Research Paper

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Woody Biomass for Power and Heat

Demand and Supply in Selected EU Member States

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Contents

Executive Summary

The use of wood for electricity generation and heat in modern (non-traditional) technologies has grown rapidly in recent years. For its supporters, the use of wood for energy offers a flexible way of supplying renewable energy, with additional benefits to the global climate and to forests. To its critics, it can release more greenhouse gas emissions into the atmosphere than the fossil fuels it replaces, and it also threatens the maintenance of natural forests and the biodiversity that depends on them. Just like the debate around transport biofuels in recent years, this has become a highly contested subject with very few areas of consensus.

This paper is one of a series on biomass produced by Chatham House. Between them these papers aim to provide an analysis of the growth in the use of wood for power and heat and a discussion of its impact on the global climate and on forests. In addition, the series intends to reach conclusions on the appropriate treatment of woody biomass for energy in policy frameworks. This paper provides background information on the use of woody biomass for power and heat within the EU – the main global source of demand for non-traditional uses of biomass – and examines patterns of demand and supply in nine EU member states, together with the policy frameworks that support the use of biomass for energy. In 2016 (the latest year for which figures are available), the countries analysed in this paper, which have been selected to include a range of different patterns of use and sourcing of woody biomass, were nine of the 11 largest consumers of energy from solid biomass for power and heat in the EU.

The EU

The EU remains the main global source of demand for wood for modern uses of biomass for power and heat. In 2016, energy from solid biomass (mainly wood) accounted for about 7.5 per cent of EU gross final energy consumption and about 44 per cent of total renewable energy consumption. Most of the biomass consumed was for heat, accounting for 78 per cent of total consumption of renewable heating and cooling; biomass supplied about 10 per cent of total generation of renewable electricity. The residential sector accounted for about 40 per cent of biomass energy consumption, industry (particularly pulp and paper) for about 31 per cent and large-scale power and heat facilities for about 29 per cent. Demand is projected to continue to grow at least until 2020, but the implementation of energy efficiency policies and growing competition from other renewable technologies, particularly in power generation, may lead to growth tailing off thereafter.

As well as being a major consumer of wood for energy, the EU is also a major producer. In 2014, it was estimated that overall, 42 per cent of harvested EU wood was used for energy, as wood fuel (often acquired informally by households for their own use), black liquor for the pulp and paper industry and industrial roundwood (usually as chips or pellets) for power and heat generation. Production is not sufficient to meet demand, however, so about a third of total consumption of wood for energy was imported, mainly from the US, Canada and Russia. The EU is the world's largest producer of wood pellets, but demand is higher, so in 2016 about 40 per cent of total consumption of pellets was from imports.

In view of the continued growth in demand for wood for energy, projections of future EU supply potential are uncertain, depending on, among other factors, the future development of industries that compete for the raw material and the potential for increased use of wood, agricultural residues and waste wood as well as the growth of energy crops. Most projections assume growth both in domestic supply and in imports.

The main driver for the increase in the consumption of biomass for power and heat has been the renewable energy targets adopted by each EU member state under the 2009 Renewable Energy Directive, which set an overall target of 20 per cent of the EU's energy mix coming from renewable sources by 2020; almost every member state would now find it impossible to meet their national targets without using biomass. The policy framework after 2020 is still under discussion within EU institutions, but higher EU-level targets for renewables and a possible relaxation of the rules regarding emissions from land use, land-use change and forestry (LULUCF) seem likely to create more incentives for growth in biomass use, particularly for heat, where competing renewable technologies are not as well developed.

The main driver for the increase in the consumption of biomass for power and heat has been the renewable energy targets adopted by each EU member state under the 2009 Renewable Energy Directive.

The new framework also includes, for the first time, sustainability criteria for solid biomass, designed to ensure that their use delivers significant greenhouse gas savings compared to the fossil fuels they replace – though because the criteria do not take emissions from the combustion of biomass into account, their ability to restrict the impact on the climate of the use of biomass for energy will be limited. Some member states have developed more strict criteria, including restrictions on the types of feedstock eligible for support (for example, Italy restricts feedstock to wastes and residues; roundwood is not allowed); it remains to be seen whether they will retain these criteria once the EU-wide criteria are finally agreed.

Selected member states

In 2016, **Denmark** produced 10 per cent of its electricity and 31 per cent of its heat from solid biomass, which is increasingly replacing coal and gas in the country's extensive network of combined heat and power (CHP) stations and district heating systems. Wood pellets and chips are the main feedstock for large-scale plants; straw, wood fuel and wood chips are used in private boilers, district heating, CHP and power-only plants, but in recent years, several of these plants have switched to pellets. Most wood fuel, wood chips, wood residues and straw are sourced domestically, but pellets are mainly imported; in 2016 Denmark was the EU's second largest importer, after the UK. Sources include other EU member states, Russia and, increasingly, the US. Government support for renewables, including biomass, is mainly in the form of feed-in tariffs and reliefs from energy and emissions taxes, which are very high compared to other countries. Voluntary sustainability criteria were introduced by the biomass industry in 2015. They include a requirement for legal and sustainable forest products, but do not account for changes in forest carbon stock; however, the standards aim to avoid the use of feedstock that 'negatively affects the quantity and quality of forest resources in the medium and long terms'.

Biomass is **Finland**'s largest single energy source, generating 12 per cent of its electricity and 49 per cent of its heat in 2016. Woody biomass comprises about 80 per cent of the bioenergy consumed, and is often co-fired with coal or peat. Industry, particularly producers of pulp and paper, is the largest consuming sector. The country's sizeable timber industry generates large volumes of wastes and residues (and black liquor from the pulp and paper industry) that can be used for energy, but there are also some imports of wood chips, mainly from Russia, partly for energy use. Renewables have been supported through feed-in tariffs and exemptions from energy and carbon taxes; private forest owners can access grants for forestry and wood fuel production. The 2016 Energy and Climate Strategy foresees a continued expansion of biomass energy, with potentially a major impact on Finnish forests.

France is the EU's second largest consumer of biomass for heat; in 2016 biomass accounted for 16 per cent of heat consumption, though use in power generation is much smaller. Most of the wood is used for heat in residential boilers and stoves, while black liquor is used in the pulp and paper industry. Small amounts of wood pellets are used in small-scale private and industrial boilers. The country is a large producer of roundwood, about half of which is used as wood fuel (a much higher proportion than in most EU member states). Government plans to expand the use of domestic forests for energy have met with some resistance, however, from local populations and other forest industries. Biomass in power generation is supported through premiums on the market price and energy saving certificates, while biomass for heat consumption receives financial support through the Heat Fund and tax credits; the steadily rising carbon tax also creates a general incentive to favour renewables.

In absolute terms, **Germany** consumes the largest amount of heat from biomass in the EU, and generates the second largest amount of electricity. In proportional terms, however, biomass is less significant than in many other countries, partly because of the strength of other renewables, particularly wind and solar PV. The country is a substantial producer of roundwood and wood fuel. Most of the wood used for energy is consumed in CHP plants, which generally source wood waste and forest residues. Biomass is also used in heating systems in households and commercial buildings, where the feedstock is mainly wood fuel, with much smaller amounts of wood pellets, chips and briquettes. Germany is also the EU's largest producer of wood pellets, mostly for domestic use. The 'Energiewende' framework has provided extensive support for the development of renewable energy for many years; for woody biomass this includes feed-in tariffs and power auctions, support for CHP plants, and grants for biomass heating systems.

Like France, **Italy** has chosen to encourage the use of biomass more for heat than for electricity; in 2016 biomass supplied 13 per cent of total heat consumption but only 1 per cent of power generation. Most wood used is domestically produced, as wood fuel for the residential sector, wood chips for CHP plants and district heating, and wood pellets for commercial and residential heating, but Italy is also a major importer of wood, including pellets, mostly from within the EU, and wood fuel, mainly from Bosnia and Herzegovina and Croatia. The government aims to develop domestic sources of biomass energy feedstock from agricultural residues and related by-products rather than from wood. Policy support has included a tradable renewable energy certificate scheme, feed-in tariffs, financial support for the construction of renewable heating systems, tax deductions and loans. These systems have proved effective but expensive, and have been scaled back in recent years. Sustainability criteria introduced in 2016 limited eligibility for the feed-in tariff to agricultural and livestock wastes and residues, and by-products from forest management and wood processing; roundwood is not included.

Poland is a major user of biomass for energy; in 2016, it accounted for 4 per cent of electricity generation (mostly through co-firing in coal stations) and 14 per cent of heat consumption. Wood from domestic forests and other wooded land provides the majority of domestic biomass energy

supply, mainly as wood fuel and wood chips, though pellet production has climbed sharply in recent years, using agricultural as well as wood residues. Poland is now a net exporter of pellets, wood fuel and wood residues, mainly to Denmark and Germany, and a substantial net importer of wood chips, mainly from Belarus. Policy support has been provided through auctions, a feed-in-tariff scheme, tax relief, loans and subsidies, with greater support for biomass power than for biomass heat.

Romania, one of the EU's poorest member states, relies heavily on biomass for heating (which accounted for 26 per cent of total heat consumption in 2016), a reflection more of the historically limited use of fossil fuels, particularly in rural areas, than of any policy support. Electricity generation from biomass is small but growing rapidly. Wood from local forests supplies most of Romania's biomass energy needs, as wood fuel and wood chips, though demand exceeds supply, so substantial quantities of wood fuel are imported, almost entirely from Ukraine. Pellet production has grown quickly but domestic consumption of pellets is low, so most is exported, mainly to Austria and Italy. The government plans afforestation efforts, the promotion of energy crops, more intense wood harvesting from forests, and greater use of wood residues, but use of the wood may be subject to competition from the wood processing and furniture industries. Policy support is limited but includes a quota system for biomass power and subsidies for both biomass power and heat.

> As a proportion of total national energy use, Sweden is the largest user of biomass for energy in the EU, mostly for heat.

As a proportion of total national energy use, **Sweden** is the largest user of biomass for energy in the EU, mostly for heat (heat from biomass accounted for 55 per cent of total consumption in 2016); the largest end-use sectors are industry (mainly pulp and paper mills) and the extensive district heating network. There is lower use for electricity generation: biomass accounted for 7 per cent in 2016. Sweden is the EU's largest producer of roundwood, and wood chips, residues and wastes provide the country's main feedstock, followed by black liquor. Sweden is the EU's second largest pellet producer, mainly for domestic use in small and medium-sized heating facilities; its pellet exports, mainly to Denmark, roughly balance imports, the majority of which come from Russia and Estonia. Extraction of forest residues for energy has increased and seems likely to grow further, particularly as the country is planning additional tree planting as part of its aim to reach net zero greenhouse gas emissions by 2045. The use of woody biomass for energy has been encouraged in particular through a tradable electricity certificate system and exemption from taxes on energy, and carbon and sulphur emissions.

Of all EU member states, the **UK** has seen the most rapid growth in the use of biomass for electricity, both relatively and absolutely; in 2016 the country accounted for 21 per cent of all the electricity generated from biomass in the EU. Electricity from biomass has grown rapidly since 2009 (reaching 6 per cent of total UK electricity in 2016), mostly from the conversion of coal-powered stations, and in particular Drax, the largest biomass-burning power station in the world. Biomass also accounted for 5 per cent of total heat consumption, mostly in the residential sector. Wood pellets dominate supply; in 2016 the UK consumed an estimated 26 per cent of all the wood pellets produced worldwide. The vast majority are imported, amounting to 7 million tonnes in 2016, including 5.7 million tonnes from outside the EU (mainly from the US and Canada). Drax alone burnt 6.6 million tonnes of biomass, almost entirely pellets, in 2016 – almost 23 per cent of total global wood pellet production. Projections suggest limited scope for further expansion, however, particularly given increased competition for feedstock. Policy support has been given through an obligation by electricity suppliers to procure renewable energy,

a system now being replaced by long-term fixed-price contracts awarded through auctions. Support for biomass heat is provided through the Renewable Heat Incentive (RHI), the world's first long-term financial support programme for renewable heat. Sustainability criteria require legal and sustainable forest products, but changes in forest carbon stock are not taken into consideration.

Accounting for biomass carbon emissions

As discussed in more detail in the Chatham House paper *Woody Biomass for Power and Heat: Impacts on the Global Climate*, published in 2017, carbon emissions from the use of forest biomass are accounted for in national greenhouse gas emission accounts in the land-use sector (at the point of production) rather than in the energy sector (at the point of combustion). However, this can result in incomplete accounting of emissions from the use of biomass for energy. The problem of 'missing', or unaccounted-for, emissions arises when a country using biomass for energy:

- Imports biomass from a country outside the accounting framework – such as the US, Canada or Russia, all significant exporters of woody biomass that do not account for greenhouse gas emissions under the second commitment period of the Kyoto Protocol;
- Accounts for its biomass emissions using a historical forest management reference level that includes higher levels of biomass emissions than in the present; or
- Accounts for its biomass emissions using a business-as-usual forest management reference level that (explicitly or implicitly) includes anticipated emissions from biomass energy; these emissions will not count against its national target.

This failure to account fully for biomass energy emissions risks creating perverse policy outcomes: where a tonne of emissions from burning biomass for energy does not count against a country's emissions target but a tonne of emissions from fossil fuel energy sources does, this creates an incentive to use biomass energy rather than fossil fuels in order to reduce the country's greenhouse gas emissions – even where this reduction is not 'real', in the sense that it is not accounted for in any country's land-use sector accounts.

The quantity of emissions missing from the international greenhouse gas accounting framework is impossible to calculate directly, but is likely to be significant. In 2015, emissions from solid biomass from the nine countries analysed here reached 313 million tonnes of carbon dioxide, equivalent to 14 per cent of their energy-related emissions. A proportion of these emissions in almost all of these countries will go unaccounted for, either because they or their main sources of imports use forest management reference levels that build in a level of biomass-related emissions or because they import from countries outside the second commitment period of the Kyoto Protocol. The UK in particular imports substantial quantities of biomass from countries outside the Kyoto Protocol framework (and, in the case of the US, potentially outside the Paris Agreement). Other member states, such as Finland, include projected significant emissions from biomass in their forest reference level, meaning these will not count against their targets – and these figures may increase if the relaxation of the LULUCF rules, voted for in the European Parliament in September 2017, goes ahead.

One solution to this problem would be to account for carbon emissions from biomass burnt for energy within the energy sector category of national greenhouse gas emission accounts rather than the land-use sector category. While additional rules would be required to ensure emissions were not double-counted in the energy and land-use sectors, this could be a viable solution given

sufficient data and guidance to promote transparency. In effect, it would shift the incentives to manage emissions from biomass energy use from the countries in which the biomass is grown to the countries in which it is burnt.

If this major revision of greenhouse gas accounting rules does not prove acceptable, four steps could nevertheless be taken within the existing framework (with biomass emissions recorded in the land-use sector accounts) to reduce the potential for missing emissions:

- All parties to the Paris Agreement should include the land-use sector, including forest management, in their national greenhouse gas emissions accounting.
- Forest management reference levels should contain detailed information on projected emissions from using biomass for energy, the origins of that biomass (additional domestic forest harvests or increased use of domestic forestry residues) and the resulting emissions.
- Countries that import biomass for energy should be required to report on whether and how the country of origin accounts for biomass-based emissions. Emissions associated with biomass imported from a country that does not account for such emissions, or from one that has built biomass energy demand into its accounting baseline, should be fully accounted for by the importing country.
- Countries using domestic biomass for energy should reconcile their energy and land-use sector accounting approaches in order to put emissions from each sector on a par with each other, if possible through using the same benchmarks – either a historical reference year/period or a business-as-usual scenario – to avoid emissions leakage between the sectors. This should be uniform across all countries.

Prospects for biomass in the EU

In most EU member states, electricity from biomass has grown along with renewable electricity as a whole; growth has been most marked in the UK. In five of the nine countries analysed here, however, and in the EU28 as a whole, biomass provided a smaller proportion of renewable electricity in 2016 than it did in 2009. Finland, France and Romania have seen small increases in the proportion of renewable electricity generated from biomass, while the UK has seen a very substantial increase.

An important reason for this slower growth of biomass power than of renewable electricity overall is the significant falls in the costs of competing renewable technologies, particularly solar PV and wind. While, on a global scale, in 2014 the levelized costs of electricity from biomass were slightly lower than those of solar PV and roughly the same as onshore wind, biomass combustion technologies are relatively mature, and therefore have a lower cost reduction potential. By the end of 2016, costs had fallen so fast that solar and onshore wind energy were less expensive than biomass and offshore wind was only slightly more costly. The role of biomass as a dispatchable power source providing a system balancing element may secure it a position in the future, but there are alternatives, including grid interconnection and battery and other storage technologies.

Heat consumption from biomass has also grown throughout the EU, along with renewable heat as a whole, but in every one of the nine countries analysed here it has fallen as a proportion of renewable heat, as alternative technologies, mainly heat pumps, solar thermal and biogas, are now beginning to find wider markets. These alternative forms of renewable heat are less well

commercialized, however. In addition, in many countries biomass has always been an important source of heating, particularly in rural households, and in several of these countries, particularly Finland and Sweden, an important part of biomass heat consumption is accounted for by the production and consumption of black liquor in the pulp and paper industry. For these reasons, biomass is likely to remain the dominant source of renewable heat throughout the EU, though growing concerns over its impact on local air quality and human health, and increasing investment in energy efficiency measures, may affect this.

Across the EU, biomass energy use is projected to continue to grow at least to 2020, but further significant growth beyond that seems less likely. Supply from the EU's own forests seems almost certain to increase, though projections are uncertain, depending on, among other factors, the future development of industries that compete for the raw material and the potential for increased use of wood, agricultural residues and waste wood as well as the growth of energy crops. Growth in imports also seems extremely likely, particularly from North America and Russia, but also potentially from non-EU Europe (e.g. Belarus, Bosnia and Herzegovina, and Ukraine) and Latin America.

Recommendations for policy

Along with the total level of consumption of biomass for energy, the type of feedstock used plays a critical role in the impact of biomass use on the global climate. As discussed in the Chatham House paper, *Woody Biomass for Power and Heat: Impacts on the Global Climate*, any increase in forest harvesting rates caused by demand for energy will in almost all circumstances increase net carbon emissions very substantially compared to using fossil fuels, because of the combustion of stored carbon in the wood, the loss of future carbon sequestration from growing trees and the release of soil carbon consequent upon the disturbance.

It is therefore important for policymakers in the EU to control the types of biomass feedstock used – and supported by EU and member states' policy frameworks – to limit the negative impacts on the climate. In principle, sustainability criteria can be used to distinguish between feedstocks with different impacts on the climate. None of the national sets of criteria currently in use yet achieves this, most notably in their failure to take account of changes in the forest carbon stock – though in limiting eligible feedstocks for support to wastes and residues, the Italian criteria do go some way to addressing this. The criteria proposed in the draft of the new Renewable Energy Directive are similarly inadequate, partly because of the weaknesses in the system of accounting for biomass emissions from the land-use sector to which they refer. Therefore, as argued in the 2017 Chatham House paper:

- In assessing the climate impact of the use of woody biomass for energy, changes in the forest carbon stock must be fully accounted for. It is not valid to claim that because trees absorb carbon as they grow, the emissions from burning them can be ignored.
- Along with changes in forest carbon stock, a full analysis of the impact on the climate of using woody biomass for energy should take into account the emissions from combustion and the supply-chain emissions from harvesting, collection, processing and transport.
- The provision of financial or regulatory support to biomass energy on the grounds of its contribution to mitigating climate change should be limited to those feedstocks that reduce carbon emissions over the short term.

- In practice, this means that support should be restricted to sawmill residues, together with post-consumer waste.

This is not to argue that fossil fuels should *not* be replaced by renewable energy for power and heat: this is essential if the world is to escape the most catastrophic impacts of climate change. It is to argue, rather, that public support and subsidy should be used for renewable technologies that reduce carbon levels in the atmosphere in the near term as well as the long term: some forms of biomass, as argued above, but primarily genuinely zero-carbon renewables such as solar or wind.

1. Introduction

The use of wood for electricity generation and heat in modern (non-traditional) technologies has grown rapidly in recent years. For its supporters, the use of wood for energy offers a flexible way of supplying renewable energy, with additional benefits to the global climate and to forests. To its critics, it can release more greenhouse gas emissions into the atmosphere than the fossil fuels it replaces, and it also threatens the maintenance of natural forests and the biodiversity that depends on them. Just like the debate around transport biofuels a few years ago, this has become a highly contested subject with very few areas of consensus.

This paper is one of a series on biomass produced by Chatham House. Between them the papers aim to provide an analysis of the growth of the use of wood for power and heat and a discussion of the debates around its impact on the global climate and on forests. In addition, the series intends to reach conclusions for policymakers on the appropriate treatment of woody biomass for energy in policy frameworks.

The first of this series, *Woody Biomass for Power and Heat: Impacts on the Global Climate*, is summarized below.[1] This paper, *Woody Biomass for Power and Heat: Demand and Supply in Selected EU Member States*, provides background information on the use of woody biomass for power and heat within the EU, which is currently the main global source of demand for non-traditional uses of biomass. (On the global scale, traditional uses of biomass for cooking and heating, usually on open fires or in simple cookstoves, account for about twice as much energy use as consumption in modern technologies such as power stations, industrial processes, biomass burners, and so on.[2] Although in some EU countries some wood is still used in this way, this is not the main focus of these papers.)

The use of biomass for energy has been increasing steadily in many EU member states as a result of the renewable energy targets adopted for each member state under the 2009 Renewable Energy Directive, which set an overall target for renewable energy of a 20 per cent share of total energy across the EU by 2020. Biomass plays a significant part in the EU's ability to meet these targets for power and heat.

Chapter 2 provides a brief overview of the situation in the EU as a whole. Chapters 3–11 look at nine key member states, selected to include a range of different patterns of use and sourcing of woody biomass: Denmark, France, Finland, Germany, Italy, Poland, Romania, Sweden and the UK. Each chapter includes an analysis of recent, current and projected consumption of woody biomass for power and heat, the main sources of supply, whether domestic or imported, the policy frameworks that support the use of biomass, and information on national sustainability criteria (where they exist), designed to minimize the environmental impact of the feedstock.

Chapter 12 analyses the carbon emissions associated with this biomass use for each country, and examines how these are reported under the current international rules for greenhouse gas accounting, which may lead to 'missing' (unreported) emissions. Chapter 13 sets out the prospects

[1] Brack, D. (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate,* Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/publication/woody-biomass-power-and-heat-impacts-global-climate.
[2] In 2015 traditional uses of biomass were estimated to account for 9.1 per cent of total final energy consumption worldwide, and non-traditional uses 5.0 per cent; REN21 (2017), *Renewables 2017: Global Status Report,* Paris: REN21 Secretariat, http://www.ren21.net/gsr-2017/ (accessed 7 Feb. 2018).

for biomass energy use in the EU, in terms of power, heat and supply, while Chapter 14 concludes with recommendations for the EU and member states on the role of woody biomass for power and heat in their future policy frameworks.

Wood for power and heat

Wood in various forms can be used for electricity generation and heat. Primary end-products that are used for this purpose, and are referred to throughout this paper, include:

- *Wood fuel* (or *firewood*): simple logs, branches, twigs and so on, produced from logging, or thinnings and coppicings from managed forests. This is the simplest form of wood for fuel and is widely used for domestic heating in many EU countries, particularly in rural areas. Log burners are also popular in some countries for their aesthetic effects (for example, in 2015, it was estimated that one in six households in southeast England burnt wood on open fires or in wood-burning stoves[3]). Due to its bulk and high levels of moisture (though this can be reduced by air drying), wood fuel tends to be more difficult and costly to collect and transport over long distances than wood chips or pellets.
- *Wood chips*: medium-sized solid material (typically 30–60 mm in size) made by cutting, or chipping, larger pieces of wood. Wood chips are easier than wood fuel to transport and store but can contain just as much moisture. Globally, most high-quality chips are used for engineered wood products such as fibreboard or particleboard, or for the production of pulp and paper; lower-quality wood chips, with contaminants such as bark or dirt, are more likely to be used for energy, particularly where the transport distances to the installation are relatively low – though the higher the level of contaminants, the greater the problems this may cause for some power stations in terms of slagging or fouling.
- *Wood pellets*: produced by compressing wood material and extruding it through a die into cylinders (normally 6–8 mm in diameter and 10–30 mm in length). This process, together with the necessary drying of the wood, requires energy input, often derived from burning local mill or forest residues. Compared to wood chips, pellets are more dense and have a lower moisture content, and are therefore better suited to transport and storage. At a rough approximation, two tonnes of green (recently cut, not dried) wood are needed to produce one tonne of wood pellets. Pellets can be made from any organic material, including agricultural wastes as well as wood wastes or roundwood (wood in its natural state as felled), and are widely used for both heating and power generation.
- *Wastes and residues*: sawmill wastes include bark, shavings, sawdust, trim ends, offcuts and so on, which can be burnt for energy on-site in the mills where they are produced, made into pellets or (depending on quality) used for engineered wood products. Forest residues from logging operations or forest management – stumps, tops, small branches and pieces too short or defective to be used for other purposes – can also be made into chips or pellets, though their quality may sometimes be too low to be used for household heating or in some power stations.

[3] DECC (2015), *Summary results of the domestic wood use survey*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/517572/Summary_results_of_the_domestic_wood_use_survey_.pdf (accessed 6 Feb. 2018).

- *Black liquor*: a waste product from the kraft pulping process used in many pulp and paper mills to produce high-quality paper (mechanical processes generally produce lower quality products). Black liquor is generally burnt in recovery boilers on-site to generate energy for the mill and often also for export to the local electricity grid. Although it is a liquid, black liquor is generally classified as solid biomass, and forms a substantial share of the wood-based fuel consumed in many EU member states with a pulp and paper industry.

These different types of wood feedstock can be used to produce electricity in thermal power stations (sometimes by co-firing with coal, which requires only limited modification of the coal plant), or heat, by burning in open fireplaces, stoves or boilers of various sizes or through heat recovery from electricity generation in CHP plants. Wood can also be gasified and the gas produced then used directly for electricity generation or (after treatment) fed into gas networks for heating or adapted for transport. The vast majority of biogas produced in the EU, however, is produced from agricultural crops or wastes or landfill waste rather than from wood.

> Wood is therefore likely to remain the biomass fuel of choice for electricity generation and heat, at least for the next 10 years and probably longer.

While there are alternatives to the use of wood in biomass power and heat, including organic wastes, agricultural residues such as straw, and energy crops such as miscanthus (elephant grass) or switchgrass, these tend to be less energy-dense and more expensive to collect and transport than wood, particularly where the wood used is offcuts, residues and wastes from industries producing wood for other uses such as construction, panels, furniture or paper. Wood is therefore likely to remain the biomass fuel of choice for electricity generation and heat, at least for the next 10 years and probably longer.

Impacts on the climate

The first paper in the Chatham House series, *Woody Biomass for Power and Heat: Impacts on the Global Climate*, reached the following conclusions:

- Although most renewable energy policy frameworks treat biomass as though it is carbon-neutral at the point of combustion, in reality this cannot be assumed. When burnt for energy, biomass emits more carbon per unit of energy than most fossil fuels.
- It is often argued that, despite this, the use of woody biomass can be assumed to be carbon-neutral because over time the growth of forests after harvesting absorbs the carbon dioxide emitted on combustion. Estimates of this 'carbon payback period' vary from a few years, for residues, to decades or centuries for longer-lived forest residues or roundwood.
- The length of the carbon payback period matters, because any short-term growth in carbon emissions increases the likelihood of irreversible climate 'tipping points' and are likely to be incompatible with the goals of the 2015 Paris Agreement, which require near-term peaking in emissions and steep reductions thereafter to net zero by mid-century.
- Accordingly, only biomass energy with the shortest carbon payback periods – residues that would otherwise have been burnt as waste or would have been left in the forest or sawmill and decayed rapidly, thus releasing their stored carbon into the atmosphere over a short period –

should be eligible for financial and regulatory support. The use of other types of feedstock risks increasing carbon levels in the atmosphere for years or decades.

- In principle, sustainability criteria can ensure that only biomass with the lowest impact on the climate are used. The current criteria in use in some EU member states and under development in the EU, however, do not achieve this as they do not account for changes in forest carbon stock.
- One reason for the perception of biomass as carbon-neutral is the fact that, under international greenhouse gas accounting rules, its associated emissions are recorded in the land use rather than the energy sector, in the country of origin rather than the country of consumption (this may, obviously, be the same). However, the different ways in which land-use emissions are accounted for means that a proportion of the emissions from biomass may never appear in national greenhouse gas accounts, understating its impact on the climate.

The paper concluded that growth in the use of woody biomass for energy posed a significant risk to efforts to mitigate climate change, particularly if policy failed to limit the use of feedstocks to those with the lowest impact on the climate.

Reflecting the lack of consensus on the climate impacts of the use of wood for energy, the paper attracted a considerable degree of criticism from the biomass industry, and some members of the research community.[4] Support for the paper's conclusions was also forthcoming, however, from several sources and further studies. The European Academies Science Advisory Council, for example, concluded in May 2017 that: 'Compared with some other renewable energy sources, the impact of biomass energy on levels of carbon dioxide in the atmosphere is very poor, and renewable subsidies should reflect this'.[5] In the run-up to the European Parliament's debate on the new Renewable Energy Directive in January 2018, groups of scientists on both sides released open letters arguing the cases for and against subsidies for biomass.[6] The debate continues, with areas of contention including the length of an acceptable payback period, which feedstocks should be supported, and the appropriate use of sustainability criteria.

Note on terminology

Bioenergy comes in different forms, and available statistics do not always distinguish between them. Figures for 'biofuels' in statistical sources sometimes include all forms of bioenergy (solid biomass, liquid biofuels and biogas), and figures for 'solid biomass' often include municipal waste and agricultural residues. Throughout this report, these terms are used:

- 'Woody biomass' includes all forms of wood, including pellets, chips, residues, wood fuel and black liquor.

[4] See, for example, Magrath, M. (2017), 'Burning wood for energy ignites fierce academic row', BBC News, 15 March 2017, http://www.bbc.co.uk/news/science-environment-39267774 (accessed 7 Jan. 2018). For the critique, see Cowie, C. et al. (2017), 'Response to Chatham House report *Woody Biomass for Power and Heat: Impacts on the Global Climate*', IEA Bioenergy, 13 March 2017, https://www.chathamhouse.org/sites/files/chathamhouse/publications/2017-04-05-IEABioenergy.pdf (accessed 7 Mar. 2018). See also the author's response to this critique, Bailey, R. (2017), 'Re: Woody Biomass for Power and Heat: Impacts on Global Climate', Chatham House, 31 March 2017, https://www.chathamhouse.org/sites/files/chathamhouse/publications/2017-04-05-ResponsetoIEABioenergy.pdf (accessed 7 Jan. 2018).

[5] EASAC (2017), *Multi-functionality and sustainability in the European Union's forests*, Halle: German National Academy of Sciences, https://www.easac.eu/fileadmin/PDF_s/reports_statements/Forests/EASAC_Forests_web_complete.pdf (accessed 7 Jan. 2018).

[6] EURACTIV (2018), 'Bioenergy at the centre of EU renewable energy policy', 15 January 2018, (https://www.euractiv.com/section/energy/opinion/bioenergy-at-the-centre-of-eu-renewable-energy-policy/ (accessed 7 Feb. 2018); and *Guardian* (2017), 'EU must not burn the world's forests for "renewable" energy', 14 December 2017, https://www.theguardian.com/environment/2017/dec/14/eu-must-not-burn-the-worlds-forests-for-renewable-energy (accessed 5 Feb. 2018).

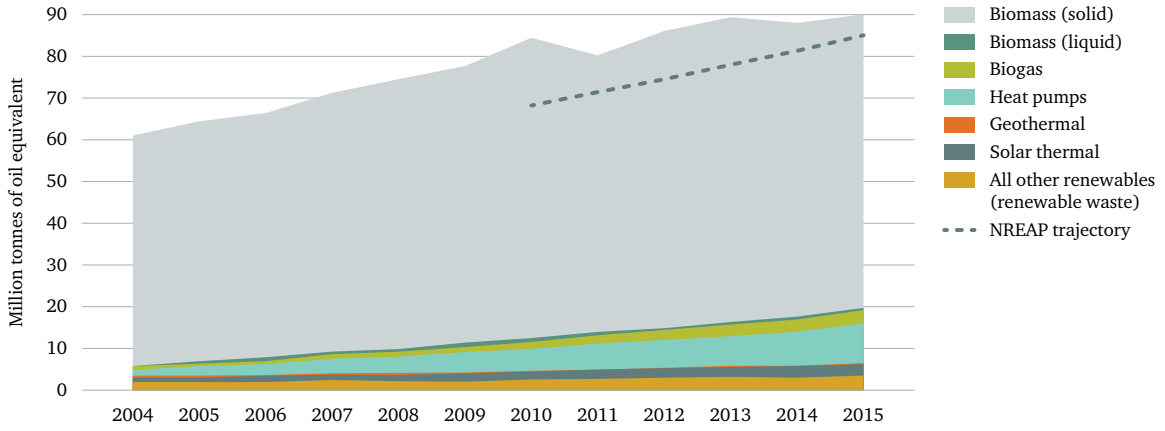
- 'Biomass' includes, as well as woody biomass, straw, bagasse, other agricultural residues and animal waste. For these purposes, it does not include municipal waste. ('Solid biomass' means the same thing; 'biomass' is used here for convenience.)
- 'Biofuels' means liquid biofuels usually generated from agricultural sources (such as corn, rapeseed oil or palm oil) and mostly used in transport, though some are used for power generation.
- 'Bioenergy' includes biomass, biofuels and biogas.

2. The EU

Demand for biomass

The EU remains the main global source of demand for wood for modern uses of biomass for power and heat. In 2016, energy from solid biomass (about 70 per cent wood[7]) accounted for about 7.5 per cent of EU gross final energy consumption and about 44 per cent of total renewable energy consumption. Most of the biomass consumed was for heat, accounting for 78 per cent of total consumption of heating and cooling from renewable sources; biomass supplied about 10 per cent of total generation of electricity from renewable sources.[8] (See figures 1 and 2.)

Figure 1: EU28 renewable heating and cooling production by source

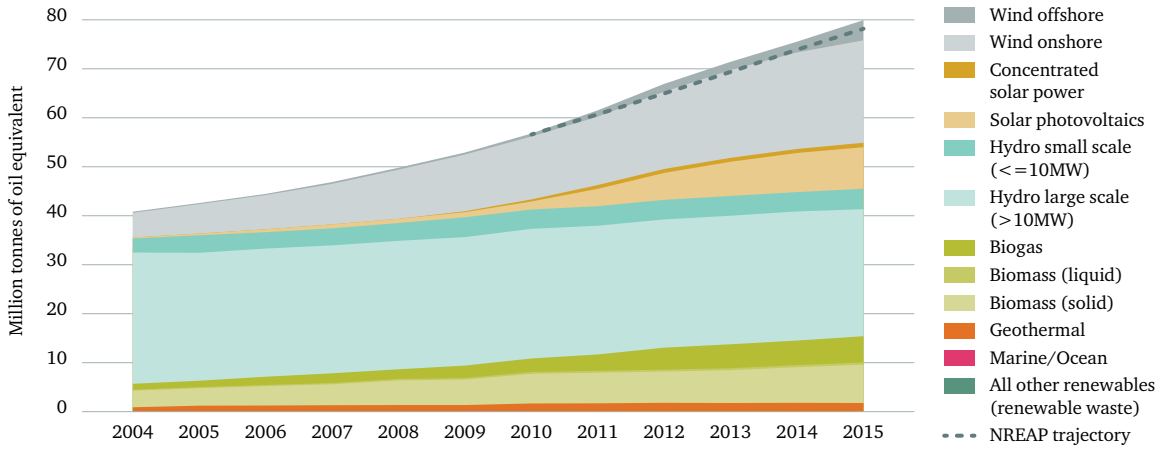


Source: European Commission (2017), *Renewable Energy Progress Report* (COM(2017) 57 final, February 2017), p. 5.

In 2015, the residential sector accounted for about 40 per cent of biomass energy consumption in the EU, industry (particularly pulp and paper producers) stood at about 31 per cent and large-scale power and heat facilities accounted for about 29 per cent.[9] Use for heating varies directly with fossil fuel prices – consumption goes up when fossil fuel prices are high – and inversely with the temperature; a succession of mild winters in 2014, 2015 and 2016 restricted growth in consumption.[10] About 40 per cent of the electricity generated from solid biomass in 2015 was produced through co-firing with coal, mainly in power stations in Central and Eastern Europe.[11]

[7] The rest is waste and agricultural residues; AEBIOM (2015), *AEBIOM Statistical Report 2015 – European Bioenergy Outlook*, European Biomass Association (AEBIOM), http://www.aebiom.org/library/statistical-reports/statistical-report-2015/ (accessed 11 Apr. 2017).
[8] Bauknecht, D. et al. (2017), *Study on Technical Assistance in Realisation of the 2016 Report on Renewable Energy*, Freiburg: Öko-Institut, https://ec.europa.eu/energy/sites/ener/files/documents/res-study_final_report_170227.pdf (accessed 11 Apr. 2017).
[9] Indufor (2017), *Outlook for Wood Energy for Biomass in the EU-28,* Birdlife, FERN and Transport & Environment, https://www.birdlife.org/sites/default/files/attachments/8090_birdlife_europe_wood_energy_outlook_final_230617.pdf (accessed 1 Dec. 2017).
[10] EurObserv'ER (2017), 'Solid Biomass Barometer' https://www.eurobserv-er.org/solid-biomass-barometer-2017/ (accessed 2 Feb. 2018).
[11] Sandbag (2017), *Something Nasty in the Woodshed: How biomass subsidies are secretly funding coal,* https://sandbag.org.uk/project/somethingnasty/ (accessed 19 Jan. 2018).

Figure 2: EU28 renewable electricity generation by source



Source: European Commission (2017), *Renewable Energy Progress Report* (COM(2017) 57 final, February 2017), p. 6.

Overall, consumption for power and heat (in both residential and large-scale installations) has been rising, primarily as a result of the EU's renewable energy targets (see further below). As can be seen from Table 1, across the EU, electricity generated from biomass grew by 6 per cent a year between 2009 and 2016, while heating and cooling from biomass grew by about 2 per cent a year.

Table 1: Key renewable and biomass energy statistics, EU27/28[12]

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	5.22	1.9%	10.0%	66.88	12.6%	84.6%	6.3%	12.4%
2016	7.86	2.8%	9.5%	77.91	15.0%	78.4%	7.5%	17.0%
Annual average growth		6.0%			2.2%		2.5%	4.6%
2020 target								20.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Biomass clearly plays a significant part in the EU's ability to meet its renewable energy targets; although other forms of renewable energy are growing more quickly, without solid biomass the 2020 target of 20 per cent across the EU would be impossible to meet. According to the member states' National Renewable Energy Action Plans drawn up in response to the Renewable Energy Directive, bioenergy (including liquid biofuels and biogas) was projected to account for 12 per cent of total European energy consumption by 2020, more than half of the 20 per cent target.[13] This implies continued rapid growth between 2016 and 2020 – though, according to projections published by the European Commission in November 2016 (accompanying the draft of the new Renewable Energy Directive), further significant growth beyond 2020 is not anticipated, due to the fall in price of

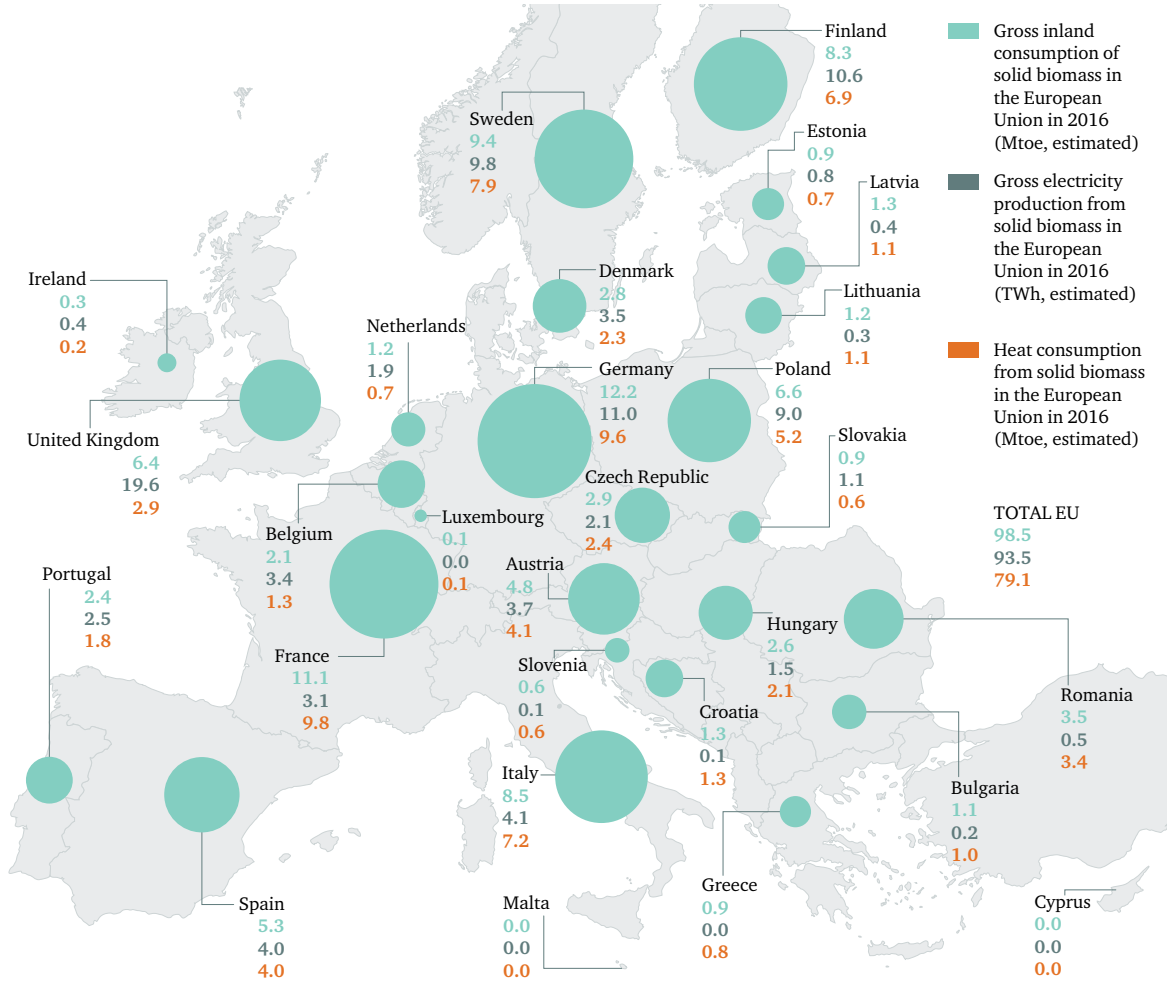
[12] Croatia, which joined the EU in 2013, is included in the 2016 figures but not those for 2009.
[13] Atanasiu, B. (2010), *The Role of Bioenergy in the National Renewable Energy Action Plans: A first identification of issues and uncertainties*, London: Institute for European Environmental Policy, https://ieep.eu/uploads/articles/attachments/208dab71-7833-4016-87b1-8cb15c3f41dc/bioenergy_in_NREAPs.pdf?v=63664509743 (accessed 13 Dec. 2016).

competing renewables such as solar photovoltaic (PV) and wind, and anticipated improvements in energy efficiency.

Looking at the consumption of biomass for energy by member state, in 2016, Germany, Finland, France, Sweden and Italy had the highest total consumption, whereas in relative terms, the largest share compared to other energy sources – in each case more than 30 per cent of total electricity, heating and cooling – was in Estonia, Latvia, Lithuania, Finland and Sweden. The UK, Germany, Finland and Sweden had the highest total generation of electricity from biomass, while Germany, France, Italy and Sweden had the highest consumption of biomass for heating (see Figure 3 and Table 2).

The nine EU member states analysed in this paper are highlighted in Table 2; they are nine out of the 11 largest consumers of biomass for energy in the EU. Between them, in 2016, these nine member states accounted for 75 per cent of EU28 electricity generation from biomass (70 per cent of total EU28 electricity generation) and 71 per cent of EU28 heating and cooling consumption from biomass (71 per cent of total EU28 heating and cooling consumption).

Figure 3: Gross inland consumption, gross electricity production and heat consumption from solid biomass in the European Union in 2016



Source: Eurobserv'ER (2017), *Solid Biomass Barometer 2017*, http://www.eurobserv-er.org/solid-biomass-barometer-2017/ (accessed 23 Jan. 2018).

Table 2: Share of renewables in energy consumption and share of biomass in electricity generation and heating and cooling consumption

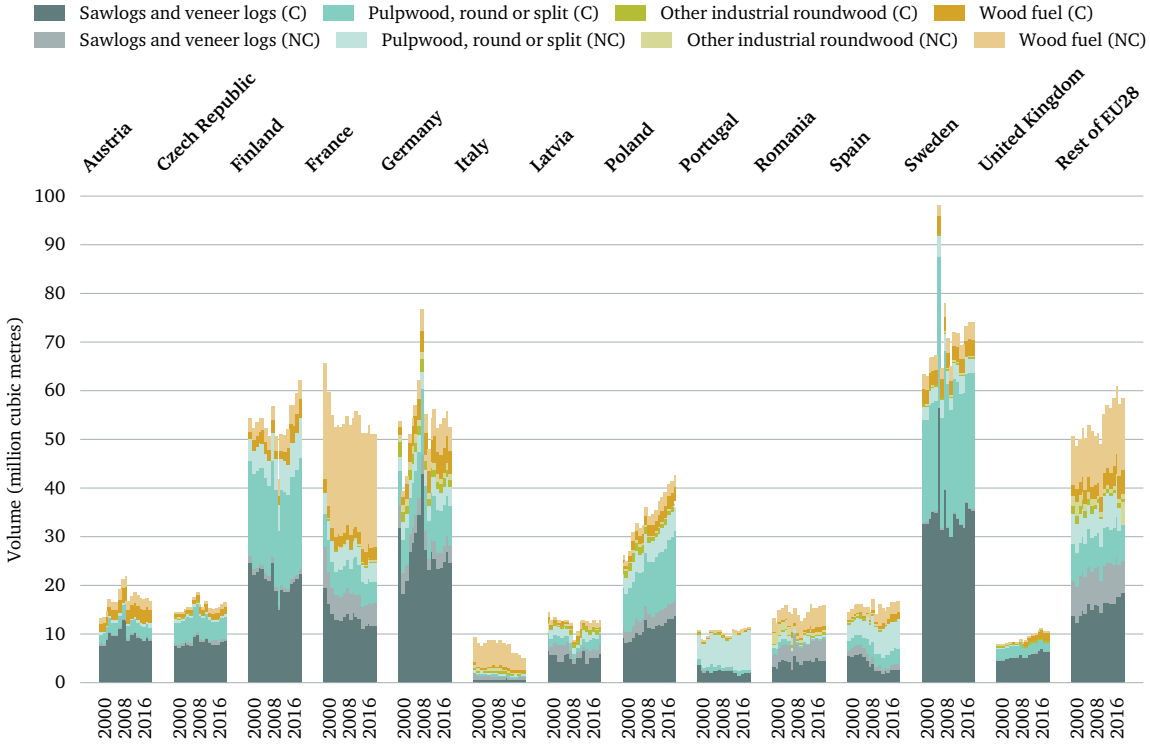
	Share of renewables in energy consumption (%)				Electricity generation, 2016			Heating and cooling consumption, 2016		
Country	*2009*	*2016*	*Projected 2020*	*Target 2020*	*Total (Mtoe)*	*Biomass (Mtoe)*	*Biomass (%)*	*Total (Mtoe)*	*Biomass (Mtoe)*	*Biomass (%)*
EU28	**12.4%**	**16.7%**	**21.0%**	**20.0%**	**278.86**	**7.86**	**2.8%**	**521.02**	**77.91**	**15.0%**
Austria	30.0%	33.5%	35.2%	34.0%	6.23	0.32	5.1%	13.99	4.09	29.2%
Belgium	4.7%	8.7%	13.9%	13.0%	7.79	0.29	3.7%	18.84	1.32	7.0%
Bulgaria	12.1%	18.8%	20.9%	16.0%	3.29	0.01	0.4%	4.01	1.01	25.1%
Croatia	23.6%	28.3%	21.1%	20.0%	1.56	0.02	1.1%	3.25	1.17	36.1%
Cyprus	5.6%	9.3%	14.8%	13.0%	0.42	0.00	0.0%	0.45	0.01	1.4%
Czech Rep	9.9%	14.9%	13.5%	13.0%	6.12	0.18	2.9%	14.09	2.44	17.3%
Denmark	20.0%	32.2%	33.8%	30.0%	3.05	0.30	9.8%	7.55	2.35	31.1%
Estonia	23.0%	28.8%	25.7%	25.0%	0.87	0.07	8.3%	1.52	0.71	46.7%
Finland	31.3%	38.7%	42.2%	38.0%	7.54	0.91	12.1%	14.12	6.90	48.8%
France	12.3%	16.0%	23.5%	23.0%	43.84	0.26	0.6%	62.66	9.82	15.7%
Germany	9.9%	14.8%	18.5%	18.0%	50.99	0.93	1.8%	109.90	9.57	8.7%
Greece	8.5%	15.2%	18.4%	18.0%	5.17	0.00	0.0%	5.62	–	0.0%
Hungary	11.7%	14.2%	13.0%	13.0%	3.83	0.13	3.3%	10.48	2.01	19.2%
Ireland	5.1%	9.5%	15.5%	16.0%	2.53	0.03	1.3%	4.53	0.19	4.2%
Italy	12.8%	17.4%	19.8%	17.0%	27.94	0.35	1.3%	55.81	7.12	12.8%
Latvia	34.3%	37.2%	40.3%	40.0%	0.64	0.04	5.7%	2.22	1.12	50.4%
Lithuania	19.8%	25.6%	24.0%	23.0%	1.03	0.02	2.2%	2.43	1.11	45.6%
Luxembourg	2.9%	5.4%	8.3%	11.0%	0.61	0.00	0.4%	1.09	0.06	5.8%
Malta	0.2%	6.0%	11.8%	10.0%	0.20	0.00	0.0%	0.09	0.00	1.3%
Netherlands	4.3%	6.0%	13.0%	14.0%	10.33	0.16	1.6%	26.54	0.71	2.7%
Poland	8.7%	11.3%	15.1%	15.0%	14.46	0.59	4.1%	37.16	5.17	13.9%
Portugal	24.4%	28.5%	33.4%	31.0%	4.64	0.21	4.6%	5.39	1.77	32.9%
Romania	22.7%	25.0%	26.0%	24.0%	5.12	0.04	0.8%	13.06	3.47	26.5%
Slovakia	9.4%	12.0%	14.3%	14.0%	2.53	0.10	3.8%	5.77	0.51	8.9%
Slovenia	20.1%	21.3%	25.0%	25.0%	1.29	0.01	0.9%	1.90	0.58	30.7%
Spain	13.0%	17.3%	20.9%	20.0%	23.99	0.35	1.5%	28.36	3.98	14.0%
Sweden	48.2%	53.8%	56.2%	49.0%	12.40	0.84	6.8%	14.35	7.85	54.7%
UK	3.3%	9.3%	14.8%	15.0%	30.44	1.69	5.5%	55.82	2.86	5.1%
Nine member states					195.78	5.92		370.43	55.11	
					70%	75%		71%	71%	

Compiled by the authors from the following sources: share of renewables in energy consumption 2009, projected 2020 and target 2020: European Commission, *Renewable Energy Progress Report* (COM(2017) 57 final, 1 February 2017); all other figures: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Electricity figures are normally given in terawatt-hours (TWh) and heating and cooling in million tonnes of oil equivalent (Mtoe). To make comparisons easier, in this table TWh are converted to Mtoe with a conversion factor of 1 TWh = 0.0859845 Mtoe.

Biomass supply

As well as being a major consumer of wood for energy, the EU is also a major producer. In 2014 it was estimated that overall, 42 per cent of harvested EU wood – 178 million m^3 out of the total harvest of 425 million m^3 – was used for energy, as wood fuel (often acquired informally by households for their own use), black liquor for the pulp and paper industry and industrial roundwood (usually as chips or pellets) for power and heat generation.[14] Within the EU, Finland, France, Germany and Sweden, followed by Poland, are the largest producers of industrial roundwood and wood fuel (see Figure 4).

Figure 4: EU production of industrial roundwood and wood fuel, 2010–16



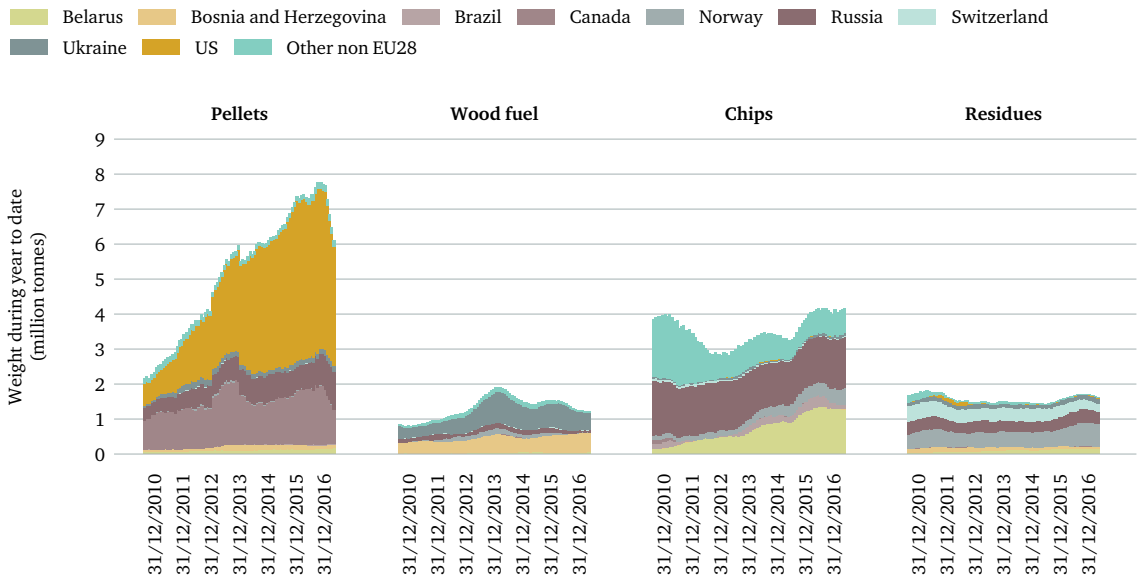
Source: Generated from FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.
Note: C = coniferous, NC = non-coniferous.

Production is not sufficient to meet demand, however, so about a third of total consumption of wood for energy is imported, mainly from the US, Canada and Russia (see Figure 5).

In 2015, about 60 per cent of the wood used for energy derived from wastes and residues, with another 12 per cent from pellets (which may themselves have been produced from residues) (see Table 3).

[14] *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A New EU Forest Strategy: for forests and the forest-based sector* (COM(2013) 659 final, 20 September 2013), p. 8, http://eur-lex.europa.eu/resource.html?uri=cellar:21b27c38-21fb-11e3-8d1c-01aa75ed71a1.0022.01/DOC_1&format=PDF (accessed 13 Dec. 2016).

Figure 5: EU28 imports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Table 3: EU28 consumption of wood for energy, by type, 2010–15 (terawatt-hours (TWh))

TWh	2010	2011	2012	2013	2014	2015	% change (2010–15)
Main products	178	198	201	221	218	218	+23%
Roundwood (firewood)	178	191	194	212	208	209	+18%
Short rotation wood	N/A	7	7	9	9	9	+29%
Primary residues	87	100	104	116	113	110	+26%
Forest industry by-products	242	256	258	252	252	260	+8%
Residue chips and sawdust	82	87	88	78	77	84	+2%
Bark	45	55	54	56	56	56	+25%
Black liquor	115	114	115	119	119	120	+9%
Wood pellets	45	53	62	89	86	94	+109%
Waste wood	77	86	87	86	87	86	+12%
Wood total	629	692	710	765	756	769	+22%

Source: Birdlife, FERN and Transport & Environment (2017), *Outlook for Wood Energy for Biomass in the EU-28*, https://www.birdlife.org/sites/default/files/attachments/8090_birdlife_europe_wood_energy_outlook_final_230617.pdf.
Note: 'Primary residues' are forest residues, including tops and branches, stumps, thinnings and logs rejected from industrial processing because of decay or other defects (shape, damage, etc.).

The fastest rate of growth has been in wood pellets, of which the EU is the largest global producer, its output reaching about 14.5 million tonnes in 2016 (half the world total); production in the EU more than doubled between 2009 and 2016.[15] Germany, Sweden and Latvia are the EU's largest producers; together, these three countries accounted for just over a third of EU production in 2016. Total EU consumption of wood pellets, however, is higher, and exports are negligible relative to

[15] FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.

consumption, so the EU is also a net importer: imports from outside the EU rose to 8 million tonnes in 2016, having more than tripled since 2009. The UK is far and away the EU's biggest consumer; in 2016 it consumed an estimated 26 per cent of all the wood pellets produced worldwide.[16] The UK, Denmark and Italy are the EU's largest importers. Most pellet-importing states in the EU source their pellets from other EU member states, but Belgium and the UK import more from outside the EU, mainly from the US, with smaller volumes coming from Canada and Russia. The Drax power station in the UK by itself accounted for two-thirds of the total of EU imports of wood pellets in 2016, mainly from the US.[17] Denmark and Sweden import almost all of the pellets that Russia exports to the EU.

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In light of the continuing increase in demand for biomass for energy in the EU, several attempts have been made to estimate the EU's ability to supply its own demand in the future. These are set against the context of a steady increase in forest area within the EU; in 2016 EU forests and other wooded land accounted for almost 182 million hectares, corresponding to 43 per cent of total land area.[18] Between 1990 and 2015 forest carbon stocks in the EU grew by 10 per cent (about 0.4 per cent a year).[19] The relationship between total forest area and the availability of wood feedstock for energy is not straightforward, however, varying, among other factors, with the extent to which forests are protected (only some of the forest area will be available for production), the size of forest industries (which generate residues and wastes, but also may compete for the raw material), rates of harvesting and the extent to which forest residues are extracted, and the costs involved in collecting, processing and transporting the feedstock (countries on the Atlantic seaboard, for example, like the UK, may be able to source feedstock more cheaply from the US or Canada).

One of the first studies of the availability of European wood for energy use, the 'EUwood' study (produced for the European Commission in 2010), estimated that that the EU's forest biomass supply would increase by 12 per cent from 2010 to 2030, but that the demand would increase by 73 per cent, leading to a significant shortfall by 2030.[20] A 2014 study by the European Forest Institute (EFI) reached a different conclusion, arguing that wood demand for material uses was likely to be lower than forecast as a result of a decline in the pulp industry and the impact of the financial crisis, and also that there was also plenty of potential to increase the use of wood residues such as sawdust and chips, and post-consumer wood, such as packaging materials, demolition wood or timber from building sites.[21] Nevertheless, the study concluded that imports would play a major role in meeting the EU's needs.

[16] FAO, Forest Products Statistics, http://www.fao.org/forestry/statistics/80938@180723/en/ (accessed 1 Feb. 2018).
[17] In 2016 the EU imported 8.1 million tonnes of wood pellets from outside the EU (Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do); Drax consumed 3.9 million tonnes of pellets from the US and 1.4 million tonnes from Canada, Drax (2017), *Annual Report and Accounts 2016*, p. 39, https://www.drax.com/wp-content/uploads/2017/03/Drax-Group-plc-annual-report-and-accounts-2016-Smart-Energy-Solutions.pdf (accessed 31 Jan. 2018).
[18] Eurostat (2017), Agriculture, Forestry and Fishery Statistics, http://ec.europa.eu/eurostat/documents/3217494/8538823/KS-FK-17-001-EN-N.pdf/c7957b31-be5c-4260-8f61-988b9c7f2316 (accessed 2 Feb. 2018).
[19] FAO (2016), *The Global Forest Resources Assessment 2015,* Rome, FAO, http://www.fao.org/3/a-i4793e.pdf (accessed 2 Feb. 2018).
[20] Mantau, U. et al. (2010), EUwood – *Real potential for changes in growth and use of EU forests,* Final Report, Hamburg: Egger Group, https://www.egger.com/downloads/bildarchiv/187000/1_187099_DV_Real-potential-changes-growth_EN.pdf (accessed 13 Dec. 2017).
[21] Pelkonen, P. et al. (2014), *What Science Can Tell Us: Forest Bioenergy for Europe,* European Forest Institute, http://www.efi.int/files/attachments/publications/efi_wsctu_4_net.pdf (accessed 4 Jan. 2018).

An analysis of member states' National Renewable Energy Action Plans, in 2011, similarly suggested that the quantity of wood required to satisfy the 2020 targets (let alone any further increase to 2030) was likely to be too large to be met by increased production within the EU. Assuming that the mix of product types remains the same, the study found that member states would need to use between 50 and 100 per cent more wood than was then consumed as fuel.[22] In some member states it was possible that changes in forest management practices could result in increased supplies, but this would take years and might not be consistent with sustainable forestry practices. This conclusion was supported by a UNECE/FAO study of the European forest sector in 2011, which concluded that a much higher rate of increase – 50 per cent – in output of biomass from forests was possible, but that:

> … the mobilisation of such high volumes would have significant environmental, financial and institutional costs. To achieve this level of highly intensive silviculture and harvesting, strong political will would be necessary to modify many framework conditions for wood supply. The very high levels of extraction of residues and stumps would negatively affect nutrient flows, soil carbon and thus water holding capacity and biodiversity. Forests would also be less attractive for recreation. [23]

A literature survey in 2013 similarly concluded that EU wood would run into scarcity between 2020 and 2025, depending on assumptions about the capacity to mobilize forest biomass resources.[24]

The impact analysis published alongside the European Commission's proposal for the EU's 2030 energy and climate package projected growth in annual domestic production of biomass feedstock from 87 million tonnes of oil equivalent (Mtoe) in 2005 to 203 Mtoe in 2030 (only a small increase from the 194 Mtoe assumed under current policies; the increase would be higher under scenarios including higher targets for renewables).[25] Of that total, 49 Mtoe (24 per cent) derived from forestry, an increase from 33 Mtoe in 2005 – i.e. 50 per cent growth from 2005 to 2030. Much higher rates of growth were assumed for energy crops (including fast-rotation plantation wood, which was classified as a perennial crop) and imports.[26] These figures were revised somewhat in the impact analysis published with the proposal, in July 2016, for a new EU regulation on the inclusion of emissions from LULUCF in the 2030 package.[27] Domestic production of biomass was projected to grow to 188 Mtoe in 2030, of which forestry accounted for 53 Mtoe, representing a harvest of forest wood for energy of 159 million m^3, a 75 per cent increase from 2005.

A more recent analysis by the BioSustain project attempted to develop plausible EU bioenergy supply and demand scenarios for 2030, taking into account other uses such as food, feed, fibre and biochemicals.[28] The study assumed a realizable potential of primary forest biomass for all uses of just over 700 million m^3 (roundwood equivalent) in 2010, of which at least 350 million m^3 could have been used for bioenergy (as noted above, the actual figures in 2014 were 425 million m^3 and 178 million m^3). The study suggested that 450–550 million m^3 could be available for energy uses

[22] Hewitt, J. (2011), *Flows of Biomass to and from the EU: An analysis of data and trends,* FERN, http://fern.org/sites/default/files/news-pdf/Biomass%20imports%20to%20the%20EU%20final_0.pdf (accessed 13 Dec. 2016).
[23] UNECE and FAO (2011), *The European Forest Sector Outlook Study II 2010–2030*, Geneva: United Nations, pp. 97–98, https://www.unece.org/fileadmin/DAM/timber/publications/sp-28.pdf (accessed 4 Jan. 2018).
[24] CAN Europe (2013), *The Future Role of Biomass in 2030 EU Energy Policy*.
[25] European Commission (2014), 'Commission Staff Working Document Impact Assessment Accompanying the Communication: A policy framework for climate and energy in the period from 2020 up to 2030' (SWD(2014) 15 final, 22 January 2014), pp. 62–63 (figures taken from GHG 40 scenario), http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2014/swd_2014_0015_en.pdf (accessed 15 Jan. 2018).
[26] Ibid., p. 64.
[27] European Commission (2016), 'Commission Staff Working Document Impact Assessment accompanying the document proposal for a Regulation of the European Parliament and of the Council on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change', (SWD(2016) 249 final, 20 July 2016), https://ec.europa.eu/transparency/regdoc/rep/10102/2016/EN/SWD-2016-249-F1-EN-MAIN-PART-1.PDF (accessed 15 Jan. 2018).
[28] BioSustain (2015), 'Background paper for the stakeholder consultation workshop of the Biosustain project', included in PWC (2017), *Sustainable and optimal use of biomass for energy in the EU beyond 2020: Annexes to the final report*, https://ec.europa.eu/energy/sites/ener/files/documents/biosustain_annexes_final.pdf (accessed 8 Feb. 2018).

by 2030; the addition came mainly from an increase in the use of residues (requiring significant technical innovation) rather than from additional harvesting. Under existing management practices, the total supply potential of wood biomass available for bioenergy in 2030 was projected to fall by 11 per cent from 2010, mainly as a result of increased demand for wood for other uses. The study also foresaw greater potential for growth in energy from agricultural residues and waste, and much greater potential for imports, which it projected would grow from 7.5 million tonnes of pellets (3.1 Mtoe) in 2014 to between 10 million and 86 million tonnes, depending on the scenario, by 2030. This included a mixture of forest products, forest residues, energy crops and agricultural residues.

An analysis published in 2014 by the International Institute for Sustainability Analysis and Strategy, EFI, and Joanneum Research took a different approach, assuming the implementation of stringent energy efficiency measures that significantly reduced final energy demand for heat and transport and held electricity demand almost constant despite growth in the economy.[29] Under the reference scenario, bioenergy from forests grew substantially by 2020, but overall demand for material uses of wood also increased so that bioenergy production fell, and was lower by 2030 than in 2010. Two new scenarios, which assumed much greater 'cascading' use of wood – a focus on resource efficiency, using wood repeatedly for material applications (including reuse, recovery and recycling) and only then for energy – both saw small increases in energy use by 2020 and falls by 2030.

Finally, a 2017 study carried out by Indufor projected a gradual rate of growth in the production of both industrial roundwood and wood fuel (including forest residues), increasing from a total of 448 million m^3 in 2015 (350 million m^3 of industrial roundwood plus 98 million m^3 of wood fuel) to 466 million m^3 in 2020 (365 million m^3 of industrial roundwood plus 101 million m^3 of wood fuel) and 506 million m^3 in 2030 (396 million m^3 of industrial roundwood plus 110 million m^3 of wood fuel).[30]

> It seems reasonable to conclude that if demand for biomass energy in the EU continues to increase then the impact on EU forests will depend heavily on the potential improvements in the efficiency with which wood resources can be used.

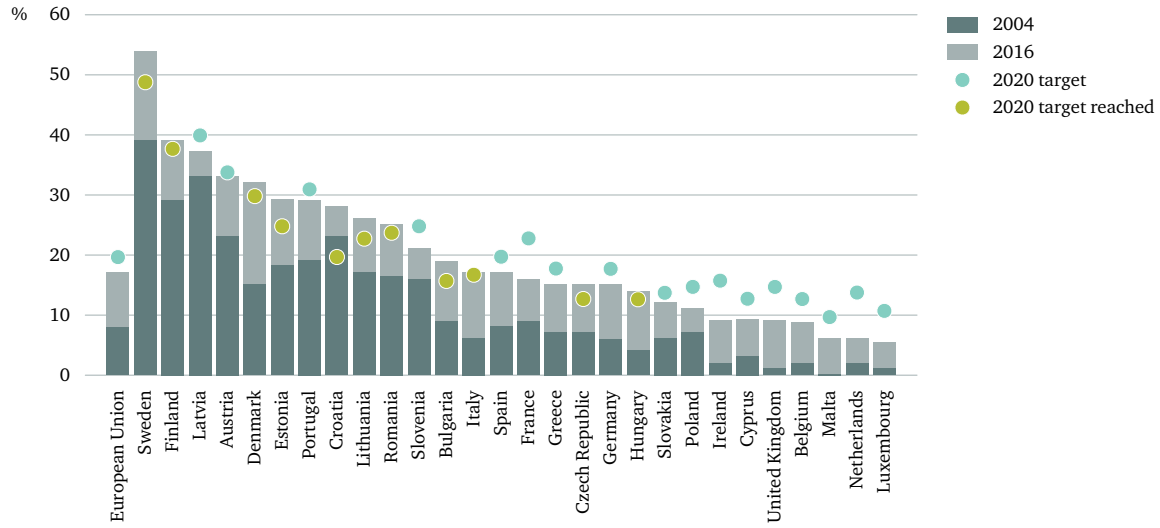
It is often difficult to compare projections such as those summarized above (which is only a small selection of those published). Often starting from insufficient data (such as accurate figures for wood fuel consumption), they generally make different assumptions about background policies and technical developments and frequently ignore price signals and likely market developments. Nevertheless, it seems reasonable to conclude that if demand for biomass energy in the EU continues to increase – which itself seems likely, unless energy efficiency measures start to have a significant impact – then the impact on EU forests will depend heavily on the potential improvements in the efficiency with which wood resources can be used, the potential for using agricultural residues and waste, and the competing demands for other uses of wood – all of which contain significant uncertainties. While domestic production of wood biomass will increase, however, it is very likely that imports will grow even more. As can be seen, most projections assume a growing role for imports, particularly from North America and Russia but also potentially from non-EU Europe (e.g. Belarus, Bosnia and Herzegovina, and Ukraine) and possibly Latin America and Africa.

[29] International Institute for Sustainability Analysis and Strategy, European Forest Institute and Joanneum Research, for BirdLife Europe, EEB, and Transport & Environment (2014), 'Forest biomass for energy in the EU: current trends, carbon balance and sustainable potential', http://www.birdlife.org/sites/default/files/attachments/IINAS_EFI_JR_2014_Forest_biomass_energy_EU.pdf (accessed 8 Feb. 2018).
[30] Indufor (2017), *Outlook for Wood Energy for Biomass in the EU-28*.

The EU policy framework

The main driver for the increase in the consumption of biomass for power and heat has been the renewable energy targets adopted by each EU member state under the 2009 Renewable Energy Directive, which set an overall target of 20 per cent of the EU's energy mix to be derived from renewable sources by 2020.[31] These targets have helped to double the share of final energy consumption from renewables over the last 12 years, which has increased from 8.5 per cent in 2004 to 17 per cent in 2016 (see Figure 6). By 2017, the EU as a whole was on course to meet its 2020 target, though some member states were not, with particular difficulties often being experienced in developing renewable energy for transport and, to a lesser extent, heat. It is up to each member state to determine how to meet their target (see chapters 3–11), but most of them are relying on woody biomass to a significant extent, particularly for heat.

Figure 6: Share of gross final energy consumption from renewable sources in EU, 2004, 2016 and 2020 targets



Source: Eurostat (2018), 'Renewable Energy Statistics', http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics (accessed 20 Feb. 2018).

Proposals for a new Renewable Energy Directive were published in November 2016, as part of a substantial package of policies to support renewable energy after 2020. This included a target of reducing greenhouse gas emissions by 40 per cent from 1990 (compared to the current 20 per cent target for 2020) and a binding EU-wide target of 27 per cent of the EU's energy coming from renewable sources by 2030, though binding country-specific renewable targets were not proposed, allowing more flexibility for member states to meet their greenhouse gas targets. Debates on the proposal started within the EU institutions in 2017. In January 2018, the European Parliament voted to increase the renewables target to 35 per cent by 2030, and also to require national governments to adopt measures to decarbonize the heating and cooling sector, with a (non-legally-binding) target

[31] EUROPA (2009), '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 and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC (June 2009)', http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN (accessed 13 Dec. 2016).

of an annual increase of 2 percentage points for renewables used in heating and cooling by 2030.[32] The final text of the directive will be negotiated in 'trilogues' between the Parliament, member-state governments and the European Commission.

EU rules on the role of forests in climate change also affect the policy framework for biomass. In July 2016 the European Commission published its proposed regulation setting rules for greenhouse gas emissions and removals from LULUCF.[33] This included a 'no-debit', or zero net emissions, target requiring total emissions from this sector not to exceed carbon removals deriving from forest harvesting or land-use change; EU member states would be required to offset all deforestation, either by equivalent reforestation or improved forest management. It also proposed a historical forest management reference level, or baseline, of 1990–2009 against which member states' emissions would be compared (see further discussion on why LULUCF accounting may not capture all emissions from biomass in Chapter 12).

In September 2017, the European Parliament voted to amend these proposals in a number of ways.[34] While supporting a more ambitious target for the LULUCF sector than the initial zero emissions target, with the aim of the sector generating negative emissions, MEPs also voted to change the forest management reference level period to 2000–12. This is significant because – unlike the Commission's proposal, and current practice – it includes the first few years of policies implemented under the Renewable Energy Directive, including policies to support the use of biomass for energy. Higher emissions associated with this use would thus form part of each country's baseline, and not be accounted for in assessing the country's progress towards reducing emissions (see Chapter 12). The vote passed after lobbying from countries such as Finland, France and Poland, all of which aim to increase their forest harvesting rates. As with the new Renewable Energy Directive, the final text is now being negotiated with the other EU institutions.

Sustainability criteria

Sustainability criteria for bioenergy are designed to ensure that their use delivers significant greenhouse gas savings compared to the fossil fuels they replace, and also that they are derived from sources that are legally and sustainably produced (in the sense of sustainable forest management). While the 2009 Renewable Energy Directive contained sustainability criteria for liquid biofuels, there was nothing similar for solid biomass. Although the topic was considered on several occasions over the following years, it was not until 2016 that proposals for EU-level sustainability criteria for biomass were put forward, as part of the proposed new Renewable Energy Directive.[35]

[32] EURACTIV (2018), 'EU Parliament wins plaudits for backing 35% renewables target', 18 January 2018, https://www.euractiv.com/section/energy/news/eu-parliament-wins-plaudits-for-backing-35-renewables-target/ (accessed 2 Feb. 2018).
[33] European Commission (2016), 'Commission Staff Working Document Impact Assessment accompanying the document proposal for a Regulation of the European Parliament and of the Council on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change', (SWD(2016) 249 final, 20 July 2016), https://ec.europa.eu/transparency/regdoc/rep/10102/2016/EN/SWD-2016-249-F1-EN-MAIN-PART-1.PDF (accessed 15 Jan. 2018).
[34] EURACTIV (2017), 'Parliament adds forest "sinks" to EU's 2030 carbon budget', 14 September 2017, https://www.euractiv.com/section/climate-environment/news/parliament-adds-forest-sinks-to-eus-2030-carbon-budget/ (accessed 2 Feb. 2018).
[35] For a longer discussion of this topic, see Brack, D. (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate,* Chapter 3, Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/publication/woody-biomass-power-and-heat-impacts-global-climate.

Given the lack of EU-wide sustainability criteria, a number of member states developed their own criteria for eligibility to subsidies or other support mechanisms.[36] These included:

- Requirements for minimum levels of energy efficiency; for example, France requires a minimum conversion efficiency of biomass into energy of at least 75 per cent, which rules out anything other than use in CHP plants, whereas Spain gives higher levels of support to biomass-consuming plants achieving higher energy efficiency through CHP.
- The provision of greater levels of support for small-scale plants; examples include Finland and Germany.
- Encouragement for or requirements that feedstock be sourced from sustainably managed forests; examples include France, Germany, Hungary, Netherlands and Slovenia.
- Support for domestically sourced feedstock instead of imports; examples include Austria, the Czech Republic and Italy.
- Restrictions on certain types of feedstock. For example, France does not allow stemwood (the main growing portion of the tree, including major branches); in Hungary feedstock cannot be of higher quality than wood fuel and no subsidies are provided for bioenergy produced from stemwood of a diameter above 10 cm; Poland only allows the use of forestry residues and requires a minimum (rising) share of agricultural biomass; Netherlands does not allow the use of stumps or more than half the volume of the annual roundwood harvest from the forest; and in the Flanders region of Belgium, biomass streams suitable for other uses, such as the pulp and paper or wood-processing industries, are not entitled to support.

For all member states, domestically produced or imported woody biomass is also subject to the EU Timber Regulation (EUTR), in force since 2013. The EUTR prohibits the placing on the EU market of products that have been illegally produced and requires companies that first place wood products on the EU market to have in place a system of 'due diligence' to minimize the risk of them handling illegal material. If fully enforced, this is likely to act as a constraint on the supply of woody biomass, in particular from Eastern European countries (including, possibly, some EU member states) and Russia.

To date, the most detailed sets of criteria have been developed in Belgium, Denmark, the Netherlands and the UK (for more detail on the Danish and British policies, see chapters 3 and 11). In general they have two components – requirements for minimum levels of greenhouse gas savings compared to fossil fuels, and requirements (often called 'land criteria') relating to the legality and sustainability of forest management; these latter criteria are often borrowed from existing public-sector procurement policies designed to purchase wood products that are legally produced and from sustainably managed forests.[37] Sometimes other criteria, such as restrictions on types of feedstock (or lists of allowed feedstocks) or on minimum plant energy efficiency levels, are also included.

[36] Except where noted, information taken from Pelkmans, L. et al. (2012), *Benchmarking biomass sustainability criteria for energy purposes*, Belgium: prepared by Vito for the European Commission, Directorate-General for Energy, https://ec.europa.eu/energy/sites/ener/files/documents/2014_05_biobench_report.pdf; Toop, G. (2013), 'Overview of EU criteria and national initiatives', Ecofys, https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiSjK6PiaPaAhXKJcAKHZB_CYIQFggpMAA&url=http%3A%2F%2Fwww.danskelbil.dk%2F~%2Fmedia%2FBiomasse%2FPraesentationer%2F6Ecofys_GemmaToop.ashx&usg=AOvVaw3siwAo5NXZ0F2cHxWtrlP6; Junginger, M. (2015), 'Sustainability regulation for solid biomass for energy in NL, BE & UK', presentation to Conference on Biomass and Sustainability, Copernicus Institute, Utrecht University, 19 October 2015, Copenhagen; and Richter, K. (2016), *A Comparison of National Sustainability Schemes for Solid Biomass in the EU,* Moreton in Marsh: Fern, http://www.fern.org/sites/fern.org/files/comparison%20of%20national%20sustainability%20schemes.pdf (all accessed 30 Dec. 2016).
[37] For more detail, see Brack, D. (2014), *Promoting Legal and Sustainable Timber: Using Public Procurement Policy*, London: Royal Institute of International Affairs, https://www.chathamhouse.org/publication/promoting-legal-and-sustainable-timber-using-public-procurement-policy.

In all cases, however, emissions of greenhouse gases from the combustion of the biomass are ignored; i.e. combustion is treated as zero carbon, in line with the general treatment of biomass energy under the Renewable Energy Directive. Only supply chain emissions from harvesting, processing and transport are taken into account. Both the Danish and Dutch criteria, however, include provisions aiming to maintain or increase forest carbon stocks; the latter requires evidence to show that the forest is managed 'with the aim of retaining or increasing carbon stocks in the medium or long term' and with a low risk of indirect land-use change[38] (see Chapter 3 for more details on the Danish criteria).

At the EU level, the debates over the sustainability criteria for transport biofuels in light of their increasingly clear impacts on forests (which ended with the decision to limit support for food-crop-based biofuels after 2020) helped to highlight the lack of consistency between the treatment of biofuels and biomass; coupled with the growth of imports of biomass for energy into the EU, and the introduction of national sustainability criteria in several EU member states, this convinced the European Commission that EU-wide criteria would be necessary to ensure genuine greenhouse gas savings and to allow for fair competition between the various uses of biomass.[39]

New proposed criteria for solid (and gaseous) biomass were finally published in November 2016, as part of the new proposed Renewable Energy Directive, to apply after 2020. The proposed criteria, which apply to installations with a capacity of 20 megawatts (MW) and greater (which covers only about half of the biomass energy generated[40]), include the following requirements for forest biomass:[41]

- The country or forest from which the forest biomass was sourced has systems in place to ensure that harvesting is carried out legally, the harvested forest is regenerated, areas of high conservation value (including wetlands and peatlands) are protected, the impacts of harvesting on soil quality and biodiversity are minimized, and harvesting is limited to the long-term production capacity of the forest.
- The country from which the forest biomass is sourced is a party to the Paris Agreement and has submitted a Nationally Determined Contribution (NDC) to the United Nations Framework on Climate Change (UNFCCC) covering emissions and removals from agriculture, forestry and land use ensuring either that changes in carbon stock associated with biomass harvests are accounted towards the country's climate commitments or that there are laws in place to conserve and enhance carbon stocks and sinks. (If evidence for these requirements is not available, forest management systems must be in place to ensure that forest carbon stock levels are maintained at the forest holding level.) This has significant implications for future supplies of biomass from the US if it persists in its decision to withdraw from the Paris Agreement.
- Minimum greenhouse gas savings compared to fossil fuels of 80 per cent for installations starting operation after 2020 or 85 per cent for installations starting after 2025 must be achieved. This relates only to supply-chain emissions, not to changes in forest carbon stock. (Suggested default values are provided for different types of feedstock and different transport distances.)

[38] Netherlands Enterprise Agency (2016), 'SDE+ sustainability requirements for solid biomass', http://english.rvo.nl/sites/default/files/2016/03/SDE%20Sustainability%20requirements%20for%20solid%20biomass.pdf (accessed 22 Dec. 2016).
[39] European Commission (2014), *A Policy Framework for Climate and Energy in the Period from 2020 to 2030,* p. 7, Brussels: European Commission, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN, (accessed 22 Dec. 2016).
[40] Birdlife International, Fern, Transport & Environment (2017), 'Bioenergy in the Recast Renewable Energy Directive', Fern, http://www.fern.org/sites/fern.org/files/Bioenergy%20in%20the%20recast%20of%20the%20Renewable%20Energy%20Directive%20final.pdf (accessed 1 Dec. 2017).
[41] European Commission (2016), *Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)*, Article 26, Brussels: European Commission, https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v7_1.pdf (accessed 16 Dec. 2016).

- Electricity must be produced from highly efficient CHP technology for installations starting operation three years after the date of adoption of the new directive (the delay is subject to further discussion).

Member states are to be permitted to apply additional sustainability requirements over and above these EU-wide criteria. Proof of compliance with the criteria is to be provided by the plant operators, subject to independent auditing as defined by the member states. It is open to the European Commission to decide that voluntary schemes (such as that of the Sustainable Biomass Partnership) comply with the criteria and to member states to establish national schemes to do the same.

The impact assessment published alongside the draft directive explained the Commission's thinking behind the proposals. It fully recognized the climate impacts of changes in forest carbon stock, noting that:

> Recent studies have found that when greenhouse gas emissions and removals from combustion, decay and plant growth (so-called biogenic emissions from various biological pools) are also taken into account, the use of certain forest biomass feedstocks for energy purposes can lead to substantially reduced or even negative greenhouse gas savings compared to the use of fossil fuels in a given time period (e.g. 20 to 50 years or even up to centuries).[42]

While considering that most biomass use in the EU conferred substantial greenhouse gas savings – since the feedstock was mostly industrial residues, harvest residues and traditional wood fuel – the Commission recognized the potential for change if demand continued to grow, including additional harvesting rather than forest residue removal, and the increased use of small roundwood and stumps. Despite this, however, the Commission concluded that it would be too difficult to include changes in forest carbon stock in the calculation of life-cycle emissions to be used for the minimum greenhouse gas savings requirements in the sustainability criteria.

The European Parliament began to debate the draft directive, including the proposed sustainability criteria, in December 2016. In January 2018, the Parliament adopted a series of amendments to the proposals, including a slight change in the definition of the area in which forest carbon stock levels should be maintained (from the 'forest holding level' to the 'supply base level'), and a relaxation of the requirement that biomass be used only in CHP facilities (electricity-only installations that achieve a net electrical efficiency of at least 40 per cent and do not use fossil fuels will also be allowed – this is a relatively high bar, with most current dedicated biomass stations falling below the 40 per cent level). The Parliament voted down a proposal to exclude stumps and roundwood from eligibility for support, and also refused to introduce stricter rules for the co-firing of biomass with coal.[43] The final text of the directive will be negotiated in 'trilogues' between the Parliament, member-state governments and the European Commission.

[42] European Commission (2016), *Impact Assessment: Sustainability of Bioenergy, Accompanying the document Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast),* Brussels: European Commission, p. 16, http://eur-lex.europa.eu/resource.html?uri=cellar:1bdc63bd-b7e9-11e6-9e3c-01aa75ed71a1.0001.02/DOC_1&format=PDF (accessed 29 Dec. 2016).
[43] 'European Parliament backs bioenergy in RED II', ENDS Waste and Bioenergy, 17 January 2018, https://www.endswasteandbioenergy.com/article/1454758/european-parliament-backs-bioenergy-red-ii (accessed 22 Jan. 2018).

3. Denmark

Table 4: Key renewable and biomass energy statistics, Denmark

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.17	5.4%	19.2%	1.72	22.3%	75.5%	11.9%	20.0%
2016	0.30	9.8%	18.2%	2.35	31.1%	74.5%	16.9%	32.2%
Annual average growth		8.3%			4.5%		5.1%	7.0%
2020 target								30.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for biomass

Denmark's Energy Agreement of 2012 set the target of 35 per cent of energy from renewables by 2020, ahead of its EU target of 30 per cent, and described a longer term aim of continuing to reduce dependence on fossil fuels, with a possible total phase-out by 2050.[44] The most recent projections suggest that in fact the country will achieve 40 per cent by 2020.[45] A new policy framework extending beyond 2020 is due to be agreed in 2018.

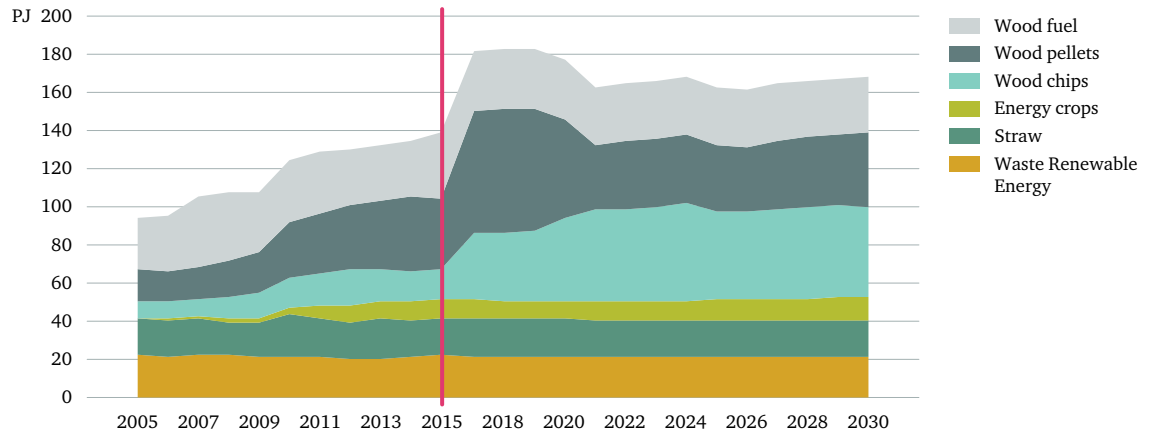
Denmark has long been a leading producer of wind turbines, and the Energy Agreement included the goal of generating 50 per cent of its electricity supply from wind by 2020. Biomass, however, is the second most important source of renewable electricity (in 2016 Denmark generated the second highest proportion of electricity from biomass of all EU member states), and the main source of renewable heat. In common with other Scandinavian countries, Denmark developed district heating systems in combination with CHP generation to increase energy efficiency and reduce dependence on imported oil following the oil crises of the 1970s. Today, Denmark is considered one of the most energy-efficient countries in the world, with the majority of households receiving district heating from CHP plants.[46]

Thermal CHP stations, including district heating systems are currently undergoing a substantial transition from coal and natural gas to biomass.[47] Several conversions and new builds have already been completed or are expected to be completed within the next few years; in February 2017 the largest Danish energy company, the state-owned DONG Energy (now renamed Ørsted), announced

[44] IEA (2012), 'Danish Energy Agreement for 2012–2020', https://www.iea.org/policiesandmeasures/pams/denmark/name-42441-en.php (accessed 4 Jan. 2018); IEA (2011), 'Energy Strategy 2050', http://www.iea.org/policiesandmeasures/pams/denmark/name-25113-en.php?s=dHlwZT1yZSZzdGF0dXM9T2s,&return=PGRpdiBjbGFzcz0ic3ViTWVudSI – (accessed 4 Jan. 2018).
[45] Danish Energy Agency (2017), *Denmark's Energy and Climate Outlook 2017*, https://ens.dk/sites/ens.dk/files/Analyser/denmarks_energy_and_climate_outlook_2017.pdf (accessed 4 Jan. 2018).
[46] Stelte, W., Hinge, J., and Dahl, J. (2015), *Country report 2014 for Denmark*, Paris: IEA Bioenergy Task 40, http://www.bioenergytrade.org/downloads/iea-task-40-country-report-2014-denmark.pdf (accessed 13 Jul. 2016).
[47] Ibid.

that it would phase out the use of coal from 2023. Biomass use is projected to continue to increase to 2020, when most major CHP stations are expected to have been converted to biomass, and remain roughly stable thereafter, though this depends on future policy development (see Figure 7). Should Denmark aim for complete phase-out of fossil fuels, biomass use can be expected to increase further; in some scenarios, energy from biomass is projected to rise to as much as 700 petajoules (PJ) by 2050 (from about 140 PJ in 2015).[48]

Figure 7: Use of biomass in Danish energy consumption, 2005–15 (actual) and 2016–30 (projected), in PJ



Source: Danish Energy Agency (2017), *Denmark's Energy and Climate Outlook 2017*, https://ens.dk/sites/ens.dk/files/Analyser/denmarks_energy_and_climate_outlook_2017.pdf (accessed 4 Jan. 2018).

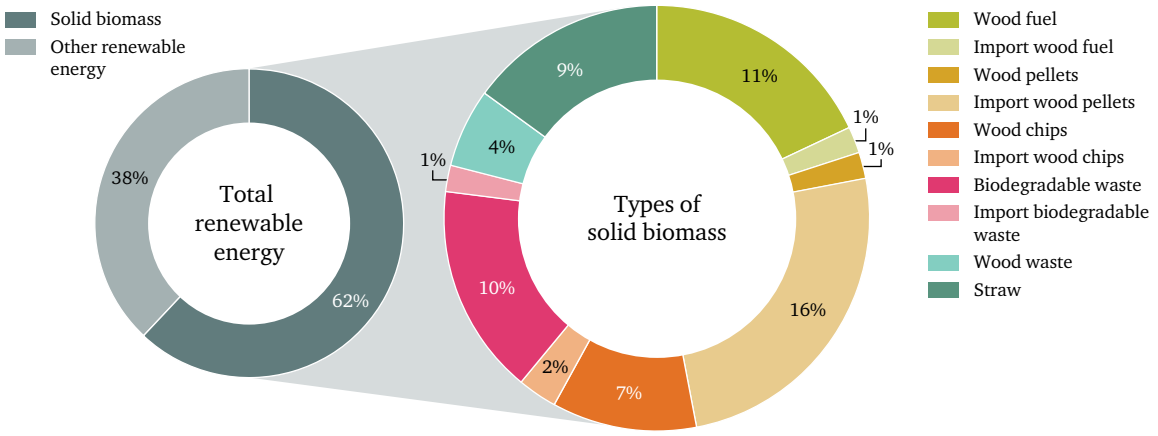
Biomass supply

Denmark's biomass supply includes a range of wood-based products and agricultural waste that are used across the domestic and industrial, power and heating sectors, most notably in large-scale CHP generation and district heating (see Figure 8). In 2014, there were a total of 39 CHP plants using at least some biomass as fuel, with a total consumption of 2.7 million tonnes.[49] Ørsted's Avedøre CHP plant near Copenhagen, which is in the process of converting from coal and gas to biomass (mainly wood pellets), alone used a third of this amount.[50]

Wood pellets and chips are the main feedstock for large-scale plants; other forms of biomass – including straw, wood fuel and wood chips – are used in private boilers, district heating, CHP and power-only plants, but in recent years, several of these plants have switched to wood pellets.[51] Most wood fuel, wood chips and wood residues are sourced domestically, though some are transported by truck or boat from Sweden and Germany, as well as from Estonia and Latvia; straw is mainly sourced domestically (see Figure 8).[52]

[48] Danish Energy Agency (2014), *Energy scenarios for 2020, 2035 and 2050,* https://ens.dk/sites/ens.dk/files/Analyser/energiscenarier_uk.pdf (accessed 23 Jan. 2018).
[49] EnergiNet DK (2015), 'Climate and Environment: Biomass', http://www.energinet.dk/EN/KLIMA-OG-MILJOE/Miljoerapportering/VE-produktion/Sider/Biomasse.aspx (accessed 13 Jul. 2016).
[50] Ibid.
[51] Stelte, W., Hinge, J., and Dahl, J. (2015), *Country report 2014 for Denmark*.
[52] Ibid.

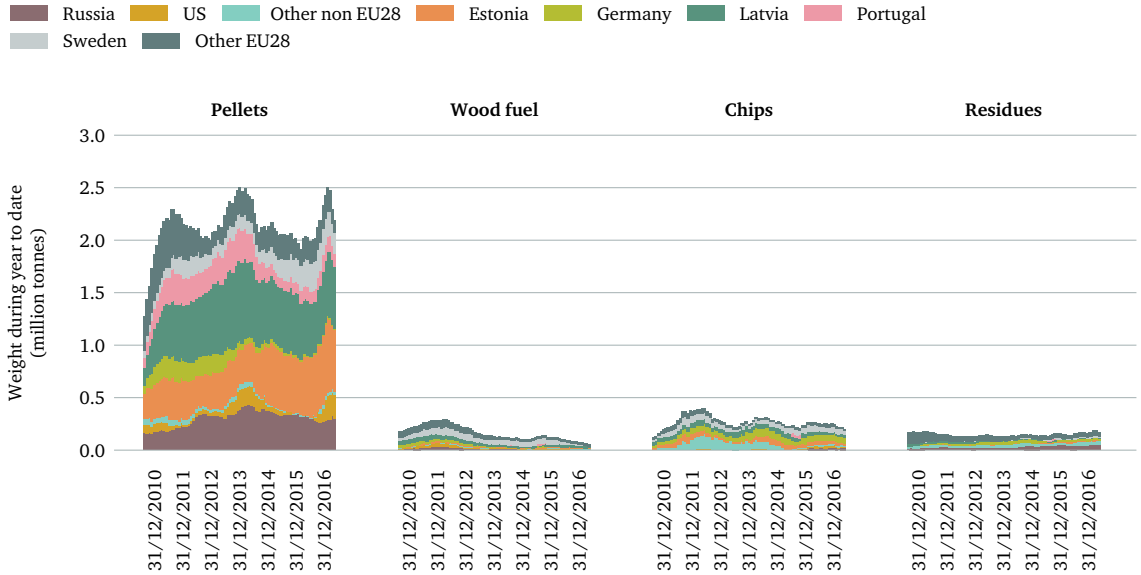
Figure 8: Use of solid biomass in Danish energy system in 2015 with share of imports, % of energy content



Source: Danish Energy Agency (2015), *Energy Statistics 2015*, https://ens.dk/sites/ens.dk/files/Statistik/energy_statistics_2015.pdf (accessed 4 Jan. 2018).

Wood pellets, however, are mainly imported; in 2016, Denmark was the EU's second largest importer after the UK. For each year between 2011 and 2016, the country imported between 2.0 and 2.5 million tonnes of wood pellets, most for replacing coal in large-scale CHP plants.[53] As shown in Figure 9, the main sources of imports of wood pellets are Latvia, Estonia and Russia, followed by Portugal and Sweden. Imports from the US have grown recently and are expected to increase further, as Ørsted has agreed a supply contract with the US pellet manufacturer Enviva.[54]

Figure 9: Denmark's imports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

[53] Stelte, W., Hinge, J., and Dahl, J. (2015), *Country report 2014 for Denmark*.
[54] *Biomass Magazine* (2017), 'Denmark's Biomass Reboot', 17 January 2017, http://biomassmagazine.com/articles/14088/denmarks-biomass-reboot (accessed 23 Jan. 2018).

Support for biomass energy

Renewable energy has received government support since the 1980s. The main current support mechanisms include feed-in tariffs and tax reliefs.[55] In addition, strict energy efficiency standards for new buildings and performance requirements for existing buildings have helped to reduce energy use per capita.

Feed-in tariffs were first introduced in 1993 for wind turbines and biomass power plants, and were extended under the 2009 Promotion of Renewable Energy Act, which introduced two sorts of feed-in premiums: variable, covering the difference between average annual electricity prices and the target remuneration, and fixed, under which plant operators receive a fixed bonus per megawatt hour (MWh) on top of the market price; in each case the premium is limited to a specified number of full-load hours of generation. Electricity from biomass, whether from co-firing or biomass-only installations, currently receives a premium of DKK 150 (about €20) per MWh. The government also subsidizes grid connections and balancing costs, as well as work to reinforce the grid to connect renewable electricity plants.

Financial support for renewable energy is provided partly from the public service obligation (PSO) levy, which is added to electricity bills. In 2016, the Danish Parliament reached an agreement to phase out the PSO gradually over the 2017–21 period and instead finance support for renewables through the national budget. Consumption is expected to rise somewhat as a result of this fall in electricity bills.

Various energy taxes have been introduced since the late 1970s to encourage fuel switching and energy efficiency; these currently include a tax on the energy content of the fuel, taxes on emissions of carbon dioxide, nitrogen oxides and sulphur dioxide, and the PSO levy (currently being phased out). The tax rates vary per use and user, with the result that households, public bodies and small businesses face very high rates (among the highest in industrialized countries); electricity for heating is taxed at a lower level and energy for industry lower still.

> Biomass used to produce heat, both in district heating and in residential use, is exempt from energy and carbon taxes, which provides an important stimulus for switching from fossil fuels to biomass.

Biomass used to produce heat, both in district heating and in residential use, is exempt from energy and carbon taxes, which provides an important stimulus for switching from fossil fuels to biomass. Indeed, it even favours biomass over electric heating generated from renewable sources such as wind, which is still subject to the energy tax, though at a lower rate than fossil fuels.

Other initiatives to promote renewable heating include a prohibition on the installation of oil and gas-fired boilers in new buildings from 2013 and oil-fired boilers in existing buildings from 2016 onwards in areas with district heating or natural gas. These regulatory measures have been accompanied by demonstration projects and awareness-raising actions such as providing advice on alternatives to oil and gas boilers.

[55] Stelte, W., Hinge, J. and Dahl, J. (2015), *Country report 2014 for Denmark;* EurObserv'ER (2017), *Renewable Energy Policy Factsheet: Denmark*; IEA (2017), *Energy Policies of IEA Countries: Denmark*.

Sustainability criteria

In Denmark, woody biomass for energy is included in the government's timber procurement policy, most recently revised in 2014, although its application to bioenergy is voluntary throughout the public sector. The policy sets out detailed definitions of the terms 'legal' and 'sustainable'. Products certified under the two main international forest certification schemes – those of the Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC) – satisfy the criteria. These schemes aim to ensure that the ways in which forests are managed and harvested meet criteria for legality and sustainability, but they do not include any criteria – such as greenhouse gas savings relative to fossil fuels – relating to the use of the products for energy.

In 2015, in response to a request from the government, the Danish District Heating Association and the Danish Energy Association introduced a voluntary sustainability standard for biomass.[56] This includes similar requirements for legality and sustainability as the government's procurement policy, and products certified under the FSC, PEFC or Sustainable Biomass Partnership schemes are considered to meet them.

The standard also requires greenhouse gas reduction levels of 70 per cent by 2015, 72 per cent by 2020 and 75 per cent by 2025, compared to fossil-fuel reference levels according to the Renewable Energy Directive methodology. This does not include emissions from changes in forest carbon stock or indirect land-use change, but the standard also aims to avoid the use of biomass that 'negatively affects the quantity and quality of forest resources in the medium and long terms', where there is regionally competing demand for high-value wood resources or if the supply of those resources derives from deforestation or inappropriate conversion of forest to agriculture. The industry is working to develop further criteria to cover these issues.

As noted, application of the standard is voluntary (and only applies to stations with capacity above 20 MW), but the associations aim to increase the level of compliance with the requirements of CHP installations (the only large-scale consumers of biomass for energy in Denmark) from 40 per cent in 2016 to 100 per cent in 2019; it is likely that if these kind of targets are not met, the government would legislate to make them mandatory. The standard will be reviewed in 2018 in light of the criteria expected to be adopted at the EU level.

[56] Dansk Energi and Danske Fjernvarme (2015), 'Industry agreement to ensure sustainable biomass (wood pellets and wood chips)', www.danskenergi.dk/~/media/Biomasse/IndustryAgreement_Biomass-20150909.ashx (accessed 29 Dec. 2016).

4. Finland

Table 5: Key renewable and biomass energy statistics, Finland

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.72	10.0%	36.5%	5.34	40.6%	94.1%	24.4%	31.3%
2016	0.91	12.1%	36.7%	6.90	48.8%	91.0%	29.5%	38.7%
Annual average growth		3.4%			3.7%		2.8%	3.1%
2020 target								38.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as a percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for woody biomass

Finland is a significant user of biomass for energy; in 2016, the country generated the largest proportion of electricity from biomass of any EU member state (the fourth largest quantity in absolute terms) and the third highest proportion of heat, behind Sweden and Latvia (the fifth largest quantity in absolute terms). It has the highest consumption of biomass energy per inhabitant in the EU.[57] In total, biomass is Finland's largest energy source (including energy for transport), even surpassing energy from the consumption of oil. Woody biomass comprises about 80 per cent of the bioenergy consumed, while much of the rest is provided by peat, often co-fired with woody biomass. In 2017, an estimated 70 per cent of Finland's coal or peat use was in power plants co-fired with at least 10 per cent biomass.[58]

Table 6: Finland's total energy consumption by fuel, 2010–16

	Petajoules						
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Wood fuels	324	318	332	338	339	331	349
Oil	350	334	325	318	310	312	317
Nuclear energy	239	243	241	247	247	244	243
Coal	186	145	123	151	126	103	127
Natural gas	149	130	115	107	96	82	73
Net imports of electricity	38	50	63	57	65	59	68
Hydro power	46	44	60	46	48	60	56
Peat	98	86	66	58	61	58	56
Wind power	1	2	2	3	4	8	11
Other energy sources	35	37	45	50	54	53	61
Total	**1,466**	**1,389**	**1,371**	**1,375**	**1,349**	**1,309**	**1,362**
Renewable energy sources* (%)	27.2%	28.5%	31.5%	31.2%	33.1%	34.7%	34.2%

Source: Statistics Finland, http://tilastokeskus.fi/tup/suoluk/suoluk_energia_en.html (accessed 20 Feb. 2018).
* Includes, inter alia, wood fuels, hydro and wind power, and the biodegradable proportion of recycled fuels.

[57] Eurobserv'ER (2017), *Solid Biomass Barometer 2017*, http://www.eurobserv-er.org/solid-biomass-barometer-2017/ (accessed 23 Jan. 2018).
[58] Sandbag (2017), *Something Nasty in the Woodshed*.

Total heat consumption accounts for about twice as much energy as electricity generation. Industry is the largest consumer, accounting for about 60 per cent of all the heat produced from biomass; the remaining 40 per cent is supplied as district heat.[59] The pulp and paper industry is a substantial producer and consumer of black liquor, a by-product of the pulp-making process, which is burnt on-site to generate energy.

In the residential sector, the consumption of wood fuel and wood chips for heat has steadily increased over the last three decades, largely due to a shift away from fossil fuels following the oil crises of the 1970s. In 2013, about 60 per cent of single-family houses used wood for at least some of their heating; an estimated 4.7 million m³ of wood in the form of logs were burnt, as well as 1.3 million solid m³ of wood residues and 0.7 million solid m³ of wood chips.[60]

Larger-scale boilers, however, consume more woody biomass in total; 80 per cent of biomass burnt for heat in 2012 was used in boilers whose capacity exceeded 20 MW. District heating is one of the most common forms of space heating in Finland, and roughly 70 per cent of total district heat production in 2012 was supplied from CHP plants.[61] While these still mainly use fossil fuels, CHP facilities that co-fire or solely fire with woody biomass are increasingly common, particularly further inland. In 2015, Finland had some of the largest biomass-fuelled CHP facilities in Europe, including, for example, the Alholmens plant, which claims to be the world's largest bio-fuelled power plant.

Nuclear power is the main source of electricity, but renewables accounted for about a third of the total in 2016. Hydropower is the main source, accounting for about half of this, while biomass is the second largest, supplying about 12 per cent of total electricity (see Table 5).

Biomass was a key component of Finland's National Renewable Energy Action Plan drawn up in response to the 2009 Renewable Energy Directive; in particular it was projected to provide the bulk of the target of 47 per cent of heat consumption from renewable energy by 2020.[62] In fact the contribution from biomass has grown faster than forecast, and in 2016 it supplied 49 per cent of total heat consumption (see Table 5).

In November 2016, the government published a new energy and climate strategy, aiming to fulfil the commitments Finland is likely to make under the EU's 2030 package and the Paris Agreement.[63] The strategy includes proposals to phase out the use of coal for energy by 2030, reduce oil imports in the 2020s to 50 per cent of the 2005 level (including by increasing the use of transport biofuels and electric and gas-powered vehicles) and raise the overall share of renewable energy to 50 per cent and energy self-sufficiency to 55 per cent in the 2020s.

The overall aim of the strategy is to achieve an 80–95 per cent reduction in greenhouse gas emissions by 2050. Since this relies heavily on the continued expansion of biomass energy, however, it is expected to be achieved at the cost of a considerable impact on Finnish forests. As the government's impact assessment of the new strategy observed, 'Forest biomass is the largest growing renewable energy source from 2015 to 2030. Existing felling potential in the Finnish forests will be large enough to supply the estimated needs of both forest and energy industries. Finnish forests will remain a carbon sink,

[59] Karhunen, A., Ranta, T., Heinimö, J., and Alakangas, E. (2014), *Market of biomass fuels in Finland – An overview 2013*, IEA Bioenergy Task 40 Country Report, http://www.bioenergytrade.org/downloads/iea-task-40-country-report-2014-finland.pdf (accessed 2 Aug. 2016).
[60] Ibid.
[61] Ibid.
[62] International Energy Agency (2013), *Energy Policies of IEA Countries: Finland*, Paris: International Energy Agency, https://www.iea.org/publications/freepublications/publication/Finland2013_free.pdf (accessed 2 Aug. 2016).
[63] Ministry of Economic Affairs and Employment (2017), *Government Report on the National Energy and Climate Strategy for 2030*. http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79247/TEMjul_12_2017_verkkojulkaisu.pdf?sequence=1 (accessed 27 May 2017).

but the carbon sink will be reduced to half of the current levels if the logging increases to an estimated 80 million cubic meters by 2030.'[64] As a result, net emissions would not fall until 2030 at the earliest.

Biomass supply

Finland's forests cover an estimated 87 per cent of the country – about 30 million hectares – and contribute to a thriving timber industry. Within the EU, Finland comes second only to Sweden in terms of total roundwood production, which is estimated at 61 million m^3 (under bark) in 2016, including 7 million m^3 of wood fuel.[65] In turn this industry generates substantial volumes of wastes and residues, which can be used for energy, though wood chips are also used to replace fossil fuels in CHP and heating. The 2016 Energy and Climate Strategy includes proposals to use energy taxation and operating aid schemes to provide incentives for the use of forest industry by-products and wood chips, though this would be reduced if the chips were produced from logs or pulpwood suitable for industrial raw material. In total the strategy aimed at the production of 48 terawatt-hours (TWh) of energy from the waste liquors of the wood-processing industry and 66 TWh from solid wood fuels, including 29 TWh from wood chips, by 2030. This corresponds to 14–18 million m^3 per year of wood chips.

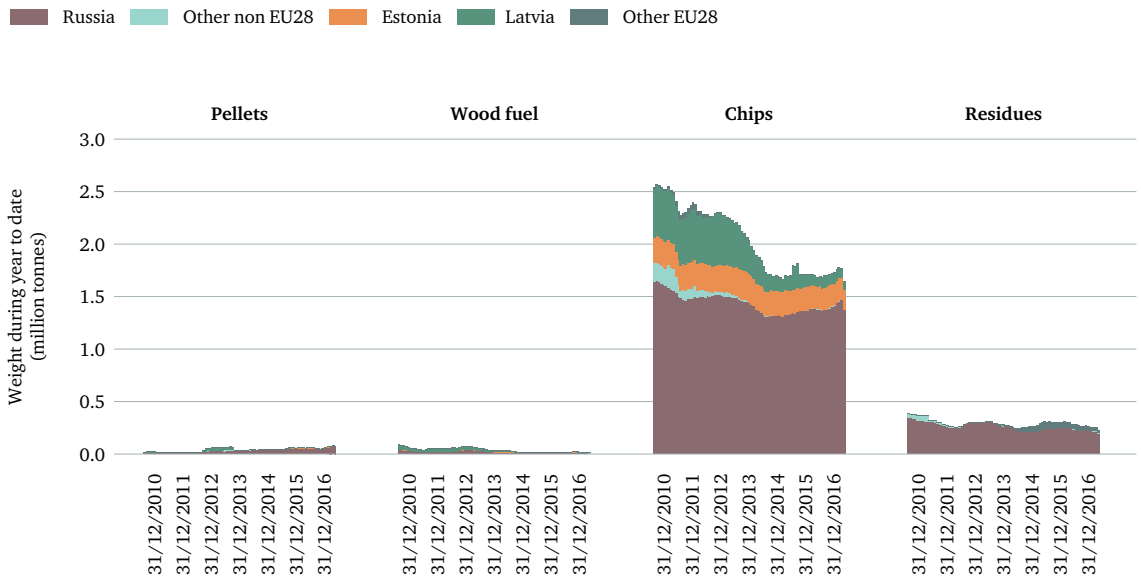
> Although pulp and paper production in Europe has still not recovered to the levels of 2007 (before the global financial crash), Finland's pulp and paper industry is set to expand.

The contribution of woody biomass to meeting Finland's renewable energy targets depends partly on the buoyancy of the pulp and paper industry, a major producer and consumer of black liquor.[66] Although pulp and paper production in Europe has still not recovered to the levels of 2007 (before the global financial crash), Finland's pulp and paper industry is set to expand, chiefly through the construction of Metsä Fibre's new bioproduct mill at Äänekoski, which was completed in 2017.[67] The new mill by itself should increase the consumption of pulpwood in Finland by approximately 10 per cent and burn sufficient woody biomass fuel to increase the share of renewables in Finland's energy mix by 3 per cent.[68]

Domestic wood pellet production is small but growing, reaching 271,000 tonnes in 2016, virtually all for domestic consumption.[69] About half is used in small heating boilers, though pellets are also increasingly competitive as fuel for large-scale power and heating plants. Finland has very little trade in wood pellets, and exports small quantities of wood fuel, wood chips and wood residues, almost all to Sweden. Imports of wood chips, mostly from Russia, are substantial, however, mostly for use either as pulpwood or in the manufacture of wood panels, though some is used directly as fuel (see Figure 10).

[64] Prime Minister's Office (2017*), Impact assessments of the Energy and Climate strategy: The summary report*, p. 4, http://tietokayttoon.fi/documents/10616/3866814/21_Energia-+ja+ilmastostrategian+vaikutusarviot+Yhteenvetoraportti/40df1f5f-c99c-47d1-a929-a4c825f71547?version=1.0 (accessed 27 May 2017).
[65] Eurostat data at http://ec.europa.eu/eurostat/web/forestry/data/database.
[66] International Energy Agency (2013), *Energy Policies of IEA Countries: Finland.*
[67] The Bioproduct Mill, 'The Next Generation Bioproduct Mill', http://bioproductmill.com (accessed 28 Feb. 2018).
[68] Mäntyranta, H. (2016), 'Will Finland use renewable energy only by 2050?', Finnish Forest Association, 27 April 2016, http://www.smy.fi/en/artikkeli/will-finland-use-renewable-energy-only-by-2050-minister-olli-rehn-calls-for-a-scenario-to-see-what-this-would-require/ (accessed 7 Aug. 2016).
[69] FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.

Figure 10: Finland's imports of woody biomass potentially for energy, 2010–16

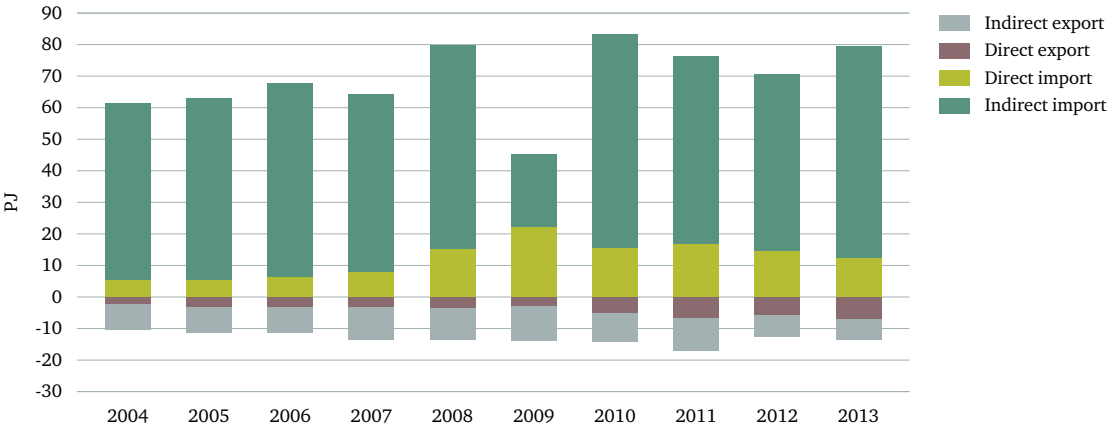


Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Although there are likely to be some concerns about the sustainability and legality of woody biomass imported from Russia, particularly given current tensions, leading companies in Finland's wood-based products industry have long experience of applying systems of due diligence.

As indicated above, Finland's direct imports are likely to supply only a small proportion of the woody biomass used for energy. A larger proportion is likely to derive from the by-products of mills that import large quantities of wood as log or sawnwood as their primary raw materials ('indirect imports').[70] Figure 11, which shows Finland's direct and indirect import and export balance for biomass fuels between 2004 and 2013, demonstrates a significantly higher amount of indirect imports, both in terms of the total amount and proportion.

Figure 11: Import and export balance of biomass fuels in Finland, 2004–13



Source: Karhunen, A., Ranta, T., Heinimö, J., and Alakangas, E. (2014), *Market of biomass fuels in Finland – An overview 2013*, IEA Bioenergy Task 40 Country Report, http://www.bioenergytrade.org/downloads/iea-task-40-country-report-2014-finland.pdf (accessed 2 Aug. 2016).

[70] Karhunen et al. (2014), *Market of biomass fuels in Finland*.

In summary, the supply of biomass for power and heat in Finland is expected to increase substantially, mostly driven by domestic supply. Imports of woody biomass as fuel are expected to increase in the short term to supply the rising demand for biomass energy particularly in coastal cities, as coal is phased out, but decline over the longer term.[71]

Support for biomass energy

The Finnish government has long provided support for the use of biomass in power and heat generation, and has introduced several mechanisms to promote its production and use. This includes tax exemptions, a feed-in tariff scheme, and grants for private forest owners.

Similar to other Nordic countries, Finland imposes an energy tax on certain fuels (fossil fuels and liquid biofuels), and a tax on carbon dioxide emissions, from which wood and other solid biomass sources used for energy are exempted.[72] In 2014, the carbon tax for fossil fuels was reduced by 50 per cent for those used in CHP production, with the aim of improving the competitiveness of CHP over separate heat production.

Feed-in tariffs have also been used to promote the use of biomass power. The feed-in tariff for electricity produced from wood fuels is guaranteed for 12 years at €83.5 per MWh minus the three-month mean market price of electricity; the tariff for plants using wood chips is variable and based on the cost-effectiveness of the fuel in power generation.[73] From 1 January 2019, the feed-in tariff will be reduced by 60 per cent for plants using wood chips made from roundwood obtained from a logging site of large-sized timber suitable for processing.[74]

Small-scale CHP is also encouraged through a feed-in tariff for wood fuels used in new plants, especially benefiting those with a capacity less than 3 MW and a thermal input of about 20 MW.[75] This feed-in tariff is expected to facilitate about 60 new investments by 2020, and to increase the use of wood fuel in small scale CHP plants by 1–1.5 TWh.

Under the 2007 Act on the Financing of Sustainable Forestry, the government has provided grants to non-industrial forest owners to encourage sustainable forestry and wood fuel production.[76] In 2010, amendments were made to separate the financing of sustainable forestry and wood fuel production and harvesting from small trees. Support for wood chipping under the 2007 Act ended in June 2015, and a new focus on low-grade wood harvesting has been proposed.[77]

Under the 2016 Energy and Climate Strategy, the taxation and other measures outlined above to support the use of woody biomass will be reviewed to encourage the cost-effective use of wood chips and forest industry by-products and peat, though support will be reduced from 2019 onwards if chips are produced from logs or pulpwood that would be suitable for industrial raw material.

Finland possesses no national sustainability criteria for solid biomass.

[71] Ibid.
[72] Ibid.
[73] RES Legal (2016), 'Legal sources on renewable energy: Finland', http://www.res-legal.eu/search-by-country/finland/ (accessed on 4 Sep. 2016).
[74] Ibid.
[75] European Commission (2012), 'National Renewable Energy Action Plan: Finland', https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans (accessed 9 Aug. 2016).
[76] Karhunen et al. (2014), *Market of biomass fuels in Finland.*
[77] Eurobserv'ER (2015), *Country policy profile: Finland*, http://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Country-Profile-2015-12-Finland.pdf (accessed 1 Aug. 2016).

5. France

Table 7: Key renewable and biomass energy statistics, France

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.11	0.2%	1.6%	8.28	12.4%	81.9%	5.4%	12.3%
2016	0.26	0.6%	3.1%	9.82	15.7%	74.4%	6.5%	16.0%
Annual average growth		13.9%			2.5%		2.7%	3.8%
2020 target								23.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for woody biomass

France is the second largest consumer of biomass for power and heat in the EU, behind only Germany, and the largest consumer of biomass for heat, mostly in the residential and industrial sectors.[78] A government target set in 2013 was to increase consumption of biomass for heat to 16.6 Mtoe by 2020,[79] including increasing the number of households served from 7.4 million to about 9 million.[80]

In 2012–13, the combustion of black liquor by industry accounted for about half of total consumption of energy from woody biomass.[81] In contrast, biomass plays only a small role in electricity generation. Although France generated 19 per cent of its electricity from renewable sources in 2016, the vast majority of this was from hydro and wind; almost all the remaining power generation was from France's large fleet of nuclear stations.

France is currently on track to meets its Renewable Energy Directive target of 23 per cent of energy from renewables by 2020. Under the Energy Transition for Green Growth Act of 2015 (drawn up among others by the then economy and industry minister, Emmanuel Macron) this target was increased further to 32 per cent by 2030.[82] Alongside a reduction of the share of nuclear power

[78] Commissariat Général au Développement Durable (2015), *Chiffres clés des* énergies *renouvelables:* Édition *2015*, http://www.developpement-durable.gouv.fr/IMG/pdf/Rep_-_Chiffres_cles_energies_renouvelables.pdf (accessed 10 Aug. 2016); ADEME (2016), 'Le Fonds Chaleur en bref', http://www.ademe.fr/expertises/energies-renouvelables-reseaux-stockage/passer-a-laction/produire-chaleur/fonds-chaleur-bref (accessed 10 Aug. 2016).
[79] ADEME (2013), *Etudes sur le chauffage domestique au bois: marches et approvisionnement*, http://ademe.typepad.fr/files/synth%C3%A8se-etude-chauffage-domestique-au-bois.pdf (accessed 10 Aug. 2016).
[80] Ministère de l'Environnement, de l'Énergie et de la Mer (2015), 'Politique de développement des énergies renouvelables en France', http://www.developpement-durable.gouv.fr/Politique-de-developpement-des,13554.html (accessed 10 Aug. 2016).
[81] Based on Institut national de la statistique et des études économiques, *Répartition de la consommation de combustibles par usage en milliers de tonnes-*équivalent-*pétrole (kTEP) selon la nomenclature des activités consommatrices*, http://www.insee.fr/fr/ppp/bases-de-donnees/irweb/irecoeacei13/dd/excel/irecoeacei13_nce_T3.xls (accessed 13 Aug. 2016); *Consommation d'énergie en milliers de tonnes-*équivalent-*pétrole (kTEP) selon la région,* http://www.insee.fr/fr/ppp/bases-de-donnees/irweb/irecoeacei13/dd/excel/irecoeacei13_reg_T1.xls (accessed 13 Aug. 2016).
[82] Ministry of Ecology, Sustainable Development and Energy (2015), *Energy Transition for Green Growth Act: User guide for the act and its attendant actions*, Paris: Ministry of Ecology, Sustainable Development and Energy, http://www.developpement-durable.gouv.fr/IMG/pdf/14123-8-GB_loi-TE-mode-emploi_DEF_light.pdf (accessed 13 Aug. 2016).

in electricity generation from 75 per cent to 50 per cent by 2025, and an increase in energy efficiency (a fall of 50 per cent in total energy consumption from 2012 to 2050), the policy aimed to increase renewables to 40 per cent of electricity generation, 38 per cent of final heat consumption, 15 per cent of final transport fuel consumption and 10 per cent of gas consumption by 2030. The expansion of renewable electricity was expected to come mainly from wind and solar PV, but thanks to its dominant role in heating, solid biomass was expected to continue to provide the largest share in the renewable energy mix at least until 2020.[83]

> In July 2017, the new administration of President Macron unveiled a Climate Plan aiming to achieve net zero greenhouse gas emissions by 2050.

In July 2017, the new administration of President Macron unveiled a Climate Plan aiming to achieve net zero greenhouse gas emissions by 2050.[84] This included a commitment to raise the carbon tax (see below).

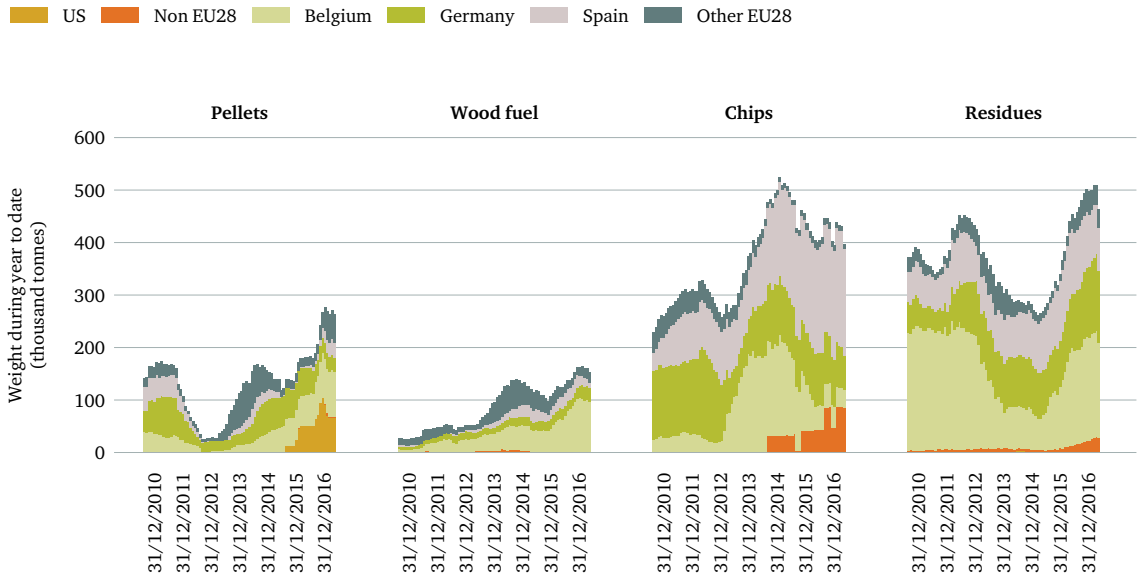
Biomass supply

France is one of the EU's leading producers of roundwood, producing over 51 million m^3 (under bark) in 2016. Approximately half of that volume – 26 million m^3 – was used as wood fuel, a much higher proportion than in most other EU member states.[85]

Accordingly, woody biomass has been, and is expected to remain, the dominant source of biomass used for energy; the use of agricultural residues is not currently significant.[86] Most of the wood is used for heat in decentralized units, such as residential boilers and stoves.[87] Small amounts of wood pellets are used in small-scale private and industrial boilers; in 2016, the country produced 1.15 million tonnes of wood pellets, mostly for domestic end use.[88] Smaller amounts are imported, though volumes have fluctuated considerably during the last few years. During 2016, imports doubled to about 300,000 tonnes (the US having joined Belgium as the leading supplier), while exports (mainly to Italy) remained at roughly 200,000 tonnes. Exports of wood fuel are more substantial, at about 500,000 tonnes a year, predominantly to Belgium (see figures 12 and 13).

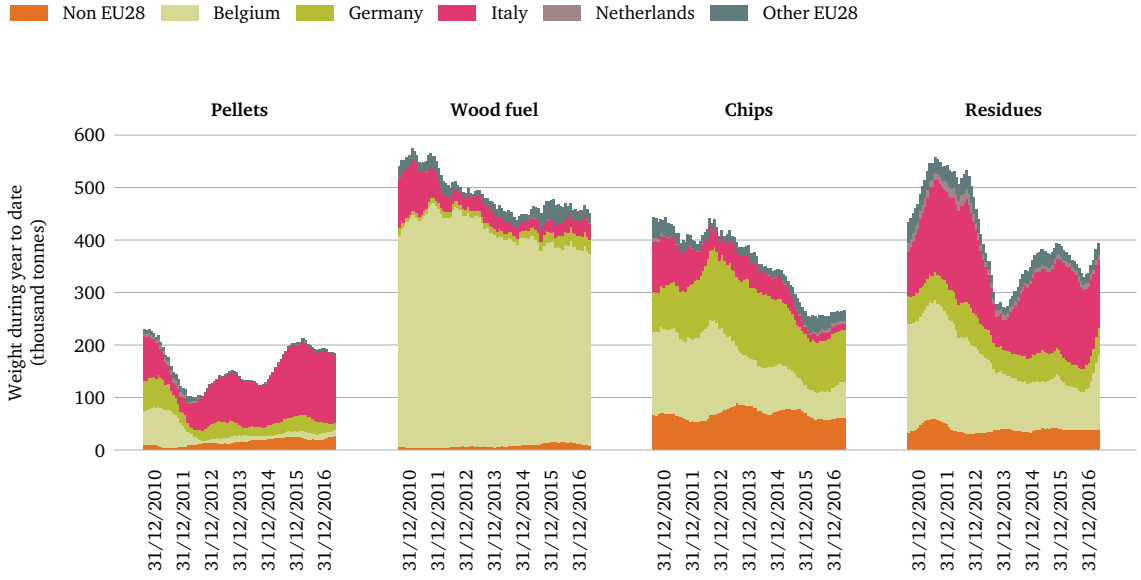
[83] Deloitte Conseil (2015), *European energy market reform Country profile: France*, https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-er-merket-reform-france.pdf (accessed 10 Aug. 2016).
[84] Government of France (2017), 'Climate Plan', http://www.gouvernement.fr/en/climate-plan (accessed 24 Jan. 2018).
[85] Eurostat data at http://ec.europa.eu/eurostat/web/forestry/data/database.
[86] Commissariat général au développement durable (2015), *Chiffres clés des* énergies *renouvelables:* Édition 2015.
[87] European Commission (2015), *Renewable Energy Progress Report*, Brussels: European Commission, http://eur-lex.europa.eu/resource.html?uri=cellar:4f8722ce-1347-11e5-8817-01aa75ed71a1.0001.02/DOC_1&format=PDF (accessed 10 Aug. 2016).
[88] FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.

Figure 12: France's imports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Figure 13: France's exports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

The government views the country's forest resources as under-exploited but difficult to mobilize, and has set out the aim of increasing future biomass supply for energy by 3–5.4 Mtoe by 2020.[89] A further 1 Mtoe of agricultural and agri-food residues, such as straw and seeds, may also be possible. Significant growth in imports is not anticipated.

[89] European Commission (2012), 'National Renewable Energy Action Plan: France'.

However, concerns have been expressed over the sustainability of biomass and its impacts on land use and on the local environment. This has been triggered in particular by Uniper's conversion of one of the units at the coal power station at Gardanne, near Aix-en-Provence, to burn biomass, with government subsidy, creating France's largest biomass power plant. Unit four of the plant, which started test operation in 2016, has a capacity of 150 MW of electricity and was expected to need 850,000 tonnes of feedstock per year. This was expected initially to be supplied from imports (including from Brazil) and local supplies, increasing over time to be 100 per cent locally sourced; half was expected to come from virgin timber and the rest from thinnings and wood residues.

Opponents took the case to court on the grounds that an inadequate assessment of the impact on local forests and other forest industries, such as pulp and paper, had been carried out; though national and local government, and trade unions, defended the project because of its potential for employment in a region once heavily dependent on coal. In June 2017, the administrative court in Marseille ruled that the company's impact study had indeed failed to take into consideration impacts on local forests, given the plant's projected consumption of 37 per cent of the forest resources within a 250 km radius, and cancelled the plant's operating licence. A week later, however, the prefecture of Bouches-du-Rhône granted a stay to the plant, suspending temporarily the Marseille court's ruling.[90] The issue has yet to be resolved.

Support for biomass energy

The development of biomass energy in France has been strongly supported by the government, particularly in the heating sector. Biomass in power generation is supported through premiums on the market price and energy saving certificates, while biomass in heat consumption receives financial support through the Heat Fund and tax credits. In addition, the 'Dynamic Bois' initiative finances the mobilization of wood energy feedstock from privately and publicly owned forests, and taxation of carbon creates a general incentive to favour renewables over fossil fuels.

Biomass in power generation is supported through premiums on the market price and energy saving certificates, while biomass in heat consumption receives financial support through the Heat Fund and tax credits.

Until 2016 renewable electricity generation was mainly supported through the obligation to purchase power from renewable sources. Small biomass combustion and CHP plants with capacity between 2 MW and 12 MW were given a purchase price, guaranteed for 20 years, of €0.043 per kilowatt hour (kWh), with an optional bonus of €0.077–0.125 per kWh depending on the plant's efficiency performance and resources used.[91] For larger plants, support was delivered through auctions, managed by the Energy Regulation Commission; the average unit cost of support for biomass plants in 2011 was €59 per MWh.[92] The new support scheme being introduced from 2016, however, began phasing out the purchase obligation and limited the duration of support to 10 years; premium tariffs

[90] Enerdata (2017), 'Uniper gets stay for Gardanne biomass-fired power plant in France', 13 June 2017, https://www.enerdata.net/publications/daily-energy-news/uniper-gets-stay-gardanne-biomass-fired-power-plant-france.html (accessed 24 Jan. 2018).
[91] La République Française (2016), 'Loi n° 2000-108 du 10 février 2000 relative à la modernisation et au développement du service public de l'électricité', https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000750321 (accessed 11 Aug. 2016); Ministry of Ecology, Sustainable Development and Energy (2013), *Report on progress in the promotion and use of energy from renewable sources*, Paris: Ministry of Ecology, Sustainable Development and Energy, http://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Article-22-France-report-EN.pdf (accessed 9 Aug. 2016).
[92] Ibid.

are to be allocated through a quasi-tendering process, where energy producers compete against each other for feed-in premium support.[93] Very small plants, less than 500 kilowatt (kW) capacity, will retain the old feed-in-tariff scheme.

The energy saving certificate scheme, introduced in 2006, requires all energy suppliers (power and heat) to reduce energy consumption among their customers; in October 2014, the government launched the third round of certificates, for 2015–17.[94]

The Heat Fund ('Fonds Chaleur'), established in 2009, is the main mechanism supporting biomass heat consumption.[95] It provides subsidies to renewable heat consumption, with the aim of ensuring that the price of renewable heat is about 5 per cent lower than conventional heat.[96] Eligible forms of biomass include wood, wood waste and residues, agricultural waste, industrial waste, and biodegradable products; imported wood can be used as long as it is temporary and limited in volume, and accompanied by an environmental evaluation. Funding ranges from €16 per toe to €95 per toe, depending on production capacity. In April 2015, the Energy Transition for Green Growth Act doubled the fund's budget to €420 million by 2017.[97] Between 2009 and 2016, the Heat Fund supported more than 1,000 small-scale installations in the housing and industrial sectors, reaching a total annual output of 1.4 Mtoe. Support for larger facilities (greater than 1,000 toe per year), through BCIAT (Biomass Heat Industry Agriculture Tertiaire), led to over 100 installations over the same period, accounting for 0.57 Mtoe of heat output.[98]

In addition, the Thermal Regulation Scheme that began to operate at the beginning of 2013 introduced measures to promote energy efficiency and renewable energy use in all new buildings.

The 2015 Energy Transition for Green Growth Act also launched a call ('Dynamic bois') for expressions of interest from private forest owners to provide support in mobilizing wood resources for energy, in association with the Heat Fund.[99] In 2015, €35 million was provided for 24 projects with the aim of mobilizing 4 million m³ of wood, mostly to be used in heating plants covered under the Heat Fund.[100] In 2016, a second Dynamic Bois call was launched to both private and public forest owners with a total budget of €20 million.[101] By August 2016, it was reported that 19 projects had been selected.[102]

The government also provides an energy transition tax credit ('Le crédit d'impôt transition énergétique') to promote the adoption of more efficient heating equipment in households.[103] Eligible equipment includes heating appliances operating on wood and other biomass. For heating or hot water production, the equipment must have an energy conversion efficiency of more than 70 per cent, and for biomass boilers at least 80 per cent. Any taxpayer is eligible to receive the tax credit, which amounts to €8,000 per person.[104]

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[93] Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: France,* https://www.eurobserv-er.org/pdf/renewable-energy-policy-factsheet-2017-france/ (accessed 24 Jan. 2018).
[94] Eurobserv'ER (2015), *Country policy profile: France.*
[95] ADEME (2016), 'Le Fonds Chaleur en bref'.
[96] Eurobserv'ER (2015), *Country policy profile: France.*
[97] ADEME (2016), *Fonds chaleurs 2016 – Secteur biomasse: Fiche descriptive et d'instruction*, Paris: ADEME, http://www.ademe.fr/sites/default/files/assets/documents/biomasse_fds_chal_mai_2016_23-05-16.pdf (accessed 11 Aug. 2016).
[98] Eurobserv'ER (2017), *Solid Biomass Barometer.*
[99] Ministry of Ecology, Sustainable Development and Energy (2015), *Energy Transition for Green Growth Act.*
[100] Ministère de l'Environnement, de l'Énergie et de la Mer (2016), *La transition énergétique pour la croissance verte*: *Dynamic Bois*, Paris: Ministère de l'Environnement, de l'Énergie et de la Mer, http://www2.developpement-durable.gouv.fr/DYNAMIC-Bois-24-projets.html (accessed 11 Aug. 2016).
[101] Ministère de l'Environnement, de l'Énergie et de la Mer (2016), 'Appel à manifestations d'intérêts Dynamic Bois', http://www.ademe.fr/sites/default/files/assets/documents/dynamic-bois-2016.pdf (accessed 11 Aug. 2016).
[102] Charpentier, M. (2016), 'Dynamic Bois: 19 nouveaux projets retenus', ActuEnvironnement, 4 August 2016, http://www.actu-environnement.com/ae/news/fonds-chaleur-dynamic-bois-projets-retenus-27316.php4 (accessed 11 Aug. 2016).
[103] European Commission (2012), 'National Renewable Energy Action Plan: France'.
[104] Ministère de l'Environnement, de l'Énergie et de la Mer (2016), 'Le crédit d'impôt transition énergétique', http://www.developpement-durable.gouv.fr/Le-credit-d-impot-transition (accessed 11 Aug. 2016).

In 2014, France introduced a carbon component (called a 'climate-energy contribution') into its existing structure of energy taxes on petrol, diesel and heating oil and consumption taxes on coal, gas and electricity.[105] The climate-energy contribution was introduced at a relatively low rate, alongside various exemptions and compensatory measures for industry and agriculture and low-income households, and was intended to rise steadily in the future. The 2015 Energy Transition Act increased it further, with the objective of reaching €100 per tonne of carbon dioxide by 2030. In 2017, the Macron government announced further rises, from €30.50 per tonne in 2017 to €44.60 in 2018, with further annual increases of about €10 a tonne, reaching €86.20 in 2022.[106] The revenue has been used to reduce taxation on employment and energy-saving measures, and direct compensation for low-income households.

Sustainability criteria

As noted, large-scale renewable energy, including biomass, is supported through tenders: companies bid for contracts to supply renewable energy at a set price above market rates. The sustainability criteria are set out in each call for tender; from 2016, they include sustainable forest management requirements (which can be met by FSC or PEFC-certified products), limits on emissions of particulates and nitrogen oxide, and a conversion efficiency of at least 75 per cent, which in practice rules out anything other than CHP plants. In addition, roundwood is not eligible. (These rules would have significantly affected the Gardanne biomass plant if they had been in place when the conversion began in 2012; not only is the plant sourcing roundwood, it is also an electricity-only station, with a conversion efficiency well below 75 per cent.)

[105] Rocamora, A. (2017), *The Rise of Carbon Taxation in France: from Environmental Protection to Low-Carbon Transition.* Kanagawa, Japan: Institute for Global Environment Strategies, https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwjPr43zpqPaAhWDLMAKHRPYDRUQFggrMAE&url=https%3A%2F%2Fpub.iges.or.jp%2Fpub_file-246%2Fdownload&usg=AOvVaw2Egie4zHo6i0BhtCe-hfjG (accessed 24 Jan. 2018).

[106] Reuters (2017), 'France raises carbon taxes, to repay EDF renewables debt', 27 September 2017, https://www.reuters.com/article/us-france-budget-carbon/france-raises-carbon-taxes-to-repay-edf-renewables-debt-idUSKCN1C21DL (accessed 24 Jan. 2018).

6. Germany

Table 8: Key renewable and biomass energy statistics, Germany

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.82	1.6%	9.5%	7.22	6.9%	74.5%	3.8%	9.9%
2016	0.93	1.8%	5.7%	9.57	8.7%	67.2%	4.7%	14.8%
Annual average growth		1.9%			4.1%		3.1%	5.9%
2020 target								18.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for woody biomass

In absolute terms, Germany, the EU's biggest economy and most populous country, was the largest consumer of biomass for total heat and power in the EU in 2016. It was the second largest consumer of heat from biomass, after France, and the second largest generator of electricity from biomass, after the UK. In proportional terms, however, biomass is less significant than in many other countries, partly because of the strength of other renewables, particularly wind and solar PV.

Wind is the main source of renewable electricity, supplying about 40 per cent in 2016; solar PV supplied about 20 per cent. Solid biomass accounted for only about 6 per cent of renewable electricity.[107] Biogas, mainly sourced from agricultural crops (primarily maize) and animal wastes, supplied three times as much renewable electricity (33 TWh compared to 11 TWh). Germany has invested more in electricity generation from biogas than any other EU member state; in 2015, it accounted for more than half of total EU generation of electricity from biogas.[108] (This has led to some concern about the impacts of sourcing mainly from agricultural crops, and from 2016 a cap was placed on the proportion of the feedstock deriving from crops.)

A large proportion of Germany's demand for electricity is driven by industry, where renewables are fast replacing fossil fuel-based power generation.[109] In contrast, the demand for heat is mostly driven by the residential sector. This demand is mostly met through natural gas and oil, though the share of renewables is increasing; in 2016, renewables contributed about 13 per cent of heat consumption, around two-thirds of which was supplied by solid biomass and a further sixth by biogas.[110]

[107] Federal Ministry of Economic Affairs and Energy (2016), 'Working Group on Renewable Energy Statistics (AGEE-Stat)', http://www.bmwi.de/EN/Topics/Energy/Energy-data-and-forecasts/working-group-on-renewable-energy-statistics,did=700522.html (accessed 8 Aug. 2016).
[108] EurObserv'ER (2017), *The State of Renewable Energies in Europe, 2016 Edition* (May 2017), https://www.eurobserv-er.org/pdf/2016/EurObservER-Annual-Overview-2016-EN.pdf (accessed 25 Jan. 2018).
[109] Thrän, D., Hennig, C., Rensberg, N., Denysenko, V., Fritsche, U.R., and Eppler, U. (2015), *IEA Bioenergy Task 40: Country Report Germany 2014*, Bioenergy Task 40 Country Report, http://www.iinas.org/tl_files/iinas/downloads/bio/IEA_BioT40_2015_Country-Report_Germany_2014.pdf (accessed 8 Aug. 2016).
[110] Federal Ministry of Economic Affairs and Energy (2016), 'Working Group on Renewable Energy Statistics (AGEE-Stat)', http://www.bmwi.de/EN/Topics/Energy/Energy-data-and-forecasts/working-group-on-renewable-energy-statistics,did=700522.html (accessed 8 Aug. 2016).

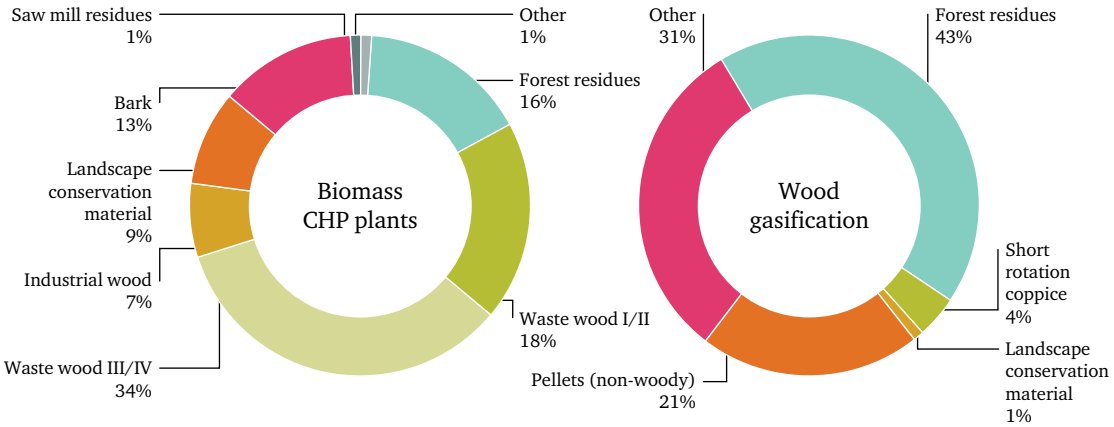
Germany is on course to meet and exceed its EU renewable energy target of 18.0 per cent by 2020.[111] Wind is expected to continue to be the main contributor to renewable electricity generation, though biomass will also play a role, mainly through combustion in CHP plants.[112] The country has a long-term goal of generating 80 per cent of electricity from renewables by 2050, with interim goals of 40–45 per cent by 2025, and 55–60 per cent by 2035 (the 2015 figure is 31 per cent).[113] In the heating sector, the use of renewables is expected to increase significantly, almost doubling compared to 2005 levels.[114] Biomass will remain the largest contributor to renewable heat consumption, at a projected 80 per cent or more by 2020. Given the larger share of heat in final energy consumption, by 2020 biomass is expected to account for nearly two-thirds of the country's renewable energy consumption.[115]

Biomass supply

Germany is the EU's third largest producer of roundwood after Sweden and Finland – 52 million m^3 in 2016 – most of which is used in industry.[116] This includes over 9 million m^3 of wood fuel, the EU's second largest production volume after France.

Most of the wood used for power and heat is consumed in CHP plants, of which there were 640 using solid biomass by the end of 2013, a ten-fold increase since 2000.[117] Figure 14 shows the feedstock used by these plants: mostly wood waste and forest residues. Many of the smallest plants (with a capacity of less than 1 MW of electricity) use wood gasification.

Figure 14: Biomass resources in solid biomass CHP plants in 2013

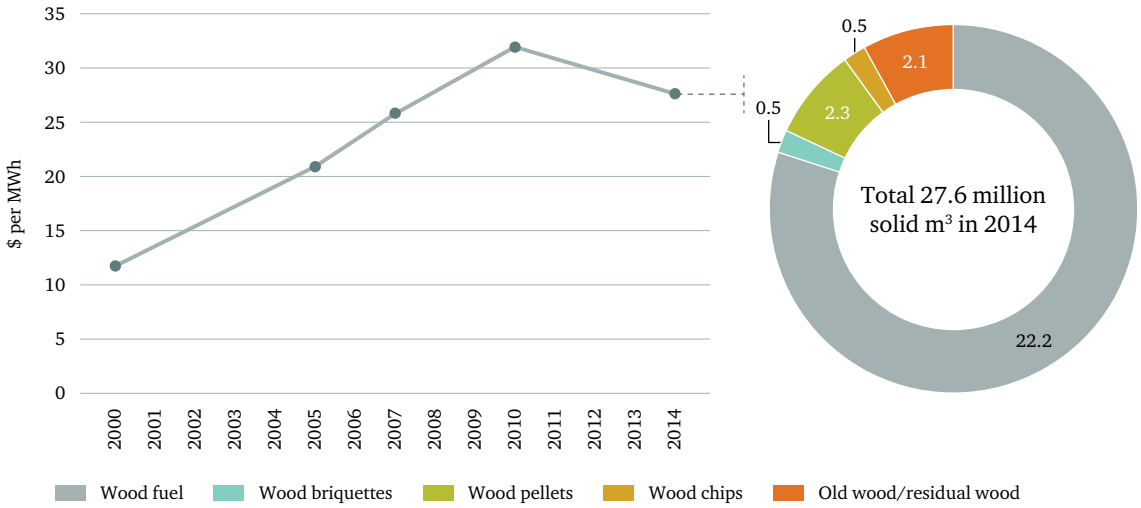


Source: Thrän, D., Hennig, C., Rensberg, N., Denysenko, V., Fritsche, U.R., and Eppler, U. (2015), *IEA Bioenergy Task 40: Country Report Germany 2014*, Bioenergy Task 40 Country Report, http://www.iinas.org/tl_files/iinas/downloads/bio/IEA_BioT40_2015_Country-Report_Germany_2014.pdf (accessed 8 Aug. 2016).
Note: Categories of waste wood refer to its quality: I is untreated; II, III and IV are treated with paint, glue and preservatives, respectively.

[111] European Commission (2012), 'National Renewable Energy Action Plan: Germany', https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans (accessed 5 Aug. 2016).
[112] Prognos AG, Institute of Energy Economics at the University of Cologne Universität, and Gesellschaft für wirtschaftliche Strukturforschung (2014), *Development of Energy Markets–Energy Reference Forecast: Executive Summary,* Report to the Federal Ministry of Economic Affairs and Energy, https://www.prognos.com/uploads/tx_atwpubdb/140716_Summary_42_pages_Energy_Reference_Forcast_2014_04.pdf (accessed 8 Aug. 2016).
[113] Eurobserv'ER (2015), *Progress report pursuant to Article 22 of Directive 2009/28/EC on the promotion of the use of energy from renewable sources*, http://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Article-22-Germany-report-EN.pdf (accessed 5 Aug. 2016).
[114] European Commission (2012), 'National Renewable Energy Action Plan: Germany'.
[115] Morris, C., and Pehnt, M. (2016), *Energy Transition, The German Energiewende* ,Berlin: Heinrich Böll Foundation, http://energytransition.de/wp-content/themes/boell/pdf/en/German-Energy-Transition_en.pdf (accessed 8 Aug. 2016).
[116] Eurostat data at http://ec.europa.eu/eurostat/web/forestry/data/database.
[117] Thrän et al. (2015), *IEA Bioenergy Task 40: Country Report Germany 2014.*

Solid biomass is also used in small to medium-sized heating systems, in households and commercial buildings; the feedstock is mainly logs (wood fuel), with much smaller amounts of wood pellets, chips and briquettes[118] (see Figure 15). (Note that this suggests much higher consumption of wood fuel than the Eurostat figures of 9–11 million m^3 per year recorded since 2010; it is likely that a significant volume of wood recorded under other headings by Eurostat is actually being used for energy.)

Figure 15: Use of wood for energy in private households



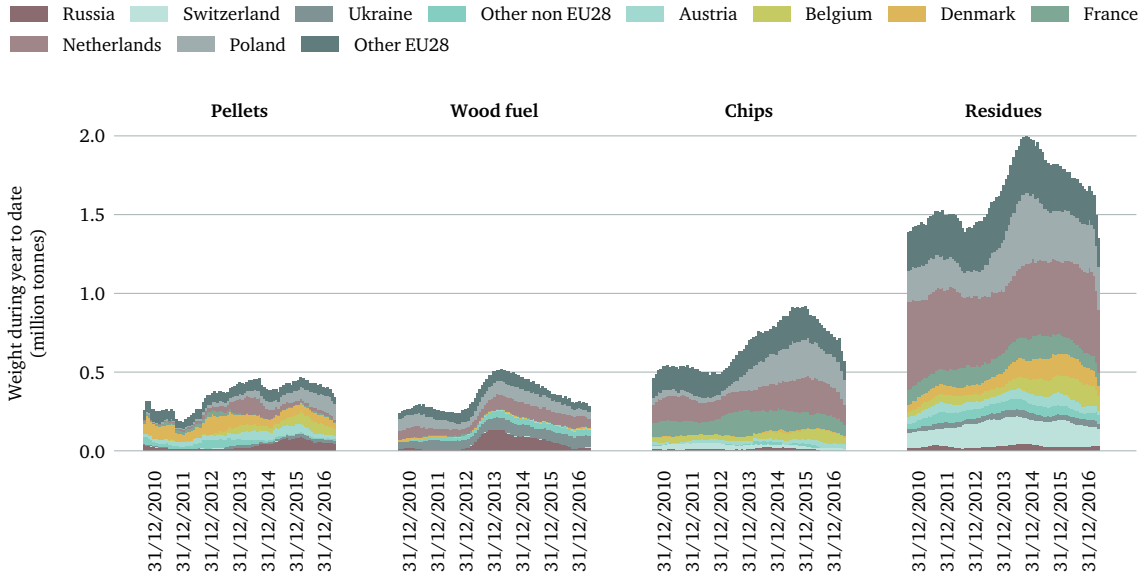
Source: German Agency for Renewable Resources (FNR), 'Bioenergy in Germany: Facts and Figures 2016', https://international.fnr.de/basisdaten/bioenergie/solid_fuels.html (accessed 20 Jan. 2018).

Wood pellets are primarily used in small to medium-sized heating stoves and boilers, which consumed in total about 2 million tonnes in 2013. Domestic pellet production has expanded rapidly since 2006 in response to this demand, and Germany is now the largest producer of wood pellets in the EU. About 60 pellet plants are in operation, mostly in the western and southern parts of the country, where large forested areas and wood-processing industries are located, with a capacity of about 3.3 million tonnes and annual production, since 2012, of about 2 million tonnes (1.93 million tonnes in 2016).[119] In recent years, however, increasing competition and a fall in activity in the sawmill industry, leading to a shortage of feedstock for pellets, has led to the closure of some of the smaller plants and a fall in capacity and production. Pellet exports have fallen and imports have risen and in 2016 roughly balanced each other out (see figures 16 and 17). Trade in wood chips, where Germany is a net exporter, and residues, where it is a net importer, is larger, but neither form of woody biomass is necessarily destined for use for energy.

As noted above, demand for biomass for energy is expected to increase, particularly for industrial process heat and for CHP; projections to 2020 suggest domestic supply of biomass reaching 1,000 PJ of primary energy, with demand reaching about 1,400 PJ.[120] Germany's National Biomass Action Plan anticipates closing this gap by increasing the use of forest and industry residues that are not in competition with food production or other material uses and by increasing the production of energy crops.

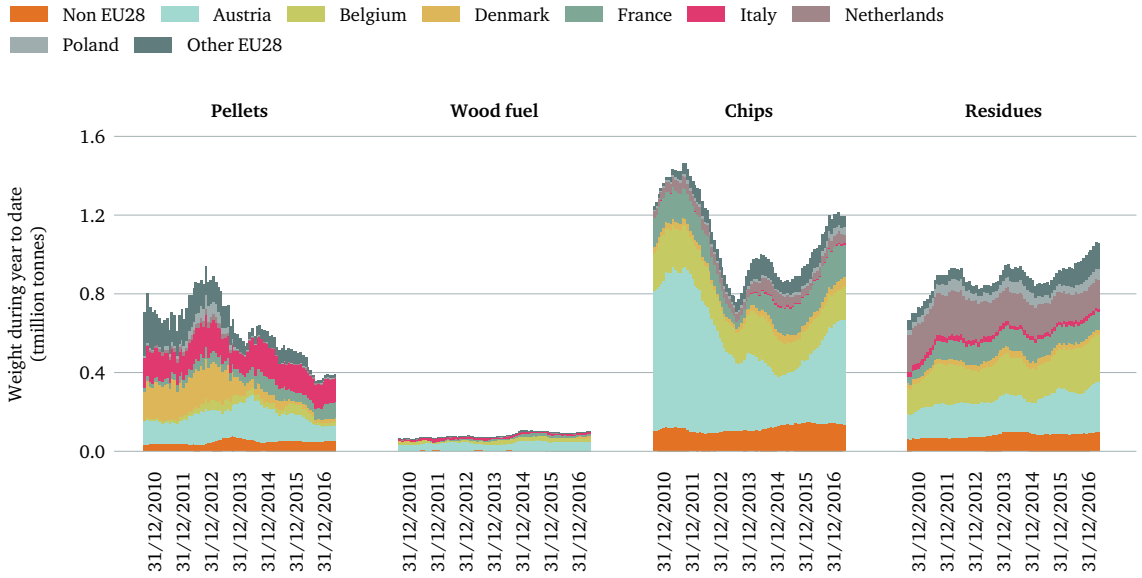
[118] Ibid.
[119] Ibid.; German Agency for Renewable Resources (FNR), 'Facts and Figures: Bioenergy – Solid Fuels', https://factsandfigures.fnr.de/bioenergie/festbrennstoffe/ (accessed 25 Jan. 2018); FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.
[120] Morris, C., and Pehnt, M. (2016), *Energy Transition, The German Energiewende;* European Commission (2012), 'National Renewable Energy Action Plan: Germany'.

Figure 16: Germany's imports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Figure 17: Germany's exports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Support for biomass energy

Germany's national laws, policy frameworks, and market mechanisms – together often referred to as the 'Energiewende' (energy transition) – have provided extensive support for the development of renewable energy for many years. For woody biomass these include feed-in tariffs and auctions under the Renewable Energy Act, support for CHP under the Combined Heat and Power Act, funding for biomass boilers under the Renewable Heat Act and bonuses for efficient biomass heating systems under the Market Incentive Programme. The Biomass Regulation requires electricity to be generated using only approved biomass sources, which excludes non-industrial residual wood waste, animal waste, sewage sludge, and peat.[121] Unlike several other EU member states, co-firing of biomass with coal is not supported.

Germany's national laws, policy frameworks, and market mechanisms – together often referred to as the 'Energiewende' (energy transition) – have provided extensive support for the development of renewable energy for many years.

Electricity generation from renewables has been supported by several successive pieces of legislation, most recently in 2017.[122] A feed-in-tariff system was introduced in 2000, with costs passed on to electricity consumers. In 2014 rates for biomass-powered plants ranged from €58.5 to €135.5 per MWh (depending on the size of the plant) paid on top of the market price; in new installations tariffs are reduced by 0.5 per cent per quarter.[123] Concerns over affordability led to a decision to replace the feed-in tariff with auctions for larger systems (for biomass, systems larger than 150 kW) from January 2017.[124] There is an annual target for each technology: for biomass, this is currently 100 MW of capacity per year (71 MW was built in 2015). Other forms of support include ensuring that renewable electricity has priority access to the grid and in transmission and distribution.

Renewable heat consumption is promoted through a range of instruments. The Renewable Energies Act encourages CHP by requiring at least 25 per cent of the electricity generated in a plant to be produced by CHP in its first year, followed by a minimum requirement of 60 per cent in subsequent years.[125] The Combined Heat and Power Act, which entered into force in 2009, provides subsidies for the construction and modernization of high-efficiency CHP plants. Heat generation from biomass is also supported through the Renewable Heat Act, which requires any new building owner to source a share of their heat from renewable energy systems, including wood-based boilers. Funding is available to homeowners, enterprises, and municipalities to introduce biomass-fired boilers with automatic feed systems (based on wood pellets), or highly efficient wood fuel gasifiers.[126] The law also requires public buildings to use renewables for heating and cooling when undertaking renovations.

The Market Incentive Programme has a target of increasing the share of renewable heating and cooling in buildings from around 10 per cent to 14 per cent by 2020. The installation of a biomass

[121] Federal Republic of Germany (2012), *Ordinance on the Generation of Electricity from Biomass (BiomasseV),* http://www.bmub.bund.de/fileadmin/bmu-import/files/english/pdf/application/pdf/biomasse_verordnung_en_bf.pdf (accessed 8 Aug. 2016).
[122] Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Germany*, https://www.eurobserv-er.org/pdf/renewable-energy-policy-factsheet-2017-germany/ (accessed 25 Jan. 2018).
[123] Appunn, K. (2014), 'Comparing old and new: Changes to Germany's Renewable Energy Act', Clean Energy Wire, 7 October 2014, https://www.cleanenergywire.org/factsheets/comparing-old-and-new-changes-germanys-renewable-energy-act (accessed 9 Aug. 2016).
[124] Morris, C., and Pehnt, M. (2016), *Energy Transition, The German Energiewende*; Appunn, K. (2016),' EEG reform 2016 – switching to auctions for renewables', Clean Energy Wire, 8 July 2016, https://www.cleanenergywire.org/factsheets/eeg-reform-2016-switching-auctions-renewables (accessed 9 Aug. 2016).
[125] Eurobserv'ER (2015), *Progress report pursuant to Article 22 of Directive 2009/28/EC on the promotion of the use of energy from renewable source.*
[126] Morris, C., and Pehnt, M. (2016), *Energy Transition, The German Energiewende.*

boiler with an output up to 100 kW in single or two-family houses receives a grant of up to €400.[127] The construction of a biomass boiler in combination with solar thermal to produce hot water, or to supplement the heating system, is eligible for a grant of €500, and increasing the efficiency of these systems in existing buildings receives a grant of €750. Larger installations, including biomass CHP plants with a heat production capacity of 100–2000 kW, and district heating networks, are supported with low-interest loans and partial debt write-offs.

Further policy measures may be introduced by the new government formed in March 2018; the coalition agreement includes commitments to increase the share of renewable electricity to 65 per cent by 2030 and to set a date in 2019 for the phase-out of coal in power generation.[128]

Sustainability criteria

Germany does not currently possess national sustainability criteria for solid biomass. Most stakeholders tend to regard it as unnecessary on the grounds that German forestry is sustainable and biomass energy mainly uses wastes and residues; imports are low in relation to output. As has been seen, support systems for renewable energy favour small-scale rather than large-scale bioenergy installations, feed-in-tariff rates for biomass are scheduled to fall steadily, and the auction system for new biomass plants is subject to an annual ceiling for new capacity.

[127] Eurobserv'ER (2015), *Progress report pursuant to Article 22 of Directive 2009/28/EC on the promotion of the use of energy from renewable source.*
[128] Clean Energy Wire (2018), 'Climate, energy and transport in Germany's coalition agreement', https://www.cleanenergywire.org/factsheets/climate-and-energy-germanys-government-coalition-draft-treaty (accessed 28 Feb. 2018).

7. Italy

Table 9: Key renewable and biomass energy statistics, Italy

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.24	0.8%	4.5%	7.79	12.6%	76.5%	6.1%	12.8%
2016	0.35	1.3%	3.7%	7.12	12.8%	67.6%	6.2%	17.4%
Annual average growth		5.5%			-1.3%		0.2%	4.5%
2020 target								17.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for woody biomass

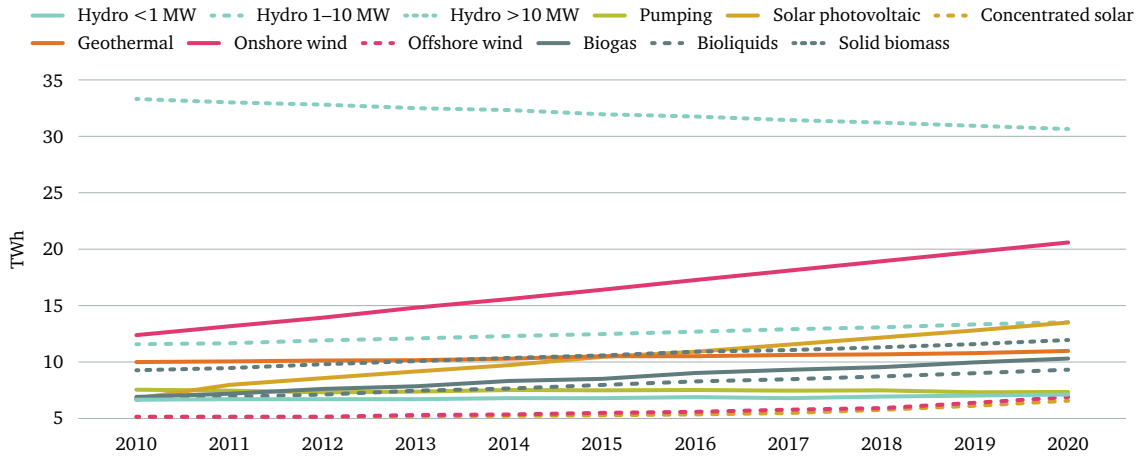
Like France, Italy has chosen to encourage the use of biomass more for heat consumption than for electricity. In 2016, it had the fourth highest consumption of heat from biomass in the EU, though this has actually fallen slightly since 2009, along with total energy consumed as heating and cooling. Italy is on track to exceed its Renewable Energy Directive target of 17 per cent of energy from renewables by 2020; current projections suggest it will achieve almost 20 per cent.[129]

About a third of the country's total consumption of electricity is generated from renewables, but less than 4 per cent of this is sourced from biomass; hydro accounts for the lion's share – 42 per cent in 2016 – with solar and wind between them accounting for a further 35 per cent. The fastest rate of growth in the future is expected in wind and solar, though some further expansion of biomass is also projected (see Figure 18). The government's National Energy Strategy published in 2013 projects the share of renewables to be 34–38 per cent of total electricity generation, and 19–20 per cent of gross final energy consumption, by 2020, and about 60–65 per cent of gross final energy consumption by 2050.[130] It also contains the objective of reducing energy consumption through improving energy efficiency.

About 19 per cent of energy for heating and cooling was sourced from renewables in 2016; about two-thirds of this was from solid biomass. As set out in Italy's National Renewable Energy Action Plan, and in the 2013 National Energy Strategy, the rate of growth of biomass for heat is expected to continue in the future, though there are no specific targets (see Figure 19).[131]

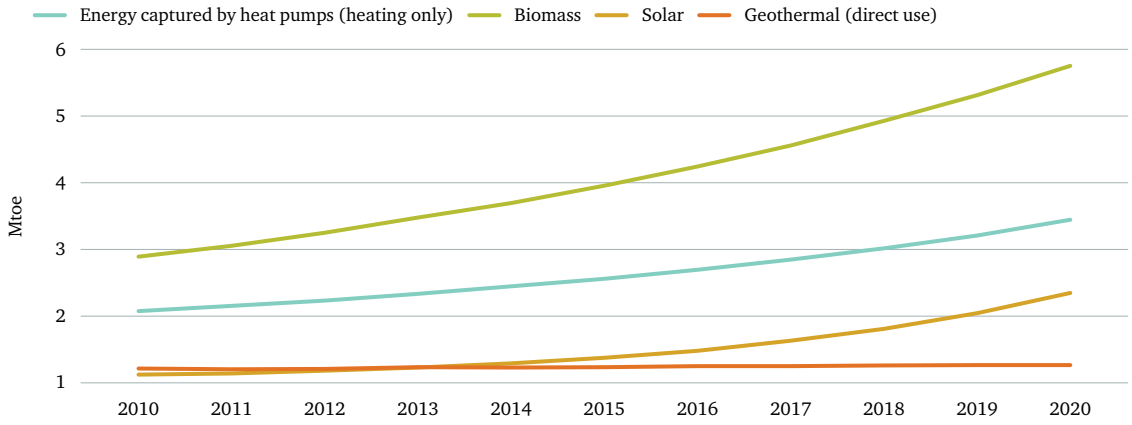
[129] European Commission (2012), 'National Renewable Energy Action Plan: Italy', https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans (accessed 15 Aug. 2016).
[130] Ministry of Economic Development (2013), *Italy's National Energy Strategy*, http://www.sviluppoeconomico.gov.it/images/stories/documenti/SEN_EN_marzo2013.pdf (accessed 15 Aug. 2016); Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Italy,* https://www.eurobserv-er.org/pdf/renewable-energy-policy-factsheet-2017-italy/ (accessed 31 Jan. 2018).
[131] Deloitte Conseil (2015), *European energy market reform, Country profile: Italy*, https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-er-market-reform-italy.pdf (accessed 15 Aug. 2016).

Figure 18: Italy's gross production of electricity from renewable sources, 2010–20



Source: European Commission (2012), 'National Renewable Energy Action Plan: Italy', https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans (accessed 15 Aug. 2016).

Figure 19: Italy's gross production of heat from renewable sources, 2010–20[132]



Source: European Commission (2012), 'National Renewable Energy Action Plan: Italy', https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans (accessed 15 Aug. 2016).

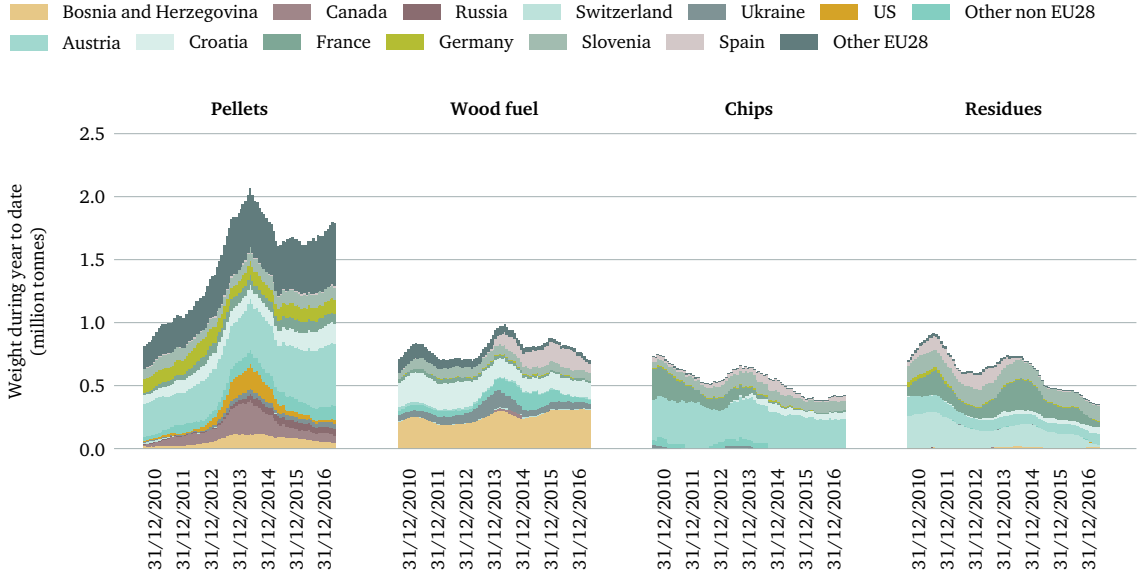
Biomass supply

Like other countries, the main source of Italy's use of biomass for energy is wood, particularly wood fuel, which supplies the majority of biomass used for heat in the residential sector, mostly in individual stoves and fireplaces.[133] Locally sourced wood chips are also used in residential heating units, though they are more commonly used in CHP plants and district heating, particularly in the smaller systems. Wood pellets are increasingly used for commercial and residential space heating.

[132] European Commission (2012), 'National Renewable Energy Action Plan: Italy'.
[133] Cocchi, M. (2012), *IEA Bioenergy Task 40, Country Profile: Italy*, http://www.bioenergytrade.org/downloads/iea-task-40-country-report-2011-italy.pdf (accessed 15 Aug. 2016).

Although Italy has a thriving wood furniture industry – third largest in the world in 2013, after China and the US – it is not a significant producer of roundwood from its own forests.[134] Accordingly, it is a major importer of wood, including pellets and wood fuel for energy use. In 2016, the country imported about 1.7 million tonnes of wood pellets, making it the EU's third largest pellet importer after the UK and Denmark. As shown in Figure 20, wood pellet imports, mostly from within the EU (Austria is the largest single supplier), increased rapidly between 2010 and 2014, but, excluding a steep decline in imports from North America during 2015, have changed little overall since then. Imports of wood fuel are very high compared to other EU member states; the main sources are Bosnia and Herzegovina and Croatia, with significant imports also from Ukraine, Slovenia and Spain.

Figure 20: Italy's imports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

There is also considerable domestic production of wood pellets, reaching approximately 400,000 tonnes in 2016.[135] Substantial quantities of wood chips and residues are also imported, but in declining quantity and not necessarily to be burnt for energy. Exports of all these forms of wood are negligible.

Italy's National Renewable Energy Action Plan included an expectation of increased competition for land use in the future between the food, energy, wood products and transport sectors.[136] The government is consequently aiming to develop its domestic supply of biomass energy feedstock, mainly from agricultural residues and related by-products; significant growth is expected from crop and livestock farming, and the agro-industry sector. Increased wood extraction from domestic forests for energy purposes is not anticipated.

[134] UNECE and UNFAO (2013), *Forest Products Annual Market Review 2012–2013*, https://www.unece.org/fileadmin/DAM/timber/publications/FPAMR2013.pdf (accessed 16 Aug. 2016).
[135] FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.
[136] European Commission (2012), 'National Renewable Energy Action Plan: Italy'.

Support for biomass energy

Italy has provided support for the development of biomass energy, alongside other forms of renewables, through a number of policy frameworks, including a tradable renewable energy certificate scheme ('green certificates'), feed-in tariffs, the Heat Account incentive, tax deductions and loans. These systems have proved highly effective in supporting renewable energy but, as a result, have led to concerns over their costs, and they have been scaled back in recent years. For biomass, policy and financial support has been focused more on heat than on power.

Italy's systems have proved highly effective in supporting renewable energy but, as a result, have led to concerns over their costs, and they have been scaled back in recent years.

The tradable green certificate scheme, which operated between 1999 and late 2012, required producers and importers of non-renewable electricity to inject a minimum quota of renewable electricity into the grid every year.[137] Eligible technologies received a different number of certificates per amount of electricity generated, depending on their cost, with the aim of avoiding excessive subsidies to the cheaper technologies. After the overall quota was met in every year since 2006, the system was ended in 2012.

Small-scale renewables, including biomass, for plants with a capacity below 1 MW, are supported through an all-inclusive feed-in-tariff scheme ('Tariffa Onnicomprensiva').[138] Electricity generated from biomass, based on forest and agricultural by-products and waste, is eligible to receive €180–€257 per MWh, depending on the size of the plant, for 15 years. Larger renewable plants, with a capacity above 5 MW, are eligible for a tendering mechanism featuring base tariffs for different renewable sources: bidders offer prices (percentage reductions of the base tariffs) and receive this premium in case of a successful tender.[139]

In the heating sector, biomass energy is mainly supported through the Heat Account ('Conto Termico'), introduced in 2013, which provides financial support for the construction of renewable heating systems and energy efficiency improvements in existing private and public buildings.[140] This incentive, which has an annual budget of €900 million (financed through a levy on gas-fired energy) provides support for between two and five years, and is calculated based on the technology type, size of the project (capacity), particulate matter emissions, and the specific climate zone.[141] For example, the installation of a low-emission biomass boiler with a capacity of 35 kW would receive up to €4,250 per year, depending on the climate zone, for a maximum of two years. A similar heating system installed in an agricultural greenhouse would receive half of that, but for up to a maximum of five years. The majority of biomass projects that have received financial support under the Heat Account are small pellet-based heating systems.

[137] International Energy Agency (2016), *Energy Policies of IEA Countries: Italy, 2016 Review*, https://www.iea.org/publications/freepublications/publication/EnergiePoliciesofIEACountriesItaly2016Review.pdf (accessed 31 Jan. 2018).
[138] Eurobserv'ER (2015), Country policy profile: Italy, https://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Country-Profile-2015-12-Italy.pdf (accessed15 Aug. 2016); European Commission (2012), 'National Renewable Energy Action Plan: Italy'.
[139] Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Italy.*
[140] Gestore dei Servizi Energetici (2016), 'Heating and cooling', http://www.gse.it/en/Heating_Cooling/Pages/default.aspx (accessed 17 Aug. 2016).
[141] Governo Italiano, Ministero dello sviluppo economico (2016), 'Decreto interministeriale 16 febbraio 2016', http://www.sviluppoeconomico.gov.it/images/stories/normativa/decreto_interministeriale_16_febbraio_2016_aggiornamento_conto_termico.pdf (accessed 11 May 2018).

Individuals or businesses upgrading to biomass heating systems are also eligible to receive a personal or corporate tax deduction of 55 per cent spread across 10 years for expenditure incurred as a result of the upgrade.[142]

In addition to these systems, the Kyoto Revolving Fund, which operated between 2012 and 2016 (when its budget was exhausted), provided loans of up to €1 million, with a yearly nominal interest rate of 0.5 per cent, for upgrading larger-scale renewable energy facilities, including biomass-fuelled thermal plants with a capacity over 5 MW.[143] Italy's system of tradable energy efficiency certificates ('white certificates') has also provided support for CHP installations, including biomass plants, alongside other energy efficiency investments. Energy taxes are relatively low, but renewables, including biomass, are exempt.

Sustainability criteria

In 2016, the government issued a decree defining the types of biomass and biogas feedstocks to which feed-in tariffs are restricted.[144] The decree includes agricultural and livestock wastes and residues, and by-products from forest management and from the processing of forest products. Roundwood is not included.

[142] Government of Italy (2013), *Italy's Second Progress Report under Directive 2009/28/EC*, Rome: Government of Italy, http://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Article-22-Italy-report-EN.pdf (accessed 15 Aug. 2016).
[143] RES Legal (2016), 'Loan (Fondo Kyoto)', http://www.res-legal.eu/search-by-country/italy/single/s/res-hc/t/promotion/aid/loan-fondo-kyoto/lastp/151/ (accessed 16 Aug. 2016).
[144] Ministry of Economic Development (2016), Decree of 23 June 2016: 'Incentives for electricity produced from renewable sources other than photovoltaics', http://www.gazzettaufficiale.it/eli/id/2016/06/29/16A04832/sg (accessed 31 Jan. 2018).

8. Poland

Table 10: Key renewable and biomass energy statistics, Poland

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.42	3.3%	56.5%	4.11	11.3%	98.1%	7.0%	8.7%
2016	0.59	4.1%	30.8%	5.17	13.9%	94.5%	8.3%	11.3%
Annual average growth		5.0%			3.3%		2.5%	3.8%
2020 target								15.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for woody biomass

Poland is a significant user of biomass for energy; in 2016, it generated the fifth highest quantity of electricity from biomass in the EU and consumed the sixth highest quantity of heat. This is partly because, compared to other countries, other sources of renewable energy are not well developed in Poland; renewables only supplied 13 per cent of electricity in 2016. Biomass and wind each accounted for about 40 per cent of this; they have both grown relatively quickly since 2009, but from a low base.

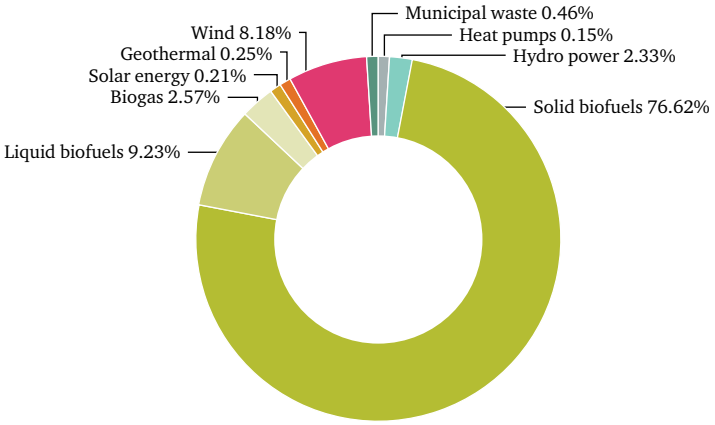
> Compared to other countries, other sources of renewable energy are not well developed in Poland; renewables only supplied 13 per cent of electricity in 2016.

The vast majority of the electricity generated from biomass is through co-firing in coal stations; Poland's economy is still heavily dependent on coal. More than a quarter is generated by the Polaniec power station in southern Poland, which has increased its biomass burn steadily over the last 10 years and converted one of its eight coal units to fully fire biomass in 2012.[145]

As in most other EU member states, biomass is a significant contributor to renewable heat, supplying about 95 per cent of the renewable heat total (which itself represented 14 per cent of total heat) in 2016. In combination, biomass accounts for over 75 per cent of all renewable energy (see Figure 21).

[145] Sandbag (2017), *Something Nasty in the Woodshed.*

Figure 21: Structure of Poland's primary energy production from renewable sources in 2014



Source: Central Statistical Office of Poland (2016), *Energy*, http://stat.gov.pl/files/gfx/portalinformacyjny/en/defaultaktualnosci/3304/1/4/1/energy2016.pdf (accessed 18 Aug. 2016).

Under Poland's National Renewable Energy Action Plan, the government expects energy consumption to increase, by 13 per cent between 2010 and 2020 and by a further 16 per cent by 2030.[146] This helps to explain why, even though renewables are projected to continue to expand, they are anticipated to account for only 16 per cent of gross final energy consumption by 2030, only 1 per cent higher than Poland's Renewable Energy Directive target of 15 per cent by 2020. The use of biomass for heat and power is expected to continue to grow, and to continue to supply the bulk of renewable energy.

Biomass supply

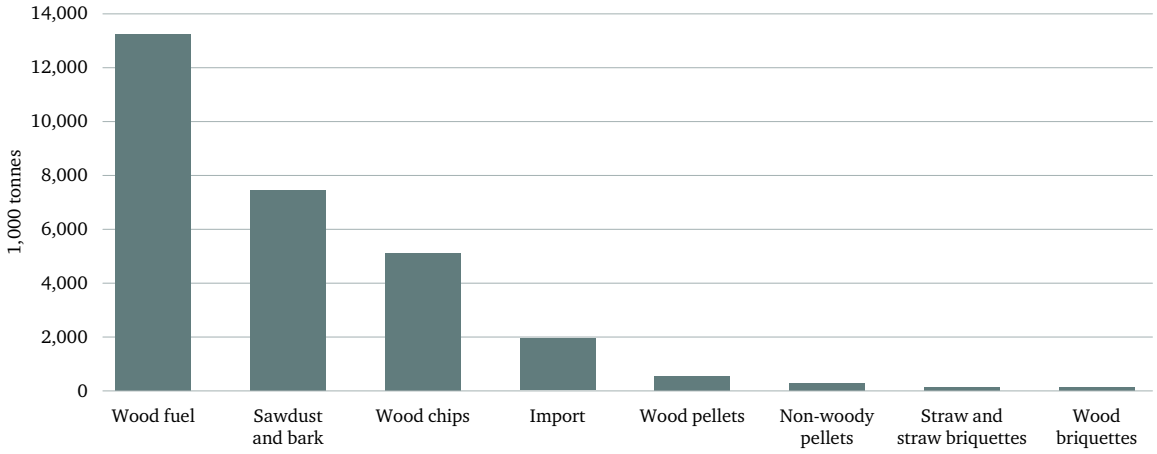
Poland has a relatively large forest industry, producing 42 million m³ of roundwood (under bark) in 2016.[147] According to the country's National Renewable Energy Action Plan, wood from domestic forests and other wooded land provided the majority of domestic biomass energy supply in 2012, amounting to 12.6 million m³ (though the government also acknowledged that data on direct and indirect supplies and imports is inadequate).[148]

Wood fuel is mainly used in the residential sector for space and water heating; in 2014, it accounted for 13 per cent of the energy consumed in Polish households.[149] Industrial and domestic waste is more commonly used in industry for process heat.[150] Coal stations co-firing biomass generally use wood chips and pellets.

[146] European Commission (2012), 'National Renewable Energy Action Plan: Poland', https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans (accessed 18 Aug. 2016).
[147] Eurostat data at http://ec.europa.eu/eurostat/web/forestry/data/database.
[148] Ministry of Economy (2014), *Interim Report on progress in the promotion and use of energy from renewable sources in Poland in 2011–2012*, http://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Article-22-Poland-report-EN.pdf (accessed 18 Aug. 2016).
[149] Central Statistical Office of Poland (2016), *Energy*.
[150] International Renewable Energy Agency (2015), *REMap 2030: Renewable energy prospects for Poland, Background Paper*, http://www.irena.org/DocumentDownloads/Publications/IRENA_REmap_Poland_paper_2015_EN.pdf (accessed 18 Aug. 2016).

Pellet production has climbed sharply since 2003, reaching 780,000 tonnes in 2016.[151] In 2012 about two-thirds was produced from wood residues (mainly sawdust) and a third from agricultural residues (mainly straw).[152] Overall, however, pellets supply only a small (though growing) proportion of total biomass energy (see Figure 22).

Figure 22: Sources of solid biomass for energy in Poland, 2012



Source: Wach, L. (2014), 'Pellet Market in Poland', Baltycka Agencja Poszanowania Energii SA, presentation at 4th Central European Biomass Conference, 15 January 2014.

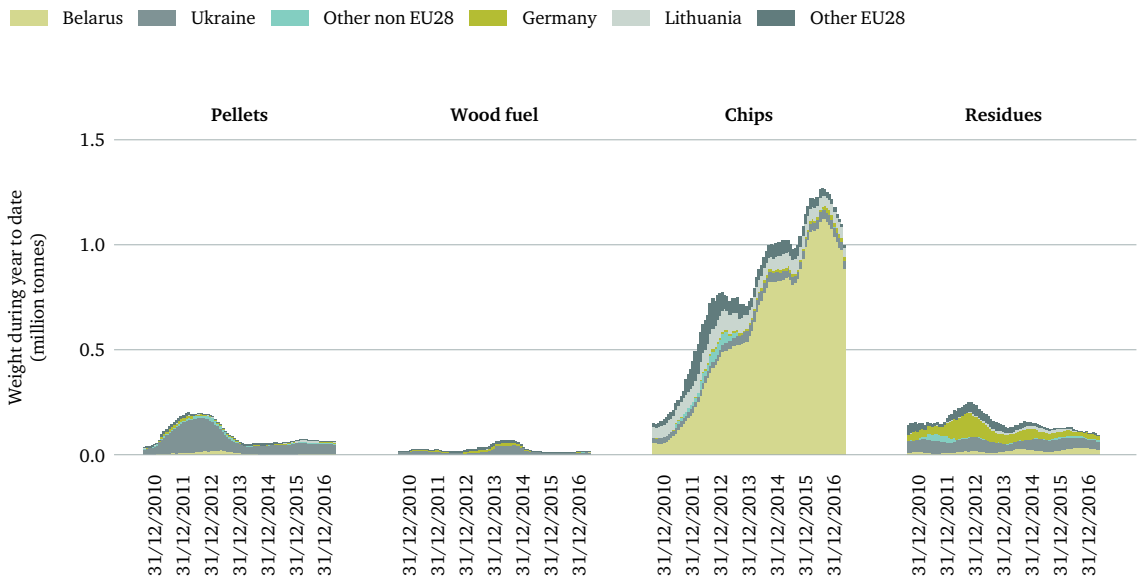
As can be seen from figures 23 and 24, Poland is now a net exporter of pellets, wood fuel and wood residues, mainly to Denmark and Germany (with some imports from Ukraine). It is also a substantial net importer of wood chips, mainly from Belarus. Much woody biomass is traded in Poland by brokers and by the owners of power stations; the increase in imports of wood chips reflects the increased use of biomass in power stations, through both co-firing and dedicated biomass.[153] Both Belarus and Ukraine have problems with illegal logging, so there is a possibility at some stage of imports falling foul of the requirements of the EU Timber Regulation.

In terms of future supply, Poland's National Renewable Energy Action Plan included proposals to increase sourcing from agricultural by-products, industrial waste and energy crops, and not from woody biomass.[154] Indeed, implementation of the Natura 2000 programme, a network of protected forest areas across the EU, was expected to reduce the future availability of biomass for energy from Poland's forests; a reduction of 2.74 million m^3 was projected from 2009 to 2020.

However, in January 2017, the government legislated to remove the obligation on private landowners to apply for permission to cut down trees, pay compensation or plant new trees, or to inform local authorities that trees had been or will be removed – though after protest the last provision was dropped.[155] Fines for non-compliance were also drastically reduced. The new legislation led to a surge in tree-felling, and is likely to make logging for infrastructure development more likely.

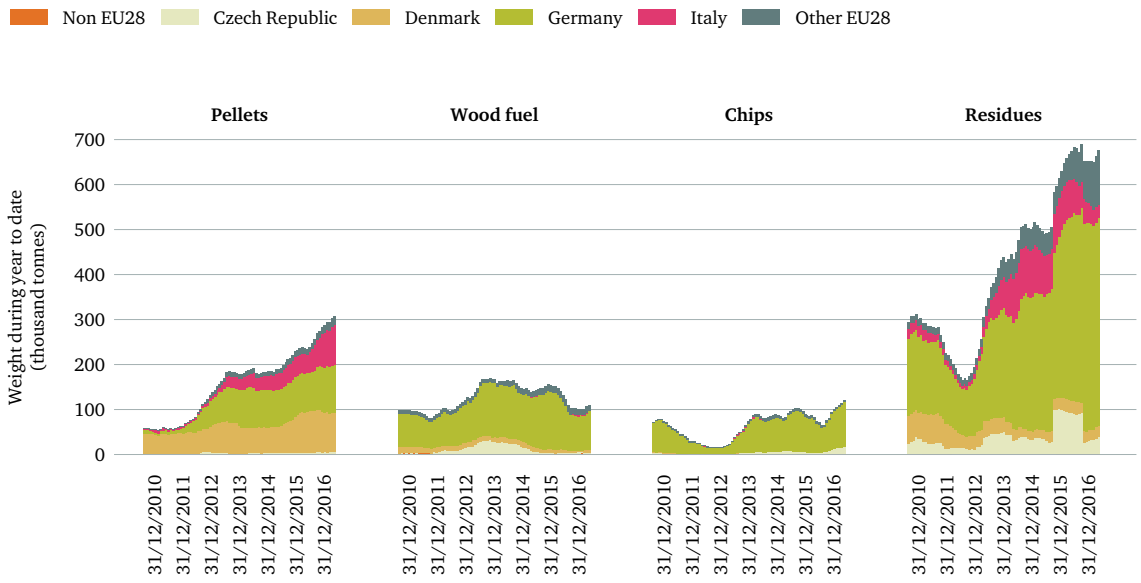
[151] FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.
[152] Wach, L. (2014), 'Pellet Market in Poland', Baltycka Agencja Poszanowania Energii SA, presentation at 4th Central European Biomass Conference, 15 January 2014.
[153] Bioenergy for Business (2015), 'Country summary reports: Poland', http://www.bioenergy4business.eu/country-summary-reports/ (accessed 19 Aug. 2016).
[154] European Commission (2012), 'National Renewable Energy Action Plan: Poland'.
[155] Davies, C. (2017), 'Polish law change unleashes "massacre" of trees', *The Guardian*, 7 April 2017, https://www.theguardian.com/environment/2017/apr/07/polish-law-change-unleashes-massacre-of-trees (accessed 8 Nov. 2017).

Figure 23: Poland's imports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Figure 24: Poland's exports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Support for biomass energy

Support for biomass power and heat is provided through a range of policy mechanisms including auctions, a feed-in-tariff scheme, tax relief, loans and subsidies. Poland provides greater support for biomass power than for biomass heat; as of 2016, there were no legislative frameworks supporting renewable heat consumption, though financial support is available through loans and subsidies.

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Until 2016, renewable power was supported through a quota system under which electricity generators and suppliers were obliged to purchase a set amount of renewable energy through a system of renewable energy certificates.[156] In 2015, a certificate from an eligible biomass-fired power plant cost PLN 303 (about €69). The system led to an over-supply of certificates, gave a substantial boost to co-firing with coal, where investment costs were lower than other renewables, and delayed the expansion of other technologies.[157]

As a result, in 2016, the quota system was replaced for new installations (existing installations remain on the old scheme).[158] Under the new system, very small installations (up to 40 kW) are supported through a version of a net-metering system, with discounts (of 70 or 80 per cent, depending on size) on the electricity price for the amount of electricity fed into the grid. Medium-sized installations with a capacity of up to 500 kW receive a feed-in tariff. Large plants, above this capacity, are entitled to a premium system, based on auctions: beneficiaries receive the premium when the market price of electricity is below the bidding price submitted in the auction, for 15 years. Generators co-firing with biomass are eligible to bid provided that at least 15 per cent of the input fuel is biomass. So far, two auctions have been conducted, in December 2016 and June 2017. These support schemes are financed by a levy on electricity consumers. In addition, operators producing renewable electricity are exempt from excise duty, saving them PLN 20 (€4.60) per MWh.[159]

Loans and subsidies are also available from a variety of sources for the installation of small and large-scale biomass power and heating systems, though policy in this area is currently undergoing a process of revision.[160]

Sustainability criteria

Under the old green certificates system, the use of roundwood in large installations (greater than 5 MW) was not eligible for support. Only residues were allowed and a minimum (increasing) share of agricultural biomass was required. New criteria are due to be drawn up to accompany the new system of support, but these have not yet been finalized.

[156] RES Legal (2016), 'Legal sources on renewable energy: Poland, Overall summary', http://www.res-legal.eu/search-by-country/poland/tools-list/c/poland/s/res-e/t/policy/sum/176/lpid/175/ (accessed 18 Aug. 2016).
[157] International Renewable Energy Agency (2015), *REMap 2030: Renewable energy prospects for Poland;* Wach (2014), 'Pellet Market in Poland'.
[158] European Commission (2017), 'State aid: Commission approves PLN 40 billion (around €9.4 billion) Polish support scheme for renewable energy', 13 December 2017, http://europa.eu/rapid/press-release_IP-17-5261_en.htm (accessed 29 Jan. 2018); Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Poland*, https://www.eurobserv-er.org/pdf/renewable-energy-policy-factsheet-2017-poland/ (accessed 29 Jan. 2018).
[159] Ministry of Economy (2014), *Interim Report on progress in the promotion and use of energy from renewable sources in Poland in 2011–2012*, http://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Article-22-Poland-report-EN.pdf (accessed 18 Aug. 2016).
[160] RES Legal (2016), 'Legal sources on renewable energy: Poland, Overall summary'; Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Poland.*

9. Romania

Table 11: Key renewable and biomass energy statistics, Romania

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.00	0.0%	0.1%	3.75	26.3%	99.3%	15.8%	22.7%
2016	0.04	0.8%	1.8%	3.47	26.5%	98.8%	14.7%	25.0%
Annual average growth		72.8%			-1.1%		-1.0%	1.4%
2020 target								24.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as a percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for woody biomass

Romania, one of the newest member states of the EU, has a much smaller economy than the other countries analysed in this paper; in terms of GDP it is the EU's second poorest country. In 2016, it was the ninth highest consumer of biomass for heating in the EU. It has already exceeded its Renewable Energy Directive target for 2020, mostly through increasing its output of renewable electricity, though biomass hardly features at all in this sector.

In 2016, renewables accounted for 43 per cent of electricity generated, 64 per cent of which was from hydro and 25 per cent from wind; biomass accounted for less than 2 per cent. Wind and solar have both grown very quickly and are projected to continue to do so, according to Romania's National Renewable Energy Action Plan; biomass electricity is also expected to grow, to an estimated 6 per cent of renewable power by 2020.[161]

Biomass is far more extensively used for heat, providing 99 per cent of total renewable heat consumption in 2016; roughly half of this was used for residential space and water heating.[162] This is a reflection more of the historically limited use of fossil fuels, particularly in rural areas, rather than of policy support for renewable heat. It is also expected to continue to grow, though fairly slowly, alongside growth in energy consumption as a whole. The National Renewable Energy Action Plan included an expansion of renewable heat consumption from 3.8 Mtoe in 2009 to 4.0 Mtoe in 2020, though in fact it has fallen since 2010, to 3.5 Mtoe in 2016.[163] A set of scenarios published by the World Bank in 2016 suggested that energy consumption in Romania will increase in industry while falling in the domestic sector, given improvements in the efficiency of domestic heating appliances and a fall in population.

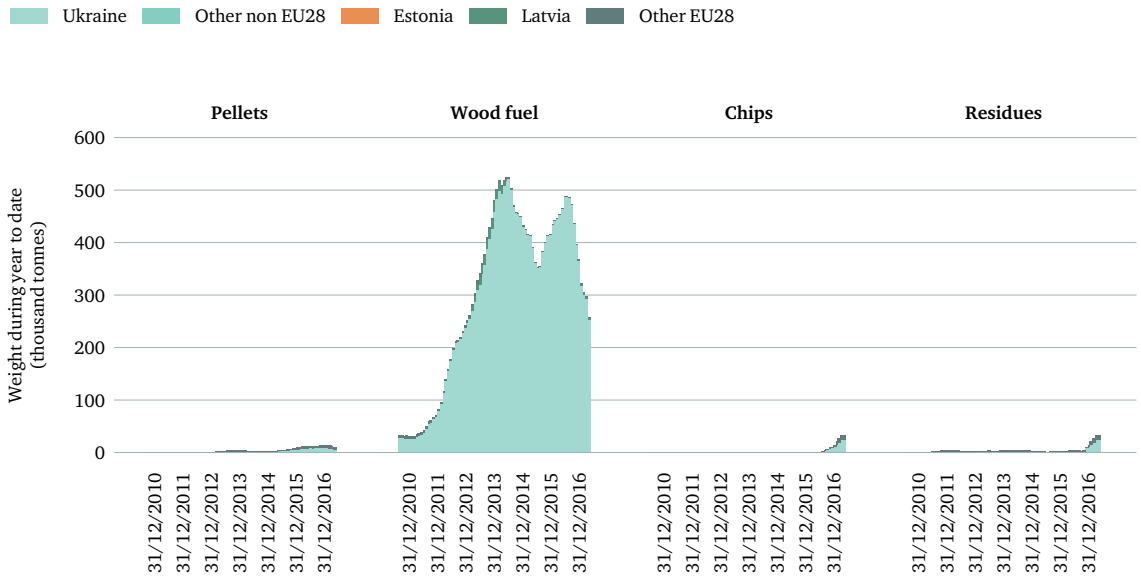
[161] European Commission (2012), 'National Renewable Energy Action Plan: Romania', https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans (accessed 22 Aug. 2016).
[162] Malla, S., and Timilsina, G. R. (2016), *Long-Term Energy Demand Forecasting in Romania: Modeling Approach*, World Bank, http://documents.worldbank.org/curated/en/982171467993734307/pdf/WPS7697.pdf (accessed 22 Aug. 2016).
[163] European Commission (2012), 'National Renewable Energy Action Plan: Romania'.

Biomass supply

Romania possesses a sizeable forest industry, producing about 15 million m³ of roundwood (under bark) in 2016, including 5 million m³ of wood fuel.[164] Wood from forests represents the country's largest source of biomass energy, particularly for private heating systems.[165] Wood chips from short rotation plantations, such as willow and poplar, are also used in local heating systems, while sawdust and bark are more commonly used in power plants.[166] By 2015, Romania had eight CHP plants using biomass, with a total installed capacity of 134 MW.[167]

Domestic production is not enough to satisfy demand, so Romania imports a substantial quantity of wood fuel (almost half a million tonnes in 2016), almost entirely from Ukraine (see Figure 25).

Figure 25: Romania's imports of woody biomass potentially for energy, 2010–16



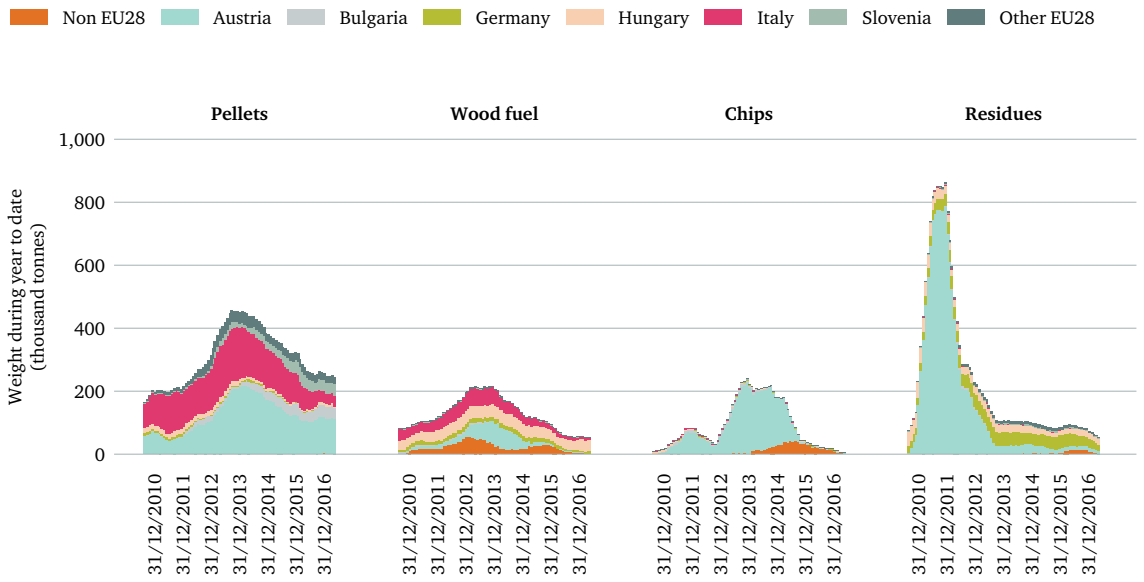
Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

As in other EU countries, pellet production has grown quickly, primarily using chips and sawdust from the expanding wood processing industries, and also agricultural residues such as straw. By 2016, pellet production had reached 700,000 tonnes; government forecasts suggested capacity of 1.2 million tonnes by 2020.[168] Domestic consumption of pellets is relatively low, as most power stations and domestic heating systems are not equipped to use them, so significant amounts are exported, mainly to Austria and Italy (see Figure 26). Exports have fallen from about 450,000 tonnes in 2013 to about

[164] Eurostat data at http://ec.europa.eu/eurostat/web/forestry/data/database.
[165] Borz, S. A., Derczeni, R., Popa, B., and Nita, M. D. (2013), *Regional Profile of the Biomass Sector in Romania*, FOROPA, http://www.foropa.eu/files/country_reports/country%20report%20romania.pdf (accessed 22 Aug. 2016).
[166] PelletsAtlas (2009), *Pellet country report: Romania*, Austria: Holzforschung Austria, http://pelletsatlas.info/wp-content/uploads/2015/09/Romania_CR.pdf (accessed 22 Aug. 2016).
[167] Borz et al.(2013), *Regional Profile of the Biomass Sector in Romania.*
[168] FAOSTAT data at http://www.fao.org/faostat/en/#data/FO; Sfaca, D. (n.d.) 'Romania: The characteristics and potential of the wooden pellets and briquettes', Romanian Pellets and Briquettes Association, http://docplayer.net/22691373-Romania-the-characteristics-and-potential-of-the-wooden-pellets-and-briquettes.html (accessed 29 Jan. 2018).

250,000 tonnes in 2016, however; whether this is due to falling production or rising domestic consumption, or both, is not known. Stakeholders in Romania's biomass industry have anticipated greater domestic use of wood pellets for heating.[169]

Figure 26: Romania's exports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

In recent years, local, national and international concerns have been expressed over illegal behaviour in the supply of logs from Romania, particularly in relation to export-oriented sawmills, some of which supply substantial quantities of wood pellets as by-products.[170] The Romanian government has estimated that roughly half of all logs extracted from Romanian forest are illegally sourced, and has described illegal logging as a threat to national security. The EU Timber Regulation, if fully enforced, could accordingly have a major impact on these sources of supply.

There are also some doubts about the legality of imports of wood fuel from Ukraine.[171] In July 2015, Ukraine introduced a 10-year ban on exports of non-coniferous species of roundwood, supposedly in response to unsustainable and illegal logging, and extended this to coniferous species from the end of 2017.[172] Given the volume of logs exported from Ukraine to Romania in recent years (see Figure 25), this may have an impact on Romania's biomass sourcing, though data for 2016 show imports increasing strongly after a dip in 2015.

[169] ARBIO and Bioenergy for Business (2015), *Romania's promising market segments for heating with solid biomass (> 100 kW)*, http://www.bioenergy4business.eu/wp-content/uploads/2015/06/B4B-WP2_Country_Summary_Report_Romania_ARBIO_31_8_2015.pdf (accessed 22 Aug. 2016).
[170] Peter, L. (2015), 'Romania acts to save forests from logging spree', BBC News, 21 May 2015, http://www.bbc.co.uk/news/world-europe-32792314 (accessed 25 Aug. 2016); Klawitter, N. (2015), 'Clear-Cutting Romania: Logging Threatens One of Europe's Last Virgin Forests', 8 May 2016, Spiegel Online, http://www.spiegel.de/international/europe/illegal-logging-in-romania-benefits-germany-a-1032253.html (accessed 25 Aug. 2016); Schweighofer (2016), 'Our saw mills at Sebes: Facts and Figures 2016', https://www.schweighofer.at/en/production-sites/sebes.html (accessed 25 Aug. 2016); Environmental Investigation Agency (2014), *Stealing the last forest: Austria's largest timber company, land rights, and corruption in Romania*, https://eia-global.org/reports/st (accessed 25 Aug. 2016).
[171] Forest Law Enforcement, Governance and Trade (FLEGT) (2016), 'Action Plan: Romania', http://www.flegtactionplan.eu/romania.htm (accessed 25 Aug. 2016).
[172] De Micco, P. (2015), *In Depth Analysis, Ukraine's will to liberalise: Tested on many fronts*, European Parliament, http://www.europarl.europa.eu/RegData/etudes/IDAN/2015/549072/EXPO_IDA(2015)549072_EN.pdf (accessed 22 Aug. 2016); http://voxukraine.org/2015/04/14/log-export-ban-in-ukraine-a-case-for-presidential-veto/ (accessed 8 Sep. 2016).

Romania's National Renewable Energy Action Plan projected supplies of woody biomass for energy increasing from 5.5 million m^3 in 2006 (2 million m^3 from fellings, 0.5 million m^3 from forest residues and 3 million m^3 from mill and other industry residues) to 6.5 million m^3 in 2015 and 7.5 million m^3 in 2020, the increases split evenly between fellings and forest residues and mill and industrial residues.[173] This was to be achieved through afforestation efforts on agricultural lands, the promotion of energy crops, more intense wood harvesting from forests, and greater use of waste from the wood industry. The use of agricultural residues was also to be encouraged. A study published by the University of Bucharest in 2014 reported that increased competition for raw wood material had led to tensions between the energy sector and the wood processing and furniture industries.[174]

Support for biomass energy

Policy support for biomass energy in Romania includes a quota system for biomass power and subsidies for both biomass power and heat.

Under the Electricity Law of 2008, power producers and suppliers are obliged to obtain a specified number of green certificates issued for electricity generated from renewable sources. Biomass plants are eligible if they present certificates of origin for the type of biomass used, granted either by the Ministry of Environment and Forests or the Ministry of Agriculture and Rural Development, depending on the feedstock.[175] In 2015, the cost of a green certificate ranged from €29 to €60. Once these are presented, biomass plants are eligible to receive two certificates per MWh of electricity generated. Highly efficient CHP plants with an installed capacity of up to 2 MW, as well as power plants using biomass from forest waste, are eligible to receive an additional green certificate.[176] The quota system is managed by Romania's Regulatory Authority for Energy, which updates the quota target annually; in 2016, the target was set at 12 per cent of final gross energy consumption.[177] Producers that fail to meet their quota obligations pay a penalty of €110 per missing certificate.

The scheme proved problematic, however, leading to complaints from renewable generators over inadequate levels of support, and from electricity consumers, particularly in industry, over the rise in electricity prices that resulted.[178] The scheme was closed to new applicants at the end of 2016; it will continue for existing installations until 2031. In March 2017, the government introduced emergency legislation clarifying a number of legal uncertainties, but there appear to be no plans for a further support scheme for new installations.

A new feed-in-tariff scheme for renewable power generation in small-scale installations of less than 500kW was announced in 2015, with implementation scheduled for the end of 2016, but this does not yet appear to have been implemented.[179]

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[173] European Commission (2012), 'National Renewable Energy Action Plan: Romania'.
[174] Rusu, M. (2014), 'Energy Forestry: A source of energy for the Romanian economy', *SEA-Practical Application of Science*, Volume II (2): pp. 667–674, https://ideas.repec.org/a/cmj/seapas/y2014i4p667-674.html (accessed 22 Aug. 2016).
[175] RES Legal (2016), 'Legal sources on renewable energy: Summary: Romania', http://www.res-legal.eu/search-by-country/romania/ (accessed 22 Aug. 2016).
[176] Eurobserv'ER (2012), *The progress report of Romania in regards to promoting and using energy from renewable sources, in compliance with Article 22 of Directive 2009/28/EC: Second Report*, http://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Article-22-Romania-report-EN.pdf (accessed 22 Aug. 2016).
[177] RES Legal (2016), 'Legal sources on renewable energy: Summary: Romania'.
[178] Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Romania*, https://www.eurobserv-er.org/pdf/renewable-energy-policy-factsheet-2017-romania/ (accessed 29 Jan. 2018); Volciuc-Ionescu SCA (2017), 'Romania – amendments to the renewables incentives scheme aimed to save the renewable energy from collapse', 7 April 2017, https://www.lexology.com/library/detail.aspx?g=6792bdca-1cf1-4c5b-b3a3-e62f90f23d16 (accessed 29 Jan. 2018).
[179] Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Romania.*

Support for the use of renewables in the heating and cooling sector is provided by investment subsidy programmes of the Romanian Environmental Fund, the National Rural Development Programme and the Ministry of Regional Development, Public Administration and European Funds. Subsidies are available, among other purposes, for investment in district heat infrastructure using bioenergy on the local level and for farmers generating their own thermal or electric energy from renewable sources.[180] In April 2017, a new state aid scheme was approved to promote energy production from less exploited energy sources, including biomass, biogas and geothermal energy.

Romania has no national sustainability criteria for biomass.

[180] Ibid.; RES Legal (2016), 'Legal sources on renewable energy: Summary: Romania'.

10. Sweden

Table 12: Key renewable and biomass energy statistics, Sweden

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.87	7.2%	12.3%	7.11	51.9%	81.6%	23.8%	48.2%
2016	0.84	6.8%	10.4%	7.85	54.7%	79.8%	24.7%	53.8%
Annual average growth		-0.5%			1.4%		0.5%	1.6%
2020 target								49.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as a percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for woody biomass

Sweden is a major user of biomass for energy, ranking third in the EU in 2016 for total power and heat from biomass, behind Germany and France, and second as a proportion of total power and heat, behind Finland. The country also has the highest Renewable Energy Directive target, at 49 per cent by 2020, which it reached in 2011; it is projected to achieve over 56 per cent by 2020.[181]

Like other Scandinavian countries, Sweden invested heavily in district heating systems after the oil crises of the 1970s in order to reduce the country's dependence on imported fossil fuels; district heating is a major user of biomass. It also developed nuclear power, which in 2014 generated over 40 per cent of the country's electricity.[182] Four of the country's ten nuclear stations are currently being phased out, however, and no replacements are expected to be built.[183]

In 2016, the Swedish coalition government concluded an agreement on long-term energy policy, setting out a road map for a transition to an entirely renewable electricity system, with a target of 100 per cent renewable electricity generation by 2040.[184] The country had already reached 65 per cent by 2016, mostly from hydro (accounting for 46 per cent of total electricity) and wind (11 per cent).[185]

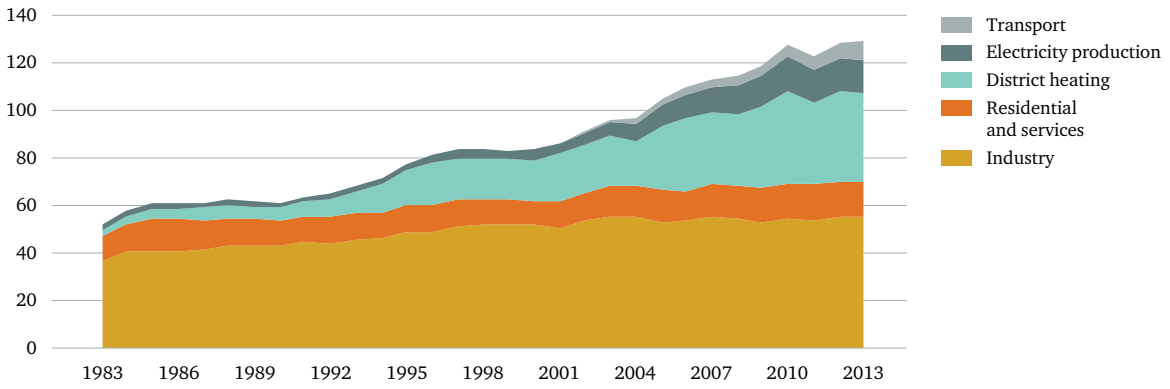
In 2017, Parliament adopted a new Climate Act, with the target of net zero greenhouse gas emissions by 2045. It was estimated that this would require at least an 85 per cent cut in domestic emissions from 1990 levels, with remaining emissions being offset through strategies such as additional tree

[181] Swedish Energy Agency (2016), 'Energy Indicators in figures 2016 – Follow-up of Sweden´s energy policy goals', http://www.energimyndigheten.se/en/news/2016/energy-indicators-in-figures-2016---follow-up-of-swedens-energy-policy-goals/ (accessed 26 Jul. 2016).
[182] International Energy Agency (2009), *Cities, towns, and renewable energy: Yes in my front yard*, http://www.iea.org/publications/freepublications/publication/cities2009.pdf (accessed 12 Jul. 2016).
[183] Reuters (2016), 'Sweden on track to meet 100-percent renewables target by 2040 – regulator', 25 October 2016, https://uk.reuters.com/article/uk-sweden-renewables/sweden-on-track-to-meet-100-percent-renewables-target-by-2040-regulator-idUKKCN12P0E8 (accessed 29 Jan. 2018).
[184] Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Sweden*, https://www.eurobserv-er.org/pdf/renewable-energy-policy-factsheet-2017-sweden/ (accessed 29 Jan. 2018).
[185] Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.

planting and possibly investing in offset activities abroad.[186] The act, which entered into force in January 2018, requires the government to present a climate report every year in its budget bill and draw up a climate policy action plan every four years to describe how the climate goals are to be achieved.

The use of biomass for energy has increased steadily since the early 1990s. The largest end-use sectors are industry (mainly pulp and paper mills) and district heating (see Figure 27).

Figure 27: Sweden's biomass energy use by sector 1983–2014 (TWh)



Source: Swedish Energy Agency (2016), 'Energy in Sweden – Facts and Figures 2016 available now', http://www.energimyndigheten.se/en/news/2016/energy-in-sweden---facts-and-figures-2016-available-now/ (accessed 20 Jan. 2018).

In 2013, biomass accounted for 38 per cent of all energy use in industry. Overall, in 2016, biomass supplied about 80 per cent of the total of renewable heat, which itself represented almost 70 per cent of total heat consumption. Sweden possesses a very large district heating network, extending for about 20,000 km, which meets most of the country's urban heating needs, particularly in multi-dwelling buildings and non-residential premises.[187] Biomass use in district heating more than doubled between 2000 and 2014, and now accounts for most of the energy used. Alongside electric appliances, biomass is also a major contributor to heating in smaller residential dwellings not on district heating networks.

There is much lower use of biomass for electricity generation. Although, in 2016, renewables supplied almost two-thirds of total electricity, hydro provided over 70 per cent of this; wind supplied a further 16 per cent, having grown very rapidly since 2009, and biomass about 10 per cent, having fallen steadily (in both absolute and relative terms) since a peak in 2009–12.

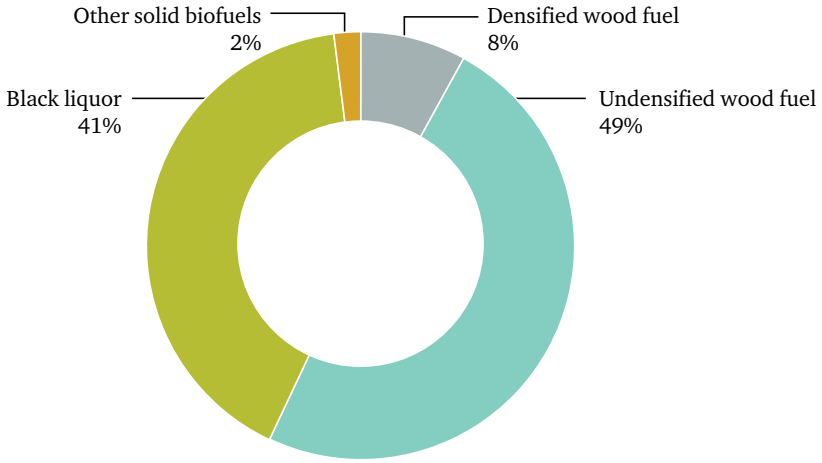
[186] Government of Sweden (2017), 'The climate policy framework', http://www.government.se/articles/2017/06/the-climate-policy-framework/ (accessed 29 Jan. 2018).
[187] European Commission (2012), 'National Renewable Energy Action Plan: Sweden', https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans (accessed 28 Jul. 2016).

Biomass supply

Sweden is the EU's largest producer of roundwood, producing over 74 million m^3 (under bark) in 2015, 7 million tonnes of which was classified as wood fuel.[188] Total annual biomass production was estimated at 76 million oven-dry tonnes in 2014, corresponding to approximately 1.4 exajoules (EJ) of energy, but more than half of this was left at forest sites due to market, technical, environmental, and economic constraints.[189]

Throughout the 1980s and 1990s, waste from Sweden's forestry industries provided an easily accessible and attractively priced source of biomass energy.[190] Increasing demand led to higher prices in the 2000s, which increased extraction from the forests. Figure 28 shows solid biomass use by fuel type in 2014; the main categories are wood chips, residues and wastes ('undensified wood fuel') and black liquor. Pellets ('densified wood fuel') accounted for only 8 per cent, but given the scale of biomass energy, this is still a significant amount; Sweden is the second largest producer of pellets in the EU after Germany, producing 1.7 million tonnes in 2016.[191] Pellets are used mainly for heating, in small and medium-scale facilities in individual households and commercial premises, and to a lesser extent for district heating; they are not widely used for electricity generation.[192]

Figure 28: Solid biomass use in Sweden by fuel type in 2014

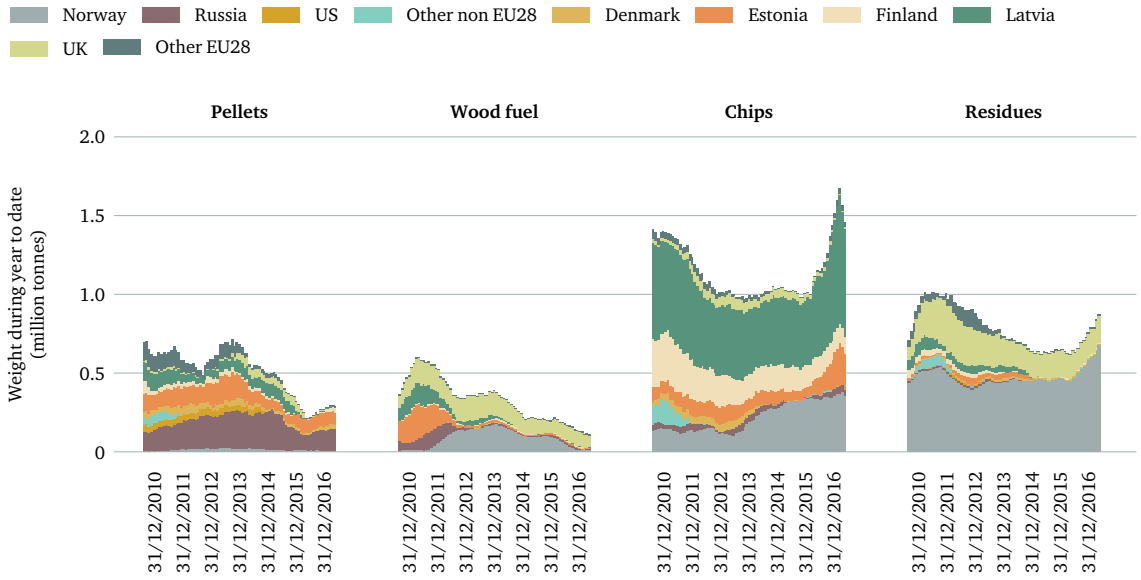


Source: Swedish Energy Agency (2016), 'Energy in Sweden – Facts and Figures 2016 available now', http://www.energimyndigheten.se/en/news/2016/energy-in-sweden---facts-and-figures-2016-available-now/ (accessed 20 Jan. 2018).

Direct and indirect biomass imports have supplied an increasing share of Sweden's energy needs, and the country is currently a net importer of wood fuel, chips and residues (see figures 29 and 30), mainly from Norway, Latvia and Finland.[193]

[188] Eurostat data at http://ec.europa.eu/eurostat/web/forestry/data/database.
[189] Hektor, B., Bruce, L., and Andersson, S. K. (2014), *Country Report Sweden*, IEA Bioenergy Task 40 Report, http://www.bioenergytrade.org/downloads/iea-task-40-country-report-2014-sweden.pdf (accessed 27 Jul. 2016).
[190] Swedish Energy Agency (2015), *Energy in Sweden 2015*, https://www.energimyndigheten.se/globalassets/statistik/overgripande-rapporter/energy-in-sweden-till-webben.pdf (accessed 26 Jul. 2016).
[191] FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.
[192] Hektor, B. et al. (2014), *Country Report Sweden*.
[193] Indirect biomass imports refer to by-products that derive from imported timber for industrial purposes. The Swedish Energy Agency considers indirect biomass imports as 'domestically produced fuel'.

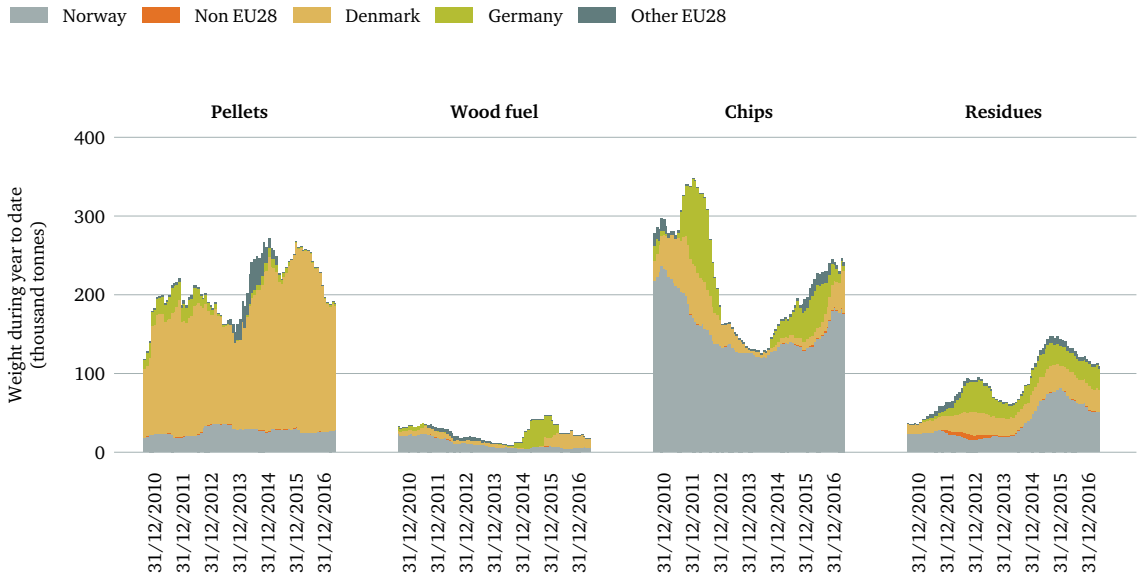
Figure 29: Sweden's imports of woody biomass potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Imported wood chips and residues are primarily used in large and medium-sized district heating utilities, generally located near ports.[194] Until recently Sweden was also a net importer of pellets, mainly from Russia and Estonia, but its exports, almost entirely to Denmark, have climbed with increasing domestic production, and from 2015 the trade in pellets has been relatively balanced. Concerns over illegal logging may lead to a tendency to reduce imports from Russia in the future.

Figure 30: Sweden's exports of woody biomass potentially for energy, 2010–16



Source: generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

[194] Hektor, B et al. (2014), *Country Report Sweden*.

The government's National Renewable Energy Action Plan foresaw an increasing use of domestically sourced biomass, consistent with the estimate that more than half of the available biomass is currently left in the forest. Clearly this will be affected by the falling prices of competing renewables, notably wind (Sweden's climate means that solar is unlikely to play a major role).

Support for biomass energy

Woody biomass use has been encouraged in particular through a tradable electricity certificate system and taxation. Sweden's Energy Tax Act of 1994 introduced a series of taxes on fossil fuels, carbon dioxide emissions, and sulphur emissions. Biomass has been exempted from all these taxes since the 1990s (peat is exempt from 'higher energy' and CO_2 taxes, though it incurs a tax on its sulphur emissions).[195] The energy tax is based on the energy content of the fuel, while the carbon dioxide and sulphur taxes are based on emissions. These taxes have been seen as largely successful in promoting renewable energy in general, for both electricity and heat.

The use of biomass has also been supported by the electricity certificate scheme, introduced in 2003, which aims to increase the proportion of renewables in electricity generation.[196] A certificate is given for every unit of electricity produced by an approved facility from a renewable energy source, which is then sold to suppliers that are required to buy a certain proportion of certificates in relation to their electricity sales or use.[197] In 2014, the average price of an electricity certificate was just under SEK 180 (€18); this represented about half the price in previous years, due to an oversupply of certificates. In terms of generation, about 17 TWh of renewable electricity was generated in 2014 under Sweden's electricity certificate scheme.

In 2012, Sweden and Norway introduced a common electricity certificate market through a collaboration mechanism under the EU Renewable Energy Directive that allows countries to trade renewable electricity certificates.[198] Together, they aimed to generate 26 TWh of renewable power in 2020, with each contributing on average 13 TWh annually thereafter until 2035. In April 2017, the two countries announced their agreement to extend the joint scheme to 2030, and Sweden increased its annual target to 18 TWh to 2030.[199]

Taxation is the main instrument for supporting renewable heat. As well as the tax exemptions discussed above, income tax deductions are also available for installation works in apartments and single-family houses when replacing conventional heating with heating supplied by renewable energy sources.[200]

Sustainability criteria

Power plants and CHP plants that use wood biomass from forests certified by either the FSC or PEFC schemes are entitled to higher levels of financial support than otherwise available.

[195] Swedish Energy Agency (2015), *Energy in Sweden 2015*.
[196] International Energy Agency (2013), *Energy Policies of IEA Countries: Sweden 2013 Review*, Paris: International Energy Agency, http://www.iea.org/publications/freepublications/publication/Sweden2013_free.pdf (accessed 27 Jul. 2016).
[197] Swedish Energy Agency (2015), *Energy in Sweden 2015*.
[198] Swedish Energy Agency and the Norwegian Water Resources and Energy Directorate (2013), *The Norwegian-Swedish Electricity Certificate Market: Annual report 2013*, https://www.energimyndigheten.se/globalassets/fornybart/elcertifikat/sv-norsk-marknad/electricity_certificate_market_annual_report_2013.pdf (accessed 31 Jul. 2016).
[199] Eurobserv'ER (2017), *Renewable Energy Policy Factsheet: Sweden.*
[200] Ibid.

11. United Kingdom

Table 13: Key renewable and biomass energy statistics, UK

	Electricity from biomass			Heating and cooling from biomass			% of total energy	
	Mtoe	*% of total electricity*	*% of ren electricity*	*Mtoe*	*% of total heat/cool*	*% of ren heat/cool*	*Biomass*	*All renewables*
2009	0.31	1.0%	14.5%	1.22	2.1%	90.7%	1.1%	3.3%
2016	1.69	5.5%	22.5%	2.86	5.1%	73.1%	3.4%	9.3%
Annual average growth		27.2%			12.9%		17.5%	16.0%
2020 target								15.0%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.
Note: Biomass as a percentage of total energy does not include solid biomass used for transport fuel (volumes are not yet significant).

Demand for woody biomass

Of all EU member states, the UK has seen the most rapid growth in the use of biomass for electricity, in absolute terms. In 2016, the UK accounted for 21 per cent of all the electricity generated from biomass in the EU. Since 2009, the use of biomass for electricity in the UK has grown by 27 per cent a year, faster than the 19 per cent growth rate of electricity from renewables as a whole, which is itself high by EU standards. Renewable energy was relatively undeveloped in the UK when the country agreed its target for 2020 under the 2009 Renewable Energy Directive; significant investment was required in all sectors. The outcome has been a very rapid growth in wind, which in 2016 accounted for 47 per cent of total renewable electricity; at the same time, biomass and solar made up 22 per cent and 12 per cent, respectively. Despite this, the UK is not on track to meet its Renewable Energy Directive target of 15 per cent of energy from renewables by 2020, partly because the Conservative governments in power since 2015 have reduced support for renewable energy generation (including ending support for new onshore wind and drastically reducing it for new solar PV, and ending the renewables exemption from the Climate Change Levy in 2016), and partly because of much slower progress in heat and transport from renewable sources than in power generation.

Although some dedicated biomass power plants have been constructed, the growing demand for biomass power is largely due to the conversion of coal-powered stations, accounting for about two-thirds of biomass electricity (co-firing with coal has now ended after reductions in the level of support), and in particular the conversion of four of the six units at the Drax power station in Yorkshire.[201] The last coal station to be built in the UK, Drax is also the largest (with approximately a 4 gigawatt capacity), supplying about 7 per cent of UK electricity. It started co-firing coal with wood pellets in 2003 and fully converted its first unit in 2013; conversion of the fourth unit started in 2017 and is due for completion in 2018. By July 2016, 65 per cent of the electricity it generated

[201] DECC (2016), *Energy Trends: June 2016, special feature article – Renewable energy in 2015*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/532963/Renewable_energy_in_2015.pdf (accessed 7 Jul. 2016); Sandbag (2017), *Something Nasty in the Woodshed*.

was from wood pellets, representing around 20 per cent of the UK's renewable power.[202] It is the largest biomass-burning power station in the world. Conversion of its two remaining coal units seems unlikely, however; the company has announced plans to replace two units with gas turbines and also invest in a large battery storage facility. The government is committed to phasing out power generation from unabated coal by 2025.

In sharp contrast to most EU member states, the use of biomass in heat generation is much smaller, though it has also grown relatively quickly. In 2016, biomass accounted for about three-quarters of total renewable heat in the UK, but renewable heat only represented 7 per cent of all heat consumed (in contrast, renewable electricity accounted for 25 per cent of total electricity). Of the heat generated from biomass in 2015, the household sector accounted for 54 per cent, industry for 22 per cent, and CHP production for 10 per cent.[203]

The government's Bioenergy Strategy published in 2012 projected that by 2020 the share of biomass in power generation would account for 5–11 per cent, with a further increase to 14 per cent by 2030.[204] Current generation is in line with these projections, but the faster than anticipated falls in the price of competing renewables, particularly offshore wind, is likely to see growth below the projected trend, though this depends partly on future government support for the various renewable technologies. The strategy document in any case foresaw much reduced growth after 2030, mostly because of higher costs and limited availability of feedstock due to increased competition in the global market; this was also the conclusion of the independent Committee on Climate Change's Bioenergy Review in 2011.[205]

The strategy projected that by 2020 the share of biomass in heat generation would account for 6 per cent but then probably fall thereafter because of restrictions in supply, though its role in industrial heating was expected to be increasingly important.[206] Given that in 2016 heat from biomass reached 5.1 per cent of total heat, the 6 per cent figure is plausible. Other renewable heat options (mainly heat pumps and solar thermal) have been slow to commercialize at scale, though their deployment is likely to increase as the UK makes further progress in decarbonizing its heat supply.

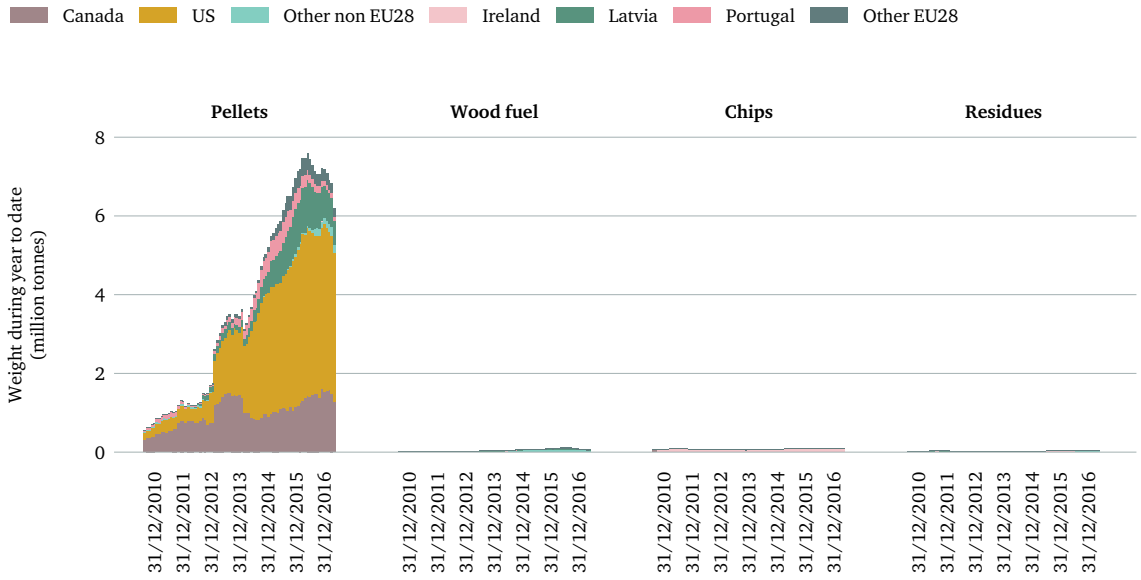
Biomass supply

The UK has a much smaller forest industry than most other EU member states, producing just under 11 million m^3 of roundwood in 2016.[207] Imports, particularly of wood pellets, therefore dominate the supply of biomass for energy. Relatively easy to transport and store, pellets are well suited to their main end uses in the UK, in large-scale power and CHP plants; in 2016, the country consumed an estimated 26 per cent of all the wood pellets produced worldwide.[208] There is some domestic production, reaching 358,000 tonnes in 2016, but a far larger volume is imported; annual imports reached about 7.5 million tonnes in the middle of 2016, though they have dropped slightly since (see Figure 31).[209] Drax alone burnt 6.6 million tonnes of biomass (almost entirely pellets) in 2016 – almost 23 per cent of total global production.[210]

[202] Drax, 'About us', https://www.drax.com/about-us/our-history/ (accessed 31 May 2017).
[203] DECC (2016), *Energy Trends: June 2016, special feature article – Renewable energy in 2015*.
[204] HM Government (2012), *UK Bioenergy Strategy*, London: DECC, DEFRA and DfT, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48337/5142-bioenergy-strategy-.pdf (accessed 8 Jul. 2016).
[205] Committee on Climate Change (2011), *Bioenergy Review*, https://www.theccc.org.uk/publication/bioenergy-review/ (accessed 7 Jul. 2016).
[206] HM Government (2012), *UK Bioenergy Strategy.*
[207] Eurostat data at http://ec.europa.eu/eurostat/web/forestry/data/database.
[208] FAO, Forest Products Statistics, http://www.fao.org/forestry/statistics/80938@180723/en/ (accessed 1 Feb. 2018).
[209] FAOSTAT data at http://www.fao.org/faostat/en/#data/FO.
[210] Drax (2017), *Annual Report and Accounts 2016*, p. 18.

The UK's biomass sources of supply have shifted greatly over the last 10 years; in 2008, Russia was the main supplier (of a far smaller volume), followed by Canada, Latvia and several other EU member states. As demand grew rapidly, sources of supply shifted to those countries that were able reliably to provide much larger quantities at low cost. In 2016, just three countries supplied over 90 per cent of UK imports: the US (58 per cent), Canada (20 per cent) and Latvia (13 per cent) (see Figure 31).

Figure 31: The UK's biomass imports potentially for energy, 2010–16



Source: Generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do.
Note: Wood chips and residues are not only used for energy generation.

Wood pellets from the southeast of the US seem likely to remain the major source of UK imports, especially when two further biomass-fired power stations begin operations: Lynemouth, a conversion of a previously mothballed coal station to biomass, and MGT Teesside, a new dedicated biomass plant. While these stations are both smaller than Drax in terms of the requirement for pellets (though Teesside, with a capacity of 299 MW, will be the largest dedicated biomass power plant in the world), they have already signed a long-term agreement to procure most of their pellets from one of the leading suppliers in the southeast of the US, Enviva.[211]

The 2012 bioenergy strategy anticipated that imports would continue to dominate supply for power and heat generation up to 2050, though with a significant fall after 2030 due to barriers in technology deployment and increased global competition for wood pellets.[212] The domestic supply of biomass was also expected to grow, mostly from agricultural residues and energy crops such as miscanthus and short rotation coppice – though in fact government attempts to encourage planting of energy crops has been unsuccessful, and the area planted with each crop in England has fallen since 2008.[213] The

[211] Enviva Partners, LP (2016), 'Enviva Partners, LP Signs Long-Term Off-take Contract', 2 June 2016, http://ir.envivabiomass.com/press-release/enviva-partners-lp-signs-long-term-take-contract (accessed 8 Aug. 2016); Enviva Partners, LP (2015), *Business Overview*, http://ir.envivapartners.com/sites/envivabiomass.investorhq.businesswire.com/files/doc_library/file/Enviva_Investor_Presentation_Feb_2016.pdf (accessed 8 Aug. 2016).
[212] HM Government (2012), *UK Bioenergy Strategy.*
[213] Department for Environment, Food and Rural Affairs (2017), *Crops Grown For Bioenergy in England and the UK: 2016*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664991/nonfood-statsnotice2016-6dec17b.pdf (accessed 31 Jan. 2018).

domestic supply of wood was also expected to increase, partly by improving supply from unmanaged woodlands – though the document noted this would require a large mobilization of resources and careful consideration of whether it might displace supplies of wood for non-energy uses.

In March 2017, however, a new analysis of the availability of biomass feedstock to the UK, commissioned by the government, was published.[214] The report analysed constraints on supply under the UK's existing sustainability criteria, the global availability of land for biomass and competition for biomass supplies. It concluded that far less biomass was likely to be available for UK energy generation by 2030 than had previously been assumed – 70–90 per cent less for imports and 30–40 per cent less for domestic production.

Support for biomass

Support for biomass energy is delivered through three main mechanisms: the Renewables Obligation scheme, which for new installations has now been replaced by the Contracts for Difference system, for electricity; and the Renewable Heat Incentive for heat. (Feed-in tariffs for microgeneration are also important for anaerobic digestion that produces biogas for electricity generation.)

Launched in 2002 to encourage large-scale renewable electricity generation, the Renewable Obligation scheme requires UK electricity suppliers to procure a proportion of their electricity from renewable sources.[215] The government sets the suppliers' obligations as a number of Renewable Obligation Certificates (ROCs), which increases annually. Eligible renewable energy generators are issued certificates by the regulator, the Office of Gas and Electricity Markets (Ofgem); the renewable power generated, accompanied by ROCs, is then sold to suppliers, which must accumulate enough ROCs to meet their obligations and avoid paying a penalty. The additional cost to suppliers is recouped through a levy on electricity bills.

> In 2015, solid biomass received over £800 million in subsidies through the Renewable Obligation scheme, of which Drax received £540 million.

The number of ROCs issued per unit of electricity is adjusted by the technology used, as a means of delivering different levels of support depending on the maturity and cost of each renewable source. For the period 2013–17, biomass electricity generated 1.4 ROCs per MWh for new dedicated biomass power plants, 1 ROC per MWh for power plants converted from coal to biomass, and 0.5–0.9 ROCs per MWh for plants co-firing biomass with coal.[216] If CHP was added, all these figures were increased by 0.4 or 0.5. (In comparison, onshore wind was eligible for 0.9 ROC per MWh, and offshore wind, tidal barrage and tidal lagoon for 1.8 ROC per MWh.) In the face of a large number of applications for new dedicated biomass stations, in 2013 the government placed a cap of 400 MW on new capacity in order to limit its development, and focus on the conversion of coal-powered stations. In 2015, solid biomass received over £800 million in subsidies through the Renewable Obligation scheme, of which

[214] Ricardo Energy and Environment (2017), *Biomass Feedstock Availability*, Department of Business, Energy and Industrial Strategy, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597387/Biomass_feedstock_availability_final_report_for_publication.pdf (accessed 31 Jan. 2018).
[215] Eurobserv'ER (2015), *Country policy profile: United Kingdom,* http://www.eurobserv-er.org/pdf/res-policy/EurObservER-RES-Policy-Report-Country-Profile-2015-12-United-kingdom.pdf (accessed 7 Jul. 2016).
[216] UK Government (2017), 'Renewable Obligation banding levels', https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211292/ro_banding_levels_2013_17.pdf (accessed 31 Jan. 2018).

Drax received £540 million.[217] By 2017 the ROC subsidy to Drax had fallen to £481 million, as the station's third unit had transferred to the new Contracts for Difference system (see below), for which it received £248 million; the total subsidy to Drax alone was thus £729 million.[218]

In January 2014, a new renewable support mechanism under the UK's electricity market reform programme was introduced to facilitate cost-effectiveness and long-term price stability: the Contracts for Difference system.[219] New applications under the Renewable Obligation incentive closed on 31 March 2017 (for solar PV, in 2016), with a few transitional exceptions, and accredited ROCs will end in 2037.

The new mechanism is intended to provide a more cost-effective way of delivering subsidies to renewable electricity generation, avoiding the problem of excessive subsidies, which the Renewable Obligation system could lead to when the market retail price of electricity was high (since the Renewable Obligation system simply added a slab of subsidy on top of the market price, whatever it was); the system is also intended to increase competition when the contracts are offered through auction. Open to all low-carbon generation (including nuclear), under the new system the government agrees with generators a 'strike price' per unit of electricity, which it guarantees to pay (for 15 years for renewables). If the retail price proves to be lower than the strike price, the government pays the generator the difference; if the retail price is higher, the generator reimburses the government for the difference.

No contracts for biomass power were awarded by the first auction under the new Contracts for Difference system in February 2015, though three contracts were awarded without auction: to Drax for the conversion of its third unit and to the Lynemouth and Teesside power stations mentioned above. The second auction, which concluded in September 2017, was open (subject to a capacity cap) to bids for dedicated biomass or waste with CHP and advanced conversion technologies, including gasification of waste or biomass. Two dedicated biomass CHP plants (including one very small station) won bids, though the auction was notable mainly for the very sharp decline in the costs of offshore wind, suggesting that the auction was indeed helping to increase competition.[220] The third auction is due in spring 2019 and is expected to focus primarily on offshore wind and biomass.[221] The system's minimum efficiency requirement for CHP plants, of 35 per cent, has been criticized as being too low (efficiencies of 70 per cent or higher are common elsewhere) and in December 2017 the government launched a consultation on raising the minimum level to 70 per cent.

Support for biomass heat is provided through the Renewable Heat Incentive (RHI), the world's first long-term financial support programme for renewable heat, which was introduced in 2011 for non-domestic buildings and in 2014 for households.[222] Similar to a feed-in tariff scheme, the RHI pays participants for each unit of heat generated, at a price guaranteed for 20 years. For biomass boilers and pellet stoves, the domestic RHI currently pays a tariff of £0.122/kWh. By December

[217] Natural Resources Defence Council (2017), *Money To Burn II: Solar and Wind can Reliably Supply the United Kingdom's New Electricity Needs More Cost-Effectively than Biomass*, https://assets.nrdc.org/sites/default/files/money-to-burn-ii-uk-biomass-ib.pdf?_ga=2.263245454.382389991.1522948212-1033467960.1487637747 (accessed 31 Jan. 2018).
[218] Drax (2018), *Annual Report and Accounts 2017*, p. 47, https://www.drax.com/wp-content/uploads/2018/03/Drax-Group-plc-2017-annual-report.pdf (accessed 26 Mar. 2018).
[219] Department for Business, Energy and Industrial Strategy, 'Contracts for Difference', https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference (accessed 31 Jan. 2018).
[220] *Biomass Magazine* (2017), 'UK awards CfDs to 2 dedicated biomass with CHP projects', 12 September 2017, http://biomassmagazine.com/articles/14668/uk-awards-cfds-to-2-dedicated-biomass-with-chp-projects (accessed 31 Jan. 2018); Cuff, M. and Murray, J. (2017), 'Government delivers £557m green energy boost ahead of Clean Growth Strategy launch', *Business Green,* 11 October 2017, https://www.businessgreen.com/bg/news/3018987/government-delivers-gbp557m-green-energy-boost-ahead-of-clean-growth-strategy-launch (accessed 31 Jan. 2018).
[221] Cuff and Murray (2017), 'Government delivers £557m green energy boost ahead of Clean Growth Strategy launch'.
[222] Eurobserv'ER (2015), *Country policy profile: United Kingdom*.

2017, non-domestic installations supported by the RHI had generated almost 1.72 Mtoe of heat since November 2011, of which slightly over 60 per cent came from small or medium-sized biomass stations. Domestic installations had generated 0.17 Mtoe since April 2014, about half from biomass – although recent installations were much more likely to have been heat pumps.[223] In the *Clean Growth Strategy* published in October 2017 the government stressed its intention to reform the RHI to encourage greater uptake of technologies such as heat pumps and biomethane.[224]

In addition to these schemes, the Green Investment Bank, which was created by the government in 2012 to support investment in a range of renewable technologies, agreed a loan to Drax in support of its conversion of three of its six generating units from coal to biomass.[225] In 2017, the bank was sold to Macquarie Group, and the Green Investment Group, as it is now known, has yet to announce any further plans for investment in biomass.

The Green Investment Bank, which was created by the government in 2012 to support investment in a range of renewable technologies, agreed a loan to Drax in support of its conversion of three of its six generating units from coal to biomass.

Growth in domestic feedstock has been supported by a variety of schemes providing financial support for new planting, woodland management and fuel and timber production in unmanaged woodland; separate schemes operate in England and the devolved administrations of Scotland, Wales and Northern Ireland. The grant schemes have been criticized as inadequate and complex, and in 2015–16, planting in England fell to its lowest level for 40 years, to an estimated 700 hectares a year, compared to a government target of 5,000 hectares a year.[226] In January 2018, the government published a 25-year environment plan, which contained a series of proposals to increase the rate of tree planting.[227]

Sustainability criteria

Following the cap on new dedicated biomass plants under the Renewable Obligation scheme, in August 2013, the government published proposals for sustainability criteria for biomass; these were finally agreed in 2014 for application in 2015. They apply to support provided to biomass under all the schemes described above.

The requirements include the detailed environmental and social criteria for legal and sustainable forest products contained in the government's existing timber procurement policy.[228] Products certified under the FSC, PEFC or Sustainable Biomass Partnership schemes have been assessed as meeting all or most of these criteria (additional information may be required in some cases),

[223] HM Government (2017), 'RHI deployment data: December 2017', https://www.gov.uk/government/statistics/rhi-deployment-data-december-2017 (accessed 31 Jan. 2018).
[224] HM Government (2017), *Clean Growth Strategy: Leading the way to a low carbon future*, https://www.gov.uk/government/publications/clean-growth-strategy (accessed 31 Jan. 2018).
[225] Green Investment Bank (2011), *Drax Power Station Biomass Conversion Project,* http://www.greeninvestmentbank.com/media/25297/108675-gib-case-study-drax-final.pdf (accessed 8 Aug. 2016).
[226] Vidal, J. (2016), 'England may be in deforestation state due to lack of tree planting', *Guardian,* 6 December 2016, https://www.theguardian.com/environment/2016/dec/06/england-deforestation-state-lack-tree-planting (accessed 16 May 2017); BBC News (2017), 'Reality Check: Are millions of trees being planted?', 26 October 2017, http://www.bbc.co.uk/news/science-environment-41551296 (accessed 31 Jan. 2018).
[227] HM Government (2018), *A Green Future: Our 25 Year Plan to Improve the Environment*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf (accessed 26 Mar. 2018).
[228] DECC (2014), *Woodfuel Advice Note*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/390145/141222_Woodfuel_Advice_Note_-_Guidance_final.pdf (accessed 20 Jan. 2018).

but since much of the biomass sourced from the US tends not to be certified (the uptake of forest certification schemes in the US is relatively low), the regulations also allow operators to supply credible evidence of a low risk of non-compliance with all the criteria for a defined region (an area across which relevant legislation is the same – e.g. a US state) – or a smaller area if they can trace it back.[229] As in the timber procurement policy, up to 30 per cent of the biomass used in a facility can be non-compliant with the sustainability requirements, though it must be legal.

The criteria also include targets for carbon emissions per unit of electricity; these strengthen over time, and are equivalent to 72 per cent greenhouse gas savings from life-cycle emissions, compared to fossil fuel alternatives, by 2020, and 75 per cent by 2025.[230] As in other EU member states, the calculation excludes changes in the forest carbon stock and emissions from indirect land-use change.

[229] DECC (2014), *Risk Based Regional Assessment: A Checklist Approach*, London: DECC, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/390148/141222_Risk_Based_Regional_Assessment_-_A_Checklist_Approach_-_Guidance_final.pdf (accessed 20 Jan. 2018).
[230] DECC (2014), *Woodfuel Advice Note*.

12. Accounting for Biomass Carbon Emissions

As noted in Chapter 1, the classification of biomass energy as carbon-neutral derives from two assumptions. The first is that the emissions released when biomass is burnt for energy are part of a natural cycle in which, over time, forest growth balances the carbon emitted on combustion. The second assumption, which derives from Intergovernmental Panel on Climate Change (IPCC) reporting rules intended to avoid double-counting, is that even if using forest biomass for energy does result in net emissions to the atmosphere, these emissions are accurately accounted for within the land-use sector. In effect, emissions are assumed to occur at the point of harvest, not at the point of combustion, and thus from the energy-sector perspective, forest-based biomass energy is carbon-neutral.

This second assumption is discussed in detail in the Chatham House paper *Biomass for Power and Heat: Impacts on the Global Climate.* Accounting for emissions in only one of the two sectors in which they could have been accounted for was a rational decision, but problems arise because of the different ways in which emissions are accounted for in the two sectors. In practice, accounting of biomass emissions in the energy sector is not fully balanced by accounting in the land-use sector, for three reasons.

First, for the second commitment period of the Kyoto Protocol (2013–20) – for which accounting for emissions from forest management is mandatory – parties were given a choice of baselines for the forest management frameworks against which they would measure changes in emissions. Three of the 37 parties to the Kyoto Protocol that adopted targets for the second commitment period chose to use historical baselines (as in other sectors, e.g. energy), and 32 chose business-as-usual baselines, where only changes in emissions compared to what was expected to occur are accounted for (the other two parties chose not to adopt baselines at all). This larger group generally chose business-as-usual baselines to minimize the potential for non-anthropogenic and/or non-additional emissions (for example from fire or disease) entering their national greenhouse gas accounts – but using such a baseline also allows a country to avoid accounting for anticipated emissions resulting from particular forest management practices or policies and measures, such as the use of forest biomass for energy.

Of the 32 that chose business-as-usual baselines, 21 included significant increases in biomass energy use in their business-as-usual projections; the other 11 might also have done so, but have not provided enough detail for a firm conclusion to be reached. In these 21 countries, if increased biomass energy use does occur, it means that emissions from harvesting forests for biomass in line with these projections will count as zero for Kyoto Protocol accounting purposes (if harvesting rates for biomass are higher, the excess will be reported as emissions). They will also count as zero in the energy sector – so in effect, although the burning of biomass is generating emissions, they are not counted against national emissions targets, giving a misleading picture of a country's progress in meeting its target. It should be noted that any increase in biomass harvesting rates from policies adopted after 2009 – which, for EU member states, includes policies implementing the Renewable Energy Directive – could not be included in the business-as-usual projections and therefore will be reported as emissions in the land-use sector.

As noted in Chapter 2, however, the proposals supported by the European Parliament in September 2017 would change the basis of forest management reference levels for EU member states. In place of the European Commission's original proposal to adopt a historical reference level based on the

1990–2009 period, MEPs supported an amendment to change this to 2000–12, a period which includes the first few years of measures to support biomass energy that were introduced in order to achieve the EU renewables targets. If this text is finally agreed (at the time of publication, it is still being negotiated among the EU institutions), it would create an additional incentive to increase harvests for bioenergy. This will have no effect on accounting against Kyoto Protocol targets, since the measures would only come into effect after 2020, after the end of the Protocol's second commitment period, but may have implications for the accounting framework to be adopted under the Paris Agreement.

The second reason that biomass emissions may not be accounted for is because emissions from imported biomass are not accounted for in the importing country's accounts, since no land-use change takes place within its borders. Whether they are correctly accounted for at all therefore depends on how they are accounted for by the exporting country. This is of most significance, clearly, for countries that import significant quantities of biomass, including, of those considered in this paper, Denmark, Italy and the UK, and to a lesser extent Finland, Germany and Sweden.

The third reason that biomass emissions may not be accounted for is because emissions from biomass imported from non-parties to the Kyoto Protocol (including Canada and the US), or from parties that have not accepted targets under the second commitment period (including Belarus, Russia and Ukraine) or from non-Annex B parties (i.e. countries without emissions targets – essentially, developing countries and some former transition economies in Eastern Europe and the former Soviet Union), will not be accounted for at all within the Protocol's emissions frameworks – so although importing countries within the Protocol are counting their biomass emissions as zero, they are not balanced by any equivalent reduction in land-use emissions in any other Kyoto Protocol party. This is a particular issue for the UK, which imports the bulk of its biomass from the US and Canada; it is also relevant to a lesser extent to Denmark, Finland and Sweden, which import primarily from Russia, and Italy, which imports from Bosnia and Herzegovina, a non-Annex B party. It is hoped that this problem will be resolved in the framework to be established under the 2015 Paris Agreement, which should cover all countries – though if the US withdraws, as it announced in June 2017, this would still cause problems for countries importing from the US, particularly the UK.

The result of the combination of these three problems is that a tonne of carbon emissions from biomass use in the energy sector is not necessarily accounted for as a tonne of carbon emissions in the land-use sector. There is clear potential for a proportion of the emissions from biomass to go entirely unaccounted for.

'Missing' emissions in the nine EU member states

To what extent is this a real problem for the nine countries analysed here? As the previous Chatham House paper on biomass discusses, it is impossible to be precise about the volumes of 'missing' – i.e. unaccounted for – emissions. In general, countries' forest management reference levels do not include enough information on the anticipated impact of biomass energy policies on the quantity of biomass utilized, the origins of the biomass (from, for example, additional domestic forest harvests, increased use of domestic forestry residues and/or imported biomass) and the resulting emissions. Although countries do report emissions from biomass in their greenhouse gas inventories (as a memo item, i.e. not included in their emissions total), some do not provide separate figures for emissions from solid, liquid and gaseous biomass, simply reporting one aggregated figure.

However, it is possible to get a rough idea of the potential scale of the problem by examining countries' reported emissions from solid biomass, the proportion of emissions that may be associated with imported biomass, and the extent to which the main countries from which they source their supply (including domestic production) treat biomass use in their forest management reference levels.

Tables 14 and 15 summarize this information for 2015, the latest year for which figures are available. For each country, Table 14 includes carbon dioxide emissions from solid biomass used for energy and from total energy use in the country as a whole (as noted above, this figure does not include emissions from biomass) and a calculation of the relative size of these two figures. In 2015, emissions from solid biomass from these nine countries reached 313 million tonnes of carbon dioxide, equivalent to 14 per cent of their energy-related emissions – about the same as the energy-related emissions of France.

Table 14 also includes rough estimates of the proportion of the carbon emissions that derive from imported biomass, divided into imports from countries with targets under the second commitment period of the Kyoto Protocol and imports from those without targets (this assumes that all the imports are used for energy, which is a reasonable assumption for pellets and wood fuel, but less so for chips).

In reality, emissions from biomass will depend on the feedstock, the facility it is burnt in, whether it is used for electricity or heat or both, and many other factors. Countries also use different emissions factors in reports to the UNFCCC.

These import-related emission figures are not precise. They are calculated based on the weight of pellets, chips and wood fuel imported during 2015 multiplied by the following carbon emission factors: 480 kg carbon (1,762 kg carbon dioxide) per tonne of wood pellets, 360 kg carbon per tonne of wood chips and 240 kg carbon per tonne of wood fuel (to allow for higher levels of moisture in chips and wood fuel compared to pellets). The 480 kg carbon figure for pellets is based on reported emissions from Drax in 2013.[231] In reality, emissions from biomass will depend on the feedstock, the facility it is burnt in, whether it is used for electricity or heat or both, and many other factors. Countries also use different emissions factors in reports to the UNFCCC. In its 2012 report, for example, the UK used the figure of 381.4 kg of carbon (1,400 kg carbon dioxide) emitted per tonne of wood biomass (based on IPCC guidance from 1997),[232] whereas in its 2014 report, it used figures of 1,055 kg carbon dioxide per tonne of wood for power stations, 1,416 kg for domestic combustion and 1,767 kg for other industrial combustion.[233] Other countries report emissions per unit of energy generated rather than per weight of wood.

[231] See discussion of emission levels in Brack, D. (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate*, pp. 14–17.
[232] Department of Energy and Climate Change (2014), *UK Greenhouse Gas Inventory, 1990 to 2012*, Annex A3, Table A 3.2.5, http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/gbr-2014-nir-15apr.zip (accessed 20 Jan. 2018).
[233] Department for Business, Energy and Industrial Strategy (2016), Baroness Neville-Rolfe answer to Parliamentary Question HL2685, 2 November 2016.

Table 14: Biomass energy emissions, nine EU member states, 2015

Country	CO_2 emissions			CO_2 emissions from imported biomass – Kyoto Protocol parties			CO_2 emissions from imported biomass – Kyoto Protocol/ Annex B non-parties		
	Solid biomass (million tonnes (Mt))	*Total energy (Mt) (biomass not included)*	*Biomass compared to energy sector (%)*	*(Mt)*	*% of total solid biomass emissions*	*Main source countries*	*(Mt)*	*% of total solid biomass emissions*	*Main source countries*
Denmark	11.54	35.02	33%	3.38	29%	Estonia, Latvia	0.66	6%	Russia
Finland	37.17	40.00	93%	0.46	1%	Estonia, Latvia	1.90	5%	Russia
France	42.73	315.70	14%	0.87	2%	Belgium, Germany	0.02	0%	
Germany*	101.91	744.33	14%	1.91	2%	Netherlands, Poland	0.36	0%	
Italy	32.09	341.67	9%	3.34	10%	Austria	0.86	3%	Bosnia and Herzegovina
Poland	31.15	290.84	11%	0.17	1%	Lithuania	1.32	4%	Belarus
Romania	16.35	68.09	24%	0.01	0%		0.35	2%	Ukraine
Sweden	14.05	37.83	37%	1.82	13%	Latvia, Norway	0.27	2%	Russia
UK	25.52	398.33	6%	3.37	13%	Latvia, Portugal	8.33	33%	Canada, US
Total	**312.51**	**2,271.81**	**14%**	**15.34**	**5%**		**14.08**	**5%**	

*Germany does not report emissions from solid, liquid and gaseous biomass separately; this figure, of total biomass, will therefore be an over-estimate of the total from solid biomass.
Source: 2017 national inventory reports to the UNFCCC, available at http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php (accessed 28 Feb. 2018). For each country, solid biomass emissions are taken from the total biomass emissions reported (as a memo item) in Table 1s2 of its inventory report, with the proportion of solid biomass calculated from the figures given in Table 1(A)b; total energy emissions are taken from Table 1s1.

The table also indicates the main source countries for imports. Clearly, some countries import significant quantities of woody biomass from countries that do not account for their emissions within the framework of the second commitment period of the Kyoto Protocol – particularly the UK, but also Denmark, Finland and Italy. In 2015, these four countries together imported solid biomass, which, if burnt, would have emitted over 12 million tonnes of carbon dioxide, on the assumptions outlined above. Emissions from imports from countries outside the second commitment period to the nine countries analysed here amounted to an estimated 14 million tonnes of carbon dioxide. These emissions will not be accounted for against any country's greenhouse gas emission targets.

In addition to this, as noted above, even for imports from parties which have adopted targets under the second commitment period of the Kyoto Protocol, and also for biomass sourced domestically, a proportion of the emissions may be unaccounted for. This depends on what level of biomass harvesting the countries of origin included in their forest management reference levels – summarized below in Table 15 for the nine EU member states under consideration here and the six other parties to the Kyoto Protocol with targets under the second commitment period that are their main sources of imports (five EU member states – Austria, Estonia, Latvia, Lithuania and Portugal – plus Norway). (Wood biomass imports from Belgium and Netherlands will have originated elsewhere, and been trans-shipped through these countries, since neither country has substantial domestic production; these countries are therefore not included.)

Of these 15 countries, Norway chose a forest management reference level based on its historical emissions, and therefore accounts for any change relative to 1990 levels, whether due to increased harvesting for biomass or any other reason. Harvesting for biomass at the 1990 level will not be accounted for, but any change since will.

All the other countries in the table elected to use business-as-usual reference levels for the second commitment period of the Kyoto Protocol, derived either from country-specific models or methodologies or from projections modelled by the European Commission's Joint Research Centre (JRC). None of these projections include emissions stemming from policies adopted and implemented after 2009, including any measures taken to implement the Renewable Energy Directive, but any harvesting for biomass as a result of pre-2010 biomass energy policies will not be included in these countries' emissions accounts.

Ten of the 14 countries in Table 15 using business-as-usual reference levels explicitly included policies encouraging the use of biomass energy within their emissions projections. In other words, these countries anticipated that some quantity of their emissions in the commitment period will result from biomass energy use – but, since this quantity is included in their reference levels, these emissions will not count against the countries' national emissions targets.

Although the other four countries did not model the impacts of such policies within their reference levels, this does not preclude the possibility that any increases in forest harvests and/or biomass use included in these countries' projections could be used for biomass energy. Any increases in emissions built into the reference level (and therefore undocumented) are not directly attributable to increased demand for biomass energy – but they could be.

> A proportion of the emissions from the solid biomass burnt for energy in almost all of the nine countries analysed here will go unaccounted for, either because they or their main sources of imports use forest management reference levels that build in a level of biomass-related emissions or because they import from countries outside the second commitment period of the Kyoto Protocol.

To summarize, a proportion of the emissions from the solid biomass burnt for energy in almost all of the nine countries analysed here will go unaccounted for, either because they or their main sources of imports use forest management reference levels that build in a level of biomass-related emissions or because they import from countries outside the second commitment period of the Kyoto Protocol. Unfortunately, it is not possible precisely to calculate the quantity of unaccounted for emissions; the information provided in countries' forest management reference level submissions is not usually sufficient to answer this question. Ideally, these submissions would have explicitly specified: (1) the anticipated impact of biomass energy policies on the quantity of woody biomass used; (2) the origins of that biomass (i.e. additional domestic forest harvests, increased use of domestic forestry residues or imported biomass); and (3) the resulting emissions. Of the countries whose reference levels explicitly included biomass energy policies, only three – Austria, Finland, and Sweden – explicitly quantified the impact of biomass energy policies on domestic forest biomass and/or the anticipated use of energy derived from forest biomass. Several other countries indicated that they had built anticipated increases in biomass energy use into their reference levels, but did not provide sufficient data to quantify the resulting impact on forest-based emissions.

Table 15: Forest management reference levels for the second commitment period of the Kyoto Protocol for the countries included in Table 14

	Type of reference level	Does reference level include policies driving biomass energy use?	Additional information
Austria	Country-specific projection	Yes; includes increase in demand for woody biomass for energy of 20 per cent from 2008–2020; gross domestic consumption of woody biomass for energy from 18 million m^3 (145 PJ in 2009 to 21–22 million m^3 (170–175 PJ) in 2020. Assumes around 20 per cent supply from imports.	
Denmark	Country-specific projection	No	Increased use of woody biomass expected to be based primarily on imported wood pellets, not on domestic sources.
Estonia	JRC projection	Yes; projection includes demand for biomass and waste for electricity and thermal energy; cannot determine type or origin of fuel.	
Finland	Country-specific projection	Yes; projection includes increased use of wood chips from 5.3 TWh in 2007 to 21 TWh in 2020, increased use of wood/wood pellets from 13.7 TWh to 16 TWh. Projection also includes black liquor, industrial wood residues, and wood chips for biofuels. Assumes increased harvesting of logging residues and stumps; reduced dependence on imports.	10–21 $MtCO_2$ from burning domestically harvested wood for energy will not be counted towards the country's emissions target.[i]
France	JRC projection	Yes; projection includes demand for biomass and waste for electricity and thermal energy; cannot determine type or origin of fuel.	
Germany	Country-specific projection	No	
Italy	JRC projection	Yes; projection includes demand for biomass and waste for electricity and thermal energy; cannot determine type or origin of fuel.	
Latvia	JRC projection	Yes; projection includes demand for biomass and waste for electricity and thermal energy; cannot determine type or origin of fuel.	
Lithuania	JRC projection	Yes; projection includes demand for biomass and waste for electricity and thermal energy; cannot determine type or origin of fuel.	
Norway	1990 (historical base year)	N/A	
Poland	Country-specific projection	No	
Portugal	Country-specific projection	Yes; projected increase in harvests of 6 per cent attributable to expansion of pulp and bioenergy sectors.	
Romania	JRC projection	Yes; projection includes demand for biomass and waste for electricity and thermal energy; cannot determine type or origin of fuel.	
Sweden	Country-specific projection	Yes; projection includes increased use of forest residues and stumps for biomass energy from 8.6 TWh in 2010 to 13.3 TWh in 2020. Area of stump harvest increases from 4,800 hectares in 2010 to 23,400 hectares in 2020.	
UK	Country-specific projection	No	Reference level assumes that up to 17 per cent of the biomass from planned harvests will be used for biomass energy; emissions from this quantity will therefore not be accounted for.

Sources: National forest management reference levels submitted to the UNFCCC, http://unfccc.int/bodies/awg-kp/items/5896.php.
[i] Net calorific value for solid wood fuels = 7.8–16 GJ/t; emission factor = 109.6 gCO_2/MJ for solid wood fuels. Statistics Finland (2014), 'Greenhouse Gas Emissions in Finland 1990–2012', Table 3.2-3, http://www.stat.fi/tup/khkinv/fin_nir_2012_2014_04_15.pdf (accessed 20 Jan. 2018).

Recommendations for policy

It is clear that emissions from the use of forest biomass have not been accurately reflected in countries' greenhouse gas accounts. The problem of 'missing', or unaccounted-for, emissions arises when a country using biomass for energy does the following:

- The country imports biomass from a country outside the accounting framework – such as the US, Canada or Russia, all of which are significant exporters of woody biomass that do not account for greenhouse gas emissions under the second commitment period of the Kyoto Protocol;
- The country accounts for its biomass emissions using a historical forest management reference level that includes higher levels of biomass emissions than at present; or
- The country accounts for its biomass emissions using a business-as-usual forest management reference level that (explicitly or implicitly) includes anticipated emissions from biomass energy: these emissions will not count against its national target.

In each of these scenarios, the accounting framework allows countries to avoid accounting for biomass energy emissions in both the energy and land-use sectors. However, such an absence of emissions from biomass energy is merely an artefact of the greenhouse gas accounting framework. It is a fall in emissions on paper only and does not change those emissions' impacts on the atmosphere. This risks creating perverse policy outcomes: where a tonne of emissions from burning biomass for energy does not count against a country's emissions target but a tonne of emissions from fossil fuel energy sources does, this creates an incentive to use biomass energy rather than fossil fuels in order to reduce the country's greenhouse gas emissions – even where this reduction is not 'real', in the sense that it is not accounted for in any country's land-use sector accounts.

The quantity of emissions missing from the international greenhouse gas accounting framework is impossible to calculate directly, but is likely to be significant. The data gaps and ambiguities highlighted above emphasize the need for more detailed reporting on the types, sources and countries of origin of biomass used for energy. Although many countries already collect these data, they are not currently available in a form that allows for a complete understanding of the impact of biomass energy use on global or national emissions.

One solution would be to account for carbon dioxide emissions from biomass burnt for energy within the energy sector, not the land-use sector. While additional rules would be required to ensure emissions were not double-counted in the energy and land-use sectors, this could be a viable solution given sufficient data and guidance to promote transparency. In effect, it would shift the incentives to manage biomass energy emissions from the countries in which the biomass is grown to the countries in which it is burnt.

If this major revision of greenhouse gas accounting rules does not prove acceptable, four steps could nevertheless be taken within the existing framework (accounting for biomass emissions in the land-use sector) to reduce the potential for missing emissions.

First, all countries should include the land-use sector, including forest management, in their national accounting. If carbon emissions from bioenergy continue to be reflected only in the land-use sector, then the practice of allowing biomass-producing countries to exclude their land-use sectors or, more narrowly, their forest management activities from accounting (as in the first commitment period of the Kyoto Protocol) has the potential to create major accounting gaps with potentially perverse

outcomes. The implementation of the 2015 Paris Agreement – for which many details remain to be negotiated – affords an opportunity to revise the accounting system to incentivize all countries to report and account fully for emissions from their land-use sectors, including their forests.

Second, forest management reference levels should contain detailed information on projected emissions from using biomass for energy, the origins of that biomass (additional domestic forest harvests or increased use of domestic forestry residues) and the resulting emissions.

Third, countries that import biomass for energy should be required to report on whether and how the country of origin accounts for biomass-based emissions. Importing biomass from a country that does not account for such emissions, or from one that has built biomass energy demand into its accounting baseline, will result in 'missing' emissions and is likely to promote the importing country's potentially perverse reliance on biomass energy. Emissions associated with this imported biomass should therefore be fully accounted for by the importing country, not the country of export.

Fourth, countries using domestic biomass for energy should reconcile their energy and land-use sector accounting approaches in order to put emissions from each sector on a par with each other. If possible, accounting for greenhouse gas emissions in the energy and land-use sectors should use the same benchmarks – either a historical reference year/period or a business-as-usual scenario – to avoid emissions leakage between the sectors, and this should be uniform across all countries. If this is not feasible, additional methodologies and rules should be devised to bring biomass energy emissions back into the accounting framework and treated in the same way as other energy-related emissions.

Although these options represent departures from current greenhouse gas reporting and accounting conventions, the scale of emissions at stake and the perverse incentives created by the current system demonstrate the need for reform of the current system to reflect more accurately the atmospheric impacts of relying on biomass for energy.

13. Prospects for biomass in the EU

In 2016 (the latest year for which figures are available), the countries analysed in this paper were nine of the 11 largest consumers of energy from solid biomass for power and heat in the EU.[234] Between them they accounted for 75 per cent of EU28 electricity generation, and 71 per cent of EU28 heating and cooling consumption, from biomass. Their experiences so far, and the prospects for the future development of biomass energy in these countries, thus provide a good indication of how EU consumption of biomass energy as a whole is likely to develop.

As discussed in chapters 3–11, all of these countries provide government support for energy from woody biomass, among other renewable technologies, through a mixture of feed-in tariffs or premiums, quota obligations on energy suppliers, tender or auction schemes for contracts at above-market prices, fiscal incentives such as grants or tax breaks (particularly in Scandinavian countries with energy and emissions taxes), and support for grid connections and installations. This mixture of measures, and frequent policy changes in many of these countries, make it extremely difficult to calculate exactly how much support, in monetary terms, has been delivered in practice, and how this compares with the support given to other renewables, but a rough idea can be gained from the growth rates in tables 16 and 17 below, particularly when compared with growth in renewable electricity and heat across all technologies. The UK in particular has seen a rapid growth in the use of biomass for both power and heat (Romania has seen the fastest rate of growth in electricity generation, but from an extremely low base).

Prospects for biomass power

Table 16 summarizes, for the EU28 and each of the nine countries analysed in this paper, electricity generation from solid biomass in 2009 and 2016, its average annual rate of growth over that period, and the proportion of total electricity and of renewable electricity generation it accounted for in 2009 and in 2016.

In each of these nine countries, except Sweden, biomass provided a larger proportion of total electricity generation in 2016 than it did in 2009. This is because the consumption of renewable electricity as a whole has increased, in line with countries' efforts to meet their Renewable Energy Directive targets. In five of the nine countries, however, and in the EU28 as a whole, biomass provided a smaller proportion of renewable electricity in 2016 than it did in 2009, and in three countries (Finland, France and Romania) only a slightly higher proportion. Only the UK has seen a substantial increase in the generation of electricity from biomass both in absolute terms and as a proportion of electricity from renewable sources.

[234] The other two were Austria and Spain, ranked 8th and 9th, respectively.

Table 16: Biomass electricity, 2009 and 2016

	Electricity from biomass			Biomass as share of total electricity (%)		Biomass as share of renewable electricity (%)	
	2009 (Mtoe)	*2016 (Mtoe)*	*Av. annual growth 2009–16 (%)*	*2009*	*2016*	*2009*	*2016*
EU28	5.22	7.86	6.0%	1.9%	2.8%	10.0%	9.5%
Denmark	0.17	0.30	8.3%	5.4%	9.8%	19.2%	18.2%
Finland	0.72	0.91	3.4%	10.1%	12.1%	36.5%	36.7%
France	0.11	0.26	13.9%	0.2%	0.6%	1.6%	3.1%
Germany	0.82	0.93	1.9%	1.6%	1.8%	9.5%	5.7%
Italy	0.24	0.35	5.5%	0.8%	1.3%	4.5%	3.7%
Poland	0.42	0.59	5.0%	3.3%	4.1%	56.5%	30.8%
Romania	0.00	0.04	72.8%	0.0%	0.8%	0.1%	1.8%
Sweden	0.87	0.84	-0.5%	7.2%	6.8%	12.3%	10.4%
UK	0.31	1.69	27.2%	1.0%	5.5%	14.5%	22.5%

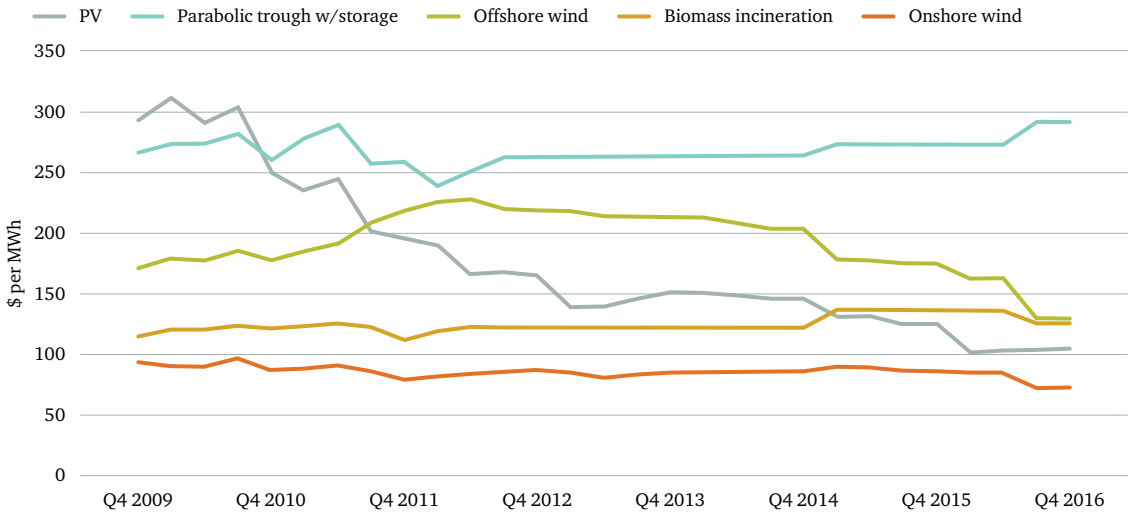
Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.

The main reason behind this slower growth of biomass power than of renewable electricity overall is the significant falls in the costs of competing renewable technologies, particularly solar PV and wind. While, on a global scale, in 2014, the levelized costs of electricity from biomass were slightly lower than those of solar PV and roughly the same as onshore wind, biomass combustion technologies are relatively mature, and therefore have a lower cost reduction potential. In 2016, the International Renewable Energy Agency (IRENA) projected a possible reduction in biomass costs of 10–15 per cent by 2025; in contrast, it anticipated a 59 per cent fall for solar PV, and 26 per cent for onshore wind, by the same date.[235] Like most forecasts of the costs of renewables, these latter two figures now seem certain to be underestimates. During 2016 alone the cost of solar PV fell by 17 per cent, onshore wind by 18 per cent and offshore wind by 28 per cent (see Figure 32).[236]

In September 2017, the UK's second Contracts for Difference auction saw two offshore wind contracts agreed at a strike price less than half the average price delivered by the industry in the first auction just two years earlier, and close to the market price of electricity (i.e. close to being free of subsidy).[237] In April 2017, DONG Energy won two contracts in a German auction for offshore wind at a subsidy rate of zero (though this excludes some of the costs of connecting to the grid, which are included in the UK contracts). In June 2017, Bloomberg New Energy Finance projected the cost of offshore wind to decline by a further 71 per cent by 2040.[238]

[235] International Renewable Energy Agency (2016), *The Power to Change: Solar and Wind Cost Reduction Potential to 2025*, http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf (accessed 13 Dec. 2016).
[236] Frankfurt School-UNEP Centre / Bloomberg New Energy Finance (2017), *Global Trends in Renewable Energy Investment 2017*, http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf (accessed 2 Feb. 2018).
[237] Carbon Brief (2017), 'Analysis: UK auction reveals offshore wind cheaper than new gas', 11 September 2017, https://www.carbonbrief.org/analysis-uk-auction-offshore-wind-cheaper-than-new-gas (accessed 2 Feb. 2018).
[238] Bloomberg New Energy Finance (2107), *New Energy Outlook 2017*, https://about.bnef.com/new-energy-outlook/ (accessed 2 Feb. 2018).

Figure 32: Levelized cost of electricity from selected renewable energy sources, Q3 2009 to H2 2016, $ per MWh



Source: Frankfurt School-UNEP Centre/Bloomberg New Energy Finance (2017), *Global Trends in Renewable Energy Investment 2017*, http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf (accessed 2 Feb. 2018).
Note: Solar thermal is parabolic trough with storage, PV is crystalline silicon with no tracking.

Although biomass is being out-competed, in cost terms, by other renewable technologies, it has the advantage over solar and wind of being dispatchable: i.e. it is a source of electricity that can be dispatched at the request of power grid operators or of the plant owner. Biomass plants can adjust their power output according to need (while stopping and starting a biomass power plant is a costly and inefficient process, adjusting the power output of an operating plant upwards or downwards is much less so); solar, wind (and hydro, apart from pumped hydro storage) are there or not, depending on the conditions. The role of biomass in balancing the renewable energy system may become more important as countries steadily increase the share of solar and wind in their energy mix – though there are of course alternatives, including a greater degree of interconnection with other countries' grids, battery storage (where costs are also falling sharply) and other storage technologies. This question will be examined in more detail in the forthcoming Chatham House paper, *Woody Biomass for Power and Heat: Global Demand and Supply*.

Prospects for biomass heat

Table 17 summarizes, for the EU28 and each of the nine countries analysed in this paper, heat consumption from solid biomass in 2009 and 2016, its average annual rate of growth over that period, and the proportion of total heat and of renewable heat consumption it accounted for in 2009 and in 2016.

Across the EU as a whole, and in every one of the nine countries analysed here, the share of biomass has risen as a proportion of total heat consumption. As with electricity, this is because of the general expansion of renewable energy encouraged by the Renewable Energy Directive targets. Throughout the EU biomass still dominates renewable heat; the smallest proportion of consumption from biomass in these nine countries is 67 per cent, in Germany, and it is over 90 per cent in Finland, Poland and Romania. Unlike the situation with electricity generation, alternatives to biomass for renewable heat have tended to be less well commercialized, at least to date. In addition, in many countries biomass has always been an important source of heating, particularly in rural households, even before the

introduction of policies supporting renewable energy. Furthermore, in several of these countries, particularly Finland and Sweden, an important part of biomass heat consumption is accounted for by the production and consumption of black liquor in the pulp and paper industry.

However, alternatives to biomass for renewable heat – mainly heat pumps, solar thermal and biogas – are now beginning to find wider markets, which helps to explain why, in both the EU as a whole and in all nine countries analysed here, biomass fell as a share of renewable heat between 2009 and 2016, though in most cases by a relatively small amount. (The largest proportionate fall, in the UK, is a reflection more of the lack of development of all renewable technologies before 2009 than of any move away from biomass; in fact the UK has also seen the fastest rate of growth of heat consumption from biomass of any of these nine countries, though from the lowest base.) This is a slow development, however, so for all the reasons outlined above, biomass is likely to remain the dominant source of renewable heat throughout the EU; other technologies will expand faster, but from a much lower base. The implementation of energy efficiency improvements in buildings may also reduce the demand for heating from all sources.

Table 17: Biomass heat, 2009 and 2016

	Heating and cooling from biomass			Biomass as share of total heating & cooling (%)		Biomass as share of renewable heating & cooling (%)	
	2009 (Mtoe)	*2016 (Mtoe)*	*Av. annual growth 2009–16 (%)*	*2009*	*2016*	*2009*	*2016*
EU28	66.88	77.91	2.2%	12.6%	15.0%	84.6%	78.4%
Denmark	1.72	2.35	4.5%	22.3%	31.1%	75.5%	74.5%
Finland	5.34	6.90	3.7%	40.6%	48.8%	94.1%	91.0%
France	8.28	9.82	2.5%	12.4%	15.7%	81.9%	74.4%
Germany	7.22	9.57	4.1%	6.9%	8.7%	74.5%	67.2%
Italy	7.79	7.12	-1.3%	12.6%	12.8%	76.5%	67.6%
Poland	4.11	5.17	3.3%	11.3%	13.9%	98.1%	94.5%
Romania	3.75	3.47	-1.1%	26.3%	26.5%	99.3%	98.8%
Sweden	7.11	7.85	1.4%	51.9%	54.7%	81.6%	79.8%
UK	1.22	2.86	12.9%	2.1%	5.1%	90.7%	73.1%

Source: Eurostat SHARES database, http://ec.europa.eu/eurostat/web/energy/data/shares.

A possible inhibiting factor, however, is the concern increasingly being expressed over the impacts on local air quality and human health of the use of biomass for household heating and other purposes. A study published in 2018, for example, estimated that exposure to smoke from domestic biomass use caused, among other impacts, at least 40,000 deaths across the EU28 in 2014, together with more than 130,000 cases of bronchitis, more than 20,000 respiratory and cardiac hospital admissions and 10 million working days lost.[239] More than 1,300 deaths a year were linked to air pollution from 27 biomass burning power stations across the EU. This topic is not considered in this report, which focuses on the impacts of biomass use on emissions of carbon dioxide and thus on climate change (though particulate emissions, or 'black carbon', also accelerate climate change), but should be borne in mind when considering future demand for biomass.

[239] Holland, M. (2018), *Covered in Smoke: Why burning wood threatens the health of Europeans*, Fern, http://fern.org/sites/default/files/news-pdf/Covered%20in%20smoke.pdf (accessed 2 Feb. 2018).

Prospects for biomass supply

EU member states' National Renewable Energy Action Plans, drawn up in response to the 2009 Renewable Energy Directive, projected that bioenergy would account for 12 per cent of total European energy consumption by 2020, more than half of the 20 per cent target set for energy from renewable sources.[240] This implies continued rapid growth between 2016 and 2020, but according to projections published by the European Commission in November 2016, accompanying the new draft Renewable Energy Directive, further significant growth beyond 2020 seems less likely, due mainly to the fall in price of competing renewables and anticipated improvements in energy efficiency.[241] One of the models used by the Commission, the Price-Induced Market Equilibrium System (PRIMES), projected a 27 per cent increase in bioenergy use between 2015 and 2020, followed by a 4 per cent increase between 2020 and 2030. Another model, Green-X, had a somewhat different trajectory suggesting that total bioenergy demand will be lower than the level projected by PRIMES in 2020, but would increase by 17 per cent between 2020 and 2025, and then remain flat until 2030.

Nevertheless, as can be seen from the country analyses, further growth in biomass use for energy can be expected at least until 2020, under the current policy framework. Projections of the EU's ability to meet this continued growth in demand from its own forests are uncertain, depending on, among other factors, the future development of industries that compete for raw materials (such as the construction industry) and the potential for increased use of wood, agricultural residues and waste wood as well as the growth of energy crops. All three models used by the Commission to estimate supply projected increased use of roundwood and increased harvesting rates in forests (alongside growth in the use of agricultural residues); this is consistent with the country analyses in this paper. One study estimated that, if the EU was to achieve its aim of providing 27 per cent of its energy consumption from renewable sources by 2030, the amount of biomass it would need was equivalent to the total EU wood harvest for all purposes in 2015.[242]

All projections also assume a growing role for imports, particularly from North America and Russia, but also potentially from non-EU Europe (e.g. Belarus, Bosnia and Herzegovina, and Ukraine) and from Latin America. This also depends on demand for woody biomass in those countries, for energy and for other purposes, and pressure on land use. As noted in Chapter 11, a 2017 analysis of the availability of biomass feedstock to the UK concluded that 70–90 per cent less biomass was likely to be available from imports than had previously been projected, partly because of limited global availability of land for biomass and competition for biomass supplies.[243] Imports may thus be less significant – and future growth in supplies more constrained – than the estimates above suggest. This topic will be discussed in more detail in the forthcoming Chatham House paper, *Woody Biomass for Power and Heat: Global Demand and Supply*.

[240] Atanasiu, B. (2010), *The Role of Bioenergy in the National Renewable Energy Action Plans*.
[241] European Commission (2016), *Commission Staff Working Document – Impact Assessment: Sustainability of Bioenergy*, section 5.1.2.
[242] Strange Olesen, A. et al. (2015), *Environmental Implications of Increased Reliance of the EU on Biomass from the South East US*, p. 8, Brussels: European Commission, https://publications.europa.eu/en/publication-detail/-/publication/8005fb30-81e9-4399-9b19-01af823fa42d/language-en (accessed 30 Dec. 2016).
[243] Ricardo Energy and Environment (2017), *Biomass Feedstock Availability*.

14. Recommendations for policy

Biomass energy feedstocks and impacts on the climate

Along with the total level of consumption of biomass for energy, the type of feedstock used plays a critical role in the impact of biomass use on the global climate. As discussed in the Chatham House paper, *Woody Biomass for Power and Heat: Impacts on the Global Climate*, any increase in forest harvesting rates caused by demand for energy will in almost all circumstances increase net carbon emissions very substantially compared to using fossil fuels, because of the combustion of stored carbon in the wood, the loss of future carbon sequestration from growing trees and the release of soil carbon consequent upon the disturbance.

Some types of biomass feedstock can be carbon-neutral, at least over a period of a few years: wastes from forest harvesting or forest industries that imply no additional harvesting, and if otherwise burnt as waste or left to rot would release carbon to the atmosphere in any case. This includes in particular sawmill wastes such as sawdust, and black liquor from the pulp and paper industry that would otherwise have to be disposed of. It can make sense to burn these types of woody biomass for energy (particularly on-site, with no need for processing or transport, but also if they replace high-carbon fossil fuels such as coal or oil), and in many instances this will be economic without the need for subsidy. Fast-decaying (small-diameter) forest residues, however, may not always be usable by biomass plants, and burning slowly decaying forest residues for energy may mean that carbon levels stay higher in the atmosphere for decades longer than if fossil fuels had been used, which is a matter of considerable concern given the current rate of global warming. If mill residues are diverted from use as wood products to use as energy (for which there is relatively little evidence to date), net carbon emissions will be higher as a result.

The carbon payback approach argues that while carbon emissions from burning woody biomass are higher than using fossil fuels, they can be absorbed by forest regrowth. The length of time this takes – the carbon payback period before which carbon emissions return to the level they would have been at if fossil fuels had been used – is of crucial importance. The many attempts that have been made to estimate carbon payback periods suggest that they vary substantially, from less than 20 years to many decades, and in some cases even centuries. As would be expected, the most positive outcomes for the climate, with short payback periods, derive from the use of mill residues (unless diverted from use for wood products). If forest residues are used that would otherwise have been left to rot in the forest, the impact is complex, as their removal may reduce levels of soil carbon and rates of tree growth. The most negative impacts involve increasing harvest volumes or frequencies in already managed forests, converting natural forests into plantations or displacing wood from other uses.[244]

Detailed data on biomass energy feedstocks are not always available, but a 2015 study for the European Commission estimated that, across the EU, wood fuel not suitable for industrial use accounted for 33 per cent of feedstock, black liquor for 27 per cent, industrial residues (e.g. from sawmills) for 24 per cent, and forest residues for 16 per cent.[245] 'Dedicated harvest of stemwood (for example

[244] See Brack, D. (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate*, pp. 27–31.
[245] European Commission (2016), *Commission Staff Working Document – Impact Assessment: Sustainability of Bioenergy*, Annex 5.

pulpwood) for bioenergy plays a marginal role in EU produced feedstocks' – but of course this has the potential to change with continued expansion of biomass energy use. (These figures differ from the 2015 study summarized in Table 3 in Chapter 2, which included equivalent figures of 27 per cent for wood fuel, 16 per cent for black liquor, 18 per cent for industrial residues and 14 per cent for forest residues.[246] Another 23 per cent, however, was accounted for by post-consumer waste wood and wood pellets, some of which were imported, so the calculation has been carried out on a different basis.)

The feedstock for imports, particularly of wood pellets from North America and Russia, is a contentious subject. While pellet and biomass energy companies generally claim their original source as mill and forest residues, the evidence suggests that, particularly in the southeast of the US (the main source of pellet exports to Europe) roundwood is used extensively. In 2015, two studies concluded that only about a quarter of the feedstock used to produce pellets in the southern US was mill residues and forest residues, and three-quarters was pulpwood.[247] (This topic is explored in more detail in the Chatham House paper, *Woody Biomass for Power and Heat: Impacts on the Global Climate.*) A further increase in EU imports of pellets from these sources – which seems likely – will, all else being equal, therefore have increasingly negative impacts on the climate, as well as on local ecosystems in the forests of origin. However, if EU or US forest industries expand – for example if climate policies encourage a greater use of wood in construction – the supply of mill and forest residues may increase, somewhat ameliorating this.

Recommendations

It is therefore important for policymakers in the EU to control the types of biomass feedstock used – and supported by EU and member states' policy frameworks – in order to limit negative impacts on the climate. The burning of forest or mill residues that otherwise have no use, or would be burnt as waste; combustion for heat rather than electricity, or through combined heat and power; minimal transport distances (as in black liquor); and higher energy efficiencies of the technology in use; all contribute to reducing the carbon payback period. It is also, of course, vital that the forest carbon stock is replaced as fast as possible, not just through replanting – which, in replacing mature trees with much smaller young trees, leads to an overall reduction in carbon stocks for a period of years or decades – but in planting more trees and expanding forest area overall (note that this is *not* the same as 'sustainable forest management', which implies simply replanting to maintain forest area).

It is important for policymakers in the EU to control the types of biomass feedstock used – and supported by EU and member states' policy frameworks – in order to limit negative impacts on the climate.

In principle, sustainability criteria can be used to distinguish between these different variables. None of the national sets of criteria currently in use achieve this, most notably in their failure to take account of changes in the forest carbon stock – though in limiting eligible feedstocks for support to wastes and residues, the Italian criteria do go some way to addressing this (see Chapter 7).

[246] Indufor (2017), *Outlook for Wood Energy for Biomass in the EU-28*.
[247] Strange Olesen et al. (2015), *Environmental Implications of Increased Reliance of the EU on Biomass from the South East US*, pp. 95–96; RISI (2015), *An Analysis of UK Biomass Power Policy, US South Pellet Production and Impacts on Wood Fiber Markets*, p. 20, http://docplayer.net/25281897-An-analysis-of-uk-biomass-power-policy-us-south-pellet-production-and-impacts-on-wood-fiber-markets-prepared-for-the-american-forest-paper.html (accessed 2 Feb. 2018).

The criteria proposed in the draft new Renewable Energy Directive (see Chapter 2) are similarly inadequate, partly because of the weaknesses in the system of accounting for biomass emissions from the land-use sector (see Chapter 12) to which they refer.[248]

Therefore, as argued in the 2017 Chatham House paper:

- In assessing the climate impact of the use of woody biomass for energy, changes in the forest carbon stock must be fully accounted for. It is not valid to claim that because trees absorb carbon as they grow, the emissions from burning them can be ignored. (From an accounting perspective, this is because absorption of carbon by forests prior to the setting of climate policies occurs in both the climate policies scenario and the fossil fuel counterfactual. Therefore, it cannot be treated as a credit in one scenario without treating it as a credit in the other.)
- Along with changes in forest carbon stock, a full analysis of the impact on the climate of using woody biomass for energy needs to take into account the emissions from combustion (which are generally higher than those for fossil fuels) and the supply-chain emissions from harvesting, collection, processing and transport. There is still some uncertainty over some of these factors, and they can vary considerably with the origin of the wood; further research would be helpful.
- The provision of financial or regulatory support to biomass energy on the grounds of its contribution to mitigating climate change should be limited to those feedstocks that reduce carbon emissions over the short term.
- In practice, this means that support should be restricted to sawmill residues, together with post-consumer waste. Fast-decaying forest residues could also fit into this category, but in practice this is small-diameter material that is likely to contain too much moisture and dirt to render it easily usable by biomass plants; and it would be difficult for policy to distinguish easily between fast and slow-decaying residues. Burning slow-decaying forest residues or whole trees means that carbon emissions stay higher than if fossil fuels had been used for decades, which is a matter of considerable concern given the current rate of global warming.

This is not to argue, of course, that fossil fuels should *not* be replaced by renewable energy for power and heat: this is essential if the world is to escape the most catastrophic impacts of climate change. It is to argue, rather, that public support and subsidy should be used for renewable technologies that reduce carbon levels in the atmosphere in the near term as well as the long term: some forms of biomass, as argued above, but primarily genuinely zero-carbon renewables such as solar or wind.

[248] For a longer discussion, see Brack, D. (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate*, p. 66.

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Cover image: An automated auger for loading processed wood chip heating fuel into a biomass boiler.

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