finally transport.

As part of its objectives in 2020 and 2050, Europe has issued a number of recommendations to achieve proportions of renewable energy in the energy mix including the famous 20% at the end of 2020. Different countries are looking at their results and refining their positioning and strategy in order to achieve those objectives and benefit from them.

Just before the Copenhagen conference on climate to be held in December 2009 and in the middle of the Swedish Presidency of the European Union (SPEU), this report aims to shed light on the contribution of biomass in the overall energy mix of the Nordic countries. It ranks these Nordic countries in the field of bioenergy compared to other European countries and presents the strategy of these countries to meet the challenges of tomorrow.

I Overview: The situation in the Nordic countries

I.1 Proportion of biomass in renewable energy

Bioenergy is currently the largest source of renewable energy in Europe. Together with hydroelectric power, they account for almost all energy from renewable sources. With waste, they represent 60% of the primary use of renewable energy in the European member countries of the IEA (see Figure 1).

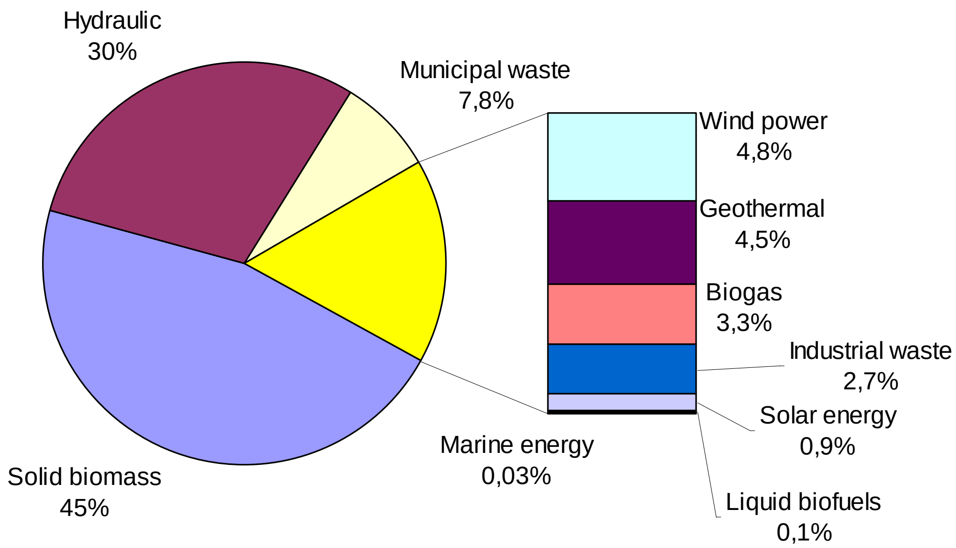

Figure 1: Consumption of primary energy from renewable sources (total of 6 457 PJ) [1]

Apart from Iceland (75%, 60% from geothermal), the renewable energy champions all have, at present, a great hydroelectric potential like Norway, or large forest resources like Sweden or Finland (see Figure 2). In Denmark, often cited as an example for its production of wind power, biomass accounts for 14.2% of energy compared to 3% for wind. At best wind power only accounts for 3% in Denmark and solar power accounts for 1.6% in Cyprus.

[1] Data published on the site of the International Energy Agency IEA for the year 2006 relating to European countries members of the IEA. http://www.iea.org/Textbase/stats/prodresult.asp?PRODUCT=Renewables

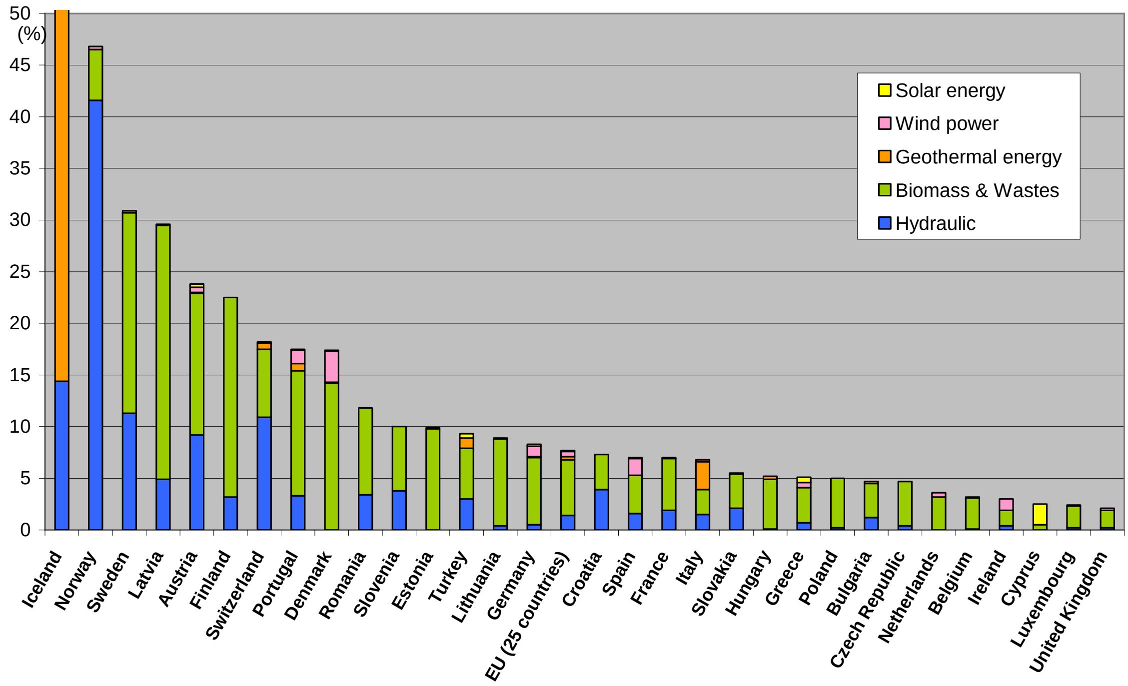

Figure 2: Proportion of renewable energies in gross energy consumption in 2007 [2]

Moreover, unlike other renewable energies such as wind and solar photovoltaics, bioenergy can be used to produce heat for urban heating, electricity, and also for the production of biofuels for transport.

Some countries like Finland and Sweden have a long tradition of bioenergy use in energy production (see Figure 3). This figure continues to evolve and we see that these countries are planning to further develop this practice. Denmark has made a considerable effort over the past ten years and has increased the share of renewables in its overall energy mix from 7% to 14%. Large countries such as France and Germany make less use of this resource. It is noteworthy that Germany, which was clearly below the European average in this area in the 90s, has made a significant effort and moved above the European average in 2007.

Biomass is all plant derived products. This represents a great diversity of products that are used differently as a source of energy.

[2] Eurostat - http://epp.eurostat.ec.europa.eu

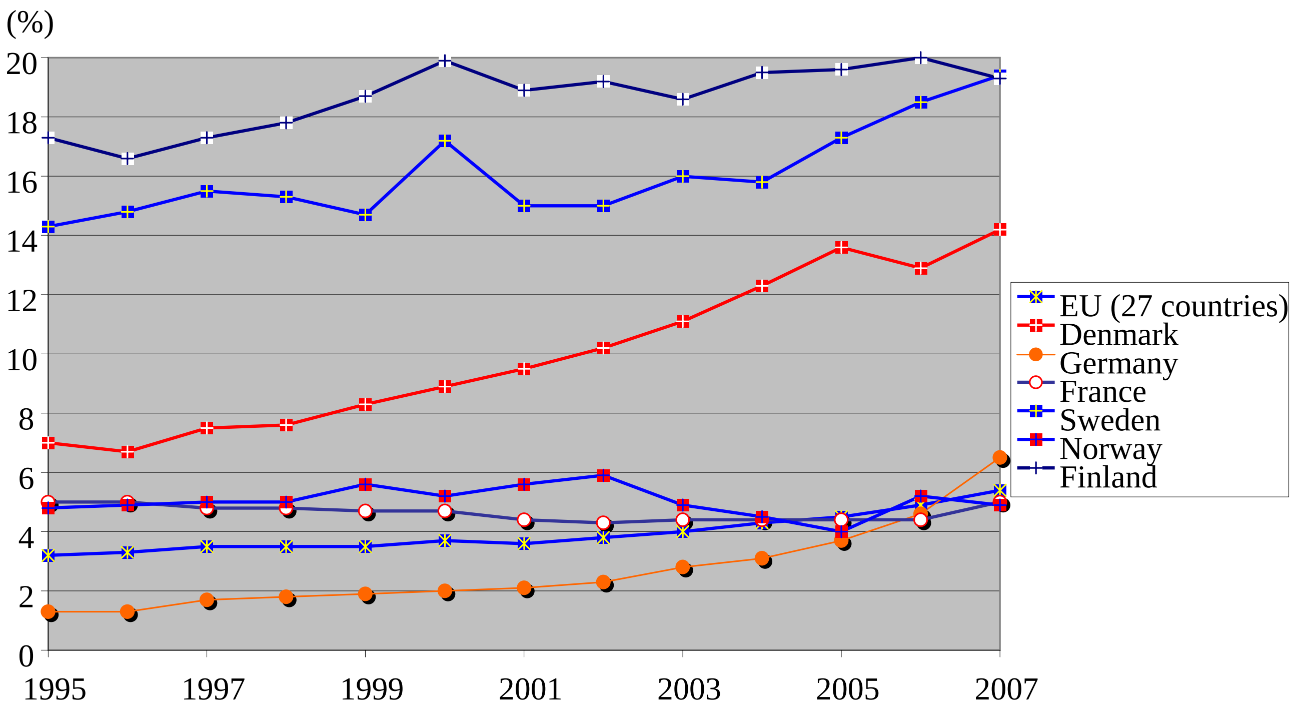

Figure 3: Development of the percentage of biomass and waste in the gross consumption of energy[3]

Among the types of biomass used to produce energy, we can cite a non-exhaustive list:

- industrial and non-industrial forest waste (wood and paper)
- agricultural waste (straw, ...)
- peat
- plantations for energy purposes (rapeseed, plants with short rotation),
- animal waste (manure, ...)
- municipal waste composting
- algae in their environment or cultured.

The forms of energy and possible areas of application are:

- production of hot water for heating
- electricity generally in cogeneration mode associated with a heat network
- production of liquid or gaseous fuels for transport and heating.

The biomass is initially a transformation of solar energy into crop production which in turn can be converted into a useful energy carrier for whatever application is targeted in our societies. For a sustainable use of this plant resource, the annual production must not exceed the annual production of biomass and should be managed in a sustainable manner which imposes constraints. This is a local resource, in close proximity to many European countries, but it can also be imported or exported as other goods, notably food. Reasonable use should not lead to competition with food or intensive use of land reserved for the preservation of biodiversity. These considerations also highlight the need for national and international regulations.

[3] Eurostat for the period 1995-2007 - http://epp.eurostat.ec.europa.eu

The use of bioenergy has greatly expanded and this trend should continue in the context of climate change (cf. II). An estimate of the potential for sustainable bioenergy is much debated (see III.4) it would amount to around 20 to 30%, excluding imports of total energy consumption in the Nordic countries. Appendix A presents some specific aspects for each country and provides a more complete picture.

I.2 The current landscape of bioenergy: the different sectors

I.2.a Wood

Wood is the "traditional" biomass source and still represents a significant proportion of biomass use. In Europe, northern countries hold the advantage in this area, particularly Sweden and Finland, which both have large resources and have learned to use them effectively. These two countries are the ones that use the most wood per capita as fuel for energy production.

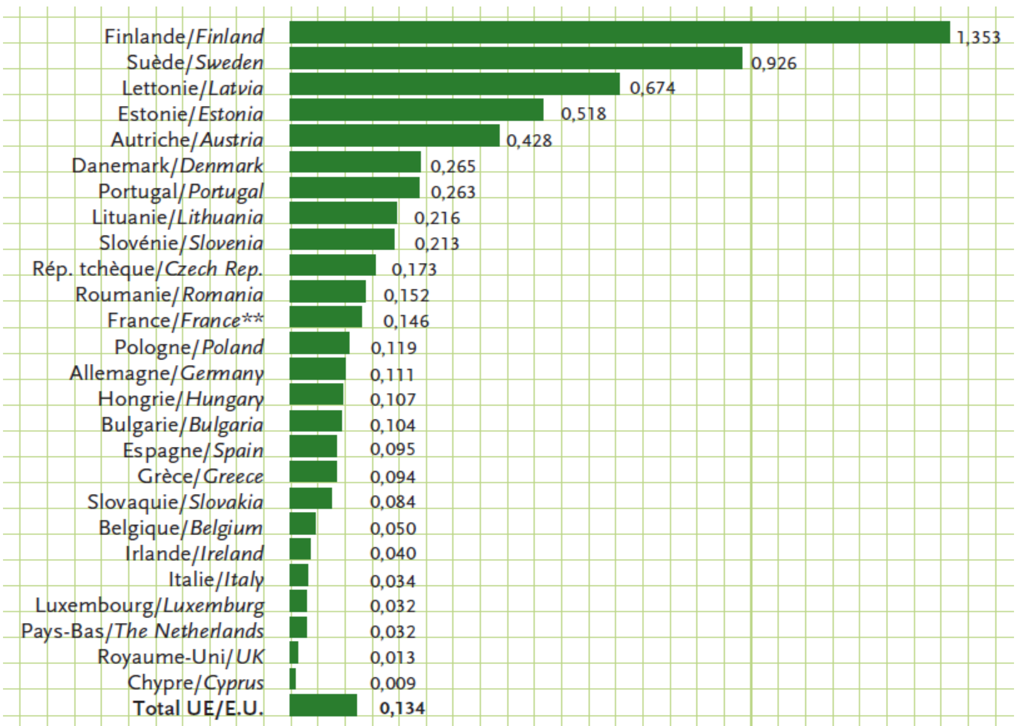

Figure 4: Energy production from wood toe per capita in 2007[4]

The potential of bioenergy in the Nordic countries is mainly forest. A quick observation can be made by considering the wealth of these countries in terms of forests. This approach is somewhat simplistic, since the production of biomass from forests depends on forest type, climate (which penalizes the Nordic countries) but also the way logging is done (in this area the Nordic countries have a distinct advantage today).

[4] The barometer of solid biomass, EurObserv'ER, December 2008 - http://www.energies-renouvelables.org

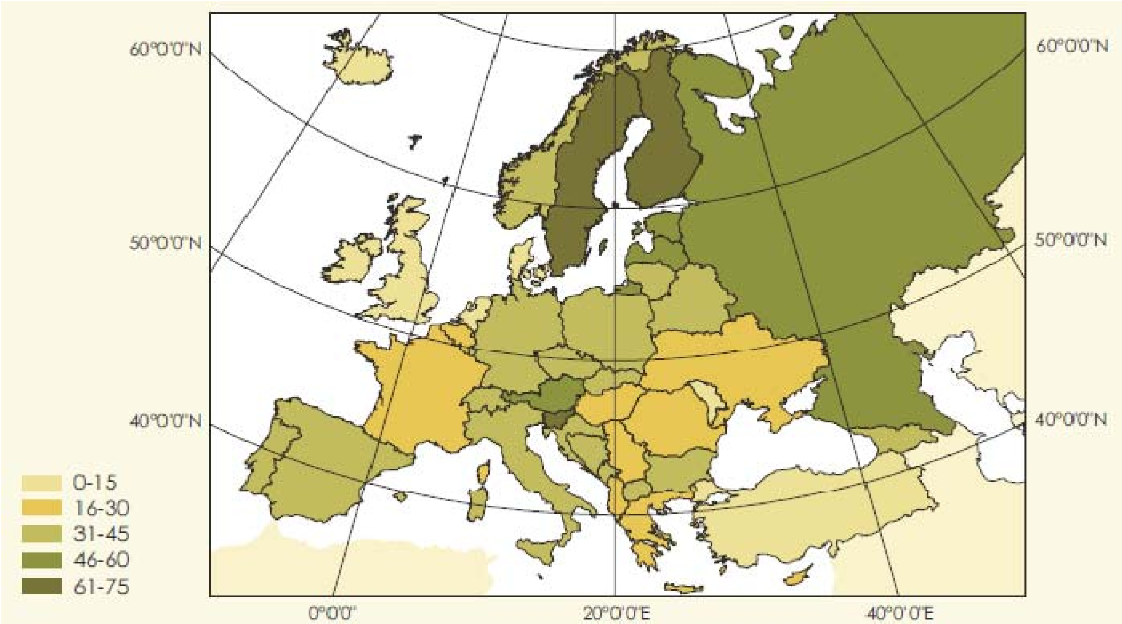

Figure 5: Percentage of forest surface area by country in 2005 [5]

One possible use for wood is logs. The wood is used as a source of heat, but the combustion efficiency, especially in so-called open fireplaces is very low. Fuels derived from wood may be used in other more efficient forms: wafers, pellets or powder. Effectiveness can also result from the use of garbage and waste from the forestry industry: for example bark is quite a bad fuel but it can be used in large boilers. Sawdust collected by the forest industry can also be used to produce pellets. These pellets are used in small automated heating units. Dense and dry, they are burned in boilers, are easy to use and energy efficient. Sweden is ahead in the use of such wood fuel processing. It is the top producer and consumer of pellets in the world (see Figure 6).

DK	*FR*	*FI*	*SW*	*NO*
60.3	*386.6*	*299.3*	*353.4*	*43.8*

Table 1: Consumption in PJ of wood fuel (wood waste included) [6]

[5] Forests of Europe 2007, Ministerial Conference on the Protection of Forests in Europe www.mcpfe.org
[6] 2007figures published by Eurostat - http://epp.eurostat.ec.europa.eu

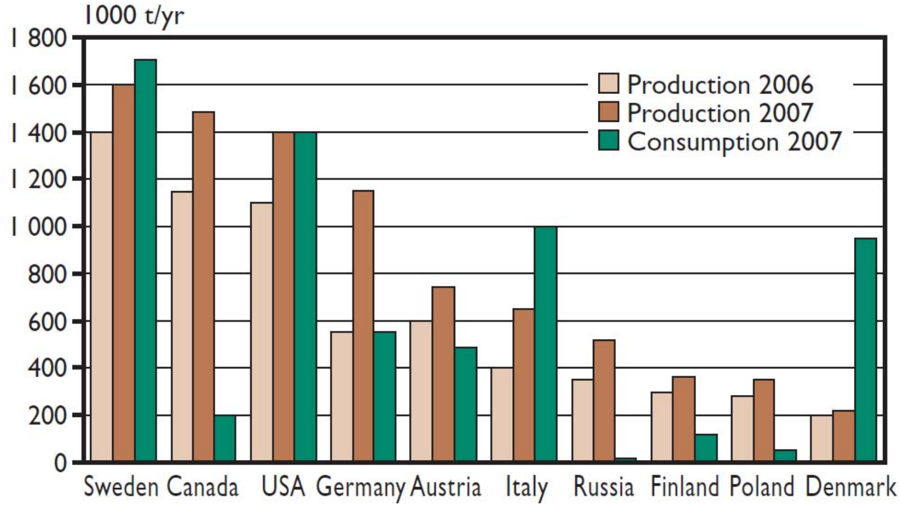

Figure 6: Production and consumption of wood pellets in the world [7]

Figure 7: The Avedøre Plant near Copenhagen uses 300 000 tons of wood pellets per year. Avedøre Unit 2 has fuel efficiency among the highest in the world (94% maximum). Its capacity is 570 MW electric power and 570 MW thermal power. Straw, agricultural residue, is also used (150 000 tonnes per year), a widespread practice in Denmark[8].

In Nordic countries, the development of bioenergy is made effective by a substantial development of combined heat and power (CHP) techniques combining district or industrial heating and power generation. In Denmark, more than 40% of electricity was produced in cogeneration units in 2007 (see Table 2). The CHP units are connected to urban heating networks, which have been constructed since the 1950s in Sweden for example. The networks were then significantly developed after the oil crises between 1975 and 1985. This technique covers about half the energy devoted to heating (10% only in individual homes). Although orders of magnitude (see Figure 8) are comparable between France and the three main Nordic countries (DK, FI, SWE), one should keep in mind the factor of close to ten in terms of population.

[7] Finnish Forest Sector Economic Outlook 2008–2009, Finish forest research institute (Metla)
[8] Current status on biorefineries in Denmark 2007, University of Copenhagen, Department of Life Sciences

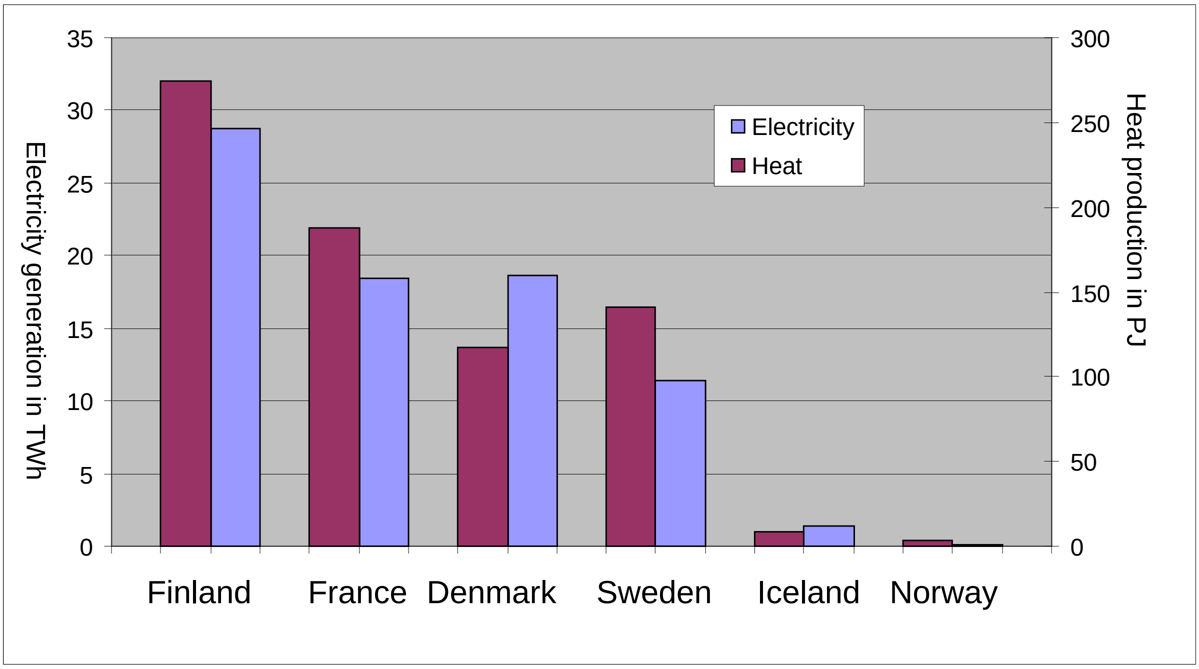

Figure 8: Production of heat and electricity from CHP plants in 2006[9]

	Heat in PJ	Fuel used in PJ	Including % of renewable fuels	Electricity in TWh	As a percentage of total electricity
European Union	3107.2	8537.2	11.6	366.3	10.9%
Finland	274.5	542.1	43.9	28.75	34.9%
France	187.4	367.2	21	18.42	3.2%
Denmark	117.2	371.1	13.4	18.63	40.7%
Sweden	141.5	231.5	62.5	11.43	8%
Iceland	8.7	43.5	100	1.43	14.4%
Norway	3.6	4.6	42.3	0.09	0.1%

Table 2: Production of heating and electricity from cogeneration in 2006 [9]

I.2.b Black liquor

Black liquor is a by-product of the paper industry. It is produced along with the pulp. It is an aqueous solution containing lignin and hemicellulose separated from the cellulose forming the paper pulp early in the process of manufacturing paper. It contains more than half of the energy contained in the wood and can be burned to produce heat or electricity. The paper industry, which is important to both Finland and Sweden, relies on this fuel for its energy needs.

In Finland, black liquor accounted for 153 PJ in 2007, which represented nearly 40% of the production of bioenergies (including peat). In Sweden, 40 TWh of black liquor (or 144 PJ) were used by the paper industry for energy production in 2007. In Norway and Denmark, black liquor plays a much less important role. More noble uses for this black liquor, such as transforming it into biofuels, are the subject of research and development in Sweden and Finland.

[9] Combined Heat and Power (CHP) in the EU, Turkey, Norway and Iceland – 2006 data ; Eurostat

Figure 9: Built in 2004 the Wisa Power plant can use black liquor as a source of energy by burning it to produce both heat (600 MW used for the production of paper pulp) and electricity (140 MW). This is one of the largest facilities of its kind in the world.[10]

I.2.c Peat

Peat comes from decaying vegetation. It is in a way an intermediate step towards coal. It can be burned to produce heat or electricity. The "renewable" character of this energy source is debatable: the timescale for the formation of peat is around a thousand years. But we can replant a forest after utilising a peat bog to obtain a carbon neutral result and a forest instead of a marshy area emitting CO_2. In Finland, peat represented 5.8% (in 2008) of primary energy use[11] and this resource has great potential for this country. Peat is considered there a "slowly renewable" source of energy.

I.2.d Liquid biofuels for transport

If biofuels are so present in the media it is because they are used both to reduce our need for oil and decrease emissions of greenhouse gases from fossil fuels whose use is almost routine in the transport sector today. They are the only renewable source that can be used for transport until electric cars or fuel cells are developed. Their use is recent, unlike other types of bioenergy presented previously.

Biofuels can be used either as they are in vehicles whose engines have been adapted (flex-fuel with the E85), or mixed with fossil fuels as is usually the case at present. For current vehicles, the acceptable amount of biofuel in the mix is often limited to a maximum of 10%.

Sweden is the only one of the Nordic countries to have established early on a political incentive for biofuels. In 2007, it was the only country to use a significant amount of biofuels in the transport sector. The fuels used today, known as first-generation, raise many questions such as competition with foodstuff; the other Nordic countries are awaiting the arrival of second generation biofuels.

EU (27)	*DK*	*OF*	*FR*	*FI*	*NO*	*SW*
2.6	*0.13*	*8.67*	*3.55*	*0.02*	*0.71*	*3.93*

Table 3: Percentage share of biofuels in energy consumption in transport [12.]

[10] Bioenergy solutions from Finland, 2008, TEKES – Finnish finance agency for technology and innovation
[11] Statistics Finland, http://www.stat.fi/tup/suoluk/suoluk_energia_fr
[12] 2007 figures published by Eurostat - http://epp.eurostat.ec.europa.eu

There are currently two sectors for biofuels: ethanol obtained by the fermentation of sugars (sugar, cereals, sugar cane ...) and biodiesel produced from vegetable oils (rapeseed, palm ...).

Sweden has tended towards bio ethanol in terms of biofuels. This country has greatly developed the use of ethanol in an 85% mix for use in adapted vehicles. In Europe, Sweden by far leads the ranking of countries that have opened E85 stations. In Sweden, bio ethanol is the main biofuel, unlike France and most European countries that produce and consume primarily biodiesel (see Table 4).

	DK		*SW*		*FI* [13]		*FR*	
Bio ethanol	*0.2*	*0*	*9*	*1.7*	*3.1*	*1.1*	*16.9*	*20.3*
Biodiesel	*0*	*3.7*	*5.4*	*4.2*	*0.5*	*3.1*	*84.6*	*65.4*

Table 4: Consumption (left) and output (right) of biofuels by country and type of fuel in PJ in 2008 [14].

A substantial portion of Sweden's ethanol consumption is imported from Brazil. More than half comes from this country that produces the cheapest ethanol in the world from sugarcane. Sweden has two players in the European arena: the companies SEKAB AB and Agroetanol AB, importers and producers of ethanol.

The figures which are still low in Denmark and Finland have evolved rapidly in recent years before the 2010 deadline agreed by the European Union to achieve the target of 5.75% biofuels (see part II .2).

I.2.e Biogas

Biogas is produced by anaerobic fermentation of moist plant products. Biodegradable household waste or animal products such as manure can be used.

Denmark is the most advanced Nordic country in the production of biogas. Danish production relies heavily on centralized co-digestion facilities (to obtain higher yields) mixing manure and waste from the food industry. In Finland, biogas is mainly produced in landfills.

SW	*FI*	*DK*	*GER*	*NO*	*FR*
2.02	*1.75*	*3.91*	*100.6*	*1.1*	*16.9*

Table 5: Production of biogas in PJ in 2007 [15].

Sweden, where biogas is mainly produced in sewage treatment plants, is developing the use of biogas as fuel. It has made the purification of biogas (which contains approximately 60% methane) into biomethane (more than 95%) its specialty. In late 2007, Sweden had

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[13] 2006 data.

[14] Barometer of biofuels, EurObserv'ER, June 2008 - http://www.energies-renouvelables.org and Eurostat - http://epp.eurostat.ec.europa.eu

[15] 2007 figures published by Eurostat - http://epp.eurostat.ec.europa.eu

a fleet of 14 400 vehicles fuelled with biogas, 86 service centres distributing the fuel and 27 stations reserved for buses.

In the city of Linköping, all buses run on biogas produced from different types of waste (see Figure 10). Ten million m^3 of biogas are produced annually and provide 4.7 million m^3 of biogas used for transport. Still in Sweden, at Örnsköldsvik, SEKAB AB operates the largest biogas unit. This produces ten million m^3 of unprocessed biogas per year from wastewater, the energy equivalent of 85 000 MWh.

Figure 10: Since 1997, the biogas production unit of Svensk Biogas AB in Linköping has been capable of processing 100 000 tonnes of waste (mainly from slaughterhouses) to obtain 4.7 million m^3 of biogas (97% CH_4). The gas is compressed to 250 bar and is used in urban buses (the entire fleet using biogas), passenger cars (12 stations) and the first train running on biogas in the world. [16]

These examples provide a glimpse of the diversity of bio-energy and the dynamism of Nordic countries in this field. Appendix B provides a somewhat more systematic view in table form identifying a number of projects and pilots especially on biofuels.

[16] 100% Biogas for urban transport in Linköping (Sweden), 2007, International Energy Agency IEA

II A booming sector: policy objectives

II.1 General framework of political ambitions for the sector

II.1.a The Kyoto Protocol

The development of renewable energies is mainly motivated by the desire to reduce emissions of greenhouse gases (GHG) to counteract the threat of global warming. Internationally, the Kyoto Protocol has set targets for each country for reducing emissions for 2008-2012 based on the reference made in 1990 (see Table 6 for the Nordic countries).

Some Nordic countries have decided to go beyond the general emissions targets for greenhouse gas emissions that were set internationally by the Kyoto Protocol. Norway has set a goal -9% instead of +1% and Sweden -4% instead of +4%. Sweden has also announced that it wants to have eliminated the use of fossil fuels in transport by 2030. The Danish Government has adopted a target of 30% of primary energy consumption from renewable sources by 2025. Nordic countries are also very ambitious in their long-term vision and want to lead by example. More recently, Norway announced its intention, along with Sweden, of becoming a carbon neutral nation by 2050.[17]

	DK	NO	SW	FI
Objective of reducing GHG (Kyoto)	- 21%	+ 1%	+ 4%	0%
Change in GHG emissions between 1990 and 2007	- 3.5%	+10.8%	- 9.1%	+10.6%

Table 6: Reduction Targets and variations in emissions of greenhouse gas in Nordic countries [18]

Norway is not part of the European Union and therefore has no set goal other than the Kyoto Protocol. Moreover, Norway has large resources of oil and gas, which gives it a special position in regard to renewable energies. Energy dependency does not pose the same problems. It has nevertheless made significant commitments to fight against global warming.

II.1.b European Directives

In addition to the Kyoto agreement, within the European Union (EU), each country has been allocated national targets for 2020 both to reduce GHG emissions and also use renewable energies[19]. In this context; Nordic countries were given very ambitious targets. Indeed, apart from Denmark whose position is unique because of its domestic production of hydrocarbons, Sweden and Finland have a good position compared to other European countries in terms of GHG emissions. They have however agreed to make greater efforts

[17] White paper "Norwegian climate policy" 2007, Norwegian Environment Ministry
[18] European Environment Agency (EEA), online data service http://dataservice.eea.europa.eu
[19] European Directive 2009/28/CE on renewable energies and decision 406/2009/CE on the emission of greenhouse gases

to reduce emissions than some major countries like France and Germany. The objectives set by the EU, aimed at reducing GHG emissions by 20% by 2020 compared to their 2005 level.

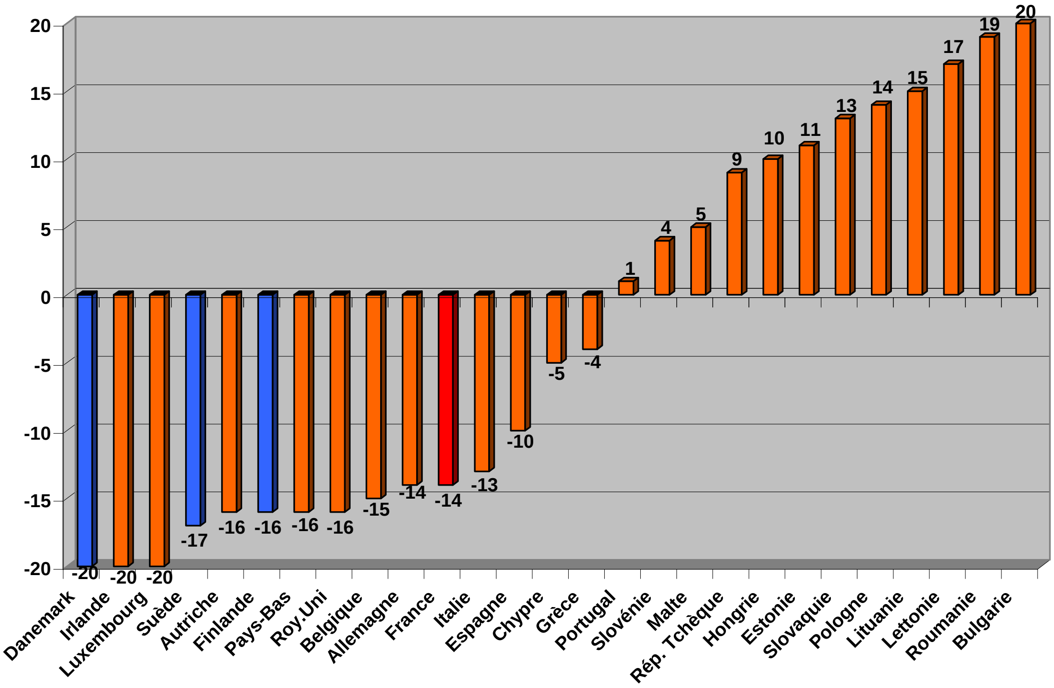

Figure 11: Breakdown by country of the effort to achieve the goal of reducing GHG emissions by 20% in Europe [20]

In terms of renewable energy, Denmark, Sweden and Finland, already well placed within the European Union, agreed again in 2005 to make a significant effort. Such efforts will place these countries at the forefront of European countries and Sweden is clearly intending to acquire half of its energy from renewable resources by 2020.

[20] European decision 406/2009/EC on the emission of greenhouse gases

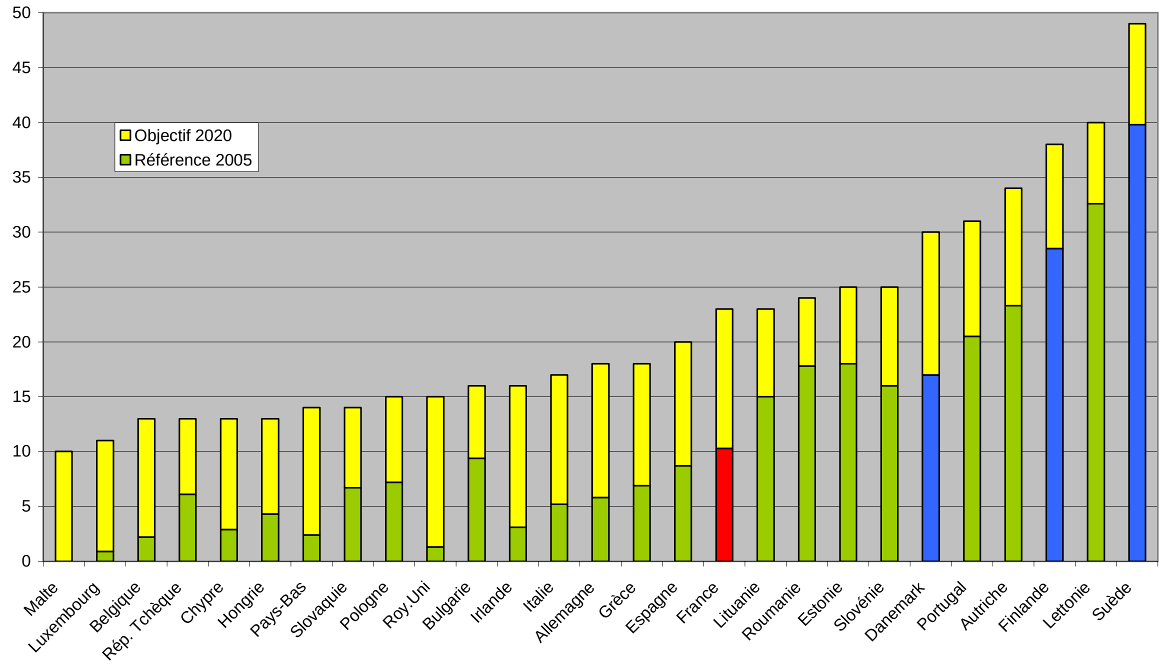

Figure 12: Breakdown by country of the effort to achieve the target of 20% renewable energy in Europe[21] (Objectif – Target, référence – reference point)

These objectives and constraints are of course meant to encourage greater use of bioenergy, but there is no specific and binding European directive on bioenergy. In 2005, the European Commission published a non-binding action plan that provides for 149 Mtoe (6238 PJ) in 2010 [22] against 69 Mtoe (2888 PJ) in 2003. According to a projection made by the Observatory of renewable energies, this target will not be achieved (see Figure 13). A Technology Platform (The Forest-Based Sector Technology Platform) has been established at European level to try to develop the use of forest products (not limited to energy use). Forest resources should play a major role in the sustainable development of our societies[23]. Finnish and Swedish players hold key positions in this platform.

At the European level, the only obligation relating to bioenergy concerns transport. In 2003, a target of 10% renewable energy (primarily biofuels) in transport by 2020 was set by a European Directive. It comes with an interim target of 5.75% by 2010[24.] An initial target of 2% in 2005 was not reached and according to a projection for 2010 by the Observatory of renewable energies, it will be the same for the figure of 5.75% (see Figure 14). In April 2009, the European Commission published a report with pessimistic conclusions for the 2010 target[25]. According to the Commission, too many countries are lagging behind in the development of biofuels and the Commission expects 5% biofuels in 2010.

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[21] European Directive 2009/28/EC on renewable energies.

[22] "Biomass action plan" European Commission , published in 2005 http://eur-lex.europa.eu/LexUriServ/site/fr/com/2005/com2005_0628fr01.pdf

[23] "Innovative and sustainable use of forest resources, vision 2030" published in 2005 by the European technology platform for the forestry sector. www.forestplatform.org

[24] Directive 2003/30/CE of 8 May 2003 aiming to promote the use of biofuels.

[25] COM(2009) 192 of the European Commission 24 April 2009 : Report on the progress of renewable energies.

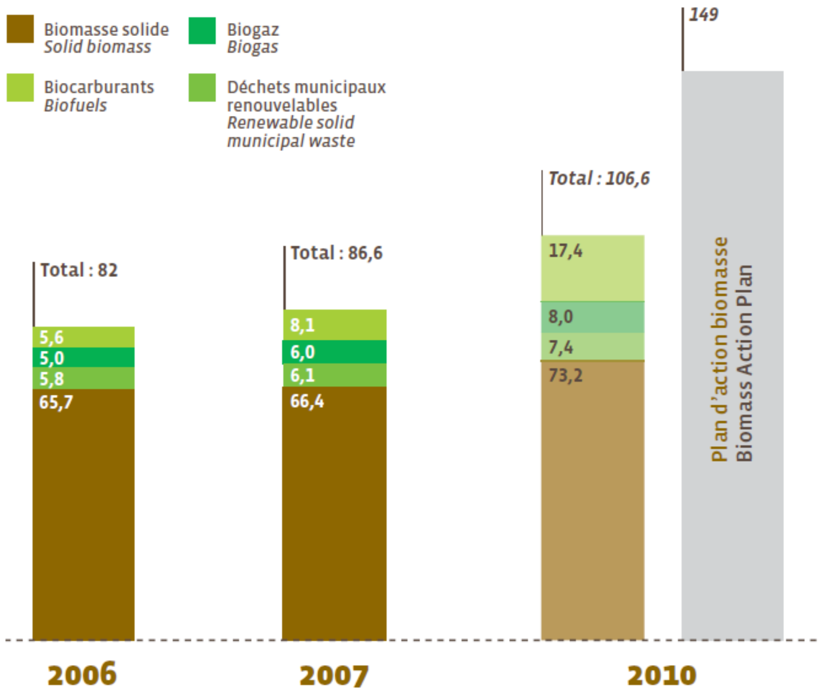

Figure 13: Consumption of primary energy from biomass in Europe[26]

In the longer term, the European Commission estimates that biofuels could account for one quarter of the energy consumption of transport [27]. In this regard, a European Technology Platform has been created (EBTP, European Biofuels Technology Platform). Nordic players are well represented on the Steering Committee of the platform (UPM, Volvo, Dong, Neste Oil) and working groups, demonstrating the dynamism of these countries in the area. The technology platform is designed to identify research needs and in 2008 presented a Strategic Research Agenda for Biofuels[28]. Substantial investment is required to reach 25% by 2030. By 2020, the estimate presented in this report is 43 Mtoe (1800 PJ), still largely first generation. Imports account for 23 to 56% of that figure. The European Commission would like about half the production to be national or regional.

[26] Figures in Mtoe. State of renewable energies in Europe, 8th balance sheet of EurObserv'ER, 2008 Edition 5,3% in 2010 corresponding to a projection made by the renewable energies observatory considering current trends. http://www.energies-renouvelables.org
[27] Biofuels in the Eruopean Union. A vision for 2030 and beyond, 2006, European Commission
[28] Strategic Research Agenda, 2008, European Biofuels Technology Platform - http://www.biofuelstp.eu

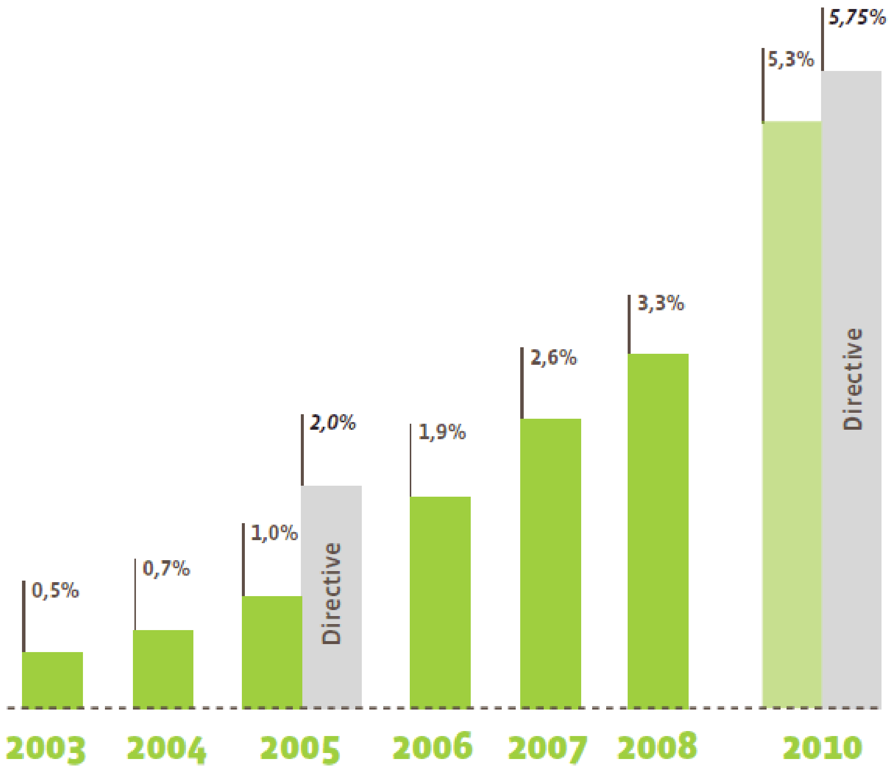

Figure 14: Use of biofuels in the transport sector [29]

II.2 Variation of major trends in each country, incentives put in place

II.2.a Green Taxation in the Nordic countries: the carbon tax

Carbon tax made its first appearance in the Nordic region: initially in Finland in 1990, then quickly imitated in Sweden, Denmark and Norway in 1991 and 1992. This tax, which applies to emissions of greenhouse gases (price per tonne emitted into the atmosphere) directly targets fossil fuels in an attempt to reduce their use and promote energy sources which do not emit carbon. It is structured differently from one country to another with the energy tax, which often pre-dates it and which applies to energy consumption. Bioenergies are usually exempt from carbon taxes, giving them an economic advantage over fossil fuels. This type of measure has greatly promoted the development of bioenergies particularly in Finland and Sweden.

	Denmark	Finland	Sweden	Norway
Carbon tax (€ / tCO_2)	12	20	106	0.57 to 0.84 NOK / l [29]

Table 7: Energy and carbon taxes in each country[30]

[29] In Norway, carbon tax is not defined by tonnes of CO_2 emitted but by litre of fuels burned

[30] In France, carbon tax will be enforced in 2010. The report of the "Conference of experts and round table on the contribution Climate and Energy" presided over by Michel Rocard recommends a tax of 32 €/tCO_2 progressively increasing to reach 100 €/tCO_2 en 2030

The laws concerning various taxes in the energy sector (mainly energy and carbon taxes, but also the tax on sulphur and nitrogen compounds) are quite complex and many schemes have been set up for especially energy intensive industries. The case of electricity generation is also treated separately and this is different in each country. It is often exempt from tax and it is electricity consumption that is taxed.

In Sweden, a single measure has been developed for the sector of electricity generation."Green certificates" (elcertifikat)[31] are assigned to certain producers of renewable electricity (the old hydroelectric capacity for example does not benefit from this system). These certificates are redeemed by electricity distributors who are required to obtain a quantity depending on their total sales (quantity determined by the state). In early 2008, a certificate for a MWh of green electricity was trading at more than 300 SEK (around 30 c € / kWh), conferring a significant economic benefit to producers.

II.2.b Measures applicable to bioenergies

Tax exemptions for renewable energy play an important role in the development of bioenergies. They are complemented by a series of incentives aimed more specifically at bioenergies (see Appendix A for details for each country).

- In Sweden, electricity produced from renewable sources benefits from the certificate system. As regards the other uses of biomass (for heat and transport), bioenergies are exempt from the CO2 tax (on fossil fuels) and energy tax. For example, these two taxes combined represent 50 c € / l for petrol. The green vehicles (including those using E85 fuel) have benefited from a purchase premium of approximately 1,100 Euros to 1st July 2009. There are also various mechanisms for supporting the installation of E85 stations and biogas or replacing old oil boilers. The government recently commissioned the Energy Agency to develop a national policy plan for the production and use of biogas as fuel. Regarding the ratio of imports to domestic production, Sweden has not set a goal and has left the free markets to find a balance.

- Denmark had initially refused to follow the EU directive, saying the country was already using bioenergies sufficiently for producing heat and electricity. In 2008, Denmark finally agreed to the target set by the EU[32]. The latter, which is 5.75%, should be reached by 2012 and the 10% target should be reached by 2020 (obligation for distributors to respect these figures). Biofuels are only exempt from the CO2 tax, the benefit is minimal and much of the production is exported to Germany, where conditions are more favourable. Regarding biogas, Denmark has introduced new legislation to boost its production. The purchase price has been increased to 0.745 DKK / kWh (10 c € / kWh) for electricity produced from biogas. Purified biogas (natural gas quality) injected into the natural gas network also has a purchase obligation 0.405 DKK per kWh (5.4 c € / kWh). The government's goal is to increase the current production of 97.9 ktoe (4 PJ) to 239 ktoe (10 PJ) in 2020, equivalent to 1.2% of Danish consumption under the deadline. Electricity

[31] Energy Indicators 2008, Swedish Energy Agency. The certificates were introduced in 2003 to increase the amount of electricty generated from renewable sources covered by the system from 6,5 TWh in 2002 to 23,5 TWh in 2016.
[32] Energy Policy Statement, 2008, Danish Ministry for climate and energy

production from other biomass is subsidized to the tune of 0.150 DKK per kWh (2 c € / kWh).

- Finland has committed itself to the EU target for transport for 2010. Fuel distributors are required to incorporate biofuels up to 2% in 2008, 4% in 2009. This requirement applies to all types of fuels However, there is no tax exemption for biofuels. For heat production, fuels are taxed based on their carbon content and bioenergies are exempt from this tax. For electricity generation, the fuels are not taxed but the use of electricity is taxed. Electricity generated from wood enjoyed subsidies until 2007. Now, only forestry residue (0.69 c € / kWh) and biogas (0.4 c € / kWh) benefit from this measure. Assistance to the tune of 30 to 50% for investments in renewable energy production is one of the main mechanisms for implementing the country's energy strategy[33].

- Norway has forecast an increase of 14 TWh (50 PJ) in the consumption of bioenergies by 2020, representing almost a doubling. Regarding biofuels, there is now a requirement to incorporate at least 2.5% bioethanol or biodiesel to fossil fuels in 2009. The minimum blend rate will increase to 5% in 2010.

To achieve the objectives set by the states and the European Union in terms of renewable energy, particularly in terms of biofuels, the sector is required to develop very quickly. The organization of the sector needs to be thoroughly reviewed and new facilities on an industrial scale need to be built.

Regarding second-generation biofuels, it is time to build pilot plants and industrial demonstrators.

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[33] Sustainable International Bioenergy Trade: Securing supply and demand - Country report of Finland", 2008, International Energy Agency IEA

III The future of bioenergies: research advances

The Nordic countries rely heavily on bioenergies to reduce emissions of carbon dioxide and therefore invest in research and development of these technologies.

III.1 New techniques for using biomass

Fluidized beds allow for flexibility as regards fuels. Techniques of co-firing are developed to accommodate the diversity of fuels and impurities from the biomass. The flexibility obtained in terms of supply can also adapt to fluctuations in price and availability of raw materials. Mixing the fuels with other fuels such as peat or coal, can also reduce the problems of corrosion and deposition.

Figure 15: The Alholmens CHP plant in Finland is one of the largest plants in the world using biomass. Each year, 19 PJ of fuels are used to obtain electric power of 240 MW and thermal power of 160 MW (100 MW of heat for industrial use and 60 MW for the heating network). The company has managed to overcome supply problems posed by the size of the facility. The fuels used are: 45% peat, 40% wood and 15% coal (Metso Power).[34]

The UPM-Kymmene company, a leader in the paper industry, invests in R & D for the different sectors of the second generation. The company recently signed an agreement with Metso Power, for the construction of a plant producing bio-oil by fast pyrolysis, which represents a step towards the production of transport fuels. The production of bio-oil by pyrolysis is also an objective of Xynego in Norway, which regards it as a first step towards the production of biodiesel (Fischer-Trop).

These examples show that the sectors considered classics in the field of bioenergies are subject to innovations and developments which are closely related to the aspects of second generation fuels research.

III.2 The processes called "second generation"

Many Nordic players are engaged in the race for the industrial production of next generation biofuels. Large oil companies in Finland (Neste Oil, ST1), players in the forestry and paper industry (Spray, UPM, Stora Enso), specialists in the production of

[34] Bioenergy solutions from Finland, 2008, TEKES – Finnish finance agency for technology and innovation

enzymes for hydrolysis cellulose (Danisco, Novozymes) and many innovative companies (Chemrec, Sunpine, SEKAB) all have the intention of being among the first to produce second generation biofuels and are exploring several pathways of research mainly the biochemical and thermochemical sectors.

Large forestry and paper companies have the advantage of their experience in collecting wood in large quantities. Large-scale, centralized fuel production actually poses logistical problems for supplying wood or other types of biomass, negatively affecting the profitability of the sector.

Following the example of papermakers that include electricity, heat and soon biofuels in their processes, there may never be second generation industrial installations using only wood or crops to produce biofuels. The biorefinery concept is attracting considerable interest and liquid biofuels production plants may also produce biogas, solid fuels and also fertilizer, animal food or any kind of bio-products from “green” chemistry.

III.2.a Thermochemical sector

The principle of the thermochemical process is to break down long molecules contained in biomass, such as wood, usually to produce synthetic gas (mainly H2, CO but also CH4 and tar). This intermediary is then either burned directly to produce heat and electricity, or used with a catalyst to produce different fuels: diesel Fisher-Trop, methanol, DME (dimethyl ether).

The company Neste Oil in Finland has developed a technique called biodiesel NexBTL which is an intermediary between first and second generation. The technology uses hydrogen to treat vegetable oils or animal fats instead of the commonly used methanol. In terms of impurities the fuel produced would be better quality than fossil diesel and could be used directly 100% in existing vehicles without adaptation. There is a plant in Porvoo, which has been producing 170 000 tonnes per year since 2007 from animal fats and imported palm oil and a second has just been inaugurated. The company built a plant in the Netherlands that should produce 800 000 tonnes per year from 2011[35].

In Sweden, the Chemrec company has planned the implementation of a gasification plant using black liquor to produce DME fuel in Piteå for the end of 2009. Chemrec uses gasification technology to 30 bar in an atmosphere of pure oxygen at about 1000 °C. The syngas obtained is of better quality than that produced directly from biomass (low methane and no tar). The company eventually expects to produce by this means the equivalent of 25% of current Swedish fuel consumption [36] (it could reach 50% in the case of Finland). Another by-product of the paper industry, tall oil, is also highlighted for the production of biofuels. The Sunpine company intends to produce 100 000 m^3 of diesel oil a year at Piteå.

Also in Sweden, the Chrisgas project [37] should help develop techniques for the gasification of wood to produce syngas rich in hydrogen. During the first phase a

[35] Bioenergy solutions from Finland, 2008, TEKES – Finnish finance agency for technology and innovation
[36] Presentation of European project BioDME (Production of DME from biomass and use as fuel in transport or industry) - http://www.biodme.eu
[37] Research project launched in 2004 mainly Swedish, financed by European Union (6th PCRD) and Swedish energy agency

prototype facility was constructed. The syngas is initially used to produce heat and electricity. It is burned directly in a gas turbine. The second phase of the project was to produce various biofuels, including DME, but funding problems have led to the termination of the project.

Figure 16: While most second generation projects are designed to produce liquid fuels whose use is easier, the project brings together GoBiGas Göteborg Energi AB, E.ON. and Chalmers University for the construction of two SNG (Synthetic Natural Gas) production plants by gasification of wood (pellets, bark ...). Production is expected to reach 800 GWh (2.9 PJ) in 2016, making it the largest methanation unit in the world. [38]

Methanol was chosen by Björn Gillberg who has decided to launch a project for biomass gasification. VärmlandsMetanol AB hopes to begin production of methanol from 2012-13 with a capacity of 90 000 tonnes of fuel per year.

Other more original directions are being studied in Denmark. The SCF Technologies company for example is trying to imitate the natural process of decomposition of biomass into oil. Using high pressure technology, called Catliq, decomposition into light oil is reproduced in the presence of catalysts over very short periods of time, to produce fuel for commercial purposes. Bionic Fuel Technologies AG, for its part, is using microwaves to help break down the long molecules of carbon contained in biomass.

III.2.b The biochemical sector

Production of first generation bioethanol comprises the alcoholic fermentation of the sugar content in cereals for example. But these sugars represent only a small portion of the biomass used, resulting in poor yields. The challenge of the second generation is to deal first with a larger part of the plants, hydrolyzed into sugars that are then degraded using conventional techniques.

Regarding the hydrolysis of cellulose, and eventually hemicellulose, to get sugar, several options are being considered. The Danish players have chosen to use enzymes to catalyze the hydrolysis of cellulose. But the enzymes are expensive to produce and sensitive to outside elements. The Swedish projects mostly use a technique of acid hydrolysis (slightly acidic). In Norway, a project of hydrolysis under strongly acidic conditions is underway. By recycling the used acid after hydrolysis (thus avoiding the acid preventing fermentation) acid costs can be reduced. In northern Sweden, Örnsköldsvik, the SEKAB company has already built a prototype for the production of ethanol from lignocellulosic materials. The unit has been producing one hundred litres per day since 2005 and an industrial demonstrator should be built by 2012, producing 4 000 tonnes per year. At Sveg, in Sweden, the National Bioenergy Company Sweden AB plans to build a unit producing 75 000 m^3 per year from 2014.

[38] Research and innovation, Demonstration & pilot, 2009, www.nordicenergysolutions.org

In Denmark, several major projects are underway for second generation demonstrators The two main leaders of the global production of enzymes, Danisco and Novozymes, are Danish and are interested in second generation ethanol production. Enzymes are indeed a key element of Danish projects and allow hydrolysis before the fermentation step. This technology is considered too expensive by the other Nordic second generation ethanol projects. The Danish players hope to gain from their experience and knowledge and produce lower cost enzymes that give a distinct advantage in the technology. The two players are respectively involved in the Inbicon and BomBioFuel projects which should start production this year.

Figure 17: Construction on the Kalunborg site in 2008 (Inbicon project). After an initial mechanical treatment, the wet straw is heated to about 200 ° C for 5 to 15 minutes to destroy the structure made of lignin and make the cellulose accessible to the enzymes then added. After this pre-treatment, there remains the classical stage of fermentation. The installation should be commissioned in late 2009 and produce 4 500 tonnes of ethanol, 8 250 tonnes of solid fuel and 11 000 tonnes of molasses C5 (sugars with five atoms of carbon) per year. This molasses will be used initially as animal feed but new technological advances could allow it to be used to produce ethanol or biogas.

In Norway, the Weyland company (who collaborates with the University of Bergen) built a prototype producing ethanol from cellulose compounds. Hydrolysis of the cellulose is done with high concentrations of acid. An advantage of this method arises because the temperature reached is lower than for slightly acid hydrolysis, which produces less fermentation inhibitors. This technique also allows greater flexibility in the choice of substrates.

In Finland, drawing inspiration from ants, the Chempolis company has developed a unique process based on the use of formic acid. With this chemical, cellulose and lignin are separated, a necessary step for the production of pulp or ethanol. The company wants to build on this concept to develop a biorefinery that produces paper and bioethanol. This separation technique allows the use of waste in paper production.

III.3 The processes called "third generation"

The definition of the third generation remains unclear and is not commonly accepted. It often means microalgae which could allow the production of oils for biofuels production (biodiesel) with yields well above those of the plants that are currently grown. This would allow production which does not compete with food production nor with forest production or use fertile soils.

The GreenFuel company in the United States, a pioneer in this field, has already built a test plant If the techniques are more advanced in the U.S., as regards basic research, Europe and especially Sweden, is at the forefront.

In Denmark, the National Institute for Technological Research[39] is conducting a project to couple the use of algae with power plants emitting CO2 which the organisms need to develop. The project brings together the Riso National Laboratory (DTU) and Dong Energy A / S.

A new trend is towards producing fuels directly from these organisms rather waiting for the harvest at the end of the growing season. Fewer steps in the chain provide a better overall performance.

At Uppsala University, a team of researchers are thinking of genetically modifying organisms already capable of photosynthesis: thus using water, carbon dioxide and sunlight to produce different fuels. It is a question of managing to direct the development of metabolic intermediaries of cyan bacteria towards the production of fuels in order to make small ethanol, butanol or even hydrogen factories. This technology therefore would use micro-organisms as a catalyst for the continuous production of fuel. Many of the drawbacks of existing biofuels (low yields, competition with food ...) will disappear with the use of micro-algae.

The team of Professor P. Lindblad at the University of Uppsala, is already preparing the biofuels of the "hydrogen society". Unicellular organisms using sunlight to photosynthesise, produce protons as intermediaries. The objective is to use the properties of these cells to produce molecular hydrogen simply from water and light. As hydrogen produces only water when it is converted into energy (e.g. in a car with a fuel cell), the cycle is theoretically clean. The total efficiency of the photosynthetic process reaches 1%. There is a Nordic project called BioH2 to develop such techniques. Another way is proposed in this project: which is to imitate the chemical mechanisms of photosynthesis of these organisms to reproduce molecules with similar properties.

III.4 The potential of different sources: forest, black liquor, waste, energy crops

Plants convert solar energy with yields ranging from 1 to 4% depending on temperature and soil nutrients. Globally, the total growth of biomass is about 2400 EJ (total consumption of primary energy in 2006 was about 500 EJ), most of which is necessary for the maintenance of ecosystems. Part of this production is also used as food or for construction. The challenge then is to discover how much can be used for energy in a sustainable manner without compromising other uses of biomass. The IEA estimates that the contribution of bioenergies could be increased during this century to 200-400 EJ, reaching one third of the total energy consumption worldwide[40].

[39] Danish Technological Institute, http://www.dti.dk
[40] Potential contribution of bioenergy to the world's future energy demand, 2007, International Energy Agency IEA

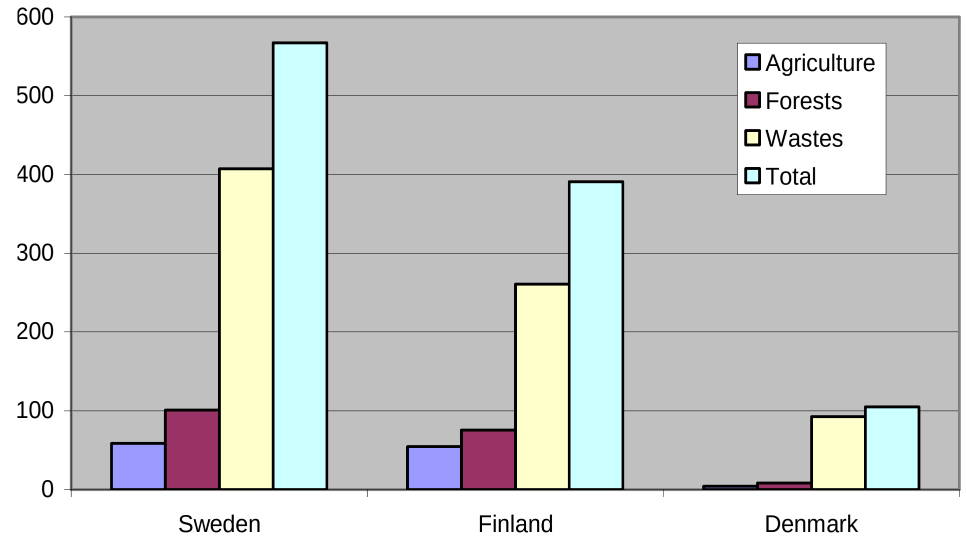

Figure 18: Potential estimated by EEA for the Nordic countries the use of bioenergies resources in 2030 in PJ 41

Bibliographic sources give different estimates For Sweden, for example, studies produce results ranging from 544 PJ by the European Environment Agency (EEA) to 892 PJ by the Swedish Bioenergy Association. These differences arise mainly from dedicated agriculture, a sensitive point for the studies aiming to determine the potential of bioenergies. On the one hand, technologies for producing biofuels are not yet mature, on the other energy energy crops cause debate because they compete with food cultivation at least for use of the available arable land. In Europe, the European Environment Agency (see Figure 18) and the Nordic Council in the Scandinavian region (see Table 8) have conducted studies to determine the potential use of bioenergies in each country. The EEA in particular, has tried to take account of various constraints to produce figures that reflect the sustainable use of this energy source. The results of the European Agency are slightly lower because they take less account of the potential energy crops. This difference is significant in regard to Denmark.

In the context of sustainable use of biomass resources, the EEA therefore believes that the growing of energy plants can only represent a small portion of the use of bioenergies. This could reach just over 50 PJ in Finland and Sweden, and this potential is virtually non-existent in Denmark. The resource comes mainly from residues and waste. This waste comes from agriculture in Denmark (e.g. straw) and from forestry operations in Finland and Sweden (black liquor, wood waste ...). Without significant energy crops, the margins of progress are therefore to be found especially in a more efficient use of this resource or imports.

[41] Figures in PJ from European Environment Agency EEA, www.eea.europa.eu, 2006 - How much bioenergy can Europe produce without harming the environment? (black liquor and other forestry by products are included in the waste category)

Denmark	*165*	*18.8% in 876*
Finland	*401*	*25.6% in 1567*
Iceland	*0.79*	*0.4% in 181*
Norway	*153 to 167.7*	*14.6% in 1092*
Sweden	*583.6*	*27.6% in 2148*
Total	*1 494 - 1 509*	

Table 8: Potential estimated at national level of resource use in bioenergies[42]

In the right column of Table 8, the potential use of bioenergies has been compared to the total energy consumption in each country in 2006[43]. It is clear that there is room for improvement but that bioenergies cannot a priori replace all sources of energy currently used. If total energy consumption remains constant, except for Iceland, sustainably used bioenergies, therefore, represent a potential maximum of 14.6% for Norway to 27.6% for Sweden.

[42] Figures in PJ collected by Nordic countries advisory agency - http://www.nordicenergy.net/bioenergy. "Facts and Figures on the Use of Bioenergy in the Nordic Countries" published in June 2008
[43] Key world energy statistics 2008, International Energy Agency IEA.

IV Conclusions

In Europe, the Nordic countries are pioneers in the use of renewable energy on a large scale. Sweden is the country in the European Union with the largest share of energy from renewable sources. At present this production is based largely on bioenergies whose use was largely developed after the oil crises in the 1970s. The motivations are different today, but bioenergies continue to play an important role in the energy policies of the Nordic countries. Fuel wood from forests, waste from agriculture and forestry and paper are collected and exploited efficiently for energy production. More recently, biofuels have emerged but only Sweden has bet on the first generation and it now imports much of Brazil's ethanol, which is a cause for some debate. The other Nordic countries are less developed but rely on the second generation, which will no longer compete with food crops for developing fuels from biomass for transportation.

In regulatory terms, the Nordic countries already advanced in Europe, however, agreed ambitious targets on reducing greenhouse gas emissions and energy production from renewable sources. Bioenergies will without doubt form an important part of efforts implemented in the coming years to achieve the various national, European and international objectives relating to the reduction of greenhouse gas emissions and production using renewable energies. Even Norway, however, which was lagging behind with regard to bioenergies, particularly because of its large hydropower production, now intends to develop the use of this resource. Indeed, the environmental objectives of Norway are no less ambitious than those of its neighbours. In the coming years, bioenergies will also play an important role in achieving these goals through a more efficient use of traditional forest resources, and the development of new, especially second generation, biofuels. In the longer term, the use of this resource may be limited and without heavy reliance on imports, bioenergies will probably represent only part of the energy consumption of the countries of Northern Europe. In some of them, this potential is still estimated in the range 15 to 27% against less than 15% currently in northern Europe and a European average closer to 5%.

For France, which has significant biomass resources, many examples may come from the Nordic countries. In the study of the EEA (European Environment Agency) the potential for this type of energy in France is estimated at almost 20% of the total energy consumption (2 000 PJ to 11 000 PJ). Technically, the use of forest resources and the development of waste can probably be improved in France on the Nordic model. Regardless of the origin of its biofuels, the example of Sweden is very interesting because the country has developed the use of these fuels by encouraging the producers of fuels and vehicles, dealers and consumers, who have accorded them an ever greater importance. Research in the Nordic countries is very dynamic especially with regard to biofuels. Large international companies are taking advantage of their position as specialists in wood, paper, fuels or enzymes to develop production technologies for second generation fuel and thus seek to position themselves quickly in this promising market. Smaller players are also very well positioned in niche technologies. Applications targeted by many players go beyond the pure energy sector and the envisaged BioRefineries form the “green” chemistry of the future.

Research is also very internationally oriented with many international partnerships. The initiative of the previous U.S. Ambassador in Sweden to identify innovative companies with high potential, for example, further improved the flow of investment from the United States in the field of cleantechs. Relationships between companies and university labs are also very good and promote innovation and technology transfer to industry. The Nordic players are also very active within the European community in this sector, as evidenced by their heavy involvement in technology platforms and European research projects in this area.

However, the example of Nordic countries cannot be simply transposed for each country or region has its specificities. Efficient use of fuel wood, for example, is intrinsically linked to combined heat and power and district heating networks which have a strong presence in northern countries, facilities requiring large investments. The nature of the resource is also different, since in the case of France, one third of this potential would come from energy crops (in the case of high energy prices according to EEA) while the Nordic countries derive benefit mainly from their forests. The current economic crisis strongly affects the wood and paper industries and forces them to reposition themselves into new promising sectors. The players in the Nordic countries have understood and are structured for a coming transition.

V Appendix A - Use of Bioenergies in each country

V.1 Finland

Finland uses mainly peat because it has very substantial resources. It is also the country that makes most use of its forest resources, mainly black liquor and other by-products of the paper industry. In 2007 Bioenergies consumption was 301 PJ, not including peat which was 106 PJ.

Solid fuels are mainly used for producing heat or for CHP (89 PJ). These are mainly logging residues. Three quarters of wood used for heating is still traditional firewood (logs).

Finland did not want to develop first generation biofuels, but wants to take advantage of new technologies that will produce liquid fuels, mainly for transport, from timber which it has in abundance.

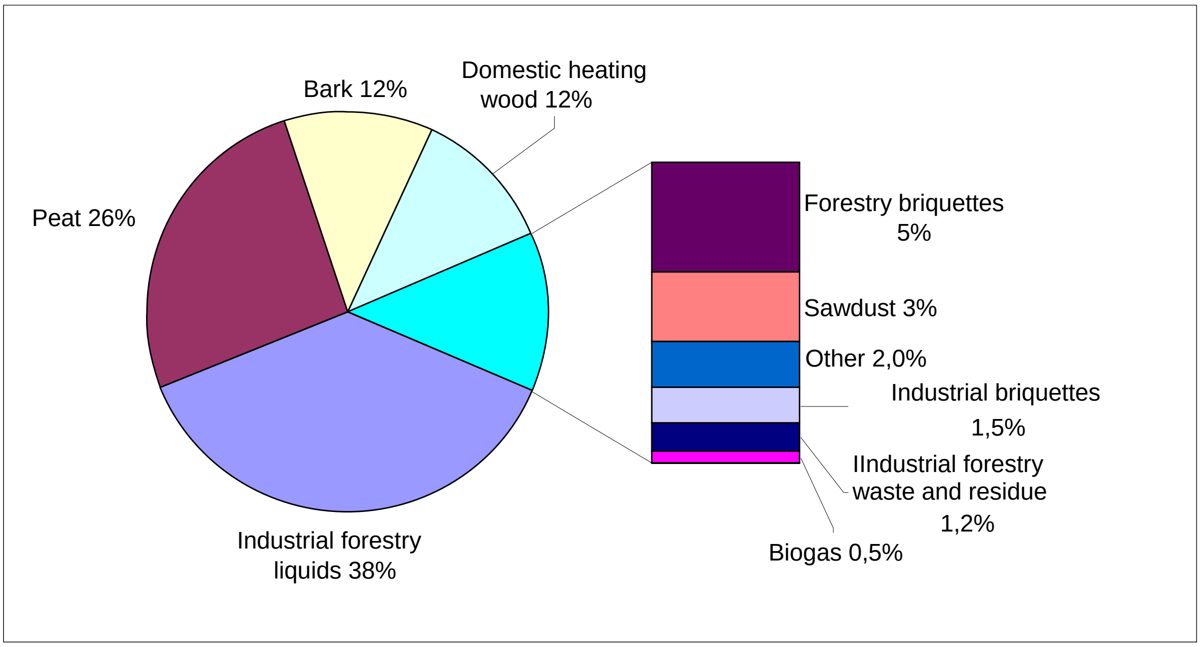

Figure 19: Proportion of different sources of bioenergies in Finland in 2007[44]

The potential for further developing the use of biomass in Finland is estimated to total about 400 PJ (excluding peat). Mainly based on forest products (160 PJ of black liquor, 70 PJ for wood residues from the forestry industry, 86 PJ of wood ...), this potential includes 20 PJ of energy crops and 10 PJ of biogas.

[44] Statistical yearbook of forestery, 2008, Finish forest research institute (Metla) - http://www.metla.fi/julkaisut/metsatilastollinenvsk/index-en.htm

V.2 Denmark

The use of biomass and waste in Denmark is based primarily on waste and the recovery of products such as straw.

Denmark, which only accepted the EU directive on biofuels at a late stage, exports its entire production of biodiesel to Germany. It amounts to 3.7 PJ according to the Danish Energy Agency. It is currently all exported, mainly to Germany. Denmark only began using bioethanol in 2006 and its consumption remains low.

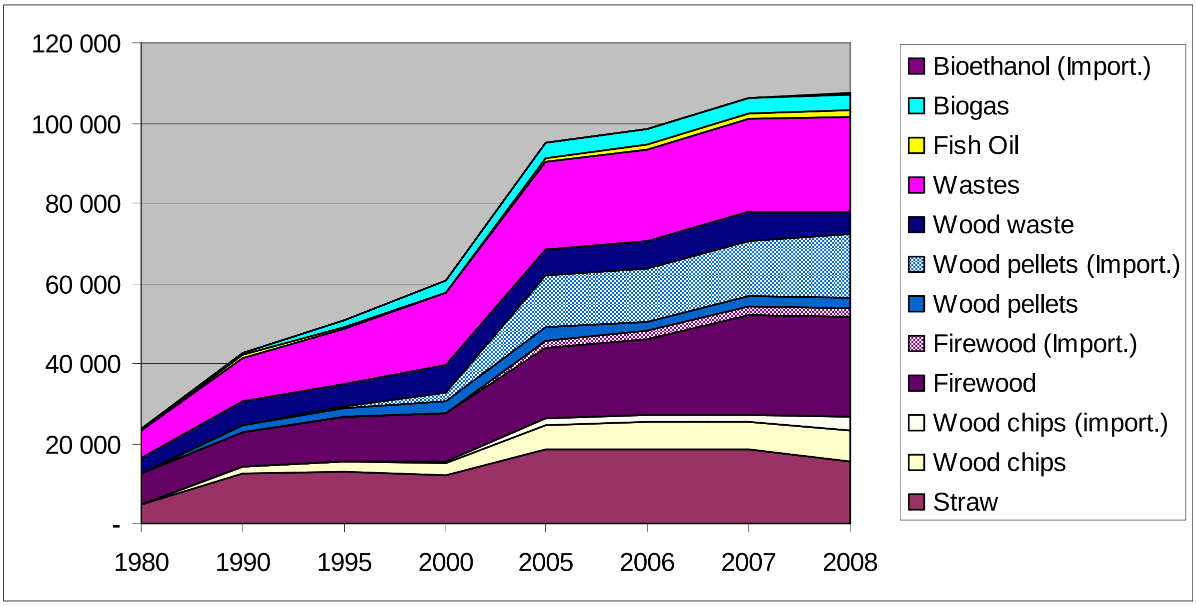

Figure 20: Consumption of bioenergies in Denmark (in PJ)[45]

Biogas production in Denmark comes mainly from collective co-digestion plants. These plants mix mostly agricultural runoff (manure) with waste from food and communities. It is estimated that 6.5% of manure available in Denmark is treated by methanation. The co-digestion technique achieves better yields and higher methane levels in the biogas.

Bioenergies potential is estimated at 165 PJ per year in the study published by the Nordic Council. Part of this resource is already widely used (40 PJ of wood and 30 of organic waste) for the rest the potential can be greatly improved (55 PJ of straw and 40 PJ of biogas).

V.3 Sweden

The biomass used comes mainly from forests. Of the 120 TWh (432 PJ) of bioenergies consumed in Sweden in 2007, 55 TWh were consumed in industry. Much of this consumption corresponds to black liquor and other by-products of the paper industry. The second use, 37 TWh, was destined for urban heating (cogeneration in most cases: power

[45] Energy Statistics 2008, published by the Danish energy agency http://www.ens.dk

generation from bioenergies is 12 TWh). The fuels used for heating are mainly unprocessed residue (sawdust, bark, branches), but processed products (pellets, briquettes) are increasingly used. Finally, domestic heating (10% of homes) consumed 14 TWh of fuels from biomass. The majority is still used as firewood, but the use of pellets is increasing (about 3 TWh). In total more than 8 TWh were consumed in the form of pellets in 2007. Sweden is a net importer of this product, although world's largest producer.

The estimated potential in Sweden is 565 PJ according to the EEA and 586.5 PJ according to the study published by the Nordic Council (which includes peat 14.4 PJ). SVEBIO, the Swedish Association for bioenergies however, considers that the potential for 2020 amounts to 248 TWh (892 PJ), rising long term to 394 TWh (1418 PJ). In this study, for the potential in 2020, 43.2 PJ comes from peat and 140 PJ from agriculture which are the essential differences from other estimates.

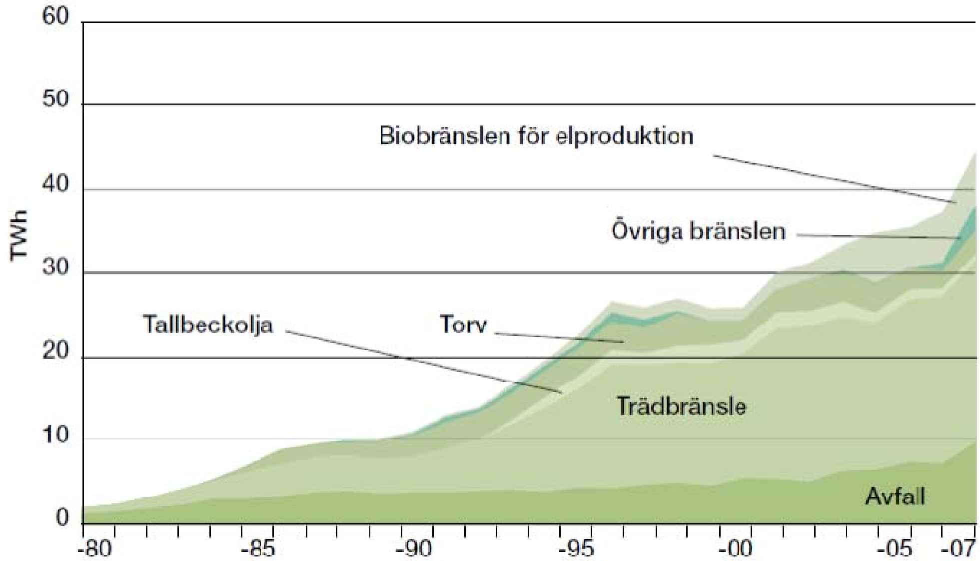

Figure 21: Use of biomass for district heating (avfall – waste, Trädbränsle – fuel wood, Torv - peat) [46]

The fuels used in Sweden are mainly ethanol and E85 ethanol blended with petrol. Sweden imports 85% of its production of ethanol. The incorporation rate was 4.9% in 2008. The use of biodiesel is new but is developing quickly. Alongside, Sweden has developed its fleet of green vehicles and petrol stations offering ethanol, gas or RME. 1 380 petrol stations were offering E85 in Sweden in February 2009, which corresponds to 42.5% of petrol stations in the country (mandatory for petrol stations selling more than 3 000 m^3 of fuel per year).

[46] Energy in Sweden 2008, Swedish energy agency
http://www.energimyndigheten.se/en/Facts-and-figures1/Publications

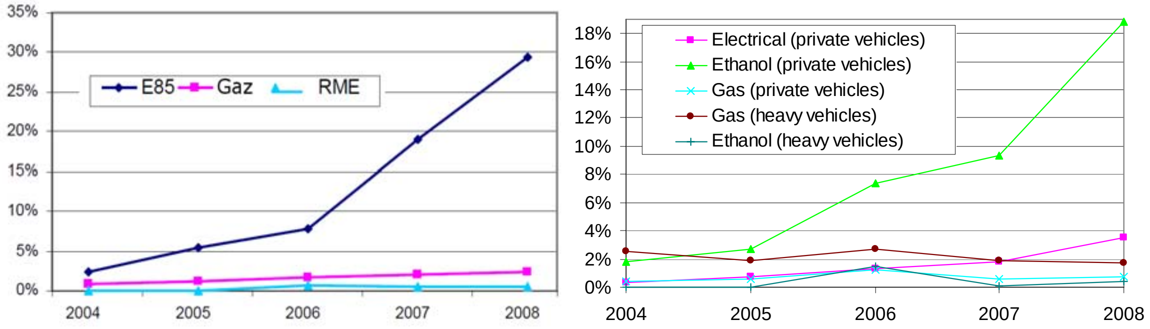

Figure 22: percentage of petrol stations offering different types of biofuels (left) and proportion of new vehicles in service that use biofuels (right).

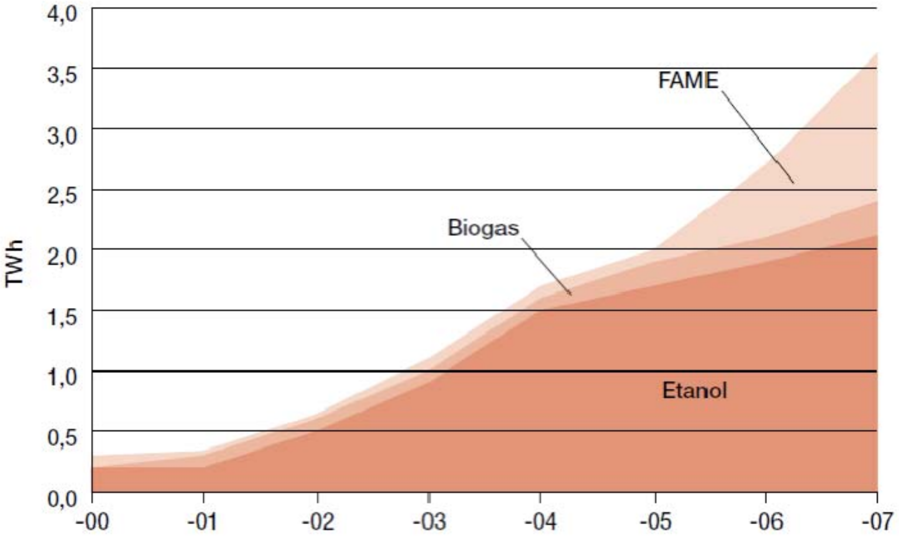

Figure 23: Use of biofuels for transport in Sweden (Etanol - ethanol, biogas - Biogas; FAME - biodiesel)

In 2008, the company Agroetanol AB was the first Swedish producer of bioethanol. It is located in Norrköping. SEKAB AB, the main player in the Swedish market, imports large quantities of ethanol from Brazil.

The country has focused on upgrading thermal power for heating networks (one third of the energy recovered). It also enhances biogas to produce fuel for electricity generation and for injection into the natural gas network.

Sweden is particularly active in the production of biogas with 37 biogas upgrading plants operational in 2007. Four of these plants inject their production into the natural gas network (replacing nearly 2 million m^3 of natural gas). During 2007, sales of biomethane for vehicle consumption (28 million m^3) were higher than sales of natural gas (25 million m^3). This corresponds to 19% of biogas production in the country. In late 2007, Sweden had a fleet of 14 400 vehicles powered by gas, 86 petrol stations distributing the fuel and 27 stations for buses.

V.4 Norway

Norway is the country that uses the least bioenergies so far. The use of bioenergies was 56 PJ in 2006. Almost all of it is used for heat production; of which 24.1PJ is wood for heating in domestic houses and 15.7 PJ is waste and residues used by the forestry industry. The production of pellets and briquettes is limited, to approximately 40 000 tons each (i.e. 1 PJ in total). Only 1.8 PJ of electricity was generated from bioenergies. Sales of biodiesel increased significantly between 2007 and 2008, reaching 103.6 million litres. This represents 4% of the total consumption of diesel in transport. 96% of the diesel was mixed with fossil fuels. In contrast, the consumption of bioethanol is very limited. The total potential for bioenergies would be around 150 PJ, the government's target is 30 TWh (or 108 PJ).

VI Appendix B - Players and projects in the field of biofuels

VI.1 Existing installations, first generation

Name	Domain	Location
Ageratec AB www.ageratec.com	Producer of equipment for biodiesel production (plants up to 60 000 m^3 per year already installed).	Norrköping, Sweden
Borregaard www.chemcell.com	Biorefinery that has produced among other things ethanol since 1989. Also producer of biodiesel via Uniola (www.uniol.no/eng) hich has just inaugurated a plant with a capacity of 100 000 m^3 per year.	Fredrikstad, Norway
Chematur Engineering AB (CEAB) www.chematur.se	Sells its product Biostil2000 for the continuous production of bioethanol	Karlskoga, Sweden
Daka www.dakabiodiesel.com	Production of biodiesel from agricultural waste (55 000 m^3 per year should be increased to 100 000 m^3). Agricultural waste and fat from slaughterhouses are used for production.	Ringsted, Denmark
Emmelev Molle A / S www.emmelev.dk	Biodiesel from rapeseed oil (90 000 m^3 per year). It is the only Danish producer using this material.	Otterup, Denmark
Lantmännen Agroetanol AB www.agroetanol.se	Production of first generation ethanol (210 000 m^3 per year).	Norrköping, Sweden
Nordisk Etanolproduktions AB www.nordisketanol.se	Major project which should begin production in 2011 from cereals and reach 130 000 m^3 of ethanol and 400 GWh of biogas (by degrading the by-products of ethanol production).	Karlshamn, Sweden
Nykomb Synergetics www.nykomb.com	Nykomb will soon import 156 000 m^3 of ethanol from Togo to Sweden. Nykomb is already associated with Chemrec in the field of biofuels.	Stockholm, Sweden
Preseco Oy www.preseco.fi	Waste treatment solutions to produce biogas or biodiesel plants (capacity up to nearly 6 000 m^3 per year).	Espoo, Finland
SEKAB AB www.sekab.com	Main Nordic player producing and importing (mainly from Brazil) first-generation ethanol. SEKAB has plans to produce ethanol in Tanzania and Mozambique.	Örnsköldsvik, Sweden
ST1 Oy www.st1.eu	Etanolix process, decentralized, producing ethanol from waste (4 200 m^3 per year).	Finland
Swedish Biogas International AB www.swedishbiogas.eu	Producing biogas from waste mainly from slaughterhouses (7.2 million m^3 of biogas produced in 2007).	Linköping, Sweden

VI.2 Research projects and second-generation

Name	Domain	Location	Partners
Bionic Fuel Technologies AG www.bionicfuel.org	Technology using microwaves to break the carbon chains in the presence of catalysts at 280 ° C. The concept has been developed and gave birth to 3 reactor designs. A prototype has been in operation since 2008 (25 kg / h or 220 t / year). The production of BFT can reach about 1000 kg / h (8 800 t / year).	Aarhus, Denmark	
BornBioFuel www.biogasol.com	Plant producing bioethanol from biomass operation started by Biogasol in 2009. 100 000 tons of wet biomass to 10 million litres of bioethanol and 10 000 tonnes of solid fuel per year. The technology developed allows the fermentation of C5 sugars.	Bornholm, Denmark	DTU, Novozymes
CenBion www.sintef.no	Research Centre for a biorefinery. Project started in 2009.	Ås, Norway	
Chempolis Oy www.chempolis.com	Production of "third generation" biofuels. Especially production of pulp from non-wood. Prototype commissioned early 2009. Use of formic acid to separate cellulose, lignin and hemicellulose.	Oulu, Finland	
Chemrec AB www.chemrec.se	Gasification of black liquor for production of 1800 t / year of DME (expected 2010).	Piteå, Sweden	Nykomb Volvo
Chrisgas www.chrisgas.com	Second-generation biofuels by thermochemical H2, DME and ethanol. City of Växsjö testing in parallel the DME in trucks. European project (most Swedish) 2004-2009, but STEM stopped funding in 2007.	Vaxsjö, Sweden	KTH
ECOPAR AB www.ecopar.se	Diesel from natural gas. Business After Chalmers University. 10 000 m^3 / year by a Fischer process-too much.	Gothenburg, Sweden	
GoBiGas www.goteborgenergi.se	Biogas provided inter alia for food pipeline (Allothermal gasification of biomass). Production is expected to gradually reach 800 GWh in 2016.	Gothenburg, Sweden	Göteborg Energi AB, E.ON.
Haldor Topsøe A / S www.topsoe.com	Company specialized in catalysis, keen interest in gasification of biomass for biofuel production (DME, methanol ...).	Denmark	In BioDME (Chemrec, Total)
Inbicon A / S www.inbicon.com	Genecor is a leading producer of enzymes for hydrolysis of cellulosic ethanol. In the USA 950 000 liters / year by late 2009. Project in Denmark for a plant of 4 500 t / year (from straw) in 2009.	Kalunborg, Denmark	Dong, DuPont
MaxiFuel www.biogasol.com	Test plant from Biogasol company that produces that produces *(sic)*, since 2006, 40 litres per day (approximately 15 000 m^3 per year) of ethanol from lignocellulosic products.	Denmark	DTU, Novozymes
Neste Oil Oy www.nesteoil.com	NExBTL biodiesel production from palm oil and animal fat; unique technology with hydrogen instead of methanol for cracking oils. 2 plants with a capacity of 170 000 t / year in	Porvoo, Finland	

	operation in Finland. Singapore and Rotterdam construction of 800 000 t / year plants.		
SCF Technologies A / S www.scf-technologies.com	Catliq The process can produce second-generation biofuels at high pressure and with suitable catalysts. The process amounts to reproducing the natural conditions of decomposition of biomass in oil (accelerating the process).	Herlev, Denmark	
SEKAB AB www.sekab.com	Ethanol from lignocellulosic biomass. Test plant operational since 2005 (some 100 t / year). Production of 4 000 tonnes per year planned from 2012-13	Örnsköldsvik, Sweden	In NILE (IFP)
ST1 Oy www.st1.eu	The bionolix process, evolution of the concept etanolix will produce second-generation ethanol from domestic waste	Finland	
Stora Enso Oy www.storaenso.com	Stora Enso is one of the leaders (Swedish-Finnish) in the forestry industry. The association with Neste Oil (NSE Biofuels Oy) should lead to the production of FT-biodiesel from forest residue and paper. Commissioning is currently scheduled 2009 (100 000 t / year).	Varkaus, Finland	Neste Oil Oy, VTT
Sunpine AB www.sunpine.se	100 000 m^3 annual unprocessed diesel produced from tall oil (industry paper). Production should begin in 2009.	Piteå, Sweden	In Solander
Taurus Energy AB www.taurusenergy.eu	Ethanol plant, no production goal, only patents. Venture capital, Ideon.	Lund, Sweden	In BAFF
UPM www.upm-kymmene.com	Leader in the paper industry, UPM intends to specialize in the production of second generation biofuels (biodiesel and ethanol). With Metso Project production of "bio-oil" by pyrolysis (towards the 2nd generation).	Tampere, Finland	Metso, Andritz / Carbona, Lassila & Tikanoja
Vapo Oy www.vapoil.fi	The Vapoil project aims to produce biodiesel via gasification of wood and peat (provides for the capture of CO2 produced by the process).	Jyväskylä, Finland	Metsäliitto
VärmlandsMetanol www.varmlandsmetanol.se	Production of biomethanol via synthetic gas biomethanol. The production of 90 000 t / year of methanol from wood scheduled to begin in 2012-13.	Hagfors, Sweden	
Weyland www.weyland.no	Hydrolysis of cellulose in strongly acidic environment (with extraction and recycling of the acid before fermentation) to produce ethanol. A pilot plant should start production in 2010 (730 t / year).	Blomsterdalen, Norway	
Xynergo www.xynergo.com	Construction of a production plant of bio-oil by fast hydrolysis (should be commissioned in 2011 with a capacity of 40 million litres per year) is a first step towards commissioning in 2014 of a production plant of 250 million litres of "Xyn-diesel" per year (from wood)	Hønefoss, Norway	Norske Skog, StatoilHydro, Choren

VI.3 Research in universities and agencies

University	Research field	Country
Risø-DTU www.risoe.dk	Pre-treatment and fermentation for the production of cellulosic ethanol	Denmark
Aalborg University en.aau.dk	Genetic manipulation of bacteria to produce ethanol by fermentation	Denmark
University of Aarhus www.au.dk	Agricultural Research for biomass production	Denmark
University of Copenhagen www.ku.dk	Main university in terms of bioenergies research covering all areas	Denmark
Technical University of Denmark (DTU) www.dtu.dk	Cellulosic Ethanol	Denmark
University of Southern Denmark www.sdu.dk	Biogas	Denmark
Helsinki University of Technology (TKK) www.tkk.fi	Bioenergies	Finland
ATV www.vtt.fi	Biomass gasification, pyrolysis ...	Finland
SINTEF www.sintef.no	Biofuels Production	Norway
University of Science and Technology Norway (NTNU, Trondheim) www.ntnu.no	Conversion of biomass into liquid fuels	Norway
Research Institute of the paper and fibre (PFI) www.pfi.no	Biorefinery, second generation biofuels	Norway
Norwegian University of Life Sciences (UMB) www.umb.no	Bioenergies	Norway
University of Bergen www.uib.no	Cellulosic ethanol	Norway
KTH (Stockholm) www.kth.se	Biomass gasification	Sweden
Centre for Energy Technology (ETC) www.etcpitea.se	Biofuels from black liquor, forestry resources ...	Sweden
Swedish University of Agricultural Sciences (SLU) www.slu.se	Biomass resources	Sweden
Technical University of Lund www.lth.se	Cellulosic ethanol, hydrogen from biomass, clean syngas	Sweden
Chalmers (Gothenburg) www.chalmers.se	Biogas, life-cycle-assessment...	Sweden
Uppsala University www.chalmers.se	Third generation	Sweden

VII Appendix C - Conversion tables of units

The following table (source: IEA) has been used in this report for the conversion of units found in various sources:

General conversion factors for energy

To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	*multiply by:*				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

For fuels, the following is recommended by the European Union:

1t bioethanol = 0.64 toe;

1t biodiesel = 0.86 toe;

1 m^3 of biodiesel = 0.78 toe;

1 m^3 bioethanol = 0.51 toe;