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BIOMASS AND BIOFUELS

A European Competitive and Innovative Edge

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EXECUTIVE SUMMARY

Assessment of the competitive position of Europe with regard to biomass and biofuels necessitates a clear understanding of Europe's aspirations in bioenergy, what it needs to do to meet these, and how development of bioenergy elsewhere in the world impinges on Europe's aspirations.

Europe's aspirations and current position

Bioenergy is important to the European Union's targets for renewable energy – and it is probable that it will be one of the major contributory technologies. In 2004 bioenergy accounted for two thirds of the renewables contribution to primary energy supplies in the EU-27, providing 4.2% of the EU's gross energy consumption. In some parts of the world bioenergy remains the dominant source of energy such that, globally, bioenergy is estimated to provide 13% of global energy supply.

A key advantage of bioenergy is that it can be derived from a large number of existing organic resources and these can be supplemented by energy crops grown on set-aside or marginal land (collectively these are known as **biomass**). Furthermore bioenergy benefits from a multiplicity of routes available to convert the organic content into useful energy, giving it great flexibility to meet the needs of energy markets, including the ability to store the feedstock until its use is required. The ability of **biofuels** to contribute now to the fuel requirements of Europe's growing transportation market puts it in a unique position amongst the renewables.

Europe has a long historical involvement in the bioenergy and has a strong industrial base from which to tackle its ambition. The use of biomass for heat, power and transport fuels is a growing industry, stimulated by:

- Strong policy drivers: **security of energy supply, greenhouse gas mitigation and agricultural diversification**;
- Increasing conventional **energy costs**;
- **Policy and regulations**, such as the RES-E and biofuels directives, renewable energy targets, EU ETS, supportive measures at the Member State level, etc.

These three factors provide a strong framework for bioenergy in the EU.

Bioenergy utilisation

Positive policies in recent years at the EU, national, regional and local level have resulted in a **71% increase in bioenergy production from 1990 to 2004** (reaching 72 Mtoe in 2004 for the EU-25). Whilst this is impressive growth, progress remains insufficient to allow the EU to achieve the bioenergy contribution foreseen for 2010 by the Commission's White Paper in 1997 (135 Mtoe from biomass for the EU-15, compared with the 62.5 Mtoe actually achieved in 2004).

Although significant growth has been achieved in **electricity** and **transport fuels**, progress on biomass heat remains significantly slower. Some of the greatest potential benefits from bioenergy are in the heat market and it is clear that a **framework for development of the heat market** needs to be developed.

Bioenergy economics

Foremost amongst the barriers to major growth for bioenergy is the **additional cost** of achieving major deployment. Whilst there is a realistic expectation that the costs of bioenergy will converge with conventional sources in due course, expanding utilisation will only occur in the current market through the application of market incentives. This means that there remains a need for **a continued programme of support at regional, national and EU level.**

Biomass supply

The EU has many **competitive advantages** in the supply of bioenergy. A number of analyses have shown that it could meet a significant proportion of its own needs, through its sophisticated agricultural and forestry sector and by realising the potential of residues and biomass wastes from other sectors. However, is not so clear what effect a switch to the production of bioenergy fuels will have on food production and prices or on the production of other commodities that require biomass feedstocks. Analysis presented in Chapter 5 indicates that these effects would be marginal at the levels of bioenergy generation envisaged in Europe. However, these analyses are theoretical and it is vital to monitor the effect of increased bioenergy on other markets. In recent years, for example, the board industry has indicated that its feedstock prices have increased in response to competition from bioenergy, which is subsidised through various biomass electricity support mechanisms. In addition demand for olive oil residues in co-firing in northern Europe has lead to rapidly increasing prices and prevented their exploitation locally.

A number of European countries currently import biomass fuels and it is likely that increasing demand within the European Union will inevitably result in increasing biomass imports. Indeed it is accepted that current targets can only be achieved through the deployment of the majority of Europe’s biomass potential and imports are likely to make a significant contribution as well. It is not possible at present to obtain accurate figures on the quantity of imported biomass fuel because trade statistics are not designed to provide such figures. As imported biomass becomes an increasingly important part of Europe’s energy provision, this situation will need to be addressed. Without this information it is not possible to undertake a detailed study of the **market consequences of biofuels and biomass imports** from across the globe, including **security of supply**.

The potential for using **waste biomass** should not be under-valued. The EU leads the world in energy from waste, with strong manufacturers across a range of technologies. However, the use of wastes as a fuel can often be complicated by definitions of what constitutes a waste, restrictions associated with waste disposal regulations and the need to secure long-term contracts for waste supply. Without sacrificing the need to maintain high standards of environmental protection, it is important to ensure that the significant potential afforded by waste to energy is available to the marketplace.

Public opinion

Whilst public opinion towards bioenergy is generally favourable, it is important that **this should not be taken for granted**. There are a number of factors that could lead to public disaffection: the level of additional costs involved, conversion of land to energy crop production; the location of new plants; environmental impacts from production and utilisation facilities; use of wastes; transportation, etc.

The role of Research, Development and Demonstration

The **EU is home to world-renowned expertise** in many areas of bioenergy. It needs to maintain this expertise by providing an active research environment in which R&D can thrive and in which technology transfer from academic research to industrial application can take place. The EU has an important role to play here through its various funding programmes and ability to bring different actors together. **The Commission has a particular responsibility to ensure a co-ordinated approach to R,D&D (and wider strategy)** for bioenergy, given its many different facets.

Standards for bioenergy

It is important for the credibility of bioenergy that well-defined **standards and definitions** are implemented in a number of areas: classification of wastes; standards for co-firing; sustainability standards for imported biomass and fuel quality standards for solid, gaseous and liquid biomass fuels. In addition it is important that air emissions standards ensure that the impact of wide scale deployment of biomass heat and power does not cumulatively increase impact on local air quality. These standards will allow bioenergy to mature and compete with conventional fuels.

Biomass Heat and Power

The **EU ETS** is encouraging many industries to consider biomass heat (and power), however there are still many barriers. The EU is at the forefront of **replacing old, inefficient coal-fired boilers** with new, more efficient ones capable of using a wider range of solid fuels. A programme to support this practice could be considered, with the aim of helping to achieve the Kyoto targets for CO_2 reduction. **Co-firing of coal and biomass** is now established as a successful power generation technology and is one of the cheapest ways to utilise biomass.

New **district heating** schemes operating on biomass power are too costly for most areas to contemplate. However, Europe has a history of successful district heating, particularly in the Nordic States. The **transfer of technology to Eastern Europe** where many inefficient district heating schemes are in operation would increase biomass use in the EU, help establish a biomass supply industry in these countries and update their heat supply systems.

Europe leads the world in application of **anaerobic digestion**, both centralised and on-farm. The EU needs to encourage **joined up thinking on hygiene and waste disposal with energy generation** to allow this technology to flourish.

Biofuels

The **EU leads the world in biodiesel production**. **Bioethanol** production is lower than in the USA or Brazil, but is expanding rapidly. However, European bioethanol may not be as cheap as bioethanol imported from abroad.

The EU has great potential for production of biofuels from lingo-cellulose and should continue to support work in this area. Research on these **second-generation biofuels** in the EU is at the forefront of work in this area. It promises in due course to provide a source of biofuels that can compete with cheap imports.

The EU is also at the forefront of work on bio-refineries and can maintain this position through the work supported under the 7th Framework Programme. It should focus on delivering technology to the market place and examine ways to encourage industry to invest in the EU. The USA has a large multi-million dollar programme of R,D & D on second-generation biofuels and bio-refineries, covering all aspects of biomass availability, sustainability, infrastructure and profitability. The EU needs to consider whether it can benefit from **working with the US programme** rather than competing with it.

Conclusions regarding Europe's competitive position

The analysis in this report has lead to a number of specific key conclusions regarding Europe's competitive position. These are summarised below and in Table ES1.

1. There are few nations worldwide that are systematically developing biomass. These tend to include the developed countries, but emerging economies such as India and China have also begun to explore the potential of bioenergy; and a number of countries in South America (most noticeably Brazil) are developing biofuels production. There are also clear indications of a growing interest in other countries in biomass supply – this includes wood or agricultural residues from Eastern Europe and the CIS countries (Russia and the Ukraine in particular) and palm oil and residues from its production in the Far East. It is difficult at present to understand how Europe should react to developments in other countries. Currently there is no clear competitor for imported biomass, but it is not likely that this situation will remain as bioenergy growth continues worldwide, particularly as emerging economies begin to compete for biomass fuels and also for food supply.
2. The infrastructure for transporting biomass around the European Union and for importing large quantities needs to be developed. Europe is in a strong position to achieve this, but needs a clear analysis of where investment is most required.
3. The need for imports is clear. The European Union needs to focus on how to establish stable, reliable markets and trading partners and to be aware of what the threats to those markets are.
4. The potential impact on food production and the prices of raw materials for other markets is not clear, either for the EU or its potential trading partners. This situation should be monitored and analysed as bioenergy use increases. It should be possible to develop of programme to monitor the use and price of key biomass feedstocks, food and raw materials through the statistics monitoring services provided by Eurostat.

Table ES1: A European competitive and innovative edge in bioenergy - key conclusions & recommendations

Conclusion	Recommendation
Bioenergy has **huge potential** to help the EU meet its new target of 20% renewables by 2020 but will only do so within the context of consistent long-term supportive frameworks at both Member State and EU level.	European Institutions have a special responsibility to provide such a framework at the EU-wide level, taking into account all of the various issues on a co-ordinated, strategic basis.
The **biomass heat** market holds considerable potential but has shown little growth compared with biomass electricity and transport biofuels.	Both European Institutions and Member States need to ensure that the heat market is given greater attention and that market incentives are put in place to encourage significant growth in this sector.
Increasing bioenergy utilisation requires a reliable **supply of sustainable biomass** feedstock at a predictable price for the market to have the confidence to make the necessary investments. Achieving the 20% renewables target will require the majority of the available EU biomass supply potential to be utilised, supplemented by sustainable **imports** from third countries. The effect of rising demand on feedstock price and alternative uses (including food production) needs greater attention.	Further work at European level is required to better understand: • the market consequences of biomass/biofuels imports on the prospects for EU domestic biomass production; • the impact of biomass production on food production and prices both in the EU and abroad; • the sustainability of imported biomass/biofuels and mechanisms for ensuring it; • the longer-term consequences for land use of increased bioenergy utilisation.
The **EU leads the world** in many aspects of bioenergy and is in a strong position to benefit from the expanding global market for bioenergy. It has a strong R&D capability and many equipment suppliers at the forefront of their field.	EU and Member State policies should continue to support EU capability in the bioenergy field to ensure the EU remains a key player on the world stage. This is best achieved by a focus on the EU's own deployment targets, whilst taking into account the global export potential.
Cost reduction remains a crucial goal for bioenergy. There is an ongoing role for R,D&D to help achieve this and a need for better information on the costs of bioenergy options, to inform R,D&D decisions.	To maximise the benefits from EU R,D&D support for bioenergy, the European Institutions should: • Ensure that the allocation of EU funding is based on strategic objectives, including factors such as market potential, cost reduction potential and export potential. These strategic objectives should be contained within an EU bioenergy R,D&D strategy; • Develop and maintain a clear view of biomass resource potentials; • Collect and publicise information on the costs of the main conversion options; • Consider export potential as well as EU deployment in allocating R,D&D support.
There is a large potential biomass energy resource in **wastes and biomass residues** in the EU and a need to ensure use of this source is maximised, whilst maintaining high environmental standards.	Key issues remain, including: • Addressing the conflicts between reuse, recycling and energy recovery. • Clarifying the definitions of wastes and the application of the Waste Incineration Directive. • Development of advanced technologies to enable efficient use of residues and wastes in an environmentally acceptable way.

1 Background and overview

1.1 Introduction

Bioenergy provides one of the most promising sources of renewable energy in the EU and worldwide. Not only is there a vast array of feedstock resources available, both existing and potential (in the form of crops grown specifically for energy conversion), but there is also a wide range of routes available to extract the energy. Biomass can be used directly for conversion to heat and/or electricity using a range of thermal processes. It can also be converted to more flexible solid, liquid and gaseous fuels via thermal and biological conversion processes. Compared with many other renewable energy forms it has the advantage that the fuels can be readily stored to meet variable demand. It is also the only form of renewable energy that currently provides a viable alternative to hydrocarbons in the growing transportation market (liquid fuels from biomass are known as biofuels).

Some definitions:

Bioenergy - refers to all forms of energy derived from biomass sources and the biodegradable element of wastes.

Biomass - the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

Biofuels - used to refer to transport fuels e.g. bioethanol, biodiesel and biogas used as a transport fuel.

Biomass is also one of the oldest forms of renewable energy exploitation; ever since humans discovered fire, wood has been used widely for heating and cooking. The ease with which biomass can be exploited makes it the dominant contributor to renewable energy use worldwide: in 2004 renewables provided 13.1% of the world's total primary energy supply, of which 79% was supplied by biomass and wastes [1]. In the EU-27, renewables contributed 6.4% to energy consumption, with 66% of this coming from biomass [2]. Nevertheless it should be noted that the majority of this is still in the form of relatively low efficiency small-scale applications, often prevalent because of the lack of real alternatives from fossil fuels. Recent decades have seen a decline in utilisation of wood for domestic heating in some European countries, due to replacement by gas or oil fired heating. However this has been compensated by an increase in biomass utilisation in higher efficiency packaged heating systems for domestic, commercial and industrial markets, often based on wood chips and automatic fuel handling systems. There have also been many examples of biomass co-fired with conventional solid fuels, particularly in coal fired power stations.

Recent decades have also seen an increase in utilisation of a much wider range of bioenergy feedstocks, especially wastes: straw, poultry litter, industrial wastes from food processing and manufacturing processes, even municipal wastes. Many of these have been developed at a significant scale, providing heat, electricity and often both through combined heat and power plants. The agriculture sector has started to exploit the opportunity of growing crops specifically for conversion to energy, in order to supplement the existing biomass resource and provide themselves with an additional source of income. However, the investment required to produce a steady supply of ‘energy crops’ will only be made if a secure market for the output exists – the classic requirement for supply and demand to develop in tandem.

The need to find alternative transport fuels has resulted in the development of a substantial biofuels capability in various parts of the world, particularly the EU, the USA and Brazil. Experience to date has centred on bioethanol as an additive to petrol and biodiesel (predominantly from oilseed crops) as a diesel substitute. Brazil and the US have invested heavily in developing an infrastructure for bioethanol from crops such as sugar cane and maize. In Europe there has been a stronger focus on developing biodiesel.

In Europe and the USA there is a recognition that current processes are limited by the availability of crops and research is now shifting to second-generation processes to produce biofuels, in an effort to achieve economic convergence with conventional fossil fuels, security of supply and to make more efficient use of feedstocks.

The EU has been at the forefront of many of the developments in the bioenergy field. There is a well-established industry that can supply and operate equipment and many European companies export successfully throughout the world. In recent years the European Union has provided strong support through the Framework R,D&D programme, the ALTENER programme (addressing non-technical barriers to uptake) and through support for deployment at the regional level. Such support has covered technologies to exploit bioenergy as well as support to enhance fuel supply. EU Member States have also made concerted efforts to encourage the deployment of technologies through R&D and market support measures (such as fiscal measures, grants, guaranteed electricity feed in tariffs and obligations on suppliers).

During the last decade the European Union has taken an increasingly active role in setting a framework for the accelerated deployment of renewables. In 1997 the EU set an indicative target of a 12% share of renewable energy in gross inland consumption by 2010, representing a doubling of the existing contribution from renewable energies. Since then, renewable energies have increased their contribution by 55% in absolute energy terms. However current projections indicate that the 12% target will not be met; the EU currently looks unlikely to reach a contribution from renewable energy sources of more than 10% by 2010. Nevertheless on 9th March 2007 the European Council agreed a binding target of a 20% share of renewable energies in overall EU energy consumption by 2020 and a 10% binding minimum target for the share of biofuels in overall EU transport petrol and diesel consumption by 2020 (as proposed in the European Commission's Roadmap published in January 2007 [3]).

This study examines the competitive position of the European Union in the development of biomass for energy, in particular how the EU can obtain and maintain a competitive and innovative edge in the biomass and biofuels market. Development of bioenergy is subject to three very strong policy drivers:

- It can make a significant contribution to the EU's security of energy supply;
- It contributes to the EU's targets for greenhouse gas reduction;
- It can contribute to the EU's goals in the field of agricultural diversification.

The study examines current state of the art in the EU, and analyses legislative support, industrial and R&D aspects of the area. We have considered the current situation, market enablement and infrastructure requirements, other potential areas where assistance is required and the need for R&D. In this background section we present the situation as it is at present within the EU and how this compares with developments worldwide.

1.2 The economics of bioenergy

Due to the wide range of bioenergy resources and conversion routes it is not possible to generalise about the economic competitiveness of bioenergy. In addition the economics are strongly dependent on the prevailing costs of conventional energy sources, which have shown great volatility in recent years.

Biomass is already fully competitive in certain segments of the heating market, hence its significant market share. Nevertheless this market is highly competitive and the industry has had to work hard to retain and expand its market share in the face of competition from oil and gas (and, in some cases, cheap electricity).

Biomass must not just compete in terms of cost; users will also compare it on the grounds of convenience, reliability and environmental performance. Renewables in the heat market have received fewer incentives than those contributing to the electricity and transport markets and the growth rates have been correspondingly lower.

Some of the routes available to generate electricity from biomass and, in particular, certain wastes are already fully competitive, however significant energy contributions are only generally available where they are supported through market incentives. The recent trend has been towards larger, highly engineered plant aiming for high conversion efficiencies and low emissions, allowing developers to take advantage of the better economics of larger scale plants. However, larger plants require larger tonnages of fuels at economic cost and this can limit their location to specific regions that have large volumes of forestry, agricultural or municipal/industrial wastes. The supply of feedstock can be expanded considerably by growing energy crops on set-aside or marginal land. However, this also considerably increases their price compared with the waste by-products of existing processes.

At the current stage of development, biofuels cannot compete with fossil fuels in the growing transportation market without financial incentives. As the technologies develop the costs are expected to converge with conventional fuels but it will be some time before subsidies can be phased out. However, one must consider this in the context that biofuels provide the only real alternative to fossil fuels in the transport market, contributing to the EU's security of supply and greenhouse gas reduction objectives. In some countries biofuels can be produced at cheaper prices due to the widespread availability of cheaper feedstocks (for example sugar cane in Brazil).

The cost of biofuels supply is discussed in some detail in the impact assessment issued by the European Commission in January 2007 as part of its renewable energy roadmap [4]. The extra cost of using biofuels depends on the cost of oil, the share of imports and the competitiveness of agricultural markets. With an oil price of $48/barrel, as in the Commission's baseline model, the extra direct cost of reaching a 14% market share for biofuels (compared to the cost of conventional fuels) is estimated at €11.5 - €17.2 bn in 2020. With an oil price of $70/barrel this would fall to €5.2 - €11.4 bn. However, even using the most modern technologies, the cost of EU-produced biofuels will make it difficult for them to compete with fossil fuels, at least in the short to medium term. According to the EU Strategy for Biofuels [5], with the technologies currently available, EU-produced biodiesel breaks even at oil prices around €60 per barrel, while bioethanol becomes competitive with oil prices of about €90 per barrel.

Figure 1.1: Average heating, transport and electricity costs for renewable energy, taking into account the external costs for fossil fuels (€/MWh) [3]

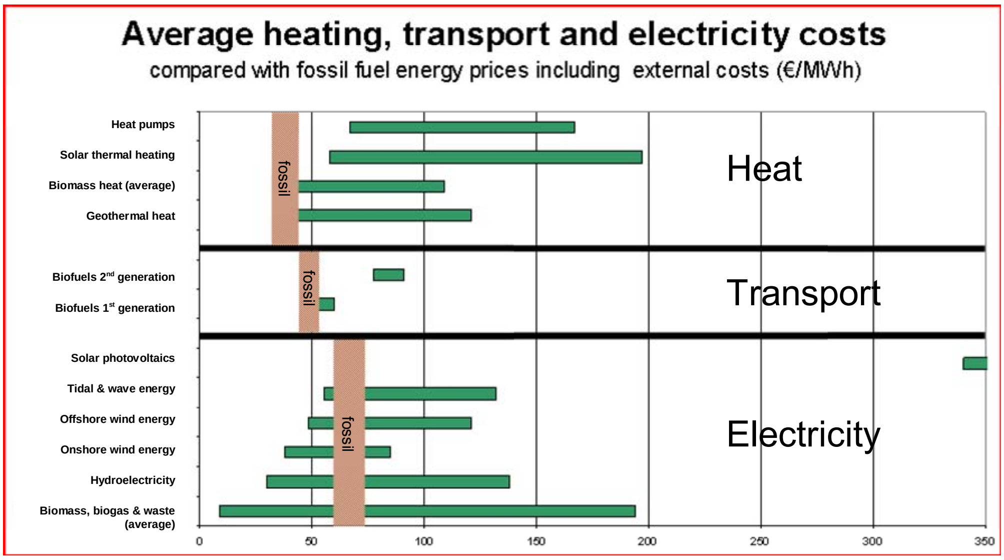


Figure 1.1 presents a summary of the current competitive position for all renewables, including biomass and biofuels, drawn from the Commission's RE Roadmap [3]. The fossil fuel energy prices are presented including their external costs in order to provide a more realistic comparison of the relative costs.

Chapter 3 examines the potential for cost reduction for the various technologies through R&D, as this will inevitably be a key determinant for their eventual market penetration.

Figures 1.2 and 1.3 provide an indication of the competitiveness of different biofuels relative to fossil fuels in both the short term (<2010; Figure 1.2) and longer term (>2010; Figure 1.3). [6]. It can be seen that, even in the longer term, biofuels will require some form of market incentive if they are to compete economically with fossil-derived transport fuels.

Figure 1.2: Biofuel cost range at the filling station for supplying different biofuels in the short term (<2010), relative to fossil derived fuel [6]

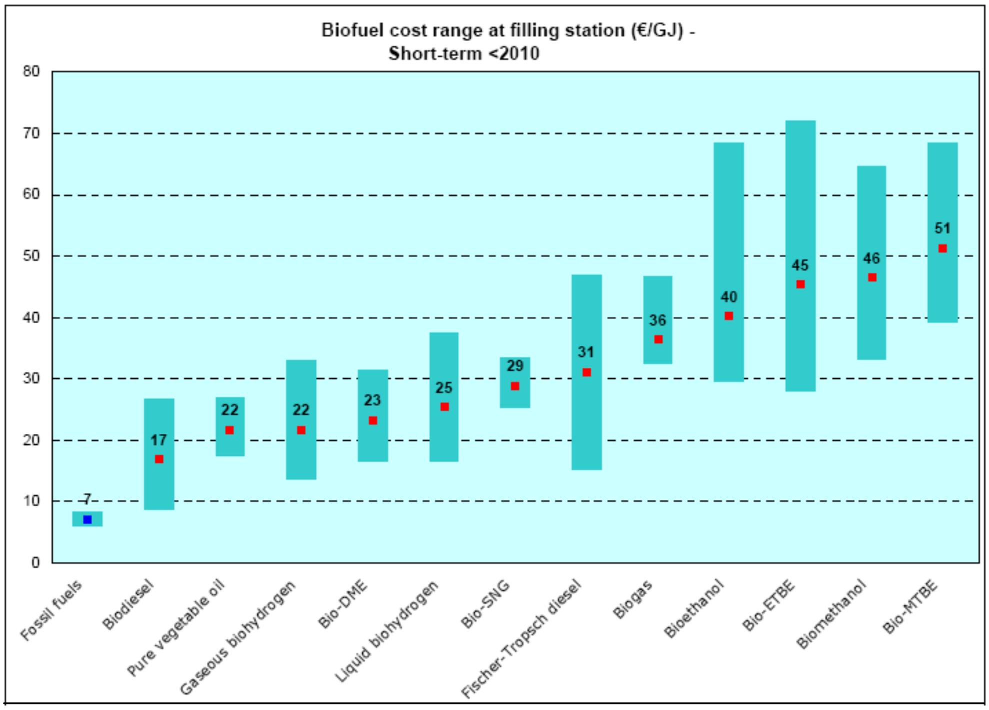


Figure 1.3: Biofuel cost range at the filling station for supplying different biofuels in the short term (>2010), relative to fossil derived fuel [6]

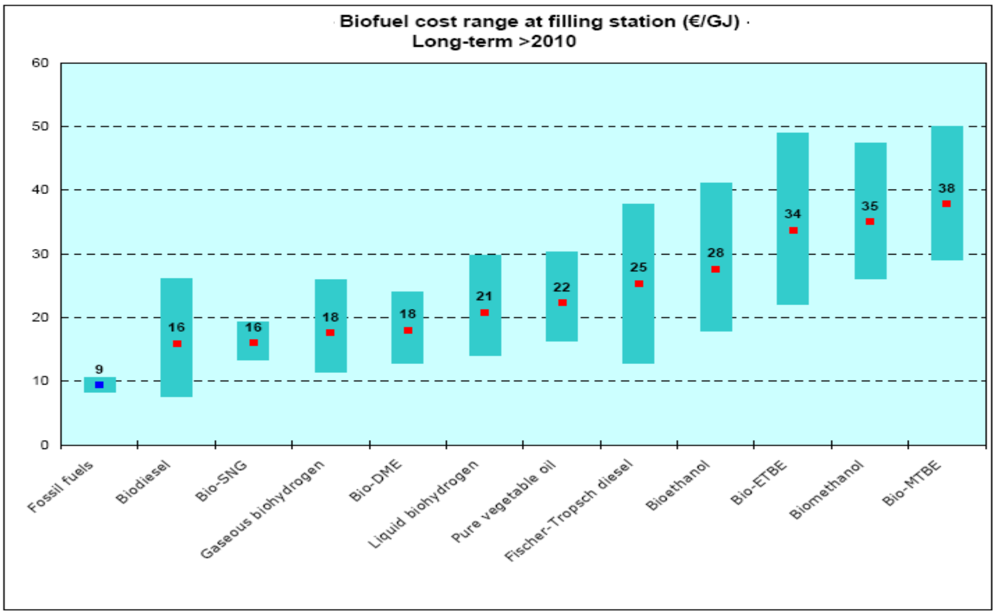
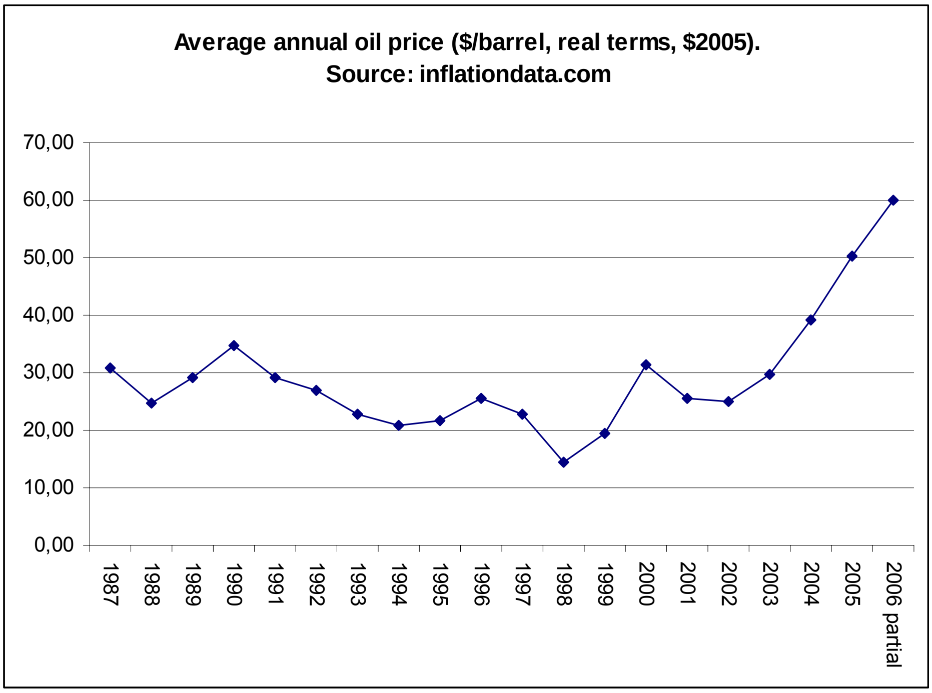


Figure 1.4 plots the average annual oil price over the last 20 years, emphasising not only its volatility but in particular its dramatic rise over the last five years. Future oil prices will clearly be one of the major determinants of the speed with which the market seeks to adopt biomass and biofuel technologies.

Figure 1.4: Average oil prices over the period 1987 - 2006



It can therefore be seen that stable markets for biomass and biofuels are unlikely to develop beyond a few niche applications unless strong support measures are taken to encourage wider use. Encouragement can take the form of clear targets, systematic removal of institutional or regulatory barriers and a framework of market incentives that provides a developing industry with the confidence to invest the considerable resources required. These areas are explored later in this study.

1.3 The bioenergy resource

Estimating the technical and economic potentials for bioenergy presents a considerable challenge, not least because of the multiplicity of resources and energy conversion routes available. This is compounded by the fact much of the potential resource exists at present only in the form of land available for growing energy crops. The available resource can be summarised into three classes:

- Forestry: sustainable forestry and residues from forestry operations.
- Wastes: organic residues from agriculture, industry, commerce and households.
- Energy crops: agricultural land used specifically for energy crop production.

In future these may be supplemented by marine biomass resources.

Bioenergy feedstock can also be imported from outside the EU (where production costs are often lower) and this important area is considered later in the study.

Table 1.1 provides a summary of biomass fuels currently in use in the EU and some alternative markets for the feedstock.

Table 1.1: Biomass fuels in the EU and their uses

Biomass fuel	Energy use		Alternative markets
	Current use in EU	**Other Potential uses**	
Wood fuels			
Energy crops such as **short rotation forestry and short rotation coppice**	Heat, power and CHP	Cooling; Gasification to synthesis gas or liquors and chars	Panel board manufacture; building and insulation materials; landscape materials; animal bedding. Potential uses include: source materials for chemical and pharmaceutical industry.
Residues: **forestry residues** (e.g. thinnings) and arboricultural residues	Heat, power and CHP		
Residues: **virgin wood processing residues**	Heat, power and CHP		
Residues: treated wood processing residues	Heat, power and CHP		
Waste materials: **used wood** (demolition wood, furniture waste, source separated wood wastes)	Heat, power and CHP		
Agricultural fuels			
Energy crops - **energy grasses** (e.g. Miscanthus, Switch grass, reed Canary grass)	Heat, power and CHP	Cooling; Second generation conversion to bioethanol and other transport biofuels.	
Energy crops – **whole cereal crops, whole grains**, oil seed rape, sugar beet.	Heat, power, CHP, bio-diesel and bioethanol.		Food, animal feed, feedstocks for edible oil manufacture; lubricants and hydraulic fluids; textiles; biopolymers.
Residues: dry residues e.g. **straw, stones, shells, husks and poultry litter.**	Heat, power, CHP.		Animal bedding and feedstuffs building and insulation materials; biopolymers;
Residues: wet residues e.g. **manures, slurries**	Heat, power, CHP from biogas using anaerobic digestion.		Landscape reclamation; fertiliser.
Residues: **Horticultural and landscape management residues**.	Heat, power, CHP.		
Wastes			
Municipal solid wastes – e.g. **refuse derived fuels, kitchen wastes, garden wastes**.	Heat, power, CHP and biogas.	Cooling; Second generation conversion to variety of chemical feedstocks for fuel use, including liquid transport fuels.	
Municipal wastes – **sewage biosolids**.	Heat, power, CHP		Landscape reclamation; fertiliser
Industrial and commercial wastes – food and drink processing residues, tallow, meat and bone meal, pulp and paper sludges and liquors, textile residues, recovered vegetable oils.	Heat, power, CHP		Some could be used as animal feed; biopolymers

Imported fuels			
Bioethanol; palm oil and Soya oil.	Liquid transport fuels	Biodiesel, providing standards are amended to allow alternative oil feedstocks.	Chemical, pharmaceutical, food and animal feed products.
Palm oil residues, olive oil residues, shea nut residues, and coconut residues.	Co-firing for heat, power, CHP, bio-diesel and bioethanol.		Animal feedstuffs

Note: Other non-energy uses for biomass materials include: lubricants and hydraulic fluids, washing powders and cleaning agents; biodegradable materials and plastics reinforced by natural fibre; building and insulation materials; feedstocks for medicine and the pharmaceutical industry; paints and lacquers; paper and cardboard; and textiles. Many of these uses are still in development or not competitive at the moment with products from fossil materials

The best estimates for the EU's biomass production potential come from Annex 2 of the European Commission's Biomass Action Plan published in 2005 [7], drawing on data from Eurostat for 2003 and from the European Environmental Agency for future predictions to 2030. Table 1.2 presents the results for the three classes of resource (forestry, waste and energy crops) for the EU-25. Inclusion of Bulgaria and Romania would boost the figures further as both of these countries have large agricultural sectors and therefore a high biomass production potential.

Table 1.2: EU-25 biomass production potential [7]

Mtoe	**Biomass consumption 2003**	**Potential, 2010**	**Potential, 2020**	**Potential, 2030**
Wood direct from forest (increment and residues)	67	43	39-45	39-72
organic wastes, wood industry residues, agricultrual and food processing residues, manure		100	100	102
Energy crops from agriculture	2	43-46	76-94	102-142
TOTAL	**69**	**186-189**	**215-239**	**243-316**

These estimates are considered conservative as they are based on the following assumptions:

- no effect on domestic food production for domestic use;
- no increase in pressure on farmland and forest biodiversity;
- no increase in environmental pressure on soil and water resources;
- no ploughing of previously unploughed permanent grassland;
- a shift towards more environmentally friendly farming, with some areas set aside as ecological stepping stones;
- the rate of biomass extraction from forests adapted to local soil nutrient balance and erosion risks.

In 2003 20 million tonnes of oil equivalent (Mtoe) biomass was used to generate electricity in the EU; and 48 Mtoe was used to generate heat, providing 4% of the EU's energy needs. The Commission's biomass action plan put forward proposals that, if implemented, could increase this to 150 Mtoe in 2010. The plan estimates that to achieve the RES 12% target for 2010, a total biomass accumulated energy production of 130 Mtoe is required, well within the available resource. The Renewable Energy Roadmap published by the European Commission in January 2007 calls for a more ambitious 20% renewables contribution by 2020. Among the "20%" scenarios considered by the Commission, the highest biomass contribution anticipated is 230 Mtoe. This includes a maximum of 63 Mtoe that would have to come from agricultural crops (if all biofuel's contribution had to come from first-generation biofuels). It can be seen that this contribution is near the resource potential expected to be available in 2020 (excluding Bulgaria and Romania), not including any imports to the EU (which could be at least 15%).

A comparable overview of the availability of bioenergy in the EU-27 was calculated by Siemons et al [8]. The biomass potential for each country has been identified based on the technical resource potentials (i.e. total production of all resources, given no economic limits) minus the amount of biomass which is not available for various reasons (e.g. because of technical, physical, environment, agronomic, silvicultural limits). The results are presented in Table 1.3.

Table 1.3: Availability of bioenergy resources in the EU-27 in 2000, 2010 and 2020 (Mtoe/year) Siemons et al., (2004) [8]

	2000	2010	2020
Tradables:			
Forestry byproducts & (refined) wood fuels	42.1	46.5	51.3
Solid agricultural residues	32.7	36.2	39.9
Solid industrial residues	12.9	14.3	15.8
Solid energy crops	18.7	18.7	18.7
Non-tradeables:			
Wet manure	14.1	15.7	17.3
Organic waste			
- Biodegradable municipal waste	7.2	19	33.7
- Demolition wood	5.9	6.4	7.1
- Dry manure	2.3	2.4	2.8
- Black liquor	10.6	11.7	12.9
Sewage gas	2.1	2.3	2.6
Landfill gas	5.1	4.7	2.5
Transport fuels			
Bio-ethanol	4.2	4.2	4.2
Bio-diesel	1.5	1.5	1.5
Total bio-energy	**159.4**	**183.6**	**210.3**

The figures are broadly in line with those in Table 1.2 but indicate that achieving the contribution from bioenergy required by the '20% by 2020' target may well require EU biomass resource to be supplemented by imports. **It is certainly likely that, as demand for feedstock increases and starts to approach the available EU production capacity, this will exert a strong upward pressure on feedstock price and may be the biggest factor in pushing the market towards cheaper imports**.

It can be seen that the main resources are forestry by-products and refined wood fuels, as well as solid agricultural residues. At present, 35% of the wood growing in the EU is unused, not counting forests in protected areas [9]. However, for economic reasons they typically need to be utilised locally, unless refined into more compact forms. In many countries there is only a limited market for small size thinnings, which can be used to produce heat and electricity. Most of the unused resources are in small private holdings, making their mobilisation difficult. Some countries have tackled this problem by setting up supply chains coupled to existing plants, and by supporting the organisation of logistics systems, forest owner cooperation and transport.

The growth in the availability of biodegradable municipal waste is most striking. This is the result of the EU wide implementation of the EC directive on the landfill of waste (1999/31/EC), discouraging the landfilling of biodegradable waste and prescribing a time schedule to reduce this manner of waste disposal [8]. Also as a result there will be halving in landfill gas by 2020, but this is an insignificant loss compared with the above gain. The availability of all other feedstocks is predicted to increase, except biofuels which are static as only production on set-aside land was considered in the study.

The Commission has just approved and presented an EU Forest Action Plan to the Council and the European Parliament (COM(2006) 302) [10]. This Action plan supports the use of forest resources as an energy feedstock, which will be particularly important for the production of solid biomass.

1.3.1 Resource for biofuels production

The European Commission has undertaken a detailed assessment of the resource requirements for the biofuels contribution required to achieve its proposed "20% by 2020" target [11]. In order to assess the economic and environmental impact of increasing the share of biofuels, scenarios were developed for two possible shares of biofuel consumption in 2020: 7% or 14%. The European Simulation Model (ESIM), used by the Commission for agricultural commodity projections and policy simulations, was used to estimate the mix of biofuels likely to enter the market if a 7 or 14% share is achieved. Table 1.4 provides an indication of the amount of arable land required to achieve these market shares.

Table 1.4: Estimated EU25 arable land use to achieve a 7% or 14% market share for biofuels in 2020 (million hectares) [11]

Biofuels penetration scenarios	**"no biofuels" scenario**	**7% or 14% with more imports**	**14% - more domestic**
Rape for biodiesel	0	2.7	2.6
Cereals for bioethanol	0	4.6	8.3
Sugar beet for bioethanol	0	0.3	0.5
Farmed wood for BTL	0	0	6.9
Total land for biofuels production	**0**	**7.6**	**18.3**
Non-biofuel arable production	87.6	84.8	80.8
Idle arable land (set-aside)	10.8	7.7	3.4
Total arable land	**98.4**	**100.1**	**102.5**

Under the scenario in which EU domestic production is maximised, biofuels production could require as much as 18% of the total arable land. The modelling work suggests that for each additional 1 million hectares needed in the EU to produce raw material for biofuels, land use will change as follows:

- 370,000 hectares of arable land will be re-orientated from exports to domestic production;
- 400,000 hectares will be taken out of set-aside;
- 220,000 hectares of land that would otherwise have fallen into other uses will remain in arable use.

Biofuels can be made from many raw materials. To achieve the greatest security of supply benefit, it is desirable to keep the range of raw materials wide. A product mix that includes domestically produced biofuels as well as imports from a variety of regions will contribute more than one that relies entirely on the lowest cost producers (e.g. Brazil for sugar cane, Malaysia and Indonesia for palm oil). It is also desirable to bring second-generation biofuels onto the market, so that an even wider range of feedstocks can be used. However, if this is done, it is important to understand the impact on alternative uses for these feedstocks, including biomass heat and power.

1.3.2 Biomass resource world wide

Global biomass use was estimated to be around 7EJ/y in 2000 [12]. Estimates of production potential vary widely, depending on the assumptions that are made: from 33 to 1135 EJ/y [13]. The main variables are land availability and yields. The actual biomass resource depends on many factors, such as accessibility, transport costs, maturity of agriculture and industry. The IEA presents work that provides an indication of the potential resource and this relies on the modelling of various scenarios, including population growth, energy demand, world trade, sustainability etc. [14].

Smeets et al have provided the following estimates of global biomass resources for the year 2050 [15]. These estimates do not differentiate between crops for heat, power or biofuels.

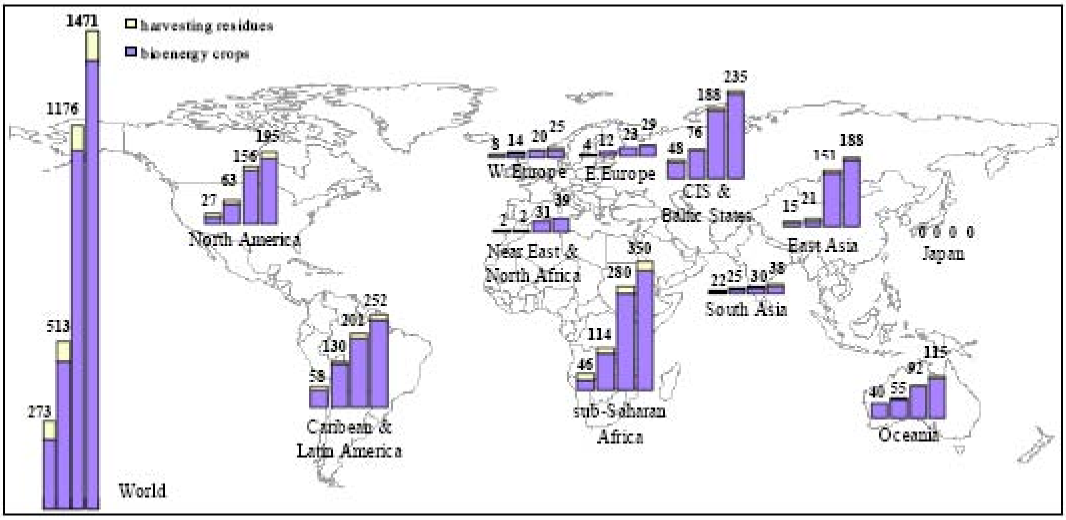
Bioenergy production from surplus agricultural land	215-1272 EJ/y	Note: 1 EJ = 10^{18} Joules or 10^{9} GJ (Giga Joules)
Agricultural residues	58-72 EJ/y	dependent on the production of crops
Surplus forest growth	0-37 EJ/y	dependant on the forest areas available for wood supply and rates of plantation establishment.

The regions with the highest potentials for bioenergy production are [15]:

- Sub-Saharan Africa (0.1-0.7Gha surplus land, equivalent to 31-317 EJ/y bioenergy by 2050) and the Caribbean & Latin America (0.2-0.6 Gha or 47-221 EJ/y in 2050). The potential from these regions is from large areas of suitable land and their present inefficient production systems.
- North America and Oceania - potential for bioenergy on surplus agricultural areas (0.1-0.3 Gha, equivalent to 20-174 EJ/y in North America and 0.2-0.4 Gha or 38-102 EJ/y for Oceania). The bulk of this potential comes from pasture land, large areas that are currently used but that could be made available if industrialised production systems are used.
- The potential for West Europe is estimated at 12-64 Mha or 5-30EJ/y by 2050.
- The CIS & Baltic States are estimated to have considerable potential if agricultural productivity can be optimised. The potential for bioenergy is 0.1-0.5 Gha, equivalent to 45-199EJ/y by 2050.
- East Europe has a potential of 4-40 Mha, equal to 3-26 EJ/y.

The authors estimate that there is sufficiently large bioenergy potential to meet global energy demand in 2050 (by some 30% to 210%). The most promising areas for large-scale supply of bioenergy are sub-Saharan Africa, the Caribbean and Latin America and East Asia, which between them account for more than half of the global potential. The potential is also high in North America and Oceania and the CIS & Baltic states. These potentials are represented diagrammatically in Figure 1.5 below.

Figure 1.5: Total bioenergy production potential in 2050 in 4 scenarios (EJ/y), according to Smeets, Faaji and Lewandowski [15]



According to this analysis the regions with the best potential to produce biomass and export surpluses are: Oceania, the CIS, the Baltic States and sub-Saharan Africa.

1.4 Bioenergy utilisation in the EU

As mentioned in the introduction, bioenergy is the dominant form of renewable energy in the European Union, providing 4.2% of the gross energy consumption in the EU-27 in 2004. The contribution from biomass and waste in relation to other forms of renewable energy and conventional energy sources is shown in Figure 1.6. The use of biomass for energy in each of the EU-27 member states is presented in Figure 1.7. Figure 1.8 shows the increasing contributions made in all of the energy sectors since 1990, though there are significant differences between sectors.

Figure 1.6: EU-27 2004 Energy Mix with Renewable Energy Sources [16]

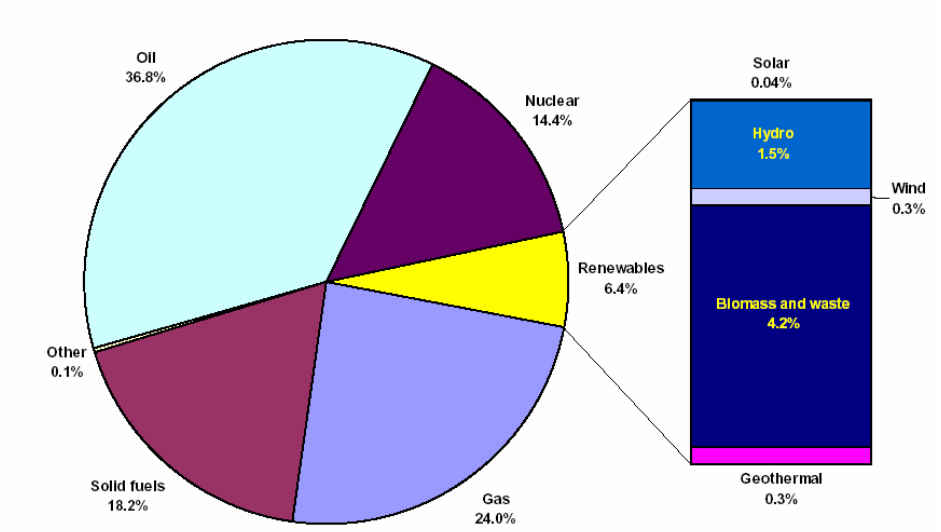


Figure 1.7: The use of biomass for energy in EU-27 member states ([17], data source [2])

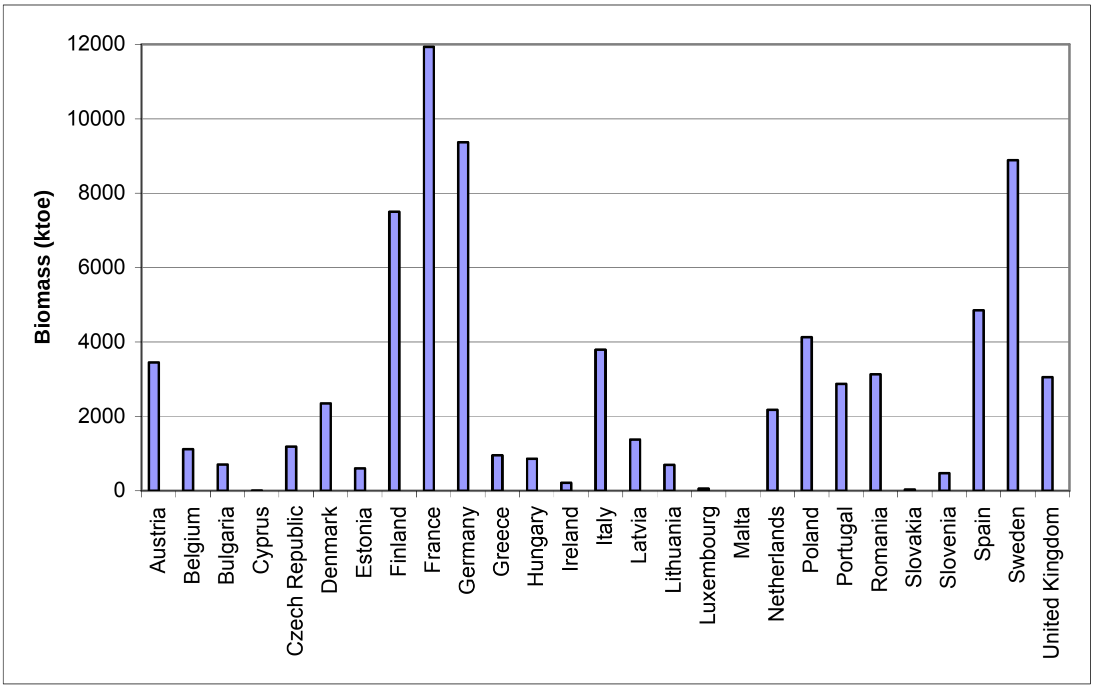
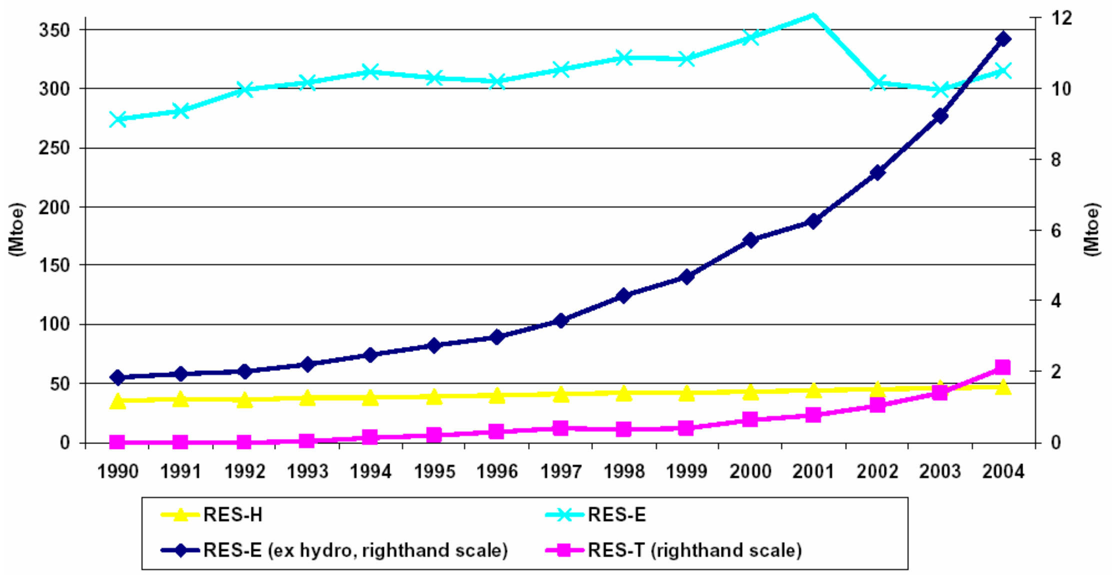


Figure 1.8: Contribution of Renewable Energy (Electricity, Transport and Heat) 1990-2004 ([16], data source DG TREN)



1.4.1 Electricity

The electricity sector (excluding hydro) has seen the biggest expansion, with an increase of almost six times, helped strongly by supportive market incentives introduced in Member States and the positive framework set by the EU's RES-E directive agreed in 2001. Figures 1.9 and 1.10 show the historical and projected contributions to 2020 for different renewables and clearly indicate the growing contributions from solid biomass, biowaste and biogas [16].

Figure 1.9: Non-hydro Renewable Electricity Generation in EU-25 (1990-2005) [16]

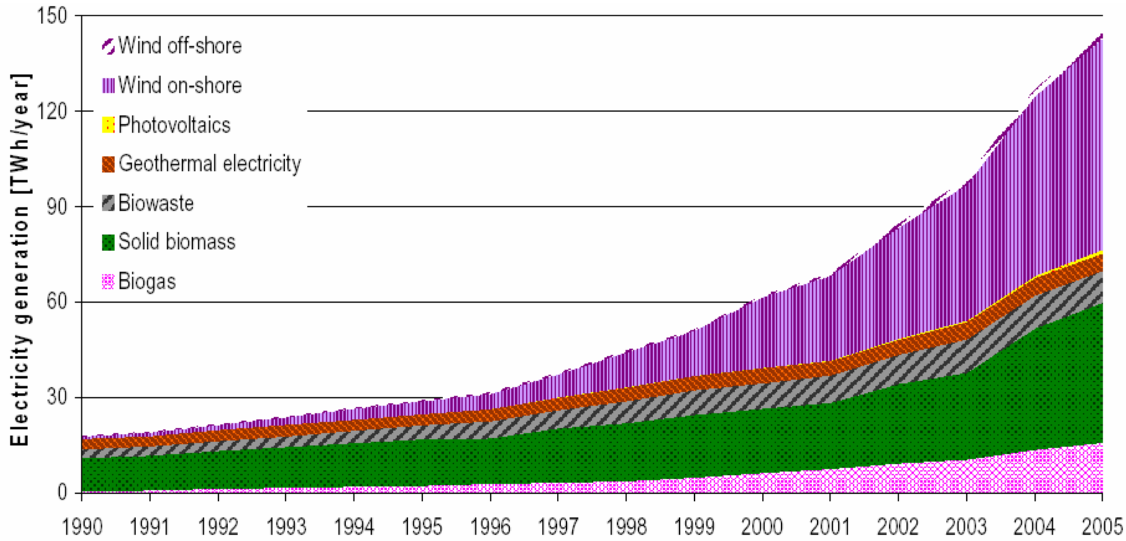
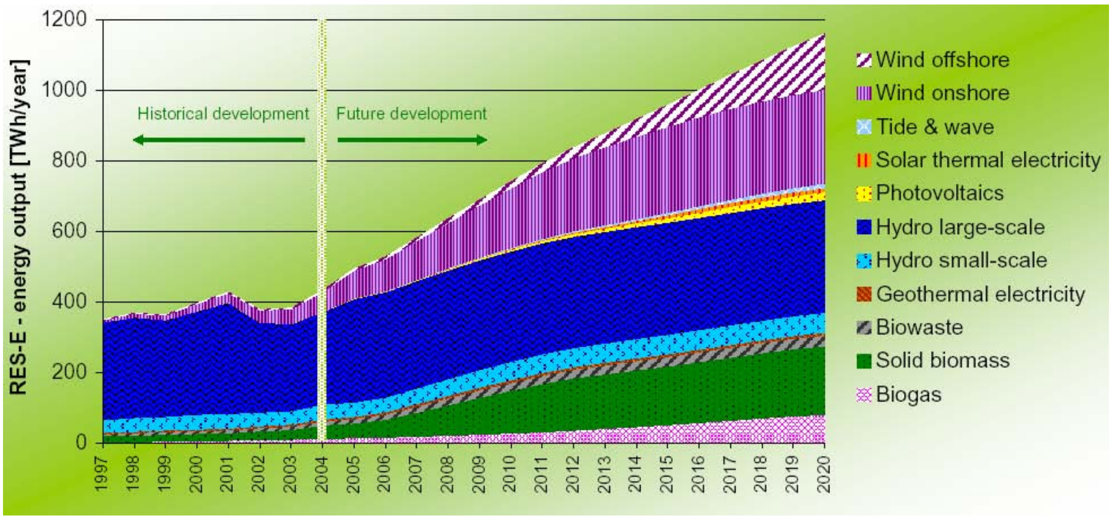


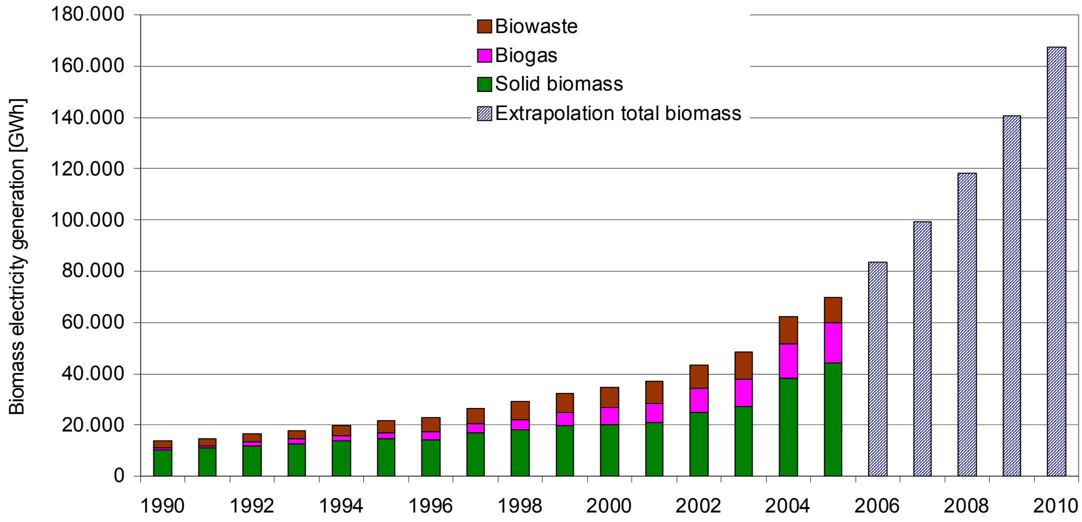
Figure 1.10: Renewables Growth: Electricity Projections up to 2020 [16]



The position is shown in greater detail for these three resources in Figure 1.11 [18]. Data come from Eurostat until 2004; the year 2005 includes provisional figures from IEA and Member States. Growth rates are impressive: 18% in 2002, 13% in 2003, 19% in 2004 and 23% in 2005. Between 2002 and 2004 about 10 TWh additional generation were added to the electricity network. The largest contributors to total biomass RES-E generation are Finland and Sweden followed by Germany, Spain, the United Kingdom, Denmark, Austria and the Netherlands. The long term traditions in the biomass sector and the importance of the forestry industry, together with the fact that most plants are large scale industrial units operating in combined heat and power (CHP) mode, are strong factors supporting the development of the biomass electricity sector in Nordic countries.

Almost half of the Member States allow co-firing of solid biomass in conventional power plants. In the UK, biomass electricity generated by co-firing processes dominated the total electricity generation by solid biomass in 2004 and grew by almost 75 % (+1,4 TWh) in 2005. Currently 630,000 tons of biomass are used as fuel in the three biggest co-firing plants in Hungary.

Figure 1.11: Historical development of electricity generation from solid biomass, biogas and municipal solid waste in the EU-25 Member States from 1990 to 2004 and extrapolation to 2010 assuming a yearly growth rate of 19% [18]



In 2005, nearly 5 Mtoe were produced from anaerobic digestion processes for energy uses in the different countries of the European Union. The total resource is estimated at more than 20 Mtoe with current waste production. Approximately two thirds of biogas is used for electricity production and one third for heat production. Electricity production from biogas is estimated at 14.9 TWh in 2004, half of it through CHP plants. Annual growth rates for biogas electricity generation have been high for the last decade and amount to 24% in 2002, 13% in 2003, 22% in 2004 and 15% in 2005.

1.4.2 Heating and cooling

From Figure 1.8 it can be seen that the growth rate for heating and cooling from renewables has been very modest compared with that for electricity and biofuels for transport. The 12% overall target for renewable energy sources set in 1997 created an implicit target for heating and cooling of an increase from approximately 40 Mtoe in 1997 to 80 Mtoe in 2010. However, the EU has not so far adopted any legislation to promote heating and cooling from renewable sources. There is no coordinated approach, no coherent European market for the technologies, and no consistency of support mechanisms. Biomass use dominates renewable heating consumption and the bulk of this is in domestic wood heating. Only limited growth has occurred in the use of efficient wood-burning stoves and boilers, or biomass CHP (for industrial use), despite their potential for reducing emissions.

Figure 1.12: Renewable energy heating and cooling projections up to 2020 [18]

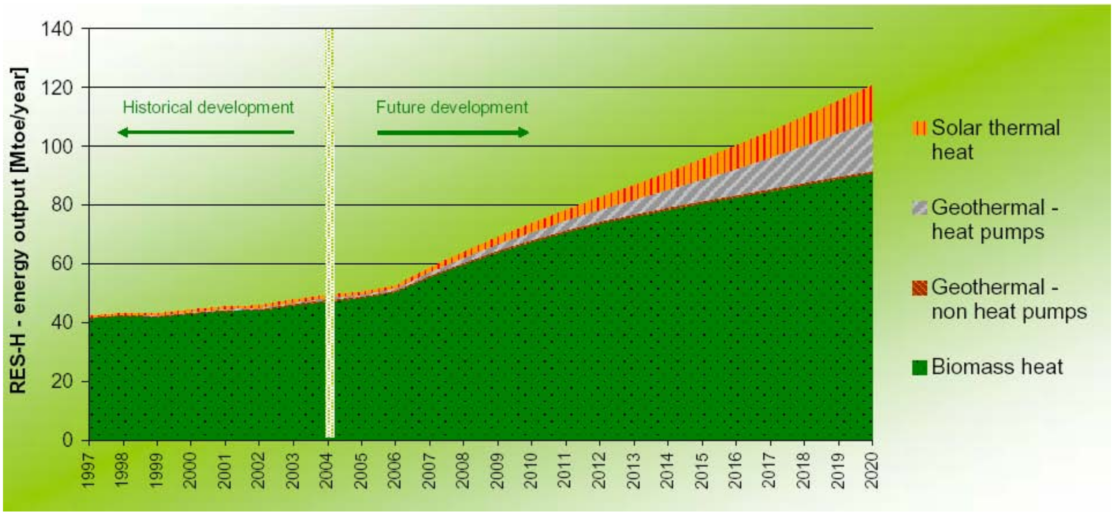
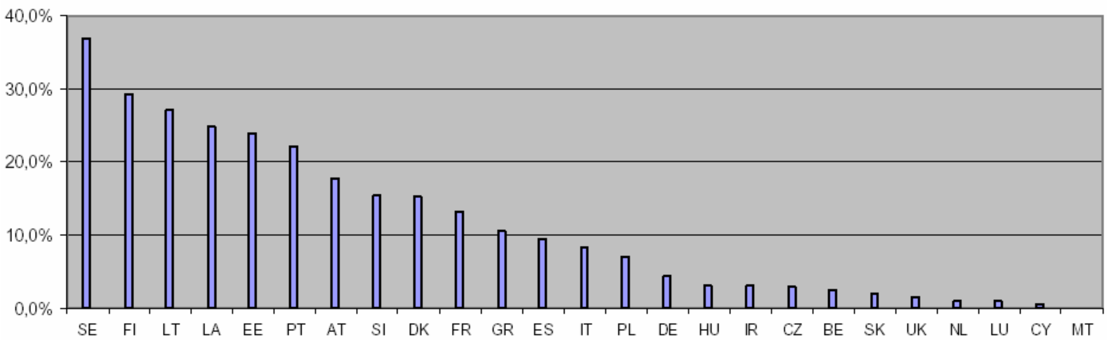


Figure 1.12 shows clearly how biomass dominates the renewable energy contributions to heating and cooling, providing 48 Mtoe in the EU-25 in 2003 (70% of the total contribution from bioenergy and representing 9% of total EU energy consumption in this sector). Figure 1.13 shows the distribution in contribution between different EU Member States. As expected the highest contributions generally occur in the countries with significant forestry resources.

Figure 1.13: Biomass contribution to heating in EU Member States



The Commission recognises that insufficient progress has been made in this area and proposes to work towards specific legislation to complement that already enacted for electricity and transport, addressing the barriers to growth in the use of renewable energies in the heating and cooling sector including administrative obstacles, inadequate distribution channels, inappropriate building codes and lack of market information [3].

1.4.3 Transport

In Europe, a few countries began to take an interest in biofuels during the 1990s. The EU began to pay serious attention to the subject in 2001, when the Commission brought forward the legislative proposals that were adopted in 2003 in the form of the biofuels directive and Article 16 of the energy taxation directive. The EU's production of biofuels amounted to 2.4 million tonnes in 2004, approximately 0.8% of EU petrol and diesel consumption. Bioethanol production was reported at 0.5 million tonnes and biodiesel at 1.9 million tonnes. This is an increase of more than 25% compared with the previous year and production capacities are increasing rapidly. Out of the EU's total arable land of 97 million ha, about 1.8 million ha were used for producing raw materials for biofuels in 2005.

The Biofuels Directive [19] sets as target values a 2% market share for biofuels in 2005 and 5.75% share in 2010. By 2005 biofuels were in use in all but 4 of the 21 Member States for which data are available. Their market share reached an estimated 1%, with biodiesel accounting for 0.8% and bioethanol 0.2%. Although this represents a good rate of progress, doubling the overall contribution in 2003, it is well short of the 2% reference value, and less than the 1.4% share that would have been achieved if all Member States had met their own indicative targets. Only Germany (3.8%) and Sweden (2.2%) reached the 2% reference value. While biodiesel achieved a share of about 1.6% of the diesel market, ethanol achieved a share of only 0.4% of the petrol market. Table 1.5 summarises the production of biofuels in the European Union during the period 2002 to 2004 ([5] data from EurObservER; http://www.energies-renouvelables.org/).

Table 1.5: EU Production of liquid biofuels during 2002 – 2004 [5]

	Bioethanol (1000 t)			Biodiesel (1000 t)		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**
Czech Rep.	5			69	70	60
Denmark				10	41	70
Germany			20	450	715	1035
Spain	177	160	194		6	13
France	91	82	102	366	357	348
Italy				210	273	320
Lithuania						5
Austria				25	32	57
Poland	66	60	36			
Slovak Rep.						15
Sweden	50	52	52	1	1	1
UK				3	9	9
from interv. stocks		70	87			
EU-25	**388**	**425**	**491**	**1134**	**1504**	**1933**

A few interesting facts to note on biofuels in the European Union:

- Spain was Europe’s first bioethanol producer, starting in 1999, and is currently the EU’s largest producer of bioethanol. France is second in production of both bioethanol and biodiesel;
- Biodiesel is primarily produced from oil-seed rape, mainly in Germany, France and Italy. Germany is by far the EU’s largest producer of biodiesel;
- In 2004 Sweden was the largest consumer of bioethanol in the EU, 80% of which was imported (the majority from Brazil). Sweden also has the highest consumption of biogas for transport;
- EU production of bioethanol in 2004 used around 1.2 million tonnes of cereals and 1 million tonnes of sugar beet. This represents, respectively 0.4% of the total EU-25 cereals and 0.8% of the EU-25 of sugar beet production;
- EU Biodiesel production from rapeseed is estimated to have used 4.1 million tonnes in 2004, slightly more than 20% of the EU-25 total oilseed production;
- About 0.9 million hectares of the set-aside area have been used in recent years for non-food production, of which 0.85 million ha is used for growing oilseeds for biodiesel. The biggest producers of oilseeds on set-aside land are France and Germany, followed by the United Kingdom and Spain;

- In 2004 the total area used for biofuel crop production was around 1.4 million ha (0.6 million ha on set-aside, 0.3 million ha with energy crop premium, 0.5 million ha without any specific support regime).

Since the beginning of 2005, 13 Member States have received state aid approval for new biofuel tax exemptions. At least 8 Member States have brought biofuel obligations into force (or have announced plans to do so), requiring fuel supply companies to incorporate a given percentage of biofuels in the fuel they place on the market. Member States have set indicative targets for 2010 which, in aggregate, would achieve a 5.45% share for biofuels, close to the directive's 5.75% target. However, on the basis of current trends, the share actually achieved in 2010 is likely to fall well short of the target.

1.5 Bioenergy utilisation worldwide

Reliable data on the worldwide utilisation of bioenergy are very hard to come by, not least because the majority of biomass use takes place in the form of small-scale, local applications (e.g. domestic), many of which are not recorded commercially. The International Energy Agency Fact Sheet, Renewables in Global Energy Supply [1] states that, in 2004, renewables accounted for 13.1% of the 11,059 Mtoe of world total primary energy supply. Combustible renewables and waste (97% of which is biomass, both commercial and non-commercial) represented 79.4% of total renewables followed by hydro (16.7%). The data are represented graphically in Figure 1.14.

Bioenergy therefore makes a very significant 10.6% contribution to total energy supplies. IEA statistics also report that, in 2004, 227TWh of electricity were generated globally from biomass and waste, representing 1.3% of global electricity supply. Of that figure, the shares between the various bioenergy sources were as follows: primary solid biomass (57%), municipal waste (21%), industrial waste (13%), biogas (9%) and liquid biofuels (0.2%).

Total renewables supply experienced an annual growth rate of 2.3% over the last 33 years, marginally higher than the annual growth of 2.2% in total primary energy supply. However, the most significant renewables growth has taken place for technologies such as wind and solar.

The position regarding biofuels for transport merits a special mention. Whilst Europe has been the world pioneer in the production of biodiesel, it is behind other world regions when it comes to bioethanol, which is by far the dominant biofuel at present. The world biofuels market situation is summarised in Annex 3 of the European Commission's EU Strategy for Biofuels [5] published in February 2006.

Figure 1.14: 2004 Fuel Shares of World Total Primary Energy Supply [1]

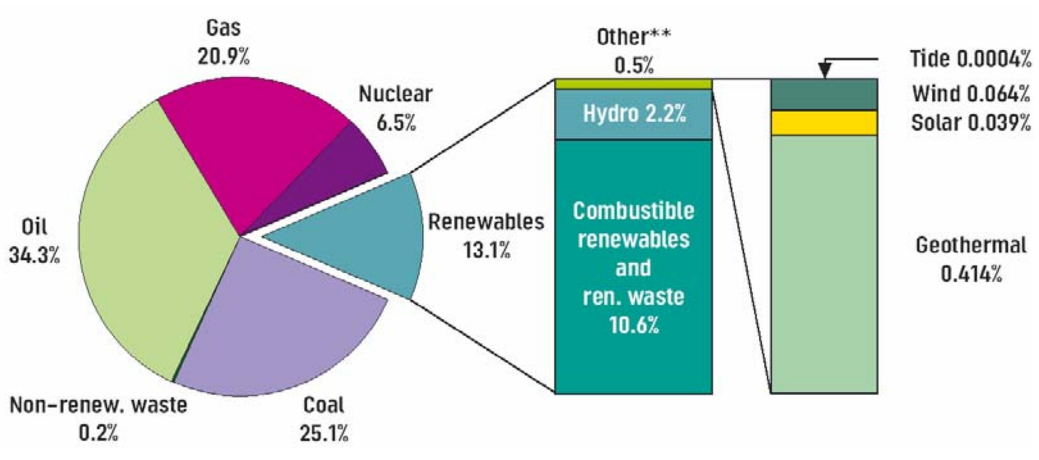
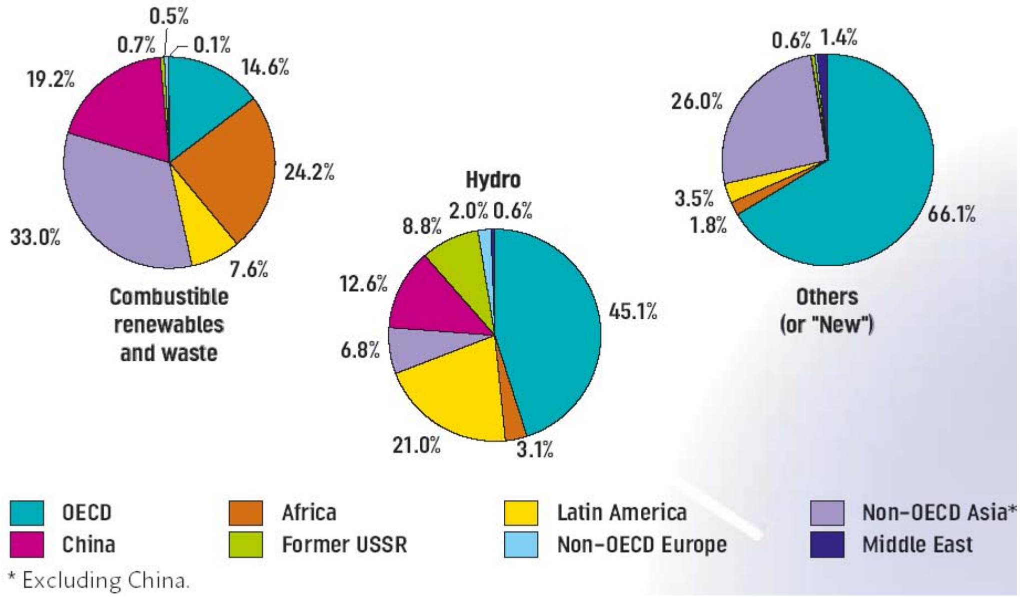


Figure 1.15 provides a regional breakdown of the renewables contribution in 2004 [1]. It can be seen that 85% of the biomass and waste utilisation takes place outside OECD countries, representing a huge potential market for EU manufacturers of modern bioenergy technology.

Figure 1.15: 2004 Regional Shares in Renewables Supply [1]



In 2004 world production of bioethanol for fuel use was around 30 billion litres. This represents around 2% of global petrol use. Production was set to increase by around 11% in 2005. Table 1.6 shows ethanol production by world region.

Brazil has long been the world's leading producer of bioethanol. The sugarcane area is constantly being extended, in order to meet growing domestic and export demand. With around 1 million fuel flexible cars expected to be on Brazil's roads by the end of 2005, the availability of bioethanol for export could be reduced, at least in the short term. In the United States bioethanol output is expanding at an unprecedented rate and now nearly matches that of Brazil. Canada is a world leader in developing second-generation bioethanol.

Table 1.6: World ethanol production, fuel and other uses [5]

Ethanol production	2005 bn litres	2004 bn litres
Brazil	16.7	14.6
United States	16.6	14.3
European Union	3.0	2.6
Asia	6.6	6.4
China	3.8	3.7
India	1.7	1.7
Africa	0.6	0.6
World	**46.0**	**41.3**

Around the world, many other countries have now launched biodiesel programmes, using a wide range of different feedstocks, from cassava to used cooking oil. The United States' National Biodiesel Board anticipated that 75 million gallons of biodiesel would be produced in 2005, or three times as much as in 2004. In Brazil a 2% biodiesel blend will become mandatory in 2008. In addition to developing soya, investments are also being made to develop production from castorseed, in particular in the poorer semiarid north-east of the country.

Malaysia, the world's biggest producer of palm oil, is developing a biodiesel industry, as are Indonesia and the Philippines. The first two countries will also supply palm oil to new plants in Singapore, from where biodiesel will be exported. The China National Offshore Oil Corporation and Hong Kong Energy Holdings are to plant 1m ha of oil palm, sugar cane and cassava over the next eight years in Kalimantan and Papua (Indonesia) and to build a bio-diesel facility in Dumai, Sumatra. This will be Indonesia's largest plant once built [20]. The obligation in India to mix 5% biodiesel with normal diesel is expected to create an immediate demand of 2.5 million tonnes of biodiesel, which may increase to 16 million tonnes if the mix is to achieve India's target of 20% in 2020. India also plans to introduce mandatory blending of 10% bioethanol in gasoline from June 2007. More than 1.12 bn l/y of bioethanol will be required to meet this requirement.

1.6 The legislative framework for bioenergy

This section concentrates on the legislative framework in the European Union, as the EU is the primary focus of this study. Most countries worldwide have active policies and programmes to support the development and deployment of renewable energy and there is an ongoing debate on the efficiency and effectiveness of these. Bioenergy features strongly in almost all of these and the information collated under the IEA's Bioenergy Implementing Agreement is a useful resource [21].

In 1997, the European Union started working towards a target of a 12% share of renewable energy in gross inland consumption by 2010, representing a doubling of the contribution from renewable energies compared with 1997. Since then, renewable energies have increased their contribution by 55% in absolute energy terms. Two key directives have been adopted addressing the electricity and transport sectors:

Electricity: Directive 2001/77/EC aims at having renewable sources provide 21% of the electricity generated in the EU's 25 Member States by 2010 [22]. The directive sets out differentiated national targets to achieve the overall figure; however these are non-binding. In addition to targets, the directive requires Member States to take appropriate measures to increase the share of renewable electricity and address such things as cumbersome administrative procedures, grid access conditions, etc. With current policies and efforts in place, and unless current trends change, the European Union will probably achieve a figure of 19% by 2010 [18].

Transport: in 2003 the EU adopted Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport [19] as well as Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity [23]. The biofuels directive includes not only a target for 2010 (5.75% share of the market for petrol and diesel in transport) but also an interim target for 2005 (2%). Member States were required to set indicative targets for 2005, taking this reference value into account. These national indicative targets, once adopted, are not mandatory. As stated in Section 1.4.3, progress since 2003 has been good but insufficient to meet the 2005 target or anticipate achieving the 2010 target.

In spite of the progress achieved since 1997, current projections indicate that the overall 12% renewables deployment target for 2010 will not be met; the EU appears unlikely to reach a contribution from renewable energy sources exceeding 10% by 2010. The European Commission has been undertaking a major review of progress, culminating in the recent publication of its "Renewable Energy Roadmap"[3]. The Roadmap and supporting documentation reviews the actions taken during the last decade, assesses progress towards the previously stated objectives and targets, and concludes that, whilst progress has generally been encouraging, more needs to be done.

It proposes the adoption of a "20% renewables by 2020" mandatory target and outlines some of the measures required to achieve this. The overall EU target will need to be reflected by binding targets on individual Member States. The European Council agreed to the proposed target in March 2007 and called for "an overall coherent framework for renewable energies which could be established on the basis of a Commission proposal in 2007 for a new comprehensive directive on the use of all renewable energy resources" [24]. The Council conclusions also call for "criteria and provisions to ensure sustainable production and use of bioenergy and to avoid conflicts between different uses of biomass".

As one might expect, bioenergy is anticipated to play a key role in meeting this ambition. However progress in the bioenergy sector(s) requires a very wide range of factors to be considered, covering supply of adequate feedstock, agricultural policy, environmental legislation, fuel standards, competitive conversion technologies, etc. Setting out a framework within which deployment of bioenergy can expand to meet its potential requires a concerted and co-ordinated approach to all these factors.

The Commission's Roadmap sets out a range of measures it is likely to propose as part of the above package. Under the legally binding targets, the proposal is for each Member State to have the freedom to determine the best renewable energy mix for its own circumstances. At the same time and in view of reaching the overall national target, Member States will be required to establish National Action Plans outlining their specific objectives and sectoral targets for each of the renewable energy sectors - electricity, biofuels and heating and cooling.

While biofuels are more expensive than other forms of renewable energy today, they are the only way to significantly reduce oil dependence in the transport sector over the next 15 years. The Council also accepted the Roadmap's proposal for a binding minimum target for biofuels of 10% of transport petrol and diesel by 2020 (taking into account the availability of sustainably produced feedstocks as well as car engine and biofuel production technologies). To ensure a smooth implementation of this target, the Commission, in parallel, intends to propose appropriate modifications to the fuel quality directive (98/70/EC) [25] including the means of accommodating the increased share of biofuels. The Roadmap stresses that targets must be defined now, as manufacturers will soon be designing future vehicles that will need to run on these fuels.

The Commission will also aim to remove unreasonable barriers to the integration of renewable energy sources into EU energy systems and develop and liberalise the internal electricity market. It proposes to co-operate with grid authorities, electricity regulators and the renewable industry to enable better integration of renewable energy sources into the power grid. Finally, it proposes to better use the Community's financial instruments, notably the structural and cohesion funds, as well as R,D&D funding.

The Roadmap calls on Member States to play their part by adopting a framework conducive to the deployment of renewables. They will be called upon to ensure rapid, fair and simple authorisation procedures for renewable energies, improve pre-planning mechanisms in which regions and municipalities have to assign suitable locations for the deployment of renewable energies and integrate renewable energies into their regional and local plans.

With specific relevance to bioenergy, the Roadmap states that the Commission will:

- propose legislation to address the barriers to growth in the use of renewable energies in the heating and cooling sector including administrative obstacles, inadequate distribution channels, inappropriate building codes and lack of market information;

- promote a proposal for an incentive/support system for biofuels that, for instance, discourages the conversion of land with high biodiversity value for the purpose of cultivating biofuel feedstocks; discourages the use of bad systems for biofuel production; and encourages the use of second-generation production processes;
- continue to pursue a balanced approach in ongoing free trade negotiations with ethanol-produced countries/regions, respecting the interests of domestic producers and EU trading partners, within the context of rising demand for biofuels;
- fully implement the Biomass Action Plan adopted by the Commission in December 2005.

Full implementation of the Roadmap would put the European Union at the forefront of renewable energy development worldwide and put EU-based renewables industry in a very strong position to exploit opportunities outside the EU. The proposed targets are challenging but achievable if accompanied by the measures proposed. The Roadmap provides a positive framework for the further development of bioenergy in the EU and requires rapid implementation if deployment targets are to be achieved.

1.7 The EU's competitive position

Europe has been at the forefront of developing renewable energy technologies, including most aspects of bioenergy, and has built up a strong industrial capability that has been active both in the EU and worldwide. A key barrier for many forms of bioenergy is their cost. This has been overcome through a wide range of market incentives implemented at national, regional and local level, aided by deployment targets and complementary measures addressing some of the barriers to uptake. Cost issues have also been addressed through significant R&D efforts, with EU programmes playing a key role. However, although cost reductions have been achieved, cost remains a significant issue for much bioenergy (with the exception of energy from waste, landfill gas, sewage gas and some niche applications) and it is likely that market incentives will be needed for some time.

In recent years many of the technologies have "come of age", moving from the laboratory through pilot implementation to full scale commercial deployment. Along the way there have been inevitable failures and it is crucial to learn from these as well as from the successes. Renewable energy technologies must prove themselves in what can be a fiercely competitive market and many of them still need nurturing if they are to progress to full-scale commercial maturity. As stated in the previous section, the Commission's Roadmap provides a very positive framework for the further development of EU renewables capability, though the magnitude of the challenges should not be underestimated.

In the bioenergy field the EU has a number of advantages:

- a strong history of developing and implementing a wide range of innovative bioenergy technologies, plus a significant presence in the world market. History has shown that, if the framework is right, markets react positively;
- a good climate for producing biomass and availability of set-aside and marginal land (though imported fuels may well undercut EU production on price);
- a generally supportive policy framework, driven by concerns over security of energy supply and the potential for global warming. This will be a particular advantage if the Roadmap is fully implemented;
- strong engineering, scientific and academic capabilities that can support bioenergy development;

- well-established markets for the full range of bioenergy products (though one must note that these can sometimes be restrictive and highly competitive);
- strong environmental regulations that encourage the beneficial use of wastes (note however that some regulations can also act as a deterrent);
- a wide range of tools available at the EU level to support bioenergy (setting targets, agricultural policy, development of an internal market, structural funds, EU emissions trading scheme, energy taxation, R&D funding, etc).

However it is important to note that development of bioenergy also faces a number of potential threats:

- implementing the Roadmap carries a significant cost and there may not be the political will to do so fully;
- it is possible that, as deployment accelerates, demand and competition for feedstock will drive up prices to uneconomic levels. It is also likely that there will be competition between alternative bioenergy routes for the same feedstock, favouring the most economic options unless additional protection is provided;
- it is also possible that if the EU sets high biomass targets without putting in place the infrastructure to support development of the biomass resource that users will increasingly turn to imports;
- bioenergy is also being actively developed outside the EU, often with significant funding, with the potential to eclipse EU efforts;
- continuing volatility of conventional fuel prices may reduce investor confidence in making the substantial capital investments required to deploy bioenergy;
- very high growth rates have the potential to lead to significant numbers of failures, that can undermine confidence in the technologies;
- at higher deployment rates it may become more difficult to maintain the support of public opinion: issues such as siting of plants, emissions from plants, competition over land use and fuel transportation could become serious barriers;
- bioenergy may be seen as a threat by certain established industries that have the ability to undermine efforts to accelerate deployment.

In general the EU is in a strong position to benefit from the opportunities afforded by the exploitation of bioenergy but policy makers need to be mindful of the challenges that exist. These are explored further in later chapters of this study.

2 PUTTING BEST-PRACTICE INTO USE – CASE STUDIES

2.1 Introduction

As mentioned in the Background chapter, there are a number of well-established technologies in the bioenergy field operating across the range of feedstocks and conversion processes. An overview of the conversion processes and technologies can be found in the European Commission's publication "Green Energy for Europe" [26][1], Development in recent years has focused on key factors such as the economics of energy conversion (i.e. cost reduction), ability to use a wider range of feedstocks (i.e. flexibility) and environmental impacts. For bioenergy to compete economically with conventional sources of energy on a large scale will require cost reductions in a number of areas and this presents manufacturers with a significant challenge.

This chapter presents examples of bioenergy plants in the EU and worldwide for a representative cross section of technologies. There are several useful sources of information for case studies, many of them supported through EU programmes:

Intelligent Energy Europe programme – http://ec.europa.eu/energy/intelligent/index_en.html

ManagEnergy - http://managenergy.net/submenu/Scs.htm

European bioenergy network II - http://www.eubionet.net/

Energie-Cités - http://www.energie-cites.org/

FEDARENE - http://www.fedarene.org/

IEA Bioenergy - http://www.ieabioenergy.com/

IEA CADDET - http://www.caddet.org/

Consequently there is a vast amount of information available on case studies on a range of demonstrated technologies for biomass. This chapter does not seek to replicate this information. Instead it presents information on key examples of best practice, particularly where policy, support and technology have come together to create an environment for the successful development and replication of biomass use within a region or country.

This chapter includes the following case studies in the EU:

- Austria: wood-fired central heating and CHP;
- Poland: straw-fired district heating;
- Finland: biomass gasification at Lahti;
- Netherlands: large scale co-firing of biomass with coal;
- Spain: bioethanol, including second generation processing;
- Germany: biodiesel, including second generation processing;
- Denmark: centralised anaerobic digestion and CHP.

And in other places in the world that are at the forefront of bioenergy production:

- Switzerland: bioenergy from municipal solid waste;
- Brazil: bioethanol and biodiesel;
- USA: biofuels and biomass energy.

[1] available at http://europa.eu/comm/research/energy/pdf/biomass_en.pdf.

2.2 EU case studies

2.2.1 Austria: small-scale biomass heating and wood-fired CHP

References: 27, 28, 29, 30, 31.

Country context and support:

Since the 1970s, Austria's energy policy has focused on developing renewables in order to reduce the nation's dependence on imported energy (more than 80% of its fossil fuels are imported). The focus has been on the largest resource being renewable wood fuel; approximately 50% of Austria is forested. Between 1990 and 2001, solid biomass heat production increased more than sixfold. Nearly all of that growth was in space-heating applications of woody biomass, thanks in large measure to new high-technology wood pellet boilers.

In 2003, biomass contributed roughly 12% (or 168 PJ) of Austria's primary energy demand. 60% was used for heating applications, 21% for process heat, 11% for combined heat and power (CHP), and 8% for district heating.

Over recent years, there has been considerable growth in capacity in the biomass sector due to favourable feed-in tariffs which are guaranteed for 13 years. However, the feed-in tariffs were only effective for new installations until December 2004, and growth in the sector has stagnated since.

Austria has chosen a policy of medium- and small-scale biomass installations, which has higher costs but is driven not only by energy policy but also by environment and rural development considerations. A majority of Austria's government R&D budget for renewables is devoted to biomass, mostly wood.

Biomass-fired central heating systems

Austria has provided some excellent examples of how deployment of biomass can be accelerated using new technologies. In almost 500,000 homes biomass is used for individual heaters or central heating systems. The majority of these installations are operated in line with modern combustion technology. As a result of strict provisions in force since the 1980s significant progress has been achieved in the technological development of combustion and controlling engineering for small-scale heating installations. Emissions have been reduced to between one tenth and one hundredth at both manually operated and automatically fed installations which in turn has had a positive effect on the sale and use of the latter.

The efficiency of the new devices rose from an average 60% to 80% in the course of recent years, while both the quality of design and comfort of handling were improved. Pellet-fired installations (2001: approx. 4,900 sold) significantly surpassed those fired with wood chips (2001: approx. 2,300 sold). During the period 1997 to 2001 altogether about 10,500 wood chip installations and some 12,300 pellet-fired plants were installed in the range up to 100 kW output. A brief case study from Upper Austria, where some 15,000 systems had been installed by 2001, can be seen at http://www.managenergy.net/download/nr39.pdf.

Wood-fired CHP for district heating and power generation

Lienz is the regional capital of East Tyrol in the south of Austria with some 13,000 residents. In 2001, a biomass-fired combined heat and power (CHP) plant, the largest in Austria, commenced operations to supply heat to the entire area of the town. This required construction of an associated district heating system.

An extensive marketing campaign was used to inform the public about the project from the very outset and to encourage people to sign heat connection contracts. The town of Lienz undertook to have its 250 housing units connected to the network. Once a threshold of 10 MW had been reached, the decision to commence construction was taken in September 2000.

Figure 2.1: The wood-fired heat station in Lienz

The biomass fuel (100,000 m^3 timber per year) is in the form of sawmill residues, wood chips from forestry operations and tree bark, supplied by regional wood processing companies. At least 10% is supplied by local farmers, which provides them the opportunity to earn money from previously unsellable small-diameter wood. The suppliers have 'just in time' delivery contracts to avoid storage problems at the plant.

The plant delivers 250 MWh heat annually through 31.5 km of district heat piping. It has two biomass-fired boilers (a high temperature boiler and a thermal-oil boiler) with a capacity of 7 MW and 6 MW respectively, and an oil-fired boiler with a capacity of 11 MW which covers peak load and provides reserve capacity. The station is fitted with a flue gas purification unit with heat recovery. In addition, a 1 MW turbine, driven by the biomass-fired thermal-oil boiler, generates electricity which is exported to the grid.

The investment required to construct the plant and piping network is estimated at €19.6 million. The cost was shared equally between the European Union, the Tyrol regional government and the Austrian federal government. In 2001 the district heat was delivered at a price of €52/MWh for small-scale customers and €35/MWh for large-scale customers. The biomass CHP plant saves 29,700 tonnes of CO_2 emissions annually, which represents a reduction of more than half (118%). Similarly, SO_2 emissions are cut by 114%, or 29.9 t, NOx emissions by 53% or 17.4 t, and particulate emissions by 37% or 1 tonne.

Summary

This case study demonstrates the importance of focused support at national level. The Austrians developed a clear sense of what their greatest strength in biomass was (their wood fuel resource) and set up targets and objectives to increase the use of this resource. The support programme was clear; and funding for technology development was targeted at delivering the improvements in efficiency and operations that were required to allow biomass to compete on a practical level. As a result there have been major achievements not only in biomass growth and innovation in technology, but also in emissions reduction.

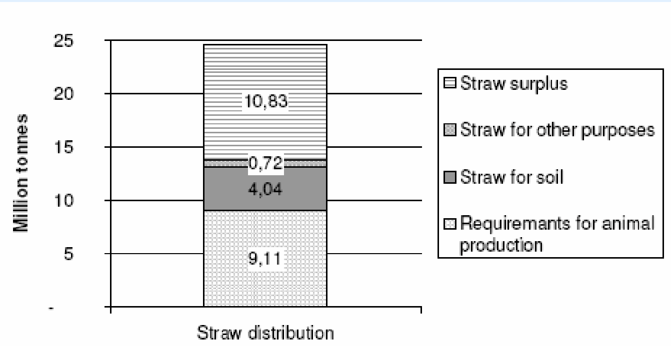
2.2.2 Poland: Straw-fired district heating

References: 32, 33, 34.

Country context and support:

Agricultural areas are a vital element of the Polish economy and occupy about 54% of total land. Polish agriculture produces about 25 million tons of straw (primarily cereal and rape straw) each year, which is used for activities such as mushroom growing, for animal feed or bedding material and as fertilizer. The agricultural utilisation of straw has been decreasing recently, due to a decrease in livestock numbers, and straw surpluses have grown as a result. The average annual surplus of straw in Poland is around 8.1 million tons, which can yield as much energy as 5.4 million tons of average-quality coal.

Figure 2.2 shows the distribution of straw in Poland in 2002:



Energy production based on straw is located mainly in northern Poland where there are largest surpluses of straw – production of cereals and therefore straw is high and the demand for straw for animal production is relatively low. The example below is of straw-fired district heating in the Municipality of Przechlewo, north west of Poland.

Przechlewo, Poland – Straw-fired district heating

A boiler plant fueled by coal dust provided heating for 18 houses, a school, a kindergarten and three office and public utility buildings. However, after thirty years of operation, the boiler plant was in a bad technical condition and the operating costs were steadily rising due to the price of coal and the repair costs. About 2000 tons of coal dust at 52.5 Euro per ton was burnt in the boiler plant each year, and the coal was transported from locations 600 km away.

A replacement straw-fired boiler plant has been in operation since 2001 and is one of the largest biomass-fired energy facilities in Poland. Calculations prior to launch of the project demonstrated that 2500 tons of straw was necessary to produce the heat; this quantity of fuel is sourced locally at 32 Euro/ton, providing extra income for local farmers. The straw had previously been mostly burned in the fields apart from some which was ploughed in or utilised by households.

Figure 2.3: The straw-fired heat plant in Przechlewo

The technical data are shown below:

Installed capacity	4,5 MW (2 x 2,25 MW)
Boiler parameters	83 % efficiency, temp. of water 90°C, Pressure 0,3 MPa
Heat production	24 000 GJ/year inclusive of 3 600 GJ/year for domestic hot water
Fuel	Compressed cereal straw
Fuel consumption	2,900 t/year
Calorific value of the fuel	16-18 MJ/kg

The total cost of the investment was 6,000,000 PLN (€1,396,000), financed by:

- The Agricultural Property Agency of the State Treasury and the Municipality of Przechlewo - 46%
- The Ekofundusz Foundation - 30%
- Preferential credit and subsidy from the Voivodeship Fund for Environmental Protection and Water Management - 24%.

In 2002 the average net cost of 1GJ delivered to consumers from Przechlewo was 30.16 PLN (€7). The economics of the plant are stable. It operates without a financial profit but the Municipality considers that this is compensated for by the plant's environmental benefits, including:

- annual reduction in emissions: CO_2 by 7000 t, sulphur dioxide (SO_2) by 100 t, nitrogen oxides (NO_x) by 90 t and particulate matter by 10 t;
- annual reduction of produced slag by 500 t; and
- its ease of operation compared with the previous coal-fired boiler, as the straw fuel only has to be loaded three times a day.

Summary

This case study demonstrates the use of funds to support advances in the use of biomass in Eastern Europe. The advantages of the development are seen not in terms of immediate financial profit, but in terms of improved environmental emissions, in security of fuel supply and benefits to local agriculture and the local community. There are ample opportunities to replicate this sort of replacement of old fossil boilers across Europe, particularly in Eastern Europe.

2.2.3 The Netherlands: Co-firing biomass with coal

References: 35.

Country context and support:

The Dutch government believes that if it is to meet its objective of having renewable energy contribute 10% of primary energy by 2020 biomass (both waste products and "clean biomass") must play a major role.

The Dutch government sees negative value waste streams as a niche application that can improve the early adoption of biomass technology in an economically attractive way through the use of waste incinerators and co-combustion (e.g., waste wood and sludge) in coal-fired power stations. Over the longer term, the focus for biomass use must shift to more advanced options such as biomass gasification. Novem implements the Energy from Waste and Biomass programme, which concentrates on ensuring the sufficient availability of biomass fuels, e.g., the production of biomass, the use of waste streams (e.g., organic waste, waste from agricultural production, wood and sludges), and the importation of biomass.

This program also funds research on pre-treatment systems; conversion technologies such as combustion of biomass, co-combustion in coal fired power plants, CHP, gasification of biomass, pyrolysis, liquefaction or carbonization, landfill gas, fermentation, and improved conversion in waste incinerators; and market conditioning and efforts to increase the societal acceptance of biomass energy. The development of conversion technologies occurs together with energy utility companies and the waste industry.

The justification for the project was based on the fact that in 1992, 240,000 tonnes of waste and demolition wood was sent for landfill disposal in the Netherlands. In the landfill, the wood decomposes and releases methane, CO_2 and other greenhouse gases into the environment.

Waste and demolition wood is collected at three sites in the Netherlands and processed into raw wood chips. In the process large objects of iron, textile or plastic etc. are removed manually. Smaller metallic and non-metallic parts are removed and small plastic and textile parts are separated by wind sifting. Stones, sand and glass particles are sieved out. The wood chips are transported in containers to the power plant.

The 635 MW_{el} pulverised coal fired power plant at **Gelderland** was retrofitted with a system for cofiring of 60,000 t/a of chipped demolition wood (4.5 % of coal input) in 1995. The pre-processed raw wood chips are delivered and stored in containers. Two mills reduce the material to a size of 1-8 mm. In a second step the wood is dried and milled again to further reduce particle size to woodpowder.

On average the electrical output based on woodpowder fuel is 20 MW, replacing 45,000 tonnes of coal yearly. The CO_2 emissions of this amount of coal equals approximately 110,000 tonnes of CO_2 (1 kg coal burned releases 2.4 kg CO_2). Since there is no net addition of CO_2 when wood is burned and therefore no contribution to the greenhouse effect, the amount of CO_2 can be seen as a reduction. In addition there is a yearly reduction of 4,000 tonnes of fly ash since the ash content of wood is ten times less than that of coal. The energy yield balance calculation shows that co-firing of waste products at Gelderland is 67% better than supplying the wood wastes through a modern waste incinerator for electricity production.

Summary

This case study demonstrates the feasibility of co-firing in Europe and the sort of work that is being done to support the development of co-firing. In addition to potential for co-firing in the Netherlands, its potential has been recognised in the UK, Germany and Scandinavia. A variety of fuels is being used (or considered) and the practical application of co-firing has been demonstrated to be capable of delivering: secure markets for biomass; carbon emission reductions from coal power generation; demonstrated use of a variety of biomass co-products and residues.

2.2.4 Finland: biomass gasification at Lahti

References: 27, 36, 37, 38.

Country context and support:

As is the case with Denmark, biomass is the largest renewable resource in Finland. With a large forest products industry and the absence of a nation-wide natural gas distribution system, Finland has come to rely on biomass based combined heat and power (CHP) plants. In 2001, Finland derived 20% of its energy (280 PJ) from wood fuels. Finland’s 2003 *National Action Plan for Renewable Energy Sources* sets a target of at least 30 % growth target in the use of renewable energy from 2001 to 2010Bioenergy is expected to increase the most, accounting for about 85 % of the total growth. Biomass use is estimated to increase from 25 TWh in 2003 to 32 TWh in 2012.

Finland has many biomass gasification plants. Eight Bioneer gasifiers ranging in capacity from 4 to 5MWth and fuelled by forestry and sawmill residues, have been operating in district heating plants for over 20 years. The Circulating Fluidised Bed (CFB) gasification process has been successfully deployed at a paper mill in Pietersaari and for co-firing at Lahti.

Finland offers tax refund and investment incentives of up to 30% for biomass-generated electricity.

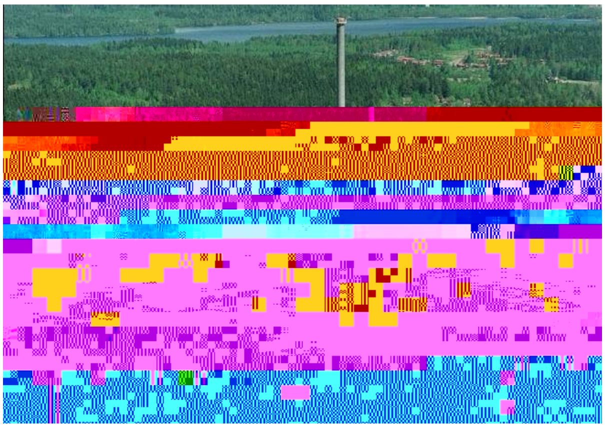
Lahti – biomass gasifier connected to a coal-fired steam boiler

The aim of the Kymijärvi Power Plant gasification project at Lahti was to demonstrate on a commercial scale the direct gasification of biomass and waste fuels and the use of hot, raw and very low calorific gas directly in the existing coal fired boiler. The gasification of biomass and co-firing of gases in the existing coal-fired boiler offers many advantages such as: recycling of CO_2; decreased SO_2 and NO_x emissions; efficient utilisation of biofuels and recycled refuse fuels; low investment and operating costs; and utilisation of existing power plant capacity.

The Kymijärvi power plant started operations in 1976 as a heavy oil fired plant. In 1982 it was modified for coal firing and in 1986, a gas turbine generator set was installed. The 60 MWth CFB biomass gasifier was added in 1998 with no commissioning problems. At present the plant is operating with the gasifier availability at > 95 %. In this process, biomass is gasified and the resulting synthesis gas is co-fired with coal in the boiler.

The Circulating Fluidised Bed (CFB) gasification technology was developed in the early 1980s. The driving force for the development work was the dramatic increase in oil prices during the oil crises of that time. The primary advantage of CFB gasification is that it enables the substitution of expensive fossil fuels (e.g. oil or gas) with a wide variety of cheaper solid fuels, including biomass and wastes.

Figure 2.4: The Kymijärvi power plant with biomass gasifier, at Lahti



The gasifier at Lahti uses locally available low-price biomass and recycled refuse fuels, namely 35,000 tonnes per year of dry municipal solid waste, construction wood, plastic and waste paper with an equivalent energy content of 300 GWh (180,000 tonnes) annually. This reduces the power plant's annual coal consumption by up to 30%.

The total investment for the biomass gasifier plant (including the fuel preparation and gasification plant) was approximately €11 million. The project received a €3 million grant from the EU's Thermie demonstration programme. The payback time for the plant has been estimated at around 8 years.

Summary

The Lahti plant is one of the most successful demonstrations of advanced thermal conversion technologies in the world. Its success lies in the fact that it matches local needs with local technology. This plant demonstrates the potential of gasification at large scale to generate power, reduce coal use and fossil greenhouse gas emissions and also provide a solution to local waste disposal.

2.2.5 Spain bioethanol – Abengoa Bioenergy

References: 39, 40, 41, 42.

Country context and support:

Spain has been the EU's largest producer of bioethanol for a number of years, with production of 240,000 tonnes in 2005, a 17% increase from 2004. Since 1994 Spain has allowed tax exemptions for bioethanol plants. The current regime is for full detaxation for pilot plants for five years and for industrial plants until at least December 2012.

The Spanish group Abengoa Bioenergy is the EU's leading producer of bioethanol for biofuels. It currently operates three bioethanol facilities in Spain with an overall installed capacity of 550 million litres per year. Abengoa Bioenergy is also the fifth largest producer in the United States with an installed capacity of 365 million litres per year.

Existing plants

The Ecocarburantes Españoles plant is located in Cartagena city, in the Murcia region of southeast Spain. It was constructed in 1999, and produces 100 million litres of ethanol, along with 130,000 tons of Dried Distillers Grain and Solubles, and 78,000 tons of food-grade CO_2 annually. In 2000, a wine alcohol distillation plant was added with an annual capacity of 50 million litres to allow for the upgrading of waste from winery processing.

Bioethanol Galicia: The plant is located in the northwest of Spain, in Galicia. It was constructed in 2001, and produces 126 million litres of fuel ethanol, along with 96,000 tons of Dried Distillers Grain, and 98,000 tons of food-grade CO_2 annually. In 2003, a wine alcohol distillation plant was added with an annual capacity of 50 million litres to allow for the upgrading of waste from winery processing.

Biocarburantes Castilla y Leon. This new facility is located at Babilafuente, Salamanca (Spain) and designed to produce 200 million liters of fuel-grade bioethanol per year. The plant will use wheat as feedstock for 87.5% of production and European wine alcohol as feedstock for 12.5% of production. The production of coproducts will be 480 t/day of Distillers Dried Grains and 416 t/day of CO_2.

Bioethanol facility in Lacq (France)

In 2006 Abengoa Bioenergy commenced construction of a bioethanol facility in Lacq that will utilise corn and wine alcohol as raw materials. It is the first bioethanol facility in Europe to utilise corn, which is the dominant feedstock in the United States. The investment to be made is approximately 180 million euro. The first phase (40,000 tons) is scheduled to come into production in 2007, with the plant's maximum production capacity of 200,000 tons of bioethanol to be reached in 2008.

World's first commercial lignocellulosic ethanol plant

Abengoa Bioenergy and the Canadian-based SunOpta BioProcess Group began construction of the world's first commercial scale plant producing lignocellulosic ethanol in August 2005, with commissioning expected in 2007. The plant is located at the new Biocarburantes Castilla y Leon cereal ethanol plant in Babilafuente. It will process 70 tonnes of agricultural residues such as wheat straw, each day and produce over 5 million litres of fuel-grade bioethanol per year.

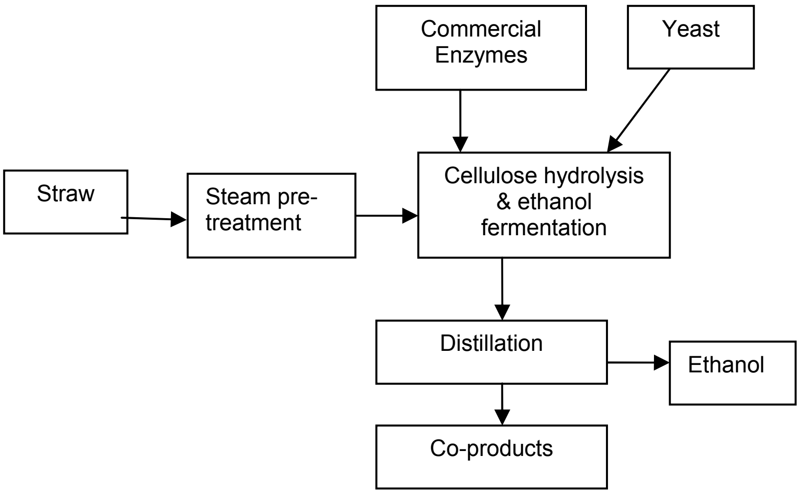
The goals for the Biomass Plant are to commercially demonstrate the lignocellulosic biomass to ethanol process, optimize plant operations, and establish a baseline for the future expansion of the ethanol industry. In addition to ethanol, the plant will generate sufficient amounts of fermentation residues for the development and testing of co-products, such as feed and chemicals.

The major processing steps of the plant are shown in Figure 2.5. The biomass feedstock, such as wheat or barley straw, is first milled and cleaned in the preparation stage and then pretreated. The pretreated biomass is digested by enzymes to release sugars, which will be further fermented by yeast to ethanol and carbon dioxide. Ethanol is recovered in the distillation process, and the fermentation residue is processed further as animal feed or to recover useful chemicals.

In a second phase of this project to be implemented in 2007/08, processed biomass will undergo fractionation, a technology currently under development, to extract lignin, pentose sugars, and manufacture feed products.

The plant represents a major step forward in the deployment of second generation biofuels. The cost of producing bioethanol via the emerging technology are still estimated to be about 50%-100% higher than that for plants which use grain as a feedstock. Small research facilities focused on cellulosic ethanol have intermittently been in operation or are in development in several U.S. States. The only other factory worldwide that currently generates energy from the breakdown of plant fibres, rather than sugar, or sugar derived from grain starches, is a demonstration facility operated by the Iogen Corporation in Ottawa, Canada. It is estimated to produce about 750,000 lires of ethanol from straw annually, as opposed to the 200 million litre capacity planned for the forthcoming Spanish plant.

Figure 2.5: Flow diagram for the Lignocellulosic Biomass Ethanol Plant



Using data collected from the plant, Abengoa will be able to conduct a life cycle analysis which, combined with their economic assessment, will provide a practical model for biomass conversion to ethanol, feed, and chemicals. The co-location and integration of lignocellulosic biomass ethanol production with a cereal ethanol plant should lead to reduced capital and operating costs for the biomass plant.

Summary

This case study demonstrates Europe's capability in bioethanol production, including its potential to develop second generation biofuels. It demonstrates that, under the right tax regime and policy framework, international companies will choose to develop plants in Europe and that Europe can deliver. As other European countries put policies in place to support liquid biofuels Abengoa are looking to expand their investment in Europe to other countries.

2.2.6 Germany: production of biodiesel

References: 43, 44, 45, 46.

Country context and support:

Germany is by far the largest producer of biodiesel in the EU, accounting for 52% of total EU production in 2005. Germany produced 1.7 million tonnes in 2005, up 61% from 2004. Only Germany and Sweden met their 2005 biofuel production targets under the Biofuels Directive.

Germany has supported biofuel production for many years. Biodiesel used as 'B100' (100%, not blended with diesel) enjoys full tax exemption, which allows the price consumers pay at the pump to be less for biodiesel than mineral diesel. This policy has led to very rapid growth of biodiesel over the past few years. Germany now has over 1900 filling stations with B100. However the government has found that this support has caused a level of 'overcompensation' and so it has announced that taxes will rise in the coming years.

Capital grants of up to 35% are also available for investment in commercial biofuel plants in certain East German regions that qualify for regional selective assistance under EU rules.

In 2003 there were 23 biodiesel plants in Germany. Rapeseed oil is by far the dominant feedstock, although one plant produces biodiesel from recycled animal fats. The German experience can offer a number of lessons about the importance of planning for feedstock availability:

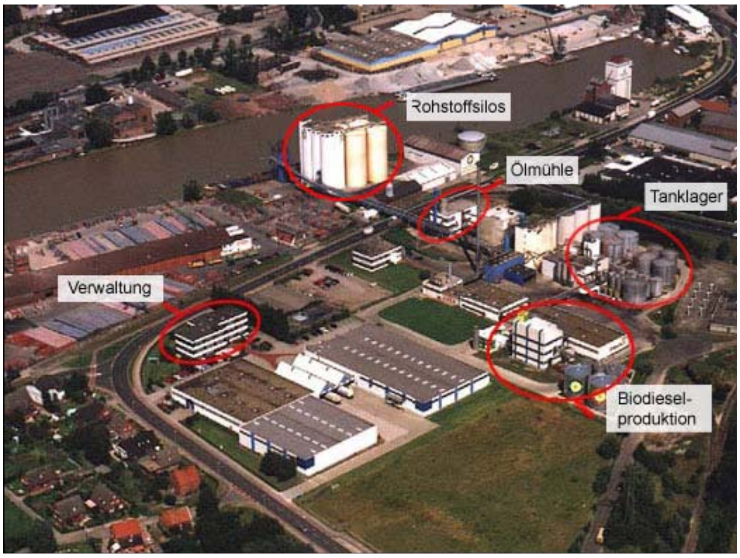
- A stable, lasting supply of rapeseed oil as a raw material is vital for ensuring the competitiveness of biodiesel production facilities, to avoid the threat of closure through a shortage of rapeseed oil and/or high rapeseed oil prices (as happened to one biodiesel plant in 2003). Oil-mill capacities are expanding from 5.5 to 7.5 million tonnes by the end of 2007. The number of decentralised pressing mills linked with biodiesel plants also risen sharply in the last three years from 98 to 300.
- Germany is increasingly importing rapeseed oil from other parts of the EU to meet demand for biodiesel feedstock. As a result new biodiesel facilities are being planned along navigable inland waterways and harbours (e.g. Regensburg, Mainz, Rostock, Neuss).

Below are examples of a plant producing biodiesel from rapeseed oil and a second generation pilot plant.

Biodiesel from rapeseed: ADM Oelmühle plant in Leer, Germany

Initially a research pilot plant of 1,000 l/day capacity was started in 1991. As a next step a technical pilot plant with a capacity of 5,000 l/day was brought into operation in 1993 as the first European industrial demonstration plant. The commercial biodiesel plant today was started in 1995 and now produces 310 t biodiesel/day. The overall investment of 10 million Euro was partially funded by the EU and the federal state of Lower-Saxony.

Figure 2.6: View of the ADM Oelmühle biodiesel plant and associated oil mill



The storage silos for oilseeds (rapeseed, sunflower) are located close to the harbour of the city Leer on the river Ems with access to the North Sea; the oil mill (including the process steps of de-gumming, bleaching and fatty acid distillation) is located between the silos to the left and the tanks for oil and biodiesel to the right; the biodiesel production plant itself is situated below the tank farm; and the administration buildings can be seen at the very left side. There is also a railway connection.

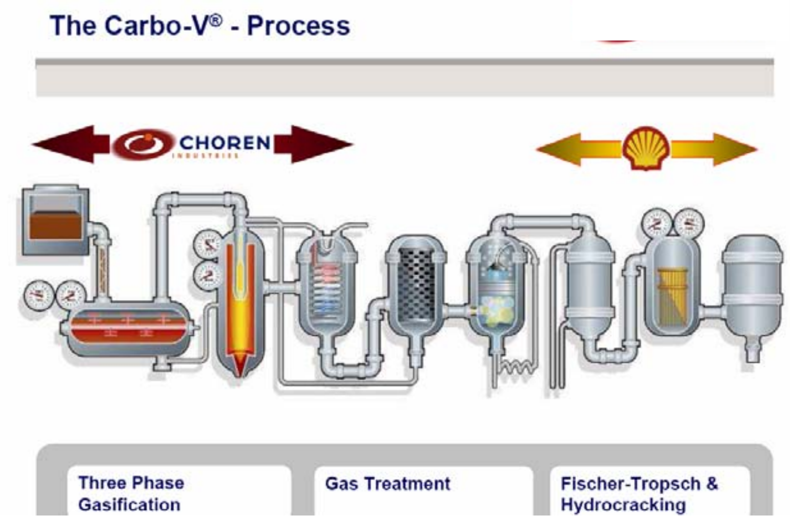
The plant was built close to an existing oil mill which provides the feedstock of around 400 t oil/day. Biodiesel delivery is flexible – it can take place by lorry, rail or ship.

Second generation biofuels: Choren biomass-to-liquid plant, Freiberg, Germany

A large-scale "biomass-to-liquid" (BTL) pilot plant (15,000 t/year) is being constructed in Freiberg, Germany, by the company Choren, funded by the German Bundesministerium fur Wirtschaft (€5.5 million), Daimler Chrysler and VW (each €1 million). The Choren ('Carbo') process obtains an especially high yield per hectare, of 4,046 litres per hectare per annum (l/ha/a), compared to regular ethanol at 2,500 l/ha/a, and biodiesel from rapeseed oil at 1,300l/ha/a.

In addition, Choren and Shell are in the process of developing a full-size prototype commercial plant with a capacity of 200,000 t/year which, depending on the experience with the pilot plant, could be operational in 2009/10. In parallel to the experience to be gained from the BTL process, a number of large-scale "gas-to-liquid" projects, several in Qatar, will deliver technology experience on the second stage (Fischer Tropsch) of the process in the years ahead.

Figure 2.7: Production of biofuel via the Carbo process, by Choren and Shell



Choren aim to produce a 200,000T/a facility in 2009, expand internationally in 2010, and have 1,000,000 t/a online in Germany by 2012.

Summary

These examples demonstrate the rapid growth of biodiesel production and increasing attraction of second generation investment, given the strong financial and policy support offered by the German government. Another key message is the need to plan for stable supplies of biofuel feedstocks.

2.2.7 Denmark: centralised anaerobic digestion

References: 47, 48, 49.

Country context and support:

Denmark and Germany are Europe's principal investors in centralised (collective) anaerobic digestion (AD) plants. These plants are able to produce biogas from animal manure and other types of organic waste that can be anaerobically digested.

The majority of Denmark's biogas production comes from its 20 centralised co-digestion plants and its 60 small on-farm AD plants (57.5 ktoe in 2005) which use 1.3 million tonnes of manure and 0.3 million tonnes of organic waste per year. Biogas combined heat and power (CHP) production is also very well developed in Denmark. It represents 99.3% of the country's biogas generated electricity (272 GWh in 2005) and 84.6% of its production of heat (19.3 ktoe in 2005).

The Danish Government supported the building of centralised AD plants in the 1980s and 1990s. Many of the plants are located to provide district heating in rural areas where it would not have been otherwise possible. Since the privatisation of energy in Denmark, with a fall in energy prices, such plants have not fared so well.

The Government has set a target of 8PJ from biogas and 40 new biogas plants to be established by 2008, representing a more than a doubling of 2003 production.

Heat production is exempted from energy and CO_2 taxation. There is a feed-in tariff for electricity which guarantees a price of 0.60 DKK/kWh for the next ten years and of 0.40 DKK/kWh for a further ten years for plants established before 2007.

Vaarst-Fjellerad Biogas CHP Plant - Aalborg

The Vaarst-Fjellerad biogas plant is located 10km from the town of Aalborg in the north of Denmark. The biogas is utilised in an existing 2MW combined heat and power (CHP) plant, thus partially displacing natural gas usage. The Vaarst-Fjellerad CHP plant supplies electricity to the grid and heat to the district heating system.

The biogas plant started operations in 1997, after a long and difficult gestation period. In 1991 a feasibility study by the Jysk Biogas company was carried out on the anaerobic digestion of cattle slurry together with organic industrial waste and household waste from the Aalborg Municipality. The purpose was to demonstrate that it is technically viable and economically profitable to replace landfilling or incineration of organic waste with a process which would transform the waste into an energy source and a soil conditioner.

Although the study found that the project would be profitable with a construction grant, Aalborg Municipality did not wish to invest in it. Jysk Biogas and PlanEnergi formed a consortium and reached an agreement with Aalborg Municipality that in the event of a privately own and run biogas plant being constructed, the municipality would be willing to direct its household waste, sorted at source, and other organic industrial waste to the plant.

There were difficulties securing loans for the project until the municipality gave a guarantee for a loan. One of the conditions of the guarantee was that ownership of the plant should be collective. To this end, the 16 farmers supplying slurry to the plant formed the Vaarst-Fjellerad Biogas Company and own the plant.

The plant operates at a "thermophilic" temperature of 53 °C using the feedstocks shown in Table 2.1.

Table 2.1: Annual quantities of feedstock and biogas production (2005 figures)

Animal manure	45,000 tons
Slaughterhouse waste	4,000 tons
Household and industrial waste	11,000 tons
Biogas production	4.5 million m^3

The plant produces 4.5 million m^3 of biogas per year, of which 30% is used by the plant itself and the remainder is exported to the Vaarst-Fjellerad CHP plant. The replacement of electricity and natural gas by biogas amounts to annual emissions reductions of 4.9 t carbon dioxide, 3.8 t nitrogen oxides and 2.4 t of sulphur dioxide.

Figure 2.8: The Vaarst-Fjellerad biogas plant

Technical difficulties (including gas leaks from the reactor vessels and inability to supply gas of sufficient pressure to the CHP plant) caused financial strain in the early years of operation. These difficulties were successfully overcome and the plant has since operated satisfactorily.

The total cost of the biogas plant was around €4.5 million, of which €750,000 was covered in grants from the European Union and €280,000 from the Danish Government. The payback period has been estimated at 7 to 9 years, depending on the price of natural gas paid by the CHP plant, and hence the price it pays to the biogas plant.

The codigestion of organic wastes with animal manure means that the plant has improved biogas productivity and better economic results than plants using only manure. In particular fatty wastes and bentonite (bleaching clay) used in the food industry dramatically increase the biogas production.

As with all AD plants the plant also provides a number of environmental benefits in addition to producing energy. In particular it makes productive use of wastes and is a relatively cheap way of reducing the greenhouse gas emissions that would otherwise be released from decomposing wastes.

Summary

Denmark has long provided financial support for the development of AD plants, recognising their environmental and socio-economic benefits. As shown by this case study, the economics of AD plants can be improved by co-digesting other wastes. Securing a long-term supply of these feedstocks (in this case from the local municipality and slaughterhouse) is an important factor in ensuring the successful operation of such plants.

2.3 Examples outside the European Union

We present Switzerland's activities aimed at recovering energy from municipal solid waste and provide an overview of the biofuels programmes and activities of the two most active countries in this area outside the EU: Brazil and the United States.

2.3.1 Switzerland: energy recovery from municipal solid waste

References: 28, 50.

Country context and support:

Switzerland's primary regulatory measure to promote renewables was the institution of feed-in tariffs in 1991. Originally set to expire in July 2003, they were extended in November 2002 for another five years to 2008. Grid owners are obliged to purchase electricity from any private producer at the feed-in tariff of € 0.10/kWh.

The Swiss Energy Action Plan, introduced in 2001, eliminated all new direct incentives for renewable energies. Voluntary measures, together with a possible CO_2 tax, are expected to achieve the two established objectives for renewables by 2010, namely to generate 0.5 TWh (equivalent to 1%) of additional electricity and 3 TWh (equivalent to 3%) of additional heat from non-hydro renewables compared to 2000 levels. This is equivalent to a 60% increase in electricity generation and a 40% increase in heat production from renewables.

In Switzerland municipal solid waste (MSW) is incinerated for electricity and heat. It is also used in anaerobic digestion plants to produce biogas for heat and as a transport fuel.

Since January 2000 all non-recyclable, combustible waste in Switzerland must be incinerated and all energy from waste plant must have heat recovery. In modern plants this heat mainly goes to industry, due to the high cost of constructing district heating networks. There is no national waste tax, although some cantons levy taxes. Waste disposal is paid for on a weight or volume basis ("pay-per-bag" principle). From 2006 land spreading of sewage sludge is banned and it will have to be incinerated.

Switzerland produced 4.9Mt of MSW in 2003, plus 0.2Mt sewage sludge: 2.5Mt of this material was recycled and 3.5Mt incinerated. 2.8Mt were landfilled. There are 29 incineration plants with a capacity of 3.5Mt (2005). These plants generated 1441 GWh electricity and

11951 TJ heat in 2003, which was used in district heating, industry and public buildings. The power capacity of these plants is: 375MWe and 584MWth.

Cement kilns in Switzerland also burn waste. Under legislation concerning the co-incineration of waste, the biomass wastes they are permitted to burn are: waste wood; sewage sludge; poor quality paper and card; paper sludge; soaps, fats or oils of animal or vegetable origin. In 2002 around 0.14 Mt of biodegradable waste was burned in cement kilns in Switzerland.

Another key feature of the Swiss bioenergy portfolio is anaerobic digestion (AD) of farm wastes as well as other organic wastes. In 2005 there were:

- 14 plants treating the organic fraction of MSW and producing biogas with an energy value of 62 GWh/y;
- 24 industrial AD plants, treating food and drink processing wastes to produce biogas of 38 GWh/y equivalent;
- 72 farm waste plants, producing more than 72 GWh/y biogas.

In particular the Swiss have been in the forefront of the development of AD for MSW. 0.64Mt of separated biodegradable waste goes to composting or anaerobic digestion (AD) plants. The solid residue from these plants is post-composted to produce a soil conditioner. These facilities produced 0.045Mt residue (50% solid and 50% liquid). The facilities have to pay for this to be land spread (around 7EUR/t in 2003). The Swiss biogas association produces guidelines for quality control.

The energy from these AD plants is used for heat power, which is a common use for biogas throughout Europe, and as a vehicle fuel. Only Sweden and Switzerland have invested heavily in this option. In 2005/06 there were at least 2,400 gas vehicles in Switzerland, nine upgrading plants and 65 fuelling stations providing biogas.

Summary

This case study demonstrates the wide range of energy applications for waste, as adopted by the Swiss – being incineration for electricity and heat, and AD for heat and vehicle fuels. These developments stem from Switzerland's waste policies banning landfilling and its financial support in the form of feed-in tariffs.

2.3.2 Brazil: biofuels programme

References: 5, 51, 52, 53.

Brazil pioneered the way in bioethanol production in the 1970s and has served as inspiration for a number of other sugar-producing countries. Economies of scale and gains in yield have allowed costs to come down over time so that bioethanol is now cheaper than petrol.

The national Proalcool programme to develop the bioethanol industry was launched in 1975 as a response to oil price shocks and as a means to develop a use for surplus sugar production. To get the industry off the ground, the Government provided subsidised credit for investors in ethanol distilleries, as well as price subsidies for consumers through tax reductions. Initially, the programme was very successful: in 1986, 90% of all new cars sold ran solely on ethanol. The industry lost some confidence in the 1990s due to a slump in world oil prices and the phasing-out of government incentives, but it is seeing a resurgence related to current high oil prices, the competitiveness of ethanol as a transport fuel and the emergence of new export markets. Brazilian law now requires fuel distributors to blend ethanol into petrol at a ratio of 23%.

Investments in agriculture and industry for the production of transport ethanol in the period 1975–89 have been estimated at close to US$5 bn, triggering benefits in terms of import savings with a value of over US$52 bn for the period 1975–2002.

There are currently no subsidies for ethanol production and the product is very competitive in the domestic market: pure bioethanol is sold for around 60–70% of the price of blended petrol and bioethanol at the pump.

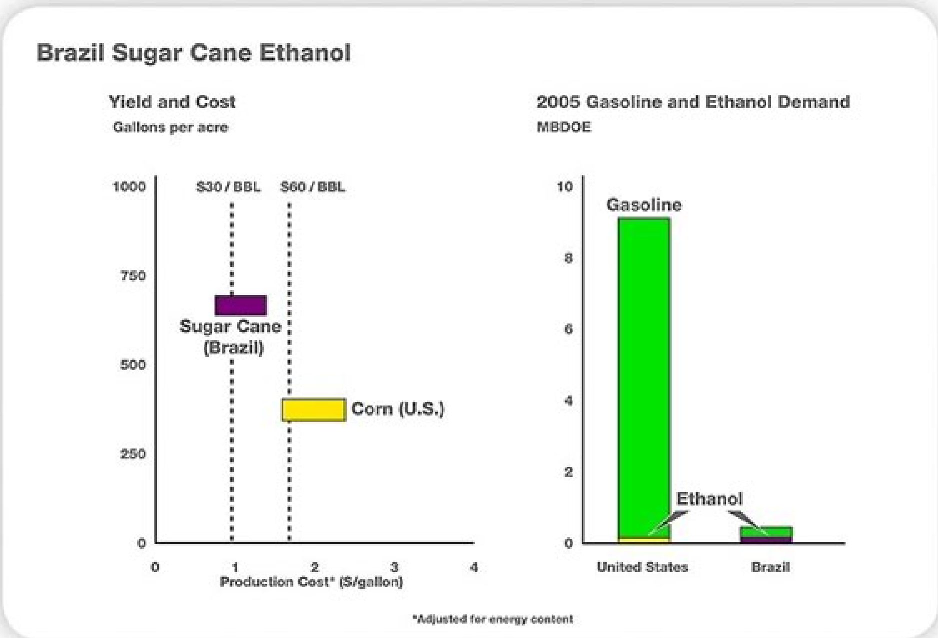
Brazil is the world's largest exporter of bioethanol. It exported 3.2bn litres in 2006, up from 2.6bn l in 2005. EU Member States, particularly Sweden, are major importers as the production cost of Brazilian bioethanol (€0.23/l) is considerably cheaper than for European bioethanol (€0.4-0.6/l). In addition, Brazil's ethanol produced from sugar-cane gives a CO_2 reduction of around a 90% compared with petrol, in contrast to only 25-55% reduction for European bioethanol, depending on the feedstock.

Bioethanol production costs in Brazil are also considerably lower than in the US, as shown in the left-side chart of Figure 2.9. This reflects the positive effects of Brazil's climate for growing sugar cane, as well as its lower labor costs. The production yield for sugar cane is also higher than corn-based ethanol.

The right-side chart shows that U.S. gasoline demand is more than 20 times that of Brazil. So while ethanol production levels are similar in both countries, Brazil's output meets 40% of its gasoline demand, while U.S. ethanol production satisfies only about 2% of its gasoline demand.

To complement the bioethanol industry and encourage a move away from the mono-cultivation of sugar cane, Brazil introduced a national Biodiesel Program in 2004. By the end of 2006 there were 21 biodiesel plants providing a total production capacity of 580million l/y. 34 more facilities are scheduled to start up in 2007. Brazilian law requires a 2% blend of biodiesel in diesel from January 2008 (~800 million l/y), which increases to 5% mix in 2013 or 2.4 billion litres. A range of feedstocks oils are used, including soy bean, jatropha, sunflower, dende palm, castor bean and canola.

Figure 2.9: Comparative production of bioethanol in Brazil and the USA [53]



Summary

This case study demonstrates the success of a focussed national programme. Brazil recognised its natural advantage in being able to produce cheap and plentiful sugar cane and thus invested in the bioethanol industry for both domestic consumption and export. Brazil's new Biodiesel Programme will complement its bioethanol production to further boost energy security.

2.3.3 USA: biofuels and biomass energy

References: 28, 53, 54, 55, 56, 57.

In 2005 the USA narrowly overtook Brazil as the world's largest producer of ethanol. The industry is rapidly expanding: there are currently 113 bioethanol plants in the US with a capacity of 5.6 bn gallons/year. The 78 new plants under construction and seven expansions will more than double capacity to almost 12 bn gallons/year.

In response to energy security and environmental concerns, US energy policy ha strongly encouraged the market for biofuels. Since 1978, bioethanol production has benefited from a partial exemption from the federal excise tax on gasoline blended in prescribed portions with ethanol. A small number of ethanol production projects also received federal loan guarantees in the 1980s. The Clean Air Act Amendments of 1990 and subsequent air quality and energy policy legislation have further encouraged the use of bioethanol.

In 2005 the US produced 5.1bn gallons of ethanol/y, more than 90% of which was produced from corn. The Renewable Fuel Standard 2005 introduced targets to use 7.5 bn gallons of biofuels by 2012. This required all petrol sold in the USA to contain 5% bioethanol. The Biofuels Security Act 2007 (under debate) increases renewable fuels standard to 30bn gallons in 2020 and 60bn gallons in 2030 and requiring fuel suppliers to offer 85% ethanol blends in half their service stations by 2017. Current technologies are thought to be unable to deliver these targets and it is thought that if the US delivers these targets using corn based feedstocks, the price of corn based food will rise world wide. This increase in the price of corn could make the economics of bioethanol from corn unattractive. Already prices for corn in Mexico have increased dramatically in the last year, as a result of increased demand from the US [54].

Production costs for bioethanol are around $2/gallon, based on a yield of approx 350 gallons/acre. Corn based ethanol currently meets 2% of US gasoline demand and requires 13% of the US corn crop. The level of 7.5 billion gallons by 2012 will require 21% of the US corn crop and based on predictions of future demand will meet about 3% of US gasoline demand.

Second generation biofuels production and the development of integrated bio-refineries are funded federally through the US Dept of Energy and Department of Agriculture *Roadmap for Bioenergy and Biobased Produsts in the USA.* Processing and conversion are the highest priority for R&D, although there is increasing support for public policy measures to support biomass development. The US Department of Energy's R&D budget for bioenergy in 2005 was some $82 million. Further information on the US Roadmap is in the box below.

Individual states are supporting the drive for second generation biofuels: a cellulose-to-ethanol plant in Rochester NY, was funded with $14.8M from NY state Energy R&D Authority. Oil Company BP has chosen to host their $500M Energy Biosciences Institutes in the US at the University of California, Berkeley, with partners at the University of Illinois, Urabana-Champaign and the Lawrence Berkeley National Laboratory.

The US has largely concentrated its bioenergy efforts on bioethanol, although it has recently introduced targets and incentives for the production of biodiesel. In addition the use of biomass for energy is increasing. Around 3% of energy consumed in the USA in 2003 was from biomass, representing some 46% of total renewable energy in the USA. In 2003 in the USA 135.6 MW of biomass power capacity was in place and a further 58.8 MW was planned. A significant amount of this biomass power came from landfill gas or co-firing. Nineteen States have obligations for the supply of renewable power as part of their Renewable Portfolio standards, including targets for the amount supplied.

Box Summary of the US Road Map to achieve its Vision for Bioenergy [55, 56, 57]

- **Biopower –** Biomass consumption in the industrial sector will increase at an annual rate of 2% through 2030, increasing from 2.7 quads in 2001 to 3.2 quads in 2010, 3.9 quads in 2020, and 4.8 quads in 2030. Moreover, biomass consumption in electric utilities will double every 10 years through 2030. Combined, biopower will meet 4% of total industrial and electrical generator energy demand in 2010 and 5% in 2020.
- **Biobased Transportation Fuels –** Transportation fuels from biomass will increase significantly from 0.5% of U.S. transportation fuel consumption in 2001 (0.147 quads) to 4% of transportation fuels consumption in 2010 (1.3 quads), 10% in 2020 (4.0 quads), and 20% in 2030.
- **Biobased Products –** Production of chemicals and materials from biobased products will increase substantially from approximately 12.5 billion pounds, or 5% of the current production of target U.S. chemical commodities in 2001, to 12% in 2010, 18% in 2020, and 25% in 2030.

The USA has an active R&D programme aimed at developing biorefineries to produce bioenergy and biobased products. The USA believes that it can achieve the production and sustainable collection of 1 billion dry tonnes of biomass feedstocks by 2030 and, by this date, use biomass to provide:

- 5% of national electricity
- 20% of transportation fuels
- 25% of chemicals and materials from biobased products.

The research to achieve these targets is described in *A Roadmap for Agriculture: biomass feedstock supply* in the United States (2003), available from the US Department of Energy, Biomass Program.

Strategic goals of the Program include:

- Targets for biomass availability
- Targets for sustainability
- Targets to improve infrastructure
- System profitability, to achieve the Road Map's aim of decreasing the cost of feedstock for a biorefinery to $30/dry ton.

The vast majority of bioethanol produced in the US is produced from corn and 40% of this is produced in Illinois, followed by 30% in Iowa. The rest is primarily produced in Minnesota and Nebraska. The use of corn to produce bioethanol pushed the price of corn from $0.14 per bushel to $1.92 per bushel. The case study below describes an ethanol plant that belongs predominantly to a "new generation co-operative" or farmer's co-operative. The interest of this to the European Parliament is the way in which the co-operative benefits from the bioethanol plant, but only if they deliver raw feedstock to the plant. In this way the plant operators ensure they have sufficient feedstock to operate the plant, while the local community benefits.

Case Study: South West Minnesota Agrifuels cooperative [58]

The Southwest Minnesota Agrifuels Cooperative (SMAC) is a "new generation cooperative", formed to provide funding and feedstock to the bioethanol plant in Binham Lake, Minnesota. The cooperative differs from traditional cooperatives in several ways:

- Farmers invest significant amounts up front by purchasing shares in the business.
- Each purchased share allows and obligates a producer to deliver a set quantity of raw product to the co-op.
- There are a limited number of shares, so that the co-op is closed or limited to a set number of producers.
- Ownership of shares can be traded among the farmers and the prices of those shares may rise or fall, as a reflection of how much the farmers expect to benefit from their membership in the future.

SMAC was originally formed to add value to its members' corn production, as corn prices were low. Today it is the majority shareholder of a dry mill fuel ethanol company, Ethanol 2000. This company produced 28 million gallons of bioethanol per year. To participate in the co-operative members were required to purchase a minimum of 5,000 shares at $2.00 per share ($10,000). They were also required to deliver one bushel of corn per share to the plant each year.

However, the investment from the cooperative was not sufficient to develop the plant at Binham Lake and a partnership with an engineering company specialising in ethanol technologies, Broin Enterprises, was formed. The total cost of developing and constructing the plant was $17.5 million, plus $1.5 million for start up, a total cost of $19million in 1997. In March 1999 the plant was expanded to 27.5 million gallons per year.

The co-operative members have benefited financially in three ways:

- The dividend payable at the end of a profitable year (over a dollar per bushel premium on top of the market rate they are paid for their corn upon delivery);
- A portion of the annual profits is retained to pay off debt or for investment in expansion. These retained earnings are allocated to members, increasing their equity investment;
- The value of member stock increased from around $4 million at start up to over $11 million in 2001.

In particular the system has the potential to benefit small and medium sized farms the greatest, because they often commit a greater proportion of their crops to the co-operative.

The new generation cooperative model has been copied throughout Minnesota – of the 14 ethanol plants in operation in the state in 2001, 12 are operated as new generation cooperatives.

Summary

The USA is now the world's largest producer and consumer of bioethanol. The US Government has backed the industry through policy targets and financial support. Their substantial R&D programme is primarily focussed on second generation biofuels and biorefineries – which are areas also being pursued in the EU. Innovative cooperative arrangements in the US ensure that both farmers and plant operators benefit through security of feedstock supply and price.

2.4 Conclusions from case studies

The case studies demonstrate a number of lessons learnt from previous bioenergy developments and these are summarised in the sections below. The information from the case studies has also been used to inform the conclusions in Chapter 6.

Support mechanisms

The case studies show that appropriate long-term support mechanisms and technology improvements lead to an increase in the uptake of bioenergy technologies. Often the use of the technology plateaus if the support mechanisms are withdrawn.

Country expertise

Many countries are particularly advanced in one particular technology. For example:

- Spain has been the EU's largest producer of bioethanol for a number of years and is now hosting the world's first commercial-scale plant producing lignocellulosic ethanol. This is a major step forward in the deployment of second generation biofuels.
- Germany is the largest biodiesel producer in the EU. A second generation 'biomass-to-liquid' pilot plant is being built in Germany.
- Austria has chosen a policy supporting medium- and small-scale biomass heat which provides renewable energy from biomass (mainly wood) but also has environmental and rural development advantages.
- Denmark and Germany are the EU's leaders in centralised anaerobic digestion.
- Switzerland is very advanced in energy production from waste.

Feedstock supply

It is important to ensure that there will be a stable and lasting supply of the biomass feedstock. The German experience shows that there is a threat of plant closure if there is a shortage of feedstock or high feedstock prices. Co-operatives where farmers are shareholders in a plant in return for providing feedstock for the plant have been used successfully in the US to ensure the supply of feedstock. However, the US use of corn for bioethanol has already increased the price of corn in Mexico and it is predicted that it will cause corn prices to rise worldwide if the US delivers its bioethanol targets. This increase in the price of corn could make the economics of bioethanol production from corn unattractive.

Imports

The case studies show that imports of both biomass feedstock and liquid biofuels themselves will have an effect on bioenergy production. For example, the EU imports bioethanol from Brazil as it is considerably cheaper than European bioethanol. The example above from the US shows that importing biomass can have an effect on worldwide prices for a particular commodity.

Environmental and other benefits

Using agricultural and forestry residues and other biomass waste for energy production often has benefits other than greenhouse gas emissions reduction, including waste management, odour control, nutrient and water quality management, and the socio-economic benefits of additional income streams for the generators of these residues and wastes.

3 R,D&D AND TECHNOLOGICAL CHALLENGES

3.1 Introduction

Bioenergy is a multi-faceted subject with a wide range of interdependencies. Widespread market uptake of biomass and biofuels will only take place if all of these dependencies are addressed. This will require the issues and barriers to be tackled on a systematic, highly strategic basis, at all levels. The European Union has a particular responsibility in setting the framework for such a strategy, encouraging all actors to play their part in achieving the envisaged growth.

Within that context, research, development and demonstration (R,D&D) plays a vital role and must, itself, be driven by strategic needs. The issues that need to be tackled range from the hard technological (ensuring that the market is provided with cost-effective and reliable equipment that meets its commercial needs), to the non-technical (designing institutional and commercial frameworks that allow the entrepreneurial spirit of the market to flourish). If is to be effective, R,D&D must be accompanied by all the other measures that complement it: information dissemination, monitoring (with feedback), involvement of the key actors, market incentives, etc.

For technology there is a continuum from basic R&D at laboratory scale through prototype development, pilot scale testing, scaling up to demonstration at commercial scale and ending eventually with full market uptake. It is rare for this process to be a smooth one and vital for effective feedback to take place between all stages. This chapter focuses on the technology aspects of R,D&D but it must be remembered that the other issues tackled through research may play just as vital a role in furthering the interests of bioenergy.

3.2 R,D&D drivers

The main issues driving R,D&D for bioenergy are:

- The need to **increase the resource available** in order to increase production to meet EU and national targets, and to **reduce the cost** of this production so that bioenergy is more competitive with fossil fuel alternatives;
- The need to provide the market with **cost-effective, reliable and environmentally acceptable** thermal and biological conversion technologies;
- The need to address non-technical barriers such as the availability of **reliable information on biomass resources**, **logistical and commercial issues**, issues of **public perception**, etc.
- The need to support the commercialisation of novel technologies by **sharing the risks** at all stages, including that of the first few full-scale commercial applications.

The primary focus should be on facilitating the exploitation of the EU's significant bioenergy potential in order to achieve deployment targets. However, R,D&D efforts should also take into account the potential for the EU to become (or remain) a world leader in certain areas with excellent export potential.

The first two factors above are particularly important for biofuels as current targets depend on the growing of energy crops (which potentially compete with food production) and biofuel production is not cost-competitive with fossil alternatives. R&D to enable the transformation of biomass fractions that are presently discarded (i.e. second generation biofuels and biorefineries that make use of the whole plant) should address these issues and also facilitate another key R&D driver: to **improve the energy and carbon balance** of biofuels production.

3.3 Barriers to deployment of bioenergy

Before describing the EU's competitive potential, current R&D efforts and future focus it is worth examining in greater detail the barriers to increased deployment of bioenergy, and to what extent these can be addressed by R&D and/or other mechanisms. In general terms, the major barriers are the availability of biomass resources and the cost of reliably converting them to the energy forms required by the market. Table 3.1 focuses on the energy crop production issues.

Table 3.1: Comparison of biomass production factors world-wide [38]

	Vegetation growth period	Land prices	Labour costs
Non-tropical industrialised countries, e.g. EU, USA	Low	High	High
Tropical non-industrialised countries, e.g. Brazil, Asia	High	Low	Low

These factors contribute to the EU and US's current R&D focus on second-generation biofuels and "biorefineries", based on using more widely available lignocellulosic feedstocks, in an effort to create economically competitive biofuels.

In contrast, biomass heat and electricity technologies are relatively proven and long-established, though issues of cost reduction, reliability and convenience remain a primary focus if significant market growth is to be achieved. The policy/uptake barriers in many areas are greater than technological barriers that can be addressed though R&D. In its Biomass Action Plan [7], the Commission recognises that "the key problems lie in market confidence and attitudes rather than costs". To address this issue there is a need for consumer information, guaranteed fuel availability, and standards and efficiency criteria to inspire confidence in using bioenergy.

A particular problem exists for energy crops: farmers need certainty before planting crops that will take several years until harvest (e.g. short rotation coppice - SRC), while new biomass conversion plants need certainty of supply – hence a classic 'chicken and egg' problem. The market needs to develop commercial terms that allow this vicious circle to be broken into, giving both sides confidence to commit the financial resources required to bring projects to fruition.

Perhaps as a result of the above factors (that the main biomass barriers are non-technical), R&D in the EU, particularly by industry, currently has a greater focus on development of biofuels and on reducing biofuel production costs, rather than on biomass. This issue needs careful consideration, given that the greatest potential for bioenergy sits clearly in the biomass heat market.

The following tables draw on our review of all sources listed in the Reference section of the study. They summarise the barriers to increased deployment of biomass for electricity and heat and biofuels for transport, assess the scope for addressing these barriers through R&D and/or other means such as Member State market support mechanisms. This analysis is thus also relevant to the following chapter (Chapter 4) about ways to foster production and processing. For barriers that can be addressed through R&D, relevant initiatives under the EU Seventh Framework Programme (FP7) are noted in the table.

Table 3.2: Barriers to bioenergy deployment and the role of R&D

BIOMASS barriers		
Barrier	**Can be addressed by R&D?**	**Can be addressed by other means?**
Efficiency of conversion processes; boiler efficiencies	Y – **FP7** – improving efficiency of biomass firing and co-firing.	N
Biomass contaminants damage power plant components; corrosion of boilers by wheat straw	Y – **FP7** - efficient removal of contaminants	N
For heating & cooling: lack of clear policy including targets; customer perception/lack of information; distribution channels	N	Y – addressed by proposals in the Commission's Renewable Energy Road Map.
Availability of heat distribution grids for CHP	N	Y – the EU's newer Member States are well placed here as many have existing district heating networks.
Limited feedstock availability, competition with 2nd generation biofuels	Y – **FP7** investigating the potential for unutilised (e.g. marine biomass) and under-utilised (e.g. abattoir waste) feedstocks.	Y – serious consideration must be given to this as the market expands.
Reliable feedstock supply chains	N	Y – e.g. European trading floor for pellets and chips initiated with support from the EU Intelligent Energy for Europe programme.
Connection to electricity and gas distribution grids.	Y – **FP7** Smart Energy Networks	Y - rules for connection & funding; support mechanisms such as feed-in tariffs or renewables obligations.
Air quality: health concerns about aerosols from biomass combustion plant, in particular domestic boilers.	Y – R&D has already delivered improved biomass combustion plant.	Y - shift to improved new plant/modified old plant driven by air quality emissions standards and fuel quality standards. Education about correct plant operation.

BIOGAS barriers		
Barrier	**Can be addressed by R&D?**	**Can be addressed by other means?**
Expensive to 'upgrade' biogas to natural gas quality. Need NG vehicles & distribution infrastructure.	Y – **FP7** - reduce costs of upgrading.	Y - facilitate uses that don't require upgrade (e.g. directly to combustion plant)
Wet biomass feedstock is bulky and expensive to transport	N	Y - encourage the siting of AD plants near a concentration of feedstock sources.
Limited future supply of feedstocks in the EU*	N	Y - partly the result of EU policy decisions: limited growth of animal production and hence manure feedstocks; also the phasing out of landfill under the landfill directive

BIOFUELS barriers & R&D		
Barrier	**Can be addressed by R&D?**	**Can be addressed by other means?**
More expensive than fossil fuel equivalents	Y – **FP7** - improve crop yields & 1st generation methods – develop 2nd generation	Y - support mechanisms and obligations. - ensure externalities are included for fossil fuels.
EU feedstock shortage, and future shortages when 2nd generation biofuels compete with biomass energy feedstocks.	Y – **FP7** - improve crop yields & 1st generation methods* – develop 2nd generation	Y – import feedstocks
Unacceptable environmental impacts (or perception of)	Y – **FP7** - studies and standards	Y – Renewable Energy Road Map proposal for support schemes that discourage use of high biodiversity value lands.
Poor energy/carbon balance	Y – **FP7** - studies and standards - development of better methods e.g. 2nd generation	Y – ensure all feedstocks/ biofuels (including imports) adhere to standards
Fuel standards limit biofuel content	Y – **FP7** pre-normative research for standard development	Y – standards being revised and new standards developed by the Commission
Blending petrol & bioethanol (pipes; vapour pressure) **	Y - EC and/or industry funded R&D could help resolve blending issues.	Y – EC working with industry. New fuel standards re vapour pressure.
Production of bioethanol worsens EU petrol/diesel imbalance	Y – **FP7** - 2nd generation Fischer-Tropsch BTL can optimise diesel rather than gasoline.	Y

Notes: * In the past decade, technical progress in EU agriculture has been mainly focussed on reducing costs and fertiliser use per tonne produced rather than to increase yields per hectare. Among the reasons for this are the tight production standards established through the CAP cross-compliance measure, including EU directives on water, soil, biodiversity protection and pesticide usage [11]

** Industry has argued that petrol blended with ethanol cannot be carried in pipelines, and that it is not practical to offer a petrol basestock with a reduced vapour pressure suitable for the direct blending of ethanol. The Commission has indicated its intention to resolve these issues with industry.

The table demonstrates a key message of this chapter as already stated: that some bioenergy barriers in the EU can be addressed through R&D while others require increased support in terms of in policy measures, education and funding; and of course some barriers can be overcome by a combination of both types of support. It can be seen that the FP7 covers most of the identified barriers that can be addressed through R&D. Further details of the research being commissioned under the programme are presented in following section.

3.4 Seventh Framework Programme (FP7)

The EU's Seventh Framework Programme, operating over the period 2007 to 2013, has recently been launched by the European Commission [60]. It continues the high level of support for biomass and biofuel R,D&D of its predecessor programmes. By the very nature of bioenergy this support is spread throughout different components of FP7 (in particular, energy, agriculture and transport) and **the Commission should give consideration to drawing these together into a common summary document in order to provide a succinct overall picture**.

Such a summary would also make it easier to highlight any duplication or gaps in the areas identified for support. The following actions related to bioenergy, with their corresponding objectives, are included in the work programmes:

Biomass for electricity, heating and cooling

The objective is to develop and demonstrate a portfolio of technologies for electricity, heating and cooling from biomass, including the biodegradable fraction of waste. This research aims at increasing overall conversion efficiency, achieving cost reductions, further reducing the environmental impact and optimising the technologies in different regional conditions. A broad range of research topics are considered including biomass availability and logistics; conversion technologies, such as combustion, co-firing and gasification; emission abatement; and land use.

Smart energy networks

A wide-ranging R&D effort to facilitate the transition to renewable energy. Research aims at effective integration of biomass installations into electricity grids and feeding biogas and synthetic natural gas into the natural gas grid.

Life sciences and biotechnology for sustainable non-food products and processes

The objective is to strengthen the knowledge base and develop advanced technologies for terrestrial or marine biomass production for energy and industry. Biotechnology will be applied to improve the productivity, sustainability and composition of biomass raw materials and to develop new bio-processes.

The Commission also attaches high importance to the "biorefinery" concept to maximise the value derived from biomass feedstocks by making full use of their components. Biorefineries could be built up by adding further fractionation and conversion steps to current biomass processing facilities (sugar, grain, pulp mills, oil refineries, etc.) to obtain a broad range of products such as food, feed, sustainable polymers, chemicals, fuels, and heat and power. Improving the cost-efficiency of biofuels through the biorefinery concept will be an important element of the Biofuel Technology Platform.

Transport biofuels

The main area of research is second-generation biofuels made from various biomass resources and wastes, e.g. Fischer Tropsch biodiesel, lignocellulosic ethanol, and bio-dimethylether (DME). The technical feasibility of converting cellulosic material (straw/wood) and organic wastes into bioethanol and biodiesel has been demonstrated, but costs need to be brought down and technology needs to be further developed and demonstrated for commercial-scale production (over 150,000 tonnes a year).

Table 3.3 summarises the current bioenergy research projects to be funded in 2007 under the Agriculture, Energy and Transport themes of FP7.

Table 3.3: Summary of bioenergy research projects to be funded under FP7 in 2007

Research area	Expected outcomes and benefits
Bioenergy feedstocks	
• New and/or improved crop feedstocks	Expanded range of profitable energy crops with enhanced traits for bioenergy production. Guidelines for farmers as to the best biomass sources according to region, climate, life cycle assessment, processing, access etc.
• Animal by-products, e.g. from abattoirs.	Use of an under-utilised resource, enhanced agricultural profitability.
• Marine biomass	Potential use of a currently unutilised resource for bioenergy production.
• Understanding plant cell walls	Ability to 'unlock' the components of plant cell walls for use in producing bioenergy and industrial products.
Biomass heat and electricity	Increased electricity production from biomass through improved power generation and CHP plants which will allow power generation costs below 0.04 €/kWh in 2020 (down from the current 0.05-0.08 €/kWh) whilst operating on a variety of sustainably produced biomass feedstocks.
• Biomass firing / co-firing	Demonstration of co-firing performance and sustainability; efficient removal of biomass contaminants that harm the plant; new technologies for dedicated biomass plants with comparable efficiency and reliability to fossil based plants.
• Gas cleaning	Production of high purity syngas for use in high-efficiency conversion technologies such as fuel cells.
• Improved heat/cool storage systems	Possibly to store and use surplus heat from summer during winter. Lower cost storage systems.
Smart energy networks	Integration of biomass electricity and biogas into electricity and gas networks.
Biorefineries	Demonstration of a working biorefinery, integrating agricultural production, forestry, chemical and biological industries.
Biofuels	
• First generation	Reduced production costs, improved environmental performance and energy/carbon balance.
• Second generation	Development of high performance enzymes and micro-organisms for biofuel production (current bottleneck). Improved conversion processes, including syngas production; lower costs.
• Promotion/facilitation of biofuels in the market	Accelerated uptake through demonstration and promotion of liquid and gaseous biofuels.
Standardisation and sustainability	Development of standards for the use of solid, liquid and gaseous biofuels; also sustainable production standards.

FP7 includes two areas of fundamental research that the Commission has described as "bottlenecks" in the development of bioenergy potential in the EU:

- Understanding plant cell walls, which have evolved to resist breakdown from mechanical and microbial forces, and so present a barrier to unlocking their components for use in producing bioenergy and industrial products;
- Availability of enzymes capable of converting lignocellulosic biomass into fermentable sugars, to produce bioethanol.

Summary

In summary it appears that the expected outcomes of R&D being commissioned under FP7 should address most of the barriers that can be addressed through R&D – as identified through a range of sources and summarized in table 3.2.

As part of FP7, the Commission supports a number of Technology Platforms, which include key industry players and involve them in defining research priorities. Relevant to bioenergy are the Biofuels Technology Platform (described further after BIOFRAC) and those dealing with 'Industrial Biotechnology', 'Plants for the future', 'Forest based sectors', 'Road Transport', and 'Zero Emission Power Generation', relevant to biomass co-firing.

Technical R&D activity under FP7 will be complemented by projects supported under the **Intelligent Energy for Europe** programme (the successor to the ALTENER programme). Its main focus is to support 'soft' measures and to remove non-technological barriers to the widespread market deployment of already demonstrated biomass and biofuel technologies.

As an example, the EU Intelligent Energy for Europe programme recently supported the development of a European trading floor for biomass pellets and chips (as current volumes are low, the Commission proposes to look at how the results can be improved, with a view towards an EU-wide trading system).

3.5 BIOFRAC & other reports/initiatives

The Biofuels Research Advisory Council (BIOFRAC) consists of members representing the major European biofuels stakeholders, including the agricultural and forestry sectors, food industry, biofuels industry, oil companies and fuel distributors, car manufacturers and research institutes. In March 2006 it delivered a report *Biofuels in the European Union: a vision for 2030 and beyond* [61] to Member States and biofuels stakeholders, which:

- Set out a vision for biofuels to contribute up to 25% of the EU demand for transport fuels in 2030 from a base of less than 1% in 2005, including views on how to overcome both technical and non-technical barriers to biofuels use;
- Proposed a Strategic Research Agenda for meeting the vision.

The vision's R&D and deployment road map proposes:

- Short term, until 2010: improving existing technologies, R&D into second generation biofuels (including demonstration plants) and biorefineries;
- Medium term, 2010-2020: Deployment of second generation biofuel production, demonstration of biorefinery concept;
- Long term, beyond 2030: Large-scale production of second generation biofuels, deployment of biorefining complexes.

For comparison these timeframes are similar to those envisaged by the Commission in the working document behind the Biofuels Progress Report [11] which states that second-generation biofuels are "expected to be commercialised between 2010 and 2015 and are likely to be more expensive than first-generation. Their costs are expected to fall by 2020. In that year, both first generation and second-generation biofuels can be expected to be in the market". Deployment of biorefineries is expected beyond 2020 [60].

The key elements of the vision's Strategic Research Agenda are:

- o **Improving existing (first generation) conversion technologies:** including the use of new enzymes for bioethanol from starch and new, more efficient conversion technologies for production of biodiesel and bioethanol;

- **Production of ethanol and ethanol derivatives from cellulosic biomass** (i.e. second generation): including more efficient biochemical systems (enzymes, yeasts), innovative fractionation and purification processes and improved flexibility of plants to convert a broad range of lignocellulosic feedstocks;
- **Production of synthetic fuels through gasification**: which would allow the use of a wide range of biomass feedstock to produce synthetic fuels including DME, methanol, Fischer-Tropsch diesel and Fischer-Tropsch kerosene.
- **Development of integrated refining concepts** (i.e. biorefineries), to produce a variety of outputs in addition to biofuels, such as co-generated electricity, chemicals, and possibly food and/or fibre products, to improve overall conversion efficiencies and the variety and value of outputs;
- **Vehicle engines**: including improvement of "flex fuel" vehicles capable of running on high proportions of biofuels;
- **Biomass resources and logistics**: improving logistic techniques and developing plants that can flexibly cope with different feedstocks depending on seasonal variations;
- **Environmental sustainability**: ensuring sustainable production of bioenergy feedstocks.

The recently established **European Biofuels Technology Platform** is now tasked with facilitating key R,D&D initiatives under the Strategic Research Agenda, towards realisation of the 2030 vision. The Platform has established five working groups to cover the spectrum of issues required to increase deployment of biofuels: Biomass (biofuel resource), Conversion, End use, Sustainability, and Marketing.

3.6 Areas with best competitive potential and potential for innovation

In trying to identify the areas in which the EU has the best competitive potential, it is important to define exactly what that means. If the primary objective is to ensure that the EU makes swiftest progress towards fulfilling ambitious deployment targets, then it is necessary to focus on the barriers and associated facilitators that will speed up EU market deployment. However if the objective is to focus on the development of a strong EU capability in areas where EU-based market players can develop a major presence on the world stage, then resources and strategy need to be focused in that direction. Of course the two objectives can be complementary and these areas of overlap should be where the greatest focus takes place, given that there is always competition for scarce resources.

In general focusing on export opportunities will mean ensuring technology compatibility with a wider range of biomass feedstocks (some of which may enter the EU as imports) and developing technologies suited to the potentially different needs of other world regions. There is a strong case to say that the EU's focus should be on meeting its own deployment targets; the expertise that will ensue as a result of this can then be applied by EU-based companies to enhance their activities outside the EU.

Biomass

EU-based companies manufacture some of the most sophisticated technologies for the use of biomass for heat and power in the world. EU and Member State funding has supported innovative technologies and various electricity support tariffs or obligations enable such plant to continue to be developed. This has allowed improvements in the handling of fuel, in the efficiency of conversion and in improvements in emissions.

The Framework programmes and national programmes allow a wide ranging R,D &D programme to continue. Much of the current work is aimed at ensuring the characteristics of biomass fuels are fully understood, that combustion is efficient and emissions are low. In addition work is being undertaken at all stages in the biomass energy chain to decrease costs to make biomass even more competitive and reliable compared to fossil alternatives.

The EU's advantages include:

- EU has a long history of using biomass for electricity and heating, with successful demonstration and utilisation of anaerobic digestion, CHP, co-firing, bioenergy supply to district heating schemes, and energy from waste;
- Biomass heat plants have been developed with improved efficiencies and automated feeding of fuel to boiler;
- Specifications for good quality, standard biomass fuels have been developed in some countries and are being developed for the whole of the EU. This enables the users to have confidence in the fuel provided and manufacturers to be able to develop equipment with the confidence of knowing the fuel characteristics. It means that the fuel can compete at the same level as conventional fossil fuels;
- The EU has a unified R&D approach through the Framework programmes, which allows exchange of information and technology across the EU;
- Legislation has been put in place to encourage the replacement of high carbon emission technologies with low carbon technologies and to ensure that low emission technologies replace old, more polluting technologies. This has successfully increased renewable energy in the EU (including biomass) and continues to provide a foundation for increased use in the future.

These advantages mean that the EU is well placed to sell its technology and know how worldwide. Given the fact that most of the EU's bioenergy potential lies in the heat and electricity markets it is important that sufficient focus and resources be given to these areas to allow that potential to be realised. For example the small-scale biomass heating market (domestic use or community use up to 500 kW) holds enormous potential but has received insufficient attention in recent years. Unless this area receives more focus there is a danger that it could lose overall market share, let alone fulfil its potential for significant growth.

It may bear more fruit to focus on market segments with the highest potential for growth, rather than try to cover all options and thereby dilute resources. We recommend that the Commission should produce a bioenergy R,D&D strategy that draws all the relevant elements together, identifies the most promising options and sets short, medium and long term goals.

Biofuels

The EU, together with Canada and the US, is at the forefront of research into second generation biofuels and biorefineries. Table 3.4 identifies the areas with the best potential, using a rating of one to three stars (see key below the table).

Table 3.4: Status of transformation processes in EU30 (developed from Ref [62])

Process	Feedstock/ primary energy	Biofuel	Technical Potential (PJ/a)	Carbon balance: low CO_2 emissions (kg/GJ)	Economics: low cost	Readiness for market
Oil pressing/ extraction	Vegetable oil	Straight Vegetable Oil	*	***	***	***
Oil pressing/ extraction & transesterification	Oilseed rape	Biodiesel: RME	*	**	***	***
Transesterification	Recovered vegetable oil	Biodiesel: FAME/ FAEE	*	***	***	***
Fermentation	sugar beet	Bioethanol	***	**	**	***
Fermentation	corn	Bioethanol	**	*	*	***
Fermentation	cereals	Bioethanol	*	*	*	***
Fermentation	potatoes	Bioethanol	***	*	*	***
Thermochemical conversion	Short rotation, Miscanthus, logging residues	Methanol	* to **	* to **	**	**
Thermochemical conversion	Wood residues trade/ industry	Methanol	**	**	***	**
Thermochemical conversion (process includes Fischer-Tropsch synthesis)	Short rotation, Miscanthus, logging and trade/ industry wood residues	Synfuel	*	* to **	** to ***	**
Electrolysis	Hydro, wind, photovoltaics, solar thermal	Hydrogen	***	** to ***	* to **	***
Thermochemical conversion	Short rotation, Miscanthus, logging residues, wood residues trade/ industry	Hydrogen	* to ***	* to ***	***	**
Anaerobic digestion, cleaning & upgrading	Wet wastes	Biogas	*	***	**	**

Note: Key to stars:

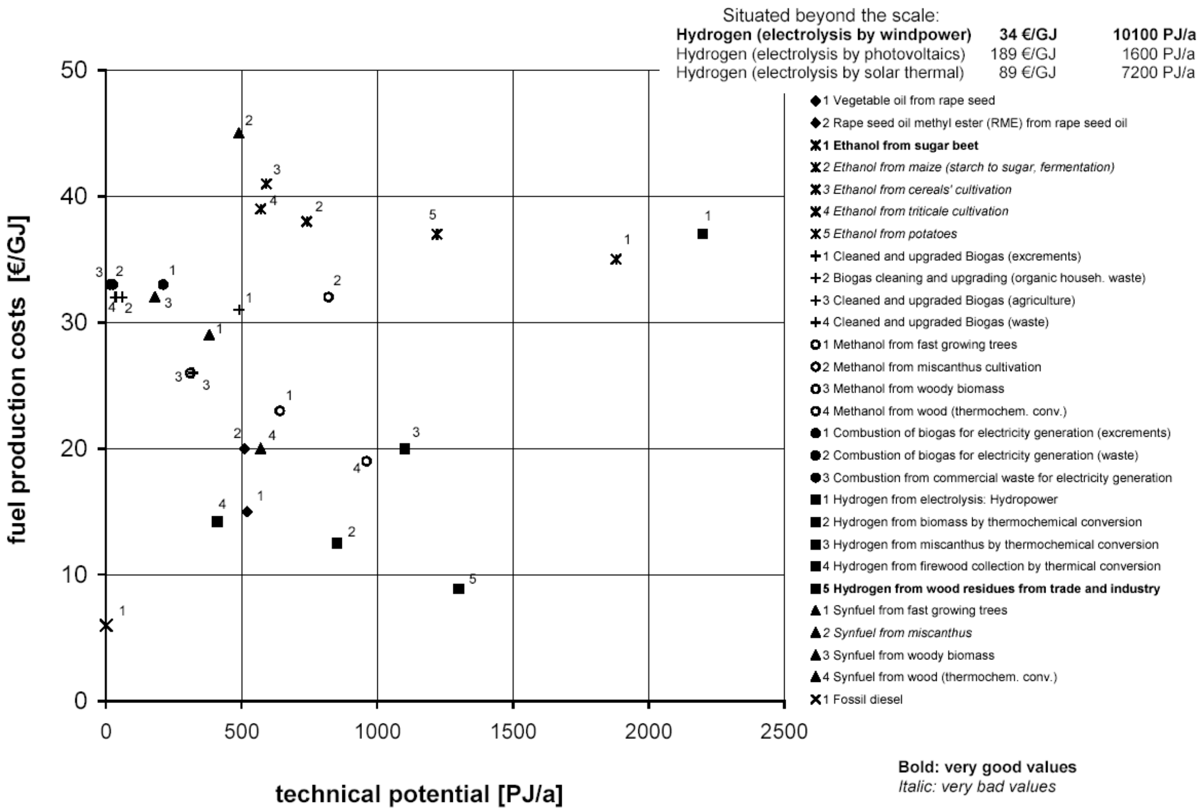
Star	Technical Potential (PJ/a)	CO_2 emissions (kg/GJ)	Economics (€/GJ)
***	>1000	up to 20	up to 20
**	600-1000	21-45	21-35
*	<600	>45	>35

Note that *** indicates a ‘good’ score:
- for carbon balance it indicates low CO_2 emissions;
- and for economics low cost.

For comparison, note that the production of bioethanol from Brazil, of hydrogen by nuclear-powered electrolysis, or fossil fuels by the refining of mineral oil would all score three stars for ‘CO_2 emissions’ and ‘Economics’. This means that many of the renewably produced biofuels in the EU are not currently competitive on these two fronts. The most optimistic figures for CO_2 emissions from second generation biofuels are the same as for tropical bioethanol currently produced from sugarcane, at around 10% of the emissions from petrol and diesel.

Figure 3.1 below plots the above technical potential data related to the calculated fuel price. It is seen that ethanol from sugar beet and hydrogen based on thermochemical processing of wood residues as well as hydrogen from wind power based electrolysis offer high potentials and comparatively low costs. Biodiesel produced from rapeseed oil is relatively inexpensive but there is a low potential for production in the EU, while bioethanol in the EU is the reverse with higher potentials particularly for sugar beet but also higher costs for the crops that can be grown in the EU (bioethanol is cheaper to produce from sugar cane). Cleaned and upgraded biogas that can be used as a transport fuel is less promising, as it has a low production potential and is relatively expensive.

Figure 3.1: Technical potentials and production costs of various fuel chains for the enlarged European Union (EU 30) [62]

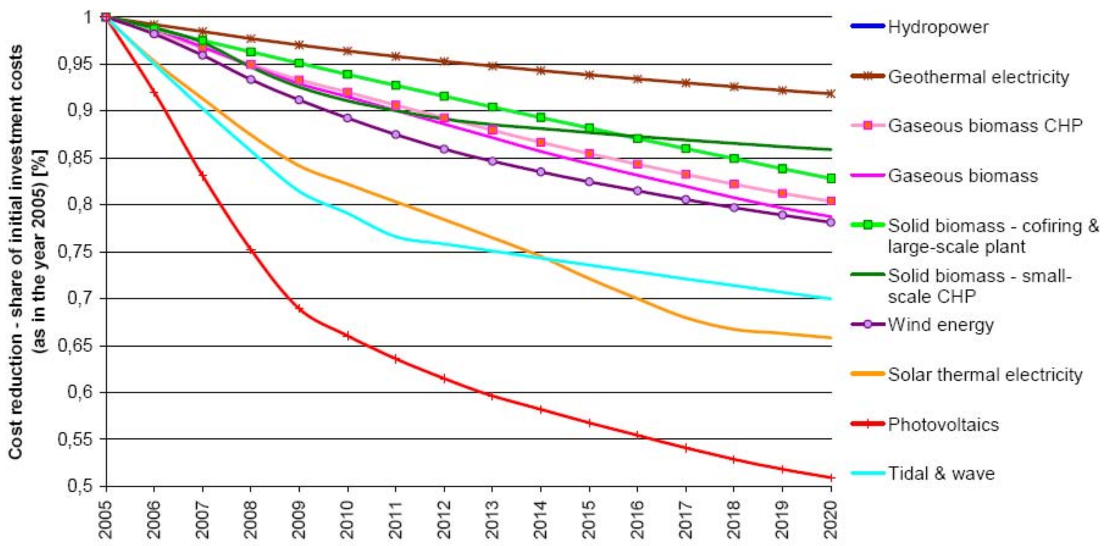


3.7 Potential for cost reduction through R,D&D

Given that one of the main barriers to market penetration is the cost of bioenergy relative to competing energy supply options, the potential for cost reduction is likely to have a key influence on future market uptake. Some of the established technologies have relatively limited cost reduction potential. For example the cost of combustion equipment is unlikely to decline significantly with time; indeed its cost may need to rise if increasingly stringent emissions abatement requirements are implemented. Similarly there is only limited potential for cost reduction for first generation biofuels processes.

R&D focus is therefore targeted at the more novel technologies such as advanced thermochemical processing, anaerobic digestion and second generation biofuels, where cost reductions can be foreseen. The information published by the European Commission in support of the Roadmap [4] provides some useful data in this area. For example Figure 3.2 shows the estimated potential for capital cost reduction for a number of renewable electricity generation technologies to 2020, relative to costs in 2005. It can be seen that the cost reduction potential for bioenergy technologies is not as good as some other renewables. Nevertheless costs can be expected to fall by 14 to 22%, with the biggest reduction assigned to gasification.

Figure 3.2: Estimated rate of unit cost reduction for renewable electricity generation technologies – reduction in cost compared with 2005 levels [4]



The Commission's impact assessment for the Roadmap has undertaken modelling of a number of renewable energy technologies relative to competing energy options, with a time horizon of 2050 [4, 63]. The modelling makes assumptions about the progression of capital costs with time, with annual cost decreases in the range 1.2 to 3.0% for biomass combustion and 1.1 to 2.7% for biomass gasification. Conventionally fuelled plants also show cost decreases, albeit lower. However there is little reliable information on the real costs of real projects, hence it is difficult to say whether these projections are realistic or optimistic. Most of the established bioenergy technologies have limited potential for cost reduction through innovation. For the more innovative technologies, the only way to find out if they can become "winners" is to support them through to commercial-scale demonstration, with careful monitoring.

As this is such an important area for making sound policy decisions, the Commission should be encouraged to undertake a thorough review of historical cost changes and carefully examine their potential for future change. Only then will it be possible to say with more certainty which of the many technical options are worthy of focused R&D support.

Focus for R&D will also depend on the key priorities to be achieved. If the priority is quick and efficient reduction of CO_2 emissions, then the easiest technology to back would be biomass heat production, due to its low risk and wide scale replication potential. If the focus was to be long term though, the ranking of bioenergy options according to carbon emissions may be useful to achieving most effective carbon-savings. However alternately, a decision could be made to support gasification technology – on the basis that this technology has the most substantial cost reduction potential. Or perhaps, the decision criteria would be deemed to centre on backing the technology with the greatest growth potential.

A comparison of the projected costs of different types of biofuel production for 2020, relative to conventional fuels, has been included in the Commission's *Review of economic and environmental data for the Biofuels Progress Report* [11]. Projections are given for 7% biofuel penetration and two scenarios of 14% penetration (with less or more imports). Results are presented in Table 3.5, based on the following four scenarios:

Scenario A: oil at $48/barrel, business-as-usual for agricultural markets

Scenario B: oil at $48/barrel, more competitive agricultural markets

Scenario C: oil at $70/barrel, business-as-usual for agricultural markets

Scenario D: oil at $70/barrel, more competitive agricultural markets

Table 3.5: Estimated biofuel costs in 2020 (€2005/toe, mid-range estimates of the cost of the cheapest biofuel production technique, rounded to the nearest €10) [11]

	JEC values	Adjusted values: "7% scenario"	Adjusted values: "14% - more domestic"	Adjusted values "14% - more import"
Biodisel from rape	700	A, B: 690 C, D: 720	A, B: 730 C, D: 760	A, B: 690 C, D: 720
Biodisel from imported palm/soy oil	670	A: 650 B: 580 C: 690 D: 620	A: 690 B: 620 C: 730 D: 660	A: 650 B: 580 C: 690 D: 620
BTL from straw	n.a.	A, B: 950 C, D: 1000	A, B: 890 C, D: 930	A, B: 950 C, D: 1000
BTL from farmed wood	1110	A, B: 1030 C, D: 1080	A, B: 960 C, D: 1010	n.a.
Ethanol from sugar beet	680	A, B: 740 C, D: 800	A, B: 760 C, D: 820	A, B: 740 C, D: 800
Ethanol from wheat	610	A: 730 B: 630 C: 810 D: 710	A: 780 B: 670 C: 850 D: 750	A: 730 B: 630 C: 810 D: 710
Ethanol from imported sugar cane	580	A, C: 690 B, D: 550	A, C: 700 B, D: 550	A, C: 690 B, D: 550
Cellulosic ethanol from straw	1030	A, B: 820 C, D: 840	A, B: 740 C, D: 770	n.a.
Diesel and petrol	A, B: 400 C, D: 580			

Note: JEC values are estimates for 2012; BTL = biomass to liquid

The 2020 figures take account of the higher shares of biofuels (7% and 14%), leading to increased demand for feedstocks and higher feedstock and biofuel prices. Offsetting this is the cost improvements expected particularly for second-generation biofuels by 2020. In their recent review of the literature, Hamelinck and Faaij [64] forecast that in the long term (up to 2030) the cost of ligno-cellulosic ethanol production in the EU will fall by 50% and the cost of BTL production will fall by a little over 25%.

Considering the wider issue of cost reduction, it is worth stating that efforts need to be made to increase the biomass resource available at a competitive price, if the EU is to stand a chance of meeting its energy targets from domestic sources. The supply chain needs to be considered a priority, to ensure strong and secure prices and routes to market – and in particular to circumvent the common phenomenon experienced thus far where weak markets have led to sharp fuel price escalations when large projects have come on stream. The consideration of resource provision could include a focus on R&D facilitating the transformation of biomass fractions that are presently discarded.

The interplay with similarly unrelated policies and legislation also need to be considered – for example, the effect of EU agricultural policy decisions, and the effects of the phasing out of landfill under the Landfill Directive.

In addition to resource, there are also common issues across all technologies, in the areas of biomass transport and storage, whose resolution and betterment will benefit biomass technology in general.

3.8 Conclusions on R,D&D and technological challenges

In summary the following conclusions can be drawn:

- Better information is required on EU biomass resource potentials, in particular the potential for supplementing existing biomass resources through energy crops. Domestic biomass supply costs need to be compared with those of imported feedstocks and a strategy for meeting the new deployment targets developed;
- Cost reduction remains a key objective. To help focus R,D&D funding there is a need for better data on the costs of real commercial projects and their historical evolution;
- The challenging bioenergy deployment targets implied by the overall “20% renewable energy by 2020” target suggests that the focus for R,D&D should be placed on supporting those technologies that have the greatest short and medium-term potential to achieve significant market penetration in the EU. Such support will also enhance the export potential of EU-based equipment manufacturers;
- There is a need for an overall bioenergy R,D&D strategy that draws all relevant elements together. The allocation of EU funding should be based on strategic objectives, including such factors as market potential, cost reduction potential, greenhouse gas savings, export potential, etc.;
- It would be helpful for the Commission to draw the support available to bioenergy under FP7 into a single, simple document.

4 FOSTERING PRODUCTION AND PROCESSING

The previous chapters have highlighted the overall background and context, identified best practice examples, and set out the technological challenges facing biomass and biofuels. We now discuss and analyse the policy measures that are relevant to promoting and enhancing biomass and biofuels across the EU. There are a number of relevant areas for consideration[2]:

- Legal and political certainty (including taxation);
- Development of standards;
- The effect of furthering biomass and biofuels against competing concerns of energy diversification and security of supply.

4.1 Legal and political certainty for biomass and biofuels

A lot of bioenergy applications are not currently competitive with conventional fuel sources. This means that it will be necessary to support the introduction of bioenergy into the marketplace, at least in the short term. The support mechanisms used will depend upon the drivers, targets and the part of the bioenergy supply chain that requires support. Certainty for the future of biomass and biofuels can be encouraged in a number of ways, including:

- The use of EU Directives, targets and associated strategies;
- Support mechanisms, such as taxation policies and obligations.

4.1.1 The use of Directives, targets and strategies

A number of EU Directives with relevance to biomass and biofuels have been adopted, as summarised below.

- *Directive 1999/31/EC on the landfill of waste (OJ L 182, 16.07.1999)* [65]
- *Directive 2000/76/EC on the incineration of waste (OJ L332/91, 28.12.2000)* [66]
- *Directive 2001/77/EC on the promotion of electricity produced from renewable sources of energy in the internal market (OJ L 283, 27.10.2001)* [22].
- *Directive 2002/91/EC on energy performance of buildings (OJ L 1, 4.1.2003).* [67]
- *Directive 2003/30/EC on the promotion and use of biofuels or other renewable fuels for transport (OJ L 123, 17.5.2003)* [19].
- *Directive 2003/96/EC on restructuring the Community framework for the taxation of energy products and electricity (OJ L 283, 31.10.2003)* [23].
- *Directive 2004/8/EC on the promotion of cogeneration (OJ L 52, 21.2.2004).* [68]

Section 1.6 of this study provides a brief summary of the directives that have had the biggest impact, namely the renewables electricity directive (*2001/77/EC)* and the biofuels directive (*2003/30/EC*). Progress towards the deployment targets included in these two directives has been reviewed recently by the Commission [18, 69].

The key Directive in the area of biofuels dates from 2003 ("Biofuels Directive") [19] and aims to promote the use of biomass and other renewable fuels in the transport sector. Under Article 3 of the Directive, Member States must ensure that a minimum proportion of biofuels and other renewable fuels are placed on their markets, and that national indicative targets are set to achieve that effect.

Table 4.1 below summarises the status of individual Member States' progress towards these indicative targets.

[2] Consideration of the possibilities for the focus and support for R&D development in biomass and biofuels is discussed in Chapter 3 of this study.

Table 4.1: **National indicative targets for the share of biofuels in 2005 and 2010, and share achieved in 2005 [69]**

EU Member State	2005 target (%)	2005 share achieved	2010 target (%)
Austria	2.5	0.93	5.75
Belgium	2	0	5.75
Cyprus	1	0	
Czech Republic	3.7*	0.05	3.27
Denmark	0.1	no data	
Estonia	2	2	5.75
Finland	0.1	no data	
France	2	0.97	7
Germany	2	3.75	5.75
Greece	0.7	no data	5.75
Hungary	0.6	0.07	5.75
Ireland	0.06	0.05	
Italy	1	0.51	5
Latvia	2	0.33	5.75
Lithuania	2	0.72	5.75
Luxembourg	0	0.02	5.75
Malta	0.3	0.52	
Netherlands	2*	0.02	5.75
Poland	0.5	0.48	5.75
Portugal	2	0	5.75
Slovakia	2	no data	5.75
Slovenia	0.65	0.35	5
Spain	2	0.44	
Sweden	3	2.23	5.75
United Kingdom	0.19**	0.18	3.5
EU-25	1.4	1 (estimate)	**5.45**

Notes: * 2006 target

**0.3% in volume terms, equating to 0.19% in energy content, assuming a 50:50 split between biodiesel and bioethanol.

Source: National reporting under the biofuels directive except France: response to public consultation on review of the biofuels directive.

Table 4.1 shows that a number of EU countries have not yet set targets for 2010 equivalent to the “reference values” needed to achieve an overall target. In the light of this uncertainty, the European Commission has reviewed the Biofuels Directive [69] to assess whether the 2010 target will be met and to consider whether targets for Member States should be made mandatory. The review concluded that **the biofuels directive’s target for 2010 is not likely to be achieved.**

Specific targets for biofuels uptake across the EU have been complemented by the issue of the Renewable Energy Road Map [3] which sets out a long-term vision for renewable energy sources in the EU (which in turn builds upon the Biomass Action Plan [7] and the Strategy for Biofuels [5]). The Road Map proposes that a renewable energy policy framework is required that will:

- Be based on long term mandatory targets and stability of the policy framework;
- Include increased flexibility in target setting across sectors;
- Be comprehensive, notably encompassing heating and cooling;

- Provide for continued efforts to remove unwanted barriers to renewable energies deployment;
- Take into consideration environmental and social aspects;
- Ensure cost-effectiveness of policies; and
- Be compatible with the internal energy market.

A key part of the Renewable Energy Road Map's conclusions is that **legally binding minimum targets for biofuels are required**, a conclusion deriving directly from the review of the "Biofuels Directive". In addition the Road Map provides a justification for stronger action in the renewable energy heating and cooling sector (including biomass) where there is no existing Directive. **The scale of the potential for renewable energy contributions to the heating and cooling sector clearly justifies further vigorous action at European level.**

The disappointing outcome to date from the "Biofuels Directive" illustrates that European Directives, targets and strategies can help to ensure that legal and political certainty is created, but that they cannot necessarily ensure delivery on their own. They are then a necessary part of the background giving greater emphasis to biomass and biofuels, but are not the only means to achieve the desired outcomes.

4.1.2 Support mechanisms

In considering the mechanisms through which biomass and biofuels might be supported by the EU and/or individual Member States, it is appropriate to review the reasons why such support might be provided. A recent enquiry by the UK House of Lords [40] identified three main reasons why the greater use of biofuels might be encouraged:

- To strengthen energy security;
- To capture environmental benefits;
- To develop agricultural economies.

This is relevant because it illustrates the different justifications that may be advanced for supporting measures in the biofuels area. This in turn suggests that support mechanisms may be defined and implemented that will address one or more of these three justifications.

A wide range of supporting measures has been used across the Member States of the European Union to encourage biomass and biofuels uptake. These supporting measures can typically be classified as:

A) Taxation measures;

B) Agricultural policies (usually involving grants or credits to fuel producers, or for capital costs of equipment);

C) Obligations, tariffs, green certificates;

D) "Flanking measures".

Ad A) Taxation and agricultural support measures

The Energy Taxation Directive [23] makes it possible for Member States to grant tax reductions or exemptions in favour of biofuels, under certain conditions. These are considered state aids so cannot be implemented without the Commission's prior authorisation. Table 4.2 below shows the current list of exemptions that have been granted state aid approval.

Table 4.2: Biofuel tax exemptions that have received state aid approval

Case	Biofuels concerned	Reference
C64/2000 FR	ETBE	OJ L 94, 10.4.2003
N461/01 IT	Biodiesel	OJ C 146, 19.6.2002
N480/02 SE	All CO_2-neutral fuels	OJ C 33, 6.2.2004
N804/01 UK	Biodiesel	OJ C 238, 3.10.2002
N512/02 SE	Biofuel pilot projects	OJ C 75, 27.3.2003
N685/02 DE	Bioethanol, biodiesel and vegetable oils	OJ C 86, 6.4.2004
N717/02 IT	Bioethanol and ETBE	OJ C 16, 22.1.2004
N407/03 UK	Bioethanol	OJ C 193, 28.4.2005
NN43/04 AT	Bioethanol, biodiesel and vegetable oils	Not published yet
N187/04 SE	Biofuel pilot projects	Not published yet
N206/04 CZ	Biodiesel	Not published yet
N427/04 HU	Biodiesel and ETBE	OJ C 133, 31.5.2005
N582/04 IT	Biodiesel (prolongation of N461/01)	Not published yet
N599/04 IRL	Biodiesel, bioethanol and vegetable oils	OJ C 28, 22.4.2005
N44/05 LT	Biodiesel, bioethanol, vegetable oils and ETBE	Not published yet
N223/05 CZ	Biodiesel	Not published yet
N314/05 EE	Bioethanol, biodiesel and vegetable oils	Not published yet

Taxation-based policies as applied to biofuels typically involve reductions in motor fuel excise taxes. Blended or undiluted biofuels are taxed at lower rates than their petroleum counterparts, and the tax reduction allows biofuels to be sold at the pump to consumers at the same or lower prices. Taxation-based policies have been very effective at increasing the use of bioethanol in Sweden (and North America) and at increasing the use of biodiesel in Germany. These policies can help keep the price of biofuels paid by the consumer low, but they typically result in reduced Government revenues. It is especially noteworthy that both Germany and Sweden have not sought to limit the quantity of biofuels eligible for tax exemption.

Biodiesel used as B100 in Germany has a 100% tax exemption, which allows the price consumers pay at the pump to be less for biodiesel than petroleum diesel. This policy has led to very rapid growth of biodiesel over the past few years. Germany now has over 1500 filling stations with B100.

The USA has introduced a series of tax measures and incentives in recent years. In 2004 the Energy Tax Act was reworked and renamed the Volumetric Ethanol Excise Tax Credit (VEETC), meaning that tax exemption now applies to all levels of blending. VEETC extended the existing ethanol tax incentive to the end of 2010 at a rate of $0.51 per gallon. It also improved the “small ethanol producer tax credit”, which allows a 10 cent per gallon tax credit for facilities with a capacity of less than 30 million gallons per year. Other federal tax incentives include income tax deduction for alcohol-fuelled vehicles and an alternative-fuels production tax credit.

In 2005 the United States also introduced a “renewable fuels standard” (RFS), with a target rising from 4 billion gallons in 2006 to 7.5 billion gallons by 2012. The industry expects eventually to achieve a 10% market penetration.

The system of tax exemptions can however lead to potential problems, including:

- A risk of high cost to the state and high payments to undertakings;
- Insufficient investor uncertainty (the Energy Taxation Directive limits the duration of tax exemptions to six years);
- The adoption of quotas in some cases, limiting the quantity of biofuel that can qualify for tax exemption and setting up a process to choose the firms that will benefit from it.

Ad B) Agricultural policies

Agriculture-based policies have also been used to help implement use of biofuels. Farming credits are provided for using biomass grown on set-aside lands that are unavailable for food production. The policies have the effect of reducing the cost of the biomass feedstock and therefore lowering the cost of the resulting biofuels. Agriculture-based policies have been used in the EU to encourage production of ethanol for conversion to ETBE. Like the taxation-based policies, agriculture-based polices help keep the pump prices of biofuels low but typically reduce Government revenues.

The European Commission's Strategy for Biofuels [5] summarises the EU policy instruments that have been used to support biofuels production, distribution and processing, which include:

- The ongoing process of **Common Agricultural Policy reform** started in 1992 has reduced price support and helped to increase the competitiveness of EU agricultural production for all possible outlets: food, animal feed, and non-food use including biofuels. This is particularly important for cereals, which are currently one of the major feedstocks for EU bioethanol production;
- The **decoupling** of income support from production introduced in 2003 will help to facilitate the supply of energy crops. In particular, crops that were eligible for direct payments only under the non-food regime on set-aside areas, may now be cultivated on any area without loss of income support;
- The **set-aside** obligation, which was introduced with the 1992 reform as a tool to balance the cereals market, has been integrated into the new single payment scheme. The cultivation of non-food crops (including energy crops) is authorised if the use of the biomass is guaranteed either by a contract or by the farmer;
- A special **aid for energy crops** was introduced by the 2003 CAP reform. A premium of €45 per ha is available, with a maximum guaranteed area of 1.5 million hectares as the budgetary ceiling;
- Major reform of the Common Market Organisation for **sugar**. Sugar beet grown for bioethanol will continue to be exempt from quotas;
- Under **rural development policy**, investments on or near farms, for example in biomass processing, as well as the mobilisation of unused biomass by forest holders, can be supported. The Commission has proposed Community strategic guidelines for rural development which emphasise renewable energy, including biofuels;
- Many of the regions covered by the Structural and Cohesion Funds, particularly in rural regions in central and Eastern Europe, have the potential to use biomass to generate economic growth and employment. Support for biomass, including biofuels, is a priority for **cohesion policy** [70] and can be given, for example, for the retraining of farmers, the provision of equipment for biomass producers and for investment in facilities to produce biofuels.

Many of the European measures identified above have focused on the support of biofuels. At Member State level, direct or indirect support for the production and utilisation of solid biomass has also been a subject for attention. Examples of these support mechanisms have been reviewed [29, 71].

A major route for support of solid biomass installations has been the use of investment subsidies. Such national subsidies have often also complemented by European support. In the case of Austria [29], major development of biomass installations has been seen in a variety of small and medium-scale sectors[3] over many years as a result of investment subsidies.

However there are also examples of regulations, plans and permitting rules at national or regional level providing barriers to the wider uptake of biomass projects [71].

Where the market for solid biomass remains local or regional (which is the case for the majority of biomass heat applications), development of schemes is likely to remain slow without a consistent and well-structured support regime, both for the production of biomass and its supply and use. This is a reflection of the fact that the production, processing and utilisation of solid biomass is typically a more localised industry and activity than for agricultural biofuels, whose end products are likely to be destined for use within major national and international markets.

Ad C) Obligations, tariffs and green certificates

Fuel mandates (or obligations) require that energy supply (heat, power or transport fuels) contain minimum percentages of renewable energy. For example, they may stipulate that motor fuels contain minimum percentages of biofuels, which can assist with implementation. Brazil, for example, requires motor gasoline to contain at least 22% ethanol. The European Union has also adopted policies that encourage minimum levels of biofuels in the motor fuel mix, and fuel mandates are being considered in many other locations including North America. Fuel mandates provide a simple, direct method to achieve biofuels implementation. This approach generally preserves Government revenues based on motor fuel taxes, but consumers may pay higher pump prices to cover any differential cost of biofuels. Table 4.3 summarises some of the main policies promoting biofuels outside the EU.

Table 4.3: Examples of fuel obligations promoting biofuels in non-EU countries [5]

Countries	Description
Brazil	All petrol must have a 22-26% blend with bio-ethanol
Canada	3.5% target for bio-ethanol by 2010
India	Public sector oil companies obliged to buy bio-oils and sell in 5% blend, rising to 20% in 2020.

[3] Forest industries, rural district heating, individual installations for schools, town halls and the domestic sector, co-generation

It can be argued that fuel obligations may be a promising way of overcoming difficulties with tax exemptions. Specifically, the burden of support is passed from the state (the tax-payer) to the consumer, resulting in a stronger adherence to the polluter pays principle and – potentially – a wider public awareness of energy and environmental issues and benefits.

Tariffs, green certificates and other related forms of market intervention are intended to provide incentives for the uptake of renewable energy sources within electricity markets. Biomass has been an important beneficiary of these forms of support. The Commission's review document on "Support of electricity from renewable energy sources" [27] summarises the overall support provided by different Member States for this aspect of the renewable energy area:

- **"Feed-in tariffs** exist in most of the Member States. These systems are characterized by a specific price, normally set for a period of around several years that must be paid by electricity companies, usually distributors, to domestic producers of green electricity. The additional costs of these schemes are paid by suppliers in proportion to their sales volume and are passed through to the power consumers by way of a premium on the kWh end-user price. These schemes have the advantages of investment security, the possibility of fine tuning and the promotion of mid- and long-term technologies.

  On the other hand, they are difficult to harmonise at EU level, may be challenged under internal market principles and involve a risk of overfunding, if the learning-curve for each RES-E technology is not build in as a form of degression over time. A variant of the feed-in tariff scheme is the fixed-premium mechanism currently implemented in Denmark and partially in Spain. Under this system, the government sets a fixed premium or an environmental bonus, paid above the normal or spot electricity price to RES-E generators;

- Under the **green certificate** system, currently existing in SE, UK, IT, BE and PL, RES-E is sold at conventional power-market prices. In order to finance the additional cost of producing green electricity, and to ensure that the desired green electricity is generated, all consumers (or in some countries producers) are obliged to purchase a certain number of green certificates from RES-E producers according to a fixed percentage, or quota, of their total electricity consumption/production. Penalty payments for non-compliance are transferred either to a renewables research, development and demonstration (RD&D) fund or to the general government budget. Since producers/consumers wish to buy these certificates as cheaply as possible, a secondary market of certificates develops where RES-E producers compete with one another to sell green certificates.

  Therefore, green certificates are market-based instruments, which have the theoretical potential, if functioning well, of ensuring best value for investment. These systems could work well in a single European market and have in theory a lower risk of over-funding. However, green certificates may pose a higher risk for investors and long-term, currently high cost technologies are not easily developed under such schemes. These systems present higher administrative costs;

- Pure **tendering** procedures existed in two Member States (IE and FR). However, France has recently changed its system to a feed-in tariff combined with tendering system in some cases and Ireland has just announced a similar move. Under a tendering procedure, the state places a series of tenders for the supply of RES-E, which is then supplied on a contract basis at the price resulting from the tender. The additional costs generated by the purchase of RES-E are passed on to the end consumer of electricity through a specific levy. While tendering systems theoretically make optimum use of market forces, they have a stop-and-go nature not conductive to stable conditions. This type of scheme also involves the risk that low bids may result in projects not being implemented."

Reference [69] provides further detail on the specifics of Member States' interventions.

The common aim of this type of support is to ensure that biomass and biofuels (or other renewable energy sources) can be introduced effectively into existing and strongly functioning commercial markets (for electricity or liquid transport fuels). **For solid biomass, it is perceived that these forms of support are potentially capable of having a beneficial effect but that factors; other than the choice of financial instrument (infrastructural barriers, installation sizes, optimal forest management and the existence of secondary instruments, etc.), considerably influence the effectiveness of support systems.**

Ad D) "Flanking measures"

This heading includes a wide range of direct or indirect support measures that adopt different approaches to influencing the biomass and biofuels areas. In general these measures are intended to create and reinforce a positive context for biomass and biofuels and so may not be the primary drivers for change.

Examples of these measures include:

- Promotional campaigns to inform farmers and forest owners of the potential benefits of biomass and biofuel crops, including best practice guides to planting and cultivation;
- Review of the workings and implementation of related legislation (e.g. waste frameworks, animal by-products) to ensure that biomass use is facilitated;
- Reviewing the operations of the internal market to ensure that – for example – no barriers are put in place to the wider adoption of biofuels and biomass;
- Support for regions where there is good potential for biomass energy (e.g. regional energy agencies or other technical agencies geared to support development within the area – these have proved useful in Austria, Sweden and the UK)

In general it is important for policy makers at all levels to solicit and take into account feedback from the market place concerning the key barriers that are preventing or slowing market uptake. For a subject as wide-ranging as bioenergy, this can be quite a detailed and complex process.

4.2 Development of standards

Without standards there would be no market rules to govern the composition and quality of biomass and biofuels – and consequently there would be little confidence in the quality of biomass fuels, which would impede market growth. The existence of standards simplifies communication between fuel suppliers and customers, enables equipment and fuels to be designed for each other, ensures that delivered fuel meets technical requirements and provides users with tools for determining the economic value of delivered fuels. This provides confidence in the fuel and the conversion equipment.

The uptake of bioenergy technologies will therefore be greatly assisted by the implementation of well-defined standards and definitions in a number of areas: classification of wastes, standards for co-firing, sustainability standards for imported biomass, fuel quality standards for gaseous and liquid biofuels, etc.

Some Member States have developed their own fuel specifications (e.g. Germany, Austria and Scandinavia have all developed strict biomass solid fuel specification standards). However the most significant development of European standards for biomass and biofuels is carried out by the European Standards Organisation (CEN), generally under mandate from the European Commission. Historically, it is unusual for varying national standards to exist – the usual route in absence of a European standard is that a national standard is created and that then evolves into a European one.

In cases where national standards are adopted in the absence of a European standard, there is a danger of trade barriers being created, and anti-competitive practice being adopted. In order to ensure that a true internal market for bioenergy develops there is therefore a strong incentive to ensure that European-wide standards are available.

European standards for use of biodiesel as an automotive fuel and as a heating fuel were put into force in 2003. Standards are under development for bioethanol for use in blends with gasoline, and for some of the blends themselves. Table 4.4 below shows the principal standards currently applying to liquid biofuels.

Table 4.4: Current principal European standards for liquid biofuels

Standard	Fuel	Requirement
EN590	Diesel	Diesel must contain no more than 5% biodiesel (of EN14214 quality) by volume
EN14214	Biodiesel	Restricts vegetable oil feedstocks
E228	Petrol	Maximum 5% ethanol (or 15% ETBE) by volume

Standards for *solid recovered fuels* and *biomass fuels* are being developed by two CEN Technical Committees. CEN Technical Committee 335 is currently examining standards for biomass fuels while CEN Technical Committee 343 is examining standards for solid recovered fuels that are prepared from non-hazardous waste. Both have not yet completed their work.

The latter Committee will be producing a standard for measuring biomass content. This will be an important method enabling biomass content to be demonstrated and is key to demonstrating biomass compliance under the EU Emissions Trading System, which requires the fuel user to demonstrate biomass content. It will be particularly important to biomass fuels derived from mixed wastes.

During the present standardisation work on solid biofuels considerable gaps in knowledge have been identified that are hindering the writing of standards. **It has been widely recognised that additional pre-normative research is needed to remove obstacles to more widespread use of solid biofuels in the EU.** This includes, for instance, the development of quality management systems for the solid biofuels chain from production to the final customer.

In addition to the development of standards for biomass fuels, there are a number of related issues, which include clarification of the situation regarding the status of biomass residues (i.e. whether or not they are wastes and come under the Waste Incineration Directive). Most clean biomass fuels have been excluded from the Waste Incineration Directive and are classed as residues not wastes. This includes food-processing residues, residues from pulp and paper manufacture and some wood processing residues. This clarification of the status of biomass residues in the EU has proved to be vital to the handling and combustion of these potential fuels.

4.3 Conclusions on fostering production and processing

In summary on fostering production and processing:

- Bioenergy is not competitive, except in niche applications, therefore the development of bioenergy needs support;
- A variety of support measures has been implemented in the EU and elsewhere. These include: taxation, obligations, grants or similar subsidies and support for key issues (best practice guidance, technical support from local agencies, development of standards etc.);
- There are strengths and weaknesses for all of these support mechanisms, including costs, administration, inflexibility and the fact that sometimes they only address one part of the bioenergy chain, without addressing weaknesses elsewhere. There can be no “one-size fits all approach”. Within the EU different bioenergy technologies are suitable in different regions, depending on local agricultural conditions and the local energy market (e.g. whether or not there is a tradition for district heating). It is important that the EU can create an appropriate context for support whilst allowing Member States the flexibility to respond to local needs and opportunities.

5 BIOMASS & BIOFUELS IN CONTEXT - COMPETITIVE OR COMPLEMENTARY?

If biomass and biofuels sources and technologies are to be fostered, it is a legitimate question to ask whether this might potentially be at the expense of other priorities for energy security, climate-changing emissions or agriculture, both in the EU and world-wide. This section reviews the evidence on these issues.

5.1 Energy security

Biomass and biofuels sources form an important part of the EU's potential renewable energy portfolio. The Commission's Renewable Energy Road Map [3] foresees important roles for biomass and biofuels in the electricity, heating & cooling, and transport sectors.

- *Electricity from biomass sources* is already a major contributor to EU requirements and has been growing fast in recent years within a supportive context;
- The level of *heating using biomass* has been essentially static across the EU for a long time. Small-scale applications for biomass heat in dwellings, and in district and community heating systems, are widespread in many countries but are failing to grow significantly in numbers to the extent implied by the Renewable Energy Road Map;
- *Liquid biofuels for transport* are in increasing use across the EU, although their use is not growing as quickly as implied within the Commission's Biofuels Strategy [5].

Are these sources and applications in competition with other renewable energy or conventional energy solutions that would represent a more effective solution to energy security concerns? This question can best be answered by considering the energy security risks that the EU faces.

For the *supply of power*, there may be many alternative sources of electricity besides those making use of biomass materials. Large-scale, bulk power sources, such as from coal, oil, gas and nuclear power, still provide the bulk of the EU's needs. However future projections undertaken for the ITRE Committee [72] show that reliance on these sources into the medium term can no longer be taken for granted. The projections within [72] all assume high uptake of biomass for electricity and wind power, as the two key ingredients on the renewable energy menu. In respect of security of biomass fuel supplies, the current position within the EU is broadly as follows.

EU Biomass Production – from "Biomass - Green energy for Europe" [26]

"Total EU land area is around 385 million hectares. Forests and woodlands cover 137 million hectares and crops 178.5 million hectares. Once the requirements of the food, wood products and paper sectors have been met, the biomass resources from these trees and crops could provide around 8 EJ energy a year – about 11% total annual EU energy consumption. In practice, we are exploiting less than a quarter of the available resource."

In summary then, biomass for electricity should be seen as a contributor to EU power demand into the future for security of supply reasons.

Biomass heating is a large existing contributor to the supply of renewable energy across the European Union. It is by far the largest current renewable energy heat source. The failure of biomass heat deployment to grow significantly in recent years should not however be taken to imply that it cannot provide security of supply. Local biomass resources applied in support of local and regionally-based schemes is still the most effective way for the EU to increase heat supply security.

Other renewable energy heat-supply sources, for example solar thermal, heat pumps or geothermal heat from low temperature sources, can all provide alternatives to biomass heat but have drawbacks such as geographically limited resources (geothermal heat) or practical limits on the size of installations (solar thermal, heat pumps).

Biomass heating can be in direct competition with the use of fossil fuels for heat but is often cost-competitive or cheaper, depending upon the location, the scale of application and the prevailing market conditions.

The current problem for biomass heat is "… no coordinated approach, no coherent European market…., and no consistency of support mechanisms" [3].

Liquid biofuels for transport should be seen as a major potential contributor to European security of energy supply. Presently they are the only available large scale substitutes for petrol and diesel in transport. The transport sector could eventually see extensive deployment of hydrogen as a future fuel, but it is not anticipated that this will become a commercial reality for at least 15 years [73].

In addition, for all biomass and biofuels sources, the variability of crop yields from year to year is potentially a security of supply issue. If the EU were ever dependent on large quantities of indigenous (or imported) biomass and biofuels for energy needs, harvest and other growing failures could be a major risk. Such a risk might best be ameliorated by diversifying geographical sources as widely as possible.

References [11] and [69] have considered security of supply issues for liquid biofuels.

5.2 Greenhouse gas emissions

The conversion processes required to generate energy from organic materials all give rise to emissions of climate-changing gases. The key advantage of biomass and biofuels compared to fossil-derived fuels is the fact that they can be grown again over short timescales, absorbing carbon dioxide during photosynthesis. So – in effect – the use of biomass and biofuels can lead to a reduction in emissions from fossil fuels provided that the trees and crops from which they came are replenished. It is generally accepted that bioenergy has considerably lower carbon emissions than fossil energy and a number of Life Cycle Analysis studies have shown this. The most controversial of these studies address liquid biofuels and waste to energy. The carbon emissions of liquid biofuels vary considerably, depending on the source of the biomass, the conversion process, what happens to the co-products and sources of process heat and power. The life cycle analysis of energy from waste varies considerably, dependent on the basic assumptions that are made, concerning the biogenic content of the waste, the displacement of methane emissions from landfill and the efficiency of the conversion process.

There are however renewable energy and other sources whose operations are essentially or completely carbon-neutral (for example wind and wave power, nuclear power). These sources do not require re-growth of organic material for fuel and so formally might be considered to be "preferable" from the perspective of greenhouse emissions.

5.3 Agricultural implications

The extent to which the *land requirements* of biomass and biofuel sources might compete with other uses of arable land - or with each other – is a subject for careful attention. Section 1.3.1 of this study summarises an assessment undertaken by the Commission of the land required to achieve the biofuels contribution towards its "20% by 2020" target [11]. As well as the potential increasing use of arable land by new biomass or biofuels sources, wider uptake will lead - through supply and demand effects – to:

- Increased demand for the raw materials used to produce biofuels, expected to lead to higher raw material prices;
- Increased supply of biofuel by-products (animal feed and glycerine), leading to lower feed costs and lower prices for meat, as well as lower glycerine prices;
- Reduced demand for oil, leading to a lower oil price.

As well as the implications for land use, the effect of expanding biofuel production will be felt in *prices of other crops and commodities* derived from crops. Table 5.1 below (from [11]) shows the predicted price effects in 2020 due to wider uptake of biofuels.

Table 5.1: Predicted price effects of biofuel promotion in 2020 (wholesale prices, €2006) [11].

Commodity	Average price 2006 (€/t)	Price change relative to 2006 average		
		no biofuel use	7% scenario	14 % (more domestic) scenario
common wheat	124	114 (-8%)	123 (-1%)	131 (+6%)
rape meal	109	158 (+45%)	69 (-37%)	63 (-42%)
rape oil	654	332 (-49%)	672 (+3%)	737 (+13%)
soy meal	170	202 (+19%)	119 (-30%)	104 (-39%)
soy oil	484	330 (-32%)	693 (+43%)	745 (+54%)
wood	no expected price effect			
oil	change relative to no biofuel use:		-1.5%	-3%
glycerine	no expected price effect			

There is 'no expected price effect' relative to 2006 average prices for:

- *wood*, because increased demand will be fully met by straw and farmed wood from new plantations, so no effect on existing wood users is expected;
- *glycerine*, where there has already been a very large price drop for glycerine, almost to zero, as a result of the increase in biodiesel production to date.

The promotion of biofuels can have a negative effect on other industries that use the same raw materials, as competition drives up prices. For example, in the table above it can be seen that the largest price impact is on vegetable (rape and soy) oils. This would be expected to have flow-on effects to the price of margarine and other products derived from vegetable oil, although this could be partly offset by switching to other types of vegetable oil.

Two examples below illustrate the risk of price rises arising from the promotion of biofuels.

Example 1. **COFALEC**, the Association of European Yeast Manufacturers, has expressed concern about the availability of sugar beet molasses, the main fermentable raw material of the yeast industry, in the face of competition from the bioethanol industry, which also uses beet molasses as a raw material [74]. COFALEC claims that a distortion in competition has been created by the current subsidies for biofuels, allowing the bioethanol industry to buy molasses at a higher price than the yeast sector. European sugar molasses is already in short supply with the implementation of the last Common Market Organisation (CMO) sugar reform. The European yeast industry is the largest in the world, producing one third of the world's total yeast and exporting one third of its production outside the EU.

Example 2. In the USA, the **Biofuels Security Act** (2007) is likely to require an increase in bioethanol production (to 30bn gallons in 2020 and 60bn gallons in 2030), and would also require fuel suppliers to offer 85% ethanol blends in half their service stations by 2017. Current technologies are thought to be unable to deliver these targets – if the USA uses corn-based feedstocks (maize) to achieve these targets, the price of corn-based food will rise world-wide. This in turn would potentially make the economics of bioethanol from corn unattractive. Prices for corn in Mexico have increased dramatically in response to increased demand from the USA [54].

The Commission concludes that overall the scale of price impacts from the promotion of biofuels "will not be dramatic". While parts of the food industry, chemical industry and forest based industries use the same raw materials and therefore face increasing costs as a result of biofuel promotion, other industries that use biofuel by-products such as rape meal, soy meal and glycerine will benefit from cost reductions.

However, we consider that experience to date suggests that the impacts may in fact be dramatic. DG-AGRI, in its "*Prospects for agricultural markets and income 2004-2011*" [75] warned that achieving the biofuels Directive target of a 5.75% share of biofuels by 2010 would have a "major impact" on cereal and oilseed prices. While recognising that this would be partially offset by price decreases for by-products, DG-AGRI points out that the EU would end up paying substantially more not only for the crops used for biofuels but also for food and animal feed. This would result in sharply increased income for growers and food prices for consumers. As highlighted above, this effect can already be seen in the USA and Mexico.

5.3.1 Competition between biomass and biofuels

Is it possible that the drive to maximise the use of biomass and biofuels could lead to competition between them? The BIOFRAC Vision for Biofuels [61] states that "up to 2010 there will be no major competition for raw materials: biofuels rely mainly on agricultural crops while biomass for electricity and heating rely mainly on wood and wastes". Beyond this time some biomass and biofuels feedstocks are the same (or potentially the same if derived by second generation methods).

However, there is already some evidence of competition for raw materials. In the UK there are indications that the current drive for biofuels is creating competition between operators trying to recruit farmers to grow energy crops, namely short rotation coppice for co-firing and oil seed rape or wheat for biofuels [76].

As the level of biomass and biofuels usage increases, it is important that energy production is concentrated on those wood fuel fractions which cannot be used to produce industrial products with higher added value. This necessitates research and development to improve the techno-economical efficiency of the production chains. In the near future it may become feasible to produce liquid biofuels from wood and wet biomass that is currently used to generate heat and electricity or pellets. In that case greater competition may emerge between biofuel policies and bioenergy policies.

5.3.2 Import of feedstocks from outside the EU

It is not anticipated that the EU should aim for self-sufficiency in the usage of biomass and biofuels feedstocks. Most regions of the world have a higher ratio between biomass production potential and expected energy demand than the EU, implying a capacity to export biomass. In practice, biomass imports are likely to make an important contribution to EU requirements.

The Commission has stated [69] that it has “opted for a balanced approach to biofuel trade. Under this approach, both domestic producers and importers should benefit from a growing EU market for biofuels. The opportunity to sell biofuels or biofuel raw materials into the EU market could provide a valuable opportunity for trading partners. It could help resolve regional or global trade negotiations, and could offer specific benefits to developing countries, including some of those affected by the reform of the EU sugar regime”.

Reference [69] also states that “in terms of development benefits, for countries which have appropriate natural resources, and develop efficient supply chains, the expansion of biofuels markets opens new opportunities in terms of economic and social development in the generally poorer rural areas (including employment creation, diversification of and value addition to agricultural activities, and rural access to energy). Certain countries with small domestic markets and relatively low costs will develop only if the world market offers possibilities for economies of scale”.

Nevertheless it is also acknowledged that growing biofuels demand will probably lead to price rises. The extent to which this will lead to net benefits or dis-benefits for different countries is not clear.

The Commission believes [69] that there has been much inaccurate information about the impacts of the EU’s consumption of biofuels, including the claim that biodiesel consumption has caused deforestation and destruction of natural habitats in Indonesia and Malaysia to clear the way for the production of palm oil. In 2005, an estimated 30,000 tonnes of palm oil was used for biofuels production, compared to a global increase of 10 million tonnes over the period 2001/02 to 2005/06 due to the food market. The Commission’s assertion that biofuels are not to blame for large rises in palm oil production may be true but avoids the important question of whether the need for palm oil for biofuels will increase further, to the detriment of overseas markets and with potential environmental consequences.

It is also instructive to review recent experience in the UK with the import of biomass material for co-firing in coal-fired power stations. With major incentives for co-firing provided by the UK’s Renewables Obligation, in 2005 UK power plants imported major quantities of overseas feedstock (notably palm products and olive waste) amounting to at least 74% by mass of the UK’s co-firing feedstock [76]. This amounted to more than 1 million tonnes of imported biomass.

If the UK’s demand for imported co-firing fuels rises beyond the 3% by mass seen in 2005, this could lead to a greater impact on worldwide demand. However the alternative use of palm oil for biodiesel production can also be expected to increase, perhaps limiting available palm oil for co-firing unless increases also occur in palm oil cultivation.

Even as recently as 2004, the International Energy Agency [77] could state that “there is also significant overproduction of some crops in many IEA countries, and the development of new markets may be able to absorb existing oversupply before drawing crops away from other purposes. This area of analysis deserves much greater attention than it has received to date”.

In response to these issues, and the possible risks to food production in developing countries associated with alternative uses for land, the Commission has stated that the concerned countries should establish appropriate policies to promote food security, as well as an equitable sharing of the benefits of biofuels development.

This is illustrated by the issues arising at an International Energy Agency conference on “Biofuels and the International Development Agenda” [78]. This conference identified four key themes relating to biofuels:

- *Emulation of success:* Would it be possible for developing countries in Asia and Africa to emulate the path to success demonstrated by Brazil, in producing and exporting ethanol and other biofuels?
- *Assistance:* Would Brazil and other leading biofuels producers be able to help other countries to plan investment, technological transfer, expertise and know-how?
- *Tariff Barriers:* The developed and developing world needed to break down barriers to trade and promote liberalisation and free trade.
- *Stakeholder consensus:* Agreement should be forged between farmers, biofuels producers, car companies, oil firms, traders and ministers that this was the right road to take.

At this meeting [76] the United Nations Conference on Trade and Development (UNCTAD) launched a Biofuels Initiative under which an international expert group was set up to help developing countries increase the production, use and trade in biofuels resources and technology.

5.4 Conclusions on European Competitiveness in Bioenergy

In summary, the EU has a number of competitive strengths in biomass and biofuels. Below first the key strengths and then the key weaknesses are summarised.

Key EU competitive strengths in biomass energy and biofuels

- The EU is technologically competent and advanced. It has applied these advantages to all forms of bioenergy and leads the world in many applications of biomass.
- European countries have good experience in biomass and biofuels, although this experience is not evenly spread across the EU.
- The EU has a good biomass resource and the potential to increase this resource through the development of energy crops and processing of biomass residues.
- The EU and its member states have developed good support mechanisms for renewable power and biofuels. Recent increases in bioenergy demonstrate that these mechanisms generally work.
- There is a strong development environment for biomass and biofuels in the EU – this includes R, D&D and development of biomass and biofuels plants by industry.
- There are some very good examples of the niche application of biomass energy. In some cases biomass can be demonstrated to be commercial without support.
- There are good case studies available through European networks and web sites that provide examples of plants in operation and developments of state of the art facilities. These help provide confidence in European technology throughout the world.
- Internet searches on bioenergy are often dominated by European sites and information, which provides a good impression of European competence in the technology.
- The EU provides a stable market for imports, which means that it can attract imports of biomass to help achieve its targets for biomass energy; there are a number of successful examples of the import of biomass for European bioenergy plants.
- The EU's excellent research environment means it has the appropriate skills and infrastructure to develop advanced bioenergy options such as pyrolysis, gasification and, ultimately, bio-refineries.

Despite these core strengths, there remain important weaknesses that threaten the EU's competitive position, the most important of which are listed below.

Key weaknesses that affect the EU's competitive position in biomass energy and biofuels

- Development of European biomass and biofuels is frequently dependent on support of some kind (e.g. grants, obligations on the supply of power or transport fuels and tax incentives). Currently many forms of bioenergy would not be viable without support. Thus development comes at a price to the taxpayer or consumers.
- The EU will be dependent on imported biomass to achieve the EU long-term targets for deployment. This enables the EU to assist the economies of third parties; however, there are also potential negative effects for the countries involved, such as an increase in local biomass fuel prices, and, perhaps, food prices. In addition there is concern that large monoculture plantations of biomass energy crops planted to meet the EU's needs, particularly in the far East, may not be the most sustainable (or carbon-effective) way to produce energy crops.
- The strong fossil fuel sector in the EU is in a position to undercut biomass energy prices, particularly for heat, and this could threaten the widespread deployment of bioenergy.
- Bioenergy plants are frequently insufficient to create a stable enough market pull for investment in biomass crops or the harvesting and collection of residues.
- Industry is reluctant to invest in biomass energy.
- Heat is the most carbon-efficient way to use biomass, but biomass CHP and heat are not increasing in the EU.
- Bankable information needed for finance, such as clear information on cost, economics, performance and technical issues, is difficult to obtain.
- Issues with supply and local infrastructure can make it difficult to demonstrate advances in technology; advanced combustion (e.g. gasification) has been affected by this.
- Biomass capital costs are high (although the fuel can be cheaper than fossil fuel) customers do not have confidence to invest in high capital cost plants and (what is perceived to be) risky supply strategies. This affects the replication of biomass heat in particular and the potential for economies of scale.
- Storage can be a problem with biomass, as biomass fuels can degrade, particularly if they are wet. This has implications to security of supply and the cost of storage for biomass that is harvested once a year (such as European energy crops).
- One of the most promising sources of biomass energy comes from wastes and industrial residues, but public perception of energy from waste or residues in the EU can prevent its development. In these circumstances planning can add major costs and delays. Other biomass combustion technologies can also suffer from similar perception issues.
- There are signs of competition between different biomass energy technologies for biomass resource.
- Skills for development of bioenergy exist in the research community but there are skills gaps which could threaten the large-scale development of bioenergy across the EU.

These strengths and weaknesses are examined in more detail in Tables 5.2 and 5.3. European competitive strengths are examined in terms of the opportunities they present and the factors that threaten the EU's competitive position. Conclusions are drawn regarding factors that need to be addressed. Weaknesses that may influence the EU's ability to compete in biomass and biofuels markets are also addressed in terms of opportunities to address these weaknesses and the way in which they may threaten the EU's competitive position. Conclusions are also drawn regarding factors that need to be addressed.

Table 5.2: The EU's competitive strengths

The EU's competitive strengths	Opportunities	Threats	Conclusions
General Bioenergy			
The EU has a strong bioenergy sector that has grown significantly over the past two decades and that represents one of its strongest renewable energy sectors. This sector is key to the EU achieving targets for RE deployment and decreased emissions of greenhouse gases. It is also recognised to be at the forefront of development worldwide. The growth in deployment of bioenergy has enabled the biomass sector in the EU to mature.	This success has resulted in improved costs. Innovative solutions have been developed to key technical barriers. Biomass fuels, their characteristics are well understood. Improved and efficient conversion technologies have been developed. As a result the EU leads the world in many aspects of bioenergy and is regarded as technically competent and advanced. As biomass is a fundamental fuel in most countries, this places the EU in a powerful competitive position.	The EU's most successful bioenergy applications are niche applications or in regions where policy and financial support have been advantageous. The success of bioenergy has still to be replicated across all of the EU and particularly in Eastern Europe. There remains a need for market support mechanisms across the EU.	**The EU's bioenergy sector has developed rapidly and is in a strong competitive position internationally. However, there are still important issues to address, including costs. Continued support is required to achieve the full potential of biomass in the EU and to provide the opportunity to establish markets abroad.**
Policy, regulation and support programmes at regional, national and EU level form a framework that provides the confidence for the bioenergy sector to continue to grow.	This framework supports the bioenergy industry, assisting the establishment of a strong industry throughout the EU.	This support comes at a price, which decreases Government income from tax and increases the price consumers pay for energy.	**Regular reviews are important to ensure support mechanisms remain cost-effective and continue to encourage deployment of bioenergy in order to meet EU and national targets.**
The EU has a good climate for growing crops and a sophisticated agriculture and forestry sector that can adapt to changing demands	There is a large biomass resource across the EU and the mechanisms to deliver this to market are being developed. The EU has the framework and infrastructure to develop/introduce new energy crops.	Analysis indicates that the EU cannot meet its own targets for biomass using indigenous supply. Imported biomass will need to be considered. In addition the agricultural section can be cynical of the benefits of growing energy crops, particularly if the market is not clear.	**The continued development of indigenous biomass fuels is important, but it needs to be complemented with development of appropriate imported biomass supply. The necessary balance between the two and factors that affect this balance need to be clearly understood.**

The EU's competitive strengths	Opportunities	Threats	Conclusions
In addition to the potential for energy crops the EU has a large resource of biomass residues and wastes.	The use of many of these biomass residues and wastes to generate energy has already been demonstrated. Europe leads the world in the development of high biomass fuels from waste. Europe leads the world in energy from waste.	Many of these potential residual and waste biomass fuels are widely dispersed and some have to be separated from non-biomass fractions. Because of the definitions of waste within the Waste Framework Directive many relatively clean biomass residues are classed as wastes and come under waste combustion regulations. This means that emissions targets must be met, often involving costly abatement technologies.	**Use of the energy value in the EU's large residual and waste biomass resource can make a vital contribution to bioenergy targets. In particular the use of clean biomass residues should be encouraged and legislation regarding their use clarified. However, these fuels are cheaper that virgin biomass and it will be important to ensure that more polluting waste fuels are not used in preference to virgin biomass.**
The EU has good infrastructure to allow it to import significant quantities of biomass.	A stable market in the EU will encourage the development of an imported biomass market.	Importing of biomass from developing nations can increase the value of biomass and may prevent it being used locally. Many of the countries with good potential to provide biomass for import are in less stable regions of the world.	**There is a need to examine what can be done to boost supply from third countries.** **The issue of security of supply from imported biomass needs to be addressed, particularly when the biomass is imported from less politically stable countries.**
The EU has many of the skills to develop a competitive bioenergy sector.	The EU has many of the technical skills to develop bioenergy, particularly at R&D level.	There is a skills gap at some fundamental levels in many regions, including the skills to build and install energy plants. This can hamper the growth of the industry and technology transfer from research to industry.	**The EU and member states have the infrastructure to work with industry to identify the gaps and develop programmes to train staff.**

The EU's competitive strengths	Opportunities	Threats	Conclusions
Biomass heat and power			
The EU has developed cost-effective and efficient small-scale biomass heat applications.	There is a need to develop an alternative to fossil fuels in heat markets across the EU. Modern biomass systems are easy to use, less polluting that fossil fuel appliances and cost effective. In rural areas they may also create local jobs in agriculture and forestry.	Public prejudice and preferential support for power has limited the more widespread deployment of these applications.	**Key factors that influence public confidence in biomass heat (such as reliable and widespread fuel supply chains) need to be addressed. Cheaper, reliable, high specification biomass fuels are required. The public need more confidence in biomass fuels and their use.**
The EU is at the forefront of replacing old, inefficient coal and biomass boilers with newer more efficient, less polluting biomass technologies.	There are many success stories in this area and the potential to develop the market in Eastern Europe, providing appropriate support mechanisms are put in place. This experience will enable the EU industry to export across the world.	Barriers to biomass heat and power remain: modern fossil fuel applications remain attractive, despite the recent increased fuel prices; the lack of established biomass supply chains creates uncertainty. In addition unfamiliarity with the fuel; capital cost of installation; and the need to store the fuel all create uncertainty.	**Mechanisms that support the conversion of inefficient coal boilers to biomass are in place in some Member States and could be replicated across the EU**. **Support needs to include technical information as well as secure biomass supply**.
The EU ETS is encouraging many energy intensive industries to consider renewable heat and power, but there are still barriers.	As the cost of carbon trading increases, the use of alternative renewable heat technologies will become more attractive to industry.	Barriers include unfamiliarity with the alternative, aggressive pricing by fossil fuel suppliers, the low cost of traded carbon, the high cost of biomass boilers and fears about the security of supply.	**Key barriers to the installation of biomass heat and power in industry are the same across the world. These need to be identified and addressed.**
The EU has extensive experience of the use of biomass fuels in district heating schemes, particularly in local municipality operated schemes.	Efficient district heating using biomass fuels is demonstrated in a number of EU member states. There is an opportunity to refurbish old, inefficient systems in eastern Europe with modern systems that are at least partially fuelled with biomass from the locality. This would create local jobs and strengthen security of energy supply locally. Experience in Eastern Europe may help EU suppliers sell into the Russian and CIS market.	There are barriers to use as listed above.	**Key barriers to the installation of biomass heat and power in district heating schemes need to be identified together with cost effective ways of addressing them.**

The EU's competitive strengths	Opportunities	Threats	Conclusions
Co-firing of biomass with coal is an established technology in Europe and a wide range of biomass fuels are used, including imported fuels. Europe is among world leaders in this technology.	This is one of the cheapest ways to use biomass and helps to establish large-scale markets and supply chains for biomass. There are many opportunities for replication, particularly in China and India.	Many of the fuels used in co-firing are imported and it has not, in general, supported the establishment of local energy crops.	**Co-firing has established international trade in biomass. The sustainability of the use of imported biomass is not well understood. Sustainability standards and certification could be introduced to ensure imported biomass is from sustainable sources.** **There is world wide market for co-firing. The EU should aim to help its industry be at the heart of this market.**
Biomass power generation has been demonstrated across the EU and European industry has pioneered the use of some agricultural residues.	The logistics of biomass power are not always easy and the EU is ahead of the world in addressing the issues that need to be considered.	Biomass power continues to need support across the EU and would not be competitive without this support.	**R, D & D should aim to improve the cost effectiveness of biomass power and decrease the costs of indigenous biomass fuels.**
Europe leads the world in the application of anaerobic digestion (AD) for farm manures and slurries and for solid wastes. It also sells AD across the world.	This is no mean feat. Many technical and logistical barriers have been overcome, particularly in farm and industrial waste AD.	There remain barriers and technical constraints in some areas and cost is an issue. Nevertheless the EU has considerable expertise in overcoming barriers and in approaches to decrease costs.	**AD continues to be costly if based purely on energy generation, particularly at small-scale. Its role in waste disposal and hygiene needs to be clarified and costed.** **Investigation of small-scale energy conversion of biogas needs to be supported, as there are potential markets worldwide.**
The EU has invested in considerable R, D& D in advanced conversion technologies and is now a world leader in pyrolysis and gasification.	Gasification of wood is well demonstrated and beginning to gain a market hold. The gasification of mixed wastes has been demonstrated successfully in Finland and Germany.	Other countries such as Japan and Switzerland have also invested heavily in these technologies and are selling their technologies abroad (e.g. to the USA). Costs, the logistics of operation and technical issues remain a challenge.	**Gasification and pyrolysis are promising technologies, particularly in the development of flexible strategies for biomass fuels for the future (e.g. as part of the bio-refinery concept). The EU's leading role on these technologies places it at the forefront of development.**

The EU's competitive strengths	Opportunities	Threats	Conclusions
Biofuels			
The EU leads the world in biodiesel production	The EU's lead is based on the demand for diesel in the EU and the ready access to precursors such as oil seed rape and recovered vegetable oils (RVO). Restrictions on quantities of biodiesel in fuel standards are being addressed through work supported by the EU.	The EU cannot supply feedstock to meet its biofuel targets and will need to import feedstocks. The classification of RVOs as wastes and their co-products as wastes for the purpose of combustion threaten efforts to decrease the carbon emissions from this biodiesel production.	**The EU's expansion of biodiesel is limited by availability of feedstock and the restrictions on biodiesel within fuel standards.** **These barriers need to be addressed to enable biodiesel use to expand.**
Bioethanol use and production is increasing.	The EU's Biofuels Directive is encouraging the use of bioethanol and the development of bioethanol plants. Second generation biofuels development should bring the cost of EU bioethanol down.	Currently, European bioethanol is not cost competitive on the world market.	**The EU needs to consider whether it can compete with cheaper bioethanol suppliers from elsewhere and the implications of relying on imported bioethanol (including the sustainability of these supplies).**
Biofuels plants are being built now and developers are trying to recruit growers for energy crops.	This is an opportunity for European farmers to diversify into a new market.	In some areas farmers are not confident of the biofuels market and recruitment of growers is slow.	**Mechanisms to enable farmers to buy into plant and benefit from profits may enable more secure indigenous biomass supply chains.**
The EU is at the forefront of work on bio-refineries	FP7 has the potential to support R, D&D in this area. In some countries (e.g. France and Germany) the chemical industry is working with academia to develop this technology.	The EU does not always succeed in persuading industry to invest in research and development. The US is more successful in developing academic-industrial partnerships.	**The EU Chemicals industry needs to be persuaded of the future of the bio-refinery concept and the value of supporting research in this area in the EU.**
The EU is a member of international agreements to share information and knowledge on renewable energy. In areas with many technological challenges such as bio-refineries these agreements could benefit the EU and enable it to be at the forefront of development.	These agreements enable the EU to gain a thorough understanding of technological development in other developed countries such as the US, Japan, Canada and Australia and to establish working agreements for exchange of information. In particular the USA has a multi-million dollar research programme to develop bio-refineries.	These agreements allow our competitors to be able to assess the status of European technology and the European market.	**The EU should consider the benefits of agreements to enable information exchange on R, D& D on bio-refinery development with the USA.**

Table 5.3: Weaknesses that compromise the EU's competitive strengths

Weaknesses in the EU's competitive position for bioenergy	Opportunities	Threats	Conclusions
General Bioenergy			
The EU does not have the biomass resources to achieve its bioenergy targets	The EU has the time and ability to develop strong international markets for the EU's biomass supply.	Many of the areas identified as places where biomass could be grown for world supply are unstable politically. This can provide uncertainties in biomass supply.	**The infrastructure for biomass import needs to be developed in the EU and in the countries of origin.**
Indigenous biomass fuels in many EU countries are more expensive that imported biomass.	If the EU is to achieve its biomass targets it will need a combination of indigenous and imported biomass. Cheap supplies from outside the EU will help establish a strong, competitive market for biomass.	There is a danger local biomass supply chains may not establish because imported biomass is cheaper. Transport costs within the EU are expensive, so this would result in many biomass plants being built on or near to the coast.	**Many European biomass sectors cannot compete with cheap and plentiful imported biomass. The impact of the import of biomass on the fledgling European biomass sector needs to be more fully understood.**
The EU has little control over the standards of production of imported biomass or the impact its production has on local ecology and biodiversity.	The potential to destroy many important habitats in order to grow energy crops (particularly palm oil) is well publicised and there is time to develop good quality standards.	The EU has little control over forestry and agricultural practices in the Far East or Africa. The potential sustainability issues are not well understood or researched. The impact of large-scale biomass plantations on water resources is not clear.	**Certification schemes to ensure biomass imports are from sustainably managed plantations are already proposed in countries such as the NL. There is potential for establishing EU-wide schemes.**
There has been limited success in replicating some bioenergy technologies across the EU.	The EU is at the forefront of the development of many biomass technologies. More R,D& D is needed to decrease the overall costs of some of these technologies before replication can be more widespread.	Some biomass technologies have only been developed with support from Government or through elevated energy pricing.	**Barriers to replication need to be clarified to enable funding and policy to be targeted effectively.**

Weaknesses in the EU's competitive position for bioenergy	**Opportunities**	**Threats**	**Conclusions**
The application of stringent emissions legislation (e.g. the Waste Incineration Directive, WID) to some biomass residues has added a burden of cost to their deployment as fuels.	Stringent emissions legislation is designed to prevent pollution and protect human health and the environment. The EU leads the world in developing standards for emissions abatement and in the technologies to meet these standards.	Some food processing and agricultural residues come under the WID (e.g. tallow, chicken litter and potentially glycerine produced from biodiesel production from recovered vegetable oils), creating additional costs in their use to generate energy. This is being examined as part of the review of the Waste Framework Directive.	**Biomass residues and wastes form a significant part of European biomass. Their sustainable use to generate heat and power is important to EU targets. This technology could be sold world wide.**
Some agriculture and forestry sectors are wary of investing in growing, harvesting and storing biomass for energy, particularly where there is not established market for the biomass fuel.	The EU has a strong, sophisticated agriculture and forestry industry. It is capable of growing new crops and selling into new markets, providing the market conditions are right. Biomass has often proved to be successful where biomass developers and growers have mutual trust and interests.	The agricultural and forestry sectors in many regions see biomass energy as high risk and require support mechanisms to grow energy crops for which there is no strong market.	**This factor could be crucial in restricting the EU's ability to meet its bioenergy targets. Solutions need to be explored (e.g. allowing biomass growers to buy into bioenergy plants as happens in US bioethanol plants).**
Some support programmes for bioenergy have resulted in biomass import rather than local energy crop supply.	The development of a stable biomass energy sector is important in the development of bioenergy. Imported biomass enables bioenergy users to establish and may lead to more local biomass fuel markets in the future.	European farmers and foresters may find it difficult to compete with cheap imported fuels. However, as demand increases costs may also increase enabling European biomass to be competitive.	**Policy makers need to understand the aims of their policies and to ensure that these aims are achieved. Review of support schemes should analyse the impact on all parts of the bioenergy supply chain.** **It is important to ensure that policies do not encourage poor quality or unsustainable biomass from outside the EU.**

Weaknesses in the EU's competitive position for bioenergy	Opportunities	Threats	Conclusions
Biomass heat and power			
The EU has been good at supporting schemes to generate power but not good at supporting heat. This means that some of the more energy efficient applications of bioenergy are not being encouraged.	The EU has been successful in developing biomass power. However, efficient generation of biomass heat results in more carbon savings.	Biomass heat has not grown significantly in the EU. In particular CHP has suffered from the desire to maximise electricity generation to obtain favourable tariffs or certificates for electricity production.	**Mechanisms for supporting and encouraging renewable heat use need to be developed.**
Electricity generation from biomass is relatively successful, but is dependent on support.	The support mechanisms have been used to successfully develop renewable power and decrease greenhouse gas emissions.	The dependence of the industry on support costs Governments and the tax payer.	**Constant review of support mechanisms is important to ensure they remain the most cost effective way of supporting biomass power generation.**
Biofuels			
The EU produces low levels of bioethanol	There are good historical and market reasons for the low production of bioethanol. Second generation production of bioethanol is more promising in the medium term.	The EU's competitors (e.g. USA and Brazil) are more successful that the EU in producing bioethanol.	**European bioethanol is expensive compared to imported supplies. The EU will not be able to compete on cost and this reality should be included in decisions to support bioethanol in the EU. The development of second-generation biofuels may be more cost-effective in the long term.**
Some biofuel production processes have relatively poor carbon balances	There are many ways to improve the carbon balance of biofuel production.	There is currently no way that the end user can know if the biofuel is produced using more sustainable means.	**The process of biofuel production should be subject to sustainability principles, so that processes with poor carbon balances are not encouraged.**
Key multi-national companies often do not invest heavily R,D & D in the EU.	There are some notable exceptions to this, e.g. in the French and German car and chemicals industry.	There are key examples where multi-nationals prefer to invest in R&D in the US to the EU.	**The EU needs to ensure it is an attractive environment for investment.**

Weaknesses in the EU's competitive position for bioenergy	**Opportunities**	**Threats**	**Conclusions**
The EU is not good at disseminating the results to R, D&D.	While there are some notable exceptions (e.g. AFB-net, EU Bionet etc.), obtaining fundamental information on biomass schemes, (e.g. on costs, emissions, quantities of biomass required, handling and storage issues etc) can be very difficult.	A lot of R,D &D is supported within the Framework programmes, but it is frequently difficult to obtain detailed information from this work. This makes replication difficult.	**Better dissemination is required and researchers should be encouraged to produce detailed reports. Case studies should also be more detailed so that potential biomass developers can obtain bankable data on performance, cost, emissions, equipment etc.**
The USA is investing in a multi-million $ programme of R&D in developing biorefineries.	The EU is also investing in this technology, using skills and experience from across the EU.	Bio-refineries will require a lot of funding, not just for fundamental technological R&D but also in the infrastructure to enable to refinery business to compete. This will require working in partnership with multi-national chemicals companies.	**Strategies for bringing industry on board and ensuring the scale up of fundamental R&D are being developed within FP7 and should be strengthened and encouraged.**

6 CONCLUSIONS

The European Union has a well developed capability in the bioenergy field and is in a strong position from which to grow. Industry and academia are involved across a wide technological spectrum and often lead the world in their field. Public policy has encouraged technological development and deployment in many areas with the result that bioenergy has experienced significant growth in many (but not all) sectors in recent years. The recent decision of the European Council to endorse a mandatory 20% target for renewables by 2020 sets a very positive framework for the future.

It is now up to Member States and the European Institutions to create a framework within which this challenging target can be achieved. This will require a concerted and strategic approach at all levels, covering R,D&D, appropriate market incentives, standards and certification procedures and the systematic addressing of barriers to deployment. It will require the involvement of a wide range of actors, in particular those from the forestry and agriculture industries. It will require some difficult issues to be tackled, such as the role for imported biomass and potential competition between bioenergy production and other land uses. Given the issues involved, the European Institutions have a particular responsibility to ensure that this framework matches the ambitions for bioenergy and ensures that the full potential can be achieved.

Chapter 2 of this study presents a range of best practice case studies from both within and outside the European Union. They demonstrate the breadth of technologies available and the ways in which innovation is enhancing the market uptake of bioenergy, as well as providing additional environmental benefits. They clearly demonstrate that innovation and more widespread uptake of bioenergy technology require long-term market support mechanisms and a stable supply of biomass feedstock at a predictable price. There are significant benefits to the agriculture and forestry industries having a financial stake in the downstream conversion technologies. There are already many examples of developers turning to imported feedstock or fuels to meet deployment targets, raising issues of sustainability, security of supply and effect on food production in countries of origin.

The case studies demonstrate that European technology is at the forefront in many areas of biomass and biofuel development. However it must be remembered that not all projects end in success, often for a range of different reasons. Those designing support schemes must take a very broad perspective and ensure that all required elements are put in place.

Chapter 3 examines the role that research, development and demonstration plays in the EU. The 7th Framework Programme provides wide-ranging support for bioenergy but that support needs to be drawn together into a single, simple document. Whilst it is clear that the areas designated for support have been advised by relevant experts, there is a need to ensure that R,D&D funding is underpinned by a full strategic assessment of market potential, taking into account factors such as biomass production potential, technology cost reduction potential and identified market barriers. Given the challenge inherent in the 20% renewables by 2020 target, EU funding should focus primarily on R,D&D that will help to achieve that target.

Chapter 4 focuses on the options available to foster production and processing. A wide range of support measures have been employed at Member State and regional level and EU directives on renewables electricity and biofuels have provided incentives via deployment targets. It is clear that, without such support, bioenergy is unlikely to progress beyond niche applications in the short to medium term. There are strengths and weaknesses for all of the support mechanisms, including costs, administration, inflexibility and the fact that sometimes they only address one part of the bioenergy chain, without addressing weaknesses elsewhere.

There can be no “one-size fits all approach”. Within the EU different bioenergy technologies are suitable in different regions, depending on local agricultural conditions and the local energy market (e.g. whether or not there is a tradition for district heating).It is important that the EU can create an appropriate context for support whilst allowing Member States the flexibility to respond to local needs and opportunities.

Chapter 5 examines the wider role that bioenergy plays in the context of energy security, climate change and agricultural diversification. The biomass resource (including energy crops) is certainly large enough to make a significant contribution to EU energy consumption; projections show that the contribution could be as high as 12% by 2020. What’s more it has the versatility to contribute to all three energy markets: heat, electricity and (importantly) transport fuels. As biomass is a renewable resource, it has significantly lower CO_2 emissions than fossil fuels (so long as biomass production and utilisation are in equilibrium). The expansion of bioenergy does have major implications for agriculture and forestry, and policy makers must gather more information on these to ensure that decisions can be based on the best evidence. In particular the impact that expanding biomass production has on alternative land use, especially food production, needs careful attention.

The issue of imports also needs very careful consideration. These will often be available at a lower cost than indigenously produced biomass or biofuels, hence there will be a strong economic incentive to use them in preference. Measures should be put in place to monitor this area, ensure that imports meet rigorous sustainability standards in their country of origin and check that they do not have unintended economic consequences for the producing country. One of the main goals in developing second generation biofuels derived from wood-based biomass is to move away from feedstocks that might compete with food production.

Table 6.1 provides a summary of the key conclusions and recommendations from this study and Appendix 1 expands on some of the potential actions. There is no doubt that bioenergy holds great promise for the European Union, which can tackle the challenge from firm foundations. However, the promise will not yield results without a concerted approach at all levels. European Institutions have a particular responsibility to create a framework that allows bioenergy production and use to expand sustainably and with full public support.

Table 6.1: A European competitive and innovative edge in bioenergy - key conclusions & recommendations

Conclusion	Recommendation
Bioenergy has **huge potential** to help the EU meet its new target of 20% renewables by 2020 but will only do so within the context of a long-term supportive framework at Member State and EU level. The major challenge of developing secure markets (persuading landowners and farmers to produce biomass fuel/ feedstock for biofuels, whilst at the same time developing the market for bioenergy) needs to be addressed. A second major challenge is to reassure the public about sustainability and environmental impact.	This framework should include: • Policy at EU and national level that is fit for purpose (targeted, strategic, informed and flexible, and responding to developments and needs). Policy must address public perception on issues of sustainability and environmental impact. • R, D&D: co-ordinated at national and EU level; evolving to respond to strategic need; and well informed, with good information dissemination, which includes data on sustainability and environmental impact. • Support at regional and national level – responsive to need and to changes in circumstances.
The **biomass heat** market holds considerable potential but has shown little growth compared with electricity and transport fuels. This is despite the fact that it has been shown that heat generation is the most carbon-efficient way to use biomass. The heat market needs special attention at EU as well as national levels.	Market incentives for heat should at least aim to provide a level playing field with other biomass use (power and liquid biofuels): • As a priority member states should ensure that substantial growth in biomass heat use is encouraged. Particular attention should be given to capital cost and support for development of supply chains. • EU institutions need to reinforce the requirement for biomass heat.
Increasing bioenergy utilisation requires a reliable **supply of biomass** feedstock at a predictable price for the market to have the confidence to make the necessary investments. Achieving the 20% renewables target will require the majority of the available EU biomass supply potential to be utilised, supplemented by **imports** from third countries. The effect of rising demand on feedstock price and alternative uses (including food production) needs special attention.	Further work is required to understand: • The consequences of imports on the prospects for EU domestic biomass production; who the key potential trading partners are and if infrastructure needs to be put in place to enable biomass trade to develop; and security of supply. Trade statistics need to be developed to assist these requirements. • The impact of biomass production on food production and prices both in the EU and abroad; • The sustainability of imported biomass/biofuels and mechanisms for ensuring it – and ensuring control of disease and pests. • The longer-term consequences for land use of increased bioenergy utilisation.
The **EU leads the world** in many aspects of bioenergy and is in a strong position to benefit from the expanding global market for bioenergy. It has a strong R&D capability and many equipment suppliers at the forefront of their field. Nevertheless many issues still need to be addressed, such as the development of mature	EU and Member State policies should continue to support EU capability in the bioenergy field to ensure the EU remains a key player on the world stage. This is best achieved by focusing on achieving the EU's own deployment targets, whilst taking into account the global export potential. Key issues include: • Addressing transport, storage, production and other infrastructure needs.

Conclusion	Recommendation
bioenergy chains.	• Addressing training/skills gap • Decisions about whether or not to co-ordinate research on second-generation biofuels and bio-refineries with the USA.
Cost reduction remains a crucial goal for bioenergy. There is an ongoing role for R,D&D to help achieve this and a need for better information on the real costs of bioenergy options.	There is a need for a EU-level R,D&D strategy to focus resources on the most promising options, including advanced conversion options. The Commission should collect and publicise information on the real costs of the main conversion options, to provide good quality bankable data, as well as better information on the resource potentials.
There is a large potential biomass energy resource in **wastes and biomass residues** in the EU and a need to ensure use of this source is maximised, whilst maintaining high environmental standards.	Key issues remain, including • Addressing the conflicts between reuse, recycling and energy recovery. • Clarifying the definitions of wastes and the application of the Waste Incineration Directive. • Development of advanced technologies to enable efficient use of residues and wastes in an environmentally acceptable way.

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GLOSSARY

Anaerobic digestion: the transformation of organic matter into biogas, consisting of methane and other gases, in the absence of air (oxygen).

Bioenergy: all forms of energy derived from biomass sources and the biodegradable element of wastes.

Biofuels: transport fuels made from biomass resources. Biofuels include bioethanol, biodiesel and biogas used as a transport fuel.

Biogas: The methane-bearing gas produced from the anaerobic digestion of biomass that can be combusted to generate energy.

Biodiesel: A liquid transport biofuel produced through transesterification, a process in which organically-derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. Biodiesel can be blended with conventional fossil diesel fuel or used as a neat fuel (100% biodiesel). Biodiesel is usually made from virgin vegetable oils such as rapeseed, palm or soybean oils, waste vegetable oils, or animal fats.

Bioethanol: Ethanol (ethyl alcohol) produced by the fermentation and distillation of sugars contained in biomass, to be used as a liquid transport biofuel.

Biomass: the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

Biorefinery: A processing and conversion facility that produces a variety of outputs in addition to liquid biofuels, such as co-generated electricity, chemicals and food and/or fibre products, to improve overall conversion efficiencies and the variety and value of outputs.

BTL: ‘Biomass to Liquid’, a second generation biofuels production process involving gasifying the biomass raw material and then transforming the gas into a liquid fuel. This commonly involves making use of all parts of a plant, for example leaves, stalk, chaff.

Co-digestion: anaerobic digestion of materials from different origins mixed together.

Co-firing: co-firing of biomass with coal in power stations.

Distillation: in bioethanol production, the process after fermentation that serves to increase the concentration of ethanol.

District heat: heat distributed though a network of pipes across an area, usually around a municipality or in an industrial area.

DME: Di-Methyl Ester, a fuel similar to methanol produced from synthesis gas derived from biomass feedstocks.

Dried Distillers Grain and Solubles: a by-product of bioethanol production that can be used as an animal feed, or alternatively as a biomass feedstock for the generation of heat and/or electricity.

Energy crop: A crop grown specifically for its fuel value, to be used as a feedstock for biomass-powered heat and electricity and/or transport biofuels. Energy crops include food crops such as wheat and sugarcane, and non-food crops such as poplar trees and Miscanthus.

ETBE: Ethyl tertiary butyl ether, produced by mixing ethanol and isobutylene and reacting them with heat over a catalyst. It is commonly blended with petrol to make it burn more cleanly and thus improve air quality. ETBE eliminates many of the impediments to the greater use of bioethanol such as increased volatility and incompatibility with petrol pipelines.

Fermentation: in bioethanol production, the conversion of sugars to ethanol.

First generation biofuels: transport biofuels produced by simple processes, including fermentation of sugars to produce bioethanol and transesterification of vegetable oils or animal fats to produce biodiesel. The feedstocks are mainly traditional food crops such as wheat, sugar beet, sugar cane and corn for bioethanol, and rapeseed, palm and soya oils for biodiesel.

Fischer-Tropsch process: A process comprising gasification of biomass feedstocks, cleaning and conditioning of the produced syngas, and subsequent synthesis to liquid (or gaseous) biofuels.

Forest residues: Material left after harvesting in commercial hardwood and softwood logging stands as well as material resulting from forest management operations such as pre-commercial thinnings and removal of dead and dying trees.

Gasification: A chemical or heat process to convert a solid fuel to a gas.

Landfill gas: Gas that is generated by decomposition of organic material at landfill (waste) disposal sites.

Lignocellulosic ethanol: Ethanol that has been produced using second generation process stages, allowing ethanol production from 'woody' feedstocks as well as crop by-products such as wheat straw and sugar beet pulp. The cellulose in these feedstocks is broken down into sugars that can then be fermented to produce ethanol.

Municipal Solid Waste (MSW): Wastes from residential, commercial, and institutional premises, which may include organic matter, metal, glass, plastic, and a variety of inorganic matter.

Pyrolysis: The heating of biomass in an atmosphere of reduced oxygen to produce a controlled mixture of gases, liquids and solid products, with proportions determined by operating temperature, pressure, oxygen content and other conditions.

Second generation biofuels: transport biofuels produced by more complex processes than for first generation biofuels. There is a suite of different second generation processes including the production of lignocellulosic ethanol, Fischer-Tropsch biodiesel and other processes involving the breakdown of biomass into smaller components that can then be rebuilt into liquid or gaseous fuels. Such processes make available a much wider range of crops including non-food woody biomass as well as food crop by-products such as wheat straw and sugar beet pulp.

Syngas: 'Synthesised Natural Gas', a natural gas equivalent produced through gasification of biomass. Syngas can be further synthesised into liquid or gaseous biofuels by the Fischer-Tropsch process.

Transesterification: The process by which conventional (first generation) biodiesel is produced from vegetable oils or animal fats.

Upgrading: the process of purifying biogas to natural gas quality, for use in natural gas distribution networks or as a transport fuel.

ABBREVIATIONS

AD: anaerobic digestion

BP: BP plc, formerly British Petroleum plc

CAP: Common Agricultural Policy

CEN: European standards organisation

CHP: combined heat and power

CO_2: carbon dioxide, the main greenhouse gas

BIOFRAC: Biofuels Research Advisory Council

BTL: biomass-to-liquid production of second generation biofuel

DG-AGRI: European Commission Directorate-General for Agriculture

DG-TREN: European Commission Directorate-General for Transport and Energy

DME: Di-Methyl Ester

EC: European Commission

EST: Emissions Trading Scheme

ETBE: Ethyl tertiary butyl ether

FP7: Seventh Framework Programme

IEA: International Energy Agency

ITRE: European Parliament Committee on Industry, Research and Energy

MSW: municipal solid waste

R&D: research and development

R,D&D: research, development and demonstration

RE: Renewable energy

RES-E: Renewable energy electricity

SRC: short rotation coppice

Units

bn: billion

ha: hectare

l: litre

M: million

t: tonne

Energy units

EJ: exajoule, 10^{18} joules

GJ: gigajoule, 10^{9} joules

GW: gigawatt, 10^{9} watts

J: joule

ktoe: kilotonnes oil equivalent, the same amount of energy as in 1000 tonnes of oil.

kW: kilowatt, 1000 watts

kWh: kilowatt hour, a measure of energy equivalent to the expenditure of one kilowatt for one hour.

Mtoe: million tonnes oil equivalent, the same amount of energy as in one million tonnes of oil.

MW: megawatt, one million (10^{6}) watts

PJ: Petajoule, 10^{15} joules

Quad: 1 exajoule or 10^{18} joules

TW: terrawatt, 10^{12} watts

APPENDIX 1 – RECOMMENDATIONS AND POTENTIAL ACTIONS

The following table provides a list of recommendations and potential actions designed to enable the European Union to:

- Maintain and improve its competitive position in biomass;
- Understand the impact of increasing indigenous biomass fuel production;
- Understand the impacts of importing biomass and biofuels on the economies of its trading partners and on European security of supply;
- Monitor the implications of policies to encourage biomass production and use.

Issue	Recommendation
General issues	
Biomass technologies	The EU is supporting a wide range of biomass use, including small-scale local heat, CHP, large scale stand alone plants, co-firing, biofuels and the use of waste feedstocks. This is generally accepted to be a good approach, and should enable the development of a range of relevant biomass technologies within the EU.
Support	Policies to support the development of biomass continue to be required. Many biomass plants are not competitive without support, primarily due to the high capital investment costs.
Integrated biomass chains	The lack of mature supply chains and a mature market for biomass fuels means that these have to be developed in parallel. It is important to have an integrated approach to the development of biomass chains in R&D and policy.
Skills	There is a need to develop skills at all levels of the biomass energy chain: • Harvesting and collection of biomass. These skills vary across Europe and training, study tours etc. would be useful for many regions. • Development of equipment for planting, harvesting, cultivation etc. is important for many types of biomass. • Procurement at SME and local authority level. These organisations are important for the development of local biomass heat and biomass heat clusters, but they find it difficult to understand which biomass plant to buy or even the potential of biomass for a variety of reasons, not least of all their unfamiliarity with biomass. Study tours and the availability of knowledgeable advice can provide a major difference.
Drivers	Government policy and energy price remain the most important drivers for biomass energy. Work at EU level must recognise this. Other important factors include: economics, carbon trading and the need to reduce carbon emissions, incomes for farmers, sustainability and security of supply.
Standards	Continued support is needed for the development of standard fuels to meet the needs of various scales of biomass use. This is important at all levels of biomass use. It provides customers with confidence in the fuels and enables equipment suppliers to develop appropriate plant.

Issue	Recommendation
Biomass supply - Indigenous	
Biodiversity and environmental impacts from plantations of energy crops	The cumulative effect of planting energy crops may result in effects on the local environment, including water supply and bio-diversity. The Commission should be aware of these and ensure policy is in place to prevent adverse effects from energy crops. This should take into account any best practice guidance that is already available at national level.
Land management	The EU has limited land available for biofuels and food crop production. Policy should be focused on the most effective management of this land. Projections indicate that there should be adequate land (see chapter 5). This must be monitored to ensure this is what happens in reality.
Price of biomass	The effect of increasing use of biomass on the price of biomass fuels needs to be clearly understood. UK experience in co-firing shows that rapid price rises can occur, but there is no record of prices at EU level. A regularly updated database of traded biomass price would be useful to enable industry to plan its use of biomass. Analysis (Chapter 5) indicates that trade in biomass fuels may have positive and negative effects on other commodities. This needs to be monitored.
Competition between biomass and biofuels	Once second generation biofuels are developed there may be some competition between the use of biomass for heat and biofuels production. The potential impact of this competition should be investigated. The drive for decreased greenhouse gas emissions should be placed at the centre of EU policy. The ranking of biomass use according to carbon emissions may be useful to achieving most effective carbon-savings.
Biomass supply - Imported	
Market consequences	The need for (the Commission) to undertake more detailed study of the market consequences (here and overseas) of biofuels and biomass imports from across the globe. This should include an assessment of the success of initiatives such as the UNCTAD initiative to encourage other countries' economies to learn from the successful experience of Brazil's bioethanol programme.
Sustainability of imported feedstocks	The Commission is working to develop sustainability standards for imported biofuels feedstocks. This analysis must include an assessment of the legal trade obligations that may affect any sustainability guidance provided. There may also be positive benefits for trading partners, which should also be used in any trade negotiations, particularly to ensure sustainability gains.
Trade statistics	There is no simple way to follow trade in biomass fuels. Information available in Eurostat is not linked to the use of the commodity traded. Data from different databases may be contradictory. The Commission should establish a methodology to monitor biomass trade more accurately. The best data are provided by the FAO Agricultural Outlook and Eurostat, but data are often contradictory.
Establishing markets	The use of imported biomass can be used to establish markets for biomass, but parallel development of indigenous fuels is important for security of supply and to keep fuel costs at economic levels.

Issue	Recommendation
Biomass use - Heat	
Security of supply	Heat is one of the most carbon effective and cost effective ways to use biomass. However, emphasis of policy and support is elsewhere, which means that heat is not competing with other biomass applications on a level playing field. The Commission needs to understand the effect of current support mechanisms on the use of biomass for heat and to review potential heat support mechanisms. It is our understanding that the Commission is already undertaking a review of heat support mechanisms. The main emphasis should be on local/regional biomass for local/regional heating demand.
Biomass use - Advanced conversion	
Advanced conversion	The use of advanced conversion technologies such as pyrolysis and gasification of wood is increasing in the EU. These technologies represent the most carbon efficient route to second generation biofuels and the most effective route to electricity generation. These technologies are particularly relevant to central and southern Europe, particularly for CHP application where the heat demand is not as high as in Northern Europe.
Biomass use – Co-firing	
Co-products from biofuels production	Encourage power stations to co-fire the co-products from biofuels production. There are issues with the classification of some of these products as wastes, which prevents their co-firing in most power stations.
Biomass use - Electricity generation	
Grid connection	There is a need to ensure that the European grid can take embedded biomass power generation, particularly for large numbers of small scale plant. Biomass electricity is a success story at present and can contribute further in the future.
Biomass use - Biofuels	
Policy for biofuels.	The EU is promoting biofuels as a security of supply issue. However, there is very little information on un-intended consequences of this support. It is important to understand the impact of growing energy crops for heat and power, on the cultivation of food etc. The policy for supporting biofuels should switch from a volume driven policy to a more sustainable approach, with commitment to greenhouse gas savings at its heart. First generation biofuels provide a current solution to transport needs. However, they are likely to be superseded by second generation biofuels and hydrogen in the longer term. In the meantime it is important that they do not stifle the development of energy crops for heat.
Co-products	Support the use of co-products from biofuels production at the biofuels plant or in local co-firing or standalone biomass plants.
Co-products	There is confusion over the status of co-products as wastes for the purposes of the Waste Incineration Directive. This is particularly relevant to the co-products from biodiesel produced from recovered vegetable oils. These are classed as wastes in some countries, but not as wastes in others.

Issue	Recommendation
Biomass use - Second generation biofuels and bio-refineries	
Second generation biofuels	The development of second generation biofuels is considered a priority in Europe, and this can be seen from the FP7. It is important to ensure that the results of R&D are rapidly transferred to commercial development. The development of consortia to ensure that R&D is transferred is important. Transfer of technology to the market place should be an important focus.
Advanced conversion technologies	Support advanced conversion technologies, particularly where they can be integrated into the “bio-refinery” concept.
The way forward	Support the comparative analysis of options for bio-refineries, including the processing of wastes as part of the development of bio-refineries.
Role of multi-nationals	Actions to encourage large multi-nationals to invest in biofuel development in Europe. Some motor car manufacturers are doing this, but some large petro-chemical companies have chosen to invest in R&D in the USA only.
International co-operation	R&D on bio-refineries and second generation biofuels is expensive and could benefit from international collaboration in some areas, particularly with North America. The USA have a multi-million $ programme on second generation biofuels and bio-refineries.
Infrastructure	
Biomass transport and storage	Biomass must be stored in an appropriate manner which allows it to remain dry and not degrade or overheat. Appropriate guidance is required for its storage and transport.
Planting and harvesting	The planting of energy crops requires the development of stock for planting and the availability of planting machinery. A “push for biomass” may be detrimental as Europe does not have adequate infrastructure to plant large amounts of short rotation coppice or energy grasses in a short time span. This infrastructure must be developed before large amounts of energy crops can be produced.
Transport	Biomass is bulky and cannot easily be transported over long distances. Infrastructure for biomass transport and storage at depots must be considered. Ports currently have limited capacity for the import of large quantities of biomass and storage and processing this biomass at the port. This situation is developing rapidly as biofuels plants are built at ports to take advantage of local indigenous feedstock and imported biomass. At some ports there are multiple proposals for biodiesel and bioethanol plants. The need to develop infrastructure at these ports to handle the demands from biomass plants should be considered.