

Six Sources of Energy – One Energy System

Vattenfall's Energy Portfolio
and the European Energy System



Biomass

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BIOMASS

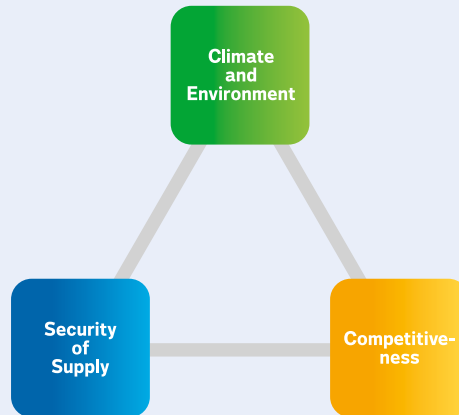
Bioenergy is a form of stored solar energy, collected by plants through photosynthesis. Biomass is an organic material that contains bioenergy. Biomass is a renewable energy source used to produce electricity, heat and fuel. Biomass and waste constitute roughly three per cent of total electricity generation in the EU.

The Energy Triangle – Biomass

Climate and environment

All energy sources have environmental impact during their life cycles. Combustion of energy sources, particularly fossil fuels, generates CO₂ emissions and contributes to global warming. In the long run, emissions from power production will need to be close to zero if greenhouse gas levels in the atmosphere are to be stabilised.

By using biomass in power production instead of fossil fuels, CO₂ emissions can be significantly reduced. Carbon dioxide is emitted into the atmosphere when biomass is burned, but when biomass grows it binds carbon dioxide through photosynthesis. Properly managed biomass is therefore carbon neutral over time.



Security of supply

Fuel shortages and unreliable electricity systems cause societal and economic problems. Securing supply means guaranteeing that primary energy is available, and that delivered energy is reliable, essentially 100 per cent of the time. This is both a political and a technical challenge.

Biomass can be converted into a stable and reliable supply of electricity and heat. Biomass can be securely sourced on small scales, but supply of larger volumes is currently difficult to secure. One important step is to establish a global trade and certification system. Biomass resources are geographically diversified and political risk is limited.

Competitiveness

Energy is a fundamental input to economic activity, and thus to human welfare and progress. The costs of producing energy vary between different energy sources and technologies. A competitive energy mix will keep overall costs as low as possible given the available resources.

Using biomass to produce electricity is currently more expensive than using energy sources such as coal, gas or nuclear power. The global biomass supply chain is developing and, over time, technological and logistical improvements will bring down prices. An increased CO₂ price will also improve the economic competitiveness of biomass.

The Development of Biomass Power Generation

An old energy source with new applications

Biomass is a renewable energy source that has been used as fuel for tens of thousands of years. Wood and other plant parts have been used since the dawn of man to prepare food and provide heat. Biomass is still the main type of fuel for the 1.4 billion people across the globe that lack access to electricity, in the form of wood burned in stoves, fires and other basic cooking devices.

Development of the different areas of application for biomass has made great strides in recent decades, and there are now a variety of methods for converting biomass into heat and electricity; everything from pellets for household heating to agricultural waste used to produce electricity in commercial power plants. However, despite the development in recent decades, biomass for large-scale electricity generation still constitutes a minor portion of total global biomass consumption for energy purposes. It is still a new technology, and its potential is substantial.¹

The share of biomass in the energy mix remains limited in many countries and is largely influenced by geographic and geological conditions. Biomass is used primarily in countries with extensive forest industries, where residues such as branches, wood chips and sawdust can be used to produce both electricity and heat. Countries with large agricultural industries and industries that produce waste products that can be used as biofuels also have potential to increase their use of biomass.

Interest in biomass within the energy industry has increased in recent years due to its climatically advantageous characteristics. Replacing fossil fuels with biomass presents potential for reducing the amount of CO₂ emitted by electricity and heat production in Europe. In the long term, biomass is likely to play an important role in the European energy mix.

Interest in biomass within the energy industry has increased in recent years due to its climatically advantageous characteristics.

DEFINITION OF BIOMASS AND BIOENERGY

Biomass is used to produce electricity, heat and fuel.

Bioenergy is actually a form of stored solar energy, collected by plants through photosynthesis. Bioenergy is present in living organisms in the form of carbon compounds. Bioenergy is also a generic term for electricity and heat production processes that use biofuels.

Biomass is an organic material that contains bioenergy. Biomass can be anything from energy crops to agricultural or forestry residues and waste. Common to these substances is an origin in photosynthesis and, as opposed to biofuels, the lack of any chemical conversion process.

Biofuel is a generic term for the fuel used to extract bioenergy. Biofuel can be various types of biomass, such as wood or chips, or fuel extracted from biomass, such as ethanol produced from sugar cane.

Among the fields of application for biomass, the focus here is on biomass used for electricity and heat production.

Biomass Becomes Electricity and Heat

At a biomass-fired power plant, biomass is converted to electricity and heat. The heating is done by burning biomass in a boiler. The most common types of boilers are hot water boilers and steam boilers. Wood chips, refuse and other types of biomass are used in the boilers, in the same way that fossil fuels such as coal, natural gas and oil are used.

Co-firing biomass with coal

Co-firing biomass with coal (i.e., replacing a portion of coal with biomass) is an effective method of using biomass for energy purposes. Most of Europe's coal-fired plants could be adapted to burn between 10 and 20 per cent biomass.² Since many kinds of biomass have a lower energy content than, for example, hard coal, using a greater percentage of biomass in the fuel mix risks impairing the plant's efficiency.

Recent research calculates that if the full potential of biomass is realised, the EU's power generation from biomass could increase by 50 to 90 TWh per year. This corresponds to 1.5 to 2.5 per cent of the EU's total electricity generation. Using biomass in the fuel mix of existing coal plants could in turn reduce

CO₂ emissions by approximately 85 million tonnes per year, equivalent to five to 10 per cent of the total reductions needed to achieve the EU's 2020 climate goals.³

The amount of biomass that can be mixed with coal depends in part on the type of biomass used. The availability of suitable biofuels such as pellets, chips and agricultural residues also limits the amount of biomass that can be used.

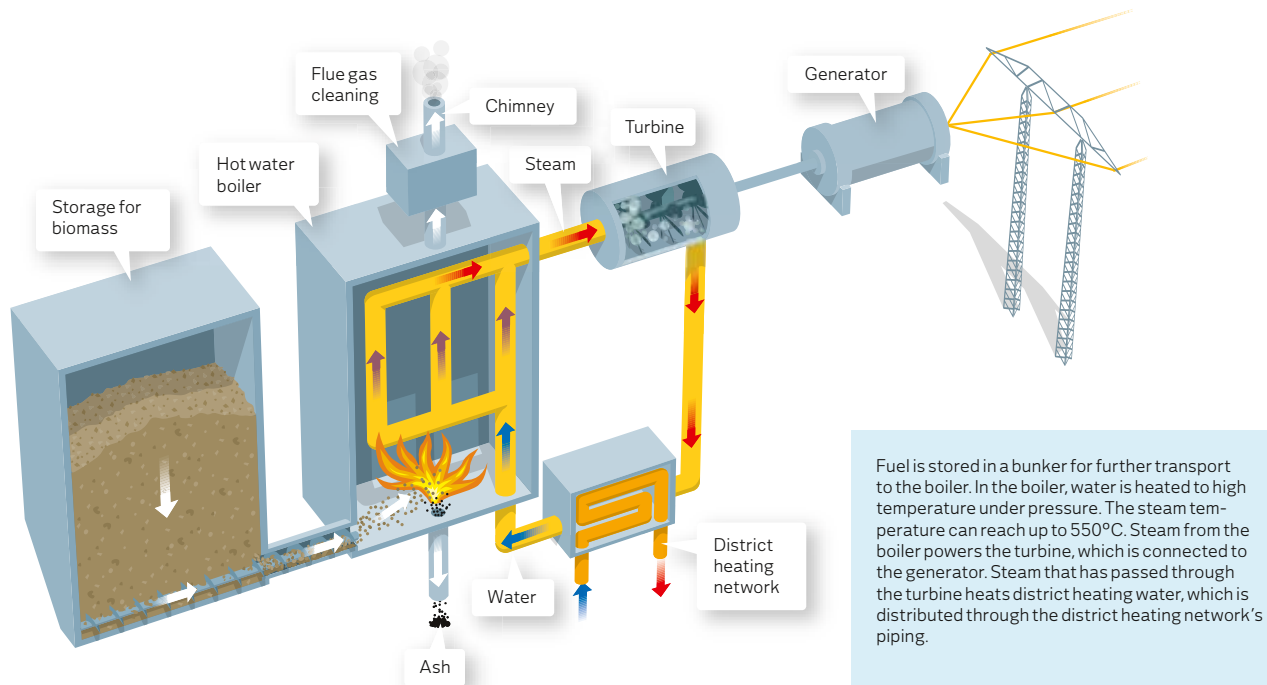
Different biofuels in power generation

The biofuels that are used today for heat and electricity generation are primarily derived from forest products, waste and other residues from the agricultural and forest industries. Farmed energy crops have thus far had a difficult time competing in terms of price with other types of biomass, such as forest products and waste.

Forest products

Wood fuel from forests and plantations constitutes the majority of today's biomass, equivalent to approximately 770 TWh of primary energy per year in Europe.⁴ Roughly half is comprised

Biomass becomes electricity and heat



of residues from the forest industry, sawmills and pulp manufacturing that can be utilised for power generation during combustion.

Pellets and briquettes are another type of biofuel. These fuels are manufactured by compressing waste material, such as sawdust, bark or higher-grade biomass. They are highly suitable for export as they have the advantage of being easy to transport. Pellets and briquettes are often used as fuel in households with boilers and stoves. In much of the world today, waste products from industry and sawmills are left in the forest. Utilisation of these waste products could increase power generation by 170 TWh by the year 2020.⁵

Energy crops

Energy crops are grown by farming and used for power generation. Today, energy crops are cultivated on roughly 50,000 hectares in the EU and provide 3 TWh of primary energy for heating and electricity.

Different types of biofuel are derived from energy crops. Tropical countries primarily produce ethanol from sugar cane.

Starchy crops such as sugar beets and potatoes are fermented to produce ethanol or diesel. Energy crops can also be used with other types of waste to produce biogas. Today's biogas plants can process a variety of different types of waste generated by, e.g., the agricultural industry and farming.

One of the advantages of energy crops is that they do not require the use of chemicals to the extent that food crops do. In Europe, most energy crops are produced locally and thus do not have negative side effects, such as long transports.

Waste, by-products and residues

Residues include manure, sewage, sludge and other degradable waste. Residues constitute the second largest source of biomass today, after wood fuel, contributing approximately 210 TWh per year. Forecasts show that this amount can be increased to 370 TWh by the year 2020. Liquid biomass waste, such as manure, household waste and sewage plant residues, can be digested to biogas.⁶



Biomass in Europe

Renewable energy sources provided approximately 18 per cent of the EU’s electricity generation in 2008. Biomass and waste constituted approximately 18 per cent of this amount, or roughly three per cent of total electricity generation. In 2009, biomass and wind power were the most important renewable energy sources for electricity generation in the EU, after hydro power.⁷

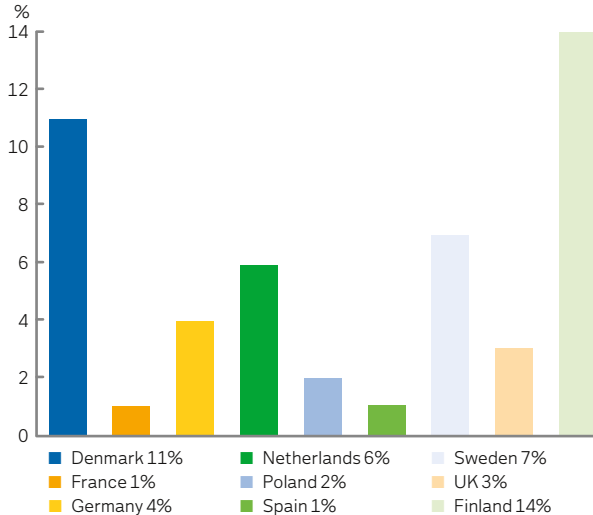
The number of power plants in Europe that run solely on biomass is expected to increase dramatically in coming years. In addition, biomass is used along with coal in many coal-fired power plants throughout Europe. The most and the largest investments in biomass power to date have been made in countries that are most able to use residues from the forest industry, mainly Sweden and Finland. But countries such as Germany, Hungary and Austria also have many biomass plants.

In Europe, biomass power investments are expected to increase dramatically in coming years. Expansion will continue in Scandinavia, which already has a well-established use of biomass for electricity and heat production, though probably not at the previous pace.

An energy source with growth potential

As a renewable energy source, biomass has potential to contribute to reducing CO₂ emissions within the European power generation industry. Studies show that the most common types of biomass used for electricity and/or heat production can contribute towards a reduction of CO₂ emissions by 55 to 98 per cent over fossil fuels.⁸

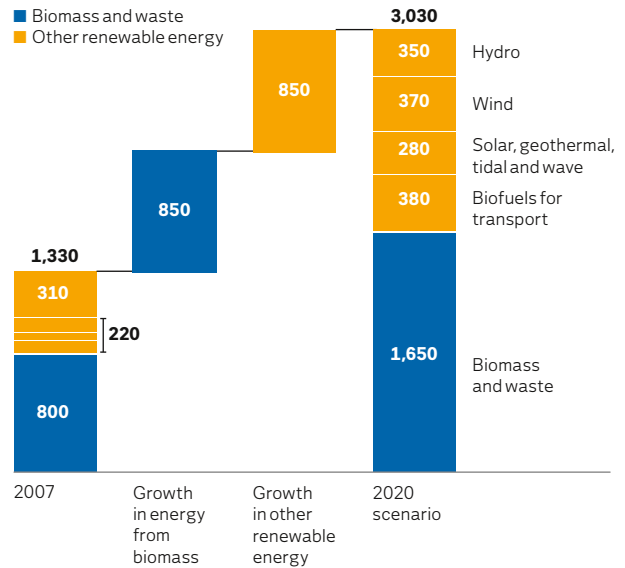
Share of biomass and waste in electricity generation (2008)



Source: IEA Statistics, Electricity Generation, 2010

Role of biomass in meeting Europe’s renewable energy targets – European Commission scenario

EU-27 final energy consumption, TWh



Source: McKinsey, Vattenfall, Sveaskog, Södra, European Climate Foundation (2010): Biomass for Heat and Power – Opportunity and Economics

After wind power, biomass power is the fastest growing energy source in Europe. Over 100 TWh of electricity was produced with biomass and waste in the EU in 2008, more than ten times as much as in 1990. The European Commission expects that biomass power’s contribution to European electricity generation will double over the next ten years. Global use of biomass is also expected to double by 2020.⁹

The EU’s official scenario for renewable power generation assumes that electricity and heat production from biomass will be 850 TWh higher in 2020 than in 2007, signifying a twofold increase over today’s level of 800 TWh.¹⁰ However, nearly 70 per cent of the biomass utilised today is burned directly for heat (e.g., in the industrial sector) and is neither sold nor distributed.

The expected growth of biomass is equivalent to the growth of all other aggregate renewable energy sources within Europe. The current rate of growth, 35 TWh per year, is only one-third of that required to achieve the established 2020 goals. If growth proceeds at the current rate, total growth by 2020 will be 300 TWh, a significant number, albeit 550 TWh lower than the targets.¹¹

Biomass – Opportunities and Challenges

Expanding the use of biomass may have both positive and negative consequences for the climate and the environment. Many challenges remain in place.

Large land areas required

A study by the UN Food and Agriculture Organisation (FAO) shows that there is technically enough land to double the area of biomass plantations by the year 2020. But available land area is not necessarily equatable with actual biomass availability. A mobilisation of biomass supply on a global level is required if demand by year 2020 is to be met.

Due to the fact that energy crops often attract higher subsidies for the landowner, there is a risk that increased demand for biomass will impact global food production and lead to increased food prices. Biomass plantations also use large land areas and may, if not properly managed, compete with other interests such as forestry industry and biodiversity.

Projects are being initiated around the world aimed at ensuring the availability of biomass for new and existing power plants. Meanwhile, an entirely new commodity market is developing where developing countries in particular see an opportunity to find a market for their “green gold”. This trend could force down food production and may endanger natural forests if clear trade and certification systems are not established on both the local and global level.

Managing sustainable biomass

If biomass is to contribute to the reduction of CO₂ emissions in the future, cultivation and production must be carried out in a controlled, sustainable manner. There are still no international criteria defining sustainable biomass. The goal is to establish a functioning system that guarantees that biomass production is carried out in an environmentally and climate neutral manner, regardless of whether the product is domestic or imported. Such a system must also take all involved parties into account, from local residents of the producing country to the energy companies that purchase biomass. Managing this balance has become crucial for politicians and decision makers.

A continuing carbon cycle makes biomass carbon neutral

Carbon dioxide is emitted into the atmosphere when biomass is burned, in the same way as when fossil fuels are burned. But when biomass grows it binds carbon dioxide through photosynthesis. The carbon dioxide released through biomass combustion is captured by growing biomass. Properly managed biomass is therefore carbon neutral over time. Biomass power may

give rise to temporary “carbon dioxide debts” since it may take a long time for slow-growing forests to re-capture the amount of carbon dioxide released through combustion.

Biomass production methods and long transport distances are other factors that impact carbon dioxide emissions. It is therefore important to take the entire value chain into consideration, from production to power plant to replanting. A future challenge is to identify calculation methods to determine the level of emissions created by power generation.

The generation of electricity with biomass produces flue gases that must be cleaned before they are emitted into the atmosphere. This is done by utilising well-developed techniques such as flue gas washing and particulate filters.

Biodiversity an important issue

Large-scale cultivation of biomass can have an indirect impact on biodiversity. Indirect land-use effects occur when biomass production displaces certain activities to other areas leading to unwanted negative impacts, such as deforestation. The carbon impact of indirect land-use change is difficult to measure and there is currently no consensus on how this should be done.

The extensive use of biomass in the form of logging residue from the forestry industry may lead to land acidification, nutrient depletion and reduced biodiversity. One method to counteract nutrient depletion and land acidification is to return the ash formed by the combustion of biofuels. The ash contains nutrients such as potassium and phosphorous. The natural balance is restored more rapidly if this ash is restored to the place where the biomass was grown.

Biomass produced from waste or agricultural residues carries the least environmental risks from production and does not affect biodiversity.

Political support varies

As an energy source, biomass receives varying degrees of political support among European countries. Meanwhile, the need increases for clear criteria for sustainable development. There are several advantages to having an increased share of biomass in the energy system. In addition to environmental and climate advantages and the opportunity to reduce dependency on fossil fuels, an increased use of biomass is viewed as positive for regional development. New jobs are created and farmers have the option of diversifying their crops.

Discussions currently underway indicate the need for a clear framework of binding sustainability criteria that take environmental, social and economic aspects into consideration.

The Future of Biomass

Untapped potential but increased imports still needed

There is potential across Europe to cultivate various energy crops for electricity and heat production. However, forecasts show that Europe will have to import biomass if it is to meet the EU's 2020 goals. Even under the most optimistic forecasts, the estimated total deficit of biomass corresponds to 150 to 750 TWh. Imports of biomass to Europe will consist primarily of pellets, which are suitable for long-distance transports. The achievement of 2020 goals will require 30 to 150 million tonnes of pellets per year, or the output from 50 to 300 large-scale pellet mills.¹²

Uncertainty about future investments

The cultivation of energy crops in Europe has remained at a stable level over the past five years and a limited number of major investments are planned for the future. It is therefore unlikely that the goals will be achieved, chiefly because there is no demand at the price level required for profitable production due to the uncertainty surrounding the future role of biomass in the European energy system.

The lead time for this type of investment and conversion is five to ten years, which means that immediate action is required

if the European biomass supply is to increase at a sufficiently rapid pace.

Cost competitiveness dependent on the price of CO₂ emissions

Another limiting factor, in addition to biomass availability, is price. It is currently more expensive to produce electricity from biomass than from fossil fuels such as coal. The price difference is affected by various types of economic control instruments such as emission rights for CO₂. Increased CO₂ prices would therefore hasten the conversion of the energy system to the benefit of biomass.

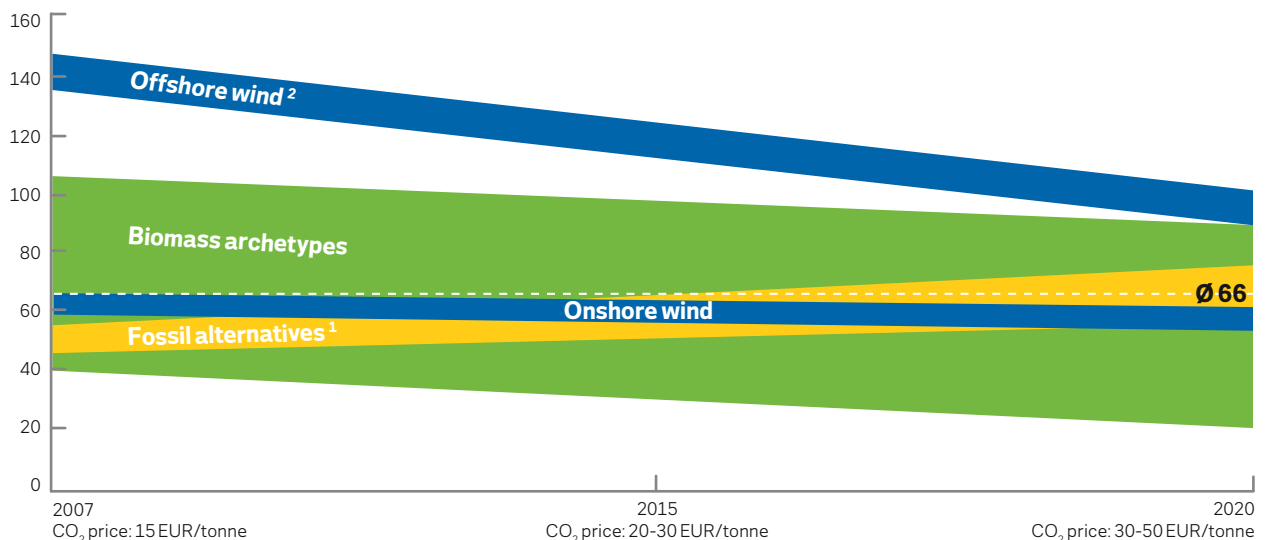
From a cost perspective, there is great potential for improvement in moving from small-scale to large-scale biofuel production. Increased volumes can produce economies of scale throughout the value chain and cost efficiency measures can boost the competitiveness of biomass relative to coal and gas.

A developing market

International trade in biomass for power generation is still limited, although it is expected to increase. This highlights the need for establishing a standardised global system for trade and

Cost competitiveness of biomass over time

Average cost, EUR per MWh electricity



¹ Hard coal condensing and natural gas CCGT. Assumes fixed fossil fuel prices over time, coal 75 USD per tonne (54 EUR per tonne), natural gas 20 EUR per MWh. Coal plant efficiency 40%, gas CCGT 55%.

² Not including grid connections

Source: McKinsey, Vattenfall, Sveaskog, Södra, European Climate Foundation (2010): Biomass for Heat and Power – Opportunity and Economics

certification. Biomass origin is crucial to the establishment of a long-term, sustainable trade in biofuels. Extracted biomass, for instance, must be replaced with new biomass (i.e., replanted) in order to be classified as a renewable type of energy and a good environmental alternative.

Future increases in biomass trade will most likely mean that fuel is produced far from where it is consumed. Production chain quality assurance will therefore be extremely important going forward. A system similar to the forest industry's, for instance, would limit many of the social and environmental risks associated with large-scale biomass production.

Biomass technology under constant development

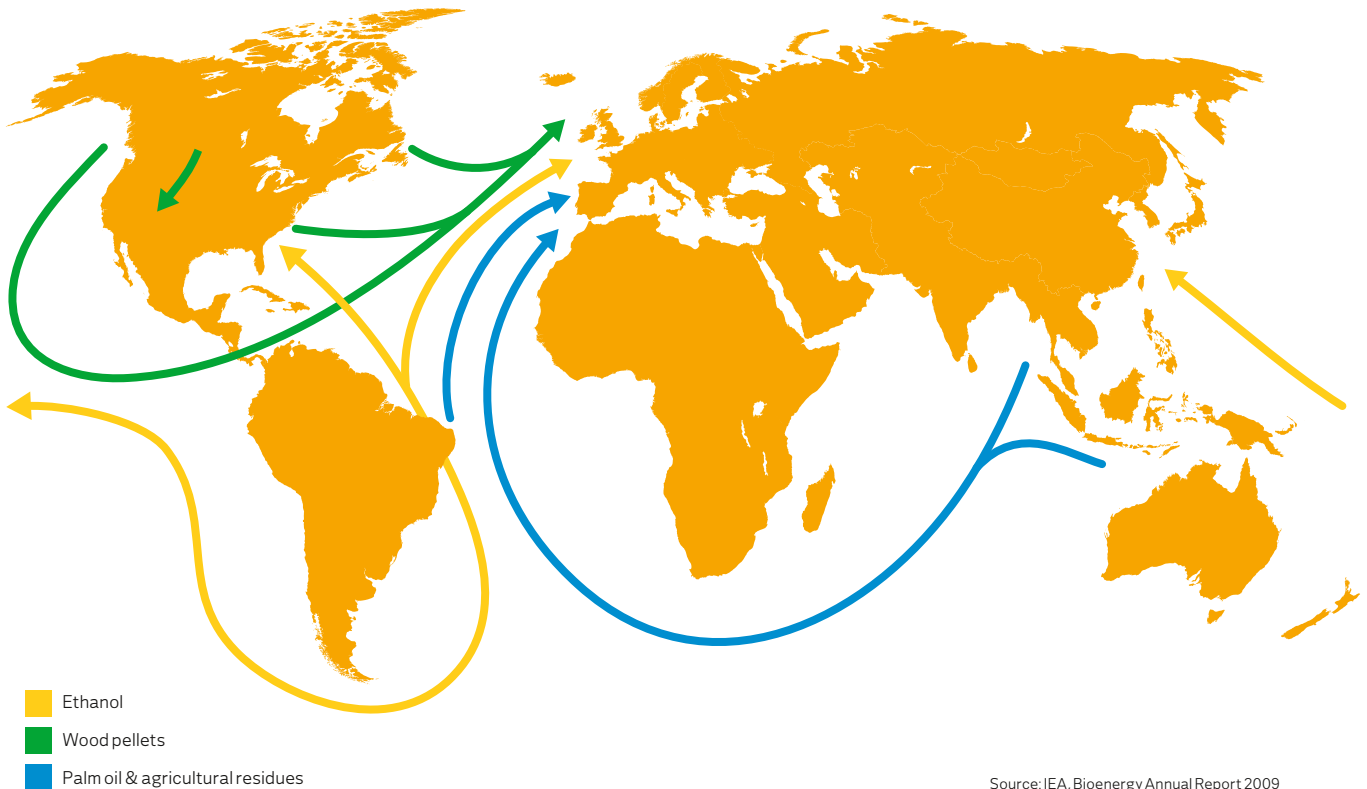
Several different production technologies have been developed to convert biomass into heat and electricity. The different methods of refining biomass are under constant development with a

focus on continuous streamlining. The conversion of raw material into more energy-dense forms facilitates transport, storage and use through the rest of the value chain. One example currently under development that would simplify future imports is the thermal processing of biofuels to produce a more efficient type of pellet with a higher energy value.

National conditions decisive

The direction of development for biomass use in different countries is determined by several factors; for example, the way in which a country values its dependency on oil and natural gas imports, and the existence of non-biomass options. Other factors include domestic alternative energy supply options and existing infrastructure for supplying energy.

International biomass trade



Source: IEA, Bioenergy Annual Report 2009

Vattenfall and Biomass

Biomass is a renewable energy source that can be used to produce both heat and electricity. It can potentially play a key role in reducing CO₂ emissions from existing European coal power plants. Vattenfall has a long history of working with biomass heat production, and plans to increase co-firing of biomass in coal-fired power plants to reduce CO₂ emissions. Vattenfall intends to allocate significant resources and efforts to build a substantial, highly reliable and sustainable biomass supply chain.

Vattenfall's biomass operations

Vattenfall is one of the world's largest purchasers of biomass for power generation. The biomass used by Vattenfall is comprised primarily of household and industrial waste (over 60 per cent) and forestry industry residue (30 per cent). The remainder is comprised chiefly of agricultural residues.

Over 40 of Vattenfall's heating and power plants are powered entirely or partially by biomass. Vattenfall uses a total of three million tonnes of biomass per year, placing Vattenfall in an industry-leading position. The use of biomass in Vattenfall's plants will increase substantially when large-scale co-firing is implemented.

Vattenfall runs several biomass projects in Europe. In Germany, biomass-fired power plants are being planned in Berlin and

Hamburg. In Poland, the Zeran and Siekierki combined heating and power plants are increasing the use of biomass and will use 400,000 tonnes by 2013. Co-firing will be stepped up in several other countries as well, including the Netherlands. New biomass plants are also being planned (e.g., in Denmark). For a full list of Vattenfall's biomass power plants, please see the production site at www.vattenfall.com/powerplants.

Sourcing sustainable biomass - rubber trees from Liberia

Vattenfall's need for biomass is increasing and volumes available in Europe are not sufficient. Vattenfall is therefore developing an international portfolio of projects to secure sourcing of the required volumes. An attractive option, both economically and environmentally, is the use of unproductive rubber trees from plantations in Liberia.

Liberia is a country with a large resource of rubber trees, and rubber export is a key component in plans to revitalise the economy. The rubber trees are cultivated in plantations and typically produce latex when they are between 7 and 30 years of age, after which they are harvested and replaced by new trees. The practice has been to let these harvested trees rot or to burn them on site, with some of the wood used for charcoal production.

Buchanan Renewables, a Canadian-owned company based in Liberia, has developed a biomass business based on making wood chips from these non-productive trees. In 2010, Vattenfall acquired 30 per cent of Buchanan Renewables Fuel together with Swedfund, the Swedish government's company for investments in developing countries, in order to secure the supply of large volumes of sustainable wood chips. Purchasing the trees that are no longer producing rubber, and which would in any case be disposed of, is an environmentally and economically efficient option.

Vattenfall's biomass operations going forward

Biomass plays a central role in Vattenfall's efforts to reduce its CO₂ exposure. In the medium term, biomass is the renewable energy source with the most growth potential. Since biomass can be co-fired in coal plants, it is an effective way of reducing CO₂ emissions. Vattenfall's goal is to burn four million tonnes of



biomass annually by the year 2014, which would reduce CO₂ emissions by five million tonnes annually.

Vattenfall will make significant biomass investments through the year 2015. These investments will be made in new power plants and in increasing the amount of coal co-firing in existing plants.

Co-firing biomass with coal in existing power plants significantly reduces the plants' CO₂ emissions. Co-firing offers many advantages, the foremost being the reduction of CO₂ emissions from existing power plants without requiring investments in new plants. Vattenfall is constantly working to increase the use of biomass in its hard coal power plants.

In terms of research and development, Vattenfall focuses primarily on new processing techniques. Biofuels produced through thermal treatment ("black pellets") and the use of such fuels is one major focus area.

Toward a sustainable biomass production

Although energy crops may be problematic to cultivate, they have the potential to become an important export commodity for many countries. Vattenfall is working to develop the entire biomass value chain, from cultivation to combustion via logistics and fuel processing.

If biomass is to increase its share in the energy mix, today's use of waste and residues will not be enough. A higher level of processing and increased international trade may allow for the utilisation of a larger portion of the residues from the global forestry industry. The production of energy crops and energy forests may also have to be increased.

One major challenge is finding suppliers that can provide large amounts of biomass that meet sustainability and affordability requirements. Cultivation of energy crops and forests can cause harm to environmentally important forests and the loss of biodiversity. One of Vattenfall's main challenges is finding producers that meet the company's stringent environmental and social sustainability standards.

SUMMARY

- Biomass is a renewable energy source that has the potential to reduce CO₂ emissions, for example through co-firing in existing coal power plants in Europe
- The biomass used in heat and electricity generation today is primarily derived from forest products, waste and other residues from the agricultural and forest industries
- Using biomass to produce electricity is currently more expensive than using energy sources such as coal, gas or nuclear power. The global biomass supply chain is developing and, over time, technological and logistical improvements will bring down prices. An increased CO₂ price will also improve the economic competitiveness of biomass
- International trade in biomass for power generation is still limited, though an increase in imports from other parts of the world is expected. The challenge lies in ensuring an environmentally and socially sustainable value chain
- The biomass used by Vattenfall is comprised of over 60 per cent household and industrial waste and 30 per cent residues from the forestry industry. The remainder is comprised chiefly of agricultural residues
- Biomass plays a central role in Vattenfall's efforts to reduce its CO₂ emissions; e.g., through co-firing in coal power plants

Footnotes – Biomass

¹ International Energy Association (IEA), World Energy Outlook 2009

² Hansson, J. (2009), Perspectives on Future Bioenergy Use and Trade in a European Policy Context, Chalmers University of Technology, Gothenburg

³ Ibid.

⁴ McKinsey, Vattenfall, Sveaskog, Södra, European Climate Foundation (2010): Biomass for Heat and Power – Opportunity and Economics

⁵ Ibid.

⁶ Ibid.

⁷ IEA Statistics, Electricity Generation, 2010, www.iea.org

⁸ European Commission (2010): Report from the Council and the European Parliament on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling.

⁹ Ibid.

¹⁰ McKinsey, Vattenfall, Sveaskog, Södra, European Climate Foundation (2010), op. cit.

¹¹ Ibid.

¹² Ibid.