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Bioenergy NoE

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Abstract

The study carried out within the Bioenergy Network of Excellence analyses the implementation of important EU directives and policies relating to bioenergy in Europe to identify major RD&D needs in the field.

Major EU directives, commonly known as the Promotion of Renewable Electricity, Biofuels and Landfill Directives, along with the EU Emissions Trading Scheme and parts of the Common Agricultural Policy, are some of the most important drivers behind the growth of bioenergy in the EU27 today. The report compares how Germany, Finland and the Netherlands have implemented the directives, examining the policy frameworks in each country and the plans and mechanisms in place to reach national targets. A wider European perspective for each directive is then drawn out, and recommendations for RD&D actions to meet the EU directive targets or obligations in each area are outlined. The report also takes a broader look at the effects the EU Emissions Trading Scheme and the Common Agricultural Policy are having on the use of biomass in the EU with RD&D recommendations for each area.

Bioenergy NoE advocates stronger communication and co-operation among various EU-wide projects and initiatives focusing on bioenergy development. Industry commitment to RD&D projects is, however, the only direct path for bringing state-of-the-art technology and products to market. Building sustainable production pathways and addressing competition with food products is crucial to developing environmentally-sound biofuels.

Research in renewable electricity from biomass should prioritize development of higher efficiency power production and power-to-heat ratios in combined heat and power plants over new technology development. In the biofuels field, RD&D should prioritize the development of more sustainable, second generation biofuels. To meet landfill diversion targets, thermal conversion and energy recovery of municipal solid waste in some EU countries will have to increase. Meeting the European targets set for 2020 requires significant technology development in order to introduce a new generation of biofuels and feedstocks: this is the focus for Bioenergy NoE RD&D.

Executive summary

In 2006–2007, members of the Bioenergy Network of Excellence carried out this study of major European Union directives and policies related to the development of bioenergy in Europe.

The report analyses the implementation of important EU directives and policies relating to bioenergy in Europe to identify major research, development and demonstration (RD&D) needs in the field. Bioenergy deployment in the EU varies greatly from country to country. While some countries are successfully using high shares of bioenergy, at least in some sectors, overall the increase in bioenergy use in the EU has been too slow, falling behind levels needed to help meet the EC's Kyoto targets. Major EU Directives, commonly known as the RES-E, Biofuels and Landfill Directives, along with the EU Emissions Trading Scheme (EU-ETS) and parts of the Common Agricultural Policy (CAP), are some of the most important drivers behind the growth of bioenergy in the EU27 today. By analyzing the implementation of the directives in specific member states, this report aims to identify RD&D priorities that, if addressed, will contribute to a substantial increase of the share of bioenergy in the EU energy mix.

In order to assess practical issues like raw material supply, concrete national markets, present and future price levels, and status of relevant technologies, the report focuses on three member states: Finland, Germany and the Netherlands. The three countries examined have quite different biomass feedstocks and quantities as well as unique policies and support mechanisms relating to bioenergy – but together they can act as a barometer for bioenergy utilization in the EU.

The analysis clearly demonstrates how careful implementation of relevant directives can increase bioenergy use. But the increase is by no means automatic or uniform. The report compares how Germany, Finland and the Netherlands have implemented the directives, examining the policy frameworks in each country and the plans and mechanisms in place to reach national targets. A wider European perspective for each directive is then drawn out, and recommendations for RD&D actions to meet the EU directive targets or obligations in each area are outlined.

The report also takes a broader look at the effects the EU Emissions Trading Scheme and the Common Agricultural Policy are having on the use of biomass in the EU with RD&D recommendations for each area.

Directive on the Promotion of Electricity produced from Renewable Energy Sources (RES-E Directive)

The RES-E Directive has driven most EU countries to set national targets for renewable electricity and establish specific feed-in tariffs for electricity from biomass. Finland is close to achieving its 31.5 per cent target but low electricity prices are hindering investment in new technologies and in small-scale CHP plants. In 2005, 6.2 per cent of the Netherlands's electricity came from renewable resources – mainly wind and additional biomass in co-firing – putting it on track to meet its 2010 target of 9 per cent. However, this depends whether licenses for large-scale co-firing facilities are approved and the recently reduced subsidies for electricity from renewables can cover the added costs of using biomass over fossil fuels. Germany looks set to beat its 2010 RES-E target of 12.5 per cent, thanks mainly to wind and hydro power. Biomass has huge potential to contribute to RES-E in Germany but high costs for untreated biomass, undeveloped use of biomass residues and complex legislation have hindered realization of some biomass power projects.

RD&D's main focus should be on improving efficiencies, improving and utilizing advanced co-firing technologies and reducing costs of utilization chains that have yet to be demonstrated, rather than new technology development. The most straightforward and immediate opportunity to increase the share of bioenergy in RES-E throughout Europe is co-firing. If conventional co-firing technologies are used, Germany is the only EU country that could meet its RES-E target for 2010, but if advanced technologies are employed, the majority of member states could meet their targets. RD&D efforts are needed to perfect advanced co-firing technologies like ultra super critical boilers and integrated gasification combined cycle (IGCC) plants. Research should also aim to increase the percentages, efficiencies and variety of feedstocks available for co-firing biomass with fossil fuels in Europe.

Biofuels Directive

The 2003 Biofuels Directive's voluntary target of a 5.75 per cent share of biofuels in the EU's total transport fuels by 2010, and later an obligation to achieve a 10 per cent share of biofuels by 2020, has spurred rapid production of liquid biofuels in many EU member states. But as late as 2005, the overall share of biofuels in the EU's total transportation fuels was just 1 per cent. To achieve the indicative target of 5.75 per cent by 2010, liquid biofuel consumption has to nearly double every year. The figure seems daunting, but it is possible: Germany achieved this scale of growth each year from 2000–2005.

A firm obligation has spurred enormous industry activity and political commitment in even the most reluctant countries. Finland, which initially set a biofuel target of just 0.1 per cent for 2005, has imposed an obligation law in 2008: that year Finland must achieve a minimum share of 2 per cent biofuels for transport, 4 per cent in 2009, and 5.75 per cent in 2010. The Netherlands has imposed a 2 per cent obligation by 2007 and its planned production capacity should exceed the 5.75 per cent obligation set for 2010.

The biggest challenge lies in the shift needed from first generation to second generation biofuels. Only second generation biofuels provide the means to meet these ambitious obligations while ensuring a sustainable system; An entirely new generation of production processes is required to be able to fulfil the EU goals of improving security of supply and reducing GHG emissions. RD&D should focus on getting efficient, environmentally sound, second generation biofuels to market by looking at both feedstock supply and production technology. Economics for existing feedstock supply chains, like wood and agricultural residues need improvement, while the whole production and supply chain for lignocellulosic crops needs refinement. Two types of production technologies for second generation biofuels have great potential and should be developed in parallel: ethanol from lignocellulosic biomass and the production of synthetic fuels.

Landfill Directive

Since the Landfill Directive's implementation in 1999, EU countries have responded very differently to meeting the directive's target of 65 per cent diversion of municipal solid waste from landfills by 2016.

The Netherlands embraced both recycling and waste-to-energy as part of its National Waste Management Act before the directive was even passed. A landfill tax doubling disposal costs resulted in a flurry of large, energy-from-waste plants being constructed across the country. The country will meet, or even exceed, the directive's targets. Germany tried a number of different approaches to municipal solid waste (MSW) diversion – incineration, alternative thermal treatment plants and mechanical-biological treatment – but all failed due to public opposition or poor technical or environmental performance. Facing a total ban on organic waste going to landfill in 2005, the Government ramped up incineration capacity by 50 per cent, enabling it to treat all residual MSW waste by 2007. Energy-from-waste via co-firing in power plants or boilers was common practice in Finland. But stricter air emissions standards introduced in the 2005 Waste Incineration Directive stopped this practice for some years, since installing new air pollution control equipment proved too expensive. The Government has released basic standards to meet the Landfill Directive targets, but a detailed strategy is lacking.

The Landfill Directive's 2016 limit of 35 per cent MSW to landfills can only be met by substantially increasing thermal treatment coupled with energy recovery in the EU. However there is no blanket solution: countries must choose the best solutions and technologies for their specific situations. RD&D to support the Landfill Directive targets should focus on devising strategies best suited to low population density and rural areas.

There are a number of important research priorities when examining the potential for energy-from-waste. Solid recovered fuel (SRF) from source separated waste presents a good opportunity, but research must determine whether SRF can reach a high enough standard for co-combustion or co-gasification in conventional furnaces. The potential of biogas from animal waste to meeting the directive's targets requires assessment. And crucially, an effective path for eco-efficient handling of residues, particularly from gas cleaning and biological processes, needs to be found.

EU Emissions Trading System

A model was developed to assess the impact of the EU Emissions Trading Scheme (EU-ETS) on the competitiveness of biomass as a fuel source in the EU. To maximise country-specific knowledge, the model examined the eight countries involved in Bioenergy NoE: France, Finland, Austria, the Netherlands, Germany, Poland, Sweden and the UK.

The EU-ETS has driven higher bioenergy use in some countries and barely touched bioenergy development in others. In Finland, the EU-ETS is central to national energy policy and its implementation has boosted biomass' competitiveness. While in Germany, the EU-ETS's impact is negligible as renewable energy use is driven mainly by state subsidies with emissions trading taking a backseat.

The European Emissions Trading Scheme can play an important role regarding investment decisions towards low carbon technologies like biomass, but the first phase of the scheme (2005–2007) had many shortcomings; incentives to invest in low emitting technologies need significant strengthening.

The impact of the EU-ETS on bioenergy development depends heavily on the weight it carries in national investment frameworks for biomass-to-energy. For example, if allowances are auctioned or sold at existing low prices, the EU-ETS would make biomass plants competitive with coal and gas in some EU countries, like Finland, stimulating construction of new bioenergy plants. While in others, like Austria, a higher CO_2 price – of over 50 €/tonne – is required to make biomass plants competitive.

To improve the role of the EU-ETS in supporting bioenergy use in Europe a number of RD&D priorities need to be addressed. A model to compare the economic competitiveness of biomass with other fossil fuels, focusing on the role of the National Allocation Plan's rules, revenue use and allocation methods is needed. The influence and relevance of the EU-ETS on biomass use in the context of other fiscal incentives like taxes, directives and support mechanisms should be assessed.

Common Agricultural Policy

Meeting the targets of the RES-E and Biofuels Directives warrants a dramatic, several-fold increase in the European production of agro-biomass for energy in the near future. The Common Agricultural Policy (CAP) is central in determining the availability, types and costs of agro-biomass to the energy sector.

There is a need to enforce a coherent set of policies to address the plethora of technical, economic and social barriers farmers face in agro-biomass production. In particular, support measures for energy crops are required across energy, environmental, economic and agricultural sectors.

Three main barriers exist in the development of agro-biomass for energy: high production costs, unproven sustainability and risk perception by farmers. Moreover, agro-biomass is not uniform across the EU. Solutions must be local and regional – and this is where RD&D focus is lacking. A tool to analyze regional production costs for all bioenergy chains should be developed alongside generic methods to assess regional field emissions. Life cycle analysis should be connected to land-use changes to better account for local impacts and territorial effects. Higher GHG-efficient bioenergy chains, like lignocellulosic feedstocks and by-products, should be prioritised over work on conventional crops like rapeseed methyl ester (RME). Similarly, research on second generation biofuels should be prioritized over direct production of first generation biofuels. Quantification of the costs of high risk perceptions by EU farmers towards energy crop production along with measures to reduce them can help overcome social barriers.

Boosting sustainable bioenergy in Europe: RD&D priorities for EU27

Building sustainable production pathways and addressing competition with food products is crucial to developing environmentally-sound biofuels and heat and power production. In January 2008, the EC proposed biofuel sustainability criteria, including minimum criteria for the greenhouse gas performance of biofuels, binding criteria for biodiversity and bans on certain types of land use changes. Meeting these criteria requires significant technology development in order to introduce a new generation of biofuels and feedstocks and this is where the thrust of scientific RD&D in Europe should be directed.

Bioenergy is a topic that cuts across many research fields: forestry, agriculture, heat and power, transport fuels and renewable chemicals. There are a number of EU-wide efforts and bodies setting research agendas in their fields – but to get a holistic picture of bioenergy's impacts and potential – it is important for these bodies to talk to one another. In this vein, Bioenergy NoE advocates stronger communication and co-operation among various EU-wide projects and initiatives focusing on bioenergy development.

European directives are crucial for creating bioenergy business. On-the-ground implementation of the directives in various EU countries helps pinpoint short and long-term RD&D priorities that, if addressed, can spur a sustainable increase in bioenergy in the EU. A number of the RD&D needs flagged in this study are pan-European and require immediate, co-ordinated action by research and industry if bioenergy is to make a substantial, sustainable contribution to the EU's renewable energy requirements in the near future. Research institutes in the bioenergy field would be wise to set research agendas to match the priorities identified.

Preface

This report is the result of a series of studies carried out by different working groups in the Bioenergy Network of Excellence (Bioenergy NoE) from 2006–2007. Major EU directives and policies affecting bioenergy were analysed to identify major research priorities, both to share with the EU scientific community and to direct Bioenergy NoE's own work.

Bioenergy NoE sees its role in the EU research community on two fronts:

- primarily collaboration in RD&D for bioenergy production and utilisation technologies both within the NoE and third parties, and
- secondly as a facilitator on the research policy front, by participating in wider EU initiatives, like Technology Platforms, ERANET-actions, and in the work of national interest groups.

Helping to improve and co-ordinate energy research policy is critical, because while measures to fight global warming are in urgent demand, much could be done to improve consensus on measures to spread the implementation of best national practises EU wide. This report is part of that effort.

Formally titled "Overcoming Barriers to Bioenergy" and sponsored by EC DG Research (SES6-CT-2003-502788), Bioenergy NoE is a partnership of eight leading bioenergy institutes that are integrating their expertise and activities to foster excellence in European bioenergy RD&D. The goal is to build a Virtual Bioenergy Research and Development Centre that will spearhead the development of a competitive bioenergy market in Europe. The institutes involved in Bioenergy NoE are co-ordinator, VTT Technical Research Centre of Finland (VTT) and partners Joanneum Research (JR), the Energy Research Centre of the Netherlands (ECN), Forschungszentrum Karlsruhe (FZK), the International Institute for Industrial Environmental Economics (IIIEE), Aston University (AU), the Institute for Fuels and Renewable Energy (IPiEO/EC BREC) and the National Institute for Agricultural Research (INRA). The authors are grateful for all efforts and inputs provided by the NoE researchers, Work Package leaders and Board members.

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Espoo, June 2008

Authors

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1. Bioenergy in 2020: Can it meet the EU targets?

In March 2007, following recommendations from the EC's *Renewable Energy Road Map* [1], the EU Parliament signed up to a binding target to source 20 per cent of its total energy from renewables by 2020. The Road Map provides a realistic path to achieving the target – but only if all Member states significantly boost their renewable energy production in the electricity, transport and heating and cooling sectors. The report hones in on bioenergy's contribution to reaching the 20 per cent target, indicating just how much it could contribute over the next decade.

In 2005, biomass contributed 70 Terawatt hours (TWh) electricity – or nearly half of the EU's non-hydro, renewable electricity. The electricity sector is well ahead of the transport and heating sectors in utilizing renewable energy. The Road Map estimates renewable electricity will reach 19 per cent by 2010, nearly hitting the 21 per cent target set by the RES-E Directive. By 2020, 34 per cent of overall electricity consumption could come from renewables. Of this, biomass could contribute about 300 TWh, mainly from solid biomass, followed by biogas, with biowaste providing the remainder.

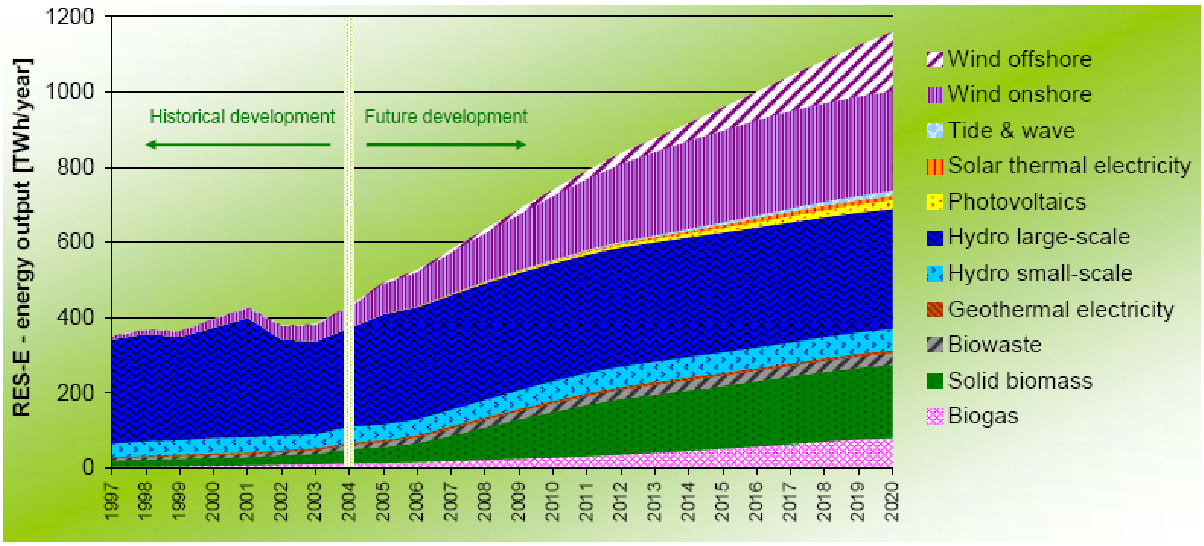

Figure 1. Production of renewable electricity in the EU by 2020 according to the Renewable Energy Road Map [1].

The heating and cooling sector accounts for nearly half of Europe's overall energy consumption, but renewable energy only powers 9 per cent of this often overlooked sector. Biomass will be the main contributor in raising renewable energy levels in the sector, with use expected to double by 2020, according to the Renewable Energy Road Map (Figure 2). Biomass will remain the dominant source of renewable heat in the long term.

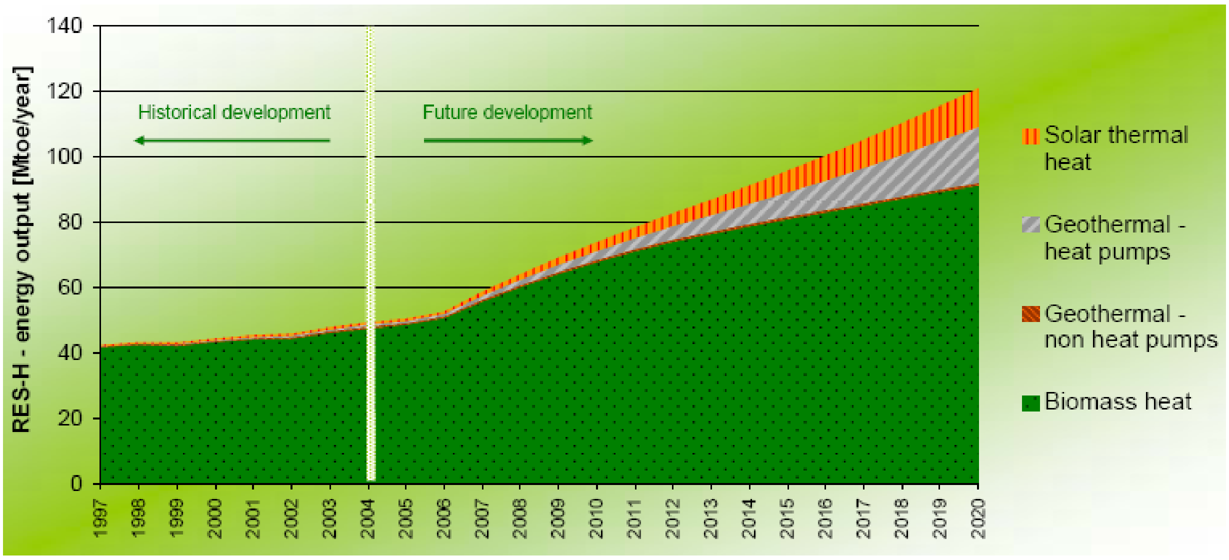

Figure 2. Production of renewable heating and cooling in the EU by 2020 according to the Renewable Energy Road Map [1].

The 2003 Biofuels Directive [2] set indicative targets for biofuels of 2 per cent by 2005 and 5.75 per cent by 2010. In 2007, worried that indicative targets were not providing strong enough incentives, the EU Parliament issued a mandatory target of 10 per cent by 2020. While the Road Map predicts biofuels will fall short of the 2010 target, it estimates that biofuels could exceed the 2020 target, accounting for 14 per cent of all transport fuels.

Meeting the 20 per cent target for renewable energy requires a large increase in biomass. The highest demand is expected to come from the heating sector, followed by biofuels. To meet the target, each member state must devise the right, individual formula for increasing renewable energy use. This is often a complex mix of tax incentives, feed-in tariffs, green certificates, public procurement policy, obligations on fuel suppliers and research technology and development.

This report outlines the status of individual directives and key policies impacting bioenergy. It highlights best practices and recommends RD&D priorities to help member states direct their efforts.

2. Needs and challenges in implementing key directives and policies

2.1 Directive on the promotion of electricity produced from renewable energy sources

2.1.1 Introduction

As a world leader in renewable energy technology, Europe plays a central role in understanding and building appropriate institutional support structures to promote a green electricity market. *The RES-E Directive* [3] is one of the legislative foundation stones upon which Europe's renewable energy sector is being built. Adopted in 2001, the RES-E Directive set a target for a 21 per cent share of electricity from renewables by 2010. Implementation of the directive by member states has been uneven, but much progress has been made: A comprehensive EU regulatory framework is in place and member states have adopted, and are working towards, national targets for green electricity. However, administrative and grid access barriers to the growth of renewable energy sources (RES) need to be removed at local, national and European levels.

A Bioenergy NoE working group analysed the implementation of the RES-E Directive in Finland, the Netherlands, and Germany focusing on electricity production from biomass.

This section begins with a look at how the RES-E Directive is being implemented in Finland, Germany and the Netherlands. The country reviews present the status of bioRES-E production, highlight trends from 1990–2005, and analyse the competitiveness of bioRES-E during this time. Technical and non-technical barriers encountered in implementing the RES-E Directive in each country are identified. Future scenarios for bioRES-E in various EU countries are outlined. A general overview of the directive's impact on the EU25 follows. Finally, the main RD&D priorities to increase electricity production from biomass are identified.

2.1.2 Impact of the RES-E Directive in Finland, Germany and the Netherlands

2.1.2.1 Finland

Finland's indicative target for the share of electricity produced from renewable energy sources is 31.5 per cent of gross domestic energy consumption by 2010 (Figure 3). Depending on hydropower production, this share has varied between 24 and 30 per cent in recent years. In years with low precipitation, it is impossible for Finland to reach the

31.5 per cent target by 2010. One of the main barriers to increased use of biomass in power production is low electricity prices. Despite recent increases, the Finnish price level in the grid remains among the lowest in Europe. Large investments in new technologies with high power-to-heat ratios and high specific investments are needed to boost biomass for electricity, but with such low profit expectations, this is not happening. Low electricity prices have also hindered investments on small-scale CHP plants. A large forest industry highly dependent on energy from wood is another major factor influencing bioRES-E production; Nearly 80 per cent of the energy from wood in Finland is generated and used in the forest sector.

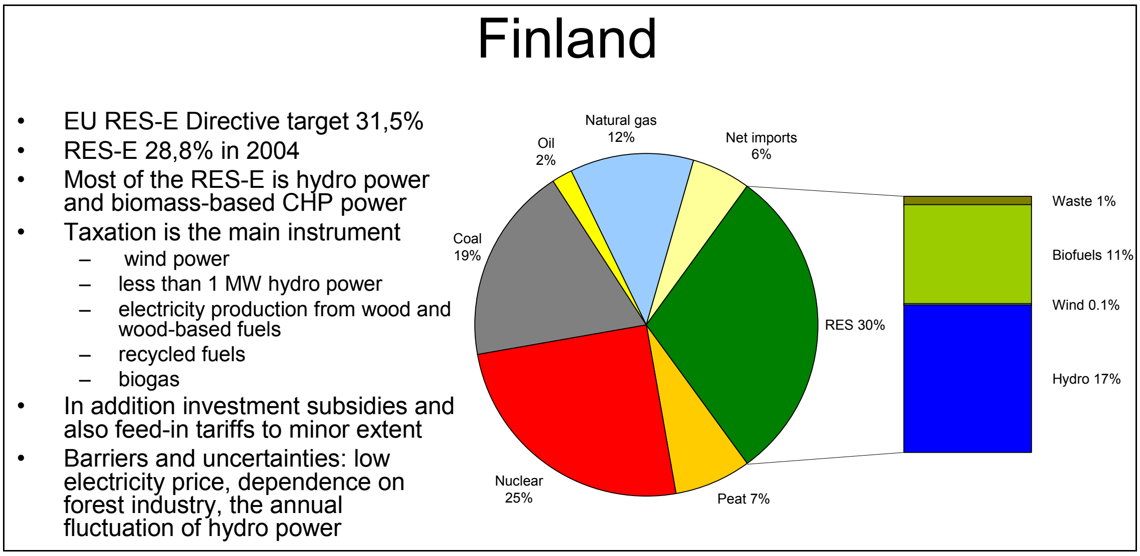

Figure 3. RES-E situation in Finland (modified from the reference 4).

The future potential of bioenergy was estimated according to the availability and costs of different biomass feedstocks in each region. Estimates for the feasible, large-scale production of heat, electricity and biofuels are based on reasonable transportation distances of feedstock, district and process heat loads, and existing heating and power plant capacity. Estimates of small-scale bioenergy use are based on statistical data on existing heating systems and their energy sources.

The additional availability of feedstock was estimated for two cost levels (Figure 4). The first uses the present price of fossil fuels, taxes and subsidies; the second nearly doubles the fuel costs. Wood fuels account for over half of the additional biomass feedstock, the remainder being agrobiomass and biowaste. The study also looks at upgrading the current use of feedstock by processes like drying and flue gas condensing. Additional availability of peat is also projected because peat covers anywhere from 30–70 per cent of the fuel demand of boilers over 20 Megawatt thermal (MW_{th}) in Finland.

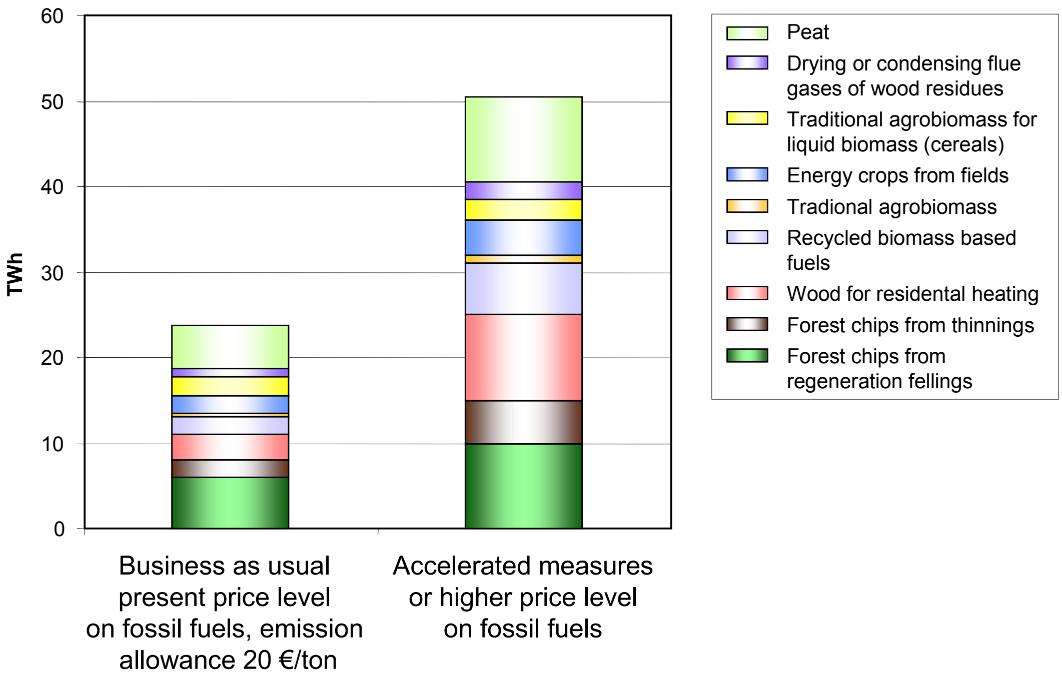

Figure 4. Additional availability of biomass in two scenarios in Finland by 2020 [27].

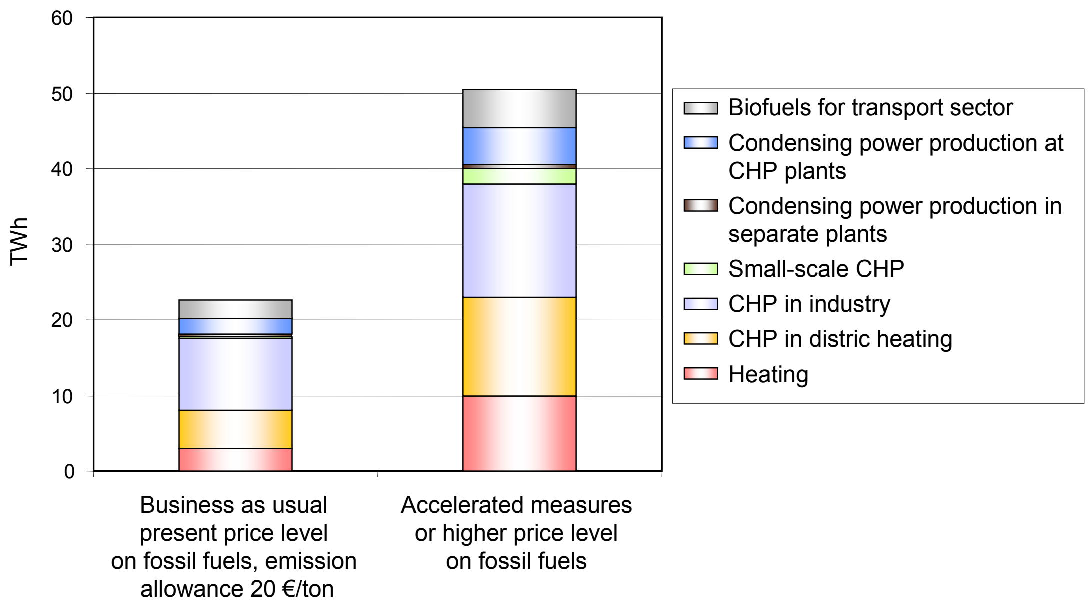

Figure 5. Additional use of bioenergy in different sectors in two scenarios in Finland by 2020 [27].

Allocating biomass for large-scale production of heat, electricity and biofuels was carried out plant-by-plant because heat loads limit new plant design and the technology of existing plants limits the share of different types of biomass that can be co-fired (Figure 5). Large-scale, combined heat and power plants were deemed able to pay the highest price for forest chips, biowaste and agricultural crops and residues, but a significant share of sawmill residues (bark and sawdust) were estimated to be used for pellet production and small-scale heating. Small-scale CHP is comprised of tens of plants, but their fuel demand will remain modest, even in the higher fossil fuel price scenario.

2.1.2.2 Germany

Germany has a target of a 12.5 per cent renewable energy share of total electricity consumption (see Figure 6). Using conventional technologies, the share of renewable energy sources in gross electricity consumption could rise from 10.2 per cent in 2005 to about 14 per cent in 2010. However, realizing some biomass power projects is improbable due to high costs, undeveloped use of residues and complex legislation. Only a small part of the country's technical power generation potential is currently exploited.

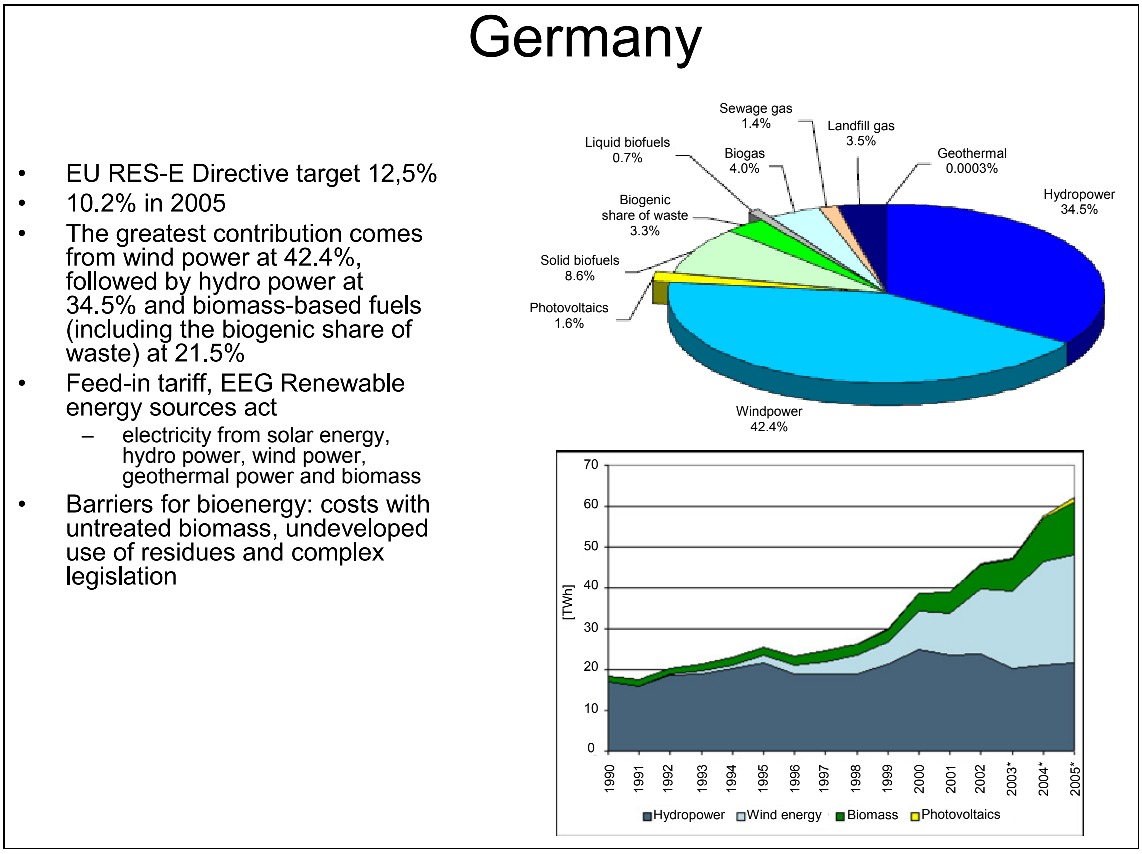

Figure 6. RES-E situation in Germany (modified from the reference 5).

Germany's high potential for RES-E production is clearly illustrated by looking at the estimate for bioRES-E using advanced technologies; by 2010 its RES-E use could far outpace both Finland and the Netherlands (Figure 7). Using conventional technologies, the RES-E targets will only be achieved in Germany. According to this estimate, Germany has huge potential for using advanced co-firing technologies. However, these estimates only evaluate technological potential; assessments of biomass resource potentials and economic evaluations of investments are not included.

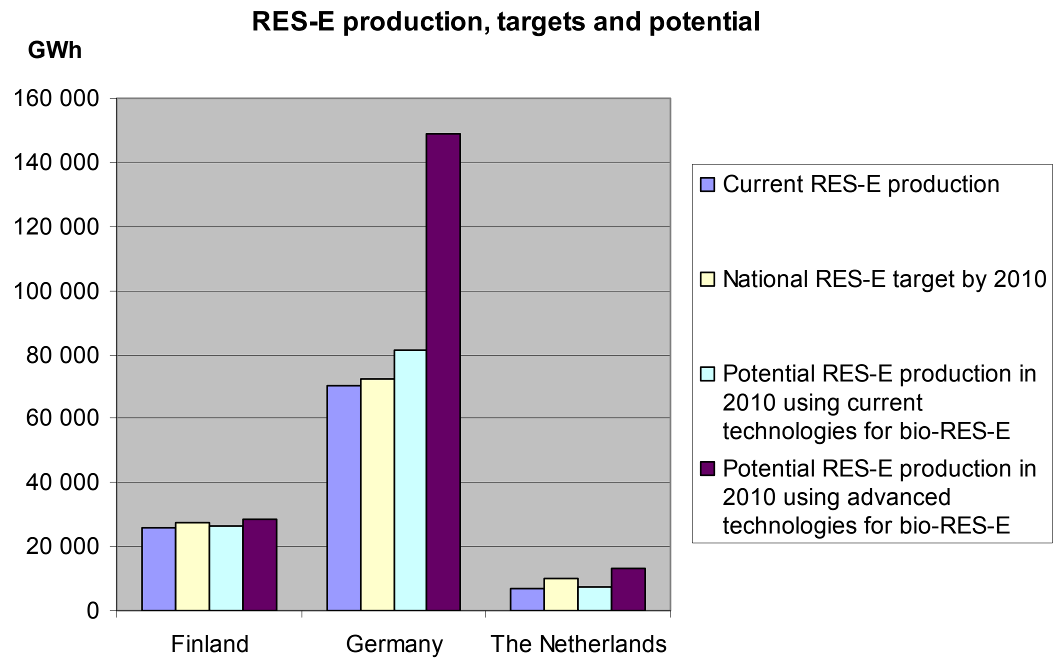

Figure 7. Current production of electricity based on renewable energy sources, national policy targets for RES-E and RES-E potential in 2010 in Finland, Germany and the Netherlands [6, 7].

2.1.2.3 The Netherlands

Electricity production from renewable energy sources in the Netherlands has increased significantly in recent years, rising from 2.5 per cent in 2000 to 6.2 per cent in 2005 (Figure 8). Although many small-scale bioenergy projects were initiated, most of the growth came from wind energy and biomass co-firing in large power plants. Current trends put the country on track meet its 9 per cent RES-E target for 2010. But there are a number of roadblocks. Large-scale co-firing installations are essential to meeting the target. While the number of planned projects is sufficient, licences for some installations are being delayed. The recent reduction of MEP Subsidy Scheme (MEP = Environmental quality of electricity production) subsidy levels – the national subsidy for RES-E production in the Netherlands – is also a concern, as it's unclear whether lower subsidies can keep biomass competitive with conventional fossil fuels. One recent study concluded that importing biomass would no longer be profitable at the lower MEP subsidy level. So while prospects look good, bioRES-E in the Netherlands remains highly vulnerable to market changes.

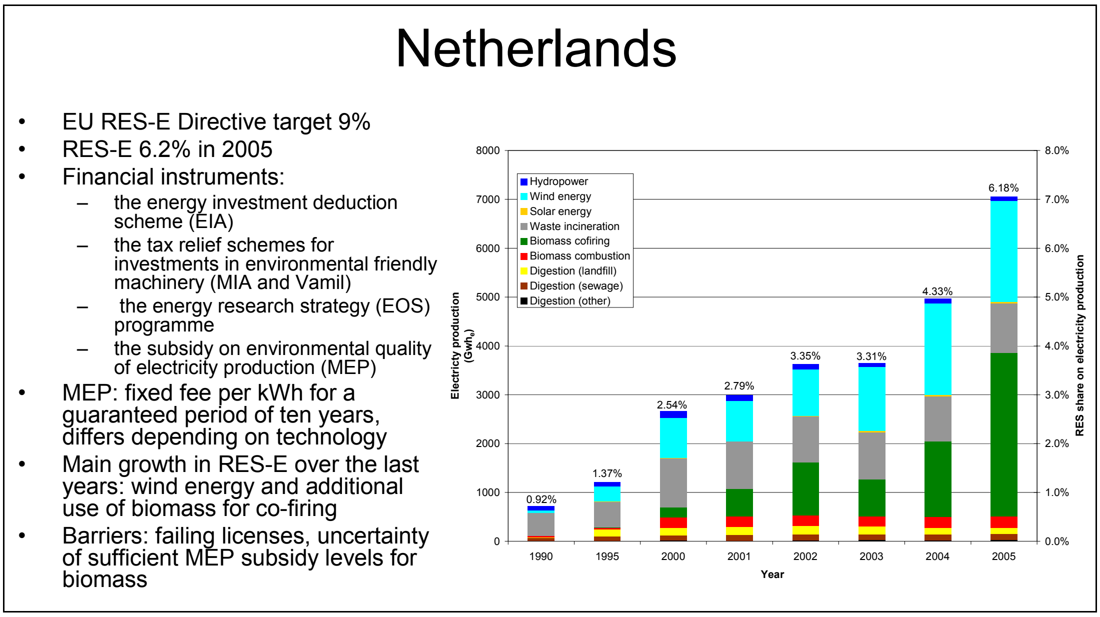

Figure 8. RES-E situation in the Netherlands.

2.1.3 The big picture: RES-E production and use in the EU

The EC's *Renewable Energy Road Map* [1] estimates that, at best, EU countries can reach 19 per cent of electricity from RES by 2010 – falling short of the 21 per cent target. Figures 9 and 10 show the individual RES-E 2010 targets set for each member state and their progress in meeting these targets as of 2003 [8]. The "2010 RES-E" bar illustrates the RES-E shortage and indicates most member states need to substantially boost their share of renewable electricity to meet their targets.

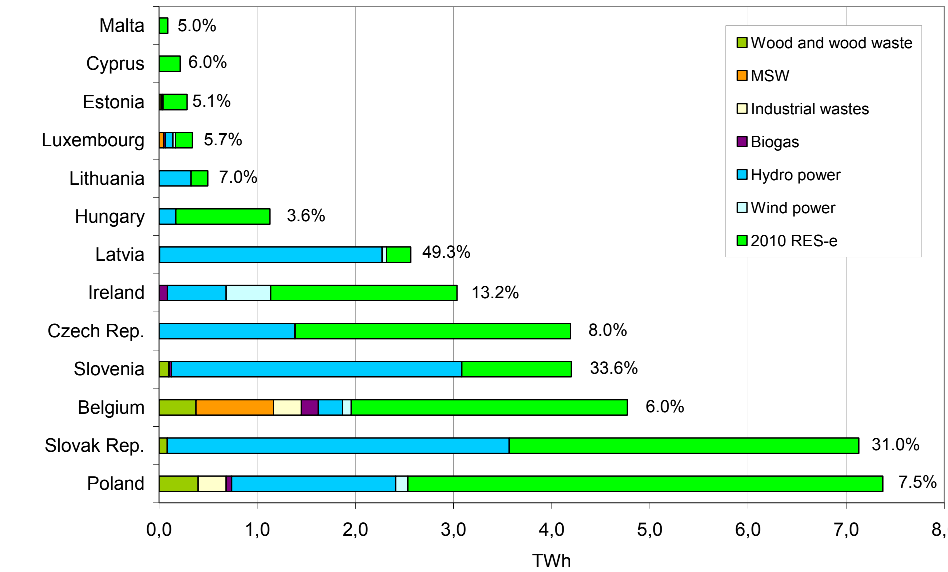

Figure 9. Indicative RES-E targets and the situation in 2003, 1 of 2 [8, 4].

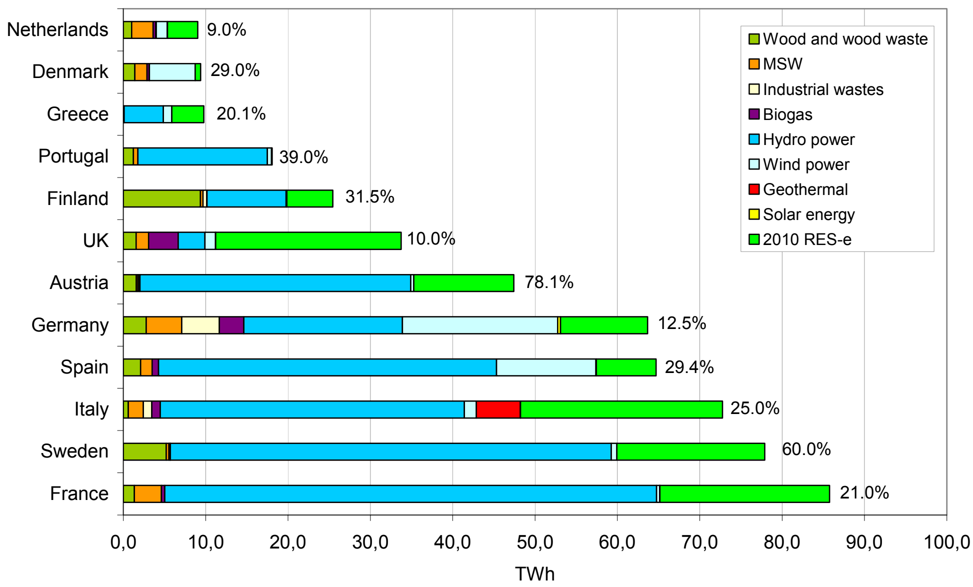

Figure 10. Indicative RES-E targets and the situation in 2003, 2 of 2 [8, 4].

The EU is already exploiting almost all of its hydropower potential, so future growth of RES-E production must come from wind, bioenergy and solar power – driving up demand for bioenergy. Most EU25 countries have special feed-in tariffs for electricity from biomass. In some countries feed-in tariffs are augmented by support for investments in bioenergy installations. The feed-in tariff is highest in Germany, up to 21.5 cents per kilowatt hour (kWh). The Netherlands's tariff is also higher than the EU25 average, at around 10 cents/kWh. Finland does not use green certificates or purchase obligations, choosing instead to promote RES-E via tax and investment subsidies.

Different national policies and incentives mean the value of bioRES-E varies from country to country (Figure 11). Countries with low electricity prices experience little investment in bioRES-E due to low profit expectations. For example, the internal rate of return (IRR) for bioRES-E production using four different technologies in Finland, Germany and the Netherlands is compared in Figure 12. Diverse feed-in tariffs also distort the market and are big drivers of international biomass trade.

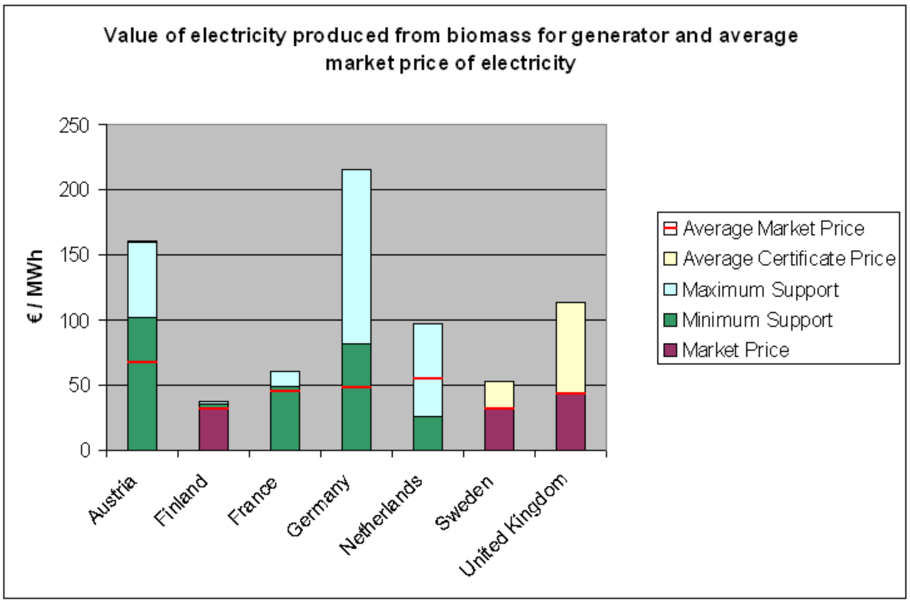

Figure 11. Value of the electricity produced from biomass for the grid in seven EU countries, €/MWh[1].

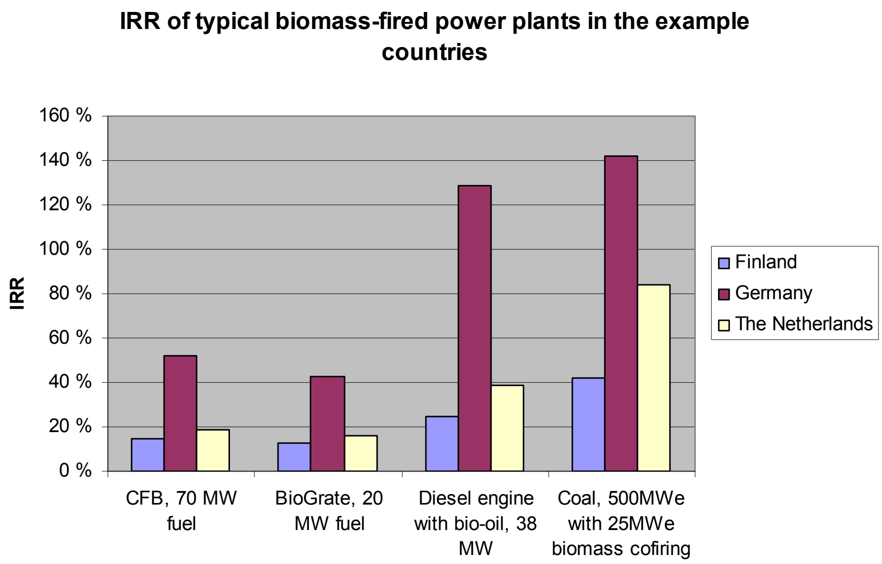

Figure 12. Internal rate of return (IRR) of some biomass-fired power plants in Finland, Germany, and the Netherlands.

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1 In the example countries the different combinations of feed-in tariffs, tax refunds, green certificates and quota obligations are used. The amount of the support depends on e.g. the type of biomass fuel used and the size of installation. The minimum support is the minimum amount of support a bioelectricity producer receives in a certain country and respectively the maximum support is the maximum amount of support a bioelectricity producer can receive. Certificate prices are estimated from average stock electricity prices. Minimum price of certificate depends on the year and approaches zero in time. The theoretical maximum price for certificates exists as the buyout price. Market prices are estimated from average regional electricity stock market prices as well.

The share of bioRES-E within the *EU Emissions Trading Scheme (EU-ETS)* [9, 10] differs considerably among member states, especially when biogenic waste is excluded. Finland's major share of biomass is used in large-scale CHP production within the emission trade sector. On the contrary, Germany uses much of its biomass in small-scale plants that are not included in the emissions trading scheme. Feed-in tariffs determine the market price for biomass trade in Germany, while in Finland the price of emission allowances and coal significantly influenced the cost of biomass-based fuels in the first phase of the EU-ETS, from 2005–2007. Many countries have set feed-in tariffs for RES-E outside the emission trade sector at levels corresponding to 50–100 € per tonne (Table 1). In these countries, limited biomass resources will largely be used outside the emissions trading scheme.

Table 1. Policies promoting electricity production from biomass in EU25 countries [11].

Member State	Policies
Austria	Feed-in tariffs for solid biomass 8.9 cents/kWh (2004 data).
Belgium	Quota and tradable certificates.
Cyprus	Feed-in tariff of 6.3 cents/kWh, investment subsidies up to 40% of investments.
Czech Republic	Fixed feed-in tariff (15 years) or green bonus. Level unknown.
Denmark	Feed-in tariff for co-firing of wood/straw in CHP plants 3.5 cents/kWh.
Estonia	Feed-in tariff for all RES-e 5.2 cents/kWh.
Finland	Fiscal subsidies equivalent to feed-in tariffs of 0.42–0.69 cents/kWh.
France	Fixed feed-in tariffs of 4.5–5.7 cents/kWh for installations up to 12 MW (for 15 years).
Germany	Fixed feed-in tariffs of 3.9–21.5 cents/kWh (for 20 years).
Greece	Tax exemptions for investments up to 75%, investment subsidies up to 40%, interest subsidy up to 40%. Guaranteed feed-in tariff of 90% of existing tariff for 10 years.
Hungary	Currently in transition from feed-in tariffs to green certificate scheme (quota).
Ireland	Feed-in tariffs of 7.2 cents/kWh (2004 data).
Italy	Quota and tradable certificates.
Latvia	Quota and feed-in tariffs between 4.8–5.7 cents/kWh.
Lithuania	Feed-in tariff for biomass power plants 5.8 cents/kWh.
Luxembourg	Feed-in tariff of 2.5 cents/kWh.
Malta	No information available.
Netherlands	Investment tax deduction. Fixed feed-in tariffs of 2.9–9.7 cent/kWh (2004 data).
Poland	Quota obligation for producers, but hardly enforced.
Portugal	Fixed feed-in tariffs. Level not known.
Slovak Republic	Tax-break and investment subsidy.
Slovenia	Fixed feed-in tariffs of 10.0 centst/kWh (2004 data).
Spain	No information available.
Sweden	Quota and tradable certificates.
United Kingdom	Quota and renewables obligation certificates.

New, lucrative business opportunities are expected as bioenergy electricity markets grow. The EC's *Renewable Energy Road Map* [1] estimates biomass-based RES-E production could increase to 300 TWh (45 000 MW) by 2020. This would require about 25–30 € billion in investments in biomass or waste-fired power production over the next 15 years.

2.1.4 RD&D priorities for RES-E from biomass

A comprehensive EU regulatory framework is in place and member states have adopted national targets for green electricity consumption and are working towards them. Administrative and grid access barriers to the growth of RES use need to be removed at European, national and local levels. As the EU is already exploiting almost all of its hydropower, future growth of RES-E production will come from wind, bioenergy and solar power. This means that national policies deriving from the RES-E Directive are likely to increase the demand for bioenergy. Most EU25 countries have special feed-in tariffs for electricity from biomass. In some countries, feed-in tariffs are augmented by support for investments in bioenergy installations, in the form of grants or loans on favourable terms, for example.

In March 2007, the EC introduced legally binding targets to achieve 20 per cent of the EU's energy consumption from renewable sources by 2020. Meeting the 20 per cent target requires substantial growth in RES-E, especially from member states that have to date taken little action in this area.

Several short and long term RD&D priorities to reach the RES-E target in a sustainable, efficient manner were identified. Increasing biomass fuels for RES-E production requires raising the use of forest residues, waste derived fuels like solid recovered fuel (SRF), agricultural residues like straw, and annual crops in combined heat and power production (CHP) in the industrial and municipal sectors. Demonstration projects of co-firing of these lower grade fuels in large-scale CHP plants at high power-to-heat ratios should be pursued.

Research on biomass co-combustion in fluidised-bed boilers should mainly focus on large-scale CHP plants in the European pulp and paper and process industries. Co-firing biomass in existing fossil-fuel fired power plants is a straightforward way to increase renewable electricity generation. Currently, co-firing is mainly limited to the use of small percentages of clean biomass in conventional pulverised coal-fired power plants. To move beyond this, research should aim to fully exploit the prospects of co-firing using higher percentages of biomass, co-gasification and co-firing in advanced coal plants (ultra super critical boilers and IGCC plants) and indirect co-firing in natural gas fired plants.

Collaborative RES-E research by Bioenergy NoE partners will focus on the following areas in order to maximise existing expertise and target some of the pressing RD&D needs identified in this study:

- building reliable, sustainable fuel supply chains based on forest, agro and solid recovered fuels
- biomass co-firing in utility boilers and biomass-based CHP production in fluidised-bed and high efficiency grate boilers
- small-scale biomass-based electricity or CHP production
- gasification and pyrolysis-oil based diesel power plants, with higher efficiencies and power-to-heat ratios than traditional steam cycle systems
- effective and sustainable methods for gas cleaning and ash residue management.

2.2 Directive on the promotion of the use of biofuels or other renewable fuels for transport

2.2.1 Introduction

Beginning in 1990, a number of EU countries began demonstration projects with first generation liquid biofuels (ethanol and biodiesel). EU member states used the fuels differently: Some countries put first generation fuels on the market, others focused on developing second generation biofuels (biofuels that require RD&D before implementation is possible), and a number of countries took little or no action to develop biofuels for transport. It wasn’t until the years just before and after the EU introduced *The Directive on the promotion of the use of biofuels or other renewable fuels for transport* (2003/30/EC) [2] that biofuel use began taking off. The directive set indicative targets for the share of biofuels for transport: 2 per cent for 2005 and 5.75 per cent for 2010. As a result, between 2003 and 2005, biofuel use more than doubled in the EU (Figure 13). Despite this mini-boom, overall consumption of biofuels for transport is still relatively low: In 2005, the share of biofuels in the EU was a mere 1 per cent of the total consumption of transportation fuels.

To meet the EU’s indicative target for 2010, liquid biofuel consumption has to increase by about 50 per cent each year. This is only the beginning of an anticipated ramp up in liquid biofuels production in Europe. In March 2007, the European Parliament announced a compulsory target of 10 per cent biofuels for transport by 2020, providing sustainable supply chains and second generation technologies are in place. The European Biofuels Technology Platform stated in its *Vision Report* [12] that by 2030, liquid biofuels could make up 25 per cent of all road transportation fuels.

A Bioenergy NoE working group analysed the implementation of the EU Biofuels Directive in Finland, Germany and the Netherlands and determined RD&D priorities that if addressed, will help meet the directive’s targets while ensuring sustainable pathways.

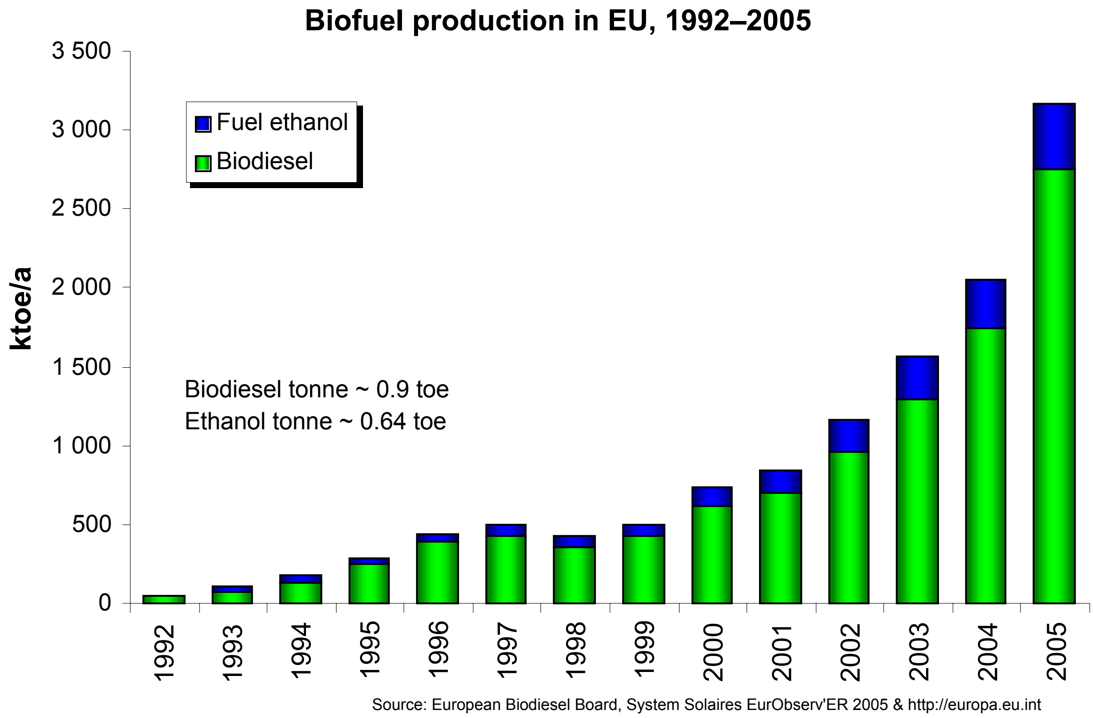

Figure 13. Growth of EU biofuel production [13].

2.2.2 Implementation of the Biofuels Directive in Finland, Germany and the Netherlands

In 2006, the International Energy Agency (IEA) projected that the global use of biofuels in transport will rise from 20 million tons oil equivalent (Mtoe) in 2005 to 92–147 Mtoe in 2030, depending on the scenario, making up between 4–7 per cent of world transport fuel demand. The 20 Mtoe used in 2005 is about 1 per cent of the total fuel use in road transportation globally. The IEA's business-as-usual (BAU) scenario projecting the growth of biofuels for transport predicts the highest increases will be in the USA, Europe and Brazil (Figure 14).

When the Biofuels Directive was announced, the three countries analysed in this study were at very different starting points. Germany was Europe's leading biodiesel producer in 2003, while biofuel consumption in Finland and the Netherlands was almost zero.

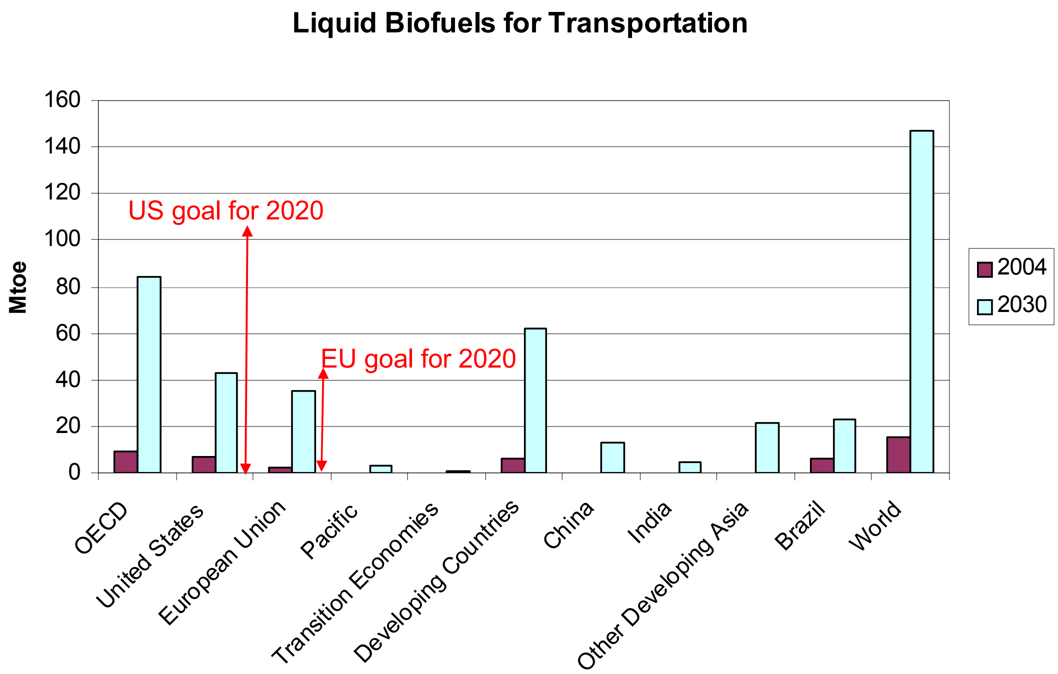

Figure 14. Increase of the use of biomass-based transport fuels according to IEA's BAU scenario [6].

2.2.2.1 Finland

Up until 2005, biofuel production in Finland was limited to small-scale demonstrations, primarily using bioethanol, along with small amounts of biodiesel and biogas. Today a variety of biofuel plants are in various stages of development. In 2006, Finland's Neste Oil reintroduced a gasoline blended mixed with either ethanol or ETBE. The following year, Neste Oil began producing a new synthetic biodiesel, NExBTL, with a capacity of 170 000 tonnes per year. The new synthetic biodiesel plant of same capacity is now under construction. St1 Biofuels has initiated small-scale ethanol production from sugar and starch containing wastes. Existing industrial investment decisions are expected to yield 9 per cent of biofuels in the country's transport fuels by 2010 if the produced biofuels are used in the Finnish fuel market. Foreign trade will play an important role for the industry.

Considering the country's low starting point (almost zero), its relatively limited possibilities for producing 1st generation biofuels, and existing use of most of its woody biomass for heat and power, Finland set a low target for 2005 of only 0.1 per cent. Project-based tax exemptions were granted in the past. Biogas is fully exempt from excise duty (and only a minor excise duty is valid for natural gas). A major turning point came in 2006, when the Finnish Government put together a national task force to conduct a detailed study into the possibilities for biofuel production in Finland. Based on the results of the study, the Parliament passed an obligation law in February 2007 to be imposed in 2008: that year Finland must achieve a minimum share of 2 per cent biofuels, 4 per cent in 2009, and 5.75 per cent in 2010. The law is deliberately flexible and based on market conditions; fuel brokers can blend bio-components flexibly when fulfilling the annual target volumes.

To meet the obligations, Finland, which has little agricultural land and stiff competition for wood resources, will need to import some biomass. About 2–3 per cent of transportation fuels can be produced from Finnish biomass in 2010 based on present cost levels and technologies. Development of new, advanced technologies could up the share to between 7–8 per cent by 2020, however, the biofuel industry will have to compete with power and heat markets for feedstock.

2.2.2.2 Germany

Germany is an EU pioneer in biodiesel production and has been an industry leader since 2000. Biodiesel accounts for the majority of biofuel use in Germany. About one third of the biodiesel is blended, another third is sold as pure biodiesel in refilling stations and the final third is used as pure biodiesel by fleet owners.

The German government fully supported the indicative target of 2 per cent share of liquid biofuels for 2005. Biofuels used for transportation or heating were fully exempt from excise duty. This spurred new growth and enabled Germany to surpass the Biofuel Directive's target. In 2006, biodiesel consumption in Germany hit 1.8 million tonnes, on the back of an average increase in biodiesel consumption of 47 per cent per year from 2000–2005. Apart from biodiesel, 196 000 tons of pure plant oil was used in Germany in 2005. In 2004, ethanol was introduced to the German market, primarily in the form of Ethyl Tertiary Butyl Ether (ETBE). The following year, Germany consumed 226 000 tonnes of bioethanol. These numbers pushed the country well past the indicative 2 per cent target for 2005 to 3.75 per cent.

However, the tax exemptions that made Germany Europe's top biodiesel producer are gradually being phased out. From the first of August 2006, the exemption was removed and a tax of 9 cents per litre was applied to biodiesel. This is part of a larger plan to equalize biodiesel and pure plant oil (PPO) with the tax on conventional diesel – to 45 cents per litre by 2012. However, a new biodiesel obligation gives the market some security; from 2007 onwards the minimum amount of biofuels in diesel must be 4.4 per cent and 2 per cent in gasoline, rising to 3 per cent in 2010. The total fuel mix has to contain at least 5.75 per cent biofuels in 2009 and 6 per cent in 2010. Fuels used to fulfil the obligation will no longer be exempted from tax.

Germany has 1.4 million hectares available for rapeseed cultivation for biofuel production. This area is sufficient to meet the 2010 target of 5.75 per cent. For bioethanol, unused or marginal agricultural land offers potential to produce up to 1.8 million m^3 of ethanol per year, or about 5 per cent of Germany's gasoline consumption. Including agricultural feedstock that is currently exported extends the potential ethanol production to 8 million m^3 or about 20 per cent of the country's gasoline consumption. For both the gasoline and diesel markets there is more than enough available feedstock to meet the 2010 target.

The capacity for biofuel production in Germany is continuing to expand at a rapid pace. In 2006, biofuel production climbed to 4.7 per cent of total transportation fuels. For biodiesel, an average increase in capacity of 50 per cent per year has been realised over the last 5 years, with a similar increase in 2006. Bioethanol production has also recently begun to take-off, with 900 000 m^3 of bioethanol produced in 2005.

2.2.2.3 The Netherlands

In the Netherlands, small-scale initiatives dominated the liquid biofuels scene. Fuels used were predominantly pure vegetable oil and some biodiesel. In 2006, Shell and BP started to blend biofuels and a number of new plants are in various stages of construction by both small and large companies. The potential is high: the total capacity under consideration for biodiesel production is about three times the amount of biodiesel the Netherlands needs to meet the 2010 target. For bioethanol, the production capacity under consideration is 120 per cent of the required amount for 2010.

In 2006, the Netherlands set a target to achieve a 2 per cent share of biofuels. The Government introduced a partial tax exemption to compensate for the higher costs of biofuels but limited it to a maximum of 2 per cent biofuels. From 2007 onwards, the Netherlands is enforcing an obligation of 2 per cent biofuel use with no tax exemption, rising to 5.75 per cent in 2010. The obligation applies to both the gasoline and diesel markets separately for all fuel suppliers, with some flexibility to shift between the two markets. Apart from the different markets, the obligation is macro – allowing for variations in biofuel shares across the country and over the year. Fuel suppliers are allowed to trade surpluses and shortages and a buy-out system is being considered. First generation biofuels limited ability to achieve greenhouse gas reductions is a major concern in the Netherlands and a system designed to stimulate more innovative, eco-efficient fuels is under consideration.

A summary of feedstock assessments in the Netherlands shows that depending on the suitability of waste streams for liquid biofuel production, between 29 and 90 per cent of the 2010 indicative EU target can be met by indigenous feedstock – or about 1.7 to 5.2 per cent of total transportation fuel consumption. The high end of the range given includes using feedstocks currently being used for food production and will only be possible if fuel producers can pay a higher price than food producers.

2.2.3 The big picture: Biofuel production pathways for the EU

With the current share of biofuels in the EU at about 1 per cent, the 5.75 per cent target for 2010 seems an enormous challenge. Biofuel use will have to double every year to meet the 2010 target. However it has been done: Germany achieved this pace from 2000–2005. Moreover, the shift from voluntary to obligatory targets caused an explosion of industrial activity in Finland and the Netherlands. The 2010 EU target is clearly ambitious, but not impossible.

Improvements in conversion technology can increase yields and decrease costs for first generation biofuels. Using residues to produce heat and power required for biofuel production can improve the environmental benefits of first generation biofuels. However, this doesn't increase the amount of biofuel the EU can produce. Prospects for increasing the yields of first generation biofuels in the conversion process are limited.

The major challenge facing the liquid biofuels industry is to increase the amount of biofuels that can be produced in an environmentally sound way. It is generally accepted that second generation biofuels offer prospects to do this. Finland launched a national development programme to produce and implement second generation biofuels in January 2007 with a total budget of 25 million €, which is expected to increase. Finland considers second generation technology a prerequisite to fully explore biofuel production from indigenous biomass sources. The Netherlands explicitly stated that a further increase in biofuels use after 2010 will only happen if second generation, or innovative biofuels are available. In its national strategy for renewable development Germany stated that second generation biomass-to-liquid fuels offer supplementary potential for biofuel production. Thus there is little doubt that second generation biofuels will play an important role in future.

As biofuel use increases, sustainable production and use of biofuels is becoming a central concern. In January 2008, the EC proposed biofuel sustainability criteria for the biofuels to be counted in the target of 10 percent. The scheme sets minimum criteria for the greenhouse gas performance of biofuels, binding criteria for biodiversity and bans certain types of land use changes.

The Finnish Ministry of Employment and the Economy and the Finnish Funding Agency for Technology and Innovation (Tekes), the country's main public funding organisation for research and development, have launched a programme to develop production technologies and introduce second generation biofuels. The emphasis is on pilot and demonstration projects using new production technologies. As a comparison to other sustainability criteria in the EU, the requirements for funded technologies are:

- Biofuels should be able to be blended in the existing fleet and distribution systems at high shares with fossil fuels.
- The use of biofuels must aim at significant greenhouse gas savings and cost effectiveness:
  - At least 30 per cent reduction in GHG emissions in the whole production chain and usage compared to fossil products.
  - Production costs of less than 65 cents/loe (liter oil equivalent) without tax support.
- The use of biofuels must aim to reduce exhaust gas emissions and external benefits related to reduction of exhaust gas emissions.
- Benefits are to be verified with European criteria for sustainable production of biofuels and greenhouse gas balance calculation methods.

The transition from first to second generation biofuels will have to occur gradually. First generation biofuels will dominate the market over the next 5–10 years. Gradually the initial second generation systems will enter the market, at first using wood and agricultural residues as feedstocks, and later using cultivated lignocellulosic energy crops. Finally, second generation biofuel plants will evolve from simple, single-output systems to more complex biorefineries co-producing high-value chemicals and products. This development path delineates a transition through different phases with plenty of options and no single solutions.

The transport sector stands to benefit from the introduction of new technologies for biofuel production, and considerable opportunities for new technologies could be seen in the transport sector. Meeting 60 per cent of the EU target for biofuels in 2010 with biofuel production via gasification and Fischer-Tropsch synthesis, would require 20–25 billion € in new investment. The EU goal for 2010 corresponds to biofuel use of about 20 Mtoe, while the goal for 2020 would more than double that to over 40 Mtoe. The USA is banking on an even bigger with plans to increase biofuel use to 100 Mtoe by 2020.

2.2.4 RD&D priorities for liquid biofuels

RD&D priorities are defined for both RD&D on feedstock supply and production technologies.

2.2.4.1 Feedstock supply

In the short to medium term, agricultural and wood residues will be the major feedstock for second generation biofuels. Typically this kind of feedstock is bulky resulting in high transportation costs. RD&D to design adequate pre-processing and advanced logistics systems is central to making the use of this bulky feedstock possible. Pre-processing can comprise relatively simple techniques like compaction and pelletisation and more complex techniques like pyrolysis.

The role of cultivated lignocellulosic energy crops is anticipated to grow. Limited research has identified hurdles in switching from traditional food crops to lignocellulosic crops. A detailed analysis of the problems is required, along with development of strategies to overcome them.

2.2.4.2 Production technology

Two major technology lines for second generation biofuels are under development: production of ethanol from lignocellulosic biomass and production of synthetic fuels, e.g. Fischer-Tropsch diesel, from bio-syngas. The first demonstration projects for these technology lines are underway but more are needed. Gaining experience with these kinds of systems is important because new and advanced systems should be developed in parallel.

For bioethanol, RD&D needs can be split into the thermochemical pre-treatment required to liberate the (hemi)cellulose and the biochemical conversion of (hemi)cellulose to ethanol. For thermochemical pre-treatment, research should focus on processes that minimise the use of chemicals and the formation of inhibitors and maximise the yield of (hemi)cellulose that can be biochemically converted to ethanol. For biochemical conversion, development of low cost enzymes, for (hemi)cellulose hydrolysis, and of yeasts or bacteria that can ferment C5 sugars is needed. Creating more efficient systems is also an important research priority: solutions need to be found to minimize water use; exploit and use inorganic residues; and co-produce high value products.

The synthetic fuel route consists of producing clean synthesis gas and later catalytic conversion to make the desired end products. Major RD&D topics for clean synthesis gas production are: pre-treatment before and/or after gasification; development of reliable high efficiency low cost gasification processes; and tailoring of gas clean-up processes for bio-syngas. Finding possibilities for environmentally benign uses of the inorganic residues from gasification is a challenge. In the short term, catalytic conversion processes developed for fossil fuel derived synthesis gas will be suitable, but

RD&D is needed to develop specific catalytic conversion processes for bio-syngas. On top of these primary routes there are several other technologies like pyrolysis oil hydrotreatment to refinery feed, spent cooking liquors processing alternatives in pulping industry, biogas and hydrogen production based on several routes etc.

Collaborative research into liquid biofuels for transport by Bioenergy NoE partners will focus on the following areas in order to maximise existing expertise and target some of the pressing RD&D needs identified in this study:

- Strategy development for the transition from traditional crops for first generation biofuels to lignocellulosic crops for second generation biofuels to ensure long-term feedstock supply
- Technology development for ethanol production from agricultural residues and woody biomass
- Technology development for synthesis gas production
- Sustainability assessment and GHG balance of second generation biofuels, with a particular focus on process residues
- Assessing prospects for synthetic natural gas from biomass for transportation and other uses.

2.3 Landfill Directive and waste-to-energy applications

2.3.1 Introduction

The EU's waste management sector is almost totally regulated by EU Directives. A core directive is the 1999 *Landfill Directive (99/31/EC)* [14], which sets standards for the final disposal of waste and aims to reduce dumping of organic or reactive waste in landfills. Other directives affecting biogenic waste are *the Framework Directive on Waste Disposal (75/442/EEC)* [15], which is under revision, and *the Waste Incineration Directive (2000/76/EC)* [16]. Article 5 of the Landfill Directive has the biggest impact on biomass and bioenergy use as it requires a reduction of biodegradable waste going to landfills. The targets are the reduction of biogenic waste from 1995 levels by:

- 25 per cent in 2006
- 50 per cent in 2009
- 65 per cent in 2016.

New accession countries have transitional periods for full adoption.

Figure 15 shows how EU countries disposed of their municipal solid waste (MSW) in 2002–2003. Two thirds of EU member states landfilled at least half of their MSW and most have a long way to go to achieving diversion targets. Meeting the Landfill Directive's limit of 35 per cent of MSW going to landfill in 2016 can only be accomplished by substantially increasing thermal treatment for inertisation coupled with energy recovery.

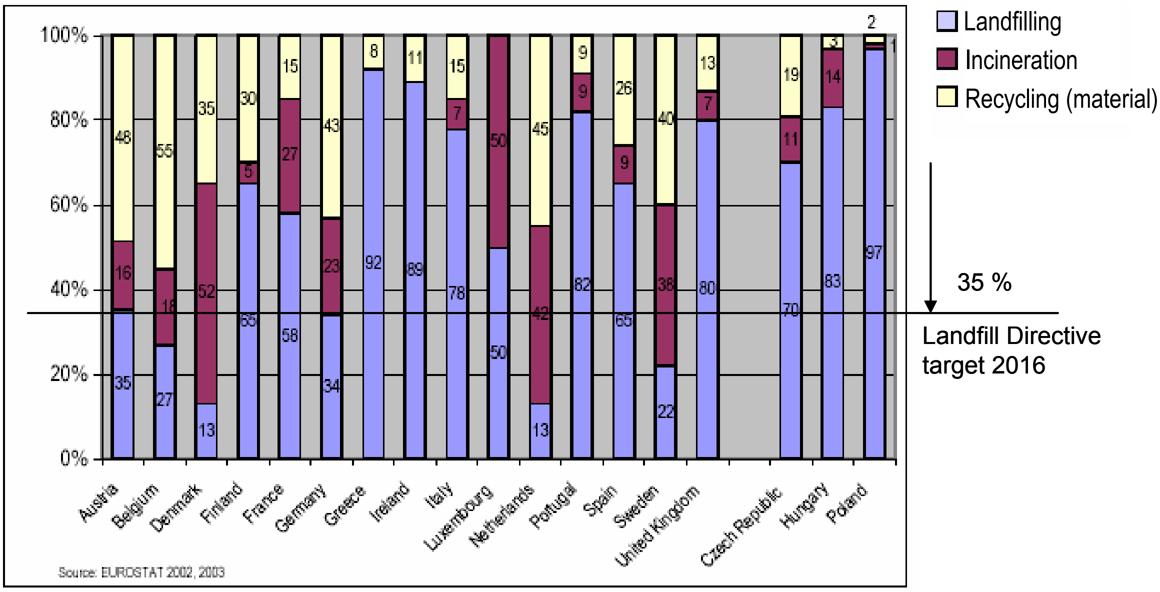

Figure 15. MSW management in selected EU countries [17].

A Bioenergy NoE working group analysed the implementation of the Landfill Directive and the EU's main regulations on waste management in Finland, Germany and the Netherlands to identify RD&D priorities that can increase the sustainable use of biogenic waste in Europe.

2.3.2 The big picture: Waste-to-energy potentials, costs and policy in EU27

Most of the EU's MSW is burnt in dedicated combustion facilities, usually in mass burners based on grate technology. Co-combustion of MSW in utility boilers and industrial furnaces plays an important role in some countries like Germany. The potential of MSW for primary energy production in the EU is high. Potential was calculated based on the amount of MSW available for waste-to-energy processes, its calorific value and the primary energy consumption in a given country (taken from the World Factbook). Two assumptions were made: a boiler efficiency of 70 per cent in the waste incineration plant; and the fraction of waste that is currently recycled or composted will not be available for energy recovery in future. This exercise provides only rough estimates of potential, but it gives an impression of the order of magnitude of MSW's substitution potential. The results are shown in Figure 16.

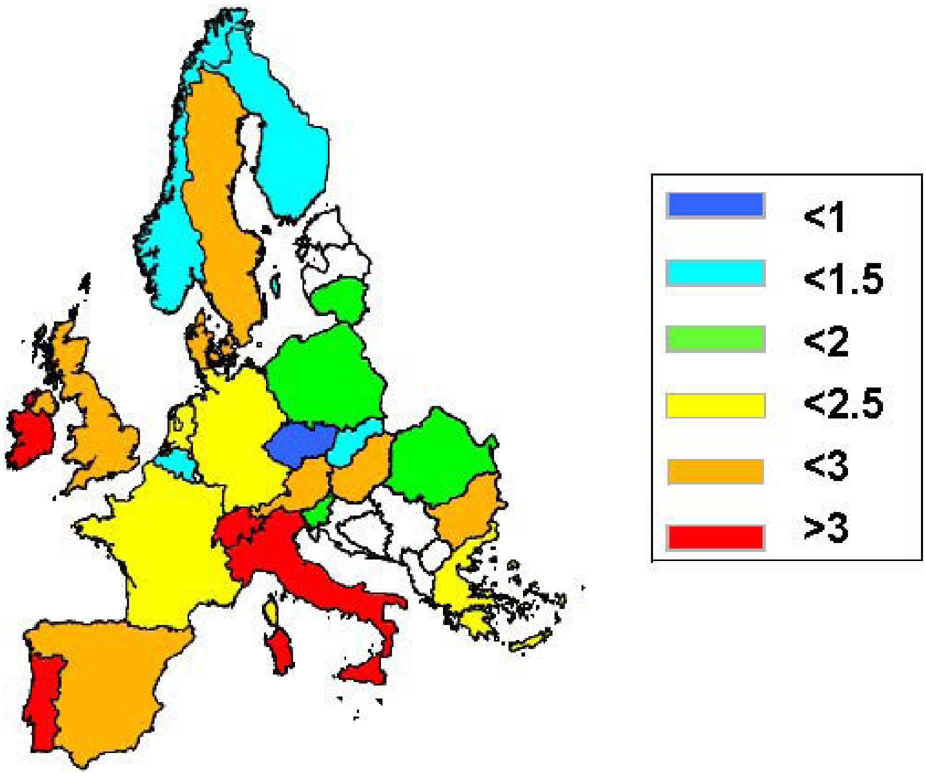

Figure 16. Potential of MSW to substitute primary energy for selected EU countries, %.

Today a number of densely populated, industrialised countries, among them Japan, Switzerland and Denmark, combust 50–80 per cent of their waste streams. Other states in Europe and America have lower combustion rates, but this is expected to increase due to the adoption of the principle of inertisation prior to disposal. European waste-to-energy plants currently thermally treat 50 million tonnes of waste each year. Plant numbers and locations are shown in Table 2.

Waste incineration costs (gate fees) vary significantly among European countries and even within a country. In Italy, gate fees are 70–90 € per tonne (2003), Sweden pays 30–60 € per tonne (2003) while German fees run at 80–200 € per tonne (2005) [18].

Table 2. Waste incineration in Europe, 2003 [19].

Country	**Number of waste incineration plants**	**Waste incinerated in 2003; Mt**	**Waste incinerated in 2003; t/inhabitant**	**Average plant size; t/a**
Austria	5	0.9	0.11	180 000
Belgium	17	1.6	0.15	90 000
Czech	3	0.4	0.04	130 000
Denmark	31	3.3	0.61	110 000
Finland	1	0.2	0.04	-
France	123	11.3	0.19	90 000
Germany	58	13.1	0.16	230 000
Hungary	1	0.2	0.02	-
Italy	49	3.5	0.06	70 000
Luxemburg	1	0.1	0.20	-
Netherlands	12	5.2	0.32	430 000
Norway	21	0.8	0.17	40 000
Poland	1	0.04	<0.01	-
Portugal	3	1.0	0.09	330 000
Spain	11	1.9	0.04	170 000
Sweden	28	3.1	0.34	110 000
Switzerland	29	3.0	0.40	100 000
UK	15	3.2	0.05	210 000

Waste incineration in Europe is predicted to increase significantly over the next five to ten years due to increasing waste volumes and tightening restrictions on waste going to landfill. In Germany, for example, the number of incineration plants grew from 58 in 2003, with a total capacity of 13.1 Mt, to 72 in 2007 with a total capacity of 17.7 Mt. A projection of waste incineration capacity in the EU in 2009 (Figure 17), shows the high rate of growth expected [20].

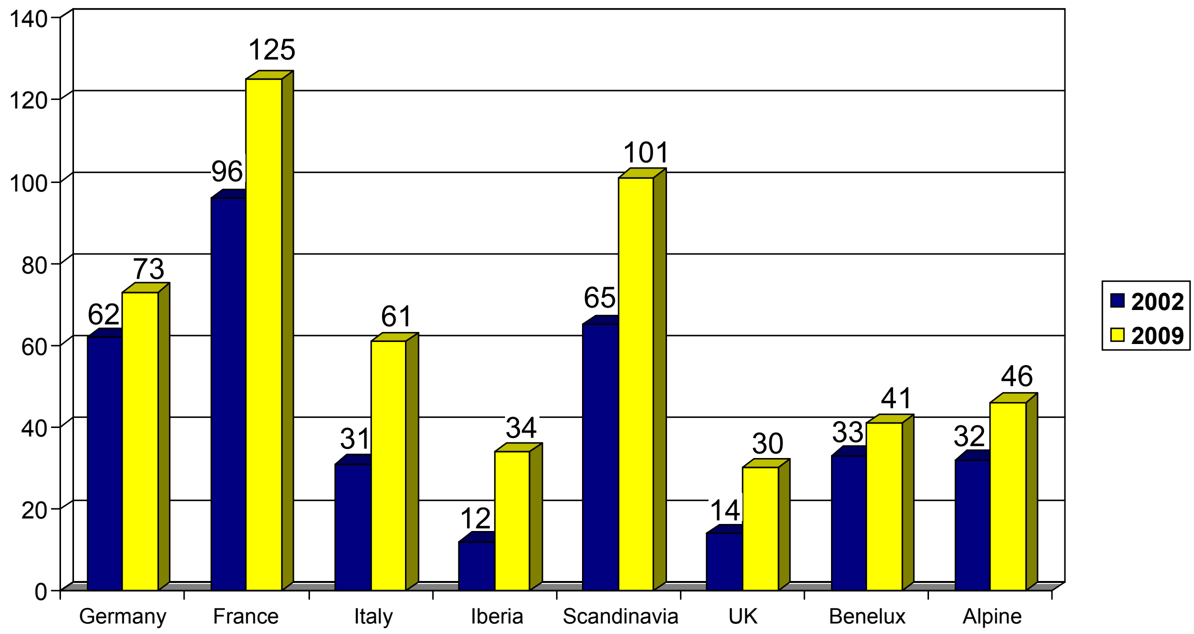

Figure 17. Number of waste-to-energy plants in Europe 2002, and projection figures for 2009.

The predominant waste-to-energy technology in the EU is grate incineration – or the European mass burner – which does not pre-treat waste. Every new waste incineration plant is equipped with an energy recovery system. In Central Europe, energy is mainly used for power alone, but combined heat and power is slowly being adopted. Colder Scandinavian countries favour heat utilisation. Industry and researchers across the EU are working to improve combustion technology and develop co-combustion systems to increase the power production efficiency of the plants.

An emerging market is Solid Recovered Fuel (SRF) produced from commercial and light industrial waste, to achieve a low-polluted fuel. The fuel is intended for mono-combustion in designated plants using grate and fluidised bed technologies and for co-combustion in power plants and industrial furnaces. As SRF quality improves, the market for fluidised bed systems will grow.

While the potential is high, waste-to-energy is contentious and its biogenic content is not universally acknowledged. The RES-E Directive considers the biodegradable fraction of waste as biomass and thus a renewable resource. But not all member states subscribe to this definition. In Germany, for instance, the biogenic origin of waste is not accepted and waste incineration plants are exempted from CO_2 trading. Yet in Sweden, 50 per cent of the power generated in waste incinerators is classified as bioenergy, and CO_2 certificates are allocated for the 50 per cent fossil fraction. The Netherlands regards 50 per cent of power from waste incineration as biogenic if the conversion efficiency exceeds 30 per cent, while Finland defines 60 per cent of the energy inventory of waste as biogenic.

There is no doubt that a significant fraction of the municipal solid waste stream is biogenic: food and garden waste, wood, paper and to a certain extent, textiles and diapers. Combining waste composition data with the share of biogenic energy per waste fraction provides a rough estimate of the share of biogenic energy in the waste. In most EU countries, the share of biogenic energy in waste is between 50 and 70 per cent. Countries that officially recognize the biogenic fraction benefit from tariffs or partial subsidization for waste-to-energy processes in line with their national renewable energy acts.

Apart from higher revenues, another benefit exists in acknowledging the biogenic fraction of MSW: the CO_2 emitted from the combustion of this fraction is deemed climate neutral. An estimate indicates that energy-from-waste processes could save significant amounts of CO_2 being emitted from incineration plants – as high as 2.5 per cent in some EU countries (Figure 18). These savings offer a significant contribution to meeting the Kyoto Protocol's emission reduction targets and the EU's 2020 renewable energy targets.

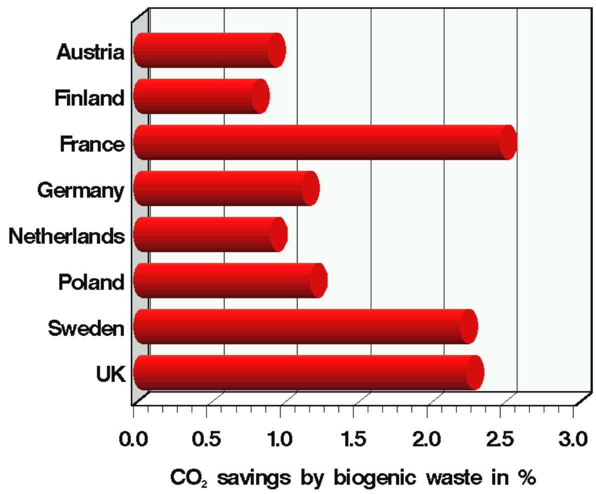

Figure 18. Potential of energy from waste for substitution of fossil CO_2 [21].

2.3.3 Implementation of the Landfill Directive in Finland, Germany and the Netherlands

The Landfill Directive has played a central role in changing the waste management practices in all three countries. However, implementation has been anything but uniform. The Netherlands and Germany are pioneers. Not only have both countries taken strong actions to comply with the targets of the Landfill Directive, their national initiatives in the early nineties formed the basis of this directive. These countries were also some of the earliest in the world to give recycling a high priority. The main difference between the German and Dutch approach is the importance given to waste-to-energy. In Finland, however, the Waste Incineration Directive almost stopped the country's long-time practice of co-firing biogenic waste in power plants or boilers due to tighter environmental regulations. The Government has set basic standards to meet the Directive's targets – but no detailed strategy is in place.

2.3.3.1 Finland

Finland's waste management situation tells a very different story of how the Directive affects national practice. Energy recovery from waste is an important pillar of the Finnish strategy. However, the sparsely populated country has few locations where pure energy recovery from waste makes economic sense so historically the method of choice was co-treatment and co-firing of solid recovered fuels in power plants or boilers. In 2005, the Waste Incineration Directive complicated this utilisation route after tighter air emission standards demanding expensive air pollution control systems made it too costly. Today, co-treatment, either by the direct addition of waste fuel or by using fuel gas from waste gasification, is only possible for very well separated and clean waste fractions, leaving the disposal of the more polluted residual waste fractions an unsolved problem. The Government released basic regulations to comply with the Landfill Directive, which include energy recovery, but a detailed strategy has yet to be devised.

Each of the three countries subsidizes biogenic waste differently, or not at all, leading to very different waste incineration costs, as is the case across the EU (Table 3). In the Netherlands, gate fees are 75–135 € per tonne while German fees run at 80–200 € per tonne. The average incineration cost in Germany is 174 € per tonne and varies between the federal states as shown in Figure 19 [22].

2.3.3.2 Germany

Strong opposition to waste incineration in Germany by NGOs, local interest groups, and to some extent, media and politicians, meant there was almost no enlargement of incineration capacity in the 1990s. Wide acceptance of the fundamentals of the German waste management strategy – prevention of disposal of reactive waste – was coupled with widespread belief that any measure apart from incineration should be applied. Germany turned to alternative thermal treatment processes like pyrolysis, gasification or combined processes. But after the failure of two full-scale projects – the 1999 the Siemens Thermal Recycling Process in Fürth and the 2004 the Thermoselect Process in Karlsruhe – all proposals for such processes were withdrawn.

The prevailing political and public preference was for mechanical-biological treatment and a great number of these plants were built. Later, the environmental quality of the plants came under fire and their residues failed to comply with the standards of the German Landfill Ordinance. The quality of the fuel fraction also came into question; High halogen and heavy metal content meant the fuel could not simply be burnt in utility boilers or industrial furnaces, but fell under the regime of the air emission regulation (17. BImSchV), making the strategy expensive and, in some cases, obsolete.

This situation only changed a few years ago when it became clear that continued failure to implement the Landfill Ordinance would mean a landfill ban of any organic waste starting in June 2005. Germany's incineration capacity soon doubled to 6 Mt. By 2007, Germany should have enough waste incinerators to treat all its residual MSW, but commercial and light industrial waste is another issue. Strong support exists for the production of SRF, which should be burnt in dedicated combustion plants equipped with air pollution control systems. SRF plants, which can also be fuelled with biomass, are an easier sell to the public who still harbour animosity toward waste incinerators. However combustion of SRF with high biogenic content runs the risk of fouling and deposition in combustion chambers and boilers due to its high alkali content.

2.3.3.3 The Netherlands

Dutch regulations made energy recovery an essential part of their National Waste Management Act in the early 1990s. This regulation, and the need for existing waste incinerators to be upgraded, led to a string of high capacity of state-of-the-art incinerators across the country. These plants even treat imported waste, mainly from Germany. A high landfill tax, which almost doubled the disposal costs, was the linchpin driving the rapid expansion of waste-to-energy facilities in the Netherlands.

Table 3. Landfill and gate fees in Germany, the Netherlands and Finland (2006).

	Germany	**the Netherlands**	**Finland**
Landfill cost incl. tax and VAT	70–150 €/t	110–130 €/t	av. 85 €/t (40–165 €/t)
Landfill tax	-	80 €/Mg	30 €/t
Gate fee for MSW incineration	av. 174 €/t (80–250 €/t)	av. 103 €/t (75–135 €/t)	
Gate fee for SRF co-combustion	35 100 €/t		-10–0 €/t
SRF production from industrial and commercial waste, gate fee	25–50 €/t		80–90 €/t

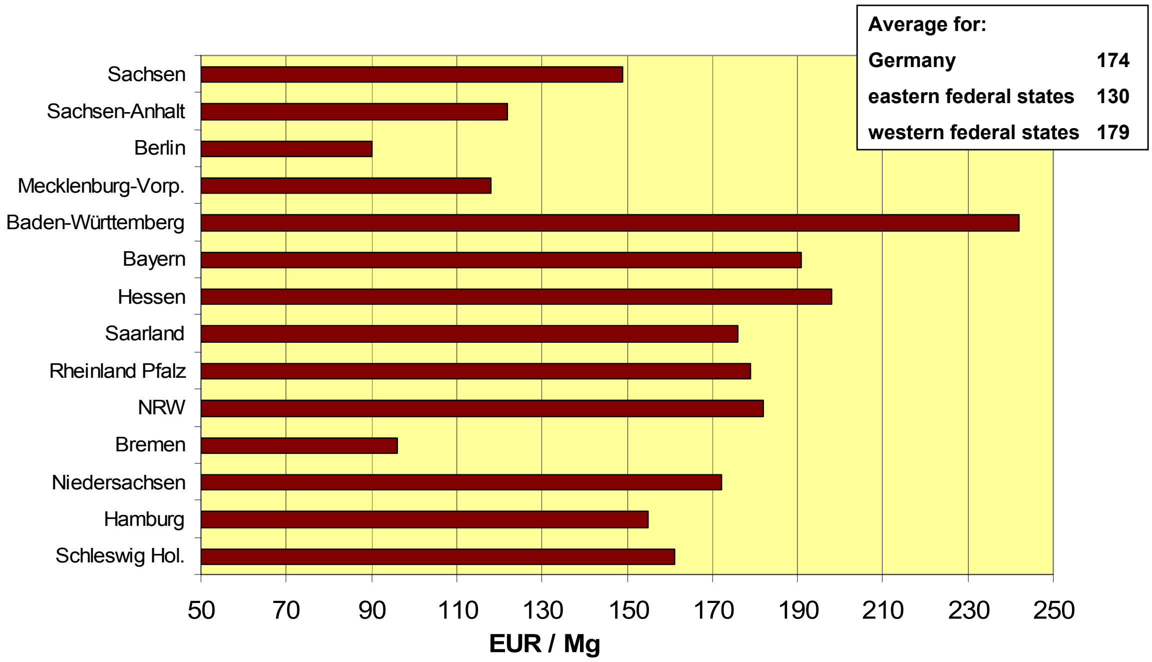

Figure 19. Incineration costs (gate fees) for MSW in federal states of Germany [22].

2.3.4 RD&D priorities for meeting the Landfill Directive targets

Adoption of the Landfill Directive by EU Member states varies from all-embracing implementation to near total inaction. Austria has already met the 2016 reduction target of 65 per cent, mainly through a high – 35 per cent – composting rate, with recycling, energy recovery, and landfill making up 20 per cent each. But questions remain as to whether the compost quality is high enough to be used and if this strategy is in line with the Landfill Directive's intention to establish an aftercare free waste disposal. The UK, on the other hand, is far from establishing any viable schedule to meet the targets of the Landfill Directive. Southern member states like Italy, Spain, and Portugal are expanding their waste-to-energy capacities, but at the same time struggling to find a use for the heat. Hot summers cancel out heat markets except for direct steam use in industrial processes, and it's been tough to establish a market for central cooling. Simply imposing a landfill tax seems a driver to increase energy recovery, however this was not the case for Germany where energy-from-waste expanded only through legal action.

Biogas could have an important role in future waste management systems, especially for rural areas. Theoretically, biogas production could become an efficient tool for wet organic waste, especially if the wet municipal solid waste fraction is be co-treated alongside agricultural residues, and eventually sewage sludge. A potential problem is the final use of the residues, which are usually composted, but better solutions may exist.

As the study shows, there is not a single recipe for waste management that can be applied to all EU countries. But to meet the Landfill Directive, more intense energy recovery can be expected in many member states. Five main obstacles need to be overcome, and EU RD&D resources should focus on tackling them:

- high costs of waste-to-energy systems
- lack of political and public acceptance
- northern countries will eventually face lower revenues for power
- southern countries lack a market for heat, preventing cheap CHP solutions
- lack of a convincing solution for final disposal of process residues, especially those from gas cleaning.

As a cautious conclusion, an increase in energy recovery from waste is expected in almost all EU countries that have not yet reached the Landfill Directive targets. There are many technologies on the market and every solution depends strongly on local conditions.

Collaborative research into biogenic waste for energy and renewable products by Bioenergy NoE partners will focus on the following areas in order to maximise existing expertise and target some of the pressing RD&D needs identified in this study:

- finding strategies best suited for low population density and mainly rural areas
- testing SRF produced from source separated waste to see if the quality is high enough for combustion or co-combustion and co-gasification in conventional furnaces
- evaluating the potential of biogas production in meeting the Landfill Directive targets
- designing methods for eco-efficient management of residues, particularly those from gas cleaning and biological processes.

The first three topics work together. For countries like Finland, which have a low population density but a well established heat and power market, 'clean' SRF is a promising option to dispose of most of the waste and comply with EU directives. More information is needed on the effects of SRF with high calorific value and/or with high biogenic content on the combustion process in conventional fluidised bed boilers, gasifiers and pyrolysers, grate systems and eventually in pulverised coal boilers and cement kilns.

Biogas production, which has strong potential for energy recovery from agricultural waste, needs more detailed investigation in terms of the applied technologies, their compliance with the Landfill Directive and their importance in the local energy supply system. Such an investigation could be supported by a case study comparing successful solutions in a highly industrialised EU member state, like Austria or Germany, and in a less industrialized country with a large, rural area like Poland.

The fourth topic – residue management – is fundamental not only for waste-to-energy systems but for biomass combustion. A major issue is the control and final destination of problem ingredients in gas cleaning residues: heavy metals and highly water soluble salts. For biomass combustion residues, more RD&D is needed to find out if nutrient recovery makes sense, especially if contaminated biomass is used. For biogas systems, RD&D is needed to find out if digestion residues could be used as fertilisers after composting if they are produced from a mix of wet organic waste, agricultural residues, and sewage sludge.

2.4 The EU Emissions Trading Scheme

2.4.1 Introduction

Ten thousand factories and plants currently participate in the *EU Emissions Trading Scheme (EU-ETS)*. Making up 40 per cent of Europe's carbon dioxide emissions, the plants involved include steel, paper, power, glass, brick, cement and oil refineries. The scheme is designed to reduce CO_2 consumption in the EU by setting individual carbon dioxide emission levels for energy-intensive plants through National Allocation Plans and allowing plants to buy and sell carbon credits to meet their targets. The EU-ETS works alongside two Kyoto Protocol mechanisms to expand its reach globally. EU countries can trade emission credits with other industrialized countries that have emission targets using the Joint Implementation Mechanism (JI) and with non-industrialized countries without emission targets through the Clean Development Mechanism (CDM). These mechanisms are designed to make emission trading as cheap as possible and encourage technology and project development in non-industrialized countries.

A Bioenergy NoE working group was setup to analyse the effects of the EU-ETS on the competitiveness of bioenergy in Europe. To take advantage of existing knowledge, the study looked at the eight countries involved in Bioenergy NoE: Germany, France, the Netherlands, UK, Poland, Sweden, Finland and Austria. The main thrust of the study was to develop a model to analyse the influence of the price of EU-ETS allowances on the competitiveness of bioenergy in the energy sector.

2.4.2 Impacts of EU-ETS on bioenergy in EU27

Based on previous IEA studies, a model was developed to make an initial assessment of the influence of the CO_2 price on investment decisions in new power plants and on possible fuel-switches in existing plants. While decisions regarding fuel-switching are based on the Short Run Marginal Costs (SRMC), investment decisions for new plants are based on the Long Run Marginal Costs (LRMC). The model analysed the competitiveness of biomass compared to other fuels using three reference plant sizes: coal 750 MW, gas 600 MW and biomass 14 MW.

The model calculated SRMC and LRMC depending on the CO_2 price, taking into account country-specific biomass prices. For SRMC, the model showed that in some countries, like Finland, where the biomass fuel price is low, biomass is a highly competitive fuel, even without the EU-ETS. While in a few countries, like Austria, a moderate CO_2 price (between 0 and 21 €) makes biomass the most competitive fuel in the short term (SRMC). In countries with high biomass fuel prices, a CO_2 price of up to 30 € per tonne is required to make biomass the cheapest option.

The LRMC results are highly country specific due to great variation in biomass fuel prices across the eight Member states. However, if the EU-ETS sets the right incentives, it can drive construction of new biomass plants. For example, if allowances are auctioned or sold at existing low prices, the EU-ETS would make biomass plants competitive with coal and gas in some EU countries, like Finland, stimulating construction of new bioenergy plants. While in others, like Austria, a higher CO_2 price – of over 50 €/tonne – is needed to make biomass plants economical (LRMC). In these countries, additional national incentives, like guaranteed feed-in tariffs, are needed to make biomass power plants competitive.

When considering the results of the short and long term modelling, it has to be noted that the model assesses competitiveness of biomass fuels at different CO_2 price levels. However, setting a firm price for CO_2 within the EU-ETS in order to make biomass competitive with other fossil fuels as an energy source is near impossible. CO_2 price levels will continue to fluctuate in future and national incentives for bioenergy are constantly changing. Member states willing to bank on EU-ETS to support greater use of biomass need to be willing to take risks.

The EU Emissions Trading Scheme has greatly impacted solid biomass use in many countries. In Finland, the EU-ETS has improved the competitiveness of bioenergy, and even with a relatively low CO_2 price, using wood for energy is cheaper than its primary use as raw material for the wood processing industry. This ramps up competition with the forest industry; the board industry has been the first to suffer because it competes for the same woody by-products as the energy industry.

Plants both inside and outside the EU-ETS have felt its impacts. Power plants in the scheme are more likely to increase solid biomass use or trading. While some plants outside the scheme, particularly those operating at less than 20 MW, are being pushed in the opposite direction. Putting a price on CO_2 emissions gives EU-ETS plants the capability to pay more for biomass fuels, and as a result, the price of solid biomass fuels tends to rise. The price increase could force smaller non-EU-ETS plants to switch from biomass to fossil fuels, offsetting some of the CO_2 savings achieved by the EU-ETS installations. It may be cheaper for example, if sawmills use peat or fossil fuels in their own boilers and sell their by-products to EU-ETS installations.

How much the EU-ETS impacts decision-making in a certain country depends on what types of financial incentives and support mechanisms for renewable energy already exist. In Germany, state subsidies greatly boost the renewable energy sector and the role of the EU-ETS is minor. But Finnish policy relies heavily on the EU-ETS to drive biomass use, lessening the impact of other subsidies.

So far, activities with industrial countries outside the EU27 via the Joint Implementation Mechanism has been negligible due to high administration costs, especially for smaller installations, and perceived higher risk than traditional investments. However, Eastern European countries have potential to develop JI projects, particularly as the EC has introduced proposals for much tighter legislation, including a clamp down on emission levels for Phase II of the EU-ETS beginning January 2008.

2.4.3 Comments on improving the EU-ETS

The EU Emissions Trading Scheme plays an important role in investment decisions towards low carbon technologies such as biomass, even if the Phase I design of the scheme has many shortcomings regarding the incentives to invest in low emitting technologies. By putting a price on CO_2 emissions the EU-ETS increases the competitiveness of low carbon fuels. The scheme deems biomass carbon neutral, meaning it has no additional CO_2 costs, giving it potential to increase biomass use, particularly in the energy sector.

In Phase I (2005–2007), free emission allowances were over-allocated by some member states. This spurred a rapid and continuous fall of CO_2 prices from September 2006 to February 2007, when the price fell to less than 2 € per tonne and has since flattened to nearly zero.

In Finland, the price drop has left small bioenergy companies in the cold. Because the anticipated price of emission allowances for 2008 has stayed on the level of 20 € per tonne, energy companies are postponing deliveries of biomass fuels until after January 1, 2008, when they stand to gain 8–10 € per MWh by replacing coal or peat with biomass. Small mobile chipping, crushing and logistics businesses have suffered significant economic losses. Alarmingly, such huge demand variations for biomass fuels lead investors to assume that the bioenergy industry is only viable for large businesses and discourages smaller companies from entering the sector. Clearly, the initial design of the EU-ETS requires improvement regarding the transition to low emitting energy sources.

Cement clinker, lime, glass and ceramics production as well as steel melting are all included in the EU-ETS. An increase in the CO_2 price would spur these sectors to become huge potential biomass users in future. For example, steel melting and cement clinker production could use biogenic waste and other low quality biomass as an energy source, or partly as raw material, for their processes. Oil refineries could also replace a portion of their fossil fuels with biomass.

Currently in the EU-ETS, about 90 per cent of CO_2 allowances are allocated free of charge, usually based on benchmarks. An incentive to invest in low carbon technologies only arises if the benchmarks are low enough to force plants to either buy CO_2 credits or reduce their emissions. In some countries, such as Germany, this is currently not the case, as fuel specific benchmarks were set too high, resulting in a large share of free allocations for plants using high emitting technologies.

The current allocation methodology for existing installations in the EU-ETS is mainly based on grandfathering – where emission limits are set based on the plant's historical emissions and the carbon credits are usually given away for free. While auctioning, whereby the government sells a percentage of its allocation allowances to installations, is only allowed to a very small extent. Introducing a higher share of auctioning would result in higher revenue that could be used by the EU to improve the investment framework for renewable energy sources, such as biomass.

2.4.4 RD&D Priorities for EU-ETS

Some of the most pressing RD&D needs to improve the EU-ETS's role in supporting bioenergy use in Europe are identified below. Collaborative research by Bioenergy NoE partners will focus on these areas:

- Develop a model to compare the competitiveness of biomass with other fossil fuels, focusing on the role of the National Allocation Plan's rules, revenue use and allocation methods

- Analysis of the influence and relevance of the EU-ETS on biomass use in the context of other fiscal incentives like taxes, directives and support mechanisms
- Delineate options to include the transport and aviation sectors in the EU-ETS
- Explore EU-ETS's potential impact on liquid biofuels development.

2.5 Agro-bioenergy production within the Common Agricultural Policy

2.5.1 Introduction

Meeting the targets of the RES-E and Biofuels Directives warrants a dramatic, several-fold increase in the European production of agro-biomass for energy in the near future. *The Common Agricultural Policy (CAP)*, which has been a main part of the EU political agenda from its very outset, is central in determining the availability, types and costs of agro-biomass to the energy sector.

A Bioenergy NoE working group looked at the effect of the CAP on regional bioenergy production using a set of case studies in Poland, France, Sweden, Austria, Italy and Finland. Competition between end use options for biomass resources from a technical and economic viewpoint as influenced by CAP measures and by recent reforms in the sugar market was assessed. Environmental and ecological impacts of implementing bioenergy chains at the regional level were reviewed. And future CAP scenarios were modelled, involving various levels of energy premiums and decoupling of subsidies and farm production.

2.5.2 The big picture: CAP and agro-biomass production

Various EU-level studies drive home the fact that any future changes to CAP will affect the availability and the unit price of agricultural feedstock. For instance, freezing or liberalisation of set-aside land will change the balance between cereal exports from, and oilseed imports into, the EU to meet the 2010 liquid biofuels target of 5.75 per cent. Growing cereals on voluntary set-aside land to increase domestic production would cost more than the projected price for buying cereals on the world-market. Another popular conclusion is that the pressure on land use from increasing biofuel and bio-product demand will inevitably impact food product prices, especially those derived from oil crops.

While these studies are useful for exploring scenarios at the European level, they rely on a simplified vision of farmers' behaviour. European agriculture is envisioned as a single farm with a central decision-making system, taking on crops and market opportunities based on their anticipated profitability, and operating under a set of constraints including the total area of arable land available and basic agronomic rules. This study took a bottom-up approach, modelling and aggregating a large set of actual, representative farms at local, regional and national levels. The model used is OSCAR, a micro-economic tool developed by researchers from the National Institute for Agricultural Research (INRA) in France. Past experience has shown that top-down and bottom-up approaches yield different results, and that the bottom-up approach is better at predicting real-life situations. There is a clear need to develop such tools at the EU level to account for regional specificities, making it possible to tailor the national modulations of CAP to these traits.

The case studies show there are myriad potential scenarios for EU countries to grow agro-biomass, whether related to climate and soils, farm structures and management, or historical background and subsidies. The example of reed-canary grass (RCG) in Finland epitomizes these peculiarities: it has a CAP subsidy level that varies according to climatic zone, reaching as high as five times the energy premium per hectare.

The model focuses on technical constraints and economic drivers, but biomass producers face other barriers, whether social, organisational, informational, or market-related. A coherent set of policies for agro-biomass production is sorely needed to address all of these barriers. In particular, support measures for energy crops are required across energy, environmental, economic and agricultural sectors.

Financial incentives, based on the positive benefits bioenergy can have on the environment and economy, are often cited as a means of improving its competitiveness. But macro-economic externalities, like job creation or reducing trade deficits, are difficult to assess, and even more difficult to pay back to the economic agents involved. Environmental benefits associated with agro-biomass production vary extremely over time and space, and detailed estimates and generic assessment methods are needed.

The only externality currently traded on the market is related to greenhouse gas savings, in the form of the EU Emissions Trading Scheme. Most calculations show the extra costs of producing and converting agro-biomass to energy make GHG savings prohibitively expensive. In France, estimates show that without tax exemptions, rapeseed methyl ester (RME) could compete with fossil fuels if CO_2 was traded at 43 € per tonne – double the value recommended by the EC. To boost the competitiveness of agro-biomass for energy, other positive externalities should be identified and internalized, and bioenergy chains with higher GHG efficiencies should be pursued. From a policy viewpoint, this means subsidizing research on second generation biofuels over direct production of first generation biofuels. Second generation biofuels are projected to be much less GHG-intensive than their first generation counterparts. An NoE case study on straw for CHP, a chain with a similar efficiencies, showed that straw could compete with natural gas for a CO_2 price of 30 € per tonne, which is still high, but lower than RME.

A French case study revealed the different effects that CAP measures for energy production can have on a particular region. The study highlighted the effect of the energy premium on the opportunity cost of rapeseed – or the price that farmers should be paid to grow rapeseed. The level of the premium is determinant as soon as rapeseed is no longer grown outside the set-aside area and begins competing with rapeseed grown for food. The differential between the current level – 45 € per hectare – and a reduced value – 10 € per hectare – remains regardless of the quantity of rapeseed used for biofuel conversion. However, when substituting rapeseed for higher margin crops, the premium only offsets 5–7 per cent of the increase in opportunity cost, much too low. There is a clear "resources ceiling" here, which again calls for the development of chains that are more intensive per unit area to increase competitiveness. Lignocellulosic feedstocks, with high output per hectare, are good candidates, along with agricultural by-products. However, the Polish case study on Salix, and the Finnish case study on RCG show that specific measures are required to compensate for high production costs. For example, scrapping CAP subsidies for RCG would likely double the price of RCG feedstock at the farm-gate in Sweden.

2.5.3 RD&D priorities to increase sustainable agro-biomass production

The set of case studies flagged three main barriers to the development of agro-biomass for energy: high production costs, unproven sustainability, and risk perception by farmers. The barriers are especially relevant to lignocellulosic crops, which will play a major role in long-term bioenergy production.

A number of RD&D activities priorities have been identified to tackle the identified barriers:

- Development of a comprehensive model to analyze production costs of all bioenergy chains that can project effects of rising bioenergy demand on the agricultural sector for any EU Member state, accounting for regional specificities.

Production costs for a given plant capacity can be estimated by developing and refining micro-economic models, such as OSCAR, explicitly taking into account the competition for land-use with other crops or industrial chains. These models can also predict the effects of policy measures, such as CAP, ETS, or tax exemptions on end-products like liquid biofuels, and can be run backwards to provide guidance to policymakers. Environmental externalities can also be measured, either by direct economic internalisation, for example, greenhouse gas emissions, or through multi-criteria assessment.

Development of a bottom-up model, like OSCAR, to handle data from various bioenergy chains and more EU countries is needed. The model could benefit from mutual inputs from member states of up-to-date data on the various steps of the chains: feedstock production, logistics, conversion, distribution and final utilization. The OSCAR model is currently limited to conventional biofuels. Generalizing the model to incorporate other chains, either agricultural by-products, annual crops, perennial crops, or short rotation forestry, is important.

Models can help guide the optimization of logistics, management, harvesting and handling of energy crops. The associated costs represent anywhere between 20–50 per cent of the total feedstock cost at the plant gate. Improving harvesting and pre-treatment methods can go a long way to reducing the cost of lignocellulosic feedstock. RD&D focusing on the optimization of plant location, harvesting dates of various crop types within the conversion plant's supply basin, or on the adaptation of farm machinery, should be undertaken.

- Develop generic methods to assess field emissions accounting for individual characteristics (soil properties, climate, crop yields, fertilizer use etc.).

- Experimental modelling should be combined with biophysical models to provide regional field emissions estimates.

Controversy over the environmental benefits and drawbacks of bioenergy chains is growing, with widely different results being reported for seemingly similar pathways. Closer examination reveals that there are differences in the life-cycle assessment (LCA) calculation hypotheses and scope, including co-product allocation methods, system boundaries, functional unit, or impact characterization. However, the emissions occurring when energy crops are cultivated in the field also have a strong influence on the outcome of the LCA. Field emissions vary widely across regions, depending on environmental conditions (soil properties and climate) and agronomic characteristics (crop yields and management, fertiliser use, etc.). This calls for the development of generic methods capable of addressing the variability in the characteristics of these supply areas. Experimental monitoring of field emissions can be combined with biophysical models to provide regional estimates of these emissions.

- Life cycle analysis should be connected to land-use changes to better account for local impacts and territorial effects.
- Development of higher GHG efficient bioenergy chains that are more intensive per unit area (i.e. lignocellulosic feedstocks and by-products) compared to conventional crops like rapeseed methyl ester.

- Research on second generation biofuels, which are projected to be much less GHG-intensive, should be prioritized and subsidized over direct production of first generation biofuels.
- Quantify the cost component of high risk perceptions toward energy crop production by EU farmers and propose measures to reduce it.

Some of the barriers identified in the case-studies were not technical or economic, and therefore unlikely to be alleviated by CAP measures. They include farmers' perceptions of energy crops, knowledge of growing methods, public acceptance of these crops, and cooperation between farmers. The latter point proved particularly crucial in the Polish case study, where farmers struggled to establish a strong position when negotiating with the local energy company. The promotion of cooperative action between farmers might be a key factor for success in the establishment of a willow supply chain in this particular region.

Growing energy crops is often perceived to be riskier than traditional crops such as rape seed or wheat. These perceptions pose a significant psychological barrier to uptake that also translates into measurable financial terms as a component in the price of agro-biomass. Current bioenergy production prices vary from quite low values to around 4–5 € per GJ. Future developments, however, can be expected to reduce production costs to around 3–4 € per GJ by 2020, making some energy crops very cost competitive with conventional crops. More work is required to quantify this cost component in various countries, and propose measures to reduce or compensate for it.

3. Boosting sustainable bioenergy use in EU27

3.1 Strengthening European bioenergy research

Networks of Excellence were created by the EC to deepen co-operation by research institutes in Europe with the objective of enhancing the quality and pace of scientific discovery and commercialization in the EU. Bioenergy NoE partners have testified to the beneficial nature of sharing knowledge, researchers and resources. Indeed, avoiding duplication of efforts and pooling expertise is crucial to building a competitive, sustainable, EU bioenergy market that employs the best technologies, support mechanisms and policies as cheaply as possible.

In this vein, Bioenergy NoE advocates stronger communication and co-operation among various EU-wide projects and initiatives focusing on bioenergy development. Open communication with relevant Technology Platforms (TP), like those on biofuels, forestry, and sustainable chemistry, should be encouraged. Strengthening interaction between individual industrial platforms is the key because bioenergy cuts across TP's. Stronger co-operation, co-utilisation of results for different purposes and common system studies should be emphasised. Only by working together can the platforms get a holistic picture of bioenergy's potential and impacts – and ensure the topic gets proper attention.

Industry commitment to RD&D projects is the only direct path for bringing state-of-the-art technology and products to market. As such, EU researchers should embrace industrial partnerships, however this commitment often closes doors to sharing research results on a given project. Bioenergy NoE, for example, faces this issue in the area of biofuels, where three partners (ECN, FZK and VTT) are working with industry to develop three different technical solutions. This is not an obstacle, but a natural product of open markets. The challenge for the EU RD&D community is to find means for constructive competition that can actually strengthen the bonds of the research community.

3.2 Bioenergy RD&D and raw material competition

The food versus fuel debate is high on the agenda – and RD&D priorities must address raw material competition. Two principal uses for biomass in this study are electricity and liquid biofuels production. Today in the EU, these production chains employ largely different types of biomass. Wood and wastes dominate production of electricity, whereas biofuels are produced from rape, wheat, sugar beet, or other agricultural crops. Prices of wood fuels have already increased in some Member states, due to increased demand for green electricity, with sharp rises in Austria and Finland over the last few years. While the price of lignocellulosic biomass fuels is expected to increase even more once the second generation biofuel production processes hit the market.

The European Environment Agency recently analysed the biomass potential for the EU. Generic potential as well as a price curve plotting supply levels of forest and waste fuels were analyzed. Figures 20 and 21 show the total bioenergy and the forest residue potential. Figure 21 includes an estimation of the cost limits and forest residue supply at the conversion plant. Note that the largest, present bioenergy source, black liquor at pulp mills, is classified as waste.

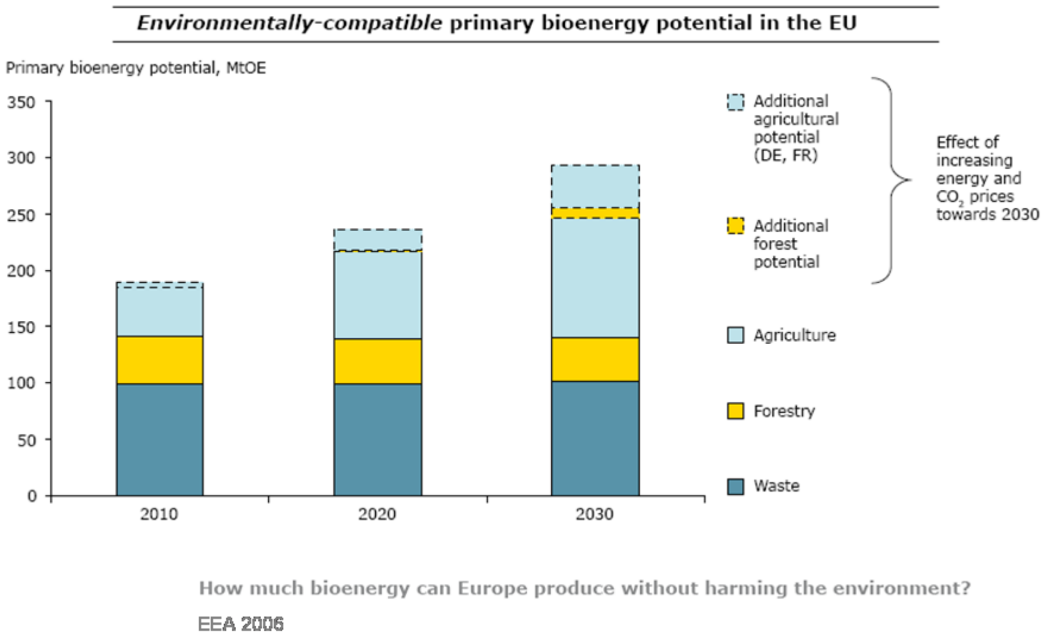

Figure 20. Total bioenergy potential in the scenario "How much bioenergy can be produced without harming the environment" [23].

Building sustainable production pathways and addressing competition with food products is crucial to developing environmentally-sound biofuels. A number of national, EU and global initiatives, roundtables and studies have been struck with the mission of defining sustainability criteria for biofuels. Bioenergy NoE supports these efforts but does not wish to duplicate activity, especially in light of the January 2008 proposal by the EC to enact concrete biofuel sustainability criteria. The proposed scheme includes minimum criteria for the greenhouse gas performance of biofuels, sets binding criteria for biodiversity and bans certain types of land use changes.

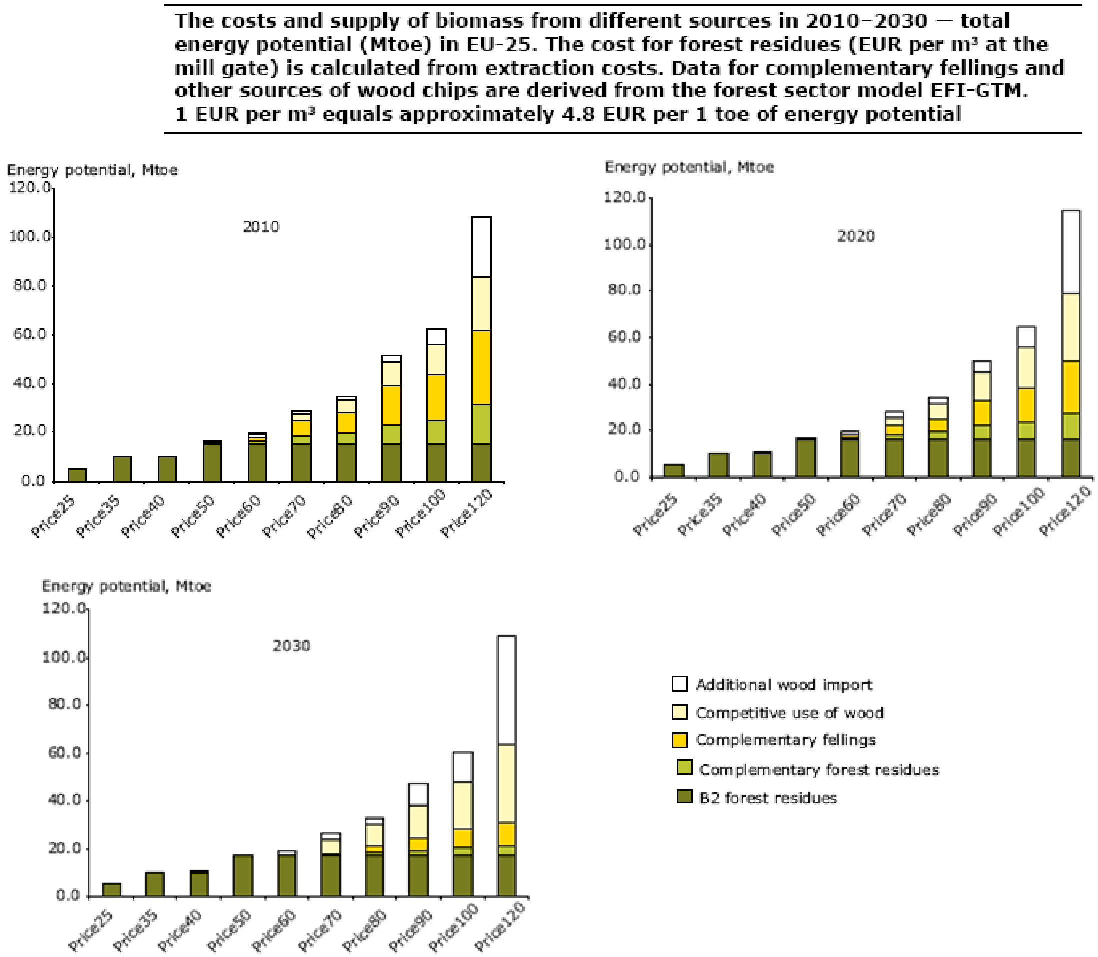

Figure 21. Cost supply curve of forest residues [24].

Meeting these criteria requires significant technology development in order to introduce a new generation of biofuels and feedstocks: this is the focus for Bioenergy NoE RD&D. NoE partners have been working on new technologies to develop second generation biofuels for years. For example, VTT Technical Research Centre of Finland [25] is developing with Finnish industry a synfuel processing route (gasification and subsequent Fischer-Tropsch synthesis), where the aim is to locate a biofuel plant on a forest industry production site using residues or by-products as feedstock. The steam cycles of the pulp mill and biofuel plant will be integrated. The Energy Research Centre of the Netherlands [26] is addressing the same challenge by developing production schemes involving biomass imports from overseas. And Forschungszentrum Karlsruhe is developing a processing chain, using low cost biomass, like straw. Biomass is harvested locally in distributed pyrolysis plants that supply a bio-slurry a centralized gasification-synthesis FT plant.

3.3 From national studies to EU27: RD&D priorities to develop a sustainable bioenergy market

European directives are crucial for creating bioenergy business. Analysis of the on-the-ground implementation of the directives in various EU countries helps pinpoint short and long-term RD&D priorities that if addressed, can spur a sustainable increase in bioenergy in the EU. A number of the RD&D needs flagged in this study are pan-European and require immediate, co-ordinated action by research and industry if bioenergy is to make a substantial, sustainable contribution to the EU's renewable energy requirements in the near future. Research institutes in the bioenergy field would be wise to set research agendas to match the needs identified.

Research in renewable electricity from biomass should prioritize development of higher efficiency power production and power-to-heat ratios in combined heat and power plants over new technology development.

In the biofuels arena, RD&D should prioritize the development of more sustainable, second generation biofuels. Differentiating taxation between first and second generation biofuels could be one effective way to stimulate industry and RD&D activity on second generation fuels. Effective policies should be developed enabling the smooth transition from first to second generation fuels.

To meet landfill diversion targets, thermal conversion and energy recovery of MSW in some EU countries will have to increase. But energy from waste is not a blanket solution. RD&D should look at national and local situations to devise the best, specific strategies depending on population density, existing attitudes and policies towards waste disposal, best technologies, emissions and costs. Paths for eco-efficient residue disposal from thermal and mechanical-biological treatment of MSW need to be addressed urgently.

In the EU-ETS area, RD&D priorities should delineate pathways to increase the percentage of auctioning over free allocation of credits via systems like grandfathering. Models to compare the competitiveness of biomass with other fossil fuels, accounting for National Action Plan rules, revenue use and allocation methods need development. The role of EU-ETS in the context of other support mechanisms for bioenergy should be explored. Options to include the transport and aviation sectors in the EU-ETS are needed.

Agro-biomass is not uniform across the EU. Solutions must be local and regional – and this is where RD&D focus is lacking. A tool to analyze regional production costs for all bioenergy chains should be developed alongside generic methods to assess regional field emissions. Life cycle analysis should be connected to land-use changes to better account for local impacts and territorial effects. Higher GHG-efficient bioenergy chains, like lignocellulosic feedstocks and by-products, should be prioritized over work on conventional crops like rapeseed methyl ester (RME). Similarly, research on second generation biofuels should be prioritized over direct production of first generation biofuels. And quantification of the costs of high risk perceptions by EU farmers towards energy crop production along with measures to reduce it can help overcome social barriers.

Finally, a powerful driver for expansion of bioenergy use in Europe is the bottom line. Research, development and demonstration in all the directive and policy areas, RES-E biofuels, biogenic waste disposal, EU-ETS and agro-biomass production, should be directed at lowering the cost of production by refining the entire bioenergy supply chain.

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Title

Bioenergy in Europe

Implementation of EU Directives and Policies relating to Bioenergy in Europe and RD&D Priorities for the Future

Abstract

The study carried out within the Bioenergy Network of Excellence analyses the implementation of important EU directives and policies relating to bioenergy in Europe to identify major RD&D needs in the field.

Major EU directives, commonly known as the Promotion of Renewable Electricity, Biofuels and Landfill Directives, along with the EU Emissions Trading Scheme and parts of the Common Agricultural Policy, are some of the most important drivers behind the growth of bioenergy in the EU27 today. The report compares how Germany, Finland and the Netherlands have implemented the directives, examining the policy frameworks in each country and the plans and mechanisms in place to reach national targets. A wider European perspective for each directive is then drawn out, and recommendations for RD&D actions to meet the EU directive targets or obligations in each area are outlined. The report also takes a broader look at the effects the EU Emissions Trading Scheme and the Common Agricultural Policy are having on the use of biomass in the EU with RD&D recommendations for each area.

Bioenergy NoE advocates stronger communication and co-operation among various EU-wide projects and initiatives focusing on bioenergy development. Industry commitment to RD&D projects is, however, the only direct path for bringing state-of-the-art technology and products to market. Building sustainable production pathways and addressing competition with food products is crucial to developing environmentally-sound biofuels.

Research in renewable electricity from biomass should prioritize development of higher efficiency power production and power-to-heat ratios in combined heat and power plants over new technology development. In the biofuels field, RD&D should prioritize the development of more sustainable, second generation biofuels. To meet landfill diversion targets, thermal conversion and energy recovery of municipal solid waste in some EU countries will have to increase. Meeting the European targets set for 2020 requires significant technology development in order to introduce a new generation of biofuels and feedstocks: this is the focus for Bioenergy NoE RD&D.

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