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ELECTRICITY FOR EUROPE

Biomass 2020: Opportunities, Challenges and Solutions



RESAP

This report is part of the EURELECTRIC Renewables Action Plan (RESAP).

The electricity industry is an important investor in renewable energy sources (RES) in Europe. For instance, it is responsible for 40% of all wind onshore investments. RES generation already represents a substantial share in the power mix and will continue to increase in the coming years.

EURELECTRIC's Renewables Action Plan (RESAP) was launched in spring 2010 to develop a comprehensive industry strategy on renewables development in Europe.

RESAP addresses the following key challenges in promoting RES generation:

- the need for a system approach to flexibility and back-up,
- the need for a market-driven approach,
- the need for a European approach to RES development.

RESAP consists of 13 task forces, including for example demand side management, market design, load and storage. The purpose of RESAP is to develop, through a series of reports and a final synopsis report, sound analysis with key recommendations for policymakers and industry experts.

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The **Union of the Electricity Industry–EURELECTRIC** is the sector association representing the common interests of the electricity industry at pan-European level, plus its affiliates and associates on several other continents.

In line with its mission, EURELECTRIC seeks to contribute to the competitiveness of the electricity industry, to provide effective representation for the industry in public affairs, and to promote the role of electricity both in the advancement of society and in helping provide solutions to the challenges of sustainable development.

EURELECTRIC's formal opinions, policy positions and reports are formulated in Working Groups, composed of experts from the electricity industry, supervised by five Committees. This "structure of expertise" ensures that EURELECTRIC's published documents are based on high-quality input with up-to-date information.

For further information on EURELECTRIC activities, visit our website, which provides general information on the association and on policy issues relevant to the electricity industry; latest news of our activities; EURELECTRIC positions and statements; a publications catalogue listing EURELECTRIC reports; and information on our events and conferences.

EURELECTRIC pursues in all its activities the application of the following sustainable development values:

Economic Development
- Growth, added-value, efficiency

Environmental Leadership
- Commitment, innovation, pro-activeness

Social Responsibility
- Transparency, ethics, accountability

Dépôt légal: D/2011/12.105/51

Biomass 2020:

Opportunities, Challenges and Solutions

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KEY POLICY RECOMMENDATIONS

Additional measures will be needed to ensure that biomass realises its potential to contribute to the EU's renewable energy targets.

- Biomass has the capability to contribute strongly to meeting the European Union's renewable targets for both heat and electricity in 2020. A significant majority of the biomass required can be produced within the EU. In order to realise this potential, the primary supply of solid biomass and biogas within the EU will have to increase substantially. We estimate a feasible increase of 82 Mtoe in 2010 to 120 Mtoe by 2020 (with an additional import of up to 40 Mtoe). **This increase in EU biomass production will not occur without the introduction of significant additional supporting policies and measures.**

Policymakers should work towards a framework that incentivises supply-side measures for sustainable biomass production within the EU and promotes long-term availability.

- **Mandatory EU-wide harmonised sustainability criteria are necessary in the immediate future, to provide reliable evidence to the general public that biomass is a sustainable fuel**. These criteria are particularly important for imported forms of biomass. We otherwise fear that the development of separate national sustainability schemes will create inefficiencies, increase costs and result in a lack of transparency. They will impede biomass trade and deter investment in biomass cultivation and biomass-powered electricity (dedicated and co-fired plants) and heat generation, as well as in biogas because of uncertainty over long-term fuel supply in a changing regulatory environment.
- EURELECTRIC understands that some member states who are already major biomass users oppose such harmonised criteria for fear of further administrative burden, **but such criteria are absolutely necessary to ensure development biomass on an EU level.** However, we would suggest for those member states that harmonised criteria should take into account existing national legislation on forestry covering sustainability, and a "fast track" compliance system should be investigated for biomass producers adhering to such legislation to minimise administrative burden.
- **Sustainability criteria should be the principally the same for all types of biomass, but must take account of the differences between different types of biomass**. While sustainability of agricultural biomass is often connected with the food chain and land-use change issues, forest biomass sustainability is more related to sustainable growth, carbon stock and biodiversity issues. Therefore the single set of criteria for these different forms of biomass must take into account the differences.
- **Additional or improved measures are required which support a greater degree of forest thinning and the enhanced collection and use of forest residues**. The European Union's forests have the potential to contribute more biomass for energy use, without any detrimental impact on the existing forest product industries.
- **Policymakers will need to realign the available support towards promoting the primary production of biomass for energy purposes, within the upcoming reform of**

the Common Agricultural Policy. The greatest potential for increasing indigenous biomass supply resides in the agricultural sector, particularly the growth of energy crops on land which is underutilised today. This potential can be realised without impacting on food production in the EU.

- **There is a need to ensure that framework policies for waste and the end-of-waste provisions, act in concert to ensure that renewable energy recovery is maximised from these supply chains.** With the mandatory reduction in the landfill disposal of biodegradable waste, waste supply chains offer considerable potential for the enhanced supply of biomass and biogas.

- **Markets for all primary biomass resources should be open and progressively integrated across the EU.** Biomass markets should not be subject to member state interference that would restrict the sale of biomass products to one particular national market or to favoured industrial sectors. Any market rules introduced should provide a level playing field for all industrial users of biomass.

Policymakers also need to pay attention to the enhancement of demand-side measures that support the use of biomass for the production of renewable energy within the EU.

- **Stable, consistent and sufficiently sufficient incentives are required for the production of electricity and heat from biomass towards the 2020 RES target.** At present, support schemes for renewable energy produced from biomass and biogas are often less rewarding than those supporting other forms of renewables, in common with which bioenergy cannot yet compete with non-renewable technologies at current costs. We recommend that the European Commission's 2012 report on member state progress reports carefully analyzes the sufficiency of national support schemes for biomass electricity and heat. Without stable and sufficient support schemes, the energy industry will lack the confidence to invest in plant and in the development of biomass supply chains. Support schemes should neither discriminate between the sizes of plants nor exclude any sustainable form of biomass.

- **Progress is required towards a harmonised approach to support for electricity and heat production from biomass.** Such harmonisation would encourage the utilisation of indigenously produced biomass in close proximity to its source of origin. It would reduce the amount of biomass transported within the EU and its associated carbon footprint, and help to limit the long-distance transfer of biomass to those forms which have a high energy density. A first step would be utilisation of the joint projects concept under the co-operation mechanisms permitted by the Renewables Directive.

The projected biomass demand-supply gap within the EU can be filled, at least in the short term, by international biomass supply.

- **Open international markets** are required to ensure the long-term security of supply for biomass imports into the EU**.**

- **Sustainability criteria developed within the EU for biomass also need to be promoted and progressively harmonised at international level,** in order to facilitate and maintain international biomass trade.

- **Competition for biomass materials on international markets is forecast to increase over the period to 2020 and beyond.** In international climate change negotiations the EU has led the way with respect to greenhouse gas emission reductions and renewable energy utilisation. If other OECD countries and the larger developing nations adopted similar targets, the international use of biomass for RES production would increase significantly. This would limit the availability of biomass materials for export to the EU, and also act to increase biomass prices.
- **This reinforces the need for policies and measures that will support the maximum production of biomass within the EU.** The inevitable future increase in the use of biomass for energy production by third countries reinforces the need for policies and measures within the EU to maximise indigenous biomass production. These policies and measures are required across all biomass categories and supply chains, but most particularly in the agricultural sector, which has the greatest potential for increased domestic supply.

KEY INSIGHTS

***Biomass use for energy will grow significantly to 2020*:**

- EURELECTRIC is convinced that **biomass is an important renewable source and will form a significant part of reaching the 2020 RES targets**.
- In addition to hydro power, biomass is one of the few forms of **dispatchable renewable power generation** and has a key role to play in providing back-up capacity to other forms of intermittent and non-synchronous renewable generation.
- **Bioenergy use will increase 2.5 times by 2020:** EURELECTRIC'S calculations, based on the national renewable energy action plans, indicate that the use of primary bioenergy (including bioliquids) will increase from the current level of 85 Mtoe to around 215 Mtoe in 2020.
- **Primary solid biomass use for the EU power and heat sector EU will increase to 146-158 Mtoe by 2020,** depending on the rate at which the thermal efficiencies of conversion facilities are improved.
- **Currently, primary production of solid biomass within the EU is around 82 Mtoe, while our projections indicate that this could increase to around 120 Mtoe by 2020.** Therefore, even if this growth in production occurs, there will still be a biomass supply gap of around 25-40 Mtoe.
- **Our analysis indicates that, at present, this supply gap could be filled by imports.** If the entire solid biomass supply gap was filled by wood pellets, the form of biomass with the highest energy density, this would imply the annual importation of 60-90 million tonnes of pellets.

This massive growth in biomass use will require:

- **Significant investment in biomass supply chains** will be required within the EU, encompassing establishment, cultivation, harvesting equipment and transportation, in order to achieve the assumed 50% increase in domestic primary biomass production.
- In the **forest-based supply chain**, a key challenge is the introduction of a **framework which incentivises owners and producers** to enhance the supply of woody biomass for energy use.
- In the **agricultural feedstock chain**, the key challenge is to **realign the provisions, supports and premiums within the Common Agricultural Policy** so that they actively support the production of biomass within the EU.
- For increased production of **short rotation coppice (SRC)**, the key challenge is the provision of support to **offset the high costs of SRC establishment**, and also **an energy crop premium** to cover the period up until the first harvest.
- **A massive expansion of biomass power and heat generation** will be required – both new build and the adaption or conversion of existing fossil plant**.**
- Installed biomass power generation capacity will need to increase from **circa 24 GW**

in 2010 to 43 GW by 2020.

- EURELECTRIC believes that **EU-wide harmonised sustainability criteria** will be needed in due time to provide reliable evidence to the general public that biomass is a sustainable fuel, especially for imports
- **Imports of biomass from outside the EU** will be required, at least to the level of the mentioned supply gap, but internal market conditions may imply that imports are even higher.
- Investment will also be required, both in **upstream processing facilities and in transportation capacity**, to deliver the increased volumes of imported biomass foreseen.
- **Markets for primary resources should be open,** progressively integrated across the EU, and not subject to political interference to restrict sales of biomass to one national market or favoured industrial sectors. Any rules should be the same for all market players – i.e. all industrial users of biomass.

Maintaining a wider perspective:

- Our evaluation indicates that the **estimated volumes of imported biomass needed in 2020 are available on the global market,** but that this could change if biomass power generation is further promoted outside of the EU.
- Concretely, there is the possibility that countries with a large fleet of coal-fired generation – e.g. USA, China, South Africa, Australia – **may also promote biomass co-firing to reduce their carbon emissions**.
- Whilst this would be a positive evolution in its own right, this would **significantly constrain the global biomass market and increase costs** for the EU. This is an issue that must be borne in mind when costing future renewables scenarios.

Table of Contents

BACKGROUND NOTES:

Statistical Units

Both fuels and the resulting products contain energy. The energy content of products – mainly electricity and heat – are recognized by the user as what can be read on the metering device at home, and what our household machinery or our heating consumes. We can find the amount of energy used on the invoices from our suppliers in kWh units (kWh = kilowatt hours).

The energy content of fuels is a more abstract value, because fuels have first to be transformed into a utilizable form – e.g. electricity. When converted from fuel to electricity, energy losses occur, depending on conversion technology, plant efficiency, etc.

This paper focuses on the EU 20% by 2020 renewable energy target of the EU. To cope with the challenge of describing the energy demand of a large economy like the EU, we are using the common unit **Mtoe** (million tons of oil equivalent). This enables us to describe large energy flows without having to use large, confusing numbers.

1 Mtoe equals about 11.63 billion kWh. Given that fuel (containing 1 Mtoe of energy) would be converted into electricity with a conversion efficiency of 40 %, and given that an average household would use 3.500 kWh per annum, one million households could be supplied for 16 months.

In forestry and agricultural operations other units have proved useful, like cubic metres, or tonnes of dry or wet material. The energy content of woody materials may vary broadly depending on plant species, moisture content, harvesting technology, etc. Therefore, in this paper, we only use these units where they are necessary to understand the basics of supply chain and use of the respective woody or agricultural sources.

Note on National Renewable Energy Action Plans

This report includes significant reference to the National Renewable Energy Action Plans (NREAPs), the initial versions of which were submitted to the European Commission by all Member States by February 2011. A number of member states have since submitted slightly revised NREAPs to the Commission. In this report, it should be noted that the figures quoted from the NREAPs Plans are only corrected to the initial versions of the plans as at February 2011, and do not reflect any later revisions to the plans. However, these later revisions are not considered to significantly affect summary results or conclusions.

Consultancy Reports

Part of the analysis is underpinned by two separate reports commissioned from Pöyry Energy Consulting:

- “An Evaluation of National Renewable Energy Action Plans”, Pöyry Energy Consulting (UK), completed in March 2011.
- “Biomass Imports to Europe and Global Availability”, Pöyry Energy Consulting (Deutschland) for VGB PowerTech and EURELECTRIC, completed September 2011.

1. INTRODUCTION

Purpose of this report:

EURELECTRIC views bioenergy as a key tool in fulfilling the EU's 2020 renewable energy targets and curbing climate change. The National Renewable Energy Action Plans (NREAPs) suggest that electricity production from biomass will increase from 90 TWh in 2006 to around 230 TWh in 2020, whilst other projections of reaching the 2020 targets have indicated rather higher levels, up to 360 TWh in 2020[1]. EURELECTRIC members will play the major role in developing this growth in biomass-fired power generation.

The most important argument for using biomass for energy purposes is that it is a low-carbon fuel, which is considered CO_2-neutral at the point of combustion as it only releases recently absorbed carbon. It therefore does not contribute to increasing the CO_2 content of the atmosphere and to the resulting aggravation of the greenhouse effect. Biomass is an essential part of the renewable portfolio; unlike other sources of renewables, it can provide baseload power generation and heating, and can also be used in existing thermal plants. Furthermore, biomass can be used as fuel in the automotive and transport sector. We favour the use of sustainable biomass, avoiding potential detrimental effects on the environment and social welfare.

The purpose of this report is set a vision of the use of biomass in the energy sector in 2020 in order to contribute to achieving the EU's 2020 renewables target and to establish the policy measures needed to reach this vision. The focus of this report is primarily upon the use of biomass in the electricity and heat sector, leaving aside significant detail on the use of liquid biofuels in the transport sector. This report is subsequently set out in the following sections:

- *Section 2: Introduction to Bioenergy*

This section provides a general introduction to bioenergy, i.e. primary resources, supply chains, etc.

- *Section 3: Overview of the current state of the biomass power sector*

This section provides an overview of the biomass power sector in terms of production capacity, technologies and an overview of types of bioenergy, including their supply chains.

- *Section 4: Biomass supply and demand balance*

This section considers the projections in the Member State NREAPs of the contribution of biomass towards the 2020 targets, and in turn whether enough biomass is available to fulfil these ambitions, both from within the EU and from external imports. Input is provided by a consultancy study from Pöyry Energy Consulting, commissioned by EURELECTRIC and VGB.

- *Section 5: Actual Supply Chains*

This section provides an overview of the three main biomass supply chains: forest-based, agriculture (including straw, short rotation coppice, and agro-industrial residues) and waste.

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[1] *360TWh figure taken from: Capros et al (2008) Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables (report for EC DG Environment, using PRIMES model, 2007 baseline)*

- *Section 6: Biomass fuels*

This section provides an overview of the types of final biomass fuels used in electricity and heat production.

- *Section 7: Support schemes for Bioenergy in the electricity sector*

This section examines the current levels of support for the utilisation of bioenergy in the electricity sector and raises the question whether support is sufficient to develop biomass electricity.

- *Section 8: Sustainability criteria and harmonisation*

This section provides an analysis of biomass sustainability and the design of and need for harmonised sustainability criteria.

2. INTRODUCTION TO BIOENERGY

Biomass can be used as a source of energy input for electricity generation, provision of heat and in the transport sector. The biomass itself is derived from three principal sources: forestry, agricultural products and biogenic waste. These areas encompass a wide range of feedstocks, as discussed in later sections, but in general forestry products consist of wood, bark, branches and stumps, agricultural products consist of oil and sugar containing plants, whilst biogenic waste is derived from the agricultural, commercial and household sectors. These sources of biomass exist in three forms: solid (e.g. plants and wood), gaseous (e.g. from biowaste) and liquid (oils from crops or biofuels produced from lignocellulosic matter).

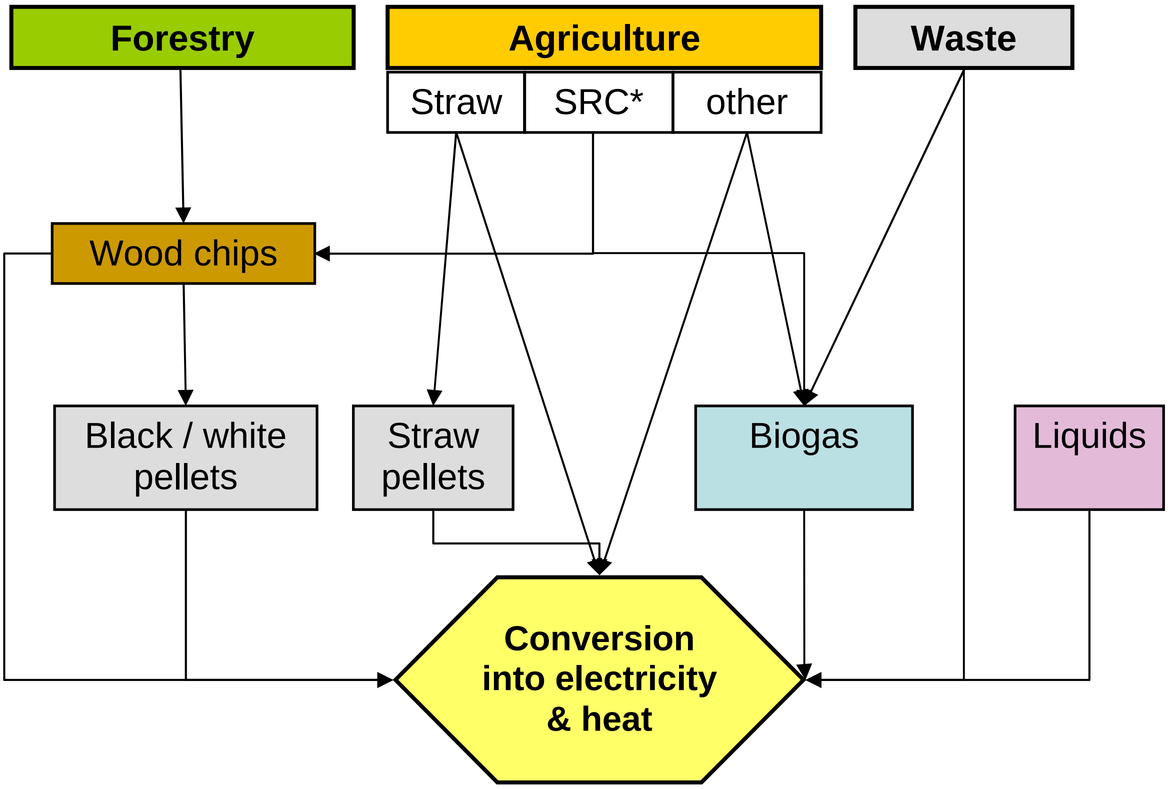

Figure 1: Overview of biomass primary resources input into electricity and heat production (SRC* = short rotation coppice)

When considering bioenergy it is useful to make a distinction between the primary feedstock and the final product for energy production (see Figure 1). Most forms of primary biomass are subject to some form of processing to convert them into useful energy products. The different forms of feedstocks and final products are described in sections 4 and 5.

Biomass can be converted into useful energy (heat or electricity) or energy carriers by both thermochemical and biochemical conversion technologies. The type of bioenergy, its physical characteristics and chemical composition influence the entire process of biomass utilisation. Biomass power plants for electricity production are similar to conventional thermal power plants.

Four thermochemical biomass conversion technologies for energy purposes exist: pyrolysis, gasification, direct combustion, and liquefaction. The selection and design of any biomass power plant is determined mainly by the characteristics of the fuel to be used, existing environmental legislation, the costs and performance of the equipment available, as well as the energy and capacity needed (heat, electricity).

At present, biomass is mostly converted into electricity by means of direct combustion. Since biomass fuels and the resulting flue gases can contain elements that may damage engines, such as fly ash particles, metals, and chlorine components, only external combustion technologies can be used. As the named elements are harmful to the environment, flue gas treatment is necessary.

In biomass gasification, biomass is converted into a gaseous fuel, the major components being carbon monoxide and hydrogen. The gas produced can be used as a fuel for generating heat and electricity, but also as a synthesis gas in the chemical industry.

Co-combustion of biomass with hard coal, lignite and peat in traditional boilers represents one combination of renewable and fossil energy utilisation that derives the greatest benefit from both fuel types. With pulverised fuel plants, biomass can readily replace up to 10% of a boiler's coal input with only minor equipment modifications. With fluidised bed plants, significantly higher levels of co-firing can be achieved – typically of the order of 50%. With further modifications, some existing coal-fired power stations can be converted to run solely on biomass.

3. Overview of the current state of the biomass power sector

3.1 Biomass power generation capacity and production – existing and future

In 2005, the total capacity of biomass power generation was 15.7 GW. With 3 GW, Germany had the highest capacity, followed by Sweden (2.5 GW) and Finland 2 GW. According to the member state National Renewable Energy Action plans (NREAPs), 2010 already saw 23.6 GW in place (real data is not yet available for 2010), whilst the ambitions for reaching the 2020 Renewables target would see 43.2 GW of capacity in place. As shown in figure 2 below, there is significant variation in the national plans to expand biomass electricity production to reach the renewables targets. Poland, for example, intends to increase capacity six-fold between 2010 and 2020; Belgium plans to quadruple capacity; and many states intend to double or triple capacity (e.g. UK, Italy, France).

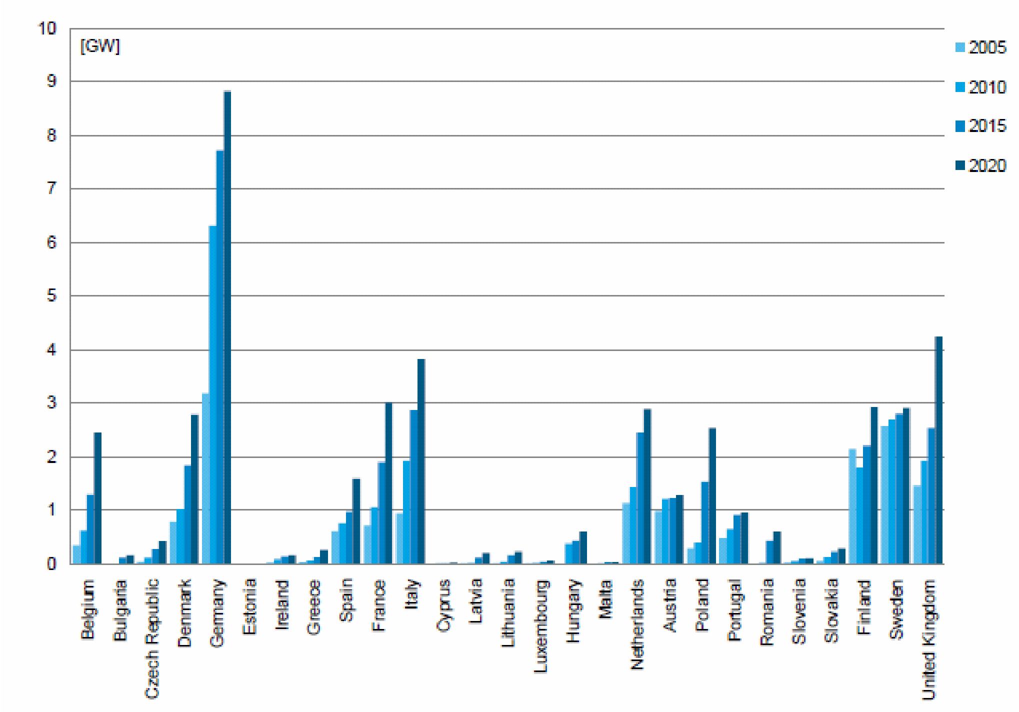

Figure 2: Biomass electricity production capacity in 2005, 2010, 2015 and 2020 in accordance with member state National Renewable Energy Action Plans[2]

This expansion in capacity is broadly consistent with the expansion in production, shown in figure 3. However, many member states apparently intend not only to expand capacity, but also to increase the average load factor of biomass plant. This pattern is notable for states such as Sweden (small rise in capacity, production almost doubled) and the Netherlands (capacity tripled, production quadrupled). There is some doubt as to whether this increase in load factors can be achieved.

[2] *ECN (2011) Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States*
Note: At the time of the publication of this report (March 2011), small updates to the Member State National Renewable Energy Action Plans are still underway, and so there may be some small modifications in these figures.

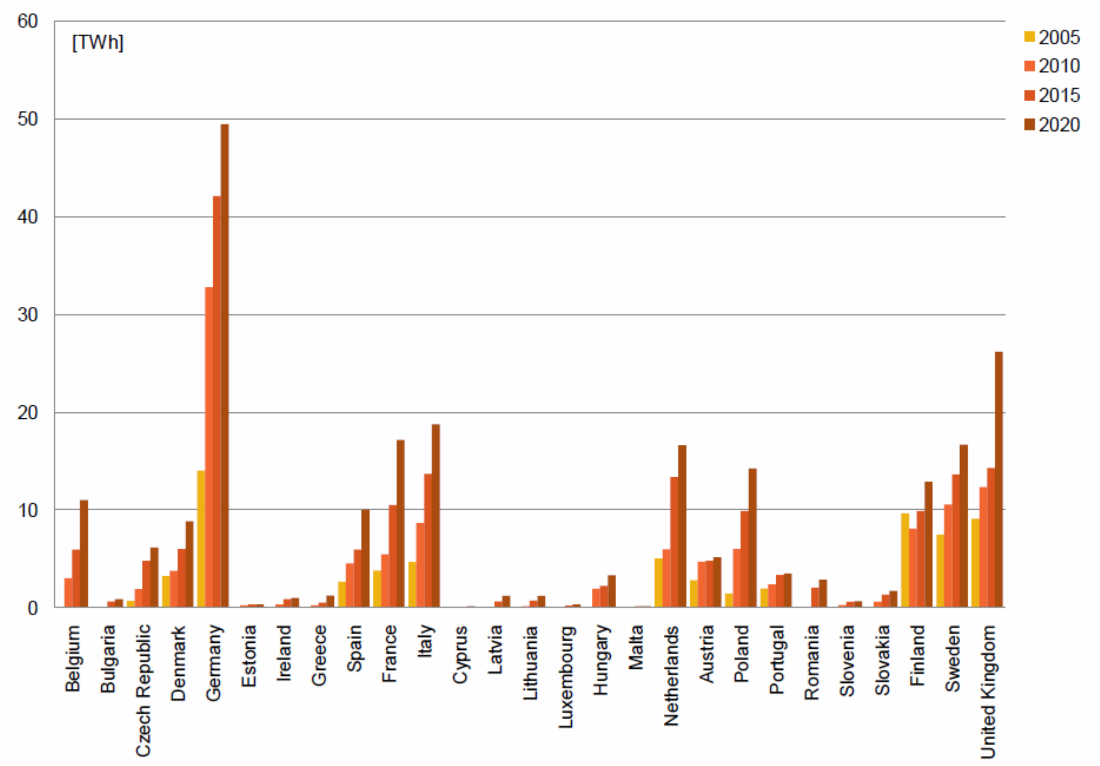

Figure 3: Biomass electricity production (TWh) in 2005, 2010, 2015 and 2020 in accordance with member state National Renewable Energy Action Plans (correct to February 2011)[3].

3.2 Efficiency of different generation technologies

Solid biomass can be used in large-scale power plant systems involving various combustion concepts and firing systems. These are:

- Mono-combustion in biomass power plants,
- Co-combustion with other fuels in existing fossil power plants,
- Mono-combustion in existing fossil power plants.

The type of firing systems that can be used for this depends not only on the plant size, but also on the fuel and its processing form. Suitable firing systems exist in principle for the mono-combustion of solid biomass, as well as for co-combustion in coal-fired plants.

The electrical output of a typical co-combustion plant in the power sector ranges from 50 MW to 700 MW. The majority of the plants are equipped with pulverised coal firing systems. However, biomass co-combustion is also implemented in fluidised bed systems (bubbling and circulated) and in other boiler designs. Basically, it is possible to divide the use of biomass in fossil fired power plants into three different biomass co-combustion concepts, which are as follows:

Direct co-combustion: Biomass and coal are burned in the same boiler or gasifier, using the same or separate mills and burners, depending principally on the biomass fuel characteristics. Coal and biomass can be mixed before milling (e.g. formerly Schwandorf

[3] *ibid.*

plant, Germany), or coal and biomass are fed and milled by separated supply chains. The latter approach is applied e.g. in the Amer 9 power plant in the Netherlands and the Avedøre Unit 2 in Denmark.

Indirect co-combustion: In a gasifier the solid biomass is converted into a fuel gas, which after cooling and cleaning can be burned in the coal boiler furnace. This approach is applied, for instance, in the Amer gasifier in the Netherlands. Alternatively the produced syngas can also be burnt directly in a joint steam boiler without further cooling or cleaning, as done in the power plants in Lahti (Finland) and Ruien (Belgium).

Parallel co-combustion: It is also possible to install a completely separate biomass boiler including flue gas cleaning and to utilise the steam produced in the coal power plant steam system. This approach is applied for example in the straw-fired boiler of the Avedøre Unit 2 power plant in Denmark.

The electrical efficiencies of standalone solid biomass plants with a capacity of 20 MW_{el} range between 35 and 38%. The total efficiency in CHP mode is about 80%.

Biomass co-firing in large-scale power plants can allow higher levels of efficiency to be achieved than when biomass is used for generating electricity in existing mono-combustion plants. Biomass co-firing in a hard coal-fired power plant at below 10% of the input fuel thermal output does not produce any noticeable reductions in efficiency.

The electrical efficiency of biogas plants is up to 30% (without taking account of energy losses in the fermentation process to produce the biogas). The total efficiency of biogas plants in CHP mode is around 65%.

For the purposes of calculation in this report, we have assumed the following efficiencies, defined under three conditions:

- Current average efficiency of plant (“Current”)
- Efficiency of plant in 2020 under “business as usual conditions” (“BAU”)
- Efficiency of plants in 2020 with additional efficiency efforts (“Improved Efficiency”)

Primary energy to final energy						
Scenario	Current		BAU		Improved Efficiency	
	Electricity	Heating and Cooling	Electricity	Heating and Cooling	Electricity	Heating and Cooling
Solid Biomass	30%	85%	34%	85%	37%	85%
Biogas	26%	67%	30%	67%	33%	67%

Table 1: Assumed plant efficiencies for the purposes of this report

4 BIOMASS DEMAND AND SUPPLY BALANCE

KEY MESSAGE: The majority of the biomass required towards the 2020 targets can be produced within the EU but this increase in EU biomass production will not occur without the introduction of significant additional supporting policies and measures. We estimate that 25-40Mtoe must be imported from outside the EU.

The analysis in this section is underpinned by a project carried out by Pöyry Energy Consulting for VGB PowerTech and EURELECTRIC, entitled "Biomass Imports to Europe and Global Availability" and completed in September 2011, and referenced simply as "Pöyry for EURELECTRIC/VGB, 2011".

4.1 Biomass demand

In quantifying the current and projected use of biomass, it is necessary to make a distinction between final and primary figures for biomass use. The amount of primary biomass is defined as the energy content of the primary input fuels to the energy conversion process, whereas final energy expresses the gross amount of useful energy – e.g. electricity or heat (except in the case of transport biofuels, where only the energy content of the biofuel is counted, not the useful energy produced from it).

In the NREAPs submitted to the European Commission, member states have provided estimates of final energy use of biomass in order to reach their 2020 renewables targets. Figure 4 shows the estimates of final energy use of biomass, aggregated across the 27 EU member states.

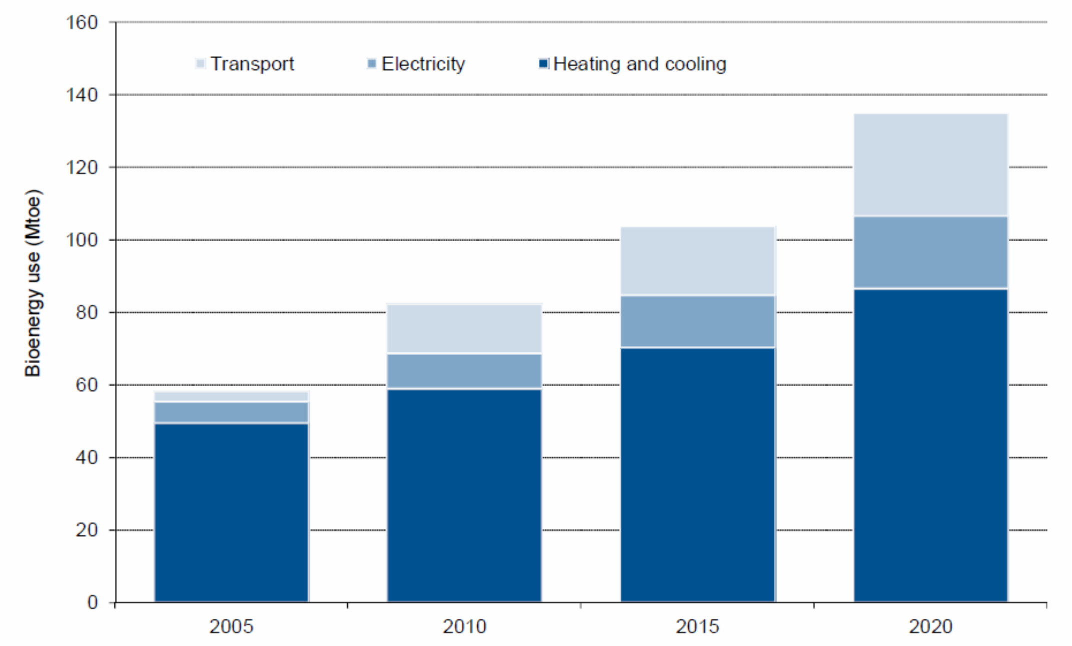

Figure 4 Member state estimates of bioenergy use towards reaching 2020 Renewable Targets, according to National Renewable Energy Action Plans (to March 2011)[4]

[4] *At the time of the publication of this report, small updates to the Member State National Renewable Energy Action Plans are still underway, and so there may be some small modifications in these figures.*

As indicated in the graph above, member states expect that use of bioenergy will increase from 82 mtoe in 2010 to 135 mtoe in 2020. The greatest increases are in the electricity and transport sector, where bioenergy use is expected to double – from 10 mtoe to 20 mtoe in the electricity sector and 14 to 28 mtoe in the transport sector. As shown in Figure 3, the growth in the electricity sector is particularly prominent in Belgium, France, Germany, Italy, the Netherlands, Poland and the UK.

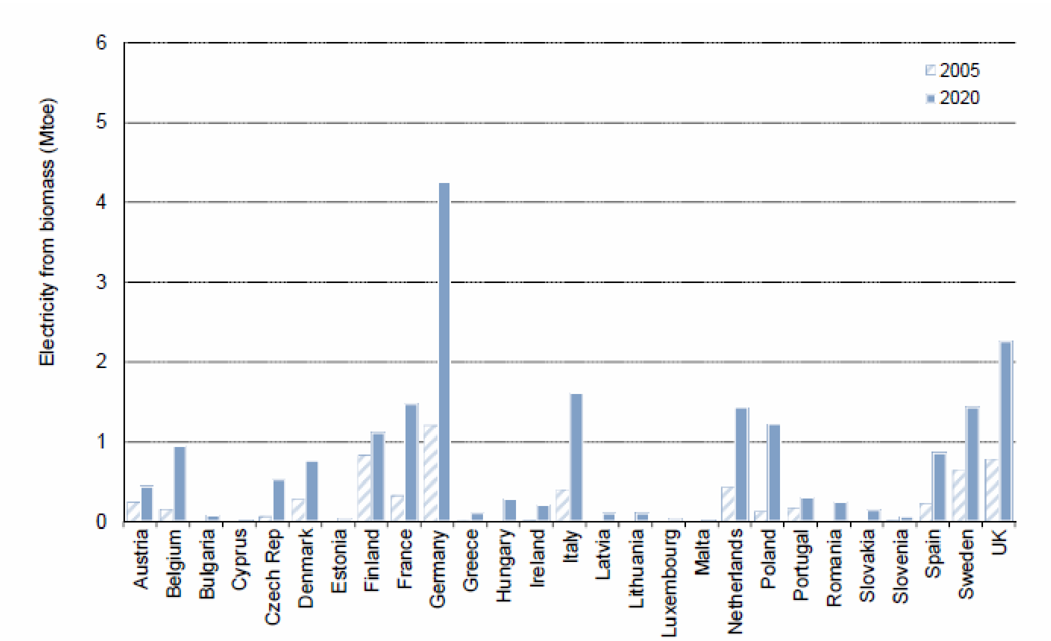

Figure 5: **Electricity from biomass in 2005 and 2020, according to National Renewable Energy Action Plans**

For this report, our primary interest concerns solid and gaseous biomass used in the electricity and heat sector, rather than liquid biofuels used in the transport sector. The final energy use of these two sectors in 2020 is expected to total 107 mtoe. In order to evaluate the amount of primary biomass required to fulfil these ambitions, we need to use some assumed efficiency figures for conversion of biomass into useful final energy. As expressed in section 3.2, the conversion efficiencies we assume in this report are given below, defined under 3 conditions:

Current average efficiency of plant ("Current")
Efficiency of plant in 2020 under "business as usual conditions" ("BAU")
Efficiency of plants in 2020 with additional efficiency efforts ("Efficiency")

Primary energy to final energy						
Scenario	Current		BAU		Improved Efficiency	
	Electricity	Heating and Cooling	Electricity	Heating and Cooling	Electricity	Heating and Cooling
Solid Biomass	30%	85%	34%	85%	37%	85%
Biogas	26%	67%	30%	67%	33%	67%

Table 2: Assumed plant efficiencies for the purposes of this report

In accordance with these defined efficiency levels, we estimate that 146 to 158 mtoe of primary biomass will be needed to produce the projected final energy of 107 mtoe – depending on how much plant efficiency increases in accordance with the table above.

4.2 Biomass availability within the EU

Pöyry Energy Consulting estimates that 82 Mtoe of domestic (European) resources (solid biomass and biogas) were available in the year 2010. Growth rates for 2010 to 2015 are expected to be 3.3% annually, and 4.7% for 2015 to 2020. To reach the NREAP goal even higher growth rates are needed. As the wood supply in central Europe is expected to remain more or less stable, an increasing amount of imports will be needed to cope with the EU 20% Renewables target.

Taking into account the availability of primary biomass within the EU to fulfil this demand, we find that there is a significant shortfall which must be fulfilled by import. In their NREAPs, member states expect primary biomass supply in 2020 to reach a total of 135 mtoe. However, we consider that these estimates are too optimistic and refer to more realistic estimates provided by Pöyry Energy Consulting, which suggest a supply of 120 mtoe in 2020. Therefore, we can conclude that there is a supply gap of 26-38 mtoe, which will need to be imported from outside the EU (as indicated in Table 3). The variation of the supply gap here is due to the three different scenarios for advances in plant efficiencies assumed in the calculations, as shown in Figure 6.

Total final use of bioenergy electricity and heating production (NREAPs)	Total use of primary solid and gaseous biomass in electricity and heating, calculated using assumed plant efficiencies (table 1) (EURELECTRIC/ POYRY)	Estimated EU production of solid/ gaseous biomass in 2010 (EURELECTRIC/ POYRY)	Estimated EU production of solid/gaseous biomass in 2020 (EURELECTRIC /POYRY)	Total import requirement for solid/gaseous biomass in 2020
107 Mtoe	146-158 Mtoe	82 Mtoe	120 Mtoe	**26-38 Mtoe**

Table 3: **Final use, primary requirement, EU production and import needs of biomass for electricity and heating according to NREAPs and EURELECTRIC/POYRY (Source: Pöyry for EURELECTRIC/VGB, 2011)**

However, this supply gap could be even larger depending on whether EU production of biomass grows in line with the projections in the table above, i.e. from about 82 Mtoe in 2010 to 120 Mtoe in 2020. As indicated in Table 4 the main growth is foreseen from the agriculture and waste sectors. Biomass from agriculture is foreseen to grow from just under 13 Mtoe in 2010 to 36 Mtoe in 2020, and the waste sector from under 6 to almost 14 Mtoe in 2020. In comparison the foreseen growth in the forest sector is rather moderate, increasing from just under 64 to 71 Mtoe in 2020.

Biomass availability in Mtoe	*Projection 2010*	*Projection 2015*	*Projection 2020*
Forestry	63.7	68.6	71.4
Agriculture	12.8	18.4	36.3
Waste	5.7	9.5	13.9
Demand			
TOTAL	**82.2**	**96.5**	**121.7**

Table 4: **Biomass availability by sector within EU, 2010, 2015 and 2020 (Pöyry for EURELECTRIC/VGB, 2011)**

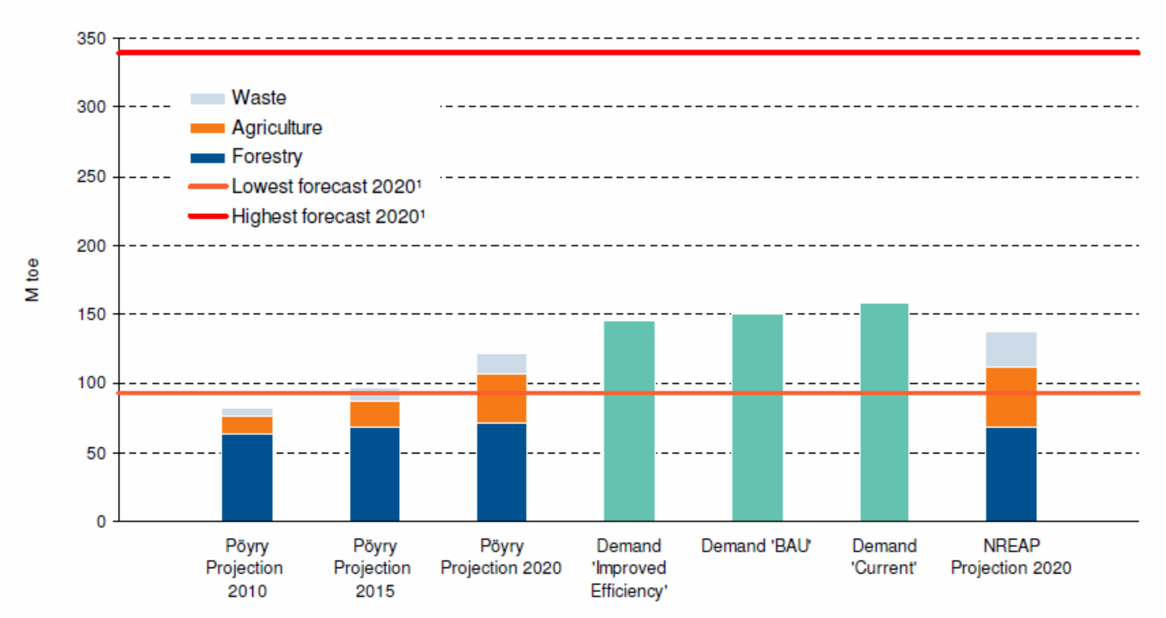

Figure 6: Demand for biomass in Europe in 2020 (in green) under 3 conditions against projects of biomass supply (Poyry – 2010, 2015, 2020), National Renewable energy action plan estimates for 2020 (Pöyry for EURELECTRIC/VGB, 2011)

Therefore, growth in biomass production within the EU is highly dependent on the development of biomass from agriculture and, inter alia, upon incentive and promotion systems in this sector. In the forestry sector, biomass availability depends on which mobilisation scheme is implemented, and whilst strong growth in this sector is not foreseen, changes in the structure of the pulp and paper sector, reducing availability of secondary forestry products presents a significant challenge in itself. In the waste sector, the key determinant is development of waste management policy and public acceptance. These issues are discussed in greater detail in the section 5 on supply chains.

4.3 Biomass import from outside EU

Solid biomass is predominantly imported to Europe in form of wood pellets. According to Eurostat data, 2.5 million tons of wood pellets were imported into the EU in 2010 (1.8 million tons in 2009).

The main origins of non-EU biomass today are Canada, US and Russia. Further potential can be found in regions with significant growth, mainly Russia, Southern US, South America and Africa. In the short run Canada is very significant due to the availability of wood from dead and diseased forests.

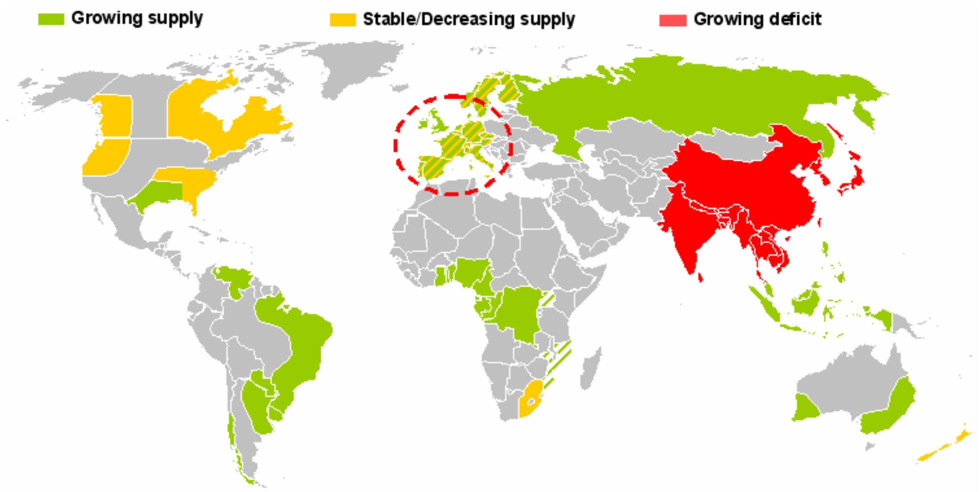

Figure 7: Global wood supply and trends (Source: Pöyry for EURELECTRIC/VGB, 2011)

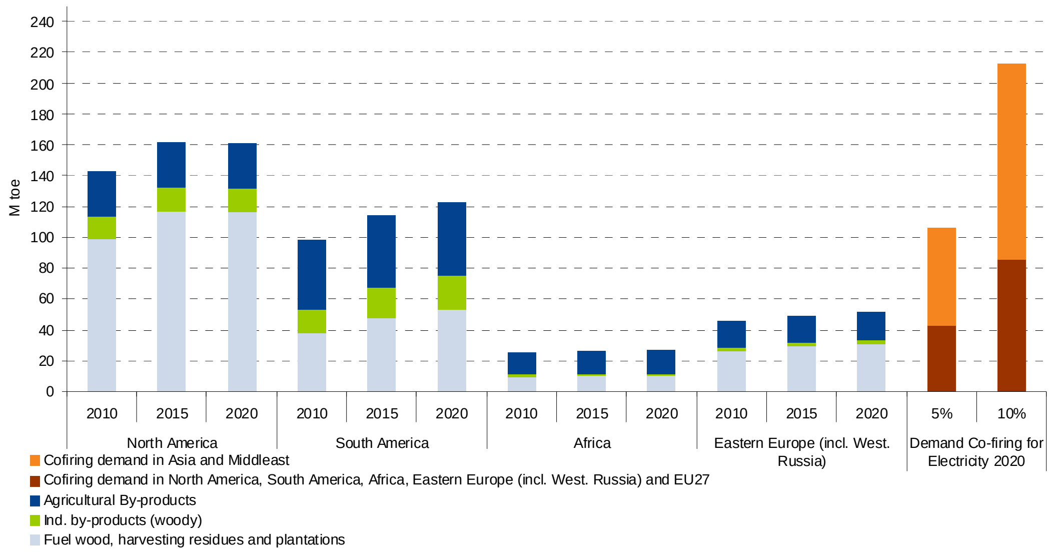

Figure 8: Technical supply potential in global regions. Co-firing demand is demand for 5% and 10% co-firing in all existing coal plants in regions mentioned. (Source: Pöyry for EURELECTRIC/VGB, 2011)

As indicated in Figure 8, there is very significant biomass potential at global level, and the amounts of solid biomass needed to deal with the supply gap of 26-38 Mtoe between projected demand and supply in Europe are in principle available on global markets. The physical amounts of import would be significant. Assuming that wood pellets would cover all import necessary to fill the supply gap, 55 to 85 million tons would be needed. It should be recognised that supply chains have not yet been established to the necessary extent, but still have to be established.

Nonetheless, enough unused land and residues from forestry and agriculture are available to meet this 2020 demand without compromising food and feed needs for the global population, without touching virgin forests or challenging the supply of the global forest products industry.

The import supply chains stretch far outside Europe. In the absence of the EU sustainability criteria, and given the urgency of the situation, the industry is already setting up its own sustainability criteria and standards for solid biomass as well as working to mature procedures for the application of these standards. These standards have to cope with extremely diverse situations in different supplying countries (economic, political framework). To keep the procedures as transparent and pragmatic as possible, and to support the efforts of the industry, there we would like to see harmonised, binding sustainability criteria set-up at EU level.

However, one significant insecurity in global markets is the possibility that other major economies may start to develop electricity and heat production. For 2020, the most relevant possibility is that biomass co-firing with coal would start to be promoted in much of the rest of the world. In the event of a new global agreement on reducing carbon emissions, this appears a possible scenario. As illustrated in Figure 8, the use of co-firing in these countries would give rise to a massive demand for biomass which would greatly constrain available biomass for import into EU. Whilst the technical supply potentials in Figure 8 would suggest that EU demand could be fulfilled even with additional international co-firing demand, it would put supply chains under significant pressure and greatly increase market prices. This should be borne in mind when placing reliance on importing biomass into the EU from world markets.

4.4 Competition with other industrial sectors for use of biomass resources

According to the European Commission, promotion of energy use from renewable sources plays a key role in the efforts to tackle climate change, secure EU energy supply and promote innovation in the related industries.

Both locally and globally, the energy industry is competing with other industries for biomass resources. These industries are the forest industry, the pulp and paper industry, panelboard makers and others. All those industries play an important role in supplying and using biomass. Biomass for all application areas needs to be understood in the context of well-functioning forestry and wood processing industries.

First of all, the forest products industry is an important provider of commercial European biomass supply. Any kind of setback to this industry due to higher feedstock prices would have a negative long-term effect on overall biomass supply and use, not least for the energy industry.

Furthermore, the energy industry is not only using the opportunities of buying biomass from the global markets (trading), but is also making the global growth potential accessible by developing sources in regions where unused residues from agriculture or forestry or unused land are available. Having structured ways to cope with sustainability issues, it will be guaranteed that global food supply, as well as virgin forest remains untouched, and indirect land use change should not occur or remain extremely limited.

If this potential is unlocked significant amounts of biomass will be imported into local European markets to supply large, but distributed consumers like dedicated biomass plants and existing coal fired power plants (for co-firing. Depending on solutions to current challenges in logistics (like suitability of different biomass types for storage), this will offer the opportunity to help local wood markets by consuming excess amounts as well as reducing use of local biomass – curbing peaks in demand and supply as well as in market prices.

If market prices fall extremely low, as frequently observed after great storms, it will help forest owners gain income from excess forest material which they need to remove from their forests. Therefore the overall concept of the energy industry will improve the conditions for sustainable forest management even in Europe – unlocking even more biomass potential locally there.

5. ACTUAL SUPPLY CHAINS

Figure 1 (in Section 2) provides a summary of the primary supply chains for electricity and heat production for biomass. The supply chains described in this section are as follows: forest-based supply chain, agricultural supply chains (including straw, short rotation coppice and agro-industrial residues), and waste. At the beginning of each sub-section, a comparison is made between the estimated primary production of biomass from the supply chain in 2010 and the feasible projected production for 2020, taken from Section 4 (from Pöyry study for EURELECTRIC/VGB, 2011).

5.1 Forest-based supply chain

KEY MESSAGE: Sufficient schemes are needed to mobilise forest owners to sell wood and to develop a stable invest climate to invest in harvesting equipment. Additional or improved incentives are required that support a greater degree of forest thinning and the enhanced collection and use of forest residues.

Estimated EU primary production from forestry in 2010: 63.7 Mtoe
Feasible projected EU primary production from forestry in 2020: 71.4 Mtoe
Feasible increase to 2020: 7.7 Mtoe (12% increase from 2010)
Data from Pöyry for EURELECTRIC/VGB, 2011

5.1.1 Description of supply chain

The supply chains of forest-based biomass are mainly determined by the position of comminution (cutting/crushing the wood into small pieces) processes in the chain and the way and form the raw material is transported (Figure 9). The main types of supply chains are[5]:

- terrain comminution: chipping at the harvesting site,
- roadside comminution (separate chipper and chip truck): comminution with a chipper or crusher at a roadside landing and road transportation of chips using a separate chip truck from the roadside to the plant,
- roadside comminution (integrated chipper-chip truck): comminution and road transportation of chips with the same unit, a so-called integrated chipper-chip truck,
- terminal comminution: forest chip raw materials (loose or bundled) are sent to the terminal for comminution, and then transportation of the chips by truck/train/barge from the terminal to the plant, and
- comminution at plant: forest chip raw materials (loose or bundled) are sent to the plant for comminution.

The supply chains can further be divided into centralised or decentralised chains. In centralised chains comminution takes place in the terminals or at the plant. In decentralised chains comminution takes place either at the roadside at harvesting sites or in intermediate storages. The centralised methods are ideal for very large volumes, which allow high load

[5] *Kärhä K (2009) Supply chains of forest chip production in Finland Metsäteho tiedote 19/2009; Metsäteho http://www.metsateho.fi/files/metsateho/tiedote/Tiedote_19_2009_1_2_Proceedings_Supply_chains.pdf*

factors for machines. This results in lower comminution costs, as all operations can be done with the same machines in the same place without delays. Because of high investment costs, comminution at the plant is suitable for bigger power plants with significant use of forest biomass. In the decentralised methods, the chipping or crushing is directly linked to the transportation system and cannot operate separately. This makes decentralised chains very vulnerable to machinery breakdowns.

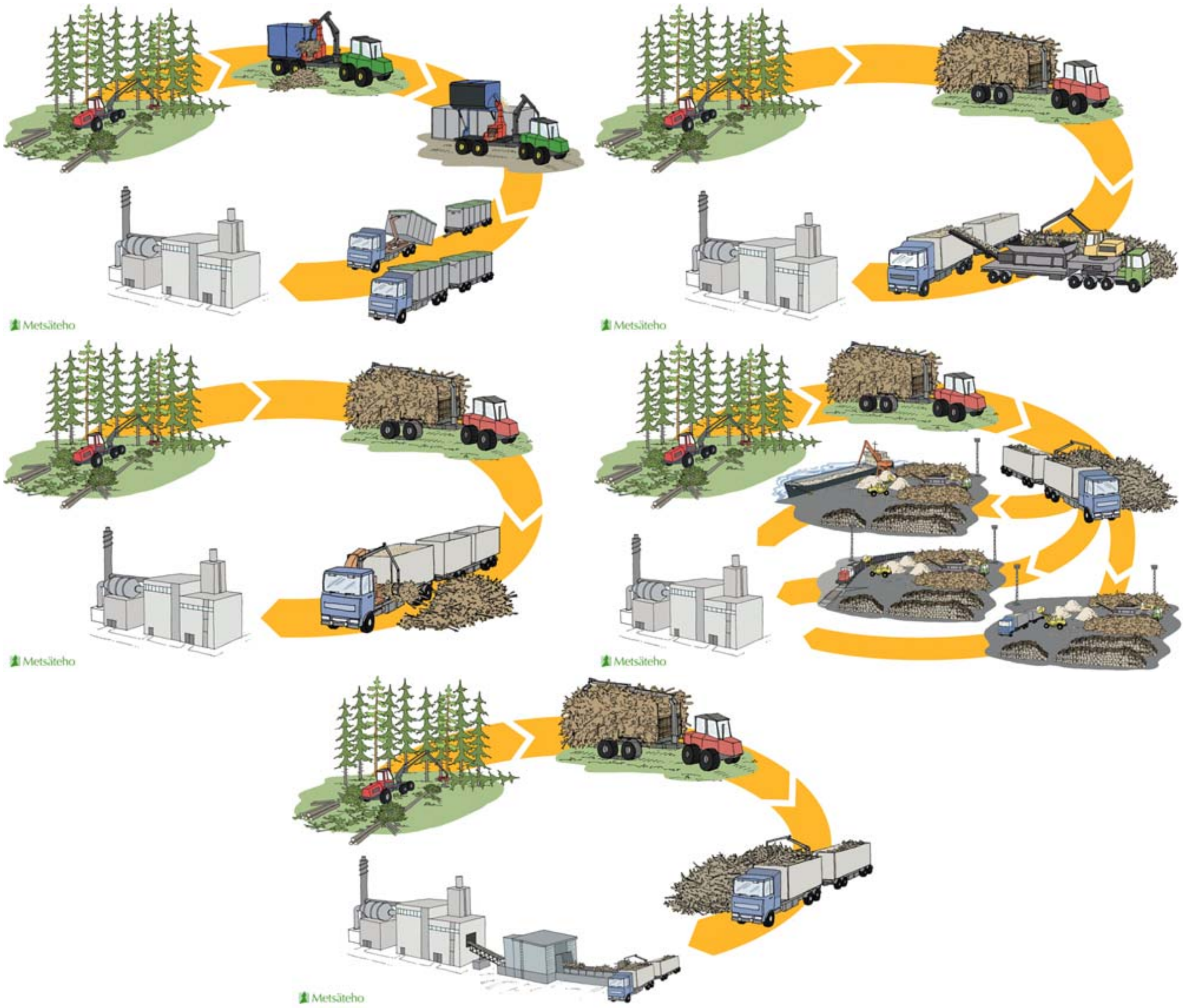

Figure 9: The principles of different supply chains for forest-based biomass fractions (Source Metsäteho Oy) Top left - terrain Chipping, Top right - roadside comminution (separate chipper & chip truck); Middle left - roadside comminution (integrated chipper-chip truck); Middle right - comminution at terminal; Bottom - comminution at plant

The transportation system typically consists of special trucks or rail wagons that depend on the material's type and destination. On the harvesting sites the residues, small diameter wood and stumps are transported to the roadside (or intermediate storages) by forwarders with a wider cargo space and grapples designed specifically for those materials. From the roadside (or intermediate storages) ready-made wood chips are then typically transported to the power plant by special made chip trucks (Figure 10). Residues, small side wood and stumps are transported to the terminal or plant by so-called residue trucks with dynamic cargo space (Figure 11).

Figure 10: The truck based chipper and chip truck[6]

Figure 11: The residue truck[7]

5.1.2 Forest primary resources

Traditionally, the primary resources for forest-based biomass and wood chips from natural forests and plantations have been divided into four main categories:

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6 *Ryymin et al: "Metsäenergian hankinnan uudistaminen"; Loppuraportti 12/2008; HSE Executive Education; ISBN 951-774-122-7; (http://www.hseee.fi/files/1388_JEME-raportti.pdf)*

7 *ibid.*

- logging residues including branches, unmerchantable stem wood, needles and leaves after final cutting operation or clear cuts,
- stumps and root wood from clear cuts on fresh mineral soils,
- round wood typically not suitable for industrial use, and
- small diameter wood or small whole wood from thinnings which are not usable in industrial processes.

Logging residues have been the most significant resource for wood chips, especially in the Nordic countries. The amount of accessible residues will depend on wood species, wood quantity, material thickness of wood, amount of branches as well as the amount of moulder wood. For instance, in the final cuttings, spruce generates more than twice the amount of residues compared to pine or birch forests. The recoverable amount of residues per round wood volume (m^3) collected on the logging area in Finnish forests is typically 0.42-0.62 for spruce, 0.23-0.32 for pine and 0.2-0.39 for birch.[8].[9]

Small diameter whole trees and unmerchantable roundwood are the main source for whole-tree chips, which are usually a mixture of wood and bark. They are mainly used in boilers or combustion processes that are more sensitive to fuel quality, in particular as regards moisture content and particle size[10].

Stumps and root wood are typically collected from the final felling of spruce with as little soil disturbance as possible. This means that one quarter of stumps and the main part of root wood is left in the soil for ecological and biological reasons. Stumps have good properties in energy use. For instance, they can be stored for a relatively long time without significant risk of decomposition or remoisturing. Stumps also have a high energy density and high net calorific value. The biggest obstacle in using stumps and root wood are related to soil, stones and other impurities that are not removed during the drying period and which increase the ash content of fuel and may cause difficulties in the combustion process[11].

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8 *Alakangas, E (2005) Properties of wood fuels used in Finland Technical Research Centre of Finland, VTT Processes, Project report PRO2/P2030/05 (Project C5SU00800) http://circa.europa.eu/Public/irc/dsis/chpwg/library?l=/statistics_30112007/working_documentpdf/_EN_1.0_&a=d*

9 *Metsäteho Oy (2009) Puupolttoaineiden saatavuus ja käyttö Suomessavuonna 2020 (in Finnish); http://www.metsateho.fi/files/metsateho/Tuloskalvosarja/Tuloskalvosarja_2009_09_Puupolttoaineiden_saatavuus_ja_kaytto_kk.pdf*

10 *ibid.*

11 *ibid.*

	Stem wood	Logging residues	Whole wood	Stumps
Chemical composition (% d)				
Carbon, C	48 - 52	49 - 52	50 - 52	48 - 52
Hydrogen, H	5.4 - 6.0	6.0 - 6.2	5.4 - 6.0	5.4 - 6.0
Sulphur, S	< 0,06	< 0.05	< 0.05	< 0.05
Nitrogen, N	0.3 - 0.5	0.3 - 0.5	0.3 - 0.5	0.3 - 0.5
Chlorine, Cl	0.01 - 0.03	0.01 - 0.04	0.01 - 0.03	
Sodium, Na	0.001 - 0.002	0.075 - 0.03	0.001 - 0.002	
Potassium, K	0.02 - 0.15	0.1 - 0.4	0.02 - 0.15	
General properties				
Net caloric values, MJ/kg (dry matter)	18.5 - 20	18.5 - 20	18.5 - 20	18.5 - 20
Moisture content, % (as received)	40 - 55	50 - 60	45 - 55	30 - 50
Net caloric values, MJ/kg (as received)	7 - 11	6 - 9	7 - 10	8 - 13
Bulk density, kg/ loose m^3	250 - 350	250 - 400	250 - 350	200 - 300
Energy density, MWh / loose m^3	0.7 - 0.9	0.7 - 0.9	0.7 - 0.9	0.7 - 1.0
Ash content, dry %	0.5 - 2.0	1.0 - 3.0	1.0 - 2.0	1.0 - 3.0

Table 5: General properties of different forest based biomass used in Finland[12,13]

It should not be forgotten that solid, chemically untreated industrial wood residues like bark and other by-products, e.g. sawdust, gutter shavings, sides of plank wood, (if not used in industrial processes such as pulp or pellet mills) constitute another important resource for wood chips used in power generation.

Before utilisation, different forest-based wood stocks are dried on fields, in roadside storages, in intermediate storages or in terminals. They are then processed to suitable form and particle size by chipping (residues and small size wood) or by crushing (stumps and round wood). Normal drying times from the initial moisture content to the delivery moisture content range from weeks for residues to several years for stumps. The main technical properties for wood chips or biomass are density (oven-dry), moisture content, net calorific value and distribution of particle sizes. The combustion method and boiler size usually determine how moist the delivered wood can be as well as the maximum particle size[14].

[12] *Vapo Oy (2011) Local fuels - Properties, classifications and environmental impacts* *http://www.vapo.fi/filebank/2035-local_fuels_in_finland.pdf*

[13] *http://www.finbioenergy.fi/default.asp?SivuID=9210*

[14] *Alakangas, E (2005) Properties of wood fuels used in Finland Technical Research Centre of Finland, VTT Processes, Project report PRO2/P2030/05 (Project C5SU00800) http://circa.europa.eu/Public/irc/dsis/chpwg/library?l=/statistics_30112007/working_documentpdf/_EN_1.0_&a=d*

Figure 12: Primary sources for wood chips. Top left logging residues, top right small diameter thinning wood, bottom left stumps and bottom right round wood (*source: Metsäteho Oy*).

The strengths and weaknesses of different primary sources are as follows (source Metsäteho Oy) :

Source	Strength	Weakness
Logging residues	– improves the quality of soil preparation – decreases the costs of soil preparation – silvicultural work becomes easier, especially mechanical tree planting increases in efficiency – decreases seedling mortality – opens up the possibility to use smaller seedling plants – promotes the birth of full and dense seedling stands – reduces nutrient losses – creates agreeable forest scenery – increases work possibilities for forest machine contractors	– causes significant nutrient loss, especially in spruce stands, if logging residues are recovered carefully with needles/leaves – decreases the growth of the next tree generation and can cause dysplasia in some high-risk sites – reduces humus growth
Stumps	– cost savings in forest regeneration – decreased risk of infection from root rot fungus (Heterobasidion annosum) – decreased risk of damage caused by pine weevils (Hylobius abietis L.) – increases work possibilities for forest machine contractors	– increases the number of naturally born trees if a lot of soil surface is disturbed – causes nutrient loss if all stumps are recovered
Small size wood (from young thinnings)	– improves the silvicultural condition of untended stands – increases the girth of remaining trees – improves the profitability of thinning operation – reduces the costs of pre-clearance – increases work possibilities for forest machine contractors	– risk of damaging remaining trees during harvesting – little nutrient loss when harvesting as whole trees

Table 6: Strengths and weaknesses of forest biomass from different sources

5.1.3 Challenges of mobilizing forest-based biomass for power generation

The main future challenges and potential bottlenecks for the utilisation of forest-based biomass in the EU-27 are related to the availability of necessary labour and machinery resources for supply chains, behaviour of forest owners and their willingness to sell wood to the market, commercial felling of the forest industry as well as sustainability and environment issues for solid biomass. Given the major resource demand together with low competitiveness of forest-based biomass, the future use of wood chips can be easily assumed to be lower than estimated in recent studies and NREAPs.

In order to mobilise the estimated higher amount of forest biomass, significant investments are needed in forest and handling machinery, transportation capacity as well as skilled labour. Using the efficiency factors, productivities and unit prices that are typical for Finnish forest operation, the minimum required investments can be as follows[15]*:*

[15] *Source: Metsäteho Oy*

	10 Mtoe *(approximation of supply growth in EU needed from 2010 to 2020)*	**40 Mtoe** *(supply growth needed in EU plus fulfilling large part of import need)*
Amount of machinery and trucks	8 700	35 000
Drivers to machinery and trucks	15 600	62 500
Man-year (total incl. indirect work):	19 600	78 400
Investment (total in *mn*.€, vat 0%):	2 500	9 800

Table 7: Cost of harvesting infrastructure in forest operation

In practice and at the EU-27 level the required investment may be even higher due to differing working practices, efficiency and productivities of machinery and trucks, and skills of the workforce.

Many of the operators in the supply chains are small companies or enterprises with few machines or trucks. It is therefore essential to ensure a stable business environment with constant biomass flow to encourage operators to undertake the necessary investments. It has been seen in practice that stop-and-go economic and political trends make markets unstable, fuelling suspicion among operators about the continuity of business possibilities and their prospects of recovering investments.

The future supply of forest-based biomass will be strongly determined by the behaviour of forest owners and especially their willingness to sell wood to the market. They are the key players who will decide if the wood is delivered from forest to industry, if the residues and stumps are used in energy production, if and by whom the thinnings of young stands are carried out, etc. If their willingness to sell decreases, serious problems will arise regarding the accomplishment of RES targets among member states. If the forest industry decreases its production in the EU, the degree of commercial fellings will be decline and residues and stumps will become difficult to source. On the other hand, if sustainability criteria are tightened, it is possible that less wood-based biomass from domestic forests will come to the market. It should be kept in mind that the same limited forest-based biomass resources will be shared by more and more market players like biofuel manufactures (with the market driven by the 10% RES transport obligation) and households, as well as those for whom the forest is important for recreational purposes.

With a larger amount of biomass to be used in energy production in the future, the daily, weekly and monthly variations of biomass demand – due to the heating requirement and power market conditions – will have a significant impact on the size of supply chains and especially on the economically viable amount of required machinery and transportation equipment. In practice the demand could vary hugely between months.

The traditional market conditions for forest-based biomass or wood-based feedstock will undergo big changes due to higher RES targets in the EU-27 within the next few years. The

traditional players will encounter new types of competition not only of the feedstock but also for the necessary skilled labour and processing/harvesting machinery, as well as transportation capacity.

SUMMARY OF POLITICAL CHALLENGES FOR FOREST-BASED BIOMASS:

- **A framework is needed that incentivises biomass producers (forest owners, farmers, etc.) to enhance and ensure continuous supply to the market.**
- **Markets for primary resources should be open and not subject to political interference to restrict sales of biomass to favoured industrial sectors. Any rules should be the same for all market players – i.e. all industrial users of biomass.**
- **A stable and predictable investment environment should be provided to ensure necessary investments for supply chains from forest to power generation as well as for a skilled workforce.**

5.2 Agricultural feedstock chain

KEY MESSAGE: Developing agricultural feedstock chains requires sufficient incentives and therefore a reformulation of existing agricultural policies that generally make it more attractive to produce food crops.

Estimated EU primary production from agriculture in 2010: 12.8 Mtoe
Feasible projected EU primary production from agriculture in 2020: 36 .3 Mtoe
Feasible increase to 2020: 23.5 Mtoe (184% increase from 2010)
Data from Pöyry for EURELECTRIC/VGB, 2011

5.2.1 Straw

Straw is a by-product resulting from the growing of commercial crops, primarily cereal grain. Of the total straw production, only a minor part is used for energy purposes. The major part is used in agriculture's own production, e.g. as bedding in livestock housing systems. A considerable amount of straw is also used for heating, grain drying etc. in agriculture.

5.2.1.1 Description of straw supply chain

Baling of Straw
The handling of straw has gradually developed into an independent discipline in the agricultural industry, with special machinery in which primarily large farms and machine pools invest.

When the grain fields are harvested, the straw is left in long rows. The farmer will normally be interested in having the straw removed as soon as possible to be able to start preparing the soil for the following year's crop, but the power plant may want the straw left in the field during one or two showers before it is gathered.

Experience has shown that straw which has been exposed to a little rain has a reduced content of chlorine and potassium, thereby reducing the risk of operational problems at the power plant.

In practice, it may, however, be difficult to gather the straw at the perfect time. Many farmers are dependent on available capacity at the local machine pool and, above all, the straw must be dry before it is gathered – otherwise it will be rejected at the power plant or the district heating plant.

In the agricultural industry, several kinds of bales are used, from small straw bales of approx. 12kg up to big bales of approx. 500kg. Power plants only accept the big bales and most heating plants also only receive the big bales.

The baler for big bales was developed more than 25 years ago. The bales are commonly known as Hesston bales. Big bales are approx. 120cm wide, 130cm high and 230-270cm long. One bale weighs approx. 500kg, but the weight has increased slightly over the years and the latest balers are able to make bales weighing up to approx. 600kg.

Transport of Straw

In many ways, big bales are an excellent solution for gathering the straw from the field, but are less effective for the transport to the power plant. A truck has room for only 24 bales, equal to 12 tonnes of straw, which is less than half the weight that the truck is allowed to carry. The poor utilisation of the capacity results not only in high transport costs, but also in extra costs for handling the straw bales and poor utilisation of the storage facilities.

Handling of Straw at the Plant

At the small power plants, the straw is unloaded with a fork-lift truck, but at the larger plants, the unloading is carried out with a so-called overhead travelling crane, which can empty a truckload in two stages. First the 12 top bales are lifted off the truck and then the 12 bottom bales are unloaded. Afterwards, the truck body is cleaned of any remaining straw before the truck again leaves the plant.

The system with the overhead travelling crane is very efficient and ensures fast handling of the straw bales to avoid queuing in the cold winter months. The crane is not only capable of unloading the bales from the truck. It also registers the weight of the straw and its moisture content. In this way, the plant is sure of a correct settlement with the farmer and able to reject straw with too high moisture content.

At the small plants, the moisture content is registered with a spear which is manually stuck into each straw bale. If the moisture content is above a certain limit, the straw is returned to the farmer.

Generally, the storage capacity of the power plants is only large enough for a few days' consumption at full load, so during the winter months the plants normally receive new supplies on all weekdays. The transport from the storage to the boiler is fully automated, which allows the small plants to run unmanned during nights and weekends.

5.2.1.2 Technical challenges for straw-based supply chain

Collected cereal straw, using tried and tested technology, is one of the most abundant and cheapest forms of agricultural residue.

It is estimated that some 170m tonnes of agricultural residue will be available in Europe for energy conversion in 2011. Straw is the dominant biomass resource in the EU-27, accounting for 80% of technical agricultural residue potential.

Agricultural residue yields are closely linked to crop yields, which show considerable national and international differences. Climatic conditions and soil quality play an important role, as do irrigation, fertilising techniques, degrees of mechanisation and different crop breeds. The average yield for wheat straw is between 2-6 tonnes per hectare.

The weighted average cost for a dry tonne straw in the EU-27 is around EUR 60. France, Germany, the UK, Spain, Poland, Italy and Romania are the main markets producing approx 75% of the entire EU-27 agricultural residue available.

While straw residues – in particular wheat straw – take the lead in overall availability, interesting local alternatives emerge in some of the country profiles. For example, in some southern European countries there are significant amounts of prunings from olive, citrus groves and grapes.

Residue yields show a clear north-south divide that is reflected in cost per tonne. In northern Europe high grain crop yields make for efficient residue collection. In Eastern European countries further increases in yields driven by improved technology and soil management are achievable.

Agricultural residue is a local resource and is unlikely to be transported over long distances unprocessed. Its effective price is a result of:

- Local and regional demand and supply,
- Competition over alternative usage,
- Bargaining power of market participants,
- Proximity to international trading routes and waterways,
- Provision of alternative biomass feedstock such as wood chips or pellets.

An agricultural residue supply chain will not invent itself, and there are some hurdles that must be overcome. Co-generation or co-firing agricultural residues for power production could offer a solution to overcome some of these barriers.

5.2.1.3 Political challenges of straw

The traditional market conditions of agriculturally based biomass will undergo significant changes due to the higher RES targets in the EU-27 and the foreseen revision of the Common Agricultural Policy. Mobilising significant resources of sustainably produced straw will require overcoming several challenges that call for policy actions to support and accelerate this supply source.

Boosting supplies of agricultural residues for energy applications is largely a question of creating demand at sufficiently attractive prices.

Challenges related to developing a professional supply chain and the regulatory framework need to be addressed to guarantee sufficient level of straw mobilisation:

- Technology needed for straw collection and storage must be established and best practice and knowledge should be transferred from countries where straw is already in use with great success;
- Investments are required to develop a reliable upstream supply chain able to mobilise a sufficient level of straw and agricultural residues, organise storage, transportation, and trading;
- Regulation needs to provide a stable framework that gives sufficient incentives and guarantees investments in the new supply chain.

5.2.2 Short rotation coppice

The sourcing of woody biomass from short rotation coppice (SRC) has become more important in recent years. Existing woody biomass sources in the EU are unlikely to be able to meet the future demand for fuel from biomass and there is a need for additional, sustainable resources to fill this gap. Both the amount of established SRC plantation and the expansion rate of new SRC plantation are still comparatively low, so that the share of short rotation coppice in woody biomass supply is still relatively small.

Definition
Short rotation coppice plantations are perennial plantations of broadleaf trees species that are, in comparison to conventional forests and forestry plantations, harvested on very short rotation cycles. The EC defines biomass from SRC as a conventional agricultural product.

Characteristics of short rotation coppice
The planting density is very high, between 6,500-10,000 plants/ha. Once established, the rootstock is capable of generating regrowth after the upper woody portions have been harvested. There are generally between 3 and 10 coppice cycles before replanting. In most plantations special energy crop clones are used as the parent material.

Tree species
A range of different tree species may be used in short rotation coppice. Depending on the soil type, temperature and rainfall, the most common species used are poplar and willow (on land with rather high rainfall) as well as robinia (on rather dry land). For both poplar and willow, a mix of different varieties and/or clones is generally used, to create genetic diversity within the plantation and lower the risk of crop diseases**.** In recent years, the cultivation of paulownia has became more common, in most cases in very warm locations and in combination with irrigation.

Other non-woody species that may be used to produce biomass include annual energy crops, such as Sorghum, which are likely to become more important in the future.

In addition, the growing of perennial herbaceous plants like miscanthus or switchgrass is also likely to become more widespread in certain regions under appropriate climatic regimes.

Planting

Most of the tree species will grow reasonably well on a wide range of soil types, although very wet or very dry soils are best avoided. Soil pH should normally fall between 5 and 7.5, although some species may be suitable for more acidic or alkaline soils.

In general, SRC is planted on underutilised agricultural land, on meadows and on fallow land. A large variety of sites may be suitable. The tree species used for SRC can also grow on rather marginal soils, albeit with lower yields. The trees are planted either as cuttings or as seedlings, manually or with a planting machine. Good soil preparation and efficient weed control are necessary for the successful establishment of the plantation.

In general, land availability in the EU for SRC seems to be quite high. Studies from Germany estimate that up to 1 million ha may be available for this purpose;. Within other EU countries, similar areas are estimated to be available on a proportional basis. However, less than 4,000 ha of SRC have so far been established in Germany; and not more than ca. 50,000 in the entire EU. The estimations of land potential have therefore to be treated with some caution.

Harvesting

Plants in SRC plantations grow for between 2-5 years and are then harvested, usually with common agricultural machinery like modified forage harvesters. After harvest, the rootstocks sprout again and can be harvested 2-5 year cycles over a total lifetime of ca. 20 years. After that, the plantation is usually uprooted and the area used as agricultural land. Fertilisation and irrigation may be required, but their rate and effectiveness strongly depends on the site type. Under normal circumstances, annual yields of between 8-25 odt/ha/annum can be expected.

Advantages / Disadvantages

L*ess herbicides and* fertiliser *are applied* on SRC *than in arable agriculture. SRC offer a possibility for the* utilisation *of* so far *unused or underutilised marginal soils and new possibilities to create income for farmers in economically underdeveloped regions. Finally, the CO2-balance of SRC is clearly positive, as the rootstocks actively sequester carbon in the soil over the ca. 20-year life of the plantation.*

Key advantages of SRC:

- ***Shorter time to provide biomass material compared to forestry,***
- ***Use of some low-grade land*** **that** ***cannot be used for other types of crops,***
- ***The plantation can be used for spreading for the disposal of sewage sludge (the sludge acts as a fertiliser, but use on agricultural land for crop production is limited)*****).**

Political challenges of SRC:
Farmers and landowners frequently have the opportunity to make more money if they grow conventional arable crops, such as wheat or corn, rather than SRC. While SRC plantation inputs and maintenance costs are fairly moderate, the establishment costs are rather high – up to €2,600/ha. Grants and other forms of subvention are therefore required for the establishment of SRC (e.g. as in UK) in order to provide the initial stimulus and financial incentives for investing in SRC.

In addition to the high cost of SRC establishment, the farmer or landowner also faces a period of 3 – 5 years without any income from the land up until the first SRC harvest. In the forthcoming reform of the Common Agricultural Policy, and in order to improve the alignment of the CAP with the EU's climate and energy policy, we would strongly urge the reintroduction of an 'EU Energy Crops Premium', to cover this 3 – 5 year period.

SRC is promoted by nearly all NGOs, and is fully accepted by the EU. However, the establishment of SRC on certain sites often causes resistance from local nature conservation groups. In order to align these potentially competing interests, a common concept is needed which defines both preference and exclusion areas for SRC.

In many SRC plantations, strong variety-dependent differences in growth behaviour can be recognised. Further research on the development of new varieties is therefore needed in order to optimise the varieties for the respective sites. In particular, improved clones and varieties with a low demand for water, and suitable for the establishment of SRC on marginal soils, could be developed through plant breeding.

Standards for the establishment and management of SRC are also needed, especially to prove and demonstrate the sustainability of SRC on both a carbon and an energy basis. Land owners need clear guidelines to ensure the establishment of environmentally friendly, sustainable management practices regarding both the silvicultural techniques employed and the treatment of any biogenic materials used for SRC fertilisation.

5.2.3 Agro-industrial residues

Agro-industrial residues exist, to a large degree, outside of the mainstream solid biomass supply chains and trade routes. Their attraction lies in the fact that, where their production is above local needs, the excess residues may be sold at prices that are cheaper, in terms of €/GJ, than conventional solid biomass materials such as wood chips or wood pellets. However, as they are non-mainstream, more effort may be needed to obtain these residue materials.

Since these materials arise as by-products from the industrial processing of harvested plant materials, the initial sources of the raw materials are generally widely dispersed. Industrial processing leads to a concentration of the harvested materials at the processing centre, with the resultant residues effectively available from a point source. However, residue materials from several of these point sources may need to be grouped to provide an economically viable volume of residues for shipping or other transport purposes.

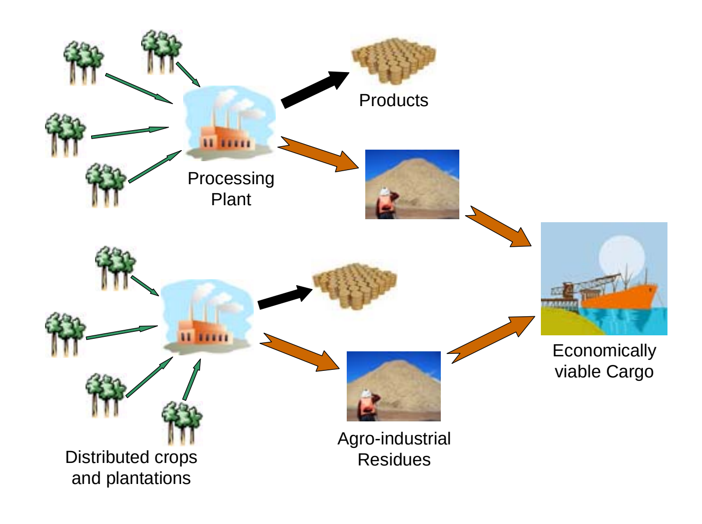

Figure 13: Agro-industrial supply chain

Some of the agro-industrial residues, such as sugar cane bagasse or palm kernel shells, are produced in countries that are a considerable distance from Europe. The most economical supply chains therefore entail the shipping of these residues to European ports in capesize (>150,000 DWT) or panamax (65,000-80,000 DWT) sized vessels. If smaller volumes are required by individual power plants, then utilities have the options of (i) using the remainder of the residues in another plant; (ii) selling on the surplus; or (iii) renting hold space in a large ship carrying other cargos from the country of residue origin.

Other raw materials which give rise to agro-industrial residues, such as soybeans, may be shipped in the raw state from their country of origin and processed in Europe. Trade statistics show that the EU imports approximately 13.5 million tonnes of soybeans each year, mainly from Brazil, the United States and Argentina. These raw soybeans are then pressed in dock-side oil mills to extract the soybean oil. The soya hull pellet residues arising from this processing will therefore be mainly available at European ports.

Where agro-industrial residues arise from plant materials grown within Europe, for example shells from almonds or pellets made from sunflower husks or olive cake, it may be economical to ship the residues in smaller vessels (5,000 - 10,000 DWT), either from port to port around the coast or along Europe's navigable inland waterways. Any onward transport to power plants not located alongside water will have to be by train or by truck. In all instances maximum unit loads and minimum re-handling will deliver the agro-industrial residues at the minimum cost.

5.2.3.1 Challenges of the agro-industrial feedstock chain

Since agro-industrial residues are outside of the main solid biomass supply chains and trade routes, access to these materials requires more effort in order to mobilise this resource. In general, utilities that wish to use agro-industrial residues as a biomass source have two options for mobilising these materials:

1. Getting directly involved in the upstream segment of the supply chain; or
2. Acting through well-established trading intermediaries.

While the crops and plantations that ultimately give rise to the agro-industrial residue may be grown in many countries in a wide latitudinal belt, large volumes are likely to arise in only a few countries.[16] Although the crops and plantations may be widely dispersed, industrial processing means that the residues will be concentrated at comparatively few point sources. As outlined in section 5.2.3, residue supply from several of these point sources may need to be compounded in order to obtain economically viable volumes for shipping purposes.

Utilities have a number of avenues for getting involved in the upstream segment of the supply chain. They may do this indirectly, utilising diplomatic channels such as embassies, consulates and trade and commercial attachés; they may decide to take part in trade missions to the country of residue origin; or they may opt to do this directly, by getting in contact with the companies that own the processing plants and the agro-industrial residues.

An alternative approach to mobilisation is through well-established trading intermediaries. There are a considerable number of large, multi-national trading groups that regularly ship oils, seeds, grains and other commodities to global markets. These trading intermediaries already have the local contacts, supply infrastructure and shipping capacity to source and deliver agro-industrial residues to European utility customers.

While it is more economical to ship large volumes of residues in capesize or panamax vessels, this may be more than a utility wants to purchase, use or store at any given time. Alternative approaches include co-purchasing arrangements, i.e. buying and shipping larger volumes to supply more than one plant, or selling on part of the cargo to another utility. One of the benefits of utilising trading intermediaries is that it facilitates the purchase of smaller volumes, which the trader can then arrange to co-ship along with other cargos.

For agro-industrial residues originating in Europe or arising through the dock-side processing of raw commodity materials, the supply chain can be readily mobilised through direct contact with the processing company or through trading/transport intermediaries. Cargo volumes are likely to be smaller than for residues shipped from other continents, and an optimum combination of smaller vessels, barges, rail and lorry transport needs to be employed to ensure that the agro-industrial residues are delivered to the power plant at the lowest possible cost.

5.3 Municipal and commercial waste feedstock chain

KEY MESSAGE: There is a need to ensure that framework policies for waste maximise energy recovery from these supply chains. Waste-to-energy plants must be encouraged consistently across Europe as part of a sustainable waste management system.

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[16] *Information on the national production of crops of interest may be obtained from various UN databases: for example see http://faostat.fao.org/site/339/default.aspx.*

Estimated EU primary production from waste in 2010: 6 Mtoe
Feasible projected EU primary production from waste in 2020: 14 Mtoe
Feasible increase to 2020: 8.2 Mtoe (142% increase from 2010)
Data from Pöyry for EURELECTRIC/VGB, 2011

5.3.1 Description of waste feedstock chain

Waste is most commonly, and according to the EU Waste Framework Directive, defined as material which an entity wishes to dispose of. National perception of this varies to a large extent. In the context of biomass, waste will occur in the forestry business as well as in agriculture. As those have already been covered, this section covers only **commercial and municipal** waste resources. The production of biogas from biogenic waste is covered in detail in section 6.1.

Waste-to-energy plants burn household and similar waste that remains after waste prevention and recycling. From this waste the plants generate electricity and/or heat.

According to EU legislation the biodegradable fraction of municipal and industrial waste is considered biomass, thus a renewable energy source. The energy output from waste-to-energy plants is typically about 50% renewable.

Waste-to-energy plants in Europe supply a considerable amount of renewable energy: some 38 TWh in 2006 and an estimated amount of at least 67 TWh by 2020.

For technical reasons the power vs. heat ratio for an incineration plant is lower than for standard fuels. Therefore, having access to a heat market such as a district heating system is a great advantage.

The use of commercial and municipal waste for energy production does not typically affect recycling rates, i.e. it does not divert waste that may otherwise be recycled. Indeed, studies show that waste-to-energy has a positive influence on recycling rates. The main alternative for a portion of the biogenic fraction of the waste is composting.

About 40% of municipal waste in Europe is still landfilled, so the potential for increasing production of power and heat is significant. The European Landfill Directive sets strict diversion targets for the landfilling of biodegradable waste. The deadline for reducing landfilling by 50% was in 2009, and European member states that miss this deadline face fines. By 2016 the biodegradable waste being sent to landfills must be reduced by 65% (based on the amount landfilled in 1995). Therefore, a significant increase in energy production from waste may be foreseen from the Landfill Directive in addition to other incentives.

5.3.2 Challenges of the waste feedstock chain

Waste-to-energy plants are not encouraged in all member states. An incineration plant needs good exhaust fume cleaning systems in place to be acceptable from an environmental view. There is also significant criticism from NGOs, claiming that waste-to-energy plant result in less re-use and recycling of waste. A well developed district heating system is valuable for maximising the value of a waste incineration plant since a large share of the energy is heat.

All of the above has meant that household waste is sometimes exported to places with district heating, good plants and where there is a reasonable public acceptance. Even if the efficiency gains from the better circumstances in the importing country often more than compensate for the transport involved, such a situation is not ideal.

6 BIOMASS FUELS

KEY MESSAGE: Further development and research is needed on bioenergy fuel products and combustion technologies, with a particular focus on fuel which can be combusted in existing plants – such as torrefied pellets.

6.1 Biogas

The term “biogas” includes all gas produced by anaerobic digestion of organic matter. In the absence of oxygen various types of bacteria break down the feedstock to form a secondary energy carrier, a burnable gas which mainly consists of methane and carbon dioxide. In this section, more detail is given that for other biomass fuels due to the wide range of feedstocks from which biogas can be derived and the limited reference to biogas production in previous sections.

Biogas as a secondary energy carrier can be produced from many different kinds of organic materials and its utilisation options can be equally versatile. Biogas can be used for electricity or heat generation, as a biofuel and more. The residues from the production (fermentation), called digestate, can also be used, for example as a fertiliser.

Biogas production has the advantage of reconciling two European Union policies. Firstly it falls in line with the main objective of the Renewable Energy Directive (2009/28/EC) that aims for a 20% renewable energy share in gross final energy consumption by 2020. It also meets the European organic waste management objectives enshrined in European regulations that require member states to reduce the amount of biodegradable waste disposed of in landfills (Directive 1999/31/EC on the landfill of waste) and to implement laws encouraging waste recycling and recovery (Directive 2008/98/EC on waste). Methanisation is considered to be the best environmental waste energy recovery method.

These policies have prompted a number of member states to encourage biogas production by setting up incentive systems for biogas-generated electricity (feed-in tariffs, green certificates, tenders). In a number of countries, the biogas market is stimulated by additional payments for the use of energy crops. They aim to spur the increase in renewable energy production, while the policy also enables farm holdings to reduce their energy dependency and diversify their incomes in the event of falling cereal, milk or meat prices. Other countries are dubious about the environmental soundness of using energy crops such as maize for methanisation, preferring to convert already existing waste feedstock.

A wide variety of feedstocks exist:

- **Landfill.** In landfills covered organic waste forms biogas (landfill gas) which builds up and can create an explosive mixture if mixed with oxygen. This gas can be collected and used for energetic purposes. However, it is often simply flared. This can be considered as a waste of resources, as the utilisation of this by-product could offer a second income for the operator of the landfill site and prevent unnecessary CO_2 and CH_4 emissions.

- **Sewage sludge** is a by-product of wastewater treatment. After the use as a feedstock for anaerobic digestion the remaining bio-solid can either be used as soil conditioner, be disposed of in a landfill, according to its toxicity (especially concentration of heavy metals), or be burned in a waste incinerator. Digestion also decreases the sewage sludge volume which reduces the disposal costs and problems.

- **Manure** is normally stored on farms for several months and then used as fertiliser. The manure already contains micro-organisms responsible for biodegradation and anaerobic digestion creating methane, ammonia and carbon dioxide which are released into the atmosphere during storage. The use of manure for biogas production offers several additional benefits:
    - It avoids CH_4 emissions during the storage of the manure,
    - It offers an additional energy carrier that does not compete with other uses,
    - The substrate as final product after the biogas production is a valuable fertiliser.

  Compared to fossil transportation fuels like petrol and diesel, biogas from liquid manure is extremely efficient in reducing CO_2 emissions overall (minus 180%, well-to-wheel). This is due to low fossil inputs and because it avoids natural emission during storage. Thus manure as renewable energy feedstock provides an efficient source of nutrients for crop cultivation and reduces greenhouse gas emissions at the same time.

- **Energy crops** for biogas are dedicated crops planted on agricultural land to be used as feedstock for biogas production. Typical crops are maize or sweet sorghum. The mix of maize and manure is the most commonly used feedstock for decentralised agricultural biogas plants. Energy crops maximise the yield (dry matter per hectare) and offer high conversion efficiencies.

- **Other agricultural feedstock**
  Second crops, or catch crops, planted after the harvest of the main crop, can also be used as biogas feedstock. This system allows two harvests per year on one piece of land. Green cuttings, material from landscape maintenance, can also be used as biogas feedstock. This type of feedstock should be available within a small radius of the biogas plant, as the transportation of feedstock with high water content is costly, both from an economic and ecological point of view.

- **Waste streams for biogas**
  Different by-products of the food industry – breweries, sugar plants, fruit processing, slaughter houses, but also food waste, used kitchen oil, the organic fraction of municipal solid waste (MSW) – can be used as biogas feedstock and thus increase the energy offered from biomass.

- **Biogas from wood**
  Apart from anaerobic digestion discussed above, biogas can also be produced from wood or woody biomass in a thermal gasification process. Although the product is the same (methane with a renewable origin), it is often referred to as synthetic natural gas (SNG). This technology has great potential as large resources of solid

biomass become available for biomethane production. The technology can be considered as close to full commercialisation and is hence included in the EU NER 300 support programme.

The obtained gas from the fermentation process can be either applied directly or upgraded to natural gas standard – biomethane (98% methane) and injected into the gas grid. In the last years different concepts for the organisation of biogas plants have emerged:

- Decentralised plants on farms etc.: production of electricity and use of heat (but using the heat is often not obvious).
- Decentralised plants in combination with biogas pipelines, transporting the biogas to a cogeneration unit situated in proximity to a district heating system. Therefore the cogeneration can make full use of the heat.
- Decentralised plants delivering the raw gas in biogas pipelines to an upgrading station and injecting the biomethane into a gas grid. The biomethane can be used for cogeneration, as transportation fuel or as high-tech process energy.
- Centralised plants in areas with high feedstock availability.

6.2 Straw bales

Figure 14: Baling device in action

Straw is a more challenging fuel for power plants than fossil fuels, but fortunately most technical challenges have been overcome. Straw has been used in district heating and power plants in many European countries for decades, thereby significantly increasing security of energy supply and reducing greenhouse gas emissions from the energy sector.

Straw used for fuel purposes usually contains 14-20% water that vaporises during burning. The remaining dry matter consists of less than 50% carbon, 6% hydrogen, 42% oxygen, and small amounts of nitrogen, sulphur, silicon and other minerals, e.g. alkali (sodium and potassium) and chloride.

	Unit	Yellow straw	Grey straw	Wood chips	Coal	Natural gas
Water content	*%*	10-20	10-20	40	12	0
Volatile components	*%*	>70	>70	>70	25	100
Ash	*%*	4	3	0.6-1.5	12	0
Carbon	*%*	42	43	50	59	75
Hydrogen	*%*	5	5.2	6	3.5	24
Oxygen	*%*	37	38	43	7.3	0.9
Chloride	*%*	0.75	0.2	0.02	0.08	-
Nitrogen	*%*	0.35	0.41	0.3	1	0.9
Sulphur	*%*	0.16	0.13	0.05	0.8	0
Calorific value, Water/ash free	*MJ/kg*	18.2	18.7	19.4	32	48
Calorific value, actual	*MJ/kg*	14.4	15	10.4	25	48
Ash softening temperature	*°C*	800 – 1000	950 – 1100	1000 - 1400	1100 -1400	

Table 8: Comparative fuel characteristics of straw and other fuels

Through boiler walls and fire tubes, the major proportion of the combustion heat is absorbed by the water in the boiler, while the remainder disappears through the chimney as a mixture of carbon dioxide, vapour, and small amounts of carbon monoxide and other gases, e.g. tar and compounds of chlorine. In addition, the flue gas contains small particles of ash and alkaline salts.

The presence of chlorine and alkali in the flue gas is challenging, since they undergo chemical reactions and develop into the extremely corrosive sodium chloride and potassium chloride, thus posing a potential threat to the steel of boilers and tubes, particularly at high temperatures.

The ash is not without problems either, since its softening temperature is relatively low compared to other fuels, beginning at 800-850°C. However, it has even been demonstrated that the ash may become viscous already at 600°C. This is of particular importance at power plants where a high steam temperature is desired in order to achieve a great efficiency.

This requires a high superheater temperature, thereby risking extensive deposits on the superheater tubes. Where a combination of straw and coal is used as a fuel, the presence of alkaline matter in the ash indicates that – contrary to pure carbon ash – it cannot be used as filler in building materials, but must be disposed of at a controlled disposal site.

6.3 Straw pellets

Handling and use of straw as fuel is often more complicated and time-consuming than for fossil fuels such as oil, coal and natural gas. Straw bales are very bulky, which means that transport costs may be high. In addition, it is important to ensure a reasonable working environment as there may be considerable nuisance in the form of dust and mould fungi.

Experiments have been carried out on the use of straw pellets, i.e. comminuted straw that has been pressed into pellets of a diameter of 8 or 10 mm. The experiments showed that straw pellets can be used as fuel in large boilers, whereas ash and particularly slagging problems make straw pellets less suitable for use in small boiler plants. Straw pellets can be pressed with molasses as a binding agent, thereby admixing an antislagging agent, e.g. kaolin, in order to make them more stable during transport and to counteract the effects of the low ash melting temperature.

Today a large quantity of straw is processed into fuel pellets to facilitate transport and handling at the power plant. Amagerværket in Copenhagen was rebuilt to introduce trial firing with straw pellets in unit 2 of the power plant. The pellets are ground into dust and blown into the boiler in the same way as coal, which makes it relatively simple to convert a coal-fired plant to fuel pellets.

6.4. Wood Pellets

Pellet production in Europe and North America started during the oil crisis in 1970s, when wood pellets were used as a substitute for solid fuels and oil.

Wood pellet production has become commercially viable again since the 1990s and has grown constantly throughout the last years. It was fostered by policies of some countries in the context of global warming, the promotion of renewable energy sources, energy security, and a rising oil price.

Wood pellets are used in large-scale plants as well as in medium-sized plants and households. Different pellet qualities are required for different types of application. In the industrial segment they can be used in dedicated biomass plants as well as in co-firing installations, depending on the materials of the pellets and the characteristics of the respective plant.

Figure 15: RWE Tilbury plant, UK: Dedicated biomass

Figure 16: RWE Amer 8 and 9, NL: Co-firing

Pellet products

Wood pellets are compressed biofuels from chipped solid biomass in the form of short cylindrical units. They are usually made of industrial wood, wood shavings, woodchips, or sawdust. They can also be made of harvesting residues. They are mainly used for heating and electricity production. The main components are cellulose, hemicellulose and lignin. Extracts e.g. of fats, proteins, resin and oils are used as binders. Dark pellets additionally contain bark, which indicates lower quality compared to “bright” wood pellets. The components influence the durability of the pellet[17].

Depending on fuel specification and standardisation, there are different types of pellet classification[18]:

– Premium pellets are high-quality pellets, which have to comply with strong standards regarding enhanced stability, clearly defined particle size distribution, high durability, the existence of a CO2 balance sheet and references regarding chain of custody. The product contains only wood, excluding all other components. The product is very suitable for large-scale pulverised fuel applications and could also be used in other large-scale, small and medium, boiler applications.
– Industrial pellets adhere to lower quality standards compared to premium pellets, for instance the wood could be mixed with landscape residues or bark. Main applications are fluidised bed boilers and grate-fired boilers, but industrial pellets could also be used in other large, medium and small-scale applications.

Typical diameters for wood pellets range from 6-12mm, and the typical length is 10-40mm.[19] The net calorific value varies between 10.8 and 18 MJ/kg (as received)[20]; the bulk density is 600 kg/m3[21] and might also be between 500 and 680 kg/m^3; water content is

17 Döring, S (2011) Pellets als Energieträger, Technologie und Anwendung
18 Ibid.
19 E.g. DIN 51731, ÖNORM M 7315.
20 Kaltschmitt, M et al (2009) Energie aus Biomasse - Grundlagen, Techniken und Verfahren (2. Auflage)
21 Ibid.

between 5-10%[22]. The respective parameter depends on the quality of the respective pellet product, with the higher values referring to premium pellets.

Throughout the years a wide range of wood pellet standards has been developed. There is no single international or European standard yet. The standards are developed differently in different regions in the EU and the US. The European Union introduced the first EN standards (EN 14961 and EN 15234) in 2010. Other standards in place include DIN 51731/DINplus in Germany/Netherlands/Belgium, ÖNORM M 7315 in Austria and SS 187120 in Sweden.

A private initiative of the largest wood pellet consumers (Dong, Drax, Electrabel, Eon, Fortum, RWE and Vattenfall) at European level is working on a standardisation of trading contracts in order to move towards the transformation of wood pellets into a global commodity. The approach contains three field of harmonisation: legal framework, technical specifications, and sustainability requirements.

Processing procedures[23]

Wood pellets are produced in a process that mainly consists of debarking, chipping, drying, grinding, pelletising and cooling.

The first step of the processing procedure is the supply of the woody material. Depending on the final material (bright or dark pellets), debarking of the round wood is necessary. Saw dust and strands from saw mills as well as chipped, woody biomass is obtained.

In a second step the moisture content is reduced from 50% (fresh) to 10% (air dry). During the drying process special techniques for emission protections are applied in order to reduce the emission of volatile organic compounds and other particulate matter.

The next step is the grinding process, in which the materials are ground in hammer mills. Afterwards the ground materials (fibres) are pressed by pelletising machines. The standard pellets are pressed, as used in plastics or feed production by well-known, state-of-the-art technologies. The pressure applied in this process is very high.

Pellets leave the press with temperatures of approx. 100° C. Then they must be cooled to harden and sieved to separate smaller particles (fines) resulting from the pelletising process. After those procedures, they are packed, depending on the end-user, in bags, big packs or bulk and stored. Finally, they are distributed via truck, train or vessel.

Advantages / Disadvantages

Pelletisation delivers solid biomass feedstock of high physical and mechanical homogeneity24. The higher volumetric energy density and unified size and shape (compared to e.g. fresh wood) leads to logistic advantages: pellets are much easier to handle and store than other woody materials. In addition, moving from 100% coal to wood pellets can decrease CO2 emissions by 75-85%, taking into account all CO2 emissions over

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[22] *Ibid*

[23] *Ibid.; Döring, S (2011) Pellets als Energieträger, Technologie und Anwendung*

[24] *EaB, Kaltschmitt*

the whole life cycle (life cycle analysis, cradle-to-grave). Overall CO2 emissions related to wood pellet production and provision depend mainly on transport distances (sourcing of biomass, local or global distribution).

A disadvantage of pellets is that they are not water-resistant and can therefore not be sufficiently stored in open places.

6.5 Torrefied pellets

Torrefaction is a thermal process by which biomass is converted into material which has similar properties to coal. Extensive research and development on torrefied pellets has been undertaken since the last decade. Some large energy companies, such as RWE and Vattenfall, have already started with the development of this application to a mature technology. Currently several medium-scale torrefaction plants are in a start-up phase, with some expected to begin operations soon. Since no commercial plant is up and running yet, no large amounts of torrefied material are traded.

Replacement of coal in power plants is one of the most significant potential that torrefied pellets provide to the market. Other future markets for torrefied biomass are use of biomass in large-scale pulverised power stations (above 100 MW_e) and as a substitute of coke for the production of steel.

Torrefied pellets product
Torrefaction improves the properties of biomass with respect to heating value, grindability, biological degradation and hydrophobic nature. The coal-like characteristics of torrefied biomass make high co-firing rates possible (5-10% for wood pellets compared to 50-80% for torrefied pellets). Use of low-grade biomass as feed and conversion of the low-grade biomass into a homogenous, well defined product will improve economics and/or allow to access additional, now unused resources

Actual findings show that the product's better grindability and hydrophobic nature lead to lower costs for internal logistics and storage at the power plant, compared to wood pellets. For instance, pellets from torrefied biomass are more hydrophobic than wood pellets and therefore do not or only barely swell when stored outside or even thrown into water.

Torrefied pellets are about as large as wood pellets, but have a higher heating value. We expected that commercial products will have a net calorific value of 18-22MJ/kg (as received, current estimate).

Moreover, with a bulk density of 600-750kg/m³, the bulk energy density of torrefied pellets is 6-10 times higher than energy density of wood chips (depending on the water content of wood chips). The water content of torrefied pellets is 2-8%.

Process
The manufacturing process for torrefied pellets is similar to the pelletising process outlined above. The main difference is the additional torrefaction step. The fresh material is chipped or shredded, dried, torrefied, milled and pelletised.

Torrefaction is a thermo-chemical treatment method, a mild pyrolisis. In the torrefaction step the biomass is heated to 250-400°C (process temperature) in the absence of oxygen. Residence times range from a couple of minutes to several hours, depending on applied technology and temperature. Reactor types used today include fluidised bed reactors, shaft reactors (fixed bed) or rotating drums. The rector type is chosen according to the feed and the target properties of the product.

6.6 Waste wood

According to Article 2 (e) of the RES Directive[25] biomass means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste.

Waste wood is a special category of biomass, which has to be treated in a special way under consideration of the requirements for treatment of waste. A distinction can be made between hazardous and nonhazardous wastes. The "Guidance on classification of waste according to EWC-Stat categories" [26], refers to the following forms of wood waste - wooden packaging, sawdust, shavings, cuttings, waste bark, cork and wood from production of pulp and paper, wood from construction and demolition of buildings. Wood is categorised as hazardous when it contains hazardous substances like mercury or tar-based wood preservatives.

In most countries, for example Germany and the UK, waste wood of all qualities is recognised as renewable energy. It is used in special biomass plants and as fuel for municipal waste incineration or for coal-firing power plants. The stringent regulatory controls on emissions from biomass energy generation operations mean that risks and hazards are controlled through emissions limits, which will be set as part of the permit required for the site.

The attributes of recycled wood that may require sample testing are[27]:

- Particle size range, including fines content,
- Moisture content,
- Colour,
- Calorific value,
- Non-wood physical contamination, including grit,
- Chemical contamination,
- Pathogen content.

[25] *Directive 2009/28/EC of the European Parliament and of the Councel of 23 April 2009 on the promotion of the use of energy from renewable sources*

[26] *EC (2010) Guidance on classification of waste according to EWC-Stat categories, Supplement to the Manual for the Implementation of the EC Regulation No 2150/2002 on Waste Statistics*

[27] *UK: Waste Resources Action Programme (WRAP) & British Standards Institution (BSI)*

One or more of these attributes may not be critical to either the intended application or end use or for health, safety and environmental considerations. In addition, the limit or the acceptable range of values for any given attribute will vary depending on the market.[28]

Waste wood is treated differently within the EU. Every member state has its own regulation and standardisation scheme for waste wood. Depending on the respective waste wood category there are strong regulations on emissions in the different countries. Therefore, not all European resources listed as waste wood could actually be used for energy purposes.

6.7 Biogenic fraction of waste

Household waste consists of both materials with fossil origin, such as plastics, and of biogenic materials such as food waste. The share of the biogenic, or renewable, fraction compared to the fossil one is not easy to establish. It depends to a large extent on which other systems for dealing with waste are in place. If composting is practised the share of biomass decreases, while systems for recycling plastics increase the biomass share.

After recycling and re-use of discarded products, energy recovery through incineration is preferable to putting the waste in landfill. The energy released in the combustion process can be used for power and/or heat production. The electrical efficiency of a waste incineration plant is typically lower than of a plant using purer biomass fuels. This has to do with the corrosive nature of the exhaust fumes, which limits the temperature levels that can be used in the steam process.

6.8 Agro-industrial residues

Agro-industrial residues arise as by-products from the industrial processing of harvested plant materials for food, energy or manufacturing purposes. They are generally lignocellulosic in nature and exhibit a wide range of forms, from fibrous material to pips, stones, husks and shells. Some of the residue materials, such as sugar cane bagasse, may be partially utilised as an energy source in the industrial process, leaving a reduced volume available for trading as a solid biomass feedstock.

In order to be economically transportable over long distances, products from agro-industrial residues must be stable and have a comparatively high energy density. Many lighter materials, such as grain or seed husks, are dried and pelletised in order to improve their handling characteristics, density and their transportability.

The principal agro-industrial residues that may be of interest as biomass feedstocks for electricity generation are set out in table 9.

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[28] *Ibid.*

Agro-industrial Residue	Principal Areas of Origin
Sugar Cane Bagasse (pellets)	S. America, Caribbean & S. Asia
Palm Kernel Shells (PKS)	S.E. Asia & Africa
Coconut Shells	S. & S.E. Asia, S. America
Cocoa Shells	W. Africa, S.E. Asia
Almond Shells	USA, S. Europe, N. Africa
Cashew Shells	W. Africa, S.E. Asia
Coffee Husks & Shells	E. Africa, S. America, S.E. Asia
Rice Husk Pellets	Asia, S. America
Sunflower Husk Pellets	E. Europe, Asia, S. America
Soya Hull Pellets	USA, China, S. America
Olive Cake Pellets	S. Europe, N. Africa
Olive Stones	S. Europe, N. Africa
Grape Seeds	Europe, USA, S. America
Cherry Pits	Europe, W. Asia, USA

Table 9: Origins of different types of agro-industrial residues

The use of agro-industrial residues as biomass feedstock must be matched to the power plant type. While fluidised bed combustion systems generally have a fairly broad particle size tolerance, pulverised fuel combustion systems require a narrower range which can be more difficult to obtain when using fibrous materials.

Critical attention must also be paid to the chemical characteristics of agro-industrial residues, particularly the alkaline halide (K^+, Na^+, Cl^- and Br^-) content (see table 10 below). These elements impact on the ash melting characteristics, and high concentrations can result in the corrosion of heat transfer surfaces and the build-up of ash deposits, which affect efficiency and require more frequent and intensive cleaning.[29]

Many of the crops from which agro-industrial residues are derived are seasonal in nature, leading to fluctuations in both volume supply and price. A considerable number of the residues also arise from crops and plantations in developing countries. As more developing nations adopt renewable energy policies, or commit to limiting their greenhouse gas emissions, the volume of residues available for external trade can be expected to decline.

The production of lignocellulose based biofuels, also known as second generation biofuels, is still largely at the research and demonstration stage. As the technology progresses, and becomes more commercial, it may be expected to affect the availability of agro-industrial residues for electricity generation. This diversion of residues towards the production of cellulose bioethanol will be driven by the fact that biofuels made from lignocellulosic materials will count double towards the renewable transport obligations laid down under Directive 2009/28/EC.

[29] *An overview of the chemical characteristics of some agro-industrial residues can be found on databases such as that established by the Energy Research Centre of the Netherlands (ECN) - see http://www.ecn.nl/phyllis/.*

Material	Moisture (%)	Ash (%)	Gross CV (GJ/t)	Sulphur (%)	Chlorine (%)	S:Cl Ratio	Sodium (mg/kg)	Potassium (mg/kg)	Ash Deform. (^oC)
Bagasse Pellets	9	9	17.9	0.12	-	-	-	8500	-
Palm Kernel Shells (PKS)	12	4	20.8	0.03	0.04	0.7	93	702	1070
Cocoa Shells	5 - 10	9 - 11	18.8	0.18	0.01	18	-	-	-
Almond Shells	10	3	21.1	0.13	0.01	13	140	5439	1240
Cashew Shells	11	2.8	21.2	0.03	0.01	3	374	5857	1180
Rice Husk Pellets	10	11	17.8	0.04	0.17	-	-	-	1180
Sunflower Husk Pellets	10	7	19.8	0.43	0.08	5	54	11695	1150
Soya Hull Pellets	14	6	17.9	0.11	0.01	11	263	13860	1250
Olive Pellets	9	7	20.3	0.12	0.17	0.7	246	18100	1250
Olive Stones	5 - 14	1.4	20.4	0.01	0.01	1	31	2475	1310
Grape Seed	12	3.5	21.2	0.11	0.01	11	104	4910	1500+
Cherry Pits	7	1.3	22.1	0.11	-	-	-	-	-

Table 10: Characteristics of agro-industrial residues

7 SUPPORT SCHEMES FOR BIOENERGY IN THE ELECTRICITY SECTOR

KEY MESSAGE: Current bioenergy support schemes in many member states are insufficient; support schemes must be developed to promote all forms of sustainable bioenergy production, without discriminating against plants by size. Progress should be made to harmonise support schemes and use joint projects to avoid unnecessary transport of biomass.

The support schemes for electricity from biomass in member states (including electricity from co-generation) are usually the same type of support as for other forms of RES-Electricity but at a different level of different restrictions on plant size. 14 member states have a feed-in tariff (FIT) as main support scheme, 2 offer only a feed-in premium (FIP) system, four offer the choice between an FIT or FIP, and six have a quota system. Malta is the only country with no support for any form of electricity production from biomass. The full range of support schemes for biomass electricity are described in the table below.

At least 14 countries link their support to the size of biomass plants, providing either higher support levels for small installations or support for small installations alone (e.g. Germany, which only supports plants under 20MW). The lack of support for other installations means that the large potential to use biomass in existing thermal plants or build new large-scale biomass plants will probably not be realised. This is illogical and means that a large portion of cost efficiency biomass-electricity production is not realised.

At least 10 countries differentiate their support between types of biomass or exclude certain types of biomass (e.g. Sweden supports olive stones/pits but not orange pips). According to the EU RES Directive support should not be given to bioliquids which do not fulfil the directive’s sustainability criteria. But apart from that, no other differentiation in support levels between different types of biomass seems valid. This will decrease the possibility of a cost-effective outcome of this policy.

Some countries support biomass only if it is used in CHP-plants. Some countries do not support co-firing of biomass and fossil fuels (e.g. Netherlands and Germany), thereby excluding measures with great potential to increase the use of biomass and thereby achieve targets in a cost-efficient way.

Sustainability criteria for other forms of biomass than liquid are in place in Hungary, the UK and Belgium. Fulfilling these criteria is a prerequisite for achieving support for solid biomass use. With the exception of Hungary and Lithuania, as well as Poland, Romania and Sweden with their quota systems, nearly all member states differentiate at least between biogas and other biomass.

In certain cases FIT are combined with a tender scheme (e.g. in France or Portugal). However, the eligible type of biomass and plant sizes, conditions concerning co-firing or CHP-use, the numbers of categories and the level of support for biomass vary quite considerably from one country to another and thus make qualitative comparisons difficult.

Differing support levels for bioenergy in different member states influence the use and transport of wood-based fuels within the EU. There is therefore a risk that biomass will not be utilised in areas where it is most cost-efficient. In addition, unnecessary transport of wood-based fuels leads to increase in environmental impact. In view of the foreseen increase in bioenergy production in the next years, this could pose a serious problem in terms of cost efficiency, sustainability and logistics. A good solution would be harmonised support levels for biomass across different member states. In the short term, similar results could be achieved by use of the "co-operation mechanisms" under the Renewables directive, which allow for implementation of joint support schemes and also joint projects between member states. This could allow the renewable energy output of a plant in one member state – closer to the source of the biomass, to contribute to the renewables target of another member state. The European Commission should therefore promote and facilitate the full use of the co-operation mechanisms.

On following pages:

Table 11: Overview: Support schemes for biomass in each Member State *(correct to March 2011)*[30]

Abbreviations in table:
n.i..: No information
FIT: Feed-in tariff

30 *Sources: NREAPs; European Renewable Energy Council www.erec.org ; TU Wien (2011) Re-shaping – Renewable Energy Policy Country Profiles (Intelligent Eerngy Europe funded project); ECOFYS/Fraunhofer/TU Wien/Ernst&Young (2011) Financing Renewable Energy in the European Market Report for EC DG Energy ; Fraunhofer ISI/TU Wien (2011) Assessment of National Renewable Energy Action Plans (part of REPAP 2020)*

Member State	Support Scheme for biomass	Special Conditions (Size, Energy efficiency requirements, etc.)	Supplementary measures	Support for co-firing?	Support level
Austria	*FIT, with different categories (size/source), Guarantee for 15 y.*	*Size limit Efficiency criteria: min. 60%*		*Yes*	*Solid Biomass 10-14.98 ct/kWh; different levels for other biomass.*
Belgium	*Green-certificate For 10 y.*	*Flanders: No size limit but lower support of co-firing Wallonia: Biomass plant up to 20MW only; also special support for biomass plant with CHP under 5MW (not given here)*	*In Flanders premium for enterprises via tender for investments in sustainable and more efficient production processes; Tax deduction up to 20.5% on investment costs for improvements in existing installations and the use of RES*	*Yes*	*Green certificate (GC) has floor price and price cap, leading to following support level: Flanders: Min. price is 90€/MWh + electricity price, maximum is 125€/MWh + electricity price (NB GC awarded only on net production minus energy required for treatment and transport of fuel) Wallonia: For biomass under 20MW, min. price is 6.5-25€/MWh + electricity price (depending on amount of avoided CO_2) maximum is 10-100€/MWh + electricity price*
Bulgaria	*FIT For 15 years available but not guaranteed*	*Mainly only for <5MW; exception: wood waste from forestry pruning >5MW*	*Credit line for investments for larger RES-E investment projects; New green investment fund*	*n.i.*	*Solid biomass: 95.35 -111.777 €/MWh; different levels for other biomass.*
Cyprus	*FIT for large projects until 2013, Guaranteed for 20 y.*		*Direct subsidies for small scale projects for wind, PV, small hydro*	*n.i.*	*Solid Biomass: 135 €/MWh (17.9 + 17.1); Different levels for other biomass.*
Czech Republic	*FIT or Premium Guaranteed for 20 y.*	*Categories based on resource, calorific value, average cost, benefits*	*Investment support*	*Yes*	*Solid Biomass: (in 2011) 68.52-142.02 €/MWh; different levels for other biomass.*
Denmark	*Feed-in-Premium For 10-20 y.*	*Maximum level of support guaranteed premium for solid biomass + biogas mixed with other fuels*	*Additional subsidies to small systems;*	*n.i.*	*Solid biomass: 15 øre/kWh (20.2 €/MWh); biogas (market price+ premium between 40.5 – max. 74.5 øre/kWh (54.4 – max. 100 €/MWh):*
Estonia	*Feed-in-premium Max. 12 y., level guaranteed*	*Cap on total volume only for wind; For biomass only if in cogeneration*	*Not for biomass*	*n.i.*	*For all biomass 53.7 €/MWh in cogeneration, 32 €/MWh in cogeneration if < 10 MW)*

Member State	Support Scheme for biomass	Special Conditions (Size, Energy efficiency requirements, etc.)	Supplementary measures	Support for co-firing?	Support level
Finland	***Feed-in-premium + FIT for small plants***	***Level for wood fuel & biogas based on the target price and market price difference, for wood chips on the costs of emission permits; size limits and differentiation between biomass type Biogas power plants not covered by premium receives fixed subsidy of 4.2 €/MWh***	***Additional heat premium for CHP using wood fuels and biogas; investment grants; fixed subsidies for e.g. biogas plants***	***Yes, for co-firing with peat***	***For wood chips: between 0 -18 €/MWh (if emission permit costs are 10€/t CO2=support of 18€/MWh, if emission permit costs are 23/t CO2= support of 0 €/MWh); For biogas and wood fuel power target price of 83.50 €/MWh;***
France	***FIT for small biomass cogeneration (guaranteed for 15-20y.) + call for tenders***	***FIT <12MW; Efficiency/methanisation bonus; tenders for larger installation (obtaining a FIT);***		***n.i.***	***Small Biomass cogen.: 43.4 €/MWh + poss. Bonus (77.1-125.3€/MWh); small Biogas/methanisation cogen.: 75-90€MWh + poss. bonus up to 30€/MWh; Biomass plants >12MW: Tender, in average in 2006 128€/MWh, in 2009 45€/MWh, in 2010 tender condition below 115€/MWh;***
Germany	***FIT (guaranteed for 20 y.) or similar premium if direct marketing***	***No FIT for biogas >5 MWel based on sewage and landfill gas and biomass installations >20 MWel; By 1.1.2012: 4 FIT levels following the plant capacity and 2 following the resource (plus separate FIT for small whole wood FIT depending on the plant capacity) + 3 bonuses for bio methane infeed into gas grids, 2 FITs for biowaste and 1 FIT for small installations (<75kW) using >80 slurry; mind. 60% in KWK or for biogas 60% slurry use; for biogas plants in operation by 1.1.2014 max. plant size of 750 KW.***	***Low interest loans for different technologies***	***-***	***Solid biomass in 2011 76.3-114.3 €/MWh + max. added bonus 110 (digression for new plants 1%/y.) Sewage and landfill gas 40.8-87 €/MWh (max. added bonus: 10-20 €/MWh) (digression 1.5% /y.); By 2012: No changes on sewage and landfill gas, Basic biomass tariff following size: 60 – 143 €/MWh + tariff following energy source: 25-80 €/MWh (paid only up to 5 MW), biomethane bonus 10 – 30 €/MWh, digression 2%/y; Good support, but insufficient above 5 MW (max. 60 €/MWh); Biomass second largest RES-E contributor***

Member State	Support Scheme for biomass	Special Conditions (Size, Energy efficiency requirements, etc.)	Supplementary measures	Support for co-firing?	Support level
Greece	***FIT*** ***Over 20Y.; yearly tariff adjustment)***	***Size specific***	***Cash grants, tax exemptions and leasing subsidies***	***n.i.***	***Solid Biomass:150-200 €/MWh*** ***Biogas:99.45-220 €/MWh*** ***Biogenic part of municipal waste: 87.85€/MWh*** ***Bonus if CHP***
Hungary	***FIT*** ***Guaranteed up to 15 y.***	***Review of FIT-system into effect by 1.7.2011: new biomass capacity thresholds; sustainability requirements; differentiation by size of plants and day/time and typ of biomass***	***Fund subsidies but then FIT period is shortened;*** ***Subsidies for energy crops***	***yes***	***Until 01.07.2011:*** ***9.37-32.10 HUF/kWh***
Ireland	***FIT*** ***Guaranteed for 15 y.***			***yes***	***In 2009:*** ***Biomass other than landfill gas 83.814 €/MWh,*** ***Landfill gas 81.486 €/MWh*** ***Anaerobic digestion: 120 €/MWh;***
Italy	***Tradable Green Certificates (TGC) with technology banding or FIT (both for 15 y.) for small plants (<1MW);*** ***From January 2013: Tender (except for biomass) or FIT for smaller plants***	***From January 2013: with a capacity above determined threshold,***		***n.i.***	***In 2011 average certificate price 87€/MWh;*** ***Banding allows for a biomass coefficient: Biomass, agricultural/forestry biogas and: 1.8, for other biogas 0.8, for biodegradable waste and other biomass 1.3;*** ***FIT between 180 (biogas) and 280 (solid biomass) €/MWh;***
Latvia	***FIT (granted by tender for 20 y., tariff reduction after 10 y.);*** ***+ guaranteed capacity payment for biomass and biogas (for 15y.)***	***FIT Volume following tender; Different tariffs for cogeneration***	***For CHP plants >4MWe might receive a supplementary support Tax exemptions and investment support,***	***n.i.***	***For first 10 y.: Biomass <4 MW ~91.05-176.99 €/MWh ; biomass >4MW, ~ 60.38-110.19€/MWh*** ***Biogas <2MW 134.51-165.47€/MWh, >2MW 75.48-141.60 €/MWh*** ***Or capacity payment (e.g. for a 1.5 MW plant ~18.52 €/kWh/month)***

Member State	Support Scheme for biomass	Special Conditions (Size, Energy efficiency requirements, etc.)	Supplementary measures	Support for co-firing?	Support level
Lithuania	***FIT - guaranteed for 10 y.; With new law of May 2011: granted/tariff set by tender; for > 30 kW fixed FIT (guaranteed for 12 y.)***		***Interest subsidies , soft loans, subsidies from rural development programme***	***n.i.***	***By January 2012: Level set by tender; for > 30 kW fixed FIT;***
Luxemburg	***FIT (tariffs guaranteed for solid biomass for 15 y. for biogas 20y(.;***	***Support for solid biomass only up to 5 MW For biogas up to 2500kW***	***Further grant for the use of RES-E in enterprises***	***n.i.***	***Tariff in 2011: Solid biomass ≤1MW 143.91€/MWh, >1MW≤5MW 124.06 €/MWh Waste wood ≤1MW 129.03 €/MWh, >1MW≤5MW 109.18 €/MWh; Biogas depending on size***
Malta	***No support***				
The Netherlands	***Feed-in-Premium (SDE, guaranteed for 12 y.)***	***One capped budget for all eligible technologies***	***Tax relief, low interest loans***	***-***	***Feed-in-premium = base price – market price max. base price***
Poland	***Quota/Certificate scheme***		***Subsidies and loans and fiscal privileges***		***In 2010: electricity price 49.3 €/MWh + max. TGC price 69.4 €/MWh***
Portugal	***FIT + tendering for forestry biomass***	***Cap to the maximum production per installation for biogas***	***Micro production and mini-production subsidy schemes for households and SMEs***	***n.i.***	***Indicative average tariffs: Biogas anaerobic digestion 115-117 €/MWh, landfill gases 102-104 €/MWh (both for 15 y.), forestry biomass 119 €/MWh (for 25 y.)***
Romania	***Quota/green certificates (GC) (for 15 y., 1 GC/MWh);***		***Additional other grants***	***Only if "green" fuel share is 75%***	***Min. and max. level of GC at 27 €/MWh and 55 €/MWh;***
Slovakia	***Feed-in-premium (set annually but guaranteed 15 y.)***	***Size specific***	***Tax exemptions + subsidies***	***n.i.***	***For 2011: 113.10 – 144.88 €/MWh***

Member State	Support Scheme for biomass	Special Conditions (Size, Energy efficiency requirements, etc.)	Supplementary measures	Support for co-firing?	Support level
Slovenia	***Choice between FIT or feed-in premium for RES plants > 5 MW and CHP > 1 MW***	***Size specific***	***Subsidies and low interest loans***	***yes***	***FIT in 2011:*** ***Biomass: <50 kW defined individually, <1 MW 233.79 €/MWh, <10MW 175.30 €/MWh;*** ***Biogas depending on origin and size*** ***Biomass: (>90%biomass) ~ 185.44 -126.42 €/MWh,*** ***Co-firing (> 5% biomass): ~ 61.41 – 63.54; biogas 80.27 – 113.81***
Spain	***Choice between FIT (guaranteed FIT for 15 y.)***	***Min. and max. premium;*** ***Special regime for high-efficient CHP or non feedstock based biomass;*** ***Capacity limit of 250 MW for biomass and biogas***	***Important role of fiscal measures***	***n.i.***	***In 2010:*** ***Biomass FIT: 10.02 – 17.16 €ct/kWh; ref. premium 2.59-12.93 €ct/kWh*** ***Biogas: FIT 8.63 – 14.11 €ct/kWh; premium 4.57 – 6.72 €ct/kWh***
Sweden	***Quota / tradable green certificates (together with Norway by January 2012)***	***Some type of biomass excluded***	***Biomass use is tax-free***	***n.i.***	***Annual average price of spot electricity certificate was 30.87€ from 2008 -2010***
UK	***Quota/RES obligation scheme (RO) with technology banding. AD projects below 5MW are able to opt for a FIT instead. New feed-in tariff with Contract for Difference to be introduced to replace RO for new projects by 2017.***	***Sustainability requirements for electricity from bioenergy (solids, liquids and gases);*** ***Differentiation between different types of biomass***	***Climate change levy exemption***	***yes***	***Total worth of ROC in 2009/2010: ~59.50€/MWh*** ***Aug. 2011: ~51.40€/MWh;***

8 Sustainability Criteria and Harmonisation

KEY MESSAGE: Sustainability criteria developed within the EU for biomass also need to be progressively harmonised at international level, in order to promote and maintain international biomass trade.

One important success factor for the increase of energy production based on biomass is the use of sustainable biomass, avoiding potential detrimental effects on the environment and social welfare. Sustainable biomass supply chains can even improve the local environment and provide positive social effects in the respective region.

European Directive on Renewable Energy

The European legal framework has not yet established binding sustainability requirements for solid and gaseous biomass. Article 17 of The Renewable Energy Directive[31] includes sustainability requirements for biofuels for transport and for bioliquids used in other energy sectors (electricity, heating and cooling). By 19 July 2011 the European Commission had recognised[32] seven voluntary schemes (as of October 2011 20 schemes are being assessed):

1. ISCC (International ***Pellet group,*** Sustainability and Carbon Certification)
2. Bonsucro EU
3. RTRS EU RED (Round Table on Responsible Soy EU RED)
4. RSB EU RED (Roundtable of Sustainable Biofuels EU RED)
5. 2BSvs (Biomass Biofuels voluntary scheme)
6. RBSA (Abengoa RED Bioenergy Sustainability Assurance)
7. Greenergy (Greenergy Brazilian Bioethanol verification programme)

Article 17(9) of the same Directive provides that the European Commission should report by December 2009 on requirements for a sustainability scheme for energy uses of biomass other than biofuels and bioliquids (i.e. solid and gaseous fuels in electricity, heating and cooling). The Commission´s report[33], published in February 2010, contains the following main findings:

– For biomass produced within the EU, the current legal framework (notably related to agriculture and forest management) gives certain assurances for the sustainable management of forest and agriculture. The same is true for some third countries – but others lack such a framework. For this reason, concerns have been expressed that an expansion of international trade of biomass and increasing imports from third countries may lead to the unsustainable production of biomass. As a result, some of the main importing countries of biomass developed further national sustainability requirements for bio-energy. Economic actors must now cope with several

[31] *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources*

[32] *On 19 July 2011.*

[33] *EC (2010) Report from the commission on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling SEC (2010) 65, SEC (2010)66.*

certification schemes (voluntary and mandatory) in the agriculture, forestry and energy sectors that are not necessarily complementary or compatible[34].

- The report focused on four main sustainability issues to be taken into consideration[35] for solid and gaseous biomass used for energy purposes:
  1. Sustainability in production (land management, cultivation and harvesting)
  2. Land use, land use change and forestry accounting
  3. Life cycle greenhouse gas (GHG) performance
  4. Energy conversion efficiency

- The European Commission recommends that national sustainability schemes for solid and gaseous biomass used in electricity, heating and cooling, should in almost all respects be the same as those laid down for liquid biofuels in the Renewable Energy Directive. The report allows minor modifications due to the characteristics of the production and use of solid and gaseous biomass in electricity, heating and cooling[36]. Additionally, the Commission intends to introduce requirements for reporting and monitoring.

As a next step the European Commission should report, as it is scheduled to do so, by 31 December 2011 on whether national schemes have sufficiently and appropriately addressed sustainability related to the use of biomass from inside and outside the EU, and whether these schemes have led to barriers to trade and barriers to the development of the bio-energy sector[37].

Further European initiatives on sustainability
Several other initiatives at the European level also have an impact on sustainability[38] assessment. For the forestry sector and agriculture, the main instruments are: illegal logging and trade regulation, the forest action plan including guidance on sustainable mobilisation of wood, forest principles agreed at the 1992 United Nations Conference for Environment and Development (UNCED) in Rio de Janeiro, the Third Ministerial Conference on the Protection of Forests in Europe (Pan-European Criteria and Indicators for Sustainable Forest Management), a green paper on "Forest Protection and Information in the EU", and the REDD mechanism. Agricultural policies also include environmental measures and bio-energy purposes: Regulation EC 73/2009 cross compliance ("CAP health check" (2007)), U.S. Environmental Quality Incentives Program, IATP, and the Forest Europe process.

Biodiversity initiatives include a post-2010 biodiversity target: "To halt the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, restore them in

[34] *Ibid. ; Environmental rules in the Common Agriculture Policy, as well as common environmental rules on nitrates, pesticides, water quality and protected areas provide for a framework for sustainable agriculture in the EU. In forestry, the applicable forest laws of Member States include either specific regulation for obligatory reforestation after final cuttings or regulate the subject as part of sustainable forest management and forest management planning (source: UNECE European Forest Sector Outlook Studies)*
[35] *Ibid.*
[36] *Ibid.*
[37] *Ibid.*
[38] *EU Consultation; see also for further information respective footnotes.*

so far as feasible, while stepping up the EU contribution to averting global biodiversity loss" and a new ten-year strategic plan for global biodiversity protection, including 20 headline targets. Furthermore the potential of green public procurement and the "Resource Efficient Europe" initiative and UNEP work on bio-energy (water nexus) are further developed.

International initiatives on sustainability are for example:

- Brazil introduced an agro-ecological zoning with designated areas where sugar cane production can be expanded without restrictions. These zones have either been used for agricultural production for a longer period of time or they are degraded. Production in the three Amazonas regions is not permitted and preference is given to areas with limited irrigation and slopes of less than 12%, allowing mechanical harvesting to avoid fire risk.
- The ERIA working group, initiated by the East Asian Summit, that developed a sustainability assessment method. The method has been tested on four pilot projects. Practice showed, however, that the guidelines were too theoretical and complex for real life application and the questionnaires were too laborious. Focusing strictly on a few GHG criteria and on social factors will make the method easier to use.
- In Thailand preservation of the environment and abatement of GHG are strictly coupled with the development of RES by a governmental decision.
- In Malaysia the government has decided to reserve 50% of the total land surface as virgin natural forest. Expansion of intensive biomass production will only be allowed on existing agricultural land and degraded forests with less than 50% biomass remaining.

National regulation and policies

With no harmonised European legal framework on sustainability requirements for solid and gaseous biomass in place, different national sustainability requirements determine the legal framework. The level of detail of the regulations and policy instruments and the impact on the respective biomass business differs between countries. Some member states have linked their sustainability requirements to the support schemes for renewable energies[39]. Countries also refer to sustainable bio-energy sourcing according to existing criteria in their general policies on agriculture, forestry and environmental protection as well as their regulation on climate change and sustainability in general[40].

Voluntary certification schemes

In addition to national policies, several worldwide voluntary standards are applied in the EU member states as well. Some of the main voluntary certification schemes that have found acceptance in the market are PEFC, FSC, GGL, SFI (US) and FFCS, some of which refer only to forestry. In the agricultural area, the ISCC, BSI & RTRS criteria are similar to the EU criteria (EUBIONET assessment).

[39] *e.g. Belgium & Germany (Biomass Sustainability Ordinance for the Electricity Sector) and in Netherlands (NTA 8080, the sustainability criteria in standard NTA 8080 will be linked to the subsidies for electricity companies in 2010)*

[40] *e.g. Belgium: "Code Forestier".*

Several existing certification schemes have not yet been harmonised at a European or international level. Certificates like FSC, PEFC and GGL develop an international approach with one set of criteria as an umbrella standard for different countries, allowing enough flexibility to take diverse approaches into account. Moreover, most of these schemes lack binding thresholds for greenhouse gas emissions and do not prohibit the use of peat lands and other lands with high carbon stock (EUBIONET).

Further initiatives on sustainability

The main market players regard harmonised and comprehensive sustainability requirements on a European and international level as a key issue for a successful, stable bio-energy production and for long-term growth of the biomass business as such.

Several initiatives are calling for the development of sustainability criteria for biomass. Associations like EURELECTRIC[41], AEBIOM&EBA[42], WBA, Council on Sustainable Biomass Production (CSBP,US), GBEP, FAO, ISO & CEN have included the sustainability issue as a key topic in their work plans. Some of them are developing an independent sustainability approach to provide a guideline to their members as well as to the market. Industrial initiatives like GGL, Drax, EBL/LBE are establishing sustainability criteria for biomass. The Initiative of Wood Pellet Buyers (whose members have a market share of more than 70 per cent in Europe) is developing a common set of sustainability requirements for industrial wood pellets, in order to establish industrial wood pellets as a transparent and globally tradable commodity.

NGOs also play an important role in the field of sustainable biomass. Their approaches differ from one other regarding the focus, the level of ambition and the context in which sustainability issues should be taken into consideration.

Main conclusion drawn from the different stakeholder's opinions

The majority of stakeholders and market players state that European-wide guiding legislation on a harmonised set of sustainability criteria for biomass fuels is necessary to ensure a stable, predictable and European harmonised framework for the market for biomass as a sustainable product. The import of biomass from countries outside the EU should also be taken into consideration, as major quantities of imported biomass will be needed to meet demand, in particular that for woody biomass.

Most stakeholders strongly emphasise environmental protection and contribution to the social welfare when using biomass resources for energy production and in other industrial sectors. With regard to integrating the European market, harmonised sustainability criteria could even foster the international market by providing a harmonised, stable and continuous framework for the biomass business and commodity trade. Regarding industrial wood pellets as a global commodity for example, a certain degree of standardisation is deemed important – the greater the standardisation, the greater the liquidity of the market and the competitiveness of the product. Therefore sustainability for biomass should also be subject to harmonisation.

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41 EURELECTRIC (2010) Position Paper on Sustainability Criteria for Solid & Gaseous Biomass (in response to SEC (2010) 65)

42 AEBIOM/EBA (2011) Position Paper on Sustainability Criteria for Solid & Gaseous Biomass

We argue for these harmonised criteria to compose a single set of criteria for all types of biomass but one that takes into account the differences between different types of biomass. While sustainability of agricultural biomass is often connected with the food chain and land-use change issues, forest biomass sustainability is more related to sustainable growth, carbon stock and biodiversity issues. Therefore the single set of criteria for these different forms of biomass must address these different issues. In the case of forest biomass, it would also be useful to take into account existing national forest stewardship legislation, which in some cases already guarantees a good level of sustainability. National forestry rules in the Nordic countries are an example of this, and in order to reduce administrative burden, the possibility of a fast-track approach to certification to common EU criteria for biomass producers already adhering to these rules should be considered.

Summing up, the different voices in the EU supporting a mandatory, harmonised European approach state that:

- The requirements should contain a harmonised set of binding guideline criteria, which the major part of stakeholders and market players feel should be mandatory;
- A single set of criteria should be implemented for all types of biomass, but respecting the specific issues of these different types of biomass
- The approach should offer a stable and reliable framework for national activities;
- The criteria should be practical, applicable and transparent;
- The implementation should avoid unnecessary administrative burdens; possible fast-track approach for producers adhering to national rules, where sufficient (e.g. Sweden, Finland)
- Monitoring and reporting is essential;
- The approach should include requirements (at least reporting and monitoring) relating to several environmental aspects like air, soil and water, and should additionally cover overall issues like e.g. greenhouse gas balance, biodiversity, land use change, local food supply, socio-economic performance, corporate responsibility and the protection of carbons stocks as well as the protection of virgin forests and natural habitats. The approach should also respect the different fragmentation of the supply chain across different member states.

LIST OF TABLES

LIST OF FIGURES

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