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## Bioenergy in Europe

Opportunities and Barriers



Bioenergy NoE



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## Abstract

The aim of this publication is to give a comprehensive overview of the opportunities for and barriers to bioenergy development in Europe. The study carried out within the Bioenergy Network of Excellence “Overcoming Barriers to Bioenergy” (Bioenergy NoE) covers EU policy issues and their implementation in Europe, biomass availability and technology development aspects, and RTD goals to overcome the barriers to bioenergy development.

Important European targets have been set for 2010, such as the White Paper targets of doubling the share of renewables to 12%, and tripling the use of biomass to 135 Mtoe (5.7 EJ) compared to 1997, the RES-E Directive target of a 21% share of green electricity, and the Biofuels Directive target of 5.75% of transport fuels to be supplied with biofuels. Recently, a Biomass Action Plan was launched. Further, a biofuels target of 20% substitution by 2020 has been proposed, and the maximum of 35% for the share of MSW to be landfilled has been set for the year 2016. EU policies and regulations are important drivers for bioenergy development in the EU countries.

In Europe, the use of biomass and wastes is presently about 2.9 EJ/a (69 Mtoe). By 2050, it is estimated that biomass and waste utilisation could rise to anywhere from 9.0 to 13.5 EJ/a (215-320 Mtoe). According to the Biomass Action Plan the measures could lead to the use of about 150 Mtoe (6.3 EJ) in 2010 or soon after. There are sufficient domestic resources to meet the EU targets set for the year 2010 but if more stringent goals are set for bioenergy in the future, it will be challenging to find sufficient resources in Europe and biomass imports from outside the EU will be necessary.

The barrier analysis carried out within the Bioenergy NoE resulted in a wide variety of non-technical and technical barriers. Overall, non-technical barriers dominate, with economic barriers being the most prominent. However, there is no single barrier that appears as the most important; it is the interaction of many barriers that impedes the rapid expansion of bioenergy use. Even omitting the economic barriers and biomass availability constraints technical barriers are critical in introducing novel production and utilization technology. Barriers defined for feedstock production, heat and power

technologies, liquid biofuels technology, and waste to energy areas are presented. R&D work is suggested to overcome a wide variety of technical barriers related to individual process steps within production and utilization schemes.

The potential for significant biomass utilisation in Europe is influenced by EU and national policies and regulations, emissions trading, availability of biomass and the logistics of feedstock supply, the development of technologies, and economic and social issues. The CAP reform in 2003 substantially influences bioenergy development.

A prerequisite for rapid implementation of new bioenergy solutions in the European market is the application of existing infrastructures in the conventional biomass production and energy sectors. Within the Bioenergy NoE, there is agreement that a considerable increase in the use of bioenergy cannot take place without industry support. Therefore the intended increase in the use of biomass can only be realised through new business opportunities.

Integration of capacities in bioenergy R&D is needed to reach the EU White Paper goals. New technologies and business concepts are needed, and Bioenergy NoE has to respond to the demands of the European Commission and industry. Integrating bioenergy production with forest industry, electricity and heat, waste recycling, liquid biofuel production and/or chemical industry improves competitiveness. Biorefineries and polygeneration of multiple products are widely seen as an important approach to efficiently utilise limited raw material resources.

## Preface

The present study was carried out within the Network of Excellence “Overcoming Barriers to Bioenergy” (Bioenergy NoE) during the year 2005. Sponsored by the EC DG Research (SES6-CT-2003-502788), Bioenergy NoE is a partnership of eight leading bioenergy institutes that are integrating their expertise and activities to foster excellence in European bioenergy RD&D. The goal is to build a Virtual Bioenergy Research and Development Centre that exploits the capabilities of the partners in building a thriving and successful bioenergy sector in Europe. The institutes in Bioenergy NoE are VTT Technical Research Centre of Finland (VTT) coordinating the Network, Joanneum Research (JR), Energy Research Centre of the Netherlands (ECN), Forschungszentrum Karlsruhe (FZK), International Institute for Industrial Environmental Economics (IIIEE), Aston University (AU), EC Baltic Renewable Energy Centre (EC BREC) and National Institute for Agricultural Research (INRA).

This publication was compiled by Coordinator Kai Sipilä, Leena Fagernäs, Allan Johansson, Carl Wilén and Yrjö Solantausta of the VTT Bioenergy NoE management team with the support of the Work Package (WP) Leaders: Satu Helynen and Tuula Mäkinen of VTT (WP1), Erik Daugherty and Reinhard Padinger of JR (WP2), Herman den Uil of ECN (WP3), Jürgen Vehlow of FZK (WP4), Tomas Käberger of IIIEE (WP5), Magdalena Rogulska of EC BREC (WP6), Ghislain Gosse of INRA (WP7) and Tony Bridgwater of AU (WP SEA). In addition, the authors are grateful to all the members of the Work Packages. Special thanks are due to Crystal Luxmore (AU) for revising the English language. Further, the Board Members including Coordinator Kai Sipilä (VTT), Josef Spitzer (JR), Tony Bridgwater (AU), Hubert Veringa (ECN), Jürgen Vehlow (FZK), Thomas B. Johansson (IIIEE), Grzegorz Wisniewski (EC BREC), and Ghislain Gosse (INRA) are gratefully acknowledged.

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Authors

# Contents

Abstract.....	3
Preface .....	5
List of abbreviations and acronyms.....	8
1. Introduction.....	12
1.1 Renewables and bioenergy in Europe .....	12
1.2 Bioenergy NoE .....	14
2. Policy issues – Which are the real drivers? .....	17
2.1 The Kyoto Protocol and its mechanisms .....	17
2.2 EU policies and directives on renewables.....	18
2.2.1 White Paper on renewable sources of energy .....	19
2.2.2 Green Paper on security of energy supply .....	21
2.2.3 Promotion of electricity produced from renewable energy sources.....	22
2.2.4 European Emissions Trading Scheme.....	23
2.2.5 Promotion of combined heat and power .....	26
2.2.6 Promotion of biofuels for transport.....	27
2.2.7 Biomass Action Plan .....	28
2.2.8 Waste management .....	29
2.3 Common Agricultural Policy – CAP.....	31
2.4 Policies as drivers for or barriers to bioenergy.....	33
2.4.1 Policies as drivers for bioenergy .....	33
2.4.2 Policies as barriers to bioenergy .....	34
3. Implementation and state of bioenergy in different EU countries.....	38
3.1 Implementation of bioenergy policies .....	38
3.1.1 The old EU15 Member States .....	38
3.1.2 The ten New EU Member States.....	42
3.1.3 Waste management in the EU25 countries .....	43
3.2 Current state and future prospects in bioenergy utilisation.....	45
3.2.1 The old EU15 Member States .....	45
3.2.2 The ten New EU Member States.....	50
3.2.3 Main conclusions .....	52
4. Biomass availability.....	54
4.1 Global potential of biomass for energy .....	55
4.2 European potential of biomass for energy.....	59



4.2.1	Analysis of potential biomass supply quantities .....	59
4.2.2	Estimation of energy wood potential .....	65
4.2.3	Biomass potential in the Biomass Action Plan .....	68
4.3	Barriers in land-use change and biomass resources .....	70
4.4	Conclusions of the potential biomass resources .....	72
5.	Bioenergy technologies and related barriers.....	74
5.1	Feedstock production.....	74
5.1.1	Production technology of forest chips.....	74
5.1.2	Agricultural crops for energy .....	77
5.2	Heat and power technologies.....	79
5.2.1	Current technologies and visions for the future .....	79
5.2.2	Barriers concerning heat and power technologies .....	83
5.3	Liquid biofuels for transport.....	85
5.3.1	Overview of biofuel production technologies.....	85
5.3.2	Barriers to liquid biofuels.....	87
5.3.3	RTD goals to liquid biofuels .....	89
5.4	Waste to energy .....	90
5.4.1	Survey on MSW in Bioenergy NoE member countries .....	90
5.4.2	Barriers and RTD goals to waste to energy .....	93
6.	Significant biomass utilisation in Europe – Wishful thinking or reality?.....	96
7.	Summary .....	102
	References .....	108

## List of abbreviations and acronyms

AU	Aston University
Bioenergy NoE	Network of Excellence “Overcoming Barriers to Bioenergy”
BG	Bulgaria
°C	Celsius
CAP	European Common Agriculture Policy
CDM	Clean development mechanism
CFB	Circulating fluidised bed
CHP	Combined heat and power
CO <sub>2</sub>	Carbon dioxide
DH	District heat
DME	Dimethyl ether
EC	European Commission
EC BREC	EC Baltic Renewable Energy Centre
ECCP	European Climate Change Programme
ECN	Energy Research Centre of the Netherlands
EEC	European Economic Community
EJ	Exajoule, 10 <sup>18</sup> J
EN	European norm
ETBE	Ethyl tert butyl ether
ETS	Emissions Trading Scheme
EU	The European Union

EU10+2	New Member States except Malta and Cyprus, and two candidate countries Bulgaria and Romania
EU15	Member States of the European Union before 1.5.2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, the United Kingdom
EU25	Member States of the European Union 1.5.2004: EU15 and Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia
EU30	EU25 and Bulgaria, Romania, Turkey, Norway and Switzerland
Eurostat	Statistical Office of the European Communities
FBC	Fluidised bed combustion
BFB	Bubbling fluidised bed
F-T	Fischer-Tropsch
FZK	Forschungszentrum Karlsruhe
GIS	Geographic Information Systems
GJ	Gigajoule
Gtoe	Gigatonne of oil equivalent
ha	Hectare
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IIIEE	International Institute for Industrial Environmental Economics
IGCC	Integrated Gasification Combined Cycle
INRA	National Institute for Agricultural Research
JI	Joint implementation
JR	Joanneum Research

kg	Kilogram
ktoe	Kilotonne of oil equivalent
kW	Kilowatt
Metla	The Finnish Forest Research Institute
Mg	Megagram
MSW	Municipal solid waste
MTBE	Methyl tert butyl ether
Mtoe	Million tonnes of oil equivalent
MW <sub>e</sub>	Megawatt, electric
MW <sub>th</sub>	Megawatt, thermal
NGO	Non-governmental organisation
NO <sub>x</sub>	Nitrogen oxides
OECD	Organisation for Economic Co-operation and Development
PC boiler	Pulverized coal-based boiler
PJ	Petajoule, 10 <sup>15</sup> J
PPF	Paper and Plastic Fraction
R&D	Research and development
RD&D	Research, development and demonstration
RDF	Refuse derived fuel
REF	Recovered fuel
RES	Renewable energy sources
RES-E	Directive on the promotion of electricity produced from renewable energy sources

RIGES	The Renewables-Intensive Global Energy Scenario
RME	Rapeseed methyl ester
RO	Romania
RTD	Research and technological development
SEA	Spreading of excellence
SRF	Solid recovered fuel
TERES II	The European Renewable Energy Study
TGC	Tradable green certificate
UK	The United Kingdom
UN	The United Nations
UNCED	The United Nations Conference on Environment and Development
UNFCCC	The United Nations Framework Convention on Climate Change
VTT	Technical Research Centre of Finland
WEC	The World Energy Council
WP	Work Package
WtE	Waste to energy

# 1. Introduction

## 1.1 Renewables and bioenergy in Europe

Greenhouse gas emissions and climate change are currently seen as the most crucial environmental problems. Combating climate change is one of the main commitments under the sustainable development strategy of the European Union. The effects of climate change are already beginning to show and are expected to become stronger as temperatures rise. Over the 20<sup>th</sup> century the global mean temperature rose by about 0.6 °C and the mean temperature in Europe by more than 0.9 °C (1). Computer climate models estimate that the average global temperature will rise by 1.4 °C to 5.8 °C during this century (2).

The dependence of the EU on energy imports is already 50% and if no action is taken, it is expected to rise over the coming years (3). To decrease that dependence, the use of renewable energy sources (RES) constitutes an important opportunity in a strategy for sustainable energy production in Europe. The RES are currently unevenly and insufficiently exploited in the EU. Although many of them are abundantly available, and the real economic potential is considerable, the use of RES, which was 103 Mtoe (4 320 PJ) in 2003, comprises only 6% of the EU's overall gross inland energy consumption (3, 4).

The main renewables are biomass, wind energy, solar energy, hydro energy, and geothermal energy. The share of these sectors in the primary energy production of the 25 EU Member States (EU25) during the years 1990–2003 is presented in Figure 1. The production of primary energy in the EU25 in 2003 was 885 Mtoe (37.2 EJ) (4, 5). The respective production of biomass and wastes was 68 Mtoe (2 850 PJ), which comprised 66% of all RES primary energy requirements of the EU. Bioenergy contributed 9% of RES electricity and about 98% of RES heat (6).

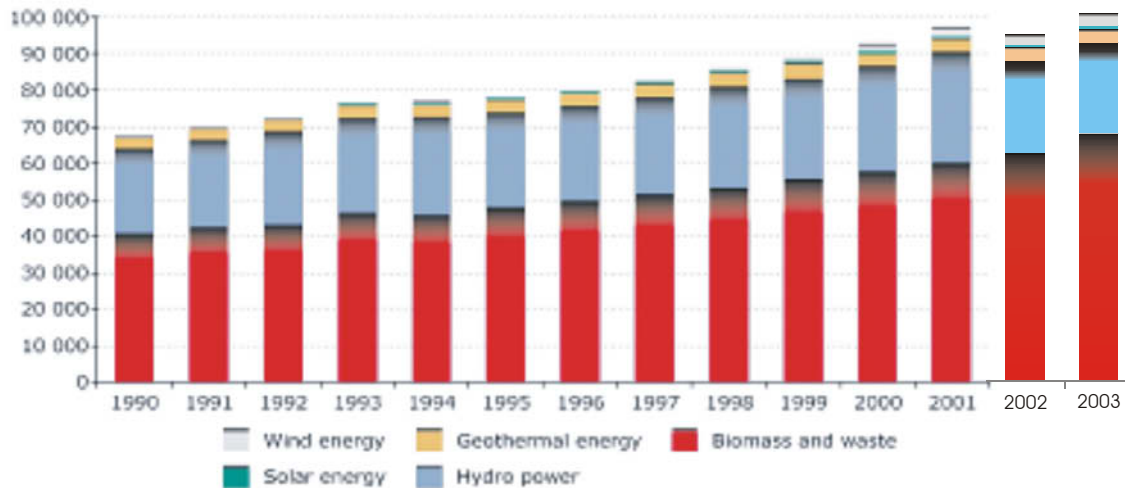


Figure 1. Share of different renewable energy sources in the primary energy production (in ktoe) in the EU25 during the years 1990–2003 (modified from the references 4 and 5).

Biomass is an abundant renewable resource, with long traditions of use in most civilisations. It is the only renewable energy resource that can easily be converted to satisfy all energy sectors – heat, power and liquid fuels for transport. It is also the only way that solar energy can be stored in large quantities. Biomass production is part of the natural eco-cycle and virtually all over the world there is long term experience of large scale biomass production, as well as its use for energy purposes.

According to *the White Paper on renewable energies* (3), biomass includes, in addition to woody biomass and the residues of the wood processing industry, energy crops, agricultural residues and agro-food effluents, manures as well as the organic fraction of municipal solid waste or source-separated household waste and sewage sludge. Woody biomass is defined as either a by-product of other forestry activities or dedicated energy plantations such as short rotation coppice or willow. Woody biomass is usually converted by combustion or gasification into heat and electricity. Energy crops are grown to produce liquid biofuels, such as rapeseed or sunflower for biodiesel and wheat or sugar beet for bioethanol. The organic fraction of industrial and urban waste can be used as biogas via anaerobic fermentation in dedicated reactors or landfills. Production units of bioenergy range from small scale to large scale. The composition of energy production from biomass and wastes in the EU25 in 2002 is presented in Figure 2.

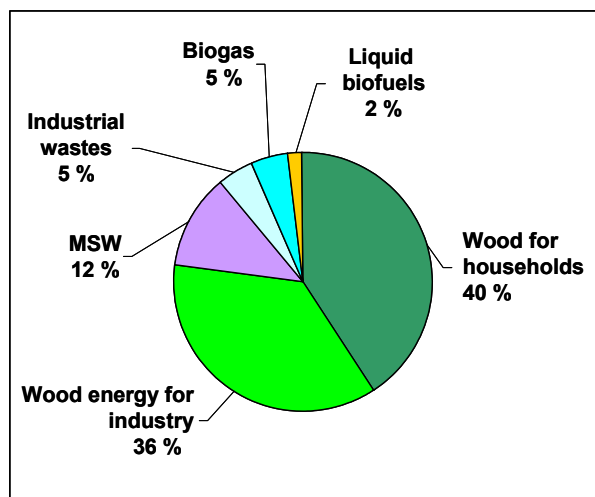


Figure 2. The composition of energy production from biomass and wastes (62 Mtoe, 2600 PJ) in the EU25 in 2002 (modified from the reference 4).

Amid increasing concern over environmental and sustainable development issues it is not surprising that bioenergy has attracted so much political attention. Possibilities to increase the use of bioenergy include utilisation and increase of the current resource-base, setting of policies and regulations, and technology development, all of which can act as drivers for the promotion of bioenergy. But there are, however, several barriers to bioenergy utilisation. These can, among others, be local availability of biomass, legislation and policy regulations, socio-economic issues, and lack of appropriate technology. To increase the use of bioenergy it is necessary to identify the barriers to bioenergy development and to outline how to overcome them.

This publication aims to give a comprehensive overview of the opportunities for and barriers to bioenergy development in Europe, considering EU policy issues, biomass availability and technology development, and to define possible RTD goals to overcome these barriers. The overview was compiled within the Network of Excellence “Overcoming Barriers to Bioenergy”.

## 1.2 Bioenergy NoE

The Network of Excellence “Overcoming Barriers to Bioenergy” (Bioenergy NoE) was launched at the beginning of 2004 as a new research and technological development (RTD) instrument in the 6<sup>th</sup> Framework programme of the European Commission. Bioenergy NoE is a partnership of eight leading bioenergy institutes that are integrating their expertise and activities to foster excellence in European bioenergy (7). The bioenergy institutes are VTT Technical Research Centre of Finland (VTT) coordinating the Network, Joanneum Research (JR), Energy Research Centre of the Netherlands



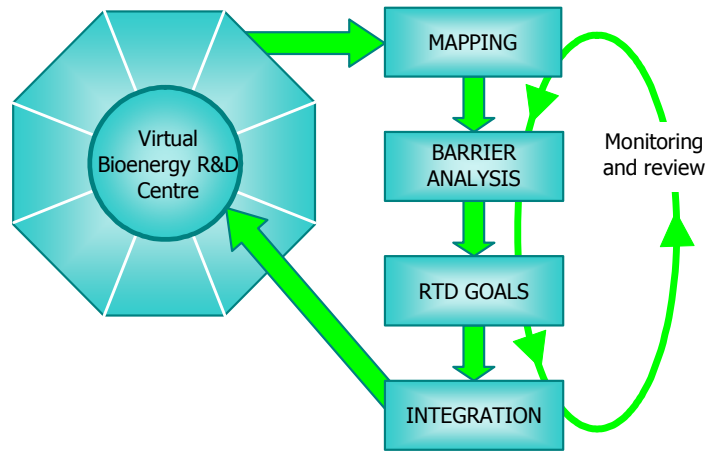
(ECN), Forschungszentrum Karlsruhe (FZK), International Institute for Industrial Environmental Economics (IIIEE), Aston University (AU), EC Baltic Renewable Energy Centre (EC BREC) and National Institute for Agricultural Research (INRA). The primary objective of Bioenergy NoE is to integrate partner activities in such a way that a deep and durable integration of the research will be developed during the project life and will continue beyond the period of Community financial support. The goal is to build a Virtual Bioenergy Research and Development Centre that exploits the capabilities of the partners in building a thriving and successful bioenergy sector in Europe.

Bioenergy NoE covers the entire field of bioenergy. To overcome the barriers to bioenergy, the entire chain from resource to end-use markets has to be considered with including all the competing alternatives. The work was initiated in the Work Packages (WP) presented in Table 1. This initial WP structure was designed to enable Bioenergy NoE to examine a broad range of barriers to bioenergy. It has now in 2006 been replaced with a new WP structure that is designed to overcome selected barriers based on business opportunities.

*Table 1. The initial Work Packages of the Bioenergy NoE.*

<b>WP</b>	<b>Work Package Title</b>
IA-1	Forest industry, Large scale systems
IA-2	Climate issues, Small scale applications
IA-3	Biofuels for transport
IA-4	Biogenic waste to energy
IA-5	Environment and socio-economics
IA-6	Land use change and biomass resources
IA-7	Agro-biomass resources
IA-8	Integration planning and periodic evaluation
SEA	Spreading of excellence
JER	Jointly executed research
MA	Co-ordination

The first phase of the project began with the mapping of partners' activities, which together with the subsequent barrier analysis and definitions of RTD goals provides the basis for final integration to jointly executed research activities (Figure 3). Barriers related to technology issues, socio-economic issues, environmental issues and feedstock availability have been identified.



*Figure 3. A map of the processes involved in Bioenergy NoE that will lead to a Virtual Bioenergy R&D Centre.*

## 2. Policy issues – Which are the real drivers?

In an effort to formulate a strategy towards sustainable energy production for Europe and to diminish strategic dependence on imported fuels, in particular oil for transport, several political initiatives have been taken within the European Commission and the individual member countries.

The targets of the energy policies of the EU are: meeting the Kyoto objectives, doubling the share of renewable energies of gross inland energy production, improving energy efficiency, and maintaining security of supply. To achieve these targets the EU has adopted different policies and measures: White Paper on energy policy, White Paper on RES & Action Plan, Green Paper on security of supply, directives on renewable electricity, emissions trading, liquid biofuels, cogeneration, and buildings, and various support programmes.

### 2.1 The Kyoto Protocol and its mechanisms

*The United Nations Framework Convention on Climate Change (UNFCCC)* and its *Kyoto Protocol* provide the international framework for combating climate change (1, 8–9). The UNFCCC was adopted in May 1992 and came into force in March 1994. It obliges all its signatories to establish national programmes for reducing greenhouse gas (GHG) emissions and to submit regular reports, and requires the industrialised signatory countries, but not developing countries, to stabilise their GHG emissions at 1990 levels by the year 2000. In the Third Conference of the Parties to the UNFCCC in December 1997, governments took a step further and adopted a protocol to the UNFCCC in Kyoto. The Kyoto Protocol, which was adopted by consensus, sets legally binding limits on GHG emissions from industrialised countries and envisages innovative market-based implementation mechanisms aimed at keeping the cost of curbing emissions low.

Under the Kyoto Protocol, the developed countries commit themselves to reducing their collective emissions of six key GHGs by at least 5% (8). Each country's emissions target must be achieved by the period 2008–2012. It will be calculated as an average over the five years. “Demonstrable progress” towards meeting the target must be made by 2005. Cuts in the three most important gases – carbon dioxide, methane, and nitrous oxide – will be measured against a base year of 1990. Cuts in three long-lived industrial gases – hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride – can be measured against either a 1990 or 1995 baseline.

The Protocol was opened for signature for one year starting in March 1998 (8). It was decided to enter into force 90 days after it has been ratified by at least 55 Parties to the Convention, including developed countries representing at least 55% of the total 1990 carbon dioxide emissions from this group. The EU and its Member States ratified the Kyoto Protocol in May 2002. Russia's ratification in November 2004 allowed the 55% threshold to be met and started the countdown to the Protocol's entry into force on the 16<sup>th</sup> of February in 2005. The Protocol has been ratified to date by 140 countries plus the European Community. Only three countries with targets under the Protocol, i.e. Australia, Monaco and the United States, have not ratified it.

Under the Protocol, the EU has committed itself to reducing its GHG emissions by 8% during the first commitment period of 2008–2012. This target is shared between the 15 EU Member States (EU15) of the EU's ratification moment in May 2002 under a legally binding burden-sharing agreement (10). Of the ten New Member States that acceded in May 2004, eight have individual reduction targets of 6% or 8%. Only Cyprus and Malta are not included in *Annex I to the Convention* and thus do not have a target. In February 2005, the Commission adopted a Communication (11) setting out the key elements of the EU's post-2012 strategy.

The Kyoto Protocol envisages three market-based mechanisms: *Emissions Trading*, *Joint Implementation (JI)* and the *Clean Development Mechanism (CDM)* (1). These allow industrialised countries to meet their targets through trading emission allowances between themselves and gaining credits for emission-curbing projects abroad. JI refers to projects in countries that have emission targets whereas the CDM refers to projects in developing countries with no targets.

With the effective implementation of existing and additional policies and measures, as well as the use of the Kyoto mechanisms, the EU is projected to meet its Kyoto target. The backbone of the Commission's effort to implement the Protocol is the *European Climate Change Programme (ECCP)*, which was launched in March 2000 (1).

## **2.2 EU policies and directives on renewables**

As a first step towards a strategy for renewable energy the Commission adopted a *Green Paper* in November 1996. A broad public debate took place during the early part of 1997 focusing on the type and nature of priority measures that could be undertaken at Community and Member States' levels (3). In the Green Paper the Commission sought views on the setting of an indicative objective of 12% for the contribution by RES to the European Union's gross inland energy consumption by 2010. Due to the positive response received, in November 1997 the European Commission adopted the

communication *Energy for the Future: Renewable Sources of Energy, a White Paper for a Community Strategy and Action Plan* (3). In November 2000 the Commission adopted a *Green Paper (12) on supply security*, in order to launch a debate on the geopolitical, economic and environmental stakes involved in securing the EU's energy supply.

The Council and the European Parliament have adopted several initiatives proposed by the Commission. These include legislation to promote renewable sources of electricity production and biofuels in road transport, legislation on the energy efficiency of buildings, the directive on establishing a scheme for greenhouse gas emission allowance trading with the directive linking JI/CDM to it, and a directive to promote combined heat and power generation.

### **2.2.1 White Paper on renewable sources of energy**

In November 1997 the European Commission adopted the communication *Energy for the Future: Renewable Sources of Energy, a White Paper for a Community Strategy and Action Plan* (3). The purpose of the White Paper was to promote RES in order to help achieve the overall energy policy objectives: security of supply, competitiveness, and to improve and reinforce environmental protection and sustainable development. In order to reach these goals the White Paper proposes to double the contribution of RES to the EU's gross inland energy consumption from 6% to 12% by 2010. The White Paper also contains a comprehensive Strategy and Action Plan to reach this objective.

A policy for the promotion of renewables requires across-the-board initiatives covering a wide range of policies: energy, environment, employment, taxation, competition, research, technological development and demonstration, agriculture and external relations policies (3). A central aim will be to ensure that the need to promote these energy sources is recognised in new policy initiatives, as well as in full implementation of existing policies, in all of the above areas. In fact, a comprehensive action plan is required to ensure the necessary co-ordination and consistency in implementing these policies at Community, national and local levels.

The overall EU target of doubling the share of renewables implies that the Member States have to encourage the increase of RES according to their own potential (3). They need to set individual objectives within the wider framework, and develop national strategies to achieve them. Some Member States had already introduced some measures to support RES and related programmes. Some have set up plans and targets aimed at developing RES in the medium and long term. *Annex III of the White Paper* (3) outlines the plans and actions of Member States for renewables development. The share of RES

in the gross inland energy consumption differs widely between the Member States, from less than 1% to over 25%.

The Community Strategy is the basic framework for action for achieving the indicative objective of the 12% share of renewables by 2010. In order to implement the Strategy, concrete measures are proposed in *an Action Plan, Annex I to the White Paper*. The Action Plan aims at providing fair market opportunities for renewable energies without excessive financial burdens. Priority internal market measures aimed at overcoming obstacles and redressing the balance in favour of renewables include fair access for renewables to the electricity market; fiscal and finance measures; new bioenergy initiatives for transport, heat and electricity; and improving the impact of building regulations on town and country planning. Other main features of the Action Plan are reinforcing community policies, strengthening co-operation between the Member States, and support measures.

The *Annex II of the White Paper* (3) outlines a set of indicative estimated contributions for each renewable energy source as well as for each market sector as a projection of one way in which the overall desired growth of RES can be achieved. The achievement clearly depends on the success and growth of the various individual renewable technologies. The main contribution of RES growth is estimated to be derived from biomass. A target was set to triple the use of biomass from the amount of 45 Mtoe (1 890 PJ) in 1997 to 135 Mtoe (5 660 PJ) in 2010. This would mean an additional biomass amount of 90 Mtoe (3 770 PJ), which will be equivalent to 8.5% of the projected total energy consumption in that year. This additional bioenergy use is derived from agricultural, forest and forest industry residues, waste streams as well as from new energy crops.

As for solid residues, a huge, unexploited potential in the form of wood and agricultural residues is identified (3). It is estimated that 30 Mtoe (1 260 PJ) of it can be mobilised annually by 2010 for power and the heating and industrial process heat market. By exploiting biogas from livestock production, agro-industrial effluents, sewage treatment and landfill it is estimated it can contribute 15 Mtoe (630 PJ) by 2010.

The contribution from energy crops is estimated at 45 Mtoe (1 890 PJ) by 2010 (3). Of this 18 Mtoe (760 PJ) is in the form of liquid biofuels. This includes liquid biofuels from non-energy crops such as wood residues, used vegetable oils, or biogas used as motor fuel. The remaining 27 Mtoe (1 130 PJ) of energy crops is estimated for biomass for heat and/or power. The paper sets out that a maximum of 10 million hectares, or 7.1%, of the agricultural area is sustainable for biomass crop production. Hence the choice of crop species for liquid biofuels needs to be limited to the most productive crops.

In order to assist a real take off of renewables for large-scale penetration, make progress towards the objective of doubling the EU RES share by 2010, and ensure a co-ordinated approach throughout the Community, in 1997 the Commission proposed a campaign for take off for renewables.

A Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions on the implementation of the Community Strategy and Action Plan on RES is produced every two years in order to evaluate the success of the strategy and recommend a revised direction and/or new actions if sufficient progress in the penetration of renewables does not appear to be made (3).

The implementation of the Community Strategy and Action Plan on Renewable Energy Sources in 1998–2000 and the share of renewable energy in the EU are presented in the Communications from the Commission (13, 14). The implementation of the White Paper strategies and the RES and bioenergy growth in different EU Member States will be dealt with in Chapter 3.

### **2.2.2 Green Paper on security of energy supply**

In November 2000 the Commission adopted a *Green Paper (12) on supply security*. The Green Paper is the response to Europe's growing future energy dependence. The EU currently imports some 50% of its requirements, a figure that will rise to about 70% in 2030, with an even greater dependence on oil and gas, if current trends persist. The EU's demand for energy has been growing at a rate of 1–2% a year since 1986.

Security of supply does not try to maximise energy self-sufficiency or to minimise dependence, but aims to reduce the risks linked to such dependence (12). The objectives to be pursued are those that balance and diversify the various sources of supply, by product and by geographical region. The EU has very limited scope to influence energy supply conditions; it is essentially on the demand side that the EU can intervene, mainly by promoting energy saving in buildings and the transport sector.

Tomorrow's priorities will be controlling the growth of demand and managing the dependence on supply. Curbing the growth in demand will be aided by completing the internal market, energy taxation, energy-saving and diversification plans, and dissemination of new technologies. While improved and durable energy supply security for the EU depends primarily on the adoption of policies controlling demand, a responsible policy for managing dependence must also consider supply. Managing will

be done by development of less polluting energy sources, maintaining access to resources, and ensuring external supplies.

The Green Paper poses 13 questions as a framework for the general debate. These triggered a number of responses and reactions both from Member States – including parliamentary and regional assemblies – and from companies, consumer associations and NGOs (15). The conclusion was that there is virtually unanimous agreement on the strategic axis of demand management: energy consumption must be guided and steered. The conclusions of the Barcelona European Council in March 2002, stressing in particular the need for better energy efficiency by 2010 and rapid adoption of energy taxation proposals, clearly give political backing to this priority. Without waiting for the debate to end, the Commission made some proposals along these lines involving actual legislation.

With energy consumption on the rise and the EU becoming increasingly dependent on external sources of energy, Europe must reduce its production of GHGs to respect its commitments under the Kyoto Protocol. In response, the Green Paper proposed a strategy to diversify energy imports, to reduce energy consumption through improved energy efficiency, and to increase the use of RES.

Later, in June 2005, the Commission adopted a *Green Paper on Energy Efficiency* (16) that seeks to put energy savings higher on the agenda. The Green Paper lists a number of options to save 20% of energy consumption by 2020 in a cost effective way. The energy efficiency initiative will help Europe achieve two fundamental goals of the Lisbon Strategy: creating more growth and better jobs. In addition, it will help Europe meet its Kyoto commitments.

### **2.2.3 Promotion of electricity produced from renewable energy sources**

*The Directive 2001/77/EC of the European Parliament and of the Council on the promotion of electricity produced from renewable energy sources in the internal electricity market* (17), known as “*the RES-E Directive*”, was adopted in 2001.

The purpose of the RES-E Directive is to promote an increase in the contribution of RES to electricity production in the internal market for electricity and to create a basis for a future Community framework thereof (17). The substance of the directive covers the following areas: setting national targets for the consumption of green electricity, evaluating national support schemes for green electricity producers, taking measures necessary to ensure transparent rules and fair treatment for RES producers seeking connection to the national electricity grid, establishing mutually recognised guarantees of origin for green electricity, and streamlining the administrative procedures for new producers (18).



The targets of the directive are to establish a framework to increase the share of green electricity from 14% to 22% of gross electricity consumption in the EU15 by 2010, to help to double the share of renewable energy from 6% to 12% of gross inland energy consumption in Europe by 2010, and to further compliance with the commitments made by the EU under the Kyoto Protocol on reducing GHG emissions (19). The 22% target set initially for the EU15 became 21% for the enlarged Union of EU25. In 2001, 15% of the electricity that Europe consumed came from RES (18).

The Member States were required to set their own indicative targets for the consumption of electricity produced from RES for a 10-year period, taking account of the European target, and ensuring compatibility with national commitments under the Kyoto Protocol (18). By creating national targets, the directive gives a quantitative framework within which each Member State can plan and implement the most appropriate measures for their own situation. Every two years, Member States will publish a report which includes an analysis of success in meeting the national indicative targets.

At present, the Member States operate various support schemes for RES: feed-in tariffs, tradable green certificates, fiscal and financial measures, and investment support (18). The directive requires Member States to ensure guaranteed access for green electricity producers to the grid. Grid-connection costs and transmission and distribution fees cannot disadvantage renewable energy sources. To support the trade in green electricity, the directive requires a guarantee of origin for electricity from RES.

The RES-E Directive provides a framework of targets and support for the growth of green electricity's share in consumption since 2001 (18). In 2004, the European Commission produced an assessment of Member States' progress towards the renewable energy targets and the implications for Europe (14). To accompany this communication, a document with the 25 Member States' profiles and their RES situation was issued (20). The Commission publishes its conclusions in bi-annually. The Commission will also present a summary report on the implementation of the directive to the European Parliament and the Council, no later than December 2005 and every five years thereafter.

#### **2.2.4 European Emissions Trading Scheme**

*The Directive on establishing a scheme for greenhouse gas emissions allowance trading, the Emissions Trading Directive (21) was adopted in 2003 to implement the EU's own internal emission trading scheme.*

The *European Union Emissions Trading Scheme (EU ETS)*, which started in January 2005, covers all 25 EU Member States and is the first multi-national emissions trading scheme in the world. The first period comprises 2005–2007. Under the scheme, EU Member States set limits on CO<sub>2</sub> emissions from energy-intensive companies by issuing allowances that determine how much CO<sub>2</sub> these companies are allowed to emit. Companies covered comprise around 12 000 steel factories, power plants with thermal capacity greater than 20 MW, oil refineries, paper mills, and glass and cement installations. Companies that emit less than the number of allowances they received can sell the surplus to companies that go over their limit or for which emissions reduction measures are too expensive in comparison with what the allowances will cost. Any company may also increase its emissions above the level of its allowances by acquiring more allowances from the market. It is estimated that the companies currently participating in the scheme account for around 45% of the EU's total CO<sub>2</sub> emissions.

In October 2004 the EU adopted an amendment to the Emissions Trading Directive, the so-called "*Linking Directive*" (22). This Directive allows European companies covered by the EU ETS to use credits from CDM projects (from January 2005) and from JI projects (from January 2008) towards meeting their commitments under the trading scheme. The directive excludes nuclear projects, in line with the Kyoto Protocol's rules, as well as carbon sinks. Carbon sinks – planting forests to soak up CO<sub>2</sub> – have been a contentious issue at the UN level because they do not bring technology transfer, they are inherently temporary and reversible, and uncertainty remains about the effects of emission removal by carbon sinks.

The EU ETS is expected to boost utilisation of bioenergy in all market sectors and to cause a major change in the operating environment, especially for energy production and for the energy-intensive industry.

Each country has allocated initial emission allowances to plants covered by the system in their National Allocation Plans. In most countries, the emission allowances allocated to companies for the first period are somewhat above what would be required for linearly achieving the Kyoto targets in the following period. Several EU countries have chosen to distribute initial allocations based on grandfathering, i.e. on emissions during the years 1998–2003 or during a shorter recent period. Some countries have also used a benchmarking criteria or a principle of Best Available Technology, especially for new plants. In most countries, industry has received initial emission allowances corresponding to their planned increases in production capacity, whereas for condensing power generation, only a part of initial emission allowances corresponding to their expected emissions has been allocated. In most countries, combined heat and power production has received most of their expected need of initial emission allowances from

the state. The second period of 2008–2012 is estimated to cover the same sectors as during the first period with reduced amounts of emission allowances allocated.

At present there is a concrete risk that the ETS will generate increased energy costs to consumers without corresponding investments towards low-emission generation capacity (23). Energy-intensive industries in Europe have been particularly concerned about the impacts of emissions trading on electricity prices and on their competitiveness. Various energy-intensive industries are in quite different relative positions with regard to emissions trading, depending on their structures of electricity supply, access to alternative energy sources and on the amounts of initial emission permits allocated to them in different EU countries.

The prices of allowances have now reached a higher level than estimated. Because the first period has modest requirements for emission reduction in most countries, the estimated price on emission allowances was 5–10 €/tonne. The price of 5 €/tonne means a 10% increase on the Nordic price market of electricity. In the summer 2005 the price level reached almost 30 €/tonne and remained over 20 €/tonne the rest of the year. The price of allowances has a significant effect on the competitiveness of different fuels. The fuel prices in Finland including different CO<sub>2</sub> prices are presented in Figure 4. Due to the increased fuel prices, the forest industry is worried about the possibility that wood raw material is flowing to energy sector.

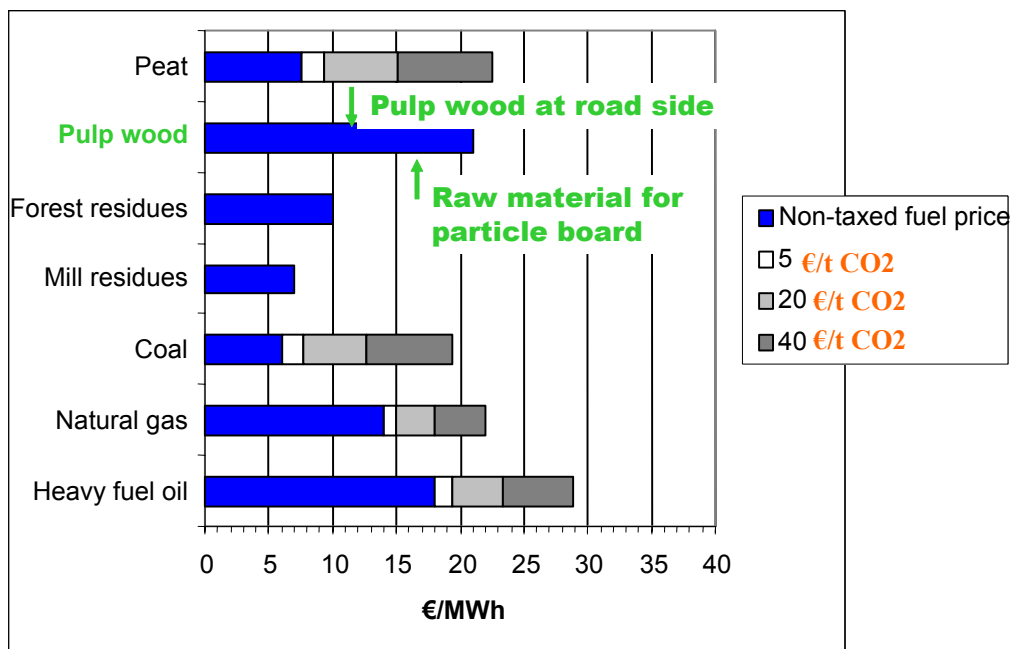


Figure 4. Effect of emissions trading – with high CO<sub>2</sub> prices – on the non-taxed fuel prices in Finland.

Emissions trading will increase the market price of electricity and thus energy costs of each consumer sector (23). On the other hand, emissions trading will improve the competitiveness of RES in all European countries. Emissions trading, as a new market instrument for a 3-year and then a separate 5-year period with unpredictable market prices, will in the beginning increase uncertainties for investors, and without national incentives, investments could be delayed. The use of Kyoto mechanisms, CDM and JI, expands the possibility of emission reduction investments to developing countries. In the long run, emissions trading is planned to replace most national incentives for promotion of RES. Presently national promotion, like investment subsidies, taxes, green certificates and feed-in-tariffs, has a greater effect on investment decisions than emissions trading.

### **2.2.5 Promotion of combined heat and power**

*The Directive 2004/8/EC of the European Parliament and of the Council on the promotion of cogeneration based on a useful heat demand in the internal energy market* (24) aims to increase energy efficiency and improve security of supply by creating a framework for promotion and development of high efficiency cogeneration of heat and power based on useful heat demand and primary energy savings in the internal energy market, taking into account the specific national circumstances especially concerning climatic and economic conditions.

Combined heat and power production (CHP), also called cogeneration, is an energy conversion process where electricity and useful heat are produced simultaneously in a single process (24). Cogeneration's advantages are that it saves energy, improves security of supply and is cost-effective. The technologies covered by the directive are combined cycle gas turbine with heat recovery, steam backpressure turbine, steam condensing extraction turbine, gas turbine with heat recovery, internal combustion engine, microturbines, Stirling engines, fuel cells, steam engines, organic Rankine cycles, and any other type of technology or combination thereof falling under the directive's definition.

In the short term, the intention of the directive is to support existing CHP installations and create a level playing field in the market (25). The directive provides harmonisation of definitions of CHP, efficiencies, micro/small scale CHP etc. and establishes a framework for a scheme for a guaranty of origin of CHP electricity. Furthermore, the Member States are obliged to ensure objective, transparent and non-discriminatory procedures for grid access, tariff criteria and administration.

The medium and long term intention of the directive is to ensure that high efficiency CHP is considered whenever new capacity is planned (25). It sets a number of criteria for an obligatory analysis of the national potential for high efficiency CHP (including small scale) in each Member State. Support schemes based on useful heat demand and primary energy savings may be continued or established in the Member States to support the realisation of the potential. Furthermore, guidelines for the implementation of *Annex II of the directive* regarding the calculation of CHP electricity, including harmonised reference values for separate production, will be issued. Finally, each Member State must report to the EU regularly about the progress in achieving the potential and the actions to promote CHP.

### **2.2.6 Promotion of biofuels for transport**

*The Directive 2003/30/EC* of the European Parliament and of the Council *on the promotion of the use of biofuels or other renewable fuels for transport* (26) was adopted in 2003. The directive aims at promoting the use of biofuels or other renewable fuels to replace diesel or petrol for transport purposes in each Member State, to contribute to objectives such as meeting climate change commitments, environmentally friendly security and promoting RES. To achieve this, the directive, accompanied by the Council *Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity* (27), sets indicative targets for biofuel substitution and then gives a legal framework for fiscal and other national measures to promote biofuels (28).

The Biofuels Directive (26) sets a European target of 5.75% substitution of conventional transport fuels with biofuels by December 2010, with an interim target of 2% substitution by December 2005. Taking these European targets into account, the Member States must set their own national indicative targets and use these to steer national policies and measures to build a minimum share for biofuels on their domestic markets (28). According to *the Communication from the Commission to the Council and the European Parliament on the Green Paper* (15) in the long term the great progress being made by substitute fuels, including biofuels, might make it technically possible to replace 20% of the petrol and diesel used for road transport with these products by 2020.

In the directives, 'biofuels' are defined as liquid or gaseous fuel for transport produced from biomass (26). The following products are considered biofuels: bioethanol, biodiesel, biogas, biomethanol, biodimethylether, bio-ethyl tert butyl ether (ETBE), bio-methyl tert butyl ether (MTBE), synthetic biofuels, biohydrogen and pure vegetable oil. Biofuels can be made available in any of the following forms: as pure biofuels or at high concentration in mineral oil derivatives, in accordance with specific quality standards for transport applications; as biofuels blended in mineral oil derivatives, in accordance

with the appropriate European norms describing the technical specifications for transport (EN 228 and EN 590); or as liquids derived from biofuels, such as ETBE.

Biofuels need financial support to compete with conventional transport fuels (28). Among the support measures available to Member States, the main one is fiscal. The companion directive on the taxation of energy products (27) contains specific provisions for reducing tax rates on energy from biomass and allowing for tax differentiation as a promotional measure. Other measures can include the promotion of biofuels in public transport, support for RTD development, and information campaigns on the benefits and availability of biofuels.

The price the consumer pays for fuel is mainly determined by national taxation policy (28). A simple approach is to reduce taxes on biofuels relative to conventional fuels. The directive on the taxation of energy products (27) gives the Member States a legal framework making it easy for them to differentiate taxation between biofuels and conventional fuels while meeting the constraints of the internal market.

To monitor progress towards the biofuel targets, the directive requires the Member States to report yearly on their biofuel promotional measures and the share of biofuels on their national markets (28). Every two years, the European Commission produces an evaluation report on progress towards the biofuel targets. The Member States reports produced on implementation of the Biofuel Directive, including measures to promote biofuels, national targets for biofuel use in 2005 and reasons for any deviation of the target, have been summarised by Deurwaarder (29), and will be dealt with later in the Chapter 3.

### **2.2.7 Biomass Action Plan**

In its Communication in 2004 on the share of renewable energy (14) in the EU, the European Commission committed itself to produce a Biomass Action Plan. A public consultation on the plan took place in 2005. A questionnaire was placed at the website of the Directorate-General for Energy and Transport and it was accessible to the public during February–March 2005. The results of the consultation have been recently reported in an assessment of the responses (30). In addition, numerous meetings with stakeholders, and bilateral meetings with Member States that have developed biomass action plans and with biomass experts were organised. The main conclusion drawn from the consultations was that the Commission should push strongly on all fronts, at the EU level and the national level, to overcome the non-technical barriers facing biomass.

In December 2005 the Commission launched a Biomass Action Plan (31). It is part of the overall EU objectives of improving competitiveness, sustainability, and security of supply. Spring 2006 will the Commission publish a fundamental review of its energy policy in a Green Paper. The Action Plan sets out measures to increase the development of biomass energy from wood, wastes and agricultural crops. It includes measures to promote biomass in heating, electricity and transport, followed by cross-cutting measures affecting biomass supply, financing and research.

In the area of heating and electricity the Commission will, among others, work towards a proposal for Community legislation in 2006 to encourage the use of renewable energy, including biomass, for heating and cooling; study how to improve the performance of household biomass boilers and reduce pollution; encourage the modernisation and conversion of district heating schemes to biomass fuel; and to closely monitor the implementation of the RES-E Directive.

Concerning transport biofuels, the Commission will publish a report in 2006 in view of a possible revision of the Biofuels Directive. This could include encouraging Member States to give favourable treatment to second-generation biofuels in biofuels obligations and proposing legislation to promote public procurement of clean and efficient vehicles, including those using high blends of biofuels.

The action is accompanied by a general impact assessment. Individual measures will be brought forward subject to specific impact assessment in line with Commission rules.

### **2.2.8 Waste management**

Municipal solid waste (MSW) is not intentionally produced as an energy source but is generated by every citizen every day. One of the challenges for our highly industrialised society is the safe and sustainable disposal of this material. That is why a number of EC directives regulate this area and these directives have already been or will in near future be adopted by national regulations in all EU countries.

The term “Solid Recovered Fuel” (SRF), formerly called “Refuse Derived Fuel” (RDF), usually refers to the segregated high calorific fraction of processed MSW. Other terms used for MSW derived fuels include Recovered Fuel (REF), Packaging Derived Fuel (PDF) and Paper and Plastic Fraction (PPF).

*The Waste Framework Directive 75/442/EEC* of the Council of the European Communities (32) as amended by *Directive 91/156/EEC* (33) aims to harmonise waste management practices across the Community by using a common definition and

emphasising priorities such as waste reduction, recovery and use of clean technologies. The directive encourages Member States to use waste as a source for energy. Other regulations are *the Commission Decision of 24 May 1996 adapting Annexes IIA and IIB to Council Directive 75/442/EEC on waste* (34) and *the Council Directive 96/59/EC on the disposal of polychlorinated biphenyls and polychlorinated terphenyls* (35).

*The Directive 94/62/EC* (36) *on packaging and packaging waste* requires Member States to introduce systems for the return and/or collection of used packaging so that it can be recovered or recycled. The directive was amended by the *Directives 2004/12/EC* (37) and *2005/20/EC* (38).

*The Directive 96/61/EC* (39) *concerning integrated pollution and control* demands that waste production is avoided and that where waste is produced, it is recovered or where that is technically or economically impossible, it is disposed of while avoiding or reducing any impact on the environment.

An important directive is *the Directive 1999/31/EC of the Council of the European Communities on the landfill of waste* (40), known as “*the Landfill Directive*”, according to which the disposal of untreated biodegradable waste going to landfill has to be reduced and is banned in a number of EU countries beginning 2005. The objective of the directive is to prevent or reduce as far as possible negative effects on the environment from the landfilling of waste, by introducing stringent technical requirements for waste and landfills. The directive sets out successive targets for reducing the landfilling of biodegradable municipal waste; biodegradable municipal waste must be reduced to 75% of the amount landfilled in 1995 by 2006, to 50% by 2009 and to 35% by 2016. The directive requires Member States to set up national strategies to implement these targets. This requires treatment of the waste prior to its final disposal in order to transform it into an inert material. The Member States will have to introduce either source-separation or implement waste sorting plants to separate the biodegradable fraction from MSW, or alternatively, divert the waste to other treatment methods such as incineration (41). In particular, Member States have to increase recycling, composting of biodegradable waste, production of biogas and other forms of recovery.

Waste incineration is one of the most tightly regulated and controlled processes in the EU. *The Directive 2000/76/EC of the European Parliament and of the Council on the incineration of waste* (42), the so-called “*Waste incineration Directive*”, defines the legal framework of this process. It aims to prevent and/or reduce pollution caused by emissions to air, soil, surface water and groundwater from incineration and co-incineration of waste. It introduces more stringent operational conditions and technical requirements and requires operators to install more sophisticated monitoring equipment.



The directive also introduces tighter emission limits (i.e. nitrogen oxides) and new controls on solid and liquid residues. It makes clear distinction between incineration and co-incineration plants and will apply to all incineration plants two years after adoption and to existing plants five years after adoption, which is early 2006 (41).

*The Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plant* (43) applies stringent limits to air emissions. The directive applies to combustion plants with a rated thermal input  $\geq 50$  MW irrespective of the type of fuel used. The definition of “fuel” excludes wastes covered by any of the incineration directives but covers combustion plants using biomass waste such as vegetable waste, cork waste and wood waste.

*The Directive 2002/33/EC* (44), amending to *the Directives 90/425/EEC* (45) and *92/118/EEC* (46), as regards health requirements for animal by-products, revises some directive texts. Most importantly, it introduces the *Regulation on Animal By-products (1774/2002)* (47) as the new health rules concerning animal by-products not intended for human consumption.

The choice of waste options in the Member States depends not only on regulations and policies regarding waste, but also on legislation and policy regarding climate change and renewable energy such as the RES-E Directive (41). The other issue affecting the potential for utilising waste as an energy source is the change occurring in the electricity market more generally. Current developments are accelerating the overlap of energy and waste policies. Policies on waste management, greenhouse gases control and energy, need thoughtful integration that takes account of the broader environmental implications.

## **2.3 Common Agricultural Policy – CAP**

In June 2003 the EU concluded a major reform of the European *Common Agricultural Policy (CAP)*. The reform completely changes the way the EU supports its farm sector (48). It shifted the CAP from paying farmers subsidies that encourage over-production, towards measures that support sustainable farming, rural development and the environment. The core of the agreement is decoupling, which means that payments will no longer be linked to production levels, but will instead depend on land being kept in good environmental and agricultural condition.

The reform will deliver better value for money to taxpayers and consumers, encourage animal welfare, reduce damage to the environment, provide opportunities to boost farm incomes and help to make world trade more equitable. Decoupling direct payments from production brings farmers closer to the market, freeing them up to provide the

safe, high quality food that people want, rather than being driven to over-produce specific commodities.

In addition to agriculture the CAP strongly impacts bioenergy. Non-food production on agricultural land has become of a greater concern in agricultural policy. Recent changes in the CAP have introduced payments for energy crops (49). Energy crops include crops for the production of biofuels and electrical and thermal energy from biomass. Energy crops that are grown on agricultural land that is not part of the set-aside area are eligible for a new annual carbon credit payment of €45 per hectare. Producers who have a contract with an energy-crop processing plant are eligible for the payment. A maximum area of 1.5 millions hectares across Europe can be used for energy crop production. In the event of the area being exceeded, aid is reduced proportionately. Certain energy crops can still be grown on set-aside land, but will not be eligible for the extra aid payment. By December 2006 the Commission will report to the Council on the implementation of the scheme, taking into account the implementation of the EU biofuels initiative.

The *Set-aside Regulation* was altered in the CAP reform. The changes remained minor for those farms that were already under set-aside obligation. However, the obligation has been expanded to apply also to several more types of farms.

Farmers applying for the area payment are subject to set-aside part of their land from production and will receive compensation for this obligation. The set-aside obligation for each farmer applying for area payments is fixed as a proportion of the area dedicated to arable crops and for which a claim is made and left in set-aside. The basic rate of compulsory set-aside is fixed at 10% for the years 2005/2006 and 2006/2007. The land set-aside can be used to produce materials for manufacture that are not directly intended for human or animal consumption, provided that effective control systems are applied; and growing legume crops on an agricultural holding, managed for the totality of its production.

According to the Biomass Action Plan in 2005 (31), the Commission will finance an information campaign about the properties of energy crops and the opportunities they offer. For example, fast-growing wood needs a new approach because farmers have to tie up land for several years and at least 4 years must pass before the first harvest.

At the time of the entry into force of the new CAP regulations, the Community consisted of 15 Member States. Since the EU enlargement New Member States have immediate access to CAP market measures, such as export refunds and intervention mechanisms. The direct payments scheme will be phased in to the New Member States by 2013. During this period direct payments are reduced to the respective percentage.

Direct payments for agricultural crops will be phased in for the New Member States over a 10-year period, starting at 25% of the EU15 level in 2004 and reaching 100% in 2013 (50). In Poland, direct payments for energy crops plantations are not available from the CAP because Poland and some other New Member States accepted a simplified support system for agriculture production.

Changes in the CAP and national policies will have a major impact on developments in rural areas. New uses for the land, like the cultivation of biomass energy crops, provide promising opportunities for EU farmers and to achieve sustainable development.

## **2.4 Policies as drivers for or barriers to bioenergy**

### **2.4.1 Policies as drivers for bioenergy**

The various EU policies, directives and regulations aim mainly at a sustainable energy production for Europe and a diminishing strategic dependence on imported fuels. As set out in the Green Paper on security of energy supply (12), key priorities for the EU energy policy are to address the Union's growing dependence on energy imports from a few areas of the world, and to tackle climate change (14). The promotion of renewable energy has an important part to play in both tasks.

Renewable energy policy strongly influences the development of the bioenergy sector. However, it is important to note that sustainability and security of supply are vastly different as far as technology and implementation strategies are concerned. To some extent they may even be competitive, and even mutually exclusive in a massive implementation phase. Thus, important political choices have to be made and priorities set at an early stage. Essentially, the technology for both avenues exists today, however much development work remains to be done before large scale implementation of bioenergy can reach the magnitude projected in the policy papers.

Renewable energy targets and EU policies, and national initiatives to reach the targets, are the driving forces for bioenergy development. For example, the Kyoto Protocol goals and the European Emissions Trading Scheme guide the energy market and energy technology development. The ETS can improve the competitiveness of bioenergy. While the CAP reform also substantially impacts bioenergy development.

In the New Member States driving forces for bioenergy are in addition to the RES targets and policies, strong agriculture and agro-industry lobby. The EU structural funds act as financial support drivers for bioenergy (51).

According to Faaij (52) bioenergy should be considered, in policy terms, an integral part of energy, agriculture and forestry, waste and industrial policy. European agriculture needs to be involved in building bioenergy production capacity.

### **2.4.2 Policies as barriers to bioenergy**

Policies function as key drivers as well as potential barriers to realizing bioenergy development. In the Bioenergy NoE “Climate Issues” Work Package, barriers surrounding the climate debate are defined as methodological consensus, national and EU policy, international policy, misinformation, and economic and market barriers. The lack of coherent policies at the national level is the greatest barrier. Few governments have explicitly realized the connection between national security, energy, land-use, employment and economic development.

There are still several basic barriers to understanding climate issues related to bioenergy. Experts around the world often utilise conflicting methodologies and system boundary assessment guidelines when assessing key factors such as forest carbon stock flows, life-cycle analysis energy and emissions flows, and future modelling efforts. Further action is needed to resolve these types of methodological discrepancies through work such as the IPCC. Incomplete and incompatible emissions factors and activity data and a lack of transparency are also barriers for consistent studies and assessments. Methodologies and system boundaries behind the data are not necessarily explained transparently, which increases the uncertainty related to the feasibility of data. Different organisations apply different methods for calculating baselines. The system needs to be unified in order to facilitate the development of emission abatement strategies.

One of the main legal obstacles facing the realization of high-level climate decisions is that these decisions are often simply crafted as policy documents and not legislation. Another potential barrier is that different policies are often considered independently rather than as part of an overall bioenergy policy; a holistic approach is needed to stimulate an increased utilization of bioenergy. Finally, a key institutional barrier is the lack of coherence between different national policies in the energy, environmental, and agricultural ministries, which is often the result of inadequate interdepartmental communication.

Climate change is inherently a global problem and therefore requires international cooperation in addressing it. There are currently several specific international policies relating to climate change and bioenergy development that are potential barriers. A potential increase in emission credits from some countries might hamper investment in bioenergy unless the CO<sub>2</sub> credit trading market maintains a respectable ‘short’ market

price. Uncertainty surrounding the upcoming emission reduction targets and the burden sharing of allowances in the post-Kyoto period is also another potential barrier. Another specific limitation in the current policy relates to the EU ETS which needs to be open to domestic offset projects. Barriers also exist within the framework of the JI/CDM mechanisms. A more general barrier to international consensus has been a perceived unequal playing field between the developed countries, which are obliged to reduce emission levels, and the developing countries, which are not held to the same limitation as the Annex I countries of the UNFCCC.

Barriers also exist in the dissemination of EU policies and directives in the Member States. Administrative barriers such as long and complex authorisation procedures persist in some countries due to insufficient coordination between different administrative bodies (14). Current regulations on grid access do not guarantee a legal framework based on objective, transparent and non-discriminatory criteria. Further progress in improving grid access for electricity from renewable energy is essential for stable growth. Slow growth in bioenergy use is caused by inadequate support systems and a lack of coordinated policies. Support systems and policy refinements should be improved to enhance bioenergy use, taking into account biomass potentials at regional and national levels.

Legislation also differs between EU countries. Although in principle legislation has been supportive for bioenergy development, several legislative barriers have been identified in different Work Packages of Bioenergy NoE. In many cases national regulations set are far more stringent than EU directives and position biofuels unequally in different member countries. The barriers identified concern ineffective or deficient incentives, standards and definitions, granting of permissions and an uncertain future.

EU rules and standards relating to the distinction between waste and bioenergy have caused some difficulties. For instance, in the Netherlands, emission regulations and permitting are complicated. This results in long wait times, of up to five years, and major complications into obtaining permission for biomass co-firing as well as dedicated biomass power plants.

Differences throughout the countries – acceptance of biogenic fraction of MSW, subsidies, and residue management – are also barriers. A major barrier for all types of recovery of bioenergy is the different definition of biomass. In many countries biomass like paper, sewage sludge, black liquor (e.g. Austria, Germany) or wood treated with organic preservatives are not acknowledged as biomass that can be subsidised if used as energy source. There is a need to establish equal conditions in the energy market throughout the EU.

A global obstacle for bioenergy systems is the unequal treatment of electric power and heat regarding tariffs and subsidies. This barrier concerns energy generation in small or large scale plants and Waste to Energy (WtE) plants. The licensing of WtE plants is in many countries (e.g. Germany, the UK) an expensive and time-consuming process. Another important sector that requires coherent regulation is the management of residues from thermal waste treatment.

In the New Member States policy barriers include a lack of clear RES targets in some countries, indicative targets instead of obligatory targets, and very weak or no incentives for heat production (51). Financial support barriers are a lack of economic instruments, limited financial resources, and a lack of support for bioenergy technology development.

There can also be problems or conflicts during policy development. Common conflicts include: whether targets should be indicative or binding; which strategies, policies or market mechanisms to apply; and harmonisation.

Rowlands (53) examined conflicts and compromises that occurred in the development of the EU directive on renewable electricity. The three issues that generated most attention were the definition of renewables and biomass, national targets and harmonisation. The percentage of the targets and whether the targets would be binding or indicative were debated. Whether to harmonise support schemes for renewable electricity in the EU, and what form that harmonisation could take, was discussed. Three of the dominant models in the EU to support schemes for renewable electricity: feed-in tariff, tendering system and tradeable certificates, were reviewed. The final document of the directive was considered to be a compromise on many issues. Rowlands (53) concludes that “in any case it remains that the definition for renewables is considerably broad, that the targets are only indicative and that all support systems can continue to operate. Such approaches, however, may turn out to be unsustainable in the long term, tough choices may eventually have to be made”.

Del Rio (54) analysed the advantages and disadvantages stemming from the harmonisation of RES-E support schemes in Europe. The RES-E Directive envisages the implementation of a community support framework in the short/medium term. Del Rio observes that a harmonised combined with RES-E trade between Member States for achieving the 2010 targets can be compared to a situation in which Member States continue to apply their current support schemes. He concludes that “if priority is given to the local/regional/national benefits of RES-E, then harmonisation in combination with a tradable green certificate (TGC) scheme is not so advantageous for countries”. “Only if the policy priority is the achievement of the RES-E Directive targets at the minimum costs, should harmonisation be favoured by national energy authorities”.

One relevant problem related to harmonisation in combination with a TGC market is the fact that immature technologies may not even have a chance to penetrate the market (54). This can also be a general argument against a TGC scheme. Therefore, the continuation of present policies compared to EU-wide harmonisation combined with a TGC system would come at a cost for the consumer and/or the taxpayer, which should be taken into account.

The main barriers and RTD goals or actions to overcome the barriers concerning EU and national policies as identified by Bioenergy NoE are summarised in the following.

<b>Barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– Methodologies for emission evaluation are incomplete/incompatible</li> <li>– Various national policies (regulations, subsidies, tariffs) influence bioenergy development differently</li> <li>– The uncertainty of the coming emission reduction targets and the burden sharing of allowances in the post-Kyoto period</li> <li>– Various waste management options, different views on sustainability of incineration and recycling schemes.</li> </ul>	<ul style="list-style-type: none"> <li>– Review methodologies for calculating GHG Emission Reduction Baselines</li> <li>– Analyse impact of climate policies on bioenergy potentials in the EU30 countries</li> <li>– Define GHG mitigation options for waste management strategies</li> </ul>

## **3. Implementation and state of bioenergy in different EU countries**

### **3.1 Implementation of bioenergy policies**

Since 2000, the Community has proposed a considerable number of new legal instruments to promote renewable energy and energy efficiency (14). The European Parliament and Council have adopted most of them. Over the last two years, Member States have been implementing the new policies in renewable energy.

The policies and regulations adopted for renewables affect the use of bioenergy in different EU countries. The Kyoto Protocol came into force in February 2005, and preparation of the post-Kyoto climate policy has been started in the EU. The Emissions Trading Scheme came into force in January 2005. Directives concerning waste management have been adopted by the Commission, for example the Landfill Directive came into operation in 2005.

The EU more than met its UNFCCC commitment to stabilise its greenhouse gas emissions at 1990 levels by 2000, as emissions were reduced by 3.3% over the period (1). In 2002, the GHG emissions of the EU15 were 2.9% below the 1990 level and those of the EU25 were 9% below the level. Since 1997, the Union has been working to achieve the ambitious target of a 12% share of renewable energy in gross inland consumption by 2010 (14). The share of renewable energy was 5.4% in 1997 and by 2001 it had reached 6%.

#### **3.1.1 The old EU15 Member States**

The Communication on the share of renewable energy (14) assesses the state of development of renewable energy in the EU. It evaluates the progress made by the EU15 towards achieving national targets for 2010 for electricity from RES; and assesses the prospects for achieving the target of a 12% share of renewable energy in overall energy consumption in the EU15 in 2010 taking into account EU legislation since 2000 and other measures in renewable energy and energy efficiency. In addition, the Communication makes proposals for concrete actions at the national and Community levels to ensure the achievement of EU renewable energy targets for 2010, and recommends a scenario for 2020.

All Member States have initiated support systems for renewable energy, such as feed-in tariffs, quota obligations and/or green certificates. In addition, all Member States have adopted national targets for the share of electricity production from RES (14). If



Member States adopt the measures necessary for the achievement of their national targets, the share of electricity production from RES in the EU15 should reach the 22% targeted by the RES-E Directive (17). However, an analysis of national reports shows that current policies and measures will probably achieve a RES share of only 18–19% of the electricity market in 2010.

Under current measures the share of RES in the EU15 will reach 10% in 2010, falling short of the 12% target (14). Considerable action is needed, particularly in the sector of renewable energy markets for heating and cooling, to enable the full 12% target to be reached. If the renewable energy share of the electricity market will be only 18–19% in 2010 presented above, then the share of renewable energy in energy consumption as a whole will reach no more than 9% instead of the 12% target.

The directive assessment (14) shows that four Member States Denmark, Germany, Spain and Finland have actively adopted measures and are therefore on line to meet their renewable energy and green electricity commitments (14, 18). Austria, Belgium, Ireland, the Netherlands, Sweden, the United Kingdom and France have started to implement appropriate policies, and for them there is a mixture of positive and negative indications as to the achievement of the targets. Greece and Portugal are not on track to achieve their national targets.

Two technologies that can be expected to deliver most of the increase in electricity from RES in the EU15 for 2010 are wind and biomass (14). Between the years 1997 and 2001, the growth of biomass electricity in EU15 was slow. Finland, Denmark and the UK were the only countries in which biomass electricity grew steadily. In some countries the biomass contribution grew comparably but intermittently, and in others it remained small. The Communication (14) pinpointed a lack of coordinated policies and financial support for RES-E in general. It emphasised that more must be done for the production of electricity from bioenergy. In the short term, specific measures are needed to kick-start green electricity from bioenergy. The Commission decided therefore to propose a Community action plan for energy from biomass by the end of 2005.

Bioenergy development in different countries over recent years has been studied by Kopetz (55). Table 2 presents the necessary total increase of bioenergy corresponding to the overall goal of the White Paper of 90 Mtoe, the realised growth in the period of 1995 to 2000, and the percentage of total growth realised in the first 5 years, in some EU countries. This last figure should be 33%, one third of the total period during 1995–2010. The analysis showed that on average only 7% of the necessary growth was realised in the EU during these first five years. Finland and Sweden lead the pack achieving 68% and 40% respectively of the total expected growth rate within the first five years, whereas in some other countries, like in France and Austria, the contribution of

bioenergy remained the same in absolute terms. In recent years rapid deployment of bioenergy occurred mainly in the Scandinavian countries and to a lesser extent in Germany. The calculations are based on the assumptions that each Member State should increase the share of bioenergy by 6% of gross inland energy consumption. Due to the results, Kopetz suggested that national and regional indicative goals that are in line with the European framework, should be developed to boost RES and bioenergy production in Europe.

*Table 2. Development of bioenergy in some EU countries (55).*

	Necessary total increase to comply with White Paper 1995–2010, Mtoe	Realised increase 1995–2000, Mtoe	Realised increase of total necessary increase, %
EU	90	6	7
Finland	2.7	1.7	68
Sweden	2.5	1.0	40
Denmark	1.1	0.2	18
France	16.2	- 0.1	0
Germany	20.5	1.7	8
UK	13.9	0.6	5
Austria	2.0	0	0
Poland	5.0	0.3	6
Hungary	1.2	- 0.1	0

The support system for green electricity in the Netherlands is one of the most complex and complicated systems in Europe according to Dinica and Arentsen (56). The Dutch government has supported renewables with fiscal instruments (green funds, tax credits and energy tax) since 1996 (57). In 2001 the government introduced a system for tradable green certificates. The development in renewable energy policy making in the Netherlands was analysed by van Rooijen (58). Dutch green electricity policy can be characterised roughly by three phases. In the early 1990s, the government negotiated voluntary agreements with the energy distribution sector on targets for green electricity sales, which were never met. In the second half of the 1990s, a regulatory energy tax was introduced, from which customers of green electricity were exempt. This led to a substantial increase in demand, which was largely met by green electricity imports, and did not lead to additional domestic renewable energy capacity. Dutch green electricity policy instruments focused on the stimulation of demand by means of price incentives, in contrast to the rest of the EU countries which introduced other incentive schemes.

Finally, in 2003 a change in policy shifted the focus from promotion of demand to promotion of supply via a system of regulated feed-in-tariffs. Despite these policies, growth of the renewable energy market in the Netherlands has been small and targets set by the government have not been fully met.

In addition to the promotion of green electricity and energy demand management, Member States have committed themselves to encourage the production of liquid biofuels and renewable energy for heat production. The fate of liquid biofuels depends largely on taxation policies (14). In March 2004, seven Member States had partly or completely removed taxes on biofuels, following European legislation: Austria, France, Germany, Italy, Spain, Sweden and the United Kingdom. It is clear that the success of liquid biofuels depends on proactive policies by Member States.

A precise regulatory framework for biofuel development in Europe has existed since the beginning of the 1990s. The first measures date from 1992 with a section of the CAP that gave Member States the possibility of growing non-food crops on fallow lands and exempting biofuels from taxes in respect of price competition. The principle of each country being assigned production quotas dates back to this same period and is still in use for some Member States (59).

The country reports produced on the implementation of the Biofuel Directive (26), that were published before April 2005 have been summarised by Deurwaarder (29). In 2004, Member States had to report their measures to promote biofuels, their national target for biofuel use in 2005 and their reasons for any deviation of the 2% target. The reports were analysed in order to provide an insight on how Member States currently deal with the directive. In particular, the reasons to deviate from the target were analysed, since they flag up barriers for the implementation of liquid biofuels for transport. It was found that five reports were not available and that many of the available reports did not contain all the information that was requested by the directive. From the information available, it was concluded that the EU would not reach 2% of biofuels for transport in 2005. Still, biofuel production was estimated to be quite considerable in 2005, mainly because large transport fuel consumers like Germany, France and Spain intended to reach the target. The main reasons for the deviations were that biofuels for transport are not considered cost-effective for reducing greenhouse gas emissions, the fuel end use is problematic and there is a limited amount of feedstock available in certain countries. Some Member States also stated that current biofuels for transport have some negative environmental aspects, there are legislative barriers, and that there is currently limited production capacity.

According to the 2005 Biomass Action Plan (31), if all Member States achieved the targets they had set for the end of 2005, biofuels would have attained a share of only 1.4%.

### **3.1.2 The ten New EU Member States**

The ten New EU Member States are subject to the requirements of the RES-E Directive. The national indicative targets for the share of electricity from RES in each New Member State are set out in the Accession Treaty (14). In most of the New Member States there is high potential for the use of biomass for both electricity and heat generation. This is particularly true for the widely unexploited potential for electricity generation in Hungary, the Czech Republic, Slovakia, Latvia, Lithuania, and Estonia. In addition, particularly in Slovenia, Hungary and Lithuania, there is still an important potential to increase hydro energy generation.

The Governments of the majority of New Member States, give bioenergy priority over other RES (51). Poland has established national targets indicating the share of RES in the primary energy balance until 2010 and 2020. In Estonia, Lithuania, Slovakia and Slovenia, although the RES are addressed in most strategic documents, clear targets and timetables are missing. To support bioenergy production in all these countries, except for Malta, support mechanisms were introduced. Feed-in tariffs for bioelectricity were introduced in all countries with the exception of Poland, where a quota obligation system started in 1997 for electricity from RES. Among other incentives for bioenergy there are government subsidies for bioenergy investments, e.g. in Cyprus and Estonia, grants and soft loans from special environmental funds, and tax relief on bioenergy investments in the Czech Republic, Estonia and Slovakia. Of all the New Member States, the Czech Republic has the most favorable conditions for bioenergy development. Strong support measures include a system of subsidies to establish energy crop plantations, subsidies for the production of liquid biofuels and tax relief for RES investments.

Regulations relating to bioenergy are usually dispersed among different policy documents mainly because bioenergy issues are strongly connected to energy policy, agricultural policy and forestry policy (51). None of the New Member States, have any consolidated document that brings together all the regulations related to bioenergy. A renewable energy act could provide transparent and complete regulations for the bioenergy sector as well as for other renewable energies. However only Poland and the Czech Republic have prepared draft renewable energy acts. There is a lack of national and regional programmes, especially those dedicated to bioenergy development, and a lack of national R&D programmes on bioenergy.

In the National and Rural Development Plans prepared for the period 2004–2006, a significant role of utilization of RES and especially bioenergy is realized in most New Member States (51). Bioenergy is recognised as being important for developing rural areas sustainably and reducing unemployment. Non-food production is supported in most New Member States, as it is consistent with the idea of multifunctional agriculture promoted within the reformed CAP. However, energy crop production is not explicitly recognized in these plans as an area worth expanding.

With the enlargement of the EU, New Member States have an opportunity to use EU structural funds (51). This opens many opportunities for RES financial support including bioenergy, especially since national and private funds are not sufficient to support the progress of RES to achieve the established targets. In the Czech Republic, Hungary, Lithuania, Poland, Slovakia and Slovenia there are operational programmes that give opportunities for bioenergy investments to be granted. The RES use has no opportunities for support from structural funds in Estonia and Latvia.

Energy crop cultivation receives support in the form of governmental subsidies only in the Czech Republic. In Poland the EkoFound foundation supports the establishment of energy crop plantations, but the area must be over 50 hectares. Unfortunately, no support for growing energy crops is available from the CAP in Poland.

The New Member States are subject to the requirements of the Biofuels Directive. Biofuels production and use is supported in form of subsidies or quantitative targets in five New Member States: in the Czech Republic production is subsidized, in Hungary there are state subsidies and 0% excise tax, in Latvia there is a program on production and use of biofuels, and Lithuania has a law on biofuels (51). Poland has also adopted a new law on the promotion of biofuels entered into force in 2004.

### **3.1.3 Waste management in the EU25 countries**

Waste management in the EU is almost totally regulated by EU directives. The directives define the political framework and they have already been adopted, or will be in the near future by national regulations in all the EU countries. Reality, however, is that most EU countries are not yet in line with EU standards. For the New Member States, the course of integration of the EU regulations into national law is laid down in the accession treaties. Specific dates defined for reaching goals are on the way to full implementation.

According to *the Landfill Directive* (40) the disposal of untreated biodegradable waste has to be reduced and has been banned in a number of EU countries in June 2005. The

consequence is that a treatment of the waste prior to its final disposal in order to transform it into an inert material is mandatory. In most cases this is done by thermal treatment, for the time being preferentially by waste incineration in grate systems. The situation in MSW management in the EU countries in recent years is presented in Figure 5. The limit of 35% of the share of MSW to be landfilled in 2016, set in the Landfill Directive, is accomplished only by substantially increasing the energy use of waste within the EU. It is estimated that 165 new WtE units are needed by 2009 on top of the over 300 incinerators currently in operation.

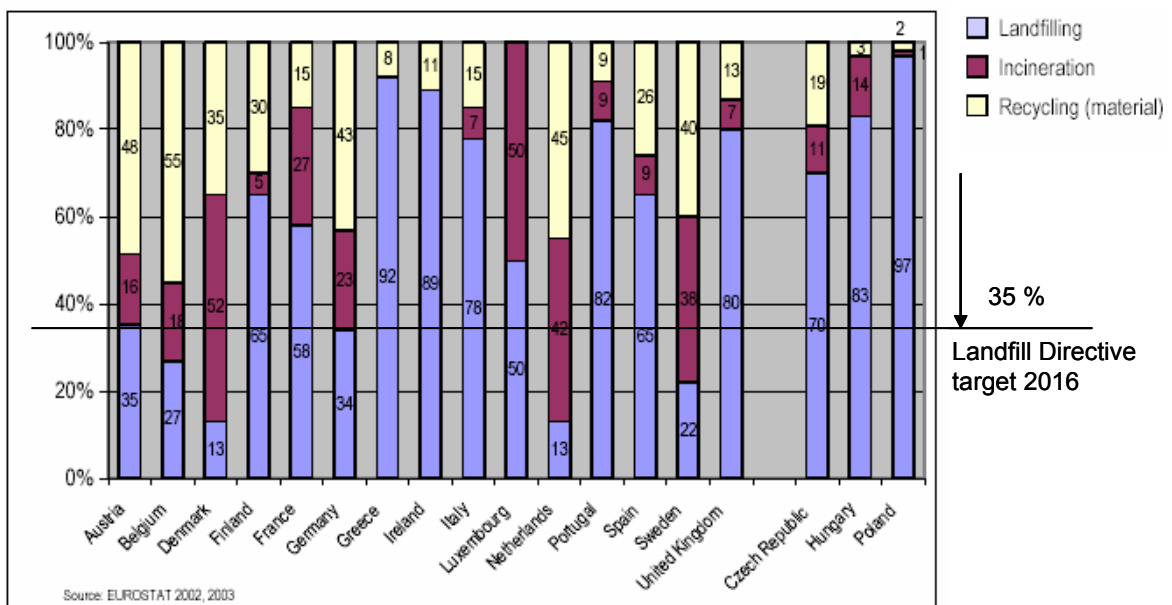


Figure 5. MSW management in the EU countries (4).

The Council Directive 91/156/EEC on waste (33) encourages Member States to use waste as a source for energy and the Waste Incineration Directive (42) defines the legal framework of this process. The Waste Incineration Directive sets stringent standards for waste incineration plant emissions. The standards have been adopted by all countries practising waste incineration with a few deviations from the EU standards in some countries such as the Netherlands which has set a much lower NO<sub>x</sub> limit and Germany, which has reduced the Hg value.

However, the adaptation of EU directives into national law also leaves room for distinctions. An important one in the context of bioenergy is the definition of waste and the acknowledgement of its partly biogenic nature since it has a great impact on subsidization and on the economy of WtE strategies. In Germany, for instance, waste is not accepted as having any biogenic origin and waste incineration plants are exempted from the CO<sub>2</sub> trading whereas in Sweden 50% of the power generated in waste incinerators is classified as bioenergy and for the 50% fossil fraction CO<sub>2</sub> certificates are allocated. The Netherlands regard 50% of power from waste incineration as

biogenic if the conversion efficiency exceeds 30%, and in Finland 60% of the energy inventory of waste is considered biogenic.

## 3.2 Current state and future prospects in bioenergy utilisation

### 3.2.1 The old EU15 Member States

In spite of the many positive initiatives going on in the bioenergy field in Europe, the overall developments in bioenergy utilisation has lagged far behind European goals. The use of bioenergy in the EU15 in 2003 was about 58 Mtoe (2 420 PJ) contributing 3.7% of the total primary energy sources (4). According to Kopetz (55) distinct regional differences occur in the utilisation of bioenergy (Figure 6). The share of bioenergy in the EU15 is highest in Finland, Sweden and Austria.

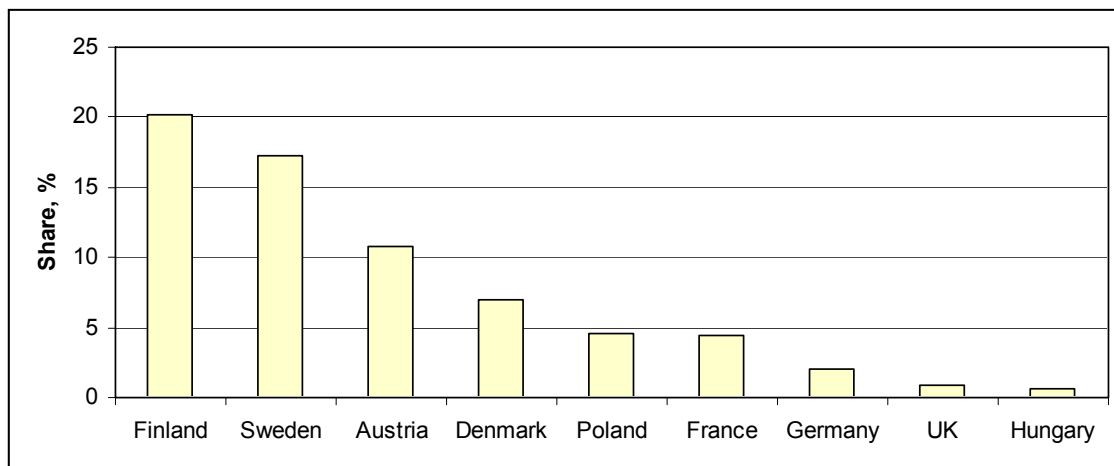


Figure 6. Share of bioenergy of the total primary energy sources in different European countries in 2000 (55).

The state of different bioenergy sectors in the EU will be presented below.

#### **Wood energy**

Wood is the renewable energy that can best be substituted for fossil fuels, and, moreover, is the leading renewable sector for primary energy production in Europe (59). According to the European Barometer 2005 (60), primary wood energy production amounted to 47 Mtoe (1 970 PJ) in the EU15 in 2004, having increased 9% from 2003. For the EU25 countries the respective production was 55 Mtoe (2 330 PJ) in 2004. Primary wood energy production includes wood waste, black liquors and solid waste from crop harvests.

The major portion of wood-energy used for primary energy generation is in the form of heat for individual homes or collective-tertiary sector buildings (59). The use of wood and wood by-products to produce electricity is growing rapidly (60). This is especially due to the development of CHP installations in certain EU countries.

France is number one in Europe in terms of absolute use figures with the estimated production of 9.2 Mtoe (390 PJ) in 2004 (Figure 7) (60). Next in line are Sweden and Finland. When considered as per the number of inhabitants, the produced energy ratios place Finland and Sweden on top (59). Finland covers 50% of its heating needs and 20% of the primary energy consumption through the use of wood energy.

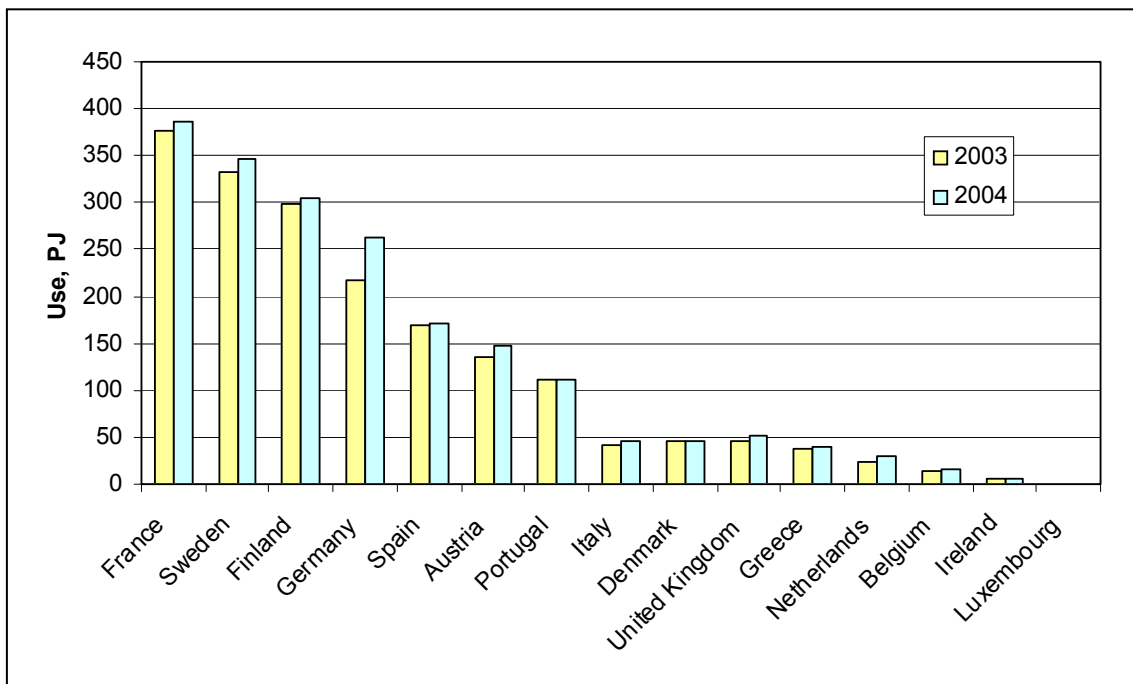


Figure 7. Primary energy use from wood energy (PJ) in the EU15 in 2003 and 2004 (modified from reference 60).

The White Paper does not contain any specific wood energy figure for the year 2010. The share of wood energy in the EU objectives was determined at 100 Mtoe (4 200 PJ) by the European Barometer (59) by calculations from the White Paper objectives. The Barometer 2004's (59) own estimate 69 Mtoe (2 890 PJ) applied the average sector growth rate observed over the last three years. While the sector is currently not growing at a satisfactory pace to reach the objectives set, the situation is far from irremediable, because of plans by France, Germany, Spain and Italy to increase the wood energy share of their primary energy. Furthermore, the efforts of Finland and Sweden show that the sector can significantly contribute to energy production. The recent forecast of the Barometer 2005 (60) for 2010 is 78 Mtoe (3 270 PJ), which considers national objectives, expert estimations and growth observed in the different countries.



## Liquid biofuels

The share of liquid biofuels in European petrol and diesel consumption is estimated at about 1% according to the European 2004 Barometer (59). However, this figure looks likely to grow rapidly because of the European Commission's objectives of 2% and 5.75% for the years 2005 and 2010.

Biodiesel from oilseeds (rapeseed or sunflower seed) is the most common liquid biofuel. Biodiesel can be used in a pure state or mixed with petroleum based diesel oil. Bioethanol, obtained from sugar beets or cereals like wheat, barley or corn, comes second and is growing rapidly. It can be used as a petrol additive directly or in the form of ETBE composed of 50% ethanol and 50% isobutylene, a petrol derivative. Other biofuels, derived from wastes and residues, account for only a small share.

2.4 million tonnes of biofuels including biodiesel and bioethanol were produced in the EU25 in 2004, representing a 26% increase over 2003 (61). These two sectors are largely dominated by biodiesel representing 80% of European biofuel production. The production of biofuels in the EU15 in 2004 was 2.3 million tonnes.

The EU is the global leader in biodiesel development. The rise of biodiesel's importance in Europe accelerated in 2004 (Figure 8) (61). Production in the EU25 was about 2 million tonnes. The EU15 countries produced 1.9 million tonnes of biodiesel fuel in 2004, representing an increase of 29% with respect to 2003.

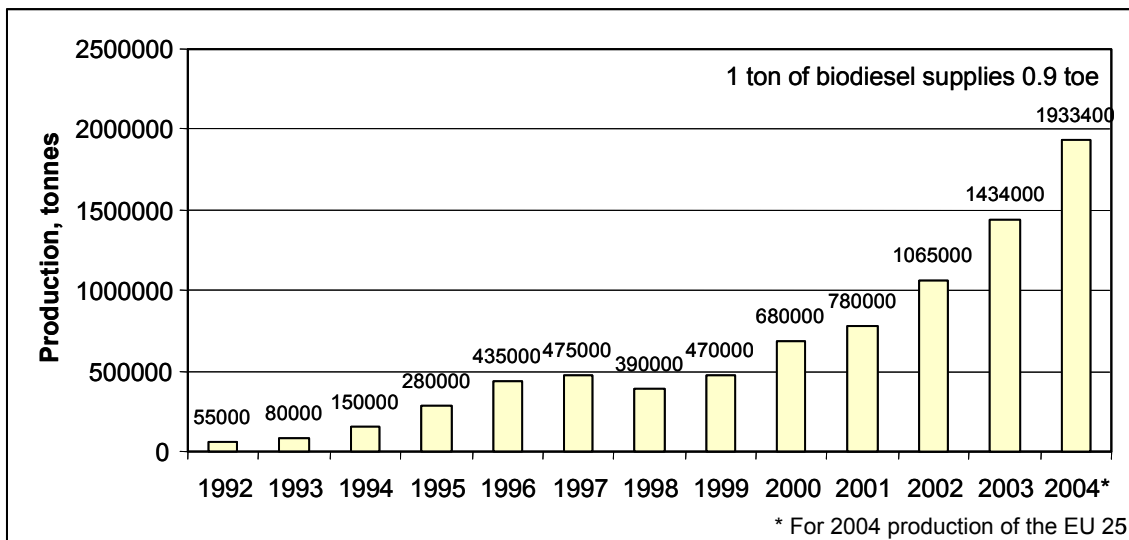


Figure 8. Biodiesel production (tonnes) in the EU during the years 1992–2004 (61).

The leading European biodiesel producer, Germany, produced 1.0 million tonnes of biodiesel in 2004 (61). The production increased by 45% over 2003 and accounts for

over half of Europe's biodiesel production. Next were France and Italy with about 350 000 and 320 000 tonnes, respectively. The rapid development in Germany can be explained by several factors such as favourable legislation, an absence of quotas, low vegetable oil prices and a high diesel price. Since January 2004, the mineral oils tax law that governs taxation of fuels has been amended. It now allows for a total tax exemption for biofuels, and this applies to both pure forms and those mixed with fossil fuels. Biofuels are also exempt from Germany's ecology tax established in 1999.

The European (EU15) ethanol production amounted to 460 000 tonnes in 2004 (61). With 190 000 tonnes, Spain is the leading producer in Europe. The sector's success in Spain can be explained by the fact that Spain does not collect tax on ethanol. In France bioethanol production in 2004 was 100 000 tonnes. In Spain and France bioethanol is transformed into ETBE. Sweden was the third largest European producer in 2003 with 50 000 tonnes. Unlike France and Spain, Sweden does not transform ethanol into ETBE in order to distribute it. Sweden consumes much more bioethanol than it produces with annual consumption of 210 000 tonnes.

Even though the objective of 5 Mtoe (210 PJ) for liquid biofuels by 2003, set in the Commission's Campaign for Take-Off of the White Paper on renewable energies (3), was not reached, future prospects for growth are favourable (59). Successful achievement of the 2010 objectives will require optimal use of fallow land in Europe. However, the production of biofuels is not only linked to farm land, since used vegetable greases and secondary biomass (straw, raw cellulose and bagasse) can also serve as raw material for biofuels. Furthermore, the arrival of New Member States, in particular, Poland and the Czech Republic, should bring a new dynamism to biofuels in the EU.

However more action is needed as the recent Biofuels Barometer (61) estimates that if the current trend continues, the target of reaching a 5.75% biofuel share in the transportation sector by the year 2010 will not be achieved.

### ***Biogas***

Unlike the other RES sectors, biogas production is not regulated because of concerns over energy, but rather from environmental preoccupations, such as eliminating pollution, treating waste and curbing greenhouse gas emissions (62). Biogas results from several different types of deposits, the main ones being waste storage centres (dumps) and urban and industrial sewage treatment plants. There are more than 4 000 biogas production sites in the EU25.

It is currently estimated that a little over half of the biogas produced in Europe is valorised, with the remainder being burned off in flare stacks. Multiple types of

valorisations make it possible to transform crude biogas into useful energy. The main type is production of heat used on the sites themselves or, in a less common practice, exploited via heat networks. Thermal valorisation mainly concerns sewage treatment plants. Electricity constitutes another type of valorisation (62). More marginally, biogas can be valorised in the form of biofuels, and it can also be injected into natural gas distribution networks. The use of biogas in electrical production is undergoing fast-expanding growth today. Moreover, installations equipped with cogeneration systems are developing (59, 62).

The total European crude biogas production was estimated at 4.3 Mtoe (179 PJ) in 2004 (Figure 9) (62). This represents an increase of 9% over 2003. The UK is the leading European country in terms of crude biogas production with 1.5 Mtoe (62 PJ) in 2004. The majority of this biogas is valorised in the form of electricity. Germany is second with 1.3 Mtoe (54 PJ), with valorisation chiefly turned towards production of electricity. Biogas in France is chiefly valorised in the form of heat.

The objective set in the framework of the Campaign for Take-Off, 2.25 Mtoe (94 PJ) for biogas in 2003 (3), was reached in 2002. The forecast is different for the year 2010. If the growth rate observed in 2004 remains the same until 2010, crude biogas production should, according to the Biogas Barometer (62), be in the region of 8.6 Mtoe (360 PJ), considerably below the White Paper target of 15 Mtoe (630 PJ) for 2010. Regulations of the dumping of waste are leading decision-makers to find new solutions to treat organic waste as soon as it is collected. In the face of this need, organic waste methanisation is one of the most relevant answers.

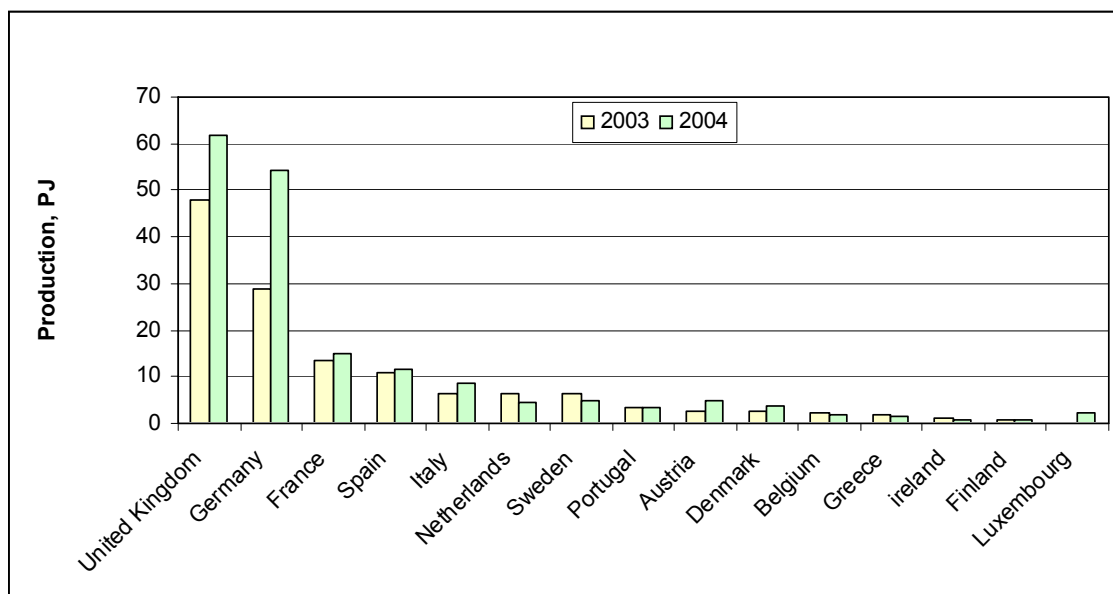


Figure 9. Crude biogas production (PJ) in the EU in 2003 and 2004 (62).

### 3.2.2 The ten New EU Member States

Biomass contribution to total renewable energy production in continental New Member States ranges from 70–95%, excluding Slovenia, in which small-scale hydropower is significant (Figure 10) (51). The highest contribution of bioenergy to total primary energy production is in Latvia amounting to 29%. Next is Estonia with 12% of bioenergy because of its large forests. Large agricultural and forest land areas also open up great opportunities for bioenergy development in Poland, Lithuania and Slovenia. The most dynamic development of the bioenergy sector is in Poland and the Czech Republic. In both of these countries studies and trials with energy crops cultivation are very intensive.

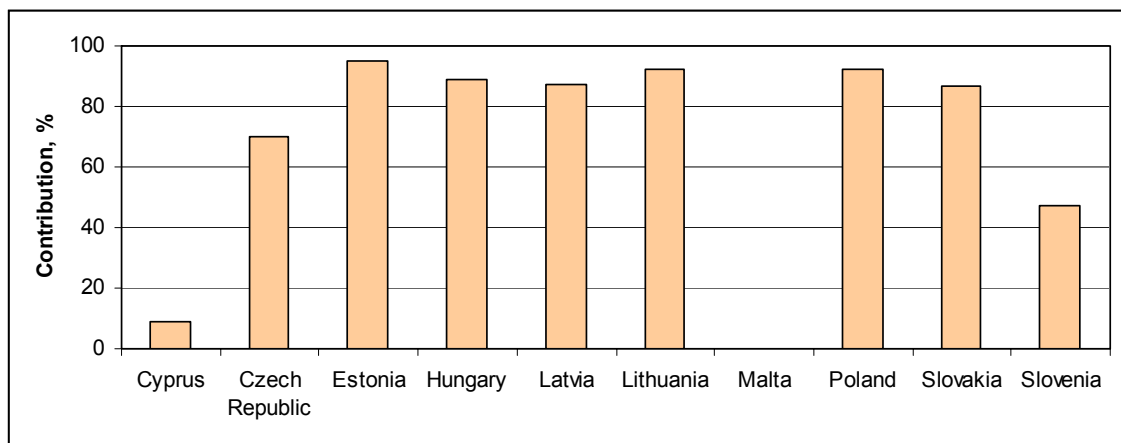


Figure 10. Contribution of bioenergy to total renewable energy production in New Member States (51).

Currently the forestry sector is the main source of biomass utilised for energy in most New Member States (Figure 11) (51). The consumption of primary energy from wood energy in the New Member States is estimated at 8.6 Mtoe (360 PJ) in 2004 (60). Current demand for wood fuels (especially fuelwood) is concentrated in rural areas mainly for heating purposes (51). Other uses, such as district heating and combined heat and power plants, are still marginal. However, their demand will likely grow as a viable energy option considering new international energy and environmental policies and the entry of the EU. Fuel wood includes low quality wood that is not relevant for industrial purposes. Forest residues utilization is still taking place on a very small scale. In most countries logging residues are not collected at all. The main barriers for forest residue exploitation are transportation costs and harvesting and handling costs, which are very high compared with the real price of the forest residues at the user facility.

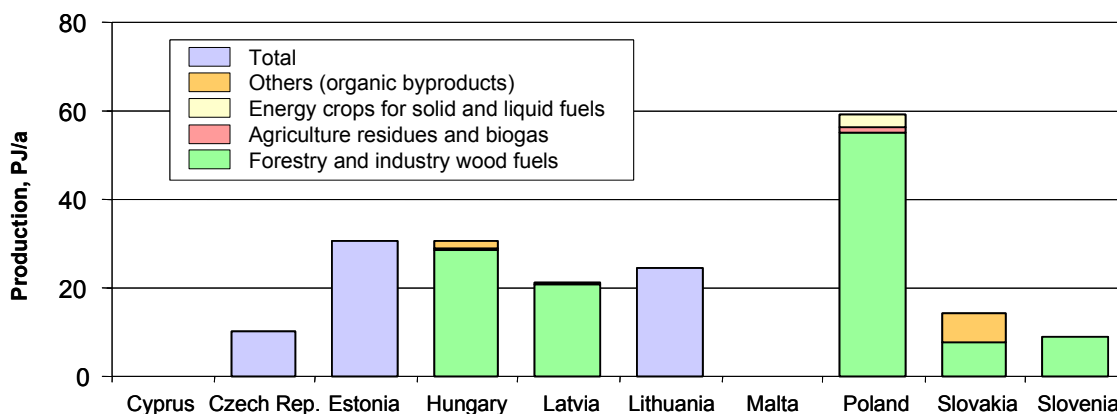


Figure 11. Bioenergy production in New Member States (PJ/a) in 1999 (63).

Pellets and briquettes production for fuel is a relatively new business in New Member States starting about ten years ago (51). The leading countries are Estonia (250 000 tonnes/a), Latvia (130 000 tonnes/a) and Poland (120 000 tonnes/a). Approximately 85–90% of briquettes and almost 100% of pellets are exported abroad, mainly to Scandinavian countries, the UK and Germany. It is anticipated that in the future, local markets for wood pellets will grow significantly. Preconditions for such a prognosis are a growing national economy, the realization of a fully automated combustion process and the development of domestic companies producing wood pellet boilers.

Straw is the primary residue from agricultural production (51). Despite large straw resources, its utilization is not very common in most New Member States. Only Poland and Lithuania, have district heating plants based totally on straw. The development of using straw as a fuel is slow due to problems related to straw storage and handling, problems with combustion process due to the high content of chlorine and potassium in straw, and lack of farmers' awareness and traditions of straw usage as a fuel.

Energy crops have recently garnered great attention. This is due to the changes in land use in the Baltic States (51). Large areas of agricultural land were abandoned during the economic transition process. Afforestation with fast growing deciduous species is one way to reemploy these lands. Non-domestic tree species such as birch, oak and alder, and trial fields of short rotation coppice have recently been introduced in some countries.

The Czech Republic is the only New Member State that has developed significant biodiesel production, amounting to 60 000 tonnes in 2004 (61). As early as 2001, biofuels accounted for 1.3% of all automotive fuels in the Czech Republic (14). Slovakia and Lithuania also produce biodiesel (60). Concerning bioethanol, Poland is the only New Member State to have developed the sector significantly. Bioethanol production in Poland in 2004 was 36 000 tonnes, a 40% decrease compared to 2003.

The sharp decline occurred because in 2004 the Polish Constitutional court did not ratify the Biofuels Law that was voted for previously in 2003 (61). This law provides a tax exemption for the production of ethanol mixed with petrol. The final percentages and the amount of the exemption are to be determined on a yearly basis. The Biofuels Law is still in the revision phase. The use of bioethanol as a direct blend in petrol is increasing. At present, France and Spain convert all their bioethanol production into ETBE, Poland uses both bioethanol and ETBE, and Sweden and the Czech Republic use bioethanol directly.

In the short term, the development of the bioenergy sector will come from forestry resources and agricultural residues (51). In Poland, Hungary and the Czech Republic in particular, agricultural residues are plentiful and carry promising for energy purposes (Figure 12). Energy crops cultivation is regarded as a medium-term option. There are also countries with very poor capabilities for bioenergy development, such as Cyprus and Malta, where priority is given to solar and wind energy.

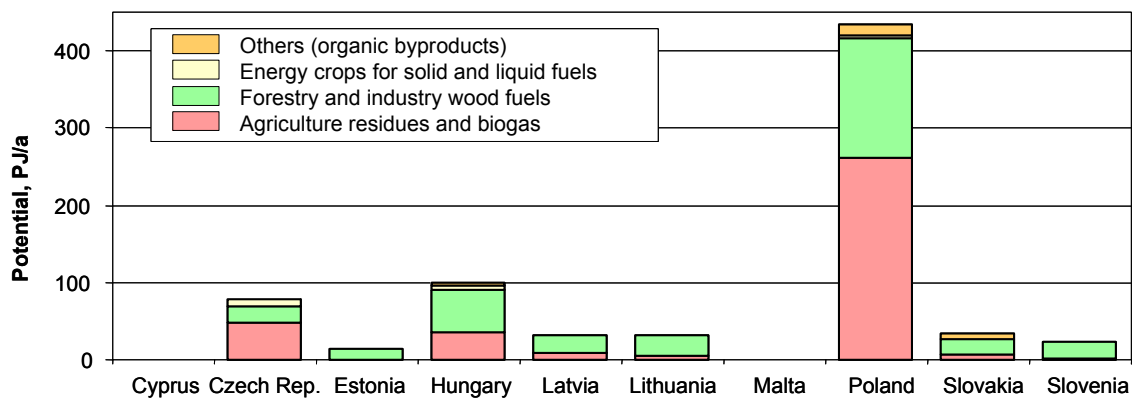


Figure 12. Short-term bio-energy potentials in New Member States (PJ/a) (63).

### 3.2.3 Main conclusions

All the EU Member States have initiated support systems for renewable energy and adopted national targets for the share of electricity production from RES. Bioenergy is regarded as the most important renewable fuel in the EU. However, under current measures, it looks like the EU is not going to reach the targets set for the RES and green electricity in 2010. More action must be taken across the bioenergy sector, in electricity, heating, biofuels and waste management, to enable the EU to meet its targets for bioenergy and RES.

The rapid increase in the use of bioenergy is mainly taking place in the Scandinavian countries and partly in Germany. Wood is the most important RES for primary energy

production in Europe. Concerning biofuels for transport, many Member States have partly or completely removed taxes following European legislation. There are, however, deviations in the national targets from the targets set by the Commission for the years 2005 and 2010. The main reasons for the deviations are that biofuels are not considered cost-effective for reducing greenhouse gas emissions, the fuel end use is problematic and there is a limited amount of feedstock available in certain countries.

Support mechanisms for bioenergy have also been introduced in all New Member States, except Malta. The mechanisms in use are feed-in tariffs for bioelectricity, government subsidies for bioenergy investments, grants and soft loans from special environmental funds, and tax relief on bioenergy investments. Furthermore, bioenergy is regarded as a key to encouraging sustainable development in rural areas, non-food production is supported, and energy crops cultivation and afforestation of abandoned land are also given priority. Biofuels production and use have been supported in form of subsidies or quantitative targets in many New Member States, of which the Czech Republic has the most favorable conditions.

Waste management is regulated chiefly by the EU. The directives define the political framework, and they have already been or will in the near future, be adopted into the national regulations in all the EU countries. In the adaptation of the directives there are distinctive differences between the countries. The definition of waste and its partly biogenic nature has a great impact on subsidization and hence on the economy of WtE strategies. The target of the Landfill Directive – a maximum 35% of the biodegradable MSW to be landfilled in 2016 – will be reached only by substantially increasing the energy use of waste within the EU.

## 4. Biomass availability

The availability of natural resources, renewable or non-renewable, is a complex issue and biomass for energy production is no exception. Many studies have been performed to evaluate the biomass potential for energy use. The results do, however, vary greatly depending on the scope and the different assumptions made in the studies.

First there is the general issue of biomass availability globally. Although the studies generally show large potential of biomass availability on a global scale, such results are of limited usability in practice as they rarely pay attention to the geographical distribution of the resources, in particular in relation to potential use.

There is also the cost issue. Global figures give evaluations, but rarely tell anything about the costs and quantities of bioenergy that can be produced locally in various places in the world. This is of course fundamental because although a transition to alternative energy supply strategies is deemed important, for political or long term survival considerations, there are always alternative strategies that can fulfil the same goals. In the end the choice must depend on what is most efficient in economic terms, all other benefits being equal.

For example in the CO<sub>2</sub> abatement issue, a perfectly viable alternative may be CO<sub>2</sub> capture and storage, which seems to be feasible and low cost. Such a strategy would then open up the possibilities for the large scale use of fossil coal resources, abundantly available even within the EU. If strategic, or political self sufficiency is the dominant goal, likewise liquid fuel production from coal through Fischer–Tropsch synthesis is a well known technology that can be implemented on a large scale. In both cases, the market advantage is that no changes have to be made in the distribution and use phase of the system. It is a rather large advantage considering the complexity of the existing infrastructure.

Thus in order to make realistic projections into the future, reliable supply curves for available biomass must be constructed as functions of time and geography yielding overall cost figures. This is a very complex undertaking for many reasons. Biomass is not a single product, it can be purposely grown for energy production, it can be collected from as yet underutilised areas, such as forest or agricultural land, or it can be collected as waste streams from other processes, such as urban waste, agricultural food production or forest industry.

Policy issues can dramatically change the price structure as has been proven in a number of cases, as for example, willow in Sweden and wind energy in Germany. This can introduce artificial and even negative elements for long term bioenergy strategies,



as for example in Sweden, where newly introduced energy subsidies make sawdust more attractive as fuel than as fibreboard. This has resulted in unwanted consequences – Sweden is now planning new support actions for the fibreboard industry to counteract this effect.

In the following section, recent studies concerning the use and potential of biomass resources for energy production and, in addition, estimates of the future potential for bioenergy, mainly through the year 2050, are presented. The review comprises global resources, in addition to European resources. Drivers and barriers concerning the biomass availability are discussed.

#### **4.1 Global potential of biomass for energy**

Biomass currently accounts for approximately 14% of world's final energy consumption. About 25% of the usage is in industrialised countries, while the other 75% is used in developing countries. Developing countries as a whole derive 33% of their energy from biomass. In many of these countries biomass provides over 90% of total energy use in the form of traditional fuel such as fuelwood, residues and dung. At present the use of biomass as traditional fuel is about  $38 \pm 10$  EJ/a, and as modern energy, such as fuel and electricity, about 7 EJ/a (64). The global availability has been presented, among others, in references 64–78.

The Renewables-Intensive Global Energy Scenario (RIGES) prepared by Johansson et al. (67) as part of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 proposes that by 2050 biomass could provide nearly 38% of the world's direct fuel use and 17% of the world's electricity, which means a total biomass contribution of 206 EJ. Detailed regional analyses (67) presented in Table 3 show, for example, how Latin America and Africa might become large exporters of biofuels (64).

Table 3. Total biomass supply for Europe according to RIGES (EJ/a of primary energy) (67).

Country	Forests <sup>a)</sup>	Residues <sup>b)</sup>		Plantations <sup>c)</sup>		Total	
	2025/2050	2025	2050	2025	2050	2025	2050
Africa	2.43	6.81	9.38	18.94	31.81	28.18	43.6
Latin America	1.59	10.92	13.59	32.3	49.6	44.81	64.78
S. and E. Asia	3.13	13.61	20.42	-	-	16.74	23.55
CP Asia	1.21	3.85	4.16	5	15	10.06	20.37
Japan	-	0.89	0.95	-	-	0.89	0.95
Australia/NZ	0.02	1.14	1.39	-	-	1.16	1.41
United States	0.61	5.86	5.68	9.6	9.6	16.07	15.89
Canada	0.04	1.43	1.42	1.2	1.2	2.67	2.66
OECD Europe	0.31	4.85	4.86	9.0	9.0	14.16	14.17
Former CP	0.58	5.28	5.68	4	12	9.68	18.26
Middle East	0.02	0.18	0.23	-	-	0.2	0.25
<b>Total</b>	<b>9.94</b>	<b>54.82</b>	<b>67.76</b>	<b>80.04</b>	<b>128.21</b>	<b>144.8</b>	<b>205.91</b>

a) Roundwood only; residues are not included.

b) Forest and forest product residues, sugarcane residues, dung, cereal residues and urban refuse.

c) Plantation energy.

CP, centrally planned.

According to a recent, and more conservative estimate of Parikka (78), total sustainable worldwide biomass energy potential is 104 EJ/a, which is about 30% of total global energy consumption today. In Table 4, biomass energy potentials and current use in different regions are presented. About 40 EJ/a of available biomass in the world is used for energy. Nearly 60% of this biomass is used only in Asia. On a worldwide level about two-fifths of the existing biomass potential is used. In most areas of the world the current biomass use is clearly below the available potential. Only in Asia does the current use exceed the available potential, indicating non-sustainable biomass use.

Table 4. Biomass energy potentials and current use (EJ/a) in different regions of the world (78).

<b>Biomass potential</b>	<b>North-America</b>	<b>Latin America</b>	<b>Asia</b>	<b>Africa</b>	<b>Europe</b>	<b>Middle East</b>	<b>Former USSR</b>	<b>World</b>
Woody biomass	12.8	5.9	7.7	5.4	4.0	0.4	5.4	41.6
Energy crops	4.1	12.1	1.1	13.9	2.6	0.0	3.6	37.4
Straw	2.2	1.7	9.9	0.9	1.6	0.2	0.7	17.2
Other	0.8	1.8	2.9	1.2	0.7	0.1	0.3	7.6
<b>Potential, Sum EJ/a</b>	<b>19.9</b>	<b>21.5</b>	<b>21.4</b>	<b>21.4</b>	<b>8.9</b>	<b>0.7</b>	<b>10.0</b>	<b>103.8</b>
<b>Use, EJ/a</b>	<b>3.1</b>	<b>2.6</b>	<b>23.2</b>	<b>8.3</b>	<b>2.0</b>	<b>0.0</b>	<b>0.5</b>	<b>39.7</b>
Use/potential, %	16	12	108	39	22	7	5	38

Hoogwijk et al. (76) studied the ranges of the global future potential of biomass for energy. Biomass resources were divided into six categories: energy crops on surplus cropland, energy crops on degraded land, agricultural residues, forest residues, animal manure and organic wastes. The analysis showed that the future geographical potential of biomass energy ranges very widely, about over a 50 year period from 33 to 1 135 EJ/a. Energy crops from surplus agricultural land had the largest potential, up to about 990 EJ/a. The potential of energy farming is the result of land availability and biomass productivity. The productivity was assumed to range from 10 to 20 tonnes/ha/a, and was considered to be determined by local factors, such as soil quality, climate, water availability and management. Availability is affected by many factors: the future demand for food, the type of food production systems that can be adopted world-wide, productivity of forest and energy crops, the increased use of bio-materials, availability of degraded land, and competing land use types, e.g. surplus agricultural land used for reforestation.

Berndes et al. (77) reviewed 17 earlier studies on the contribution of biomass to future global energy supply. From the demand-driven studies it was concluded that bioenergy demand may increase to several hundred EJ/a in the future. At the same time, the reviewed resource-focused studies have resulted in widely different conclusions about the possible potential of biomass ranging from below 100 EJ/a to above 400 EJ/a in 2050. The major reason for the differences in the potentials is that the two most crucial parameters – land availability and yield levels in energy crop production – are very uncertain, and subject to widely different opinions. For example, the biomass supply from plantations in 2050 ranges from below 50 EJ/a to about 240 EJ/a. As well, the expectations about future availability of forest wood and of residues from agriculture and forestry vary substantially among the studies.

The studies reviewed illustrated what a future large-scale bioenergy supply of several hundred EJ/a could look like, and that such a supply is indeed technically feasible (77). The question of how an expanding bioenergy sector would interact with other land uses, such as food production, biodiversity, soil and nature conservation, and carbon sequestration was found to be insufficiently analysed in the studies. It is therefore difficult to establish to what extent bioenergy is an attractive option for climate change mitigation in the energy sector. Integrated land-use/energy-economy models were regarded as most suitable for a more comprehensive assessment of the prospects for biomass in a future sustainable global energy supply. A refined modelling of interactions between different land uses and bioenergy, food and materials production – i.e., of competition for resources, and of synergies between different uses – would facilitate an improved understanding of the prospects for large-scale bioenergy and of future land-use and biomass management in general.

In the studies of Fischer and Schrattenholzer (73) estimates of world regional potentials of the sustainable use of biomass for energy uses through the year 2050 were presented. Estimates were based on a classification of total land into four major land-use categories: arable land, grassland, forests and “other” land. The bioenergy was classified into five bioenergy categories: crop residues, energy crops, wood from forests and forest residues, animal waste, and municipal waste. The total bioenergy potential of the base year 1990, was estimated at 225 EJ or 5.4 Gtoe. By the year 2050, this potential was estimated to have grown to between 370 and 450 EJ (8.8 and 10.8 Gtoe) (Figure 13). The potential growth occurs in all categories considered. The slowest growth occurs in the crop residues category.

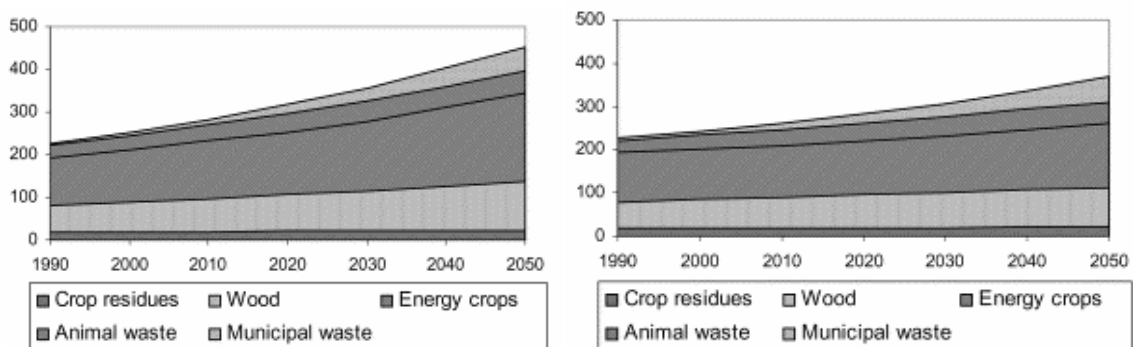


Figure 13. Global bioenergy potentials (EJ) as high and low estimates in 1990–2050 (73).

The estimated potentials of Fischer and Schrattenholzer (73) are consistent with scenarios of agricultural production and land use developed at the International Institute for Applied Systems Analysis (IIASA). They thus avoid inconsistent land use, in particular conflicts between the agricultural and bioenergy land use. According to a global energy scenario with high economic growth and low greenhouse gas emissions, developed by IIASA and the World Energy Council (WEC) (71), bioenergy contributes

153 EJ to global primary energy supply by 2050. This scenario was summarised by Fischer and Schrattenholzer (73) with their potential estimate, to express a fairly favourable but not extreme assumption that bioenergy could contribute more than 150 EJ to global primary energy supply by the year 2050. Such a contribution is consistent with a scenario of global food production that makes comparable assumptions about global economic growth and technological developments.

## **4.2 European potential of biomass for energy**

### **4.2.1 Analysis of potential biomass supply quantities**

According to Hall (64) biomass energy supply in 1997 was at least 2 EJ/a in Western Europe, representing about 4% of the then primary energy use of 54 EJ. Estimates show a likely potential in Europe in 2050 of 9.0–13.5 EJ/a depending on land areas (10% of useable land, 33 Mha), yields (10–15 oven-dry tonnes/ha/a), and recoverable residues (25% of harvestable). The relative contribution of biofuels in the future depends on markets and incentives, on continuous research and development, and on environmental requirements. The proportion of the current bioenergy use of the total potential in Europe is 22% according to Table 4 (78) showing a large energy potential for biomass in Europe. Estimates of biomass energy use in EU25 in 2004 (60–62) amounted to 2.8 EJ corresponding to about 4% of the gross inland energy consumption.

Biomass availability in Europe has recently been evaluated in the project “Bioenergy’s role in the EU Energy Market” (Lot 5) (79). The purpose of the study was to prepare supply curves for biomass fuels in terms of qualities, quantities and costs in Europe for the further assessment of the role of biomass in the European market. The 24 European countries considered were the older EU Member States except Luxembourg (here later referred to EU15), and the New Member States except Malta and Cyprus, in addition to the two candidate countries Bulgaria and Romania (hereafter referred to EU10+2 and in Figures 14–17 to Accession countries).

In the “Lot 5” study (79), the work was organized in four different tasks: classification of biomass sources according to fuel quality and supply sector; analysis of potential supply quantities; analysis of delivery costs; and analysis of the sectors that serve as biomass suppliers, i.e. agriculture, forestry, industry and wastes. The biomass resources considered were classified in agricultural, forest, industrial and waste biomass categories. ‘Agricultural’ biomass includes agricultural residues (straw, orchard prunings, corn stems and cobs), livestock wastes (wet animal manure, dry manure) and energy crops (perennial grasses, short rotation coppice, oil crops, sugar and starch crops). ‘Forest’ biomass includes wood fuel and forest residues produced during logging

activities, forest thinnings and cleanings. ‘Industrial’ residues includes residues produced mainly from forest and food industry, either dry lignocellulosic material (sawdust, husks, kernels) or wet cellulosic material (sugar bagasse), and, in addition, black liquor. ‘Biomass waste’ consists of demolition wood, municipal solid waste, landfill gas and sewage sludge gas. This is the first resource assessment to find country information on the technical resource potential, defined as the total annual production of all resources given no limits, as well as country information on the available resource potential, defined as all resources available with estimated, realistic limits. Finally the energy potential of different biomass resources is estimated. The reference year for the data is 2000. Current use and resource potential of the different biomasses are presented in Figures 14–17.

In the EU15 countries agriculture occupies 40% (130 million ha) of the total land area (323 million ha) (79). Agricultural activities lead to the production of a large amount of agricultural residues and by-products. The total resource potential of agricultural crop residues is estimated at 1 064 PJ/a (25 Mtoe) for the EU15 and at 306 PJ/a (7 Mtoe) for the EU10+2 (Figure 14). The respective values for livestock waste are 600 PJ/a (14 Mtoe) and 132 PJ/a (3 Mtoe). According to the data collected, the total arable land in the EU in 2000 was 73.5 million ha from which 5.6 million ha were included in the set-aside scheme, and in the EU10+2 countries 44.1 million ha from which 2.2 million ha can be considered available for the cultivation of energy crops.

The European continent is made up of nearly 215 million ha of forests and other wooded land, accounting in total for nearly 30% of the continent’s land area and about 5% of the world’s forests (79). The total energy potential of forest biomass in the EU15 was estimated at 1 292 PJ/a (31 Mtoe) and for the EU10+2 at 315 PJ/a (7.5 Mtoe) (Figure 15).

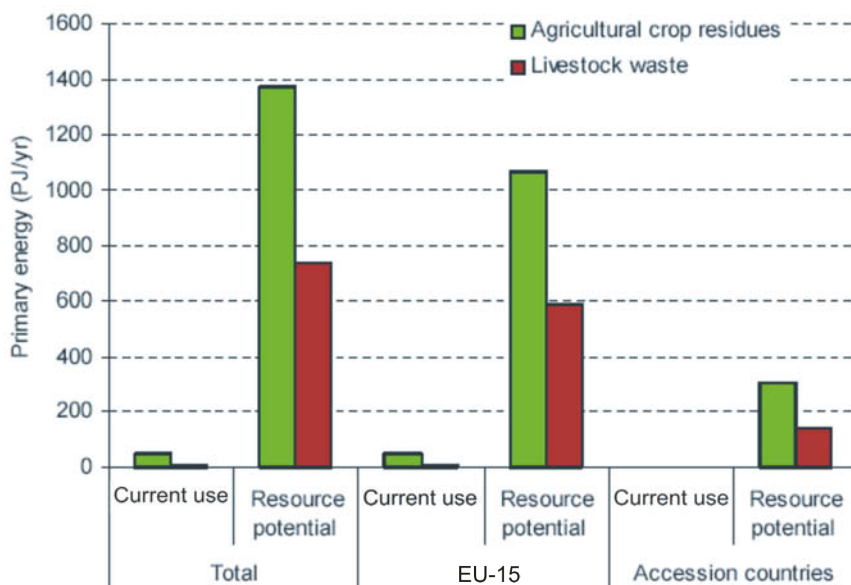


Figure 14. Current use and resource potential of agricultural crop residues and livestock waste in Europe (79).

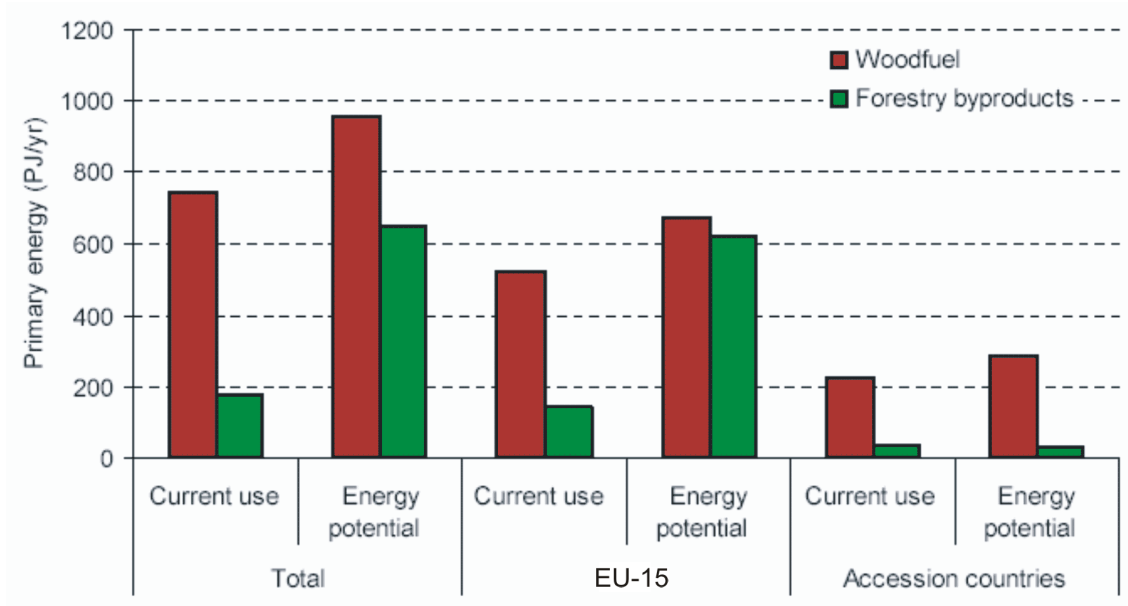


Figure 15. Current use and resource potential of forest biomass in Europe (79).

The total energy potential of industrial biomass and waste is estimated for the EU15 at 878 PJ/a (21 Mtoe) and for the EU10+2 at 229 PJ/a (5 Mtoe) (Figure 16). The total energy potential of waste in the EU15 was 736 PJ/a (18 Mtoe) and for the EU10+2 countries 110 PJ/a (3 Mtoe) (Figure 17).

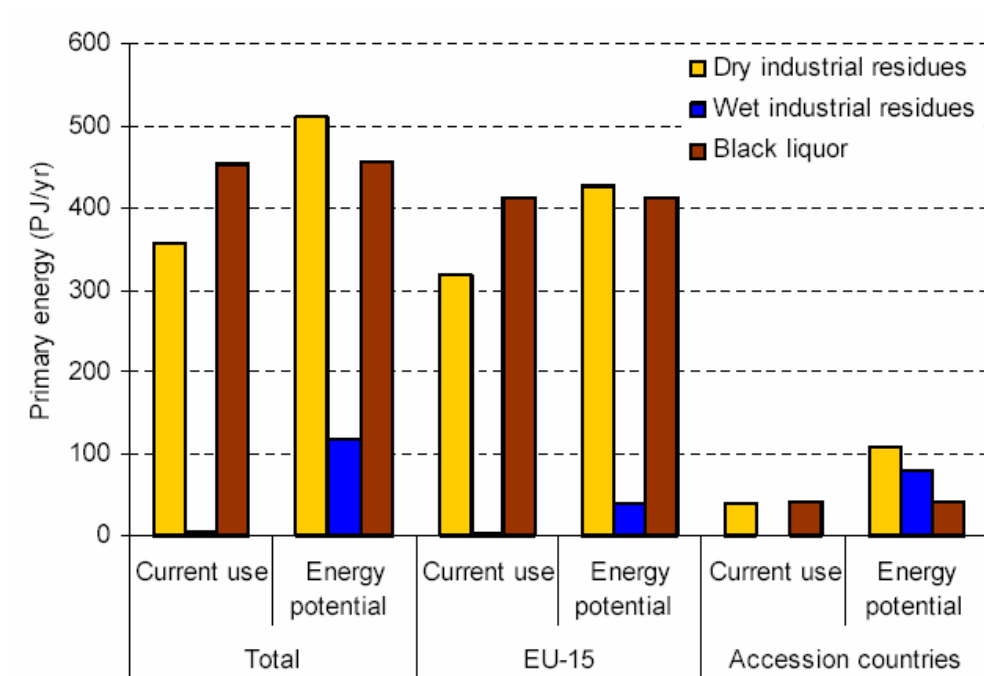


Figure 16. Current use and resource potential of industrial residues and waste in Europe (79).

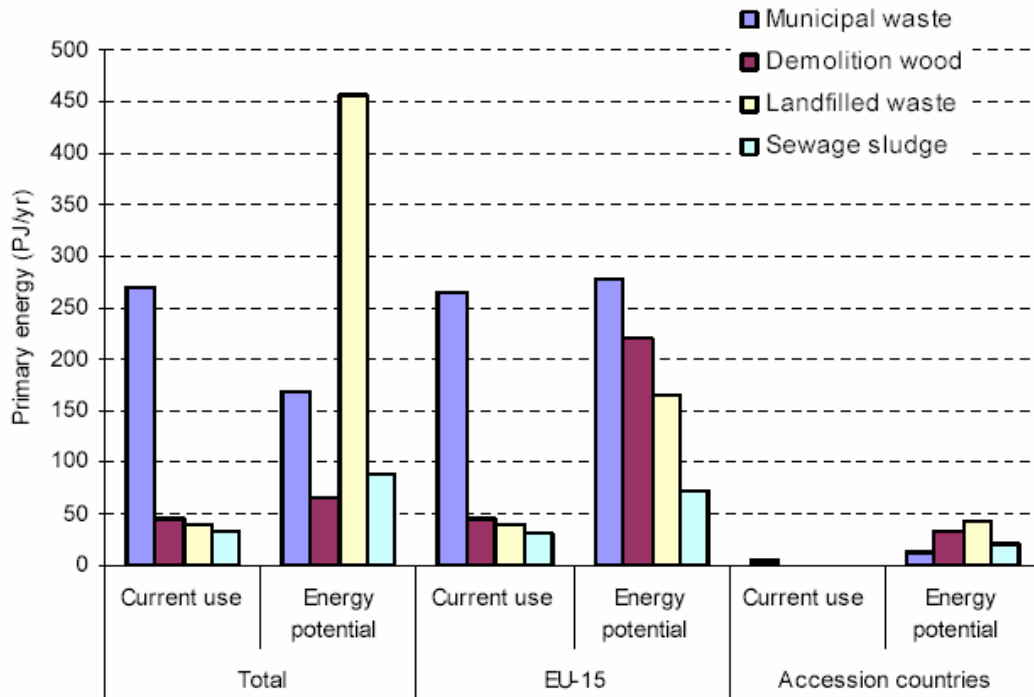


Figure 17. Current use and resource potential of biomass waste in Europe, Note: according to the text landfilled waste should be landfill gas and sewage sludge should be sewage sludge gas (79).

In the “Lot 5” study (79) estimated energy potential of solid agricultural residues and forest residues amounts to about 40 Mtoe (1 680 PJ) for the EU15, in line with the respective target 30 Mtoe (1 260 PJ) of the White Paper for renewable energies (3) for 2010. The White Paper estimates of biogas exploitation from agro-industry effluents, animal waste, sewage treatment and landfill for 2010 is 15 Mtoe (630 PJ). In the “Lot 5” study the respective estimate was 16 Mtoe (670 PJ). Further, in the European biomass survey by EUBIONET (80) the potential of the EU countries in terms of biogas production from animal waste, sewage sludge and landfill gas was estimated at nearly 18 Mtoe (750 PJ). To achieve the White Paper target of 45 Mtoe from energy crops in 2010, 10 million ha of land should be cultivated with these types of crops while only 5.6 million ha of arable land had been set-aside in the EU in 2000 (79). A surface area of 17 million ha will be necessary in 2010 based on the EU25 (80).

The delivery cost of the different types of biomass for the different European countries are recorded and analysed if possible in the following cost factors: production costs of biomass fuels, transportation costs from production site to energy conversion plant, and other costs, such as storage and handling (79). In the cases where biomass had an alternative market and therefore an opportunity cost, this cost is also recorded separately. Since the collection of reliable data for biomass was difficult, cost ranges in the results are used.



The cost of biomass is an important element in the cost of produced energy contributing 40% to 50% to the cost of electricity (79). The cost of crop residues in the EU15 ranges from 1.4 to 6.45 €/GJ and in the EU10+2 from 1.5 to 2.65 €/GJ. The cost of energy crops for solid biofuels in the EU15 ranges from 1.72 to 4 €/GJ and in the EU10+2 between 1.82 and 18.6 €/GJ. Limited information on the cost of energy crops for biodiesel production is found, recorded costs range from 4.5 to 24.28 €/GJ in the EU15 and from 5.6 to 14.24 €/GJ in the EU10+2. Information on the cost of energy crops for bioethanol production is only given for France (20.8 €/GJ) and Spain (9.2 €/GJ). In the EU10+2 these costs range from 3.3 to 22.75 €/GJ. The cost of woodfuel in the EU15 ranges from 2.1 to 8.7 €/GJ and in the EU10+2 from 1.05 to 7 €/GJ. The cost of forestry by-products in EU15 ranges from 1.4 to 6.7 €/GJ and in the EU10+2 between 0.8–7.7 €/GJ. The cost of solid industrial residues in the EU15 ranges between 0.92–3.3 €/GJ and in the EU10+2 between 0.8–6.9 €/GJ.

Based on market trends and policy developments, the future potential of biomass resources in Europe was analysed in the “Lot 5” study (79) (Table 5).

*Table 5. Future trends in biomass availability in Europe (79).*

Sector	Resource	Fuel category	2010 increase or decrease of available biomass energy potential compared to 2000	2020 increase or decrease of available biomass energy potential compared to 2000	Comment
Agriculture	Dry crop residues	Dry lignocellulosic	10%	20%	+1% a year
	Livestock waste	Wet and dry lignocellulosic	5%	10%	+0.5% a year
		Set aside or idle agricultural	10%	20%	+1% a year
	Energy crops				
Forestry	Woodfuel	Dry lignocellulosic	10%	20%	+1% a year
	Forestry	Dry lignocellulosic	10%	20%	+1% a year
Industry	Industrial residues	Dry lignocellulosic	10%	20%	+1% a year
		Wet cellulosic	20%	40%	+2% a year
		Black liquor	10%	20%	+1% a year
Waste	Regulated waste	Municipal waste	10%	20%	+1% a year
		Demolition wood	10%	20%	+1% a year
	Non-regulated waste	Landfilled waste	-30%	-60%	-3% a year
		Sewage sludge	20%	40%	+2% a year

According to the “Lot 5” project (6) a total availability of biomass fuels in the EU15 is 130 Mtoe/a (5 450 PJ/a) for the year 2000, growing to 170 Mtoe/a (7 120 PJ/a) in 2020 (Table 6). Added with the EU10+2, the respective values amount to 160 Mtoe/a (6 700 PJ/a) in 2000 and 210 Mtoe/a (8 800 PJ/a) in 2020. These overall figures are indicative. An inaccuracy in the range of  $\pm 10\%$  in these figures is the result of an assumption on land use for energy crops, i.e. that the current set-aside area (about 10% of the arable land) is available for energy cropping, and that 50% of that area is available for the raw materials of bio-diesel and bio-ethanol. If instead, solid energy crops are produced here, the figures presented would increase by 10 Mtoe/a (420 PJ/a). If on the other hand, liquid biofuels replace the preferential energy crops, the availability would drop by 10 Mtoe/a (420 PJ/a).

*Table 6. Availability of bioenergy (Mtoe/a) in Europe in 2000, 2010 and 2020 (6).*

	EU15			Accession States + BG, RO		
	2000	2010	2020	2000	2010	2020
<b>Tradeables:</b>	<b>86</b>	<b>93</b>	<b>101</b>	<b>21</b>	<b>22</b>	<b>24</b>
Forestry byproducts & wood fuels	34	38	42	7.9	8.7	9.6
Solid agricultural residues	25	28	31	7.3	8.1	8.9
Solid industrial residues	11	12	13	2.1	2.4	2.6
Solid energy crops <sup>a)</sup>	16	16	16	3.2	3.2	3.2
<b>Non-tradeables:</b>	<b>40</b>	<b>53</b>	<b>66</b>	<b>7.1</b>	<b>9.4</b>	<b>13</b>
Wet manure	11	12	13	3.4	3.8	4.2
Organic waste:						
– Biodegradable municipal waste	6.7	17	28	0.5	2.5	5.7
– Demolition wood	5.3	5.8	6.4	0.6	0.6	0.7
– Dry manure	1.9	2	2.3	0.4	0.4	0.5
–Black liquor	9.9	11	12	0.7	0.8	0.9
Sewage gas	1.7	1.9	2.1	0.4	0.4	0.5
Landfillgas	4.0	3.8	2.1	1.1	0.9	0.4
<b>Transport fuels:</b>	<b>4.9</b>	<b>4.9</b>	<b>4.9</b>	<b>0.8</b>	<b>0.8</b>	<b>0.8</b>
Bio-ethanol <sup>a)</sup>	3.7	3.7	3.7	0.5	0.5	0.5
Bio-diesel <sup>a)</sup>	1.2	1.2	1.2	0.3	0.3	0.3
<b>Total bio-energy</b>						
<b>Mtoe/a</b>	<b>131</b>	<b>151</b>	<b>172</b>	<b>28</b>	<b>32</b>	<b>38</b>
<b>EJ/a</b>	<b>5.49</b>	<b>6.33</b>	<b>7.21</b>	<b>1.17</b>	<b>1.34</b>	<b>1.59</b>

a) It is assumed that 50% of the set-aside area is available for solid energy crops and 25% each for biodiesel and bioethanol.

The availability of tradeable biofuels in the EU15 amounts to 86 Mtoe/a (3 600 PJ/a) in 2000 and to 100 Mtoe/a (4 200 PJ/a) in 2020, and that of non-tradeable biofuels amounts to 40 Mtoe/a (1 680 PJ/a) in 2000 and 66 Mtoe/a (2 765 PJ/a) in 2020 (Table 6) (6). The total availability of tradeable biofuels added with the EU10+2, amounts to 107 Mtoe/a (4 480 PJ/a) in 2000 and to 125 Mtoe/a (5 240 PJ/a) in 2020. The respective values for non-tradeable biofuels amount to 47 Mtoe/a (1 970 PJ/a) and to 80 Mtoe/a (3 350 PJ/a). The growth in the availability of organic wastes is the most striking, due to the Landfill Directive (40). On average, supply costs of tradeable biomass fuels varied from 1.6 €/GJ (solid industrial residues) to 5.4 €/GJ (solid energy crops). Single average supply costs of 23–29 €/GJ were determined for bio-ethanol and bio-diesel.

#### **4.2.2 Estimation of energy wood potential**

The energy wood potential in Europe was recently estimated by Karjalainen et al. (81). The work is divided into estimation of roundwood balance and estimation of felling residues. The study is limited to the forests available for wood supply. Roundwood balance, which is the difference between the net annual increment and fellings, illustrates the unutilised increment that could be used for industrial purposes, energy production or left in the forests. Felling residues that are usually left in forests are becoming an increasingly important source of wood-based energy production.

Forest resources in Europe have increased in the last 50 years (81). Roundwood balance is approximately 186 million m<sup>3</sup>/year or 32% of the net annual increment (Figure 18). The roundwood balance has been highly positive for a long time, and thus an increasing amount of wood is accumulating in the forests, resulting in denser forests and older age class structures. Roundwood balance can be regarded as a surplus or reserve that is currently left in the forests. Competition for wood resources is increasing and fulfilment of the demands for industrial use, energy production and protection require compromises. Use of roundwood directly for energy purposes depends on the prices of roundwood, sawnwood, pulp, paper and energy. Estimating how much of the unutilised increment could and would be utilised in the future for energy purposes is difficult. Most likely, more wood for energy production will be used than today.

The potential sources of forest fuels are felling residuals and stumps from current fellings and the roundwood balance, consisting of the stem wood balance, its crown mass and stump wood (81). It is estimated that annual felling residues total 173 million m<sup>3</sup> (Figure 18). Annually harvestable residues are estimated to be 63 million m<sup>3</sup>. In addition, about 9 million m<sup>3</sup> stump wood (out of 78 million m<sup>3</sup> of total potential) could be used for energy production. When 25% of the roundwood balance is directed to energy use, 64 million m<sup>3</sup> of above ground biomass and about 4 million m<sup>3</sup> of stump

wood could be used for energy annually. Thus the available forest fuel totals about 140 million m<sup>3</sup> per year, or about 56 million oven-dry tonnes of wood, equivalent to about 280 TWh of energy or 24 Mtoe (1 000 PJ). This would be about 24% of the current use of renewables in the EU25. For comparison, available forest fuels constitute about 37% of the current annual fellings. Volumes of available felling residues and stump/root biomass in the top 10 EU countries having highest available potential are presented in Figure 19.

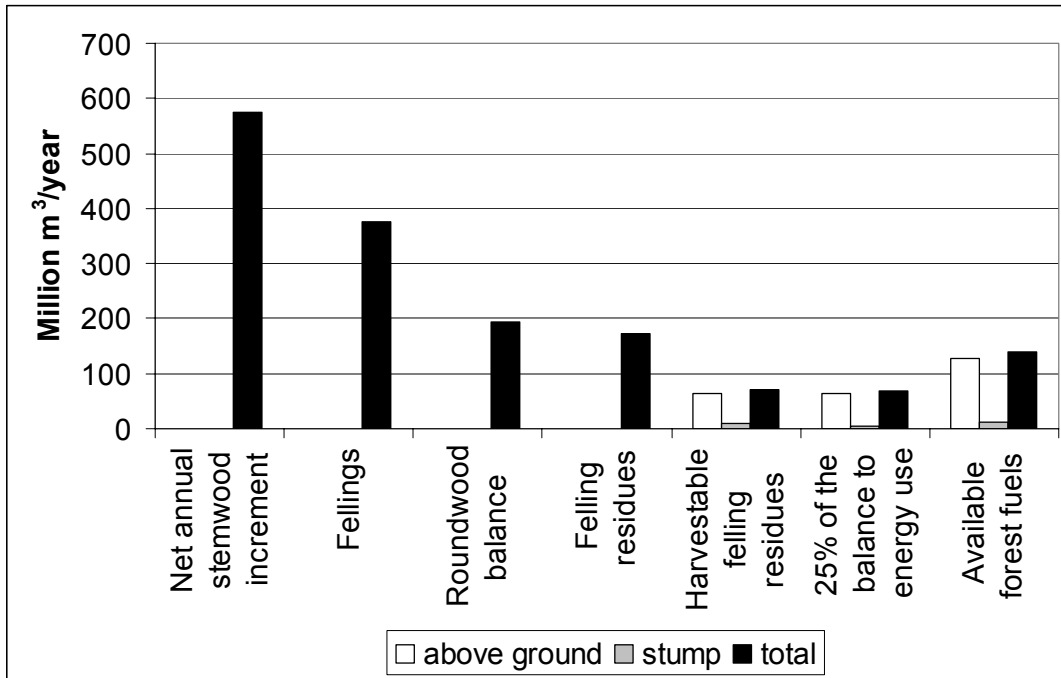


Figure 18. Net annual stemwood increment, fellings, roundwood balance, felling residues and available forest fuels in the EU25 on forests available for wood supply, 1 million m<sup>3</sup>  $\cong$  2 TWh (81).

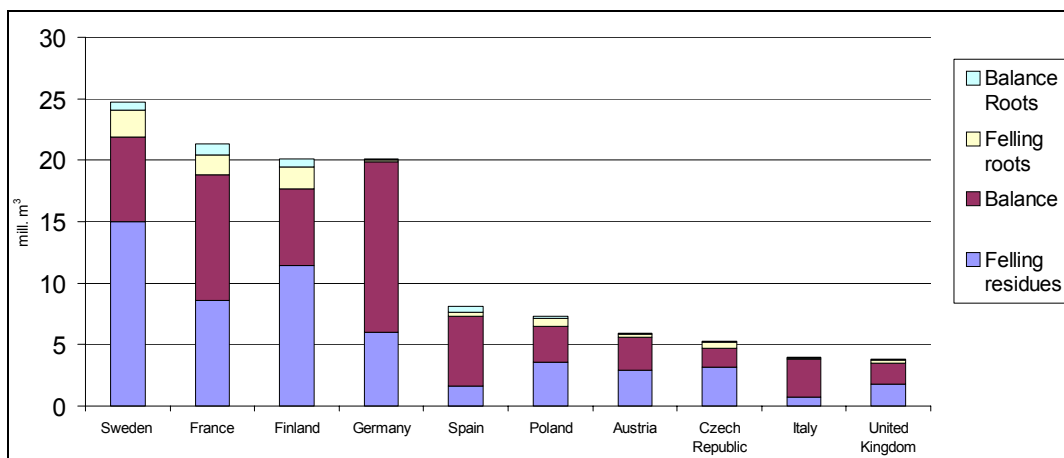


Figure 19. Volumes of available felling residues and stump/root biomass in the top 10 EU countries having highest available potential, 1 million m<sup>3</sup>  $\cong$  2 TWh (81).

The estimate of the available forest fuels 24 Mtoe, of Karjalainen in the EU25 is considerably lower than the estimate of the “Lot 5” project, about 35 Mtoe (1 470 PJ) for the EU25. Reasons for the differences may be in the defining of forest fuels and in the methods used in estimation. In the “Lot 5” project the forest resources included (refined) wood fuels and forest residues. The studies of Karjalainen et al. are limited to the forests.

Estimation of economic availability of felling residues was carried out for Finland, France, the Netherlands and Poland (81). The radius of the procurement district around the plant in a country is defined by the annual use of forest fuels at the plant and the annual harvestable amount of forest fuels in the surroundings of the plant. The annual harvestable amount varies considerably in different parts of Europe. This impacts on long distance transport costs in particular. In addition, site conditions and mix of harvestable fuel can also vary considerably within the country. The study presents country averages, while regional differences are only discussed.

The availability of felling residues is based on the total potential of the residues. Share of timber coming from clear-cuts is 24% in the Netherlands, 44% in Poland, 76% in France and 70% in Finland. The availability of chips from felling residues in each country is expressed in terms of an annual availability of fuel (solid volume of green biomass), around consumption point (e.g. power and district heating, plant) at a given marginal cost of fuel delivered at the plant. Hourly cost structures of a forwarder and a chipper differ considerably between eastern and western Europe primarily due to differences in the labour, fuel and capital costs. Also, organization and machinery employed in the supply chain could be different. In the study, a fairly common supply chain is used in all three countries to make the results comparable.

The annual availability by given fuel cost at plant is obtained in the following manner. Roadside costs for chips are calculated for average conditions in each country. The average cost of chips at the roadside was first determined based on the productivity and hourly costs of forwarding and chipping. The road transport cost is then added by increasing the radius gradually in 10 km intervals. The radius of the procurement area is determined as transport distance along the road network. The winding coefficient is used to reduce the effective area. The quantity of chips that could be harvested from that radius is simply determined by multiplying the area by the density of material.

When availability and harvesting cost figures are summarized, the cumulative availability of felling residues and their costs delivered at the plant can be estimated (Figure 20). By the marginal price 20 €/m<sup>3</sup> (10 €/MWh or 2.8 €/GJ) a plant is able to get about 370 000 m<sup>3</sup>/a (0.74 TWh, 2.7 PJ) of fuel in Finland and 470 000 m<sup>3</sup>/a (0.94 TWh, 3.4 PJ) in Poland, but none in France and in the Netherlands. If the marginal cost is raised to 30 €/m<sup>3</sup> (15 €/MWh or 4.2 €/GJ), the available amount of fuel at a plant

located in France would be close to 180 000 m<sup>3</sup>/a (0.36 TWh, 1.3 PJ) and in the Netherlands about 60 000 m<sup>3</sup>/a (0.12 TWh, 0.4 PJ).

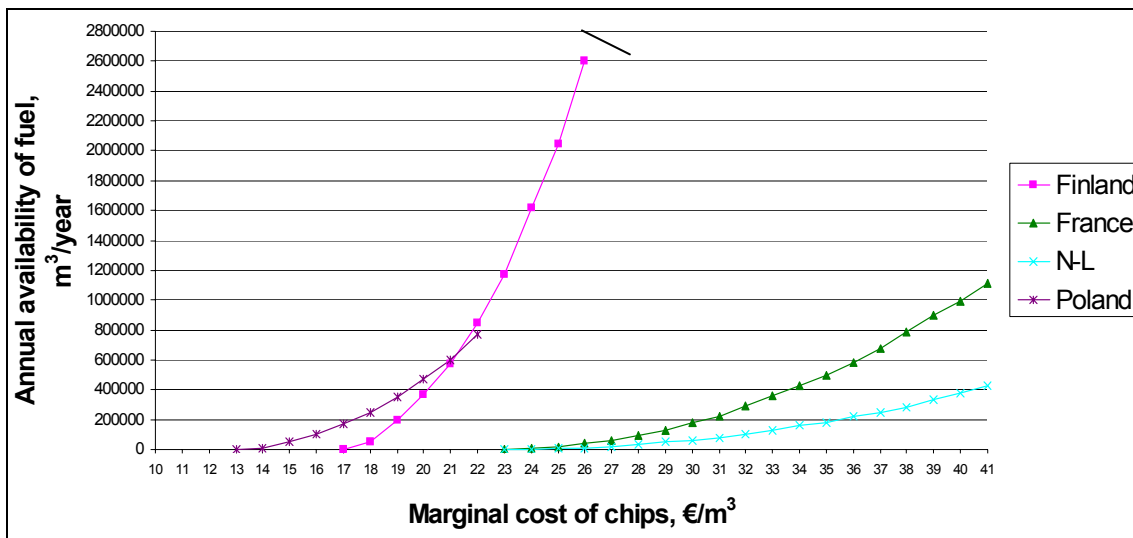


Figure 20. Cumulative availability of felling residues at given marginal costs (cost of fuel delivered at plant) in Finland, France, Poland and the Netherlands and examples of respective radius of procurement area defined as the distance along the road network, 1 mill m<sup>3</sup>  $\cong$  2 TWh (81).

#### 4.2.3 Biomass potential in the Biomass Action Plan

The European biomass potential was estimated in 2005 within the Biomass Action Plan (31). If the EU made full use of its potential, it would more than double biomass use by 2010 – while complying with good agricultural practice, safeguarding sustainable production of biomass and without significantly affecting domestic food production. According to the estimates for the EU25 (Table 7), the potential for 2010 is 2½ times the contribution today, the potential for 2020 is 3 to 3½ times and the potential for 2030 is 3½ to 4½ times that of today. Forests, wastes and agriculture are the main contributors to this potential for growth. The increase from forestry comes from both fellings and use of residues. The increase from agriculture is driven by the reform of the CAP. The Commission estimates that the measures of the Biomass Action Plan could lead to an increase in biomass use to about 150 Mtoe (6,3 EJ) in 2010 or soon after. This is less than the full potential; but it is in line with the indicative renewable energy targets.

Table 7. EU biomass production potential (31)<sup>a)</sup>.

<b>Mtoe</b>	<b>Biomass consumption 2003</b>	<b>Potential 2010</b>	<b>Potential 2020</b>	<b>Potential 2030</b>
Wood direct from forest (increment and residues)	67 <sup>b)</sup>	43	39–45	39–72
Organic wastes, wood industry residues, agricultural and food processing residues, manure		100	100	102
Energy crops from agriculture	2	43–46	76–94	102–142
<b>Total, Mtoe</b>	<b>69 (2,9 EJ)</b>	<b>186–189 (7,8–7,9 EJ)</b>	<b>215–239 9,0–10 EJ)</b>	<b>243–316 10–13 EJ)</b>

a) Sources: 2003 data (4), projections for 2010, 2020 and 2030 (82).

b) The figure includes 59 Mtoe of wood and wood wastes; 3 Mtoe of biogas; and 5 Mtoe of municipal solid waste.

A scenario of the Biomass Action Plan (31) to increase biomass energy using current technologies is presented in Table 8. The scenario is drawn from the 2004 communication (14) expanded to the EU25 and it is compatible with achievement of the Community's targets. The Commission believes that this scenario can be achieved in three sectors – electricity, heat and transport – through the measures in the Action Plan – if not in 2010, then within a year or two of that date. The scenario serves as the basis for the impact assessment on this Communication.

Table 8. A scenario to increase biomass energy using current technologies (31).

<b>Mtoe</b>	<b>Current (2003)</b>	<b>Future (2010)</b>	<b>Difference</b>
Electricity	20	55	35
Heat	48	75	27
Transport	1	19	18
<b>Total</b>	<b>69 (2,9 EJ)</b>	<b>149 (6,2 EJ)</b>	<b>80 (3,4 EJ)</b>

The Commission is preparing a forestry action plan, to be adopted in 2006 that will address energy uses of wood. The Commission will review the impact of the energy use of wood and wood residues on forest based industries.

### **4.3 Barriers in land-use change and biomass resources**

Within the Bioenergy NoE, barriers to bioenergy related to land-use change and biomass resources have been analysed and identified and are presented below.

“Land use change” is defined as effects of changing land use patterns and land use functions on ecosystems and economy. Land is the very first element of the whole bioenergy chain, moreover the following steps are in some sense a consequence of biomass availability. Land availability is the main limiting factor for biomass production. The importance of biomass availability causes the need for land use change analysis, where a deeper look into feedstock genesis is most important.

The common economic barrier is the profitability issue of land conversion into biomass production for energy in relation to the present land utilisation. The present land utilisation for agricultural purposes has been stabilized and fixed by complex subsidy systems and market configurations. Different conversion directions such as food, biomass production, and set-aside land, can be distinguished. A strong barrier appears when a new production profile is becoming reality. A crucial driving force is production profitability, on which the CAP has the most important influence. The planned CAP reform will contain regulations dedicated directly to energy crops. Therefore the changes in the subsidy mechanism and recognition of the importance of energy crop production are designed to make land use conversion more profitable.

Land use in the context of biomass production is regulated by agricultural, environmental and energy category regulations. The energy regulations are a driving force, while agricultural and environmental regulations provide some economic incentives and restrictions. Besides European directives, there are national regulations reflecting specific circumstances that must be carefully examined. The most important legislation barriers at the European level are current subsidy mechanisms for agricultural production, land status and environmental constraints. At the national level, barriers are forestry programmes and acts, forestry owning structure, and environmental restrictions related to the exploitation of peatlands. From the sectorial perspective, interaction on the legislative level between agriculture, forestry and energy is crucial.

Procedural barriers are connected with the investment processes. Energy crop cultivation and bioenergy plants are not formally fixed into the legal planning process. A lack of unique guidelines for binding resources, local conditions and suggested technology is an important procedural barrier.

Biomass supply needs to be considered in supply-demand relation with strong attention to the level of analysis. Complications of biomass assessments are inversely



proportional to the level of analysis. At the regional level, where medium and large-scale bioenergy plantations are operating, there is a strong need for reliable biomass assessments with operational delivery plans. Land productivity seems to be the most common barrier. It is very likely that policies assign and favour mainly low quality land for energy crops which can produce insufficient yields. The agricultural production system is also important especially in countries where an extensive production system is dominating. In the use of forest residues for energy purposes there are still strong barriers. Even in Nordic countries with well developed forest technologies there is unused potential. Transport distances and associated costs are common barriers for all agro and forestry resources.

For investors at the practical level, natural supply constraints of biomass availability are basic barriers. Large plants naturally demand a wider availability analysis. Further, competition for biomass between sectors, as well as competition in the internal bioenergy market, is a crucial barrier.

Sustainability in terms of exploiting bioenergy resources can be defined in terms of maintaining biodiversity and reducing environmental impact. The consideration of special status areas, such as protection and conservation, is very crucial. Therefore, barriers are connected to biodiversity, environmental requirements and long-term effects of biomass production. Those issues justify the incorporation of an ecosystem perspective into land use change programmes, including enlargement of energy crop plantations.

Referring to the already utilized biomass resources, additional aspects are assurance of appropriate nutrient circulations in forest management and implementing good practices for energy crops. In the case of forest management, well elaborated good practices exist, but a lack of long-term practical experience in the exploitation of forest residues is still a barrier for making sustainable management a reality. Similar barriers can be pointed for energy crops, good practices guidelines are urgently required.

The majority of social barriers identified by Bioenergy NoE pinpoint public perception of bioenergy development. While in principle the public is aware of bioenergy, raw material production seems to be unknown. Public opposition is often a result of social barriers connected to landscape intrusion, monoculture and introduction of industrial cultivations. On the other hand, biomass production can have positive effects on rural development and employment and help to increase diversification of energy sources at the same time. The barrier then is a lack of public awareness and education campaigns. Convincing the agricultural sector, which in principle is accustomed to traditional production profiles, is a real challenge. Wood fuel utilization, on the contrary, has long traditions and high public awareness.

## 4.4 Conclusions of the potential biomass resources

Several studies have been carried out on the biomass energy potential today and for the future. In the studies, biomass resources have been classified into different categories in various ways. The main classifications are agricultural residues, forest residues, wood from forest, energy crops, and wastes.

At present about 40 EJ of the available biomass in the world is used annually for energy. The present global biomass energy potential has been projected to be 100–270 EJ. Estimates of the future potential range very widely. The potential through the year 2050 has been quantified at 33–1 135 EJ/a. In many estimates the potential is about 100–400 EJ in 2050. Concerning different continents, the widest reserves are in Africa and Latin America. Large potentials also exist in North America, Europe and the Russian Federation.

In Europe the use of biomass and wastes for energy production is presently about 3 EJ/a. The potentials for the years 2010 and 2020 are calculated to be about 8 and 9 EJ/a, respectively. The potential in 2050 is estimated to range from 9 to 13.5 EJ/a. According to the studies, biomass resources and potentials in Europe are considerably large. However the potentials estimated are often theoretical and too optimistic.

Future bioenergy potentials will be affected by many factors including future demand for food, productivity of forest and energy crops, availability of degraded land, competing land use types, recoverable residues, environmental requirements, markets and incentives, and continuous research and development progress.

EU goals for bioenergy use are ambitious. To reach the targets forest resources, agricultural biomass and biogenic urban wastes are needed. Based on the estimates of biomass potentials it is probable to reach the EU White Paper targets for 2010. However, to achieve the target set for energy crops it has been calculated that 10 million ha in the EU15 and 17 million ha in the EU25 need to be cultivated, corresponding around 14% of agricultural area.

If more stringent goals are set for bioenergy in the future, for example the suggested 20% contribution of transport fuels by biofuels in 2020, the availability and the price of biomass will be limiting factors for the expected growth. Importing biomass from outside the EU, for example from the Southern Hemisphere to Europe, could help boost insufficient European biomass resources.

A crucial driving force is production profitability, on which the CAP has the most important influence. Energy regulations are a driving force, while agricultural and environmental regulations provide some economic incentives and restrictions. Important

barriers on the European level are current subsidy mechanisms for agricultural production, land status, and environmental constraints. Land productivity can also be an important barrier.

Public opposition to bioenergy production creates social barriers which are connected with landscape intrusion, monoculture and introduction of industrial cultivations. On the other hand, biomass production can have positive effects on rural development and employment.

## **5. Bioenergy technologies and related barriers**

### **5.1 Feedstock production**

#### **5.1.1 Production technology of forest chips**

The development of production technology of forest chips presented in the following is based on the results of a “Wood Energy Technology Programme” of Tekes, the National Technology Agency in Finland (84). A forest chip production system consists of a sequence of individual operations performed to process biomass into commercial fuel and to transport it from source to plant. The main phases of chip procurement are purchase, cutting, off-road transport from stump to roadside, comminution, measurement, secondary transport from roadside to mill, and receiving and handling at the plant. The system offers the organization, logistics and tools to control the process.

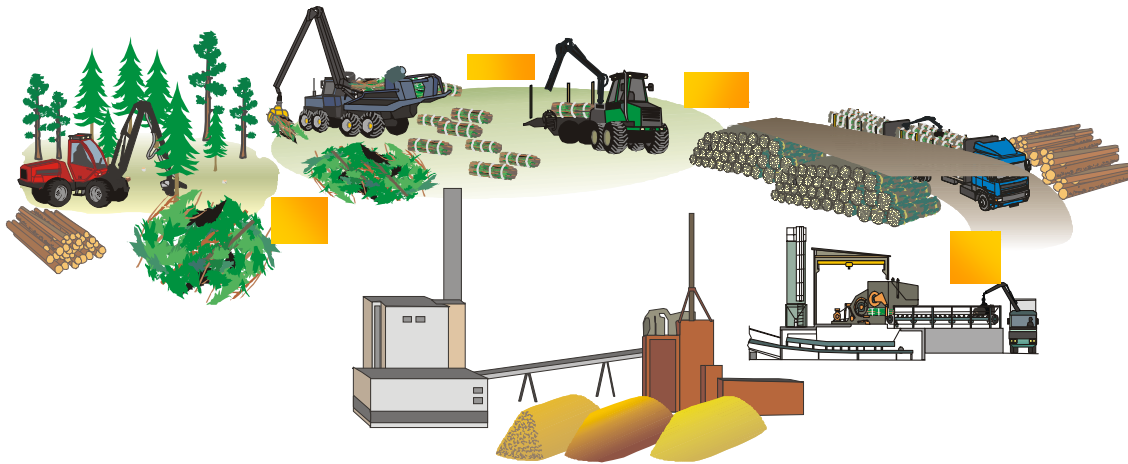
The efficiency of a procurement system is highly dependent on the environment and infrastructure in which it is operating. In addition, economic, social, ecological, industrial and educational factors, as well as local traditions, have an effect on the efficiency. Consequently, no single production system is optimal in all countries, or in all conditions within a given country. Production processes need to be improved in order to reach the targets given for bioenergy and make forest chips a viable alternative to other fuels. Every link in the production chain has to be optimised to improve profitability without compromising on quality and supply security.

A forest fuel production system is built around the comminution phase. The position of the chipper or crusher in the procurement chain largely determines the state of biomass during transportation and, consequently, whether subsequent machines are dependent on each other. Comminution may take place at the road side or landing site, at the source, at a terminal, or at the plant where the chips are to be used.

Comminution at the landing is the traditional option of forest chip production. The biomass is hauled by forwarders to the landing and bunched into 4 to 5 m high piles. Comminution is performed at the landing. Comminution in the terrain, or at the source, requires a highly mobile chipper suitable for cross-country operations equipped with a tippable 15–20 m<sup>3</sup> chip container.

Comminution at the plant makes the chipper and chip truck independent of each other (Figure 21). The technical and operative availability of the equipment increases, control of the procurement process is facilitated, demand for labour is decreased, and the control of fuel quality is improved. The larger the fuel flow, the more obvious the advantages become. Since the investment cost is high, only large plants can afford a

stationary crusher. The low bulk density of the biomass is the weak link in the system, because truck transportation takes place in the form of loose logging residues.



*Figure 21. Forest fuel production system based on comminution at a plant. Logging residues are from final harvest (84).*

In recent years, truck transportation of uncomminuted biomass has been developed. In a new system, logging residues are compressed and tied into 70 cm diameter, 3.2 m long bales or composite residue logs (Figure 21). A bale of green residues weighs 500 kg and has an energy content of about 1 MWh (3,6 GJ). Bales are transported to the road side using a conventional forwarder and on to the plant using a conventional timber truck. With many indirect cost savings and better supply security, bundling has proved to be an effective solution for large-scale forest chip production.

The system based on residue bales and comminution at a plant was developed in the “Wood Energy Technology Programme” (84) jointly by the companies UPM-Kymmene Oyj, Pohjolan Voima Oy, Oy Alholmens Kraft Ab and Timberjack to supply forest biomass to the world’s largest biofuel-fired CHP plant of Alholmens Kraft in Finland. Since then, several large plants have installed a stationary crusher and started to apply the same technology. At the beginning of 2004, 24 residue balers were operating in Finland. Their total capacity is 0.6 million m<sup>3</sup> or 1.2 TWh/a (4.3 PJ), corresponding to one third of the forest chips used by all heating and CHP plants.

Production logistics refers to the control of fuel flow from stump to plant. Developing the logistics is aimed at improving the operational availability, rather than the technical availability, of machines deployed by a fuel procurement system. From the viewpoint of logistics, large-scale production of forest chips is a demanding task. In the development of logistics moving comminution to a plant or terminal was found to be an effective measure. By means of forest residue bales the system becomes less vulnerable, waiting times between machines are eliminated, winter storage is facilitated and the entire

process becomes easier to control. The current baling technology is only suitable for large-scale operations, and a precondition is a crusher at the plant. Nevertheless, it remains more common for forest fuels to arrive at a plant as chips.

Machine compatibility has not been achieved in the procurement of forest chips, because logging conditions vary from the early non-commercial thinning of young stands to the final harvest of mature stands, and the technology is still new. Several alternative production systems are in use, and each system employs special equipment that is not necessarily compatible with other systems. Whenever possible, it is preferable to use conventional equipment for the harvesting and transportation of forest biomass. However, special equipment is needed in many phases of the chain.

The state of feedstock production development concerning forest residues differs greatly between different EU countries. The insufficient availability of low-cost biomass is a problem. Lack of suitable and cost-effective harvesting technology exists in many countries, for example no technology is available for harvesting residues in a mountainous terrain. In Austria, most of the biomass comes from mountainous terrain.

The most important barriers, technical and non-technical, and RTD goals to overcome the barriers, determined in Bioenergy NoE are summarised below.

<b>Technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– Lack of cost-effective harvesting technology for forest residues especially in Central and South Europe</li> <li>– Poor application of biomass production chains for local conditions</li> </ul>	<ul style="list-style-type: none"> <li>– Technology transfer, learning from Finnish and Swedish experience</li> <li>– Optimisation of production chains and logistics to local conditions.</li> </ul>
<b>Non-technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– The insufficient availability of low-cost biomass-based fuels</li> <li>– Competition for biomass with pulp and paper industry</li> <li>– Uncertainties concerning subsidy levels in the longer term</li> <li>– Unsustainable harvesting can reduce the amount of nutrients needed for the forests</li> </ul>	<ul style="list-style-type: none"> <li>– RD&amp;D technologies for co-production of fibres (agrofibre and fibre containing waste) and energy for paper mills</li> <li>– Development of ash recycling technologies</li> </ul>

### 5.1.2 Agricultural crops for energy

Energy production from agricultural biomass has typically been limited to local heat production from straw, and in some cases biogas is produced from manure and other type of farm biomass. Straw has a significant potential in Europe, however with present price levels of solid fuels and electricity, it has not often been competitive with other forms of primary energy. It may play an important local role, particularly by providing farmers with additional income. In Denmark, Spain and Romania straw and other residues already play a significant role in energy production. Straw and annual crops, such as Miscanthus and reed canary grass, are used in commercial grate boilers for heat production. There are also a few fluidised-bed boilers where straw and coal are co-fired.

Some small-scale power production technologies exist (using a steam cycle with relatively low efficiency), but they yield high power production costs. For heat and power production the main barriers are fuel logistics, fuel quality fluctuations, for example, due to variable rainfall, and fuel price fluctuation due to varying interest and economic possibilities for farmers and fuel companies to deliver the fuel. Baling, storage and transport technologies are available in various size classes. However, technical improvements in harvesting, storage, transport, fuel preparation and other measures are still needed.

If the Biofuels Directive (26) is accepted as mandatory, it is expected that 2% of the 5.75% requirement can be produced from European agricultural biomass sources. Biodiesel and bioethanol are commercial examples today, the main producers being Germany, France, Italy and Spain. They are mostly used in transport, although rapeseed methyl ester (RME) is mainly used in boilers replacing light fuel oil in Italy. Raw rapeseed oil may also be used in diesel power plants for heat and power production, as is demonstrated by a German operation. Recycled cooking oils are currently used for energy and feed for RME production in addition to virgin vegetable oil, for example in Austria.

Environmental impacts of current liquid biofuels are mainly positive. However life cycle analysis demonstrates that the greenhouse gas benefit in transport sector is not always positive. The main barrier is economics. The production costs of RME and ethanol are 2 to 6 times higher than fossil fuel refinery prices. As the consumer price for transport fuels in Europe is significantly higher than the refinery price, taxation policy is the key for getting liquid biofuels into the markets.

It has been estimated that about 5 million hectares of set-aside land could be used for non-food applications in the EU15. The energy sector could utilise various products, if the prices are competitive. With an average yield of annual crops of 15 tonnes dry matter/ha, the energy yield is typically 50–60 MWh/ha (180–216 GJ/ha). There are

significant differences in various test plots in Europe reflecting the various climate conditions. Production of 1 million hectares gives a potential of about 5–6 Mtoe/a (210–250 PJ/a) solid fuel corresponding to about 0.8–1.2 Mtoe/a (33–50 PJ/a) liquid biofuel (rapeseed assumed).

Annual crop cultivation for non-food applications is an area of effective research, development and demonstration in many countries, as in the UK, Sweden, France, Spain and Italy. For example, both Sweden and the UK are experienced in Salix cultivation and in Sweden the wood fuel has been co-fired in biomass boilers. In Sweden today, there are 3 500 ha of reed canary grass production and over 15 000 ha in Salix cultivation. In Finland, 9 000 ha of reed canary grass is cultivated for energy. In countries like Poland there is growing interest for new bioenergy markets and opportunities based on Swedish experiences. Barriers to overcome are technical, economic, local, and farming issues, including the large scale reforestation views of set-aside land.

There are two major external barriers for bioenergy production from agro-biomass. The first is soil and climate conditions which introduce necessarily distortion in productivity yield between countries at the world level and between countries inside the EU25. The second is the food demand at the world level, the situation today and uncertainty in mid- and long-term development.

The main barriers related to production are harvesting, logistics and economic factors, including aspects of the CAP. How the future CAP subsidies will catalyse non-food options and the mechanisms by which solid and liquid fuel alternatives will receive energy or fuel taxation benefits, still remain to be solved on the European and national levels. Periodically, demonstrations of agro-biomass production and utilisation are successfully carried out in various sites in Europe which help change public perceptions of energy crop production.

The present practices and future trends are related to local farmer and co-operative policies and practices. Straw, rapeseed and cereals based heat, power and liquid biofuel production is commercially available, barriers are mainly economic and socio-economic. The challenges are different for non-food alternatives, mainly annual crop and short rotation forest based concepts. The barriers identified mainly concern the production of lignocellulosic material.



The most important barriers, technical and non-technical, and RTD goals to overcome the barriers, determined in Bioenergy NoE are summarised below.

<b>Technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– Lack of know-how in transfer from food crops production to fuel crops production</li> <li>– Scale-up of lignocellulosic crops production</li> </ul>	<ul style="list-style-type: none"> <li>– Whole chain system analysis: focus on lignocellulosic feedstocks (including lignocellulosic content of classical energy crops)</li> </ul>
<b>Non-technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– Sustainability unproven, especially for lignocellulosic crops</li> <li>– Unpredictable economic conditions &amp; legislation</li> </ul>	<ul style="list-style-type: none"> <li>– Evaluation of environmental impacts</li> <li>– Demonstration of scale-up: experimental farm based on lignocellulose</li> </ul>

## **5.2 Heat and power technologies**

### **5.2.1 Current technologies and visions for the future**

The main technologies to produce heat and power from biomass are combustion, gasification, combined heat and power (CHP) production, co-firing and production of refined biomass fuels, such as pellets and pyrolysis oil.

Bioenergy technologies have achieved significant cost reductions over the past decade in several areas such as dedicated large and small scale combustion, co-firing with coal, incineration of municipal solid waste, biogas generation via anaerobic digestion, district and individual household heating, and in certain geographical areas, liquid biofuels such as ethanol and biodiesel (85).

The pulp and paper industry is a natural platform for the large-scale use of bioenergy, due to the optimal integration of fuel supply and energy, process steam and power demand. The biggest users of bioenergy within the pulp and paper industry are Finland and Sweden, which are also the most important pulp producers in Europe. Portugal, Spain, Austria, Germany, Norway and France also have significant use of bioenergy in the pulp and paper industry.

Another important user of bioenergy in large-scale plants is heat production and CHP production for district heating systems and other process industry, especially in

Scandinavia and Austria. Cement and other building material industries and also metal and chemical industries are looking for possibilities to decrease their use of fossil fuels. Like the forest industry, the food industry has a potential to use their biomass residues and waste for energy production.

Co-firing of biomass in pulverised coal boilers (pc boilers) presents another important opportunity to produce bioenergy on a large-scale. Most of those boilers are used for electricity-only production for utilities. In some countries, utilities are obligated to have a certain percentage of renewable electricity in their supply.

In the future new technologies will make it possible to increase the use of bioenergy in new sectors such as CHP with higher power-to-heat ratio, high efficiency power generation, production of liquid and gaseous biofuels and utilisation of new biomass resources. Integration of bioenergy production into the forest industry, waste recycling, liquid biofuel production or chemical industry will improve competitiveness. Cogeneration will widen to trigeneration or polygeneration.

### ***Combustion and gasification technologies***

Grate combustion represents traditional combustion technology. It is the most common combustion method for solid fuels in small and medium-sized units (less than 10 MW) (86). Grate combustion is most commonly used in industrial wood residues combustion plants, in smaller district heating plants using wood chips, sod peat and industrial wood residues, and in boilers for heating individual buildings.

Combustion applications of fluidised bed combustion (FBC) technology were commercially developed in the 1970's. FBC can be implemented either in a bubbling fluidised bed (BFB) or in circulating fluidised bed (CFB). FBC's advantages are the possibility to use different fuels, low-cost sulphur removal and low emissions of nitrogen oxides and unburned components.

Gasification of biomass and waste is seen as an attractive alternative to produce power and heat. However, despite many achievements it is only commercial for heat applications. A few gasifiers have been in operation for twenty years and a number of gasification processes are under industrial development at pilot and demonstration scale. Gasifiers are available from Foster Wheeler and Condens Oy in Finland, Lurgi AG in Germany, Vølund in Denmark, TPS Termiska Processer AB in Sweden, PRM Energy Systems, Inc. in the United States and Repotec in Austria.

In small scale gasifiers of less than 15 MW<sub>th</sub>, the most competitive gasification processes are based on fixed bed gasification (86). The traditional fixed-bed gasifiers

are suitable only for particle-shaped fuels like wood chips or sod peat. The most well known fixed-bed gasifier operated with a range of biofuels is the Bioneer gasifier, which has been in successful commercial operation in Finland and Sweden since the mid-1980's. Most of the gasifiers in operation are located in small district heating plants.

Condens Oy and VTT in Finland have developed a new generation fixed bed Novel gasifier, which is based on forced fuel flow and consequently allows the use of low-bulk-density fibrous biomass residues (86). A demonstration CHP plant has recently been constructed in Kokemäki, Finland. In Guessing, Austria a biomass CHP process is demonstrated, where a gasifier is coupled to a gas engine to produce electric power and heat. The gasifier is a steam blown fluidised bed gasifier.

The competitiveness of fluidised bed technology based gasification processes is optimal at a larger scale. All developed gasification processes: CFB, BFB and Novel fixed-bed, seem to have their own suitable size classes and markets (CFB > 60 MW, BFB 20–60 MW and Novel < 20 MW).

Since 1983, commercial CFB biomass gasifiers supplied by Foster Wheeler Energia Oy (previously A. Ahlström Oy), have replaced fuel oil in lime kilns in Finland, Sweden and Portugal. In 1998 a new 60 MW<sub>th</sub> CFB gasifier supplied by Foster Wheeler Energia Oy began operating in the Kymijärvi power plant in Lahti, southern Finland. The gasifier is connected to an existing coal-fired boiler. A similar kind of gasifier has been in operation since spring 2003 at a power plant in Ruien in Belgium. The capacity of the Ruien gasifier is 50–86 MW, depending on the moisture content of the fuels. The first commercial atmospheric-pressure BFB technology application in Finland was realised in Varkaus, Central Finland, by Corenso United Ltd. This gasifier utilises plastics and aluminium containing reject material from the recycling process of liquid cartons.

The main market for biomass-based Integrated Gasification Combined Cycle (IGCC) plants is in combined heat and electricity production in a medium-size range (30–100 MW<sub>e</sub>) (86). The most promising process alternative is the so-called simplified IGCC based on air gasification and subsequent hot gas cleaning. This process was demonstrated in 1993–1999 by Foster Wheeler Energia Oy and the Swedish utility company, Sydkraft AB. A demonstration plant (6 MW<sub>e</sub> and 9 MW<sub>th</sub>) was constructed in Värnamo, southern Sweden.

### ***Combined heat and power production***

One of the main options to increase the efficiency of power generation and the competitiveness of bioenergy has been the switch from separate condensing power plants and heating plants to combined heat and power production (87). Cogeneration

plants have a typical overall annual efficiency of 80–90%. This is much higher than the 25–45% efficiency of condensing power plants that generate only electricity. CHP is typically the most profitable choice for power production with biomass if heat, as hot water or as process steam, is needed, and if biomass resources are limited.

In the Nordic Countries, district heat production has offered a natural heat load for CHP production (87). Fossil fuels, oil, natural gas and coal, have been replaced consistently by biomass since the energy crises of 1970's. Low market prices of electricity reduced the conversion in 1980's but promotion incentives of RES have boosted the construction of bioenergy plants since 1990's. In Finland, biomass-based fuels are used nearly completely in heat and CHP production. The number of large scale CHP plants in Finland is nearly 100 and the total capacity is over 1500 MW<sub>e</sub>. Most pulp mills using unbarked logs have installed CHP plants. Chemical pulping provides self-sufficiency of energy, but residues from mechanical pulping cover only a small share of the energy demand of the mill. The Alholmens Kraft CHP plant in Pietarsaari, Finland, is the largest biofuelled power plant in the world. The plant produces steam for the adjacent paper mill and for a utility generating electricity and heat. The electricity output is 240 MW<sub>e</sub>, the process steam output 100 MW<sub>th</sub> and the district heat output 60 MW<sub>th</sub>.

Fluidised bed boilers offer several benefits for using biomass as fuel (87). The use of agricultural residues, such as straw, bagasse or rice husk, requires special materials and construction, but they have been burnt successfully in many plants.

The improvement of power-to-heat ratios in CHP plants using biomass is based on the increase in the superheated steam temperature and pressure of steam boilers. The largest plants are designed for 165 bar/545°C and supercritical values will be introduced in the near future in the fluidized bed boilers. The annual fuel consumption of large CHP plants is several TWh (or 10–20 PJ) which, in most cases, requires co-firing of biomass and fossil fuels. CFB combustion is optimal for co-firing with good possibilities to reach low sulphur and nitrogen oxide emissions without flue gas cleaning.

The future target is CHP plants for ever-smaller heat consumers, because available large heat loads for district and industrial process heating are limited. Diesel and steam engines, and steam and gas turbines are now applied in small-scale CHP of 200 kW – 3 MW electricity. Microturbines, solid oxide fuel cells, Organic Rankine Cycle and Stirling engines are presently demonstrated for smaller capacity classes. All of these options, need standardised concepts and mass or serial production to obtain competitiveness without significant subsidies or other promotion measures.

### ***Pyrolysis technology***

The pyrolysis process is able to produce high yields of liquid products which can be shipped, stored and utilised more economically than solid fuels in the small to medium size class (88). Fast pyrolysis is a thermal decomposition process in which material is thermally cracked using a short vapor residence time in the reaction zone. The yields and properties of the pyrolysis liquid depend on the feedstock, process type and conditions, and the product collection train efficiency.

Pyrolysis processes have been developed in Canada, the United States and Europe. For the moment, the capacity of the largest reactor in operation is about 1 tonne/h. A number of fast pyrolysis processes are under industrial development at pilot or demonstration scale. These are aimed at power, heat, fuel and chemicals, all of which have been shown to be feasible. Several fast pyrolysis technologies have reached near-commercial status. However, there are not yet any large-scale, commercial demonstration plants (85, 89). Only Ensyn's circulating fluidized bed plants, Red Arrow and Rhinelander plants in the United States, have been operated commercially for the production of chemicals.

DynaMotive has now entered the commercialization phase with the launch of the world's first BioOil co-generation facility located at the Erie Flooring and Wood Products facility in West Lorne, Ontario (90). The 2.5 MW plant combines Dynamotive's fast pyrolysis technology with Magellan Aerospace Orenda Division's OGT 2500 gas turbine. Erie Flooring will provide wood residue from its operations and utilize electricity produced from the turbine to power its mills and steam to heat its lumber kilns, with the balance of the electricity exported to the Ontario power grid.

Pyrolysis oil produced with fast pyrolysis has been estimated to be the most inexpensive liquid biomass based fuel. Before commercialisation, however, the homogeneity of the produced oil needs to be proved. The competitiveness of biofuel oil varies between different countries, depending on taxation.

### **5.2.2 Barriers concerning heat and power technologies**

In nearly all Bioenergy NoE partner countries similar barriers related to heat and power technologies are found but the importance given to each barrier differs considerably between the countries. In the UK and the Netherlands, the public acceptance of large scale plants is very low and thus the permission procedures are very long. Weak competitiveness of bioenergy is the main barrier that slows down bioenergy adoption in Poland. The insufficient availability of low-cost biomass-based fuels, and/or uncertainties

concerning subsidy levels in the long term hinders increased use of bioenergy in the Netherlands, Germany, Sweden, Finland and Austria. Technological development is a key to improving the economics of bioenergy, increasing availability of low-cost biomass resources and reducing negative impacts on the environment. Security of fuel supply and technological problems are among the most important barriers.

Slagging, fouling and corrosion are still a big problem in plants using biomass. The advantages of co-firing biomass with fossil fuels should be studied further to solve these problems. Different biomass types have different type of support fuels, such as fossil fuels, other biomass or waste fuels.

In pc boilers, direct co-firing of biomass in the main combustion chamber is limited to a range of some 5–10% of coal. In this range, the impact on boiler performance, emissions and ash quality is generally limited because of coal's buffering capacity. Thus the associated risks of higher maintenance cost and unscheduled outages are relatively small. The main challenge lies then in the milling and feeding of the biomass. There is only limited experience on direct co-firing of biomass in higher percentages (10–20% energy basis) in state-of-the-art pc boilers. Higher percentages, even up to 30–40% in specific cases, are feasible but the risk of problems related to fouling, corrosion, emissions and ash quality are considerable. Utilisation of ashes from co-combustion is difficult. Biomass mixed with coal deteriorates the ash that could be used for cement. Lack of on-line monitoring techniques, for example for fouling, corrosion and agglomeration, is a hot technological question at the moment because on-line monitoring can lower the high risks associated with increasing the percentage of biomass in direct co-firing.

Supercritical fluidised bed boilers bring new arising problems when steam temperature and pressure are increased in supreme levels. Problems can be solved by fuel optimisation, superheater material selection, modelling, and monitoring. Use of chemicals to prevent corrosion when difficult biomasses are used should be developed. Fouling and slagging mechanisms are not known well enough, but cleaning mechanisms are even less known.

Biomass co-firing should be taken into account in the development of next generation coal conversion technologies such as UltraSuperCritical boilers, IGCC and oxy-fuel combustion. Furthermore, IGCC concepts should be commercialized for biomass.

The main barriers and actions or RTD goals to overcome the barriers concerning heat and power technologies, identified by Bioenergy NoE are summarised below.

<b>Technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– Co-firing is limited to 5–10% of coal in pc boilers. Problems in co-combustion in supercritical fluidized-bed boilers</li> <li>– Conversion technologies for high ash biomass, slagging and fouling problems</li> </ul>	<ul style="list-style-type: none"> <li>– Development of boiler materials and boiler cleaning methods, feed optimisation and monitoring</li> <li>– Develop appropriate technologies for high-ash biomass (combustion, gasification, pyrolysis)</li> </ul>
<b>Non-technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– High specific investment cost, low electricity prices</li> <li>– Competition for biomass with pulp and paper industry</li> </ul>	<ul style="list-style-type: none"> <li>– RD&amp;D for high power-to-heat ratio, high-efficiency, low-cost co-generation, encourage co-generation</li> <li>– RD&amp;D of new biofuel (incl. hydrogen, SNG) production technologies as co-production with existing industry</li> <li>– RD&amp;D technologies for co-production of fibres (agrofibre and fibre containing waste) and energy for paper mills (and system studies)</li> </ul>

## **5.3 Liquid biofuels for transport**

### **5.3.1 Overview of biofuel production technologies**

Liquid transportation fuels that are currently produced commercially from biomass are bioethanol from sugar and starch crops and residues and biodiesel from vegetable oils. Brazil and the United States are the major producers and consumers of fuel ethanol, together accounting for more than 95% of fuel ethanol use. The European Union is the major producer and consumer of biodiesel and responsible for about 90% of the biodiesel production and consumption. In 2002 the total worldwide fuel ethanol production amounted to about 22 million m<sup>3</sup> and the total biodiesel production to 1.5 million m<sup>3</sup> (91).

In the EU the major biodiesel producers are Germany, France, Italy, Denmark, the Czech Republic and Austria. The major producers of fuel ethanol in the EU are Spain, France, Sweden, Poland and Germany. In 2004 about 1.9 million tonnes of biodiesel were produced in the EU25 and about 0.5 million tonnes of fuel ethanol (61). This is an

increase of 25% compared to 2003. Total liquid biofuel production in the EU25 in 2004 is the equivalence of about 2 million tonnes of oil. The indicative target of 5.75% set in the Biofuels Directive (26) for the biofuel share in road transportation fuels in 2010 would mean a biofuel utilisation of about 17–18 Mtoe/year (710–750 PJ) in the EU.

### ***Biofuel technology and new options***

The production of bioethanol and biodiesel from agricultural crops and waste streams is a mature commercial technology. Ethanol can be produced from either sugars or after hydrolysis from starch or cellulose. Sugars required are available either from residue streams from the sugar industry or from sugar crops like sugar beets. The starch required is available either from residue streams from food industry or from starch crops like corn, barley or wheat. Biodiesel in the EU is primarily produced from rapeseed and some minor amounts from waste cooking oils (92). Ethanol can be used directly in pure form, as an additive to gasoline or in the form of ETBE. Biodiesel can be used in a pure form as well as in mixtures with petroleum-based diesel.

Other biofuel production technologies are not yet commercial (23). Current biofuel options are more expensive than petroleum gasoline and diesel and require supporting measures from the authorities, like almost complete tax relief or subsidisation of production plants. The feedstocks used for current, or conventional liquid biofuels are classical agricultural feed crops that require high quality agricultural land for growing (93). Advanced or second generation liquid biofuels can be produced from lignocellulosic biomass feedstock like wood, straw and grasses. Advanced liquid biofuels are generally considered to have a number of advantages over the conventional liquid biofuels. These are lower costs, a wider range of different feedstocks suitable, a higher reduction of greenhouse gas emissions, and a smaller requirement of land when biofuels are produced from cultivated crops.

The advantages of advanced liquid biofuels and the new Biofuels Directive (26) have resulted in increased support for R&D of new processes for production of biomass-based transportation fuels. In the R&D phase there are several alternative routes for the production of biofuels for transportation (Figure 22). The main routes are the production of liquid fuels, such as methanol and Fischer–Tropsch diesel, from synthesis gas produced by biomass gasification, and ethanol production by fermentation of sugars produced from lignocellulosic biomass. In addition, other options have been presented, e.g. tall oil esters and refining biocomponents from bio-oil produced by pyrolysis or hydrothermal upgrading. Ethers, such as MTBE and ETBE, can be produced from methanol and ethanol by commercial technologies for utilisation as fuel additives in fossil fuels.



Commercial: agricultural crop-based  
biodiesel and bioethanol

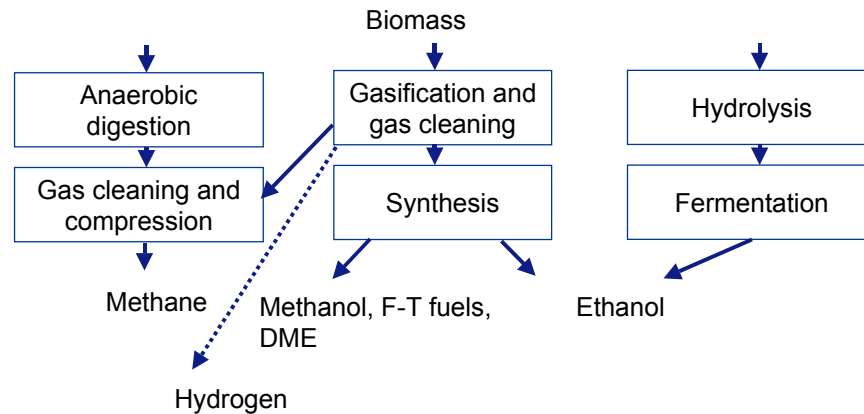


Figure 22. Biofuels for transport production technologies under development (23).

For both the synthesis gas route and the ethanol route a number of demonstration plants are on the way. Two examples in the EU are the Etek plant for ethanol and the Choren plant for synthesis gas based fuels. The Etek plant is a Process Development Unit in Örnsköldsvik in the northern part of Sweden (94). The plant is designed to convert softwood to fermentable sugars in three steps. The first two steps use diluted acid hydrolysis as a catalyst for the conversion of the hemicelluloses in softwood, whereas last step uses enzymes in hydrolysis for cellulose. The plant is designed to convert two tonnes of dry softwood into 0.4–0.5 m<sup>3</sup> of ethanol per day. In the Choren plant in Germany, feedstock is converted by pyrolysis into volatiles and charcoal (95). Both the volatiles and the charcoal are used for synthesis gas production in an entrained-flow gasifier. In a 1 MW<sub>th</sub> pilot plant synthesis gas has been produced from biomass feedstock. The synthesis gas has been used for the production of methanol as well as Fischer–Tropsch liquids. Currently Choren is developing the first production plant with a production capacity of 13 000 tonnes/day of synthetic automotive fuel from wood chips and straw.

### 5.3.2 Barriers to liquid biofuels

The costs of liquid biofuels for transport are, like for other bioenergy options, a major barrier. R&D on feedstock cultivation as well as liquid fuel production technologies can help to reduce the price gap between liquid biofuels and petroleum-based transportation fuels, but cost difference will remain an important barrier. Apart from costs, a large number of different barriers are mentioned in literature as well as in the country reports on the EU Biofuels Directive. However, successful introduction of liquid biofuels for transport in a number of EU countries shows that it is possible to overcome all these barriers. Furthermore, it should be realised that some of the barriers are not unique for liquid biofuels but are general to any new development, like problems with legislation

and long licence trajectories. Other barriers not unique to liquid biofuels, but general for bioenergy are high capital costs, high feedstock costs, availability of feedstock, and logistics of feedstock supply.

Barriers specific for liquid biofuels for transport are typically related to the end-use: automotive transport. As highlighted previously, these kinds of barriers exist but have been overcome in some EU countries. Some typical examples of barriers specific for liquid biofuels for transport given in literature and the country reports on the EU Biofuels Directive are given below.

Existing fuel standards within the EU as well as standards defined by car manufacturers are a barrier to the use of liquid biofuels for transport. Standards within the EU relate to safety and the environment, whereas standards defined by car manufacturers relate to the performance of the cars. The European standards for unleaded petrol (EN228) and for diesel (EN590) limit the blending of respectively bioethanol in gasoline and biodiesel in petroleum based diesel to 5%. Clearly, this limit is a result of discussion with stakeholders (oil companies and car manufacturers) and can be subject to change in the future.

The blending of ethanol is limited by the vapour pressure. Although the vapour pressure of both ethanol and petrol is below the limit specified in the EU standard for unleaded petrol, mixtures can have a vapour pressure exceeding this limit due to the formation of azeotropes. This effect has its maximum at levels of a few percent of ethanol and disappears at above 22% ethanol level. For biodiesel, cold-flow properties may present problems. Biodiesel has a higher viscosity than petroleum diesel. At lower temperatures this can cause crystal formation resulting in difficulties in pumping and blocking of filters.

Both bioethanol and biodiesel have properties that can affect the storage stability and make them incompatible with materials used in cars. Ethanol and bio-diesel are good solvents for many compounds and will dissolve coatings that have formed from the use of petrol or diesel. Dissolving these coatings can result in blocked filters. The solvent properties of ethanol and biodiesel can result in incompatibilities with materials, like elastomers, used in the fuel supply system. Ethanol is hygroscopic and can contain acids. This combination can result in failure of fuel pumps and fuel injectors due to corrosion. Biodiesel can contain double carbon-carbon bonds. These double carbon-bonds increase the reactivity with other compounds and can cause polymerisation, also called gumming. For all these barriers solutions exist. Nevertheless implementation of biofuels for transport might require time because the modification of cars is required.

Lack of infrastructure for blending and distribution is regularly mentioned as a barrier. Successful implementation of liquid biofuels in a number of countries shows that this

barrier can be solved. Furthermore, the introduction of new petroleum-based products, such as unleaded gasoline in the past, and low-sulphur diesel recently, shows that this does not seem to be a major problem.

### **5.3.3 RTD goals to liquid biofuels**

The major barrier is that the liquid bio-fuels are not competitive with petroleum based fuels, and are not expected to be so in the near future. Other barriers exist, but solutions for these barriers also exist. The major RTD goal is therefore to decrease the price gap between liquid biofuels and petroleum based fuels by:

- Development of technology for the production of advanced liquid biofuels. Advanced liquid biofuels, ethanol from lignocellulose and fuels like Fischer–Tropsch diesel from syngas, offer prospects for lower costs compared to current conventional liquid biofuels. Technology for these options is being developed and currently demonstrated in pilot-plants. Further RD&D will be required to develop these routes to mature technologies.
- Co-production of high value products, such as chemicals, which is also called bio-refining, can help to further reduce costs of liquid biofuels for transport. Further development of the bio-refining concept is required to reduce the costs.

More general, as for all bioenergy options, the availability of feedstock and the logistics of feedstock supply are considered to be a major barrier for liquid biofuels for transport. Clear strategies on feedstock supply and logistics need to be developed.

Another barrier not unique for liquid fuels for transport is the need to communicate existing knowledge with authorities, the public and industry. Communication on the benefits of liquid biofuels is important in order to convince the authorities and the public that producing large amounts of liquid biofuels is possible and that financial incentives required for liquid biofuels are justified. Communication of best practices on implementation of liquid biofuels is required to accelerate the implementation of liquid biofuels in the EU and help certain countries overcome barriers that have already been solved in other parts of the EU.

The main barriers and actions or RTD goals to overcome the barriers of liquid biofuels for transport identified by Bioenergy NoE are summarised below.

<b>Technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– Lack of infrastructure for blending and distribution</li> <li>– Process limitations: low conversion of lignocellulose in hydrolysis, tar problems related to syngas production</li> </ul>	<ul style="list-style-type: none"> <li>– Technology development for syngas production, ethanol production from lignocellulose (hydrolysis), and pyrolysis oil upgrading</li> <li>– Optimisation of feedstock production and logistics</li> </ul>
<b>Non-technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– High production costs of bio-transportation fuels</li> <li>– Existing fuel standards in the EU and standards defined by car manufacturers</li> </ul>	<ul style="list-style-type: none"> <li>– Co-production of high-value products (chemicals), whole chain demonstration</li> </ul>

## **5.4 Waste to energy**

### **5.4.1 Survey on MSW in Bioenergy NoE member countries**

Within the Bioenergy NoE, a survey carried out on the generation and energy recovery from MSW in the partner countries gives an impression of the potential role of waste in the bioenergy sector. The data supplied were mainly taken from references (96–101).

The waste generation per capita and annum in Bioenergy NoE partner countries varies between 270 and 610 kg, with the lowest production figure being for Poland, and the other countries being closer to each other as visualised in Figure 23. The figure also documents country-specific disposal strategies. Finland and Poland practise almost no waste incineration, whereas the Netherlands and Sweden incinerate a great amount of their MSW. The figures for different waste management routes should be looked at with caution. The recycling data are often, like in the case of Germany, those waste streams which are collected for recycling. Information about the actual recycled fraction and the sorting of process residues is in most cases not available. MSW treatment processes in other EU countries are presented in Figure 5.

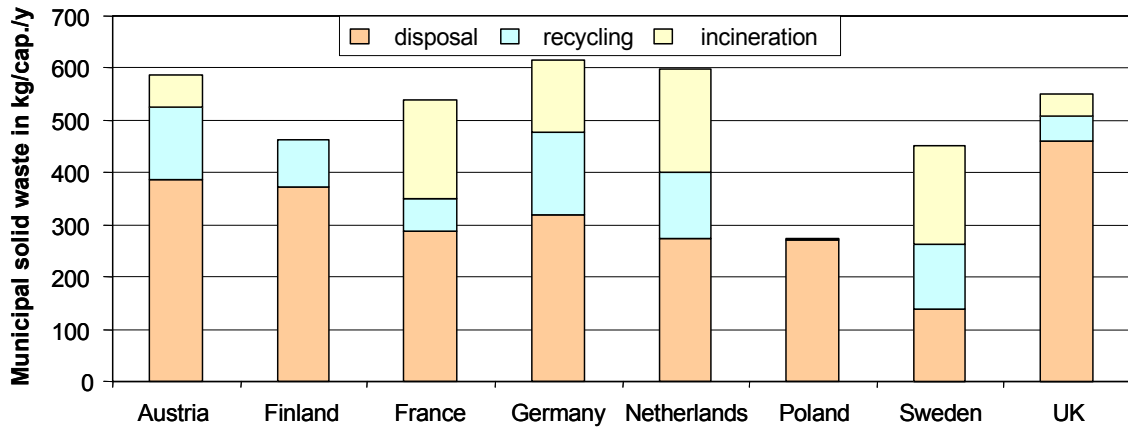


Figure 23. Generation and management of MSW in different Bioenergy NoE partner countries.

The data do not include co-combustion of waste in industrial furnaces. Actual numbers for this application are difficult to obtain and it can be assumed that most fuel derived from waste and used today, the solid recovered fuel (SRF), comes from well defined waste streams, e.g. light industrial waste or packaging waste, and the amount separated from mixed MSW is not very high.

To assess the importance of waste and especially its biogenic fraction – which is for most countries 50–60% in terms of energy inventory – as an energy source, state-of-the-art waste incineration plants were used as energy recovery facilities. In such plants, approximately 70% of the energy inventory of waste is available for heat recovery and the efficiency for power generation is typically 20%. With these data the potential to substitute primary energy by waste incineration has been calculated for the partner countries of Bioenergy NoE. The results are plotted in Figure 24 and indicate an average substitution potential of 1–2% for most countries. Due to climate conditions, Finland and Sweden have a higher energy consumption and hence a lower substitution potential. The surprisingly high potential for the UK can be explained by their high waste generation and their rather low recycling quota of only 9.6% compared to approximately 27% for Germany. The respective calculation in terms of electric power substitution results in a potential of some 2–5% with the UK at almost 9% and again the Nordic Countries at the lower end.

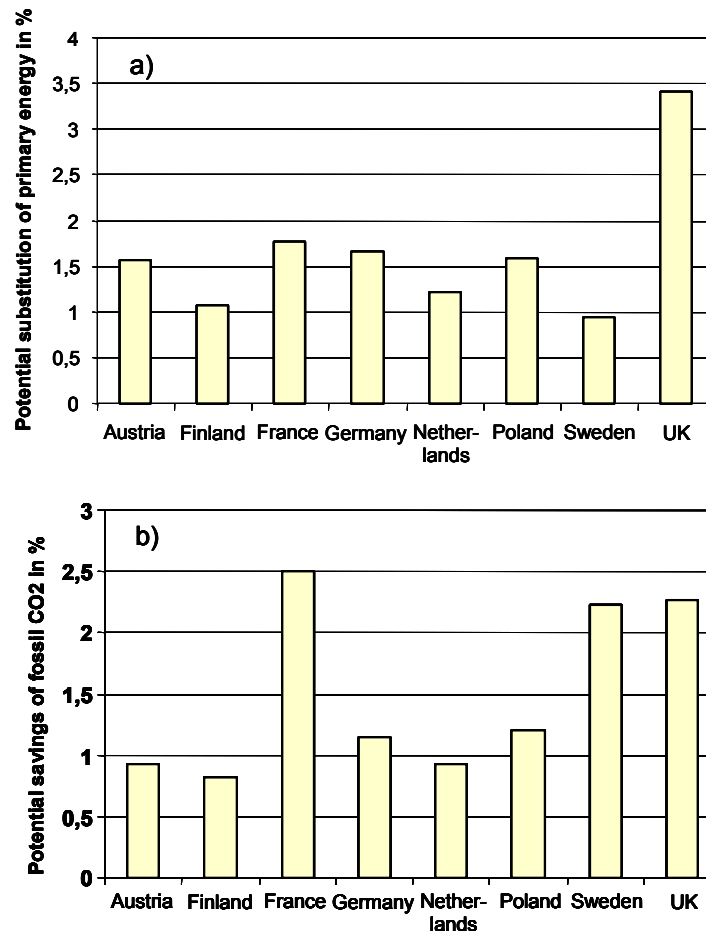


Figure 24. Potential of energy from waste to substitute a) primary energy and b) fossil CO<sub>2</sub>, in different Bioenergy NoE partner countries.

Mixed MSW has an average carbon content of approximately 25%, which is almost totally converted to CO<sub>2</sub> in the combustion process. The CO<sub>2</sub> emitted from biogenic waste fractions has to be looked upon as originated from regenerative fuel. A rough estimate on the basis of total CO<sub>2</sub> emission data taken from OECD statistics (99) indicates a theoretical proportion of approximately 1% for five countries and more than 2% for France, Sweden and the UK. These figures give an idea of the importance of consequent utilisation of the energy inventory of MSW for savings and replacement of fossil CO<sub>2</sub>.

The data presented above represent potentials which are in most countries not yet reached. However, in the EU15 states, the landfill ban has been in force since 2005 and that means the pre-treatment of waste prior to its final disposal has to be extended. It can be envisaged that this push will, to a great extent, increase the thermal treatment of waste and consequently its energy recovery. Combined heat and power utilisation is the method of choice for optimising energy recovery from MSW.

Hence the potential of waste for substitution of fossil fuel in the energy market will be maximised in the near future to a much greater extent than today. Thus energy from waste is expected to become one of the fastest growing sectors in the bioenergy market.

#### **5.4.2 Barriers and RTD goals to waste to energy**

Costs are one of the major barriers in all bioenergy scenarios. In most cases, the energy from biomass is more expensive compared to that from fossil fuels, and thermal processes for energy recovery from waste are especially expensive due to the effort in gas cleaning in order to comply with stringent air emission limits. During the last decade a lot has been done to optimise gas cleaning and reduce its costs. Furthermore, energy recovery is becoming increasingly efficient. Without the revenues from energy sales such processes, which are required for the inertisation of waste prior to its final disposal, would be even more expensive and hence in the WtE sector the costs should be seen more as a driver rather than as a barrier.

Legislative barriers differ between countries with the major ones being the acceptance of the biogenic fraction of waste, subsidies, and residue management. A major and common barrier to all types of bioenergy recovery from waste is the different definition of biomass.

In the context of sustainability, the environmental aspect is a central concern for WtE scenarios. WtE processes have to balance the inertisation of the waste stream and maximising energy generation of energy from partly biogenic material, with restricting emissions as much as possible by the elimination, destruction or fixation of pollutants to guarantee an aftercare free disposal. For the first topic no major specific barriers are to be seen, but in the second the sustainability of all activities is the central focus: the treatment for disposal or utilisation of any kind of waste in any process has to be performed in a way that any direct and also future negative effects on human health and on the environment are totally excluded. The open question for this task is the definition of final sinks of pollutants present in the process residues, first of all the halogen and alkali compounds, but also the heavy metals.

Regarding social aspects, the main barrier is the lack of public acceptance which is based on negative perceptions of WtE's impact on health and the environment. Reasons for opposition and non-acceptance vary widely depending on a range of factors such as one's attitude, political views, level of involvement, and morals and values. There is a lack of public acceptance to specific processes like waste incineration. Another type of opposition against WtE is based on the assumption that material recovery is preferential and if optimised, no waste should be left for treatment or disposal. Another area which needs more attention is that of occupational health.

There is no barrier in material supply to WtE plants since waste is generated every day. An obstacle for the conversion process is, of course, the poor homogeneity of mixed solid waste and its inventory of contaminants. A particular challenge for waste incinerators is the increasing delivery of special waste fractions like residues from sorting or recycling plants.

The biomass contribution to the calorific value of waste varies greatly not only by country but also by season and region. However the range of its variation is also difficult to discern making it difficult to get precise information on the actual biogenic energy inventory of waste or of SRF which is fed into the process. Such knowledge would help to pave the way for legal acceptance of the biogenic energy content in the above mentioned fuels.

The technology of conventional waste incineration is well developed and there is experience of long-term operation of full scale plants. This is not the case for other WtE processes. Harmful ingredients, such as halogens, phosphorous, sulphur, alkali and heavy metals, in MSW respectively in SRF, are the major reason for special technical measures in thermal WtE processes. The partitioning and behaviour of the pollutants is well understood in conventional waste incineration in mass burn systems but less known in pyrolysis and gasification processes and has just begun to be investigated in co-combustion scenarios in utility boilers and industrial processes.

Although the fundamentals of the implemented technical processes are known, process control, eco-efficient off-gas cleaning and residue management are still not easy tasks. Numerous efficient technologies are available to clean off-gas from combustion plants but not to the same extent for gasification and pyrolysis processes. Another risk caused mainly by halogens, phosphates and alkali compounds is corrosion and fouling in the boiler and wear of refractory material in combustion processes, which requires high maintenance expenditures. The same harmful ingredients also need to be taken care of in biological treatment like anaerobic digestion for biogas production. For the WtE processes used today different maturity and operation experience exists. Various WtE processes have different optimum throughput capacities.



The main barriers and actions or RTD goals to overcome the barriers of waste to energy as identified in Bioenergy NoE are summarised below.

<b>Technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– Expensive management of WtE process residues</li> <li>– Competition between material recycling and energy recovery</li> <li>– Emission control especially in novel WtE processes: gasification, pyrolysis and co-combustion</li> </ul>	<ul style="list-style-type: none"> <li>– Development of standard criteria for disposal and/or utilisation of WtE residues</li> <li>– Macro-economic assessment and environmental effect of waste management strategies</li> </ul>
<b>Non-technical barriers</b>	<b>RTD goals</b>
<ul style="list-style-type: none"> <li>– Lack of public acceptance</li> <li>– Differences in legislation concerning biogenic fraction, subsidies and residue management</li> <li>– Licensing of WtE plants</li> </ul>	<ul style="list-style-type: none"> <li>– Public information on environmental data of plants in their vicinity</li> </ul>

## **6. Significant biomass utilisation in Europe – Wishful thinking or reality?**

The potential for significant biomass utilisation in Europe is affected by many factors, such as EU and national policies and regulations, emissions trading, biomass availability and the logistics of feedstock supply, technology development, and economical and social factors. Making significant biomass utilisation a reality in Europe depends largely on the development of these factors.

Policies are important drivers in the implementation of bioenergy. Of all the renewable energy sources, bioenergy is considered most important. To promote renewables several political initiatives have been taken within the European Commission and by the individual member countries during the last ten years. The 1997 White Paper on renewable energy is still important. In 2005 the Kyoto Protocol entered into force, the Emissions Trading Scheme started in Europe, and the first targets of the Landfill Directive were required. In addition, the Commission published a new Biomass Action Plan.

Important European targets have been set for 2010, such as the White Paper targets of doubling the share of renewables to 12%, to an equivalent of some 180 Mtoe (7.5 EJ) and tripling the use of biomass to 135 Mtoe (5.7 EJ), the RES-E Directive target to increase the share of green electricity to 21%, and the Biofuels Directive target of 5.75% substitution of conventional transport fuels with biofuels. The Commission estimates that the measures of the Biomass Action Plan could lead to an increase in biomass use to about 150 Mtoe (6.3 EJ) in 2010 or soon after. Further, targets for the year 2020 have been proposed, for example the biofuels target of 20% substitution. Limiting the share of MSW to be landfilled to 35% has been set for 2016. CO<sub>2</sub> price premium is potentially an important driver for long term development, as it can bridge the often significant cost gap towards alternatives.

The European Renewable Energy Study (TERES II) (102) assessed four policy frameworks and considered the various European targets for renewable energy. It was concluded that under a “best practice” framework, renewables can contribute up to 14% of Europe’s primary energy by 2020, provide over half a million jobs and reduce annual CO<sub>2</sub> emissions by 830 000 tonnes. Figure 25 presents the renewable energy penetration by technology for the EU15. From the figure it can be seen that for most of the technologies their penetration will more than double adopting the “best practice” policies; biomass has the highest potential of all sources; and that the 12% target for the renewables is within reach with “best practice” but not with “present policies”. The potentials of different biomass sources to reach the target for biomass and wastes, 135 Mtoe in 2010, have been inserted into the figure.

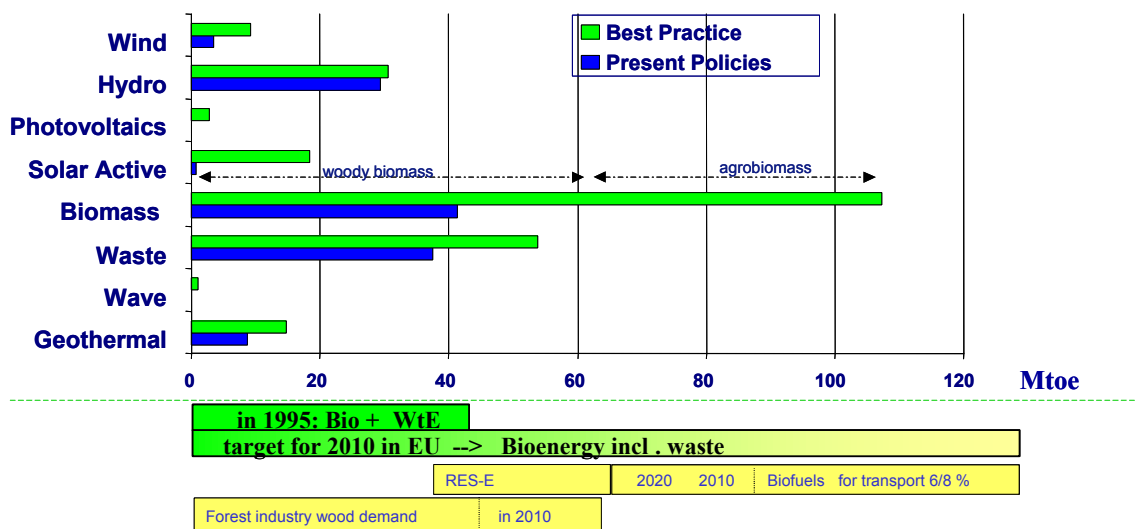


Figure 25. Renewable energy penetration in the EU15 in 2010 (modified from the reference 102).

At present about 40 EJ/a of the available biomass in the world is used for energy. The estimates of the future potential range very widely, through the year 2050 from 33 to 1135 EJ/a. In Europe the use of biomass and wastes is presently about 2.9 EJ/a (69 Mtoe), and the potential in 2050 has been estimated to range from 9.0 to 13.5 EJ/a (215–320 Mtoe). Thus the biomass resources and potentials for Europe are very large taking into consideration, in addition to the European reserves, import possibilities. On the basis of the estimates, it seems that there are sufficient domestic resources to meet the EU targets set for the year 2010. But if more stringent goals are set for bioenergy in the future, it will be challenging to find sufficient resources in Europe and biomass imports from outside the EU will be necessary. Anyway to reach the European goals for bioenergy all the main biomass sources: forest resources, agricultural biomass, and biogenic urban wastes, will be needed.

Future potentials are affected, for example, by demand for food, productivity of forest and energy crops, availability of degraded land, competing land use types, recoverable residues, environmental requirements, markets and incentives, and R&D progress. Actual developments of these factors will determine the future biomass potential and the competitive use of biomass.

The CAP reform in 2003 substantially influences bioenergy development. The changes in the CAP have introduced payments for energy crops. The CAP development is an important factor for agricultural biomass, as it contains strong drivers through employment and decreasing subsidies. An EU bioenergy policy that considers agriculture at its heart would be an important instrument as it seems that any kind of

large-scale bioenergy implementation in Europe must be built around the agricultural problem. The order of magnitude of the set-aside area (10%) is in agreement with estimated needs, around 14% of agricultural area, for bioenergy cultivation.

There is a land-use trade-off between crops for transportation fuels and crops for energy generation. Production goals should be adjusted based on local conditions and priorities. As a consequence of the limited land, bioenergy, especially in large scale, has to be incorporated in an optimal way. The present land use structure has to be changed in a sustainable way that maintains the functions of food production, supplying other industries, and recreation and landscape. A strategy for biomass deployment needs to focus on demand rather than supply with a switch in emphasis from using agricultural policies to other policy tools and market approaches. Bioenergy, when developed as recognizable and important sector, will generate increased demand for resources. Limiting to energy crops deployment and identifying necessary adaptations of energy crops to site conditions need further consideration and understanding on a regional basis before large-scale deployment takes place. The problem of water conditions and requirements in particular requires careful estimation. Supply chains and production processes need to be improved in order to reach the targets set for bioenergy. Every link in the production chain has to be optimised to improve profitability without compromising on quality and supply security.

The “Environment and Socio-economics” Work Package of Bioenergy NoE evaluated theoretical barriers in a set of case studies to verify the relevance of different barriers and to define their RTD goals (103). The theoretical barriers identified are economic conditions, know-how and capacity, and supply chain coordination. The eight case studies are located in six different Bioenergy NoE member states; two examples are presented in references 104 and 105. The case studies cover a range of inputs (forest residues, agriculture residues, energy crops, peat, municipal solid waste) and outputs (heat, electricity, wood pellets, rapeseed cake, biodiesel, biogas, steam), as well as different technologies for conversion. There are four examples of success and four examples of unrealised potential in the set of case studies. If the case studies can be transformed to success by removing or managing the barriers, and if interactions with the actors in the case studies of success can be utilised in constructive ways it would promote biomass use within the EU. Possibly the most important research objective is to release the potential of bioenergy in the New Member States of the EU. The need for a common market in the Europe on biomass for energy purposes is highlighted because the conversion technologies for bioenergy are often established in the western countries of the EU and the biomass resources are in the eastern countries.

Concerning heat and power technologies, the pulp and paper industry is a natural platform for the large use of bioenergy, due to the optimal integration of fuel supply and

energy, process steam and power demand. Other important users of bioenergy in large scale plants are heat producers and CHP producers for district heating systems and other process industries. The third large sector is the co-firing of biomass in pulverised coal boilers. In the future, new technologies will make it possible to increase the use of bioenergy in new sectors such as CHP with a higher power-to-heat ratio, high efficiency power generation, production of liquid and gaseous biofuels and utilisation of new biomass resources.

The use of liquid biofuels for transport is currently limited to about 2 Mtoe (84 PJ) in the EU. With a total final energy consumption for road transport of 280 Mtoe (12 EJ) in the EU, the share of liquid biofuels equals 0.7%. Estimates of the potential contribution of conventional liquid biofuels show limited prospects. Use of the whole EU15 set-aside area for the production of bioethanol alone would yield a gasoline replacement 5.8% to 18% dependent on the type of crop used (106). Similarly, use of the whole EU15 set-aside area for the production of biodiesel alone could replace diesel by 3.2–4.0% (107). Advanced biofuels offer the prospects of much higher yields per ha of land (91, 93). Furthermore, requirements for cultivation of lignocellulosic biomass, used as feedstock for advanced fuels, are less stringent than for the feedstock used for the conventional liquid biofuels, increasing the area of land that is suitable for cultivation.

Current gasoline and diesel use in the world are 1 132 respectively 1 050 billion litres or in total 74 EJ. Considering the estimates for world wide biomass potential ranges and a conversion efficiency of 35% to liquid fuels a world wide potential for liquid biofuels ranges from 12 to 455 EJ (92). Clearly, there seems to be a significant potential for liquid biofuels. A number of factors presented in Figure 26, will however influence the development.

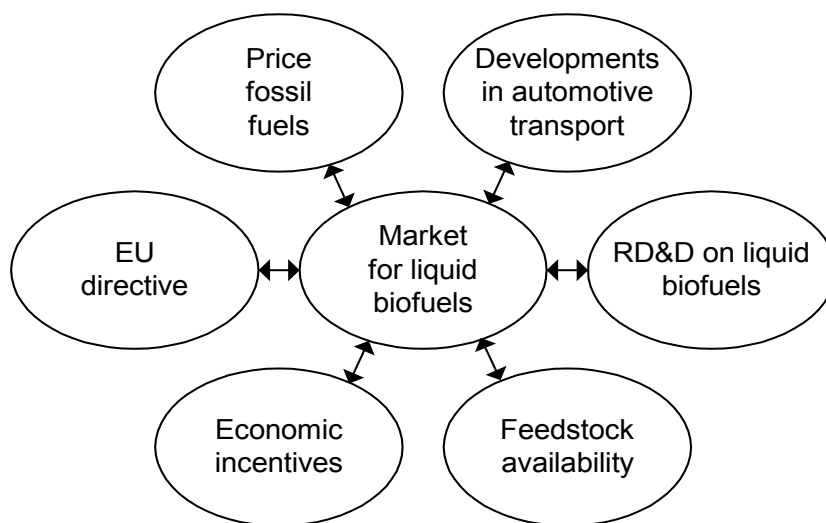


Figure 26. Factors that influence the implementation of liquid biofuels in the EU.

For the short term, the EU Biofuels Directive and accompanying economic incentives will help the market for liquid biofuels to take off. Current developments in the production of conventional liquid biofuels show that in the short term feedstock availability and biomass conversion technology are not the limiting factors or barriers. Once conventional liquid biofuels have reached their potential the challenge will be to develop the advanced liquid biofuels as they alone will make the largest contribution to the liquid biofuels market. This will require RD&D on advanced liquid biofuels. Clearly, market development initiated by the conventional liquid biofuels will help to change the RD&D on advanced liquid biofuels from “technology push” to “market pull”. Initially, advanced liquid biofuels can be produced from residue streams like wheat straw and residues from e.g. pulp and paper industry. Once residuebased advanced liquid biofuels have entered the market, the conversion technology will be ready and feedstock availability will have to be increased by biomass cultivation.

The most important factor for bioenergy development is the generation of new, innovative business schemes through which bioenergy utilization can grow naturally from sound economic principles, and is not based on artificial economic subsidies that are likely to disappear in a short time. It is also essential to understand that mere technical development will not bring about fundamental changes, new schemes and strategies for implementation constitute the real bottleneck. A prerequisite for rapid implementation of new bioenergy solutions on the European market is the use of existing infrastructures in conventional biomass production (i.e. agriculture, forest industries and the waste sector) and energy industry. In fact there are a number of possibilities for practical implementation which could have significant impact on a rather short time frame.

Within Bioenergy NoE, there is agreement that a considerable increase in the use of bioenergy cannot take place without industry support. Therefore the intended increase in the use of biomass can only be realised through new business opportunities. It also means that the integration process of partner organisations will serve the analysis of business opportunities, and it eventually will support implementation of these opportunities. The structure and the visions for case studies of new business ventures to be analysed within Bioenergy NoE are presented in Figure 27.

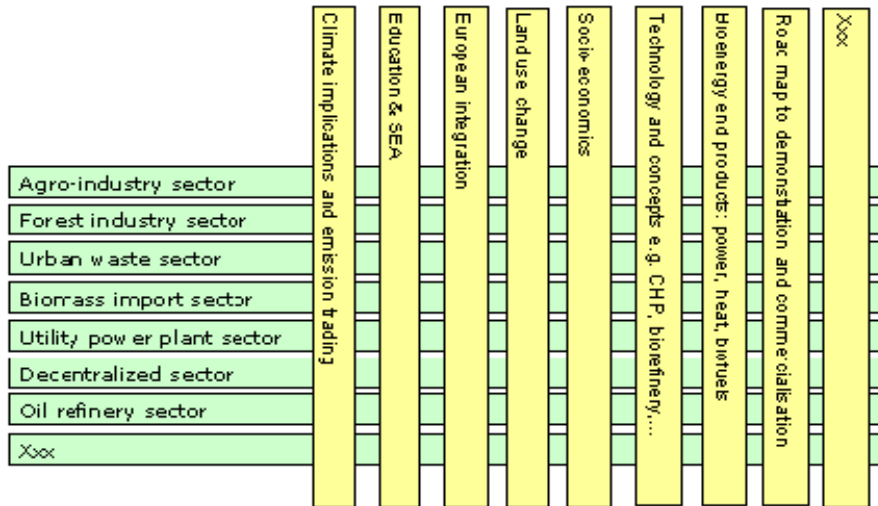


Figure 27. A structure to analyse bioenergy business opportunities within the Bioenergy NoE.

Integration of capacities in bioenergy R&D is needed to reach the EU White Paper goals of doubling the use of bioenergy by the year 2010. New technologies and business concepts are needed, and Bioenergy NoE has to respond to the demands of the European Commission and industry. The critical tasks of Bioenergy NoE will be: to support the generation of new bioenergy opportunities through improved RTD capabilities, to back-up and influence policies and legislation, and to enhance knowledge sharing, education and mobility.

In fact the revived concept of biorefinery is effectively calling for a novel economic synergy of biomass-based products, including energy related ones, but not necessarily new technical processes, as is often believed. Integrating bioenergy production with forest industry, electricity and heat, waste recycling, liquid biofuel production and/or chemical industry improves competitiveness. Biorefineries and polygeneration of multiple products is largely seen as an important approach to efficiently utilise limited raw material resources. Cooling, desalination of sea water, production of liquid biofuels, green chemicals, and renewable products will be integrated to bioenergy plants for optimising the use of biomass.

The basic logic is to make the most of the raw material, which is a principle that lies at the heart of common-sense engineering. Biomass as a limited resource should be used as efficiently as possible. Thus the concept of a biorefinery does not offer advice for new processes, but rather a new frame for thought in bioenergy related activities. Modern technical development has brought in new opportunities for innovative, systems based solutions – small scale, combined to existing infrastructure through automation, flexible systems and multipurpose equipment. Economy of scale is a largely unexploited opportunity in the traditional area of bioenergy production and distribution.

## 7. Summary

The present study was carried out within the Network of Excellence “Overcoming Barriers to Bioenergy” (Bioenergy NoE), which started in 2004 as a new RTD instrument in the Sixth Framework Programme of the European Commission. Bioenergy NoE is a partnership of eight leading bioenergy institutes that are integrating their expertise and activities to foster excellence in European bioenergy. Identification and analysis of barriers to bioenergy and definition of RTD goals to overcome the barriers have been carried out within the different Work Packages of the Network.

The aim of this publication is to give a comprehensive overview of the opportunities for and barriers to bioenergy development in Europe, considering EU policy issues and their implementation in Europe, biomass availability and technology development aspects, and RTD goals to overcome the barriers to bioenergy development.

Combating climate change is one of the main commitments under the sustainable development strategy of the European Union. In an effort to formulate a strategy towards sustainable energy production for Europe and to diminish strategic dependence on imported fuels, in particular oil for transport, several political initiatives have been taken within the European Commission and the individual member countries.

Important European targets have been set for 2010, such as the White Paper targets of doubling the share of renewables to 12% [an equivalent of about 180 Mtoe (7 540 PJ)] and tripling the use of biomass to 135 Mtoe (5 660 PJ) compared to 1997, the RES-E Directive target to increase the share of green electricity to 21%, and the Biofuels Directive target of 5.75% substitution of conventional transport fuels with biofuels. Recently, the Commission launched a Biomass Action Plan. It is part of the overall EU objectives of improving competitiveness, sustainability, and security of supply. Further, targets for the year 2020 have been proposed, for example the biofuels target of 20% substitution. Limiting the share of MSW to be landfilled to 35% has been set for 2016.

The policies and regulations adopted for the renewables affect the use of bioenergy in different EU countries. In February 2005 the Kyoto Protocol entered into force, and preparation of the Post-Kyoto climate policy has been started. The Emissions Trading Scheme started in January 2005. Directives concerning waste management have been adopted by the Commission, for example the Landfill Directive came into operation in 2005. The Commission is carrying out a fundamental review of its energy policy in a Green Paper in spring 2006. The action plan sets out measures to increase the development of biomass energy from wood, wastes and agricultural crops. It includes measures to promote biomass in heating, electricity and transport, followed by cross-cutting measures affecting biomass supply, financing, and research.



In spite of the many positive initiatives going on in the bioenergy field in Europe, the overall developments in bioenergy utilisation has lagged far behind European goals. The use of bioenergy in the EU15 in 2003 was about 58 Mtoe (2 420 PJ) contributing 3.7% of the total primary energy sources. All the EU Member States have initiated support systems for renewable energy and adopted national targets for the share of electricity production from RES. Bioenergy is regarded as the most important renewable fuel in the EU. However, under current measures, it looks like the EU is not going to reach the targets set for the RES and green electricity in 2010. More action must be taken across the bioenergy sector, in electricity, heating, biofuels, and waste management, to enable the EU to meet its targets for bioenergy and RES.

The rapid increase in the use of bioenergy is mainly taking place in the Scandinavian countries and partly in Germany. Wood is the most important RES for primary energy production in Europe. Concerning biofuels for transport many Member States have partly or completely removed taxes following European legislation. There are, however, deviations in the national targets from the targets set by the Commission for the years 2005 and 2010. Support mechanisms for bioenergy have also been introduced in all New Member States, except Malta. The mechanisms in use are feed-in tariffs for bioelectricity, government subsidies for bioenergy investments, grants and soft loans from special environmental funds, and tax relief on bioenergy investments. Furthermore, bioenergy is regarded as a key to encouraging sustainable development in rural areas, non-food production is supported, and energy crops cultivation and afforestation of abandoned land are also given priority. Biofuels production and use have been supported in form of subsidies or quantitative targets in many New Member States, of which the Czech Republic has the most favorable conditions.

The waste management is regulated chiefly by the EU. The directives define the political framework, and they have already been or will in the near future be adopted into the national regulations in all the EU countries. In the adaptation of the directives there are distinctive differences between the countries. The definition of waste and its partly biogenic nature has a great impact on subsidization and hence on the economy of WtE strategies. The target of the Landfill Directive will be reached only by substantially increasing the energy use of waste within the EU.

At present about 40 EJ of the available biomass in the world is used annually for energy. Estimates of the future potentials range very widely. The potential through the year 2050 has been quantified at 33–1 135 EJ/a. In Europe, the use of biomass and wastes for energy production is presently about 2.9 EJ/a (69 Mtoe), and the potential in 2050 is estimated to range from 9.0 to 13.5 EJ/a (215–320 Mtoe). The Commission estimates that the measures of the Biomass Action Plan could lead to an increase in biomass use to about 150 Mtoe (6.3 EJ) in 2010 or soon after. Thus the biomass

resources and potentials for Europe are very large taking into consideration, in addition to the European reserves, import possibilities. On the basis of the estimates, there are sufficient domestic resources to meet the EU targets set for the year 2010, but if more stringent goals are set for bioenergy in the future, it will be challenging to find sufficient resources in Europe and biomass imports from outside the EU will be necessary. Anyway to reach the European goals for bioenergy all the main biomass sources will be needed, forest resources, agricultural biomass, and biogenic urban wastes.

The future biomass potentials are affected, for example, by demand for food, productivity of forest and energy crops, availability of degraded land, competing land use types, recoverable residues, environmental requirements, markets and incentives, and research and development progress. Actual developments of these factors will determine the future biomass potential and the competitive use of biomass.

The activities of the Work Packages defined in the Bioenergy NoE cover practically the entire field of bioenergy, from production to utilization. The barrier analyses resulted, as expected, in a wide variety of non-technical and technical barriers. Overall, non-technical barriers dominate, with economic barriers being the most prominent. However, there is no single barrier that appears as the most important; it is the interaction of many barriers that impedes the rapid expansion of bioenergy use.

Insufficient availability of low cost biomass feedstock was seen as a major barrier in most areas, except biowaste to energy applications. There might be competition for biomass resources in large scale applications, e.g. forest industry and liquid biofuel production. Furthermore, competition for land use is discussed in terms of energy crops. The price structure of biomass is influenced by local, national and European policy issues, environmental and energy taxes as well as supporting and legislative instruments. A deeper penetration of economic barriers related to availability of low cost biomass feedstock therefore usually leads to more detailed case studies on a local level.

In addition to non-technical barriers, a large number of technology related barriers were identified within the different areas of bioenergy. Even omitting the economic barriers and biomass availability constraints technical barriers were considered critical in introducing novel production and utilization technology e.g. in the area of transportation biofuels. Inadequate feedstock and fuel standards were considered to hamper the large scale market introduction of biomass fuels. A whole-chain approach and demonstration were emphasized. The barriers defined for feedstock production, heat and power technologies, liquid biofuels technology, and waste to energy areas were presented. R&D work was suggested to overcome a wide variety of technical barriers related to individual process steps within production and utilization schemes.

The main technologies to produce heat and power from biomass are combustion, gasification, combined heat and power production, co-firing, and production of refined biomass fuels, such as pellets and pyrolysis oil. In nearly all Bioenergy NoE partner countries similar barriers were found but the importance given to each barrier differs considerably between the countries. Technological development is a key to improving the economics of bioenergy, increasing availability of low-cost biomass resources and reducing negative impacts on the environment. Security of fuel supply and technological problems are among the most important barriers. In pulverised coal-based boilers, direct co-firing is limited to 5–10% of coal. Problems are found in co-combustion in supercritical fluidized-bed boilers. Slagging, fouling and corrosion are still a big problem in plants using biomass.

Liquid transportation fuels that are currently produced commercially from biomass are bioethanol from sugar and starch crops and residues and biodiesel from vegetable oils. Brazil and the United States are the major producers and consumers of fuel ethanol. The European Union is the major producer and consumer of biodiesel and responsible for about 90% of the biodiesel production and consumption. In the EU, the major biodiesel producers are Germany, France, Italy, Denmark, the Czech Republic, and Austria. The major producers of fuel ethanol are Spain, France, Sweden, Poland, and Germany. In 2004, about 1.9 million tonnes of biodiesel and about 0.5 million tonnes of fuel ethanol were produced in the EU25. The indicative target of 5.75% set in the Biofuels Directive for the biofuel share in road transportation fuels in 2010 would mean a biofuel utilisation of about 17–18 Mtoe/year (710–750 PJ) in the EU.

The costs of liquid biofuels for transport are, like for other bioenergy options, a major barrier. R&D on feedstock cultivation as well as liquid fuel production technologies can help to reduce the price gap between liquid biofuels and the petroleum based transportation fuels, but cost difference will remain an important barrier. Other barriers are lack of infrastructure for blending and distribution, low conversion of lignocellulose in hydrolysis, tar problems related to syngas production, and existing fuel standards in the EU, and standards defined by car manufacturers.

The potential for significant biomass utilisation in Europe is affected by many factors, such as EU and national policies and regulations, emissions trading, biomass availability and the logistics of feedstock supply, technology development, and economical and social factors. Making significant biomass utilisation a reality in Europe, depends largely on the development of these factors.

The CAP reform in 2003 substantially influences bioenergy development. The changes in the CAP have introduced payments for energy crops. The CAP development is an important factor for agricultural biomass, as it contains strong drivers through

employment and decreasing subsidies. An EU bioenergy policy that considers agriculture at its heart would be an important instrument as it seems that any kind of large-scale bioenergy implementation in Europe must be built around the agricultural problem. The order of magnitude of the set-aside area (10%) is in agreement with estimated needs, around 14% of agricultural area, for bioenergy cultivation.

Possibly the most important research objective is to release the potential of bioenergy in the New Member States of the EU. The need for a common market in the Europe on biomass for energy purposes is highlighted because the conversion technologies for bioenergy are often established in the western countries of the EU and the biomass resources are in the eastern countries.

Supply chains and production processes need to be improved in order to reach the targets set for bioenergy. Every link in the production chain has to be optimised to improve profitability without compromising on quality and supply security.

Concerning heat and power technologies, the pulp and paper industry is a natural platform for the large use of bioenergy, due to the optimal integration of fuel supply and energy, process steam and power demand. Other important users of bioenergy in large scale plants are heat producers and CHP producers for district heating systems and other process industry. The third large sector is the co-firing of biomass in pulverised coal boilers. In the future, new technologies will make it possible to increase the use of bioenergy in new sectors such as CHP with a higher power-to-heat ratio, high efficiency power generation, production of liquid and gaseous biofuels, and utilisation of new biomass resources.

The use of liquid biofuels for transport is currently limited to about 2 Mtoe (84 PJ) in the EU, corresponding 0.7% of the total final energy consumption for road transport in the EU. Estimates of the potential contribution of conventional liquid biofuels show limited prospects. Advanced biofuels offer the prospects of much higher yields per ha of land. Furthermore, requirements for cultivation of lignocellulosic biomass, used as feedstock for advanced fuels, are less stringent than for the feedstock used for the conventional liquid biofuels, increasing the area of land that is suitable for cultivation.

For the short term, the EU Biofuels Directive and accompanying economic incentives will help the market for liquid biofuels to take off. Current developments in the production of conventional liquid biofuels show that in the short term feedstock availability and biomass conversion technology are not the limiting factors or barriers. Once conventional liquid biofuels have reached their potential the challenge will be to develop the advanced liquid biofuels as they alone will make the largest contribution to the liquid biofuels market. This will require RD&D on advanced liquid biofuels.

Clearly, market development initiated by the conventional liquid biofuels will help to change the RD&D on advanced liquid biofuels from “technology push” to “market pull”. Initially, advanced liquid biofuels can be produced from residue streams like wheat straw and residues from e.g. pulp and paper industry. Once residue based advanced liquid biofuels have entered the market, the conversion technology will be ready and feedstock availability will have to be increased by biomass cultivation.

A prerequisite for rapid implementation of new bioenergy solutions on the European market is the use of existing infrastructures in the conventional biomass production and energy industry. Within Bioenergy NoE there is agreement that a considerable increase in the use of bioenergy cannot take place without industry support. Therefore the intended increase can only be realised through new business opportunities.

Integration of capacities in bioenergy R&D is needed to reach the EU White Paper goals of doubling the use of bioenergy by the year 2010. New technology and business concepts are needed, and Bioenergy NoE has to respond to the demands of the European Commission and industry. The critical tasks of the Bioenergy NoE will be: to support generation of new bioenergy opportunities through improved RTD capabilities, to back-up and influence policies and legislation, and to enhance knowledge sharing, education and mobility.

Integrating bioenergy production with forest industry, electricity and heat, waste recycling, liquid biofuel production or the chemical industry improves competitiveness. Biorefineries and polygeneration of multiple products is largely seen as an important approach to efficiently utilise limited raw material resources. Cooling, desalination of sea water, production of liquid biofuels, green chemicals, and renewable products will be integrated to bioenergy plants for optimising the use of biomass.

The basic logic is to make the most of the raw material, which is a principle that lies at the heart of common-sense engineering. Biomass as a limited resource should be used as efficiently as possible. Thus the concept of a biorefinery does not offer advice for new processes, but rather a new frame for thought in bioenergy related activities. Modern technical development has brought in new opportunities for innovative systems based solutions – small scale, combined to existing infrastructure through automation, flexible systems and multipurpose equipment. Economies of scale are a largely unexploited opportunity in the traditional area of bioenergy production and distribution.

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<b>Title</b> <b>Bioenergy in Europe Opportunities and Barriers</b>			
<b>Abstract</b> The aim of this publication is to give a comprehensive overview of the opportunities for and barriers to bioenergy development in Europe. The study carried out within the Bioenergy Network of Excellence "Overcoming Barriers to Bioenergy" (Bioenergy NoE) covers EU policy issues and their implementation in Europe, biomass availability and technology development aspects, and RTD goals to overcome the barriers to bioenergy development.  Important European targets have been set for 2010, such as the White Paper targets of doubling the share of renewables to 12%, and tripling the use of biomass to 135 Mtoe (5.7 EJ) compared to 1997, the RES-E Directive target of a 21% share of green electricity, and the Biofuels Directive target of 5.75% of transport fuels to be supplied with biofuels. Recently, a Biomass Action Plan was launched. Further, a biofuels target of 20% substitution by 2020 has been proposed, and the maximum of 35% for the share of MSW to be landfilled has been set for the year 2016. EU policies and regulations are important drivers for bioenergy development in the EU countries.  In Europe, the use of biomass and wastes is presently about 2.9 EJ/a (69 Mtoe). By 2050, it is estimated that biomass and waste utilisation could rise to anywhere from 9.0 to 13.5 EJ/a (215–320 Mtoe). According to the Biomass Action Plan the measures could lead to the use of about 150 Mtoe (6.3 EJ) in 2010 or soon after. There are sufficient domestic resources to meet the EU targets set for the year 2010 but if more stringent goals are set for bioenergy in the future, it will be challenging to find sufficient resources in Europe and biomass imports from outside the EU will be necessary.  The barrier analysis carried out within the Bioenergy NoE resulted in a wide variety of non-technical and technical barriers. Overall, non-technical barriers dominate, with economic barriers being the most prominent. However, there is no single barrier that appears as the most important; it is the interaction of many barriers that impedes the rapid expansion of bioenergy use. Even omitting the economic barriers and biomass availability constraints technical barriers are critical in introducing novel production and utilization technology. Barriers defined for feedstock production, heat and power technologies, liquid biofuels technology, and waste to energy areas are presented. R&D work is suggested to overcome a wide variety of technical barriers related to individual process steps within production and utilization schemes.  The potential for significant biomass utilisation in Europe is influenced by EU and national policies and regulations, emissions trading, availability of biomass and the logistics of feedstock supply, the development of technologies, and economic and social issues. The CAP reform in 2003 substantially influences bioenergy development.  A prerequisite for rapid implementation of new bioenergy solutions in the European market is the application of existing infrastructures in the conventional biomass production and energy sectors. Within the Bioenergy NoE, there is agreement that a considerable increase in the use of bioenergy cannot take place without industry support. Therefore the intended increase in the use of biomass can only be realised through new business opportunities.  Integration of capacities in bioenergy R&D is needed to reach the EU White Paper goals. New technologies and business concepts are needed, and Bioenergy NoE has to respond to the demands of the European Commission and industry. Integrating bioenergy production with forest industry, electricity and heat, waste recycling, liquid biofuel production and/or chemical industry improves competitiveness. Biorefineries and polygeneration of multiple products are widely seen as an important approach to efficiently utilise limited raw material resources.			
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The study carried out within the Bioenergy Network of Excellence aims to give a comprehensive overview of the opportunities for and barriers to bioenergy development in Europe. The goal of the Bioenergy NoE is to build a Virtual Bioenergy Research and Development Centre that exploits the capabilities of the partners in building a thriving and successful bioenergy sector in Europe.

Important European targets for the use of renewables and bioenergy have been set for 2010. The potential for significant biomass utilisation is influenced by EU and national policies and regulations, emissions trading, availability of biomass and the logistics of feedstock supply, the development of technologies, and economic and social issues. There are sufficient domestic resources to meet the EU targets for 2010 but if more stringent goals are set in the future, it will be challenging to find sufficient resources in Europe and biomass imports from outside the EU will be necessary. Integration of capacities in bioenergy research and development, and development of new technologies and business concepts are needed to reach the EU goals. Integrating bioenergy production with forest industry, electricity and heat, waste recycling, liquid biofuel production and/or chemical industry improves competitiveness. Biorefineries and polygeneration of multiple products are widely seen as an important approach to efficiently utilise limited raw material resources.



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