Research Paper

Environment and Society Programme

October 2021

# Greenhouse gas emissions from burning US-sourced woody biomass in the EU and UK

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# Summary


- Many national and intergovernmental policy frameworks, including those of the EU and UK, currently treat biomass energy as zero-carbon at the point of combustion, and grant it access to financial and regulatory support available for other renewable energy sources.
- These incentives have driven a rapid increase in the consumption of biomass for energy, even though its combustion may increase atmospheric concentrations of carbon dioxide ($CO_2$) for years or even decades to come.
- Although the $CO_2$ should eventually be absorbed, the elevated levels in the interim are likely to be incompatible with the 2015 Paris Agreement on climate change. They also increase the risk of reaching a climate tipping point.
- The treatment of biomass as zero-carbon in policy frameworks will give policymakers in consumer countries a false sense of optimism about the progress being made in decarbonizing their energy supply, while producing countries have no corresponding incentive to reduce future emissions in compensation for the loss of sequestered carbon.
- Subsidies for biomass energy have been delivered – and seem likely to continue – with little to no differentiation between feedstocks and therefore no effective means of limiting the impact on the climate.
- In 2019, according to our analysis, US-sourced wood pellets burnt for energy in the UK were responsible for 13 million–16 million tonnes of $CO_2$ emissions, when taking into account emissions from their combustion and their supply chain, forgone removals of $CO_2$ from the atmosphere due to the harvest of live trees and emissions from the decay of roots and unused logging residues left in the forest after harvest.
- Almost none of these emissions are included in the UK's national greenhouse gas inventory; if they were, this would have added between 22 and 27 per cent to the emissions from total UK electricity generation, or 2.8–3.6 per cent of total UK greenhouse gas emissions in 2019. This volume is equivalent to the annual greenhouse gas emissions from 6 million to 7 million passenger vehicles.
- Emissions from US-sourced biomass burnt in the UK are projected to rise to 17 million–20 million tonnes of $CO_2$ a year by 2025. This represents 4.4–5.1 per cent of the average annual greenhouse gas emissions target in the UK's fourth carbon budget (which covers the period 2023–27), making it more difficult to hit a target which the government is already not on track to achieve.

- While emissions are likely to fall by 2030, with the end of government support for power stations converted from coal to biomass, they could rise again thereafter if bioenergy with carbon capture and storage (BECCS) plants are developed at scale.
- It is projected that woody biomass sourced in the US and used for energy generation within the EU27 will be responsible for 8 million–10 million tonnes of associated $CO_2$ emissions in 2025, with that figure falling back to 5 million–6 million tonnes in 2030. The 2030 figure could be higher still if further coal-to-biomass conversions go ahead.
- The type of feedstock used in biomass plants is critical. We recommend that only those categories of feedstock with the lowest 'carbon payback periods' should be eligible for financial and regulatory support. This is consistent with the Paris Agreement's aim of peaking global emissions 'as soon as possible', and reduces the chance of reaching a climate tipping point.
- The EU and UK's current sustainability criteria for supporting biomass feedstocks do not take account of the real impacts of different feedstocks on the climate. We therefore recommend that EU and UK criteria be amended to limit support only to those categories of feedstock with the lowest carbon payback periods: sawmill and small forest residues and wastes with no other commercial use whose consumption for energy does not inhibit forest ecosystem health and vitality.
- Emissions from any type of biomass used for energy not satisfying the proposed criteria should be included in full in the consuming country's greenhouse gas totals when judging progress against their national targets and in any relevant policy frameworks, such as the EU's Emissions Trading System. Since these categories of feedstock have longer carbon payback periods than those eligible for support under our recommendations, this would be an effective way of ensuring that the period during which carbon concentrations in the atmosphere are higher than they would otherwise have been is not simply ignored, as it is under existing policy frameworks.

# 01 Introduction

**Forests make an important contribution towards meeting net zero emissions targets by storing sequestered carbon. However, the growing use of forest biomass for energy has raised concerns over the immediate emissions from burning wood.**

The growing number of countries adopting national targets for net zero greenhouse gas emissions is helping to focus attention on the policy mixes needed. The role of forests as stores of sequestered carbon is an important element of this debate, as is the use of forest biomass to generate electricity and heat. Policy frameworks in many countries, including the EU and UK, treat biomass energy as zero-carbon at the point of combustion and, accordingly, grant it access to financial and regulatory support available to other forms of renewable energy. These incentives have helped to drive a rapid increase in the consumption of biomass for energy and stimulated a debate about its impact on the climate.

When burnt in the presence of oxygen, wood and other forms of vegetation biomass emit carbon dioxide ($CO_2$), almost always at higher concentrations per unit of electricity or heat generated than fossil fuels. The classification of biomass as zero-carbon at the point of combustion derives from either or both of the following two assumptions.

First, that biomass emissions are part of a natural cycle in which forest growth absorbs the carbon emitted by burning wood for energy. The problems with this assumption are examined at length in the first paper published by Chatham House on biomass, *Woody Biomass for Power and Heat: Impacts on the Global Climate* (2017),[1] and in many other publications.[2] To summarize, harvesting and burning trees for energy results in a substantial initial increase in carbon emissions,

**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/2017/02/woody-biomass-power-and-heat.
**2** See, e.g. Haberl, H. et al. (2012), 'Correcting a fundamental error in greenhouse gas accounting related to bioenergy', *Energy Policy*, 45 (225-5), pp. 18–23, doi: 10.1016/j.enpol.2012.02.051; European Academies Science Advisory Council (EASAC) (2017), *Multi-functionality and sustainability in the European Union's forests*, https://easac.eu/fileadmin/PDF_s/reports_statements/Forests/EASAC_Forests_web_complete.pdf; EASAC (2018), *Commentary on Forest Bioenergy and Carbon Neutrality*, https://easac.eu/publications/details/commentary-on-forest-bioenergy-and-carbon-neutrality.

creating a 'carbon debt' on land. While the regrowth of trees and the displacement of the fossil fuels that would have been used instead will eventually pay off this carbon debt, regrowth takes time and its effectiveness is uncertain because of the potential effects of climate and land-use changes. As many studies have shown, wood burning increases atmospheric $CO_2$ levels for decades or even centuries until the regrowing forest can accumulate enough carbon to replace that lost previously to harvesting – the 'carbon payback period' – with potentially significant impacts on global warming.

If natural forests are replaced by plantations, the stored carbon may never be replaced, even if the number or density of trees is maintained. Plantation forests have higher growth rates than natural forests and are typically harvested at a relatively young age, while naturally regenerated forests tend to be older and have larger trees when harvested. Therefore, more stored carbon is lost when natural forests are harvested, as it takes longer to replace the stored carbon that was emitted to the atmosphere. Where residues or wastes are used instead of whole trees, the impact on carbon levels in the atmosphere is lower – though potentially still significant – depending on what would have happened to these wastes and residues had they not been burnt for energy. However, current policy frameworks do not distinguish accurately between different categories of feedstock in allocating financial and regulatory support. Feedstock category definitions are too vaguely written to permit accurate distinctions between whole trees and residues or, sometimes, between wood from plantations and from natural forests.

**Wood burning increases atmospheric $CO_2$ levels for decades or even centuries until the regrowing forest can accumulate enough carbon to replace that lost previously to harvesting.**

Second, to avoid double-counting emissions from biomass energy within the energy sector (when the biomass is burnt) and the land-use sector (when the biomass is harvested), the international greenhouse gas reporting and accounting frameworks established under the UN Framework Convention on Climate Change (UNFCCC) and the 1997 Kyoto Protocol provide that emissions should be reported within the land-use sector only.[3] As explored in detail in the 2017 Chatham House paper, this approach makes sense for the system of global *reporting* which allows overall carbon flows to be measured. However, it has resulted in significant gaps in the context of national *accounting* – measuring emissions levels against countries' targets under the Kyoto Protocol, the 2015 Paris Agreement on climate change (where countries' Nationally Determined Contributions – NDCs – contain such targets) or under national legislation, such as the UK's Climate Change Act. This is the case particularly where the countries of production and consumption are different, as land-use sector reports do not distinguish between different uses for harvested biomass.

**3** Non-$CO_2$ greenhouse gas emissions from burning biomass (e.g. methane) for energy *are* reported in the energy sector, as they do not exist in the land-use sector.

As a result, countries have used subsidies and regulatory incentives to encourage energy companies to replace fossil fuels with biomass, leading to a growth in $CO_2$ emissions, with at least a portion – specifically that associated with biomass combustion – not reflected anywhere in emissions accounting against national greenhouse gas reduction targets.[4]

This paper examines this issue with regard to one particular source of woody biomass: wood pellets sourced from the US and burnt for electricity and combined heat and power (CHP) in the EU and UK. Although this represents less than 5 per cent of the total woody biomass consumed for energy in the EU, the market has grown rapidly in recent years. US-sourced pellets account for the majority of wood pellet imports to the UK, which alone consumed 21 per cent of all the wood pellets produced worldwide in 2018. Most UK imports have been burnt at one facility – the Drax power station – which since 2013 has converted four of its six units from coal to biomass. Although consumption of US wood pellets in the EU27 is lower, they remain an important source. Imports to Belgium, Denmark and the Netherlands are already significant, and are forecast to grow further to the latter two countries, as well as to Germany.

Chapter Two of this paper discusses in detail the issues summarized at the start of this chapter – the different feedstocks used for biomass energy and their impact on the climate, plus the challenges faced in accounting for these emissions against national greenhouse gas emission reduction targets.

Chapter Three reviews data on the use and sources of woody biomass for energy in the EU and UK, and on emissions from the consumption of biomass for energy, as reported to the UNFCCC. It then calculates the full emissions associated with the consumption of US-sourced biomass in the EU and UK, under three categories: 1) emissions from the combustion of wood pellets; 2) emissions from energy use in the supply chain, including harvesting, processing and transporting; and 3) the impact on forest carbon emissions and stocks in the forests of the southern US from which the pellets are sourced. The detailed methodology is set out in the Annex.

Chapter Four analyses likely future demand for US wood pellets in the EU27 and UK over the next 10 years, including estimates for imports in 2025 and 2030. It then uses the emissions figures calculated in Chapter Three to outline the associated impacts on the climate.

Chapter Five concludes by proposing a series of changes to the sustainability criteria currently used in the EU and UK, with the aim of restricting support for biomass energy. We recommend that the criteria should be changed to restrict eligible feedstocks to those with the lowest impacts on the climate, and also that much tighter definitions of feedstock categories be introduced to prevent whole trees being treated in the same way as genuine residues. Emissions from any non-residue feedstock used for energy should be counted in full against the consuming country's climate targets.

**4** See, for example, 'Letter from Scientists to the EU Parliament Regarding Forest Biomass', 14 January 2018, http://www.pfpi.net/wp-content/uploads/2018/04/UPDATE-800-signatures_Scientist-Letter-on-EU-Forest-Biomass.pdf; 'Letter regarding the use of forests for bioenergy', 11 February 2021, https://www.dropbox.com/s/hdmmcnd0d1d2lq5/Scientist%20Letter%20to%20Biden%2C%20von%20der%20Leyen%2C%20Michel%2C%20Suga%20%26%20Moon%20%20Re.%20Forest%20Biomass%20%28February%2011%2C%202021%29.pdf?dl=0.

# 02 Greenhouse gas emissions from biomass for energy

**The use of biomass for energy can increase atmospheric concentrations of $CO_2$ for years or even decades. Yet many countries grant it financial and regulatory support, ignoring the emissions from its combustion.**

This chapter reviews the types of woody biomass feedstock that are burnt for power and heat, and the impact their emissions have on the global climate, in particular, the carbon payback period – the length of time taken before forest regrowth absorbs the emissions from combustion. It looks at the way in which biomass emissions are reported and accounted for and the problems this may cause for countries' policy frameworks and accounting of emissions against national targets. (All of these issues are discussed further in *Woody Biomass for Power and Heat: Impacts on the Global Climate*, published by Chatham House in 2017.[5])

**5** It should be noted that, reflecting the lack of consensus on the climate impacts of the use of wood for energy, the 2017 Chatham House paper attracted a considerable degree of criticism from the biomass industry and some members of the research community. For a critique from the IEA Bioenergy technology support group, see Cowie, A. 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.ieabioenergy.com/wp-content/uploads/2017/03/Chatham_House_response_supporting-doc.pdf. However, this critique raised no relevant issues that had not been fully addressed in the paper. See response: Bailey, R. (2017), 'Re: Woody Biomass for Power and Heat: Impacts on Global Climate', Chatham House, 31 March 2017, https://www.chathamhouse.org/sites/default/files/publications/2017-04-05-ResponsetoIEABioenergy.pdf. See also this commentary on the dispute: Sargent, P. (2017), 'IEA-Bioenergy's extraordinary attack on Chatham House's bioenergy report', *The Whole Starfish* blog, 23 March 2017, https://philipsargent.wordpress.com/2017/03/23/iea-bioenergys-extraordinary-attack-on-chatham-houses-bioenergy-report.

## 2.1 Biomass feedstocks

Wood, along with other forms of biomass, has always been burnt for energy in traditional uses such as open fires or simple cooking stoves. These uses are still important in rural areas of many developing and even industrialized countries. Wastes and residues from timber harvesting operations have long been used to generate energy on-site in sawmills and pulp mills. In recent years, however, the creation of incentives to use biomass for power and heat production has seen a much greater uptake of wood feedstocks for those purposes.

In fact, almost any organic material can be used to generate biomass energy, but the practicalities of harvesting and collection, and the degree of contamination of some categories (e.g. municipal waste) in practice limit the types of feedstocks that are of commercial utility. The main categories used for energy in the EU, UK and elsewhere are various types of forest biomass:

- Wood fuel (also referred to as firewood): logs, branches and twigs burnt in that form. (The term 'roundwood' is also often used:[6] while in production statistics, roundwood is an aggregate of wood fuel and industrial roundwood for other uses, terms for different types of wood are not always used consistently.)
- Forest residues from logging operations for other wood products or forest management: stumps, tops, small branches and pieces either too short or irregular to be used for other commercial purposes. Trees cut but not removed from the forest and unmerchantable trees may also be defined as forest residues after a timber harvest. Typically, about one-third of the wood in a harvested tree is contained in roots and small branches. Leaving these in the forest to decompose contributes positively to forest ecosystem health and vitality, and excessive extraction is harmful.
- Sawmill residues: bark, shavings, sawdust, trim ends and offcuts produced in sawmills. Recently these have mostly been used for panelboard manufacture and in pulp mills. They can also be burnt on-site to provide energy for the mill itself.
- Black liquor: a waste product from the kraft pulping process used in many pulp and paper mills to produce high-quality paper. Black liquor is generally burnt in recovery boilers on-site to generate energy for the mill, and also sometimes for export to the local electricity grid.

For ease of transport, logs or forest residues may be converted to wood chips, but are now commonly transformed into pellets, produced by drying and compressing wood material and extruding it through a small cylinder-shaped die. Roughly two tonnes of green – i.e. recently cut, not dried – wood are needed to produce one tonne of pellets. Sawmill and agricultural residues can also be used. Wood pellets are increasingly favoured for long-distance transport and storage, as they are denser and contain lower moisture content than other products. Pellets are now widely used in the EU and UK for both heating and power generation.

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**6** According to FAO definitions, roundwood means all wood harvested in its round form, or split, roughly squared or in other form (e.g. branches, roots and stumps).

Available statistics do not always distinguish between different types of solid biomass. The organic fraction of municipal solid waste is sometimes included, alongside forest and agricultural sources. Black liquor, which is generally categorized as solid biomass despite being a liquid, forms a substantial share of the wood-based fuel consumed in those EU member states with a large pulp and paper industry, such as Finland and Sweden. Estimates suggest that in 2018 various types of wood (including wood fuel, wood residues and by-products and wood pellets) accounted for 77 per cent of the solid biomass burnt for energy in the EU. Black liquor accounted for a further 14 per cent. The remaining 9 per cent was agricultural crop and animal residues and wastes.[7]

**Estimates suggest that in 2018 various types of wood accounted for 77 per cent of the solid biomass burnt for energy in the EU. Black liquor accounted for a further 14 per cent.**

The term 'residue' is often used very loosely, whether in the context of forestry or sawmill residues. It can sometimes include any kind of roundwood not suitable for wood products – i.e. not the straight, unblemished and appropriately sized logs that sawmills generally demand. This can include, for example, 'low-value' or 'unmerchantable' wood, or diseased and storm-damaged trees. Regulators' definitions, both in the EU and UK, are not always clearly drawn and often permit whole trees to be classified as 'residues'. Company reports sometimes include 'low-value wood' in the same category as residues. 'Thinnings' – the selective removal of trees, primarily undertaken to improve the growth rate or health of the remaining trees – can be identified separately, but are also sometimes grouped together with genuine residues.

A 2021 report from the EU's Joint Research Centre (JRC) concluded that almost half (49 per cent) of wood-based bioenergy production in the EU during 2009–15 could be classified as 'secondary woody biomass': forest-based industry by-products and recovered post-consumer wood.[8] 'Primary woody biomass' harvested from forests made up at least 37 per cent of the input mix of wood for energy: about 20 per cent was stemwood (the main part of the tree, including larger branches) and 17 per cent forest residues. The remaining 14 per cent of the mix was uncategorized in the reported statistics, but the report's authors believed it was likely to be primary wood. This category showed faster growth than the others over the study period, causing some concern over the ability of the data to reflect the real impact on the climate of using wood biomass for energy. Since 2015 the rate of extraction has increased significantly. As another JRC analysis concluded,

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**7** European Commission/Navigant Consulting (2020), *Technical assistance in realisation of the 5th report on progress of renewable energy in the EU: Analysis of bioenergy supply and demand in the EU (Task 3)*, https://op.europa.eu/en/publication-detail/-/publication/b9c0db60-11c7-11eb-9a54-01aa75ed71a1/language-en.
**8** Camia, A. et al. (2021), *The use of woody biomass for energy production in the EU,* Brussels: Publications Office of the European Union, doi: 10.2760/831621.

the total area of forests clear-cut in the EU during 2016–18 was 49 per cent higher than in 2011–15.[9] This may mean that the proportion of primary woody biomass burnt for energy has grown in recent years.

Looking more narrowly at US-sourced wood pellets burnt for energy, supply reports from Drax from 2015–19 indicate that on average almost one-half (48 per cent) of the wood was sourced from sawmill residues (25 per cent) and forest residues (23 per cent). Just over one-half (51 per cent) was from whole trees: 21 per cent from 'low-grade roundwood' and 30 per cent from thinnings. This is discussed further in the Annex.

## 2.2 Impacts on the climate

This discussion of feedstocks matters because the impact on the climate of burning wood for energy varies substantially depending on the type of feedstock used. As discussed in *Woody Biomass for Power and Heat: Impacts on the Global Climate* (Brack, 2017), burning any kind of wood for electricity or heat will produce more $CO_2$ than if fossil fuels are used to generate the same amount of energy (with a few exceptions for certain types of coal). For the same energy output, burning wood releases about 10–15 per cent more $CO_2$ than anthracite and about 100 per cent more than gas (under laboratory conditions, with the complete combustion of the fuel in the presence of oxygen). Biomass stations tend to have lower thermal and electrical efficiencies than coal or gas plants, so the real world differences will be larger.[10]

Assuming that the harvested trees are replaced by new planting, these carbon emissions will be absorbed over time by forest regrowth, so the net impact on the climate depends on the balance between the level of emissions produced during harvesting, collecting, processing, transporting and burning the biomass and regrowth, and, crucially, what would have happened to the forest or the feedstock in the absence of demand for wood for energy – the counterfactual.

### Carbon payback periods

Many attempts have been made to measure the net impact on the atmosphere of using different biomass feedstocks compared to using fossil fuels. The initial combustion, along with the associated life cycle emissions of the biomass feedstock, create what can be termed a 'carbon debt' – i.e. the additional emissions caused by burning biomass instead of the coal or gas it replaces, plus the emissions absorption forgone from the harvesting of the forest. Regrowth of the harvested forest removes this carbon from the atmosphere over time, reducing the carbon debt. The period until carbon parity is achieved – the point at which the net cumulative emissions from biomass use are equivalent to those from a fossil fuel plant generating the same amount of energy – is usually termed

**9** Ceccherini, G. et al. (2020), 'Abrupt increase in harvested forest area over Europe after 2015', *Nature*, 583 (7814), pp. 72–7, doi: 10.1038/s41586-020-2438-y.
**10** Brack (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate*, pp. 14–16.

the carbon payback period. After this point, as regrowth continues, biomass may begin to yield 'carbon dividends', in the form of atmospheric greenhouse gas levels lower than would have occurred if fossil fuels had been used. Eventually carbon levels in the forest return to the level at which they would have been if the trees had been left unharvested.[11]

The attempts made to estimate carbon payback periods suggest that they vary substantially, ranging from less than 20 years to many decades, and in some cases centuries, depending on the feedstock used and the efficiency of combustion. As would be expected, the shortest payback periods derive from the use of residues and wastes from forest harvesting or forest industries that imply no additional harvesting and, if otherwise burnt as waste or left to decompose, would release carbon to the atmosphere in any case. This includes, in particular, sawmill wastes (unless they are diverted from use for wood products), and black liquor that would otherwise require disposal. In many cases, burning these types of woody biomass for energy will be economic without the need for subsidy, particularly if burnt on site or if replacing high-carbon fossil fuels such as coal and oil.

If forest residues are used that would otherwise have been left to decompose in the forest, the impact is complex, as decay rates vary significantly depending on local climatic conditions. Burning slowly-decaying forest residues may mean that $CO_2$ levels stay higher in the atmosphere for decades longer than if fossil fuels had been used. In addition, excessive removal can reduce levels of soil carbon and rates of tree growth, increasing the period needed for the residual trees or new trees to compensate for the lost carbon.

The most negative impacts on carbon concentrations in the atmosphere derive from increasing harvest volumes or frequencies in already managed forests, harvesting natural forests or converting natural forests into plantations, or displacing wood from other uses. Where whole trees are harvested and used for energy, not only is the stored carbon in the tree released to the atmosphere immediately, but the tree's future carbon sequestration capacity is lost.

On the other hand, in the absence of forest management, the rate of net carbon absorption by most forests falls as the incidence of dead and diseased trees increases, and over time the forest may also become more vulnerable to wildfire or other disturbances. There can, therefore, be long-term benefits from some level of harvesting. However, due to the urgency of the need to reduce greenhouse gas emissions, immediate benefits are more desirable.

The EU JRC's recent report summarized a range of studies to suggest that only the use of fine woody residues from forest operations (tops, branches and needles) had short carbon payback periods (10–20 years) compared to the use of coal or gas. The use of coarse residues (snags, standing dead trees and high stumps), with generally slower decay rates, extended the carbon payback periods to more than 50 years.[12]

**11** Some of the literature employs the term 'carbon payback period' to describe this longer period, but it refers more commonly to the time to parity with fossil fuels. For a longer discussion, see Brack (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate*, pp. 27–31.
**12** Camia et al. (2021), *The use of woody biomass for energy production in the EU*.

Plantation forests have higher growth rates than natural forests and are typically harvested at a relatively young age. Naturally regenerated forests tend to be older and have larger trees when harvested. Therefore, more stored carbon is lost when natural forests are harvested, and it takes longer to replace that stored carbon emitted to the atmosphere. The conversion of natural forests to fast-growing plantations will therefore lead to a large release of carbon at the time of conversion, plus a lower stock of carbon when trees are harvested. While this may be somewhat offset by faster tree growth rates in the plantation, the net impact on forest carbon storage will be negative. A study looking at this scenario in the southern US found that the carbon payback period would be 60–70 years compared to using coal and 120 years compared to gas.[13] Regular harvesting and clearing of plantations releases stored $CO_2$ back into the atmosphere every 10–20 years.

Limiting the types of feedstocks that may be burnt for energy can help to minimize negative impacts on the climate. This is why the 2017 Chatham House paper concluded that only sawmill residues and post-consumer wood waste should be eligible for subsidy. (While fast-decaying forest residues could also be acceptable, the practical challenges of identifying and verifying them are substantial.) The JRC paper similarly recommended that the use of coarse woody residues should be strictly constrained and that biomass produced from plantations established on recently cleared natural forest should not receive support.[14]

Two further points about carbon payback periods are worth noting. First, the use of coal is being phased out steadily in the EU and rapidly in the UK, while the deployment of other renewables, particularly wind and solar, is increasing in both. Carbon payback periods measured comparatively to coal or gas are therefore not representative of current fuel mixes. The real payback periods compared to the average EU or UK fuel mix, with falling amounts of coal and rising amounts of renewables, are much longer.

Second, even if the carbon payback period is relatively short, there is still an impact on the climate during the years when $CO_2$ emissions are higher than they would otherwise have been. Some have argued that the length of the carbon payback period does not matter, as long as all emissions are eventually absorbed. A recent paper in *GCB Bioenergy*,[15] for example, drew attention to the Paris Agreement's aim of achieving 'a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century',[16] which would therefore allow the use of feedstocks with carbon payback periods potentially up to 75–80 years. Yet the Paris Agreement also calls for parties to 'aim to reach global peaking of greenhouse gas emissions as soon as possible',[17] a reference which is curiously omitted from the *GCB Bioenergy* paper.

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**13** Sterman, J. D. et al. (2018), 'Does replacing coal with wood lower $CO_2$ emissions? Dynamic lifecycle analysis of wood bioenergy', *Environmental Research Letters*, 13(1), doi: 10.1088/1748-9326/aaa512.
**14** Camia et al. (2021), *The use of woody biomass for energy production in the EU*, p. 162.
**15** Cowie, A. L. et al. (2021), 'Applying a science-based systems perspective to dispel misconceptions about climate effects of forest bioenergy', *GCB Bioenergy*, 13, pp. 1210–31, doi: 10.1111/gcbb.12844.
**16** United Nations Framework Convention on Climate Change, *The Paris Agreement*, Article 4(1), p. 2, https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf.
**17** Ibid.

As well as the provisions of the Paris Agreement, there is increasing concern over the possible existence of 'climate tipping points', when a small rise in global temperature prompts a large and potentially irreversible change in the global climate. Examples include boreal forest dieback, Amazon rainforest dieback, the loss of Arctic and Antarctic sea ice and the melting of the Greenland and Antarctic ice sheets.[18] Although in 2013 the Intergovernmental Panel on Climate Change (IPCC) concluded that there was as yet no evidence for global tipping points, more recent studies have concluded that the probability is much higher than previously thought.[19] The *GCB Bioenergy* paper cited a 2018 study that found a low probability of crossing a tipping point in the global climate system if warming does not exceed 2°C.[20] Since the world is not currently on track to restrict warming to 2°C, this is not particularly reassuring.

All these arguments reinforce our conclusion that only biomass energy with the shortest carbon payback periods should be eligible for financial and regulatory support.

## Sustainability criteria

Attempts have been made in current policy frameworks to constrain the feedstock that is to be eligible for financial and regulatory support through the use of sustainability criteria. (The term 'sustainability' is somewhat misleading in this context. It is borrowed from the concept of sustainable forest management, which focuses on maintaining the extent of forest cover, not carbon stocks.) In the EU, the sustainability criteria for solid biomass introduced in the 2018 Renewable Energy Directive include requirements to ensure that the country of origin has either laws or forest management systems in place to ensure that forest biomass is legally harvested and sustainably sourced. These requirements include ensuring that the harvested forest is regenerated, that protected areas remain protected, that the impacts of harvesting on soil quality and biodiversity are minimized and that harvesting is limited to the long-term production capacity of the forest.[21]

The country from which the forest biomass is sourced is required to be a party to the Paris Agreement which has submitted an NDC covering emissions and removals from agriculture, forestry and land use. The NDC must ensure 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 or strengthened.

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**18** For a short summary, see, e.g. Lenton, T. M. et al. (2019), 'Climate tipping points – too risky to bet against', *Nature*, 575, pp. 592–95, doi: 10.1038/d41586-019-03595-0.
**19** See, for example, Wunderling, N. et al. (2021), 'Interacting tipping elements increase risk of climate domino effects under global warming', *Earth System Dynamics*, 12, pp. 601–19, doi: 10.5194/esd-12-601-2021.
**20** Fischer, H. et al. (2018), 'Palaeoclimate constraints on the impact of 2°C anthropogenic warming and beyond'. *Nature Geoscience*, 11(7), pp. 474–85, doi: 10.1038/s41561-018-0146-0.
**21** Official Journal of the European Union (2018), 'Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)', Article 102, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32018L2001.

There are also requirements for minimum greenhouse gas savings compared to fossil fuels: 70 per cent for installations starting operation after 2020 and 80 per cent for installations starting after 2025. (This relates only to supply-chain emissions, not to combustion emissions or changes in forest carbon stocks.) Finally, new biomass stations – i.e. those starting operation from 2022 – producing electricity with above 100 MW total rated thermal input (equating to about 30 MW electricity output capacity) must either use CHP technology or achieve a net electrical efficiency of at least 36 per cent or be a bioenergy with carbon capture and storage (BECCS) plant. (Stations between 50 and 100 MW have more relaxed efficiency rules and those below 50 MW no rules at all, though individual member states can decide to apply them.)

None of the above criteria apply at all to stations below 20 MW thermal rated input (about 7 MW electricity output capacity), though member states may choose to apply them, and, more broadly, may also choose to apply their own additional criteria.

In July 2021 the European Commission published a proposal for a revision of the criteria, as part of the 'Fit for 55' package of measures aimed at ensuring the EU meets its new target of a 55 per cent reduction in greenhouse gas emissions by 2030.[22] The proposed changes include:

- The extension to forest biomass of the provision that feedstock must not be produced from land that was, at any time after 2008, classified as highly biodiverse grasslands, primary forest, highly biodiverse forest, protected areas, or be from wetlands or (with some exceptions) peatlands. This currently applies only to agricultural biomass.
- No support to be given to the use of saw logs, veneer logs, stumps or roots for feedstock.
- National legislation (or, where this is not available, forest management systems) should avoid harvesting of stumps or roots, the degradation of primary forests or their conversion into plantation forests and harvesting on vulnerable soils.
- The extension of the minimum greenhouse gas saving figure of 70 per cent to stations starting operation before 2021.
- The ending of support for the use of forest biomass in electricity-only installations after 2026, unless they are BECCS plants or are situated in a 'region identified in a territorial just transition plan […] due to its reliance on solid fossil fuels' (i.e. a coal-dependent region).
- The extension of the sustainability criteria to stations equal to or above 5 MW total rated thermal input.

**22** European Commission (2021), 'Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652', COM(2021) 557 final, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2021:557:FIN.

The proposal must be agreed by the European Parliament and the Council of the European Union before it becomes law. Amendments can be expected.

The UK currently operates a simpler set of criteria, including similar requirements for legal and sustainable sourcing and targets for greenhouse gas savings per unit of electricity. These targets become stronger over time and, for existing contracts, currently average over the year at 200 kg $CO_2$eq/MWh, falling to 180 kg $CO_2$eq/MWh from April 2025 (with a higher ceiling for individual consignments of biomass). In August 2018, however, the UK government decided to lower the threshold for future contracts to 29 kg $CO_2$eq/MWh, which represented the median value of emissions from solid and gaseous biomass plants then operating in the UK.[23] (As with the EU, the calculation includes only supply-chain emissions. It excludes emissions from combustion, changes in forest carbon stocks and emissions from indirect land-use change.)

For comparison, Drax's annual supply-chain emissions from 2014 to 2019 came to an average of 124 kg $CO_2$eq/MWh, comfortably under the old threshold (and representing about a 70 per cent emissions saving compared to the life cycle emissions of hard coal of 414 kg $CO_2$eq/MWh), but well above the new one. About one-half of these emissions derived from the pelletizing process and 20 per cent from shipping (see Annex, section A2). The former figure could be reduced by using renewable sources of power, but it will be difficult to reduce the contribution of emissions from shipping. The new limit will therefore place severe constraints on the types and sources of biomass feedstock that can be used in future biomass stations, encouraging more local sourcing and possibly ruling out future imports of wood pellets entirely. In addition, new biomass plants will be required to have a minimum overall conversion efficiency of 70 per cent, which would require them to be CHP plants. Electricity-only stations generally have efficiencies below 40 per cent. These requirements do not apply to the contracts currently in place in the UK.

The proposed changes to EU sustainability criteria published in July 2021 seem unlikely to do much in practice to constrain the use of feedstocks, making them only slightly more effective in practice.[24] None of the criteria currently apply to the smallest stations – i.e. those below 20 MW thermal rated input, which represents the majority of biomass plants in the EU and perhaps about 25 per cent of total feedstock consumption. The proposed lowering of the threshold to 5 MW would capture many of these. The efficiency criteria apply only to larger new plants, thus excluding the older and smaller plants that are more likely to have low efficiencies. The greenhouse gas saving criteria currently apply only to new plants, though the new proposals will extend them to existing plants too; however, they are not

**23** Department for Business, Energy and Industrial Strategy (BEIS) (2018), 'Contracts for Difference scheme for renewable electricity generation: Government response to consultation on proposed amendments to the scheme – Part B', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/736588/Part_B_Consultation_Response.pdf.

**24** For a longer exploration of this issue, see Searchinger, T. et al. (2018), 'Europe's renewable energy directive poised to harm global forests', *Nature Communications*, 9(3741), doi: 10.1038/s41467-018-06175-4; Booth, M. S. and Mitchell, B. (2020), *Paper Tiger: Why the EU's RED II biomass sustainability criteria fail forests and the climate*, Partnership for Policy Integrity, http://eubiomasscase.org/wp-content/uploads/2020/07/RED-II-biomass-Paper-Tiger-July-6-2020.pdf; and Fern (2021), *Unsustainable and Ineffective: Why EU Forest Biomass Standards won't stop destruction*, https://www.fern.org/publications-insight/unsustainable-and-ineffective-why-eu-forest-biomass-standards-wont-stop-destruction-2348.

particularly stringent, particularly in comparison with the new UK criteria, which are far stricter. The proposal to extend support after 2026 for the use of forest biomass in electricity-only installations in coal-dependent regions is an open invitation to coal-to-biomass conversions.

The sourcing criteria relate mainly to the existence of regulatory frameworks, rather than their implementation or effectiveness. Many of the conditions, such as the limitation of extraction to the 'long-term production capacity of the forest', are fairly loose. The European Commission's July 2021 proposals help to tighten them somewhat, through banning sourcing from primary forests or plantations converted from primary forests, but there is very little primary forest left in the areas of the US (or EU) from which biomass is sourced, and the requirements are only retrospective to 2008. Sourcing from plantations that were converted from primary forest before 2008 would still be permitted.

**The proposal to extend support after 2026 for the use of forest biomass in electricity-only installations in coal-dependent regions is an open invitation to coal-to-biomass conversions.**

Most importantly, the current criteria do not deal with the variability of carbon payback periods discussed above. The proposed ban on feedstock from saw logs, veneer logs, stumps or roots is welcome in so far as it introduces to the criteria the principle of limiting feedstock by category. In reality, though, specifying those categories will have very little effect. Saw logs and veneer logs are generally too valuable to use for energy, while stumps and roots are difficult and costly to extract. There is therefore still a strong argument for limiting support to the categories of feedstock with the shortest carbon payback periods. In January 2018 members of the European Parliament attempted to amend the draft directive to that effect but were defeated.

### The impact of harvesting for biomass on forest and carbon growth rates

Another key element of the discussion is the question of whether the use of biomass for energy is likely to result in increased harvesting levels and a reduction in the overall volume of carbon stored in the forest. Claims are sometimes made that demand for wood for energy provides additional income to landowners, thereby encouraging them to maintain and possibly expand their forests, rather than allowing clearance. These claims are based on economic theory and are not consistent with the empirical evidence, which suggests the opposite. Demand for wood for energy leads to a reduction in the forest carbon store because the total area and volume harvested increases to meet this demand.

In 2014 the USDA Forest Service reported that, while forest hardwood inventories were expected to continue increasing to 2020, the rate of growth of forest carbon stocks would be lower as a result of demand for biomass for energy. It concluded:

'Even assuming full utilization of mill residues and increased utilization of logging residues, harvest of pine and hardwood non-sawtimber feedstock increases […] hardwood inventories continue to increase although these end at lower levels' than without new bioenergy demand.[25] Subsequent projections by the USDA Forest Service indicated that increased demand for forest products (including bioenergy) would increase the area harvested, and a recent independent study used a similar harvest response scenario based on macroeconomic modelling.[26] In 2018 a survey of forest professionals in the area of the three pellet mills in the southern US that supply the Drax power station in the UK concluded that demand for pellets led to additional harvesting in privately-owned pine plantations, mainly through thinning (although it was not leading to the overall expansion of plantations).[27] A further study of the same area in 2021 confirmed that forest management practices on the non-industrial private forest pine plantations included thinning harvest treatments in the presence of pellet demand, and that thinnings were largely forgone in the absence of demand for wood pellets.[28]

An average of 30 per cent of the feedstock for US-sourced wood pellets burnt by Drax during 2015–19 derived from thinnings. It is sometimes claimed that the practice of thinning can increase forest carbon storage, but almost all the studies on which this claim rests focus on volume growth of the remaining trees, conclude that this does not lead to an increase in total stand volume compared with an uncut stand, and have not reported statistics about carbon uptake by the ecosystem. A literature review in 1985 summarized how thinning affects growth and yield as measured by changes in volume, the metric reflecting the usual purpose of thinning – i.e. to increase merchantable volume.[29] Most of the studies reviewed indicated that thinning would have no influence on total cubic volume yield or would reduce the total yield, unless the thinning were applied to extremely dense young stands in order to prevent stagnation of growth. In most cases, thinning increases the size of individual trees by redistributing the site's growth potential to fewer stems through removals of suppressed or dying trees.

Until recently, almost all studies on thinning reported effects on volume, but not tree or ecosystem carbon. In 2010, however, results from three study sites where carbon fluxes were measured before and after thinning showed that it either had no effect on net ecosystem production or resulted in a reduction that rebounded after one or more years.[30] Further studies have shown that the use

**25** Abt, K. L. et al. (2014), *Effect of Policies on Pellet Production and Forests in the U.S. South: A Technical Document Supporting the Forest Service Update of the 2010 RPA Assessment*, Washington, DC: US Department of Agriculture (USDA) Forest Service, https://www.srs.fs.usda.gov/pubs/gtr/gtr_srs202.pdf.
**26** USDA Forest Service (2016), *Future of America's Forests and Rangelands: Update to the Forest Service 2010 Resources Planning Act Assessment* (General Technical Report WO-94), https://www.srs.fs.usda.gov/pubs/53212; Favero, A., Daigneault, A. and Sohngen, B. (2020), 'Forests: Carbon sequestration, biomass energy, or both?', *Scientific Advances*, 6(13), doi: 10.1126/sciadv.aay6792.
**27** Buchholz, T., Gunn, J. and Kittler, B. (2018), 'UK wood pellet derived electricity: Carbon emission estimates from trees, thinnings and residues sourced in mixed pine-hardwood forests and pine plantations in the southeastern US', *Spatial Informatics Group*, https://www.southernenvironment.org/uploads/publications/Drax_emissions_-_SIG_report_Phase_1_2018-10-25.PDF.
**28** Buchholz, T., Gunn, J. S. and Sharma, B. (2021) 'When Biomass Electricity Demand Prompts Thinnings in Southern US Pine Plantations: A Forest Sector Greenhouse Gas Emissions Case Study'. *Frontiers in Forests and Global Change*, 4(642569). doi: 10.3389/ffgc.2021.642569.
**29** Nebeker, T. E. et al. (1985), *Thinning Practices in Southern Pines – With Pest Management Recommendations*, (Technical Bulletin 1703), USDA Forest Service, http://handle.nal.usda.gov/10113/CAT89231794.
**30** Amiro, B. D. et al. (2010), 'Ecosystem carbon dioxide fluxes after disturbance in forests of North America', *Journal of Geophysical Research*, 115(G4), doi: 10.1029/2010JG001390.

of thinnings for energy does not reduce net greenhouse gas emissions for years at best, and can, under some circumstances, increase them.[31] In general, intact forests with high tree species diversity largely free from human intervention have been shown to be the most carbon-rich ecosystems, with higher rates of biological carbon sequestration.[32]

## 2.3 Reporting, accounting and incentives

### Reporting greenhouse gas emissions

Parties to the UNFCCC are required to submit regular national inventory reports of their greenhouse gas emissions according to guidelines drawn up by the IPCC. While clearly recognizing that the harvesting of woody biomass and its burning for energy results in atmospheric emissions, the IPCC also acknowledged that reporting them in both the land-use sector – at the point of harvesting and removal from the forest – and in the energy sector – at the point of combustion – would result in double-counting. It was therefore determined that biomass emissions should only be included in the land-use sector. As mentioned in Chapter One, this categorization of emissions has contributed to many policymakers perceiving biomass as a carbon-neutral energy source, although this was not the IPCC's intention.

This issue was addressed in the 2017 Chatham House paper,[33] where it was suggested that reporting of biomass energy emissions should be moved to the energy sector, while at the same time additional rules should be implemented to avoid double-counting in the land use sector. This would shift the incentives to control emissions from producing to consuming countries – where the two are not the same, i.e. where biomass is traded internationally – and could thereby reduce incentives for the latter to use biomass for energy. However, this proposal could also lead to the inverse problem, of giving biomass-producing and exporting countries no incentive to control their use of forest biomass for energy. There would be no reason for them to limit production, since the associated reduction in their forest carbon stores would be transferred to the consuming countries' energy sector reports (though demand from consuming countries would, presumably, fall in such circumstances). It would also complicate the reporting of the harvesting of wood for other uses, such as wood products, as some of this may end up being used for energy as post-consumer waste.

**31** See, for example, Hudiburg, T. et al. (2011), 'Regional carbon dioxide implications of forest bioenergy production', *Nature Climate Change*, (1), doi: 10.1038/nclimate1264; Dore, S. et al. (2012), 'Recovery of ponderosa pine ecosystem carbon and water fluxes from thinning and stand-replacing fire', *Global Change Biology*, 18(10), doi: 10.1111/j.1365-2486.2012.02775.x; Ruiz-Peinado, R. et al. (2016), 'Carbon stocks in a Scots pine afforestation under different thinning intensities management', *Mitigation Adaptation Strategies for Global Change*, 21, pp. 1059–72, doi: 10.1007/s11027-014-9585-0; Krofcheck, D. J., Remy, C. C., Keyser, A. L. and Hurteau, M. D. (2019), 'Optimizing Forest Management Stabilizes Carbon Under Projected Climate and Wildfires', *JGR Biogeosciences*, 124(10), pp. 3075–87, doi: 10.1029/2019JG005206.
**32** For a summary of evidence from US forests, see Moomaw, W. R., Masino, S. A. and Faison, E. K. (2019), 'Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good', *Frontiers in Forests and Global Change*, 2(27), doi: 10.3389/ffgc.2019.00027.
**33** Brack (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate*.

## Accounting against national targets

In any case, however, it is not the global *reporting* of emissions under IPCC guidelines – which simply ensures that the global carbon budget balances – that causes the problem, but the impact on *accounting* against national targets for reducing greenhouse gas emissions, especially (though not only) where the countries producing and consuming the biomass are not the same. When importing countries replace fossil fuels with biomass for heat and power, they see an immediate fall in their emissions totals, since biomass combustion emissions are not included in their national figures. This enables them to make faster progress towards their targets than would otherwise be the case. Unless this is countered by the exporting countries recording a corresponding increase in their emissions totals and, as a consequence, adopting measures to reduce their other emissions accordingly, the system will not work to ensure that both producer and consumer countries achieve their respective climate goals.

This problem has been recognized by the IPCC itself. Its 2019 *Special Report on Climate Change and Land* observed: 'One of the complications in assessing the total GHG [greenhouse gas] flux associated with bioenergy under UNFCCC reporting protocols is that fluxes from different aspects of bioenergy lifecycle are reported in different sectors and are not linked. […]Thus, the whole lifecycle GHG effects of bioenergy systems are not readily observed in national GHG inventories or modelled emissions estimates.'[34] Similarly, the 2021 EU JRC report drew attention to the same problem existing within countries, as well as between them, given the mismatch between policy signals for the energy and land-use sectors and the need for national policies to be guided by a full awareness of bioenergy-land-use links and trade-offs.[35]

Resolving this problem can pose significant challenges. The weaknesses of the framework created under the 1997 Kyoto Protocol to the UNFCCC – the first international attempt to agree national targets for greenhouse gas emissions reductions – were explored in detail in the 2017 Chatham House paper.[36] It identified the problem of 'missing' emissions – i.e. emissions unaccounted for against national targets – which could arise for two main reasons.

First, when a country using biomass for energy imported biomass from a country outside the accounting framework – e.g. the US, Canada and Russia, all significant exporters of woody biomass, that were either not parties to the Protocol or did not account for greenhouse gas emissions under its second commitment period.

Second, when a country using biomass for energy accounted for its biomass emissions either using a historical forest management reference level – its baseline – that included higher levels of biomass emissions than in the present or using a business-as-usual forest management reference level that included anticipated emissions from biomass energy. These problems arose from the complexity of establishing forest management reference levels (mainly because

**34** IPCC (2019), *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*, p. 583, https://www.ipcc.ch/srccl.
**35** Camia et al. (2021), *The use of woody biomass for energy production in the EU*, p. 164.
**36** Brack (2017), *Woody Biomass for Power and Heat: Impacts on the Global Climate*, pp. 37–55.

of the desire to allow for natural, as well as anthropogenic, changes in forest cover) and the decision to give parties to the Kyoto Protocol a choice of baselines against which they would measure changes in emissions. Most of them chose business-as-usual baselines that included – sometimes implicitly rather than explicitly – assumptions of increased growth in the use of forest biomass for energy. Emissions from harvesting forests for biomass in line with these projections would therefore count as zero for Kyoto Protocol accounting purposes, but would also count as zero in the energy sector. They were therefore 'missing' – unaccounted-for but nevertheless real – emissions.

The Kyoto Protocol's second commitment period closed at the end of 2020, and in effect, its greenhouse gas reduction targets have now been replaced by the NDCs of the Paris Agreement. This helps to deal with the problem of importing biomass from countries outside the international framework, since almost every country is a party to the agreement, but it does not solve the double counting problem. Indeed, since the Paris Agreement does not establish any overall global framework for accounting for emissions, or any common means of setting forest management reference levels, the problem of 'missing emissions' is likely to be worse.

This problem may never be resolved within the Paris Agreement framework, since signatories are not required to include the land-use sector in their NDCs, or to include it in a consistent manner. The treatment of the land-use sector in the agreement was the subject of intense negotiations in the run-up to the Paris Conference in 2015. The agreement itself contains only limited references to it. While the decision of the Conference that accompanied the Agreement encouraged parties to 'strive to include all categories of anthropogenic emissions or removals in their nationally determined contributions and, once a source, sink or activity is included, continue to include it',[37] they may choose not to do so. They may also choose to include land use or forests in broader economy-wide targets or to adopt separate quantitative targets expressed in non-emission metrics, such as a reduction of deforestation or an increase in forest cover.

A 2019 analysis of 167 NDCs submitted by January of that year found that 39 did not include any targets for the land use, land-use change and forestry (LULUCF) sector, 46 contained no separate targets, but integrated them into broader economy-wide targets, and only 27 contained separate LULUCF targets.[38] Only 13 of those NDCs anticipated the use of any kind of accounting rules for their integrated targets and only 18 set out measures and policies for LULUCF mitigation. Where accounting for LULUCF emissions and removals was mentioned, the submitting countries chose a variety of accounting methods. Some proposed essentially the same system as all other emissions and removals (known as 'net-net' accounting). Some opted to use a variant of the Kyoto Protocol accounting rules and others intended to set accounting rules at a later date. Overall, the paper concluded that the combination of these ambiguities could cause an uncertainty in overall emission levels of about 3 gigatonnes of $CO_2$ ($GtCO_2$) per year in 2030, larger than the estimated total human-made land-use sink (-2 $GtCO_2$/year).

**37** Twenty-first session of the Conference of the Parties to the UNFCCC, Decision 1/CP.21, 'Adoption of the Paris Agreement', para 31(c), p. 5, https://unfccc.int/files/home/application/pdf/decision1cp21.pdf.
**38** Fyson, C. L. and Jeffery, M. L. (2019), 'Ambiguity in the land use component of mitigation contributions toward the Paris Agreement goals'. *Earth's Future*, 7(8), pp. 873–891, doi: 10.1029/2019EF001190.

The EU has taken steps to improve its own LULUCF sector accounting. Under the LULUCF Regulation (2018/841), it will measure the climate impact of forest management using the 'Forest Reference Level' (FRL) concept: the projected level of forest emissions and removals for the period 2021–25, against which future emissions and removals will be compared. Whereas in the past these projections could include policy assumptions (for example, support for the use of wood for energy), with the risk of inflating the real impact of mitigation actions, the FRLs described in the regulation are exclusively based on the continuation of forest management practice and wood use during the period 2000–09. This should ensure that the kind of policy assumptions that could influence reference levels in accounting under the Kyoto Protocol are excluded and the carbon impact of any changes in management or wood use relative to a historical period is fully counted towards national climate targets. The 2021 JRC study suggested that this, combined with other measures, could allow the LULUCF sector to be treated, at least from 2030, like any other sector, which would: 'introduce an important simplification of the LULUCF jargon, facilitate communication (i.e. it would be more evident that all the carbon impact of bioenergy is accounted for) and thus bring more transparency also in the accounting of forest bioenergy emissions'.[39]

**In January 2021 the US rejoined the Paris Agreement, having left it less than two years before. We do not know yet what targets it will set, or how it will treat the LULUCF sector and biomass for energy.**

In January 2021 the US rejoined the Paris Agreement, having left it less than two years before. We do not know yet what targets it will set, or how it will treat the LULUCF sector and biomass for energy. In 2015, during negotiations prior to the Paris Agreement, the US indicated that it intended to track its greenhouse gas mitigation, including in the land-use sector, against a 2005 baseline.[40] In 2005 US emissions from 'forest land remaining forest land' plus 'land converted to forest land' were -788.8 million tonnes of carbon dioxide equivalent ($MtCO_2e$) (a net carbon sink, represented as negative emissions). By 2018 this had fallen slightly to -773.8 $MtCO_2e$, with the reduction coming entirely from within the 'forest land remaining forest land' category.[41]

Whether this reduction in the size of the forest carbon sink can be attributed to the extraction of wood for energy is impossible to determine from the US's national inventory reports. The latest report included the comment that: 'If timber is harvested to produce energy, combustion releases C immediately, and these emissions are reported for information purposes in the Energy sector while the harvest (i.e. the associated reduction in forest C stocks) and subsequent

**39** Camia et al. (2021), *The use of woody biomass for energy production in the EU*, p. 165.
**40** UNFCCC (2015), 'U.S. Cover Note, INDC and Accompanying Information', http://www4.unfccc.int/submissions/INDC/Published%20Documents/United%20States%20 of%20America/1/US%20Cover%20Note%20INDC%20and%20Accompanying%20Information.pdf.
**41** US Environmental Protection Agency (EPA) (2020), *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2018*, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018.

combustion are *implicitly estimated* in the LULUCF sector (i.e. the portion of harvested timber combusted to produce energy does not enter the HWP pools).' [Authors' own emphasis – HWP stands for harvested wood products.][42]

In other words, while emissions from the combustion of US-sourced biomass are definitely *not* accounted for against the national greenhouse gas targets of the EU or the UK (or of other countries importing biomass from the US), there is currently no way of knowing whether they *are* accounted for – at least to the same extent – against the US's own targets. It should be possible to disaggregate this data, but if US data is as uncertain as EU data on the source of the wood used for energy (see above), the figures will not give an accurate picture of emissions from the extraction of wood for energy.

## Incentives

In any case, even if the figures could be accurately estimated and the accounting challenges overcome, the point remains that by treating biomass emissions as zero at the point of combustion, the system creates a significant incentive for consuming countries to burn wood for energy, despite $CO_2$ emissions to the atmosphere increasing (relative to fossil fuels) for a period of up to centuries as a result.

The incentives are even stronger at industry level. In the UK and most EU member states, energy companies are paid to burn biomass and face no responsibility to ensure that their emissions are compensated for elsewhere. Even if the country of origin reports higher land-use emissions as a result, that has no bearing on the activities of the company burning the biomass. And, as discussed above, it is not clear whether the country of origin will in reality come under pressure to reduce emissions elsewhere to compensate for higher land-use emissions. That depends on its own system of targets and incentives. Finally, as discussed above, even if the accounting rules and incentives can be adjusted to deal with these challenges, the policy framework will still lead to higher $CO_2$ levels in the atmosphere for the duration of the carbon payback period than would have occurred in the absence of support for burning biomass.

**42** Ibid., pp. 6–25.

# 03
# US-sourced biomass in the EU and UK: consumption and associated emissions

**The impact on the climate of the use of forest biomass for energy is a combination of emissions from its combustion, its supply chain and the impact on carbon stocks in the forests from which it was sourced.**

This chapter reviews current patterns of demand for wood for energy in the EU and the UK, and the feedstock sources which supply it. It includes the figures for the $CO_2$ emissions from biomass combustion in the EU and UK reported to the UNFCCC, but also provides a more complete analysis of the levels of carbon emissions associated with the use of US-sourced biomass for energy. The emissions associated with the consumption of US-sourced biomass in the EU, UK and Drax are calculated from the combustion of wood pellets, from the energy used in the supply chain (harvesting, processing and transport) and from the impact on forest carbon emissions and stocks in the forests in the southern US from which the pellets are sourced. The detailed methodology for each of these calculations can be found in the Annex.

## 3.1 Biomass for energy in the EU

Over the last ten years the former EU28[43] has been the main global source of demand for wood for modern (non-traditional) uses of biomass for power and heat. This has been a result largely of the policy support frameworks put in place by EU member states following the 2009 Renewable Energy Directive, which set targets to be achieved by each member state for the proportion of energy supplied by renewables by 2020. This framework has led to the EU27's share of final energy consumption from renewables more than doubling between 2004 (9.6 per cent) and 2019 (19.7 per cent).[44] The overall EU target of 20 per cent by 2020 is expected to be met, as several member states have overshot their targets, compensating for the few that are likely to have failed to meet them.

All sources of renewable energy in the EU have grown, including bioenergy, which is the largest single source, accounting for 60 per cent of gross consumption of renewable energy in 2018.[45] Solid biomass accounted for 68.4 per cent of that figure (i.e. 41 per cent of renewable energy), with the remainder comprising renewable municipal waste, bioliquids and biogas. Across the former EU28, solid biomass supplied 9 per cent of generation of electricity from renewable sources (3 per cent of total electricity generation) and 76 per cent of heat from renewable sources (15 per cent of total heat).

In fact, the proportion of renewable energy accounted for by solid biomass has slowly fallen in recent years, even as total consumption has increased. This is due to the faster rates of growth of other renewable technologies, particularly wind and solar for electricity.[46] Alternative sources of renewable heat are not as strongly commercialized, however, and to date they have received lower levels of government support. As a result, solid biomass can probably expect to retain its dominant position for renewable heat for several years to come.

## 3.2 Biomass for energy in the UK

Of all 28 EU member states, the UK saw the greatest growth in the use of biomass for electricity in absolute terms. Between 2009 and 2019, the use of biomass for electricity in the UK grew by an average of 23 per cent per year, faster than the 19 per cent average annual growth rate of electricity from renewables as a whole – which was itself high by EU standards.[47] In 2018 the UK accounted for 24 per cent of all electricity generated from biomass throughout the EU. As in other countries, the growth rates of electricity in the UK from wind and solar have been faster in recent years, meaning that biomass is gradually falling as a proportion of total

**43** The former EU28 includes the UK, which ceased to be a member of the EU on 31 January 2020. References to the EU27 denote the remaining 27 member states.
**44** Eurostat (2020), 'Renewable Energy Statistics', https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics. The corresponding figures for the former EU28, including the UK, are 8.6 per cent in 2004 and 18.9 per cent in 2019.
**45** European Commission/Navigant Consulting (2020), *Technical assistance in realisation of the 5th report on progress of renewable energy in the EU*.
**46** Eurostat (2021), SHARES (Renewables) database, http://ec.europa.eu/eurostat/web/energy/data/shares.
**47** Ibid. Throughout this paper, all time period averages are compound average growth rates (CAGR).

renewable electricity generation. In 2018 biomass accounted for 22 per cent of renewable electricity generation (7 per cent of total electricity), down from 25 per cent in 2015.[48]

Although some dedicated biomass power plants have been built (and one large one is still under construction), the growing demand for biomass power has largely been due to the replacement of coal, originally through co-firing with biomass but more significantly through the conversion of coal stations to biomass, in particular the conversions of four of the six units at the Drax power station. (Co-firing has now ended after reductions in government support.) The last coal station to be built in the UK, Drax is also the largest (with approximately 4 GW capacity), supplying about 7 per cent of all UK electricity. It began co-firing wood pellets with coal in 2003 and fully converted its first unit to biomass in 2013. Conversion of the fourth unit was completed in 2018. (Drax does not plan to convert the remaining two units.) By 2019, some 95 per cent of the electricity generated by the plant was derived from biomass.[49] Drax is the largest biomass-burning power station in the world, consuming more than 7 million tonnes of wood pellets in both 2018 and 2019.

The UK is not on track to meet its 2020 Renewable Energy Directive target of 15 per cent of energy from renewable sources, however, because of much slower progress in the development of renewable heat and transport. As in other EU member states, solid biomass is the main source of renewable heat generation, accounting for 78 per cent in 2018 but only 5 per cent of the overall total. In fact, this proportion has increased slightly since 2015, as growth in other renewable technologies has slowed down.[50]

## 3.3 Production, consumption and trade of wood pellets

As well as being a major consumer of wood for energy, the EU is also a major producer. Over the last forty years the volume of wood harvested for energy in the EU has steadily risen, alongside harvests for other purposes, both in absolute terms and as a proportion: 22.7 per cent of roundwood production was harvested specifically for energy in 2017, compared to 18.7 per cent in 2000.[51] However, due to the use of wood and associated products not specifically harvested for energy (such as residues and black liquor), total woody biomass consumption for energy is much higher. In 2014 an estimated 42 per cent of harvested EU wood was used

**48** Eurostat (2021), SHARES (renewables) database.
**49** Drax Group PLC (2020), *Enabling a zero carbon, lower cost energy future: Annual report and accounts 2019*, https://www.drax.com/wp-content/uploads/2020/03/Drax_AR2019_Web.pdf. Note: proportion for Drax Power Station only, not Drax Group.
**50** BEIS (2021), *Digest of UK Energy Statistics (DUKES) Chapter 6: Renewable Sources of Energy*, https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes.
**51** Calderón, C. and Colla, M. (2019), *Bioenergy Europe Statistical Report 2019: Biomass Supply*, Bioenergy Europe, https://bioenergyeurope.org/index.php?option=com_attachments&task=download&id=736:Biomass-Supply-2019_Final_web.

for energy.[52] As noted in Chapter Two, the 2021 JRC study concluded that over the period 2009–15, 49 per cent of wood-based bioenergy production in the EU derived from secondary woody biomass (forest-based industry by-products and recovered post-consumer wood) and 37 per cent from primary woody biomass harvested from forests, with the remaining 14 per cent uncategorized, but likely also to be primary wood.[53]

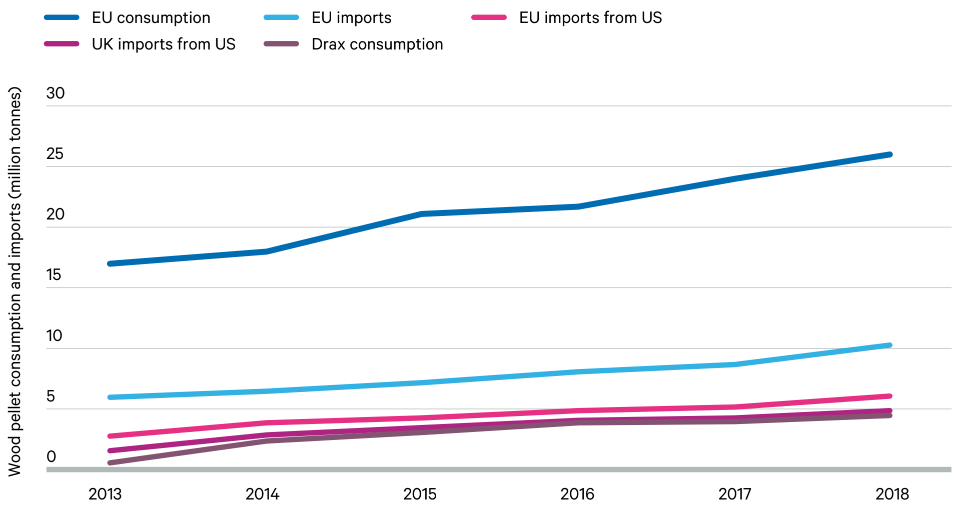
An increasing proportion of the woody biomass burnt for energy is now in the form of pellets, which could be produced from any of these sources. The EU is now the world's largest producer of wood pellets: in 2018 the EU produced 16.9 million tonnes of pellets, accounting for 46 per cent of the world's total production of 38.9 million tonnes.[54] However, the EU is a net importer of pellets, as its total consumption of wood for energy is higher than production.

**The EU is now the world's largest producer of wood pellets: in 2018 the EU produced 16.9 million tonnes of pellets, accounting for 46 per cent of the world's total production of 38.9 million tonnes.**

Data for 2017 from the Food and Agriculture Organization of the UN (FAO) indicate that imports accounted for 9.4 per cent of total primary energy production from solid biomass.[55] While some wood fuel and other feedstocks are imported, the main international trade is in wood pellets, which, as noted above, are much easier to store and transport over long distances than other wood feedstocks. Imports of pellets from outside the former EU28 rose to 10.3 million tonnes in 2018, almost five times the quantity imported in 2010 (see Figure 1). This accounted for almost 40 per cent of total former EU28 consumption of wood pellets. The US has been the largest single source of imports from outside the EU, accounting for 59 per cent by weight of former EU28 imports of wood pellets in 2019.

**52** European Commission (2013), '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, p. 8, https://eur-lex.europa.eu/resource.html?uri=cellar:21b27c38-21fb-11e3-8d1c-01aa75ed71a1.0022.01/DOC_1&format=PDF.
**53** Camia et al. (2021), *The use of woody biomass for energy production in the EU*.
**54** FAOSTAT (2021), Forestry Production and Trade database, http://www.fao.org/faostat/en/#data/FO.
**55** UN Economic Commission for the Europe region/FAO (2019), *Forest Products Annual Market Review 2018–19*, https://digitallibrary.un.org/record/3849730/files/SP48.pdf. This figure cannot be precise, since trade data cannot determine whether imports of wood chips and residues are destined for use for energy or for other purposes. Both are also used for engineered wood products and for the production of pulp and paper.

**Figure 1.** Wood pellet data, 2013–18: EU28 consumption and imports (all sources and US), UK imports from US, and consumption at Drax Power Station (tonnes)




Source: Import figures generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do?noredirectnewsession=true; Drax consumption figures from Drax Group annual accounts.

Total consumption of wood pellets in the EU28 reached 26 million tonnes in 2018; Bioenergy Europe (the European biomass industry association) projected that this would rise to almost 31 million tonnes in 2020.[56] An estimated 40 per cent is used for residential heat, a further 16 per cent for heating in commercial uses and CHP plants, and the remaining 44 per cent for industrial purposes, almost entirely for power generation.[57] However, patterns of use vary significantly across member states. In Belgium, the Netherlands and the UK, wood pellets are overwhelmingly used for electricity generation, while in most other EU member states they are used mainly for heating. In the Nordic countries, significant quantities are consumed in CHP plants.

The UK is by far the world's biggest consumer of wood pellets. In 2018 it consumed an estimated 8.3 million tonnes, equivalent to 21 per cent of all wood pellets produced worldwide. In comparison, the second largest consumer, South Korea, consumed 3.6 million tonnes – less than half the UK total.[58] UK production of wood pellets in 2018 was only 279,000 tonnes. Therefore almost all of its pellet consumption is supplied by imports.[59] In 2019 production rose by about 20,000 tonnes, but imports rose by about 900,000 tonnes, together reaching a consumption total of 9.2 million tonnes.

**56** US Department of Agriculture (2020), *Biofuels Annual: European Union*, Washington, DC: USDA, https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_The%20Hague_European%20Union_06-29-2020.
**57** Ibid.; Calderón, C. and Colla, M. (2019), *Bioenergy Europe Statistical Report 2019: Pellet*, Bioenergy Europe, https://epc.bioenergyeurope.org/wp-content/uploads/2020/02/SR19_Pellet_final-web-1.pdf. The breakdown is calculated by assigning two-thirds of CHP pellet consumption to heat and one-third to power.
**58** FAOSTAT data adding production to imports. Calderón and Colla (2019), *Bioenergy Europe Statistical Report 2019: Pellet* gives a slightly higher total for consumption of 8.5 million tonnes. Pellets may be produced and imported in different years from those in which they are consumed, so the two figures may not always match.
**59** FAOSTAT data.

Apart from the UK, Belgium, Denmark, Italy and, since 2019, the Netherlands are the EU's largest importers of wood pellets. Most 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 the UK sourcing smaller volumes from Canada and both countries from Russia.

US wood pellets comprised 75 per cent of UK pellet imports in 2019. The Drax power station alone accounted for 40 per cent of total former EU28 imports of wood pellets in that year and 68 per cent of former EU28 imports from the US. Drax consumed 18 per cent of the wood pellets produced worldwide in 2019. During 2013–18 the UK accounted for 78 per cent of US wood pellet imports to the former EU28, Belgium for 12 per cent, Denmark for 5 per cent and other countries combined for a further 5 per cent.

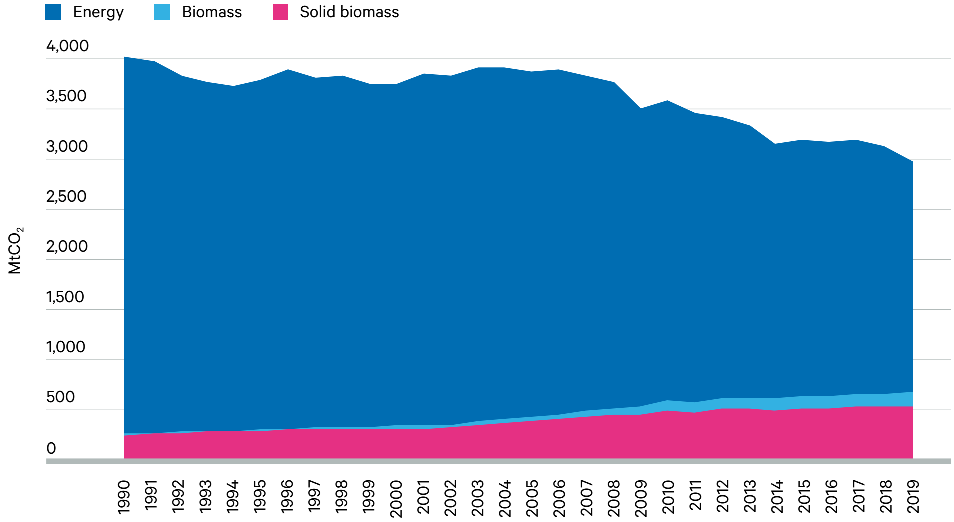
## 3.4 Reported emissions from the use of biomass for energy

Although emissions from the combustion of biomass are not included in total emissions from energy, it is possible to calculate their volume. This is because, under the UNFCCC, Annex I parties (essentially, industrialized countries) report $CO_2$ emissions from biomass used for energy as a separate line item (referred to as a 'memo item') in their greenhouse gas inventories.[60] (These are only emissions from combustion, not life-cycle emissions reflecting changes in forest carbon stock.)

Between 1990 and 2019, EU emissions from solid biomass used for energy increased from 192 $MtCO_2$ to 482 $MtCO_2$, at an average growth rate of 3.2 per cent a year. In 1990, if solid biomass emissions had been included in emissions from other energy use, they would have added 4.8 per cent to total EU energy-related emissions. By 2019 this figure had grown to 16.3 per cent, as biomass use rose and emissions from other energy sources fell. (See Figure 2, which also includes emissions from biomass used for energy in liquid and gaseous forms.) In 1990 solid biomass accounted for 92 per cent of total biomass emissions, but this had fallen to 78 per cent by 2019.

**60** UNFCCC (2020), 'National Inventory Submissions 2020', https://unfccc.int/ghg-inventories-annex-i-parties/2020. Total reported $CO_2$ emissions from biomass energy in greenhouse gas inventories are calculated, and reported, in two different ways, using a bottom-up 'sectoral approach' and a top-down 'reference approach'. The estimates resulting from these two approaches are very rarely, if ever, equivalent, and it is not possible to compare these values directly. The analysis in this paper uses the reference approach, mainly because these estimates are also broken down into solid, liquid and gaseous biomass. In general, the figures in the reference approach are slightly higher (by about 5–6 per cent) than in the sectoral approach.

**Figure 2.** $CO_2$ emissions from energy and biomass in the EU28, 1990–2019

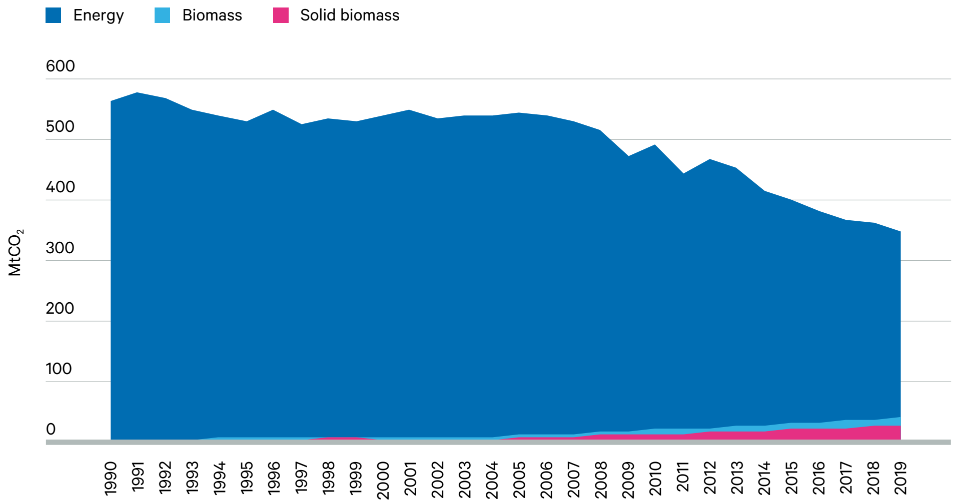



Source: EU National Inventory Report to UNFCCC, at https://unfccc.int/ghg-inventories-annex-i-parties/2021.

As noted in Chapter Two, emissions from biomass are not included in the headline figures reported to the UNFCCC or used to account for progress against the targets set under national climate commitments under the Kyoto Protocol and the Paris Agreement. According to this calculation, energy-related emissions across the former EU28 fell by 26 per cent between 1990 and 2019. If emissions from biomass of all types are included, the reduction is just 15 per cent. (As discussed in Chapter Two, a proportion of the emissions from using biomass will be reflected in the land-use section of the national inventory reports to the UNFCCC, but these do not contain enough information to be able to identify the end uses of the biomass extracted.)

In the UK, emissions from solid biomass used for energy increased much faster, though from a much smaller base, from 2.0 $MtCO_2$ in 1990 to 23.3 $MtCO_2$ in 2019, representing an average growth rate of 8.8 per cent a year. In 1990 solid biomass emissions would have added just 0.4 per cent of emissions to UK energy use (excluding biomass). By 2019 this had grown to 6.9 per cent for solid biomass and 10.7 per cent for total biomass. (See Figure 3.) Excluding emissions from biomass, energy-related emissions in the UK fell by 38 per cent between 1990 and 2019. If emissions from biomass of all types are included, the reduction declines to 32 per cent.

**Figure 3.** UK $CO_2$ emissions from energy and biomass, 1990–2019




Source: UK National Inventory Report to UNFCCC, at https://unfccc.int/ghg-inventories-annex-i-parties/2021.

## 3.5 $CO_2$ emissions from burning US-sourced biomass in the EU and UK

The UNFCCC emissions data is not broken down by source, so the only way in which to reach an estimate is to multiply the volumes of biomass imported from the US to the EU and UK (see Section 3.3) by an emissions factor accounting for emissions from the combustion of the biomass – in this case, wood pellets. This paper bases its calculations on actual emissions from the combustion of wood pellets as reported by Drax in 2013–19. (See Annex.)

The use of biomass for energy also produces emissions from the supply chain: in this case, from the energy used in harvesting, processing and transporting wood pellets. Again, this paper uses estimates reported by Drax for its wood pellet feedstock in 2014–19. (See Annex.) Unlike the combustion figures, these emissions should be included in full in the energy-related greenhouse gas reports of the countries in which the harvesting, processing and transport takes place. Emissions from countries' shares of international transport are not always included in *national* greenhouse gas targets, however. They are currently excluded, for example, from the UK's carbon budgets, although they are to be included from the sixth carbon budget, which covers the years 2033–37.

The use of woody biomass for energy also affects carbon concentrations in the atmosphere because of the impact of the harvesting of trees on the total amount of carbon stored in the forest. Harvesting trees reduces this carbon stock and also forgoes the carbon that would have been sequestered had those trees been left unharvested. Regrowing trees then replaces this lost and forgone carbon over a period of time. Some of the carbon taken from the forest for pellets is included in the calculation above through the combustion of biomass, but unused logging debris, stumps and tree roots are left behind after logging. These carbon pools decompose and this emitted carbon also needs to be included in the calculation of the overall impact on the climate.

Calculating these effects is a significantly more complex process than the calculation of emissions from combustion and the supply chain. The methodology is explained in full in the Annex. Briefly, the analysis involved the following elements:

- A group of pellet mills in the southern US that export pellets to the UK was identified, along with their assumed wood procurement areas.
- The type of source material used by each mill was identified from available databases.
- Forest inventory data and harvest records from the USDA Forest Service were used to characterize the impact of harvesting roundwood (live trees of merchantable size) and smaller trees for pellets on the carbon stocks and stock changes in the procurement areas.
- Estimates are reported for 'lost forest growth' and 'decay of logging residue', i.e. the increases in emissions from changes in carbon stocks and from logging debris that would not have occurred if the harvesting had not taken place.

'Lost forest growth' was estimated by multiplying the area-equivalent[61] harvested for pellets by the difference between the reduced growth from harvesting live trees and the growth that would have occurred if the trees had not been harvested, accumulated over the number of years it would take to reach the pre-harvest rate of carbon increment. These values were estimated from growth rates by age class from forest inventory data and assumed ages of 17.5 years for commercial thinning and 27.5 years for final harvest of naturally regenerated forests, and 12.5 years for commercial thinning and 22.5 years for final harvest of planted forests.[62,63] Calculations were carried out separately for planted and naturally regenerated forests owing to the significant difference in average growth rates and harvest ages between the two categories (see Section A3 of the Annex for further detail).

'Decay of logging residues' was estimated as the loss of carbon from the decay of roots and from the decay of unused logging debris in harvested forests attributed to increasing pellet production. Our calculations used average ratios of roots and logging debris to the biomass of the harvested tree bole (main stem) of 1.25 and 1.172, respectively. These ratios are based on estimates of the carbon stored

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**61** Since harvested wood is often used for different types of products, including pellets, the area represented by only the volume of wood used for pellets was calculated as a proportion of the total area harvested for all products and labelled 'area-equivalent'.
**62** Gonzales-Benecke, C. A. et al. (2011), 'A Flexible Hybrid Model of Life Cycle Carbon Balance for Loblolly Pine (Pinus taeda L.) Management Systems', *Forests*, 2(3), pp. 749–76, doi: 10.3390/f2030; Buchholz, Gunn and Kittler (2018), 'UK wood pellet derived electricity: Carbon emission estimates from trees, thinnings and residues sourced in mixed pine-hardwood forests and pine plantations in the southeastern US'.
**63** Hoover, C. et al. (2014), 'Quantifying Greenhouse Gas Sources and Sinks in Managed Forest Systems', in Eve, M. et al. (eds) (2014), *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory* (Technical Bulletin Number 1939), Washington, DC: Office of the Chief Economist, USDA, https://www.fs.fed.us/nrs/pubs/jrnl/2014/nrs_2014_hoover-c_001.pdf.

in different tree parts, as reported in the forest inventory database for the assumed procurement areas, using component ratio biomass equations. Logging debris used for products other than pellets was excluded from the calculations.

Since there is no publicly available quantitative data on how much of the roundwood used in the pellet mills comes from commercial thinning and how much from final harvest, and because the type of harvest determines the impact, two scenarios were used to estimate lower and upper bounds for the impact of using roundwood on forest carbon. In scenario 1, all harvest is from commercial thinning. In scenario 2, all harvest is from final clearcut. This approach provides for a wide range of estimated impacts on forest carbon stocks and sequestration following harvest, with the actual values expected to lie within those extremes.

As a result of this analysis, annual net emissions of $CO_2$ from pellets sourced from the southern US and burnt at Drax were estimated to be between 11 million and 13 million tonnes in 2019 (see Table 1). This estimate includes:

— Emissions to the atmosphere from burning the pellets (calculated from emissions reported by Drax: 8.3 million tonnes (top three rows of Table 1).

— Emissions from the supply chain (calculated from emissions reported by Drax, detailed in Annex section A2): 1.1 million tonnes.

— Emissions from the decay of roots and unused logging residues left in the forest after harvest, and forgone removals of $CO_2$ from the atmosphere due to the harvest of live trees: between 1.5 million tonnes in scenario 1 and 3.6 million tonnes in scenario 2.

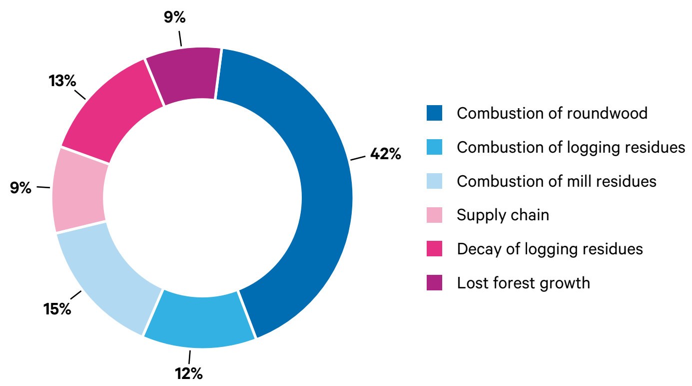
**Table 1.** Net emissions in 2019 (tonnes $CO_2$) by source, from biomass used for pellets exported from the southern US to the UK for Drax, regardless of where emitted

| Source | Scenario 1 | Scenario 2 |
|---|---|---|
| **Combustion emissions** | | |
| Roundwood used for pellets | 4,566,677 | 5,550,775 |
| Logging residue used for pellets | 1,968,196 | 984,098 |
| Mill residues used for pellets | 1,768,176 | 1,768,176 |
| **Supply-chain emissions** | | |
| Supply chain | 1,114,334 | 1,114,334 |
| **Impact on forest carbon** | | |
| Decay of logging residues | 1,432,293 | 1,740,945 |
| Lost forest growth | 115,280 | 1,882,909 |
| **Total** | **10,964,956** | **13,041,237** |
| Additional percentage of combustion from lost forest growth and decay of residues | 19% | 44% |

Source: Compiled by the authors.
Note: ‘Lost forest growth’ and ‘decay of logging residues’ represents the removal of $CO_2$ from the atmosphere that would not have occurred if the roundwood had remained unharvested.

Of the different emission sources, the midpoint of the two scenarios suggests that the combustion of roundwood accounted for about 42 per cent of total emissions (Figure 4) and 61 per cent of combustion emissions from burning pellets. Based on the amount of biomass harvested by stand origin for all products including pellets (not shown in table), 56 per cent of the roundwood used for pellets comes from forest plantations and 44 per cent from stands established by natural regeneration.

**Figure 4.** $CO_2$ emissions associated with US-sourced wood pellets burnt at Drax, 2019




Source: Compiled by the authors.

The combustion of logging and mill residues, which are often cited as a main source of wood for pellets, accounted for 12 per cent and 15 per cent of the total net emissions, respectively, for the midpoint of the two scenarios. Decay of unused logging residue accounted for 1.4 million–1.7 million tonnes in 2019 (13 per cent of all emissions) according to the average of scenarios. The largest difference in estimates among the source categories for scenarios 1 and 2 is for lost forest growth (0.1 million–1.9 million tonnes in 2019). This is due to the dual effects of using less roundwood and only wood from thinnings (which has a faster growth recovery) in scenario 1, compared with using more roundwood and only wood from clearcut harvest in scenario 2.

All sources considered, the actual emissions associated with burning the pellets are 19 to 44 per cent higher than combustion emissions alone when accounting for changes in the net carbon balance of the forests (decay of residues plus lost forest growth) in the procurement areas. The real impact is likely to be somewhere in between these two figures.

We use the same methodology to calculate the climate impact of burning all US-sourced biomass in the EU and UK. Combustion emissions and supply-chain emissions are calculated based on the figures reported by Drax. The decay of residues plus lost forest growth are calculated based on the percentages derived above. Tables 3.2 and 3.3 combine these emissions estimates (combustion, supply chain and impact on forest carbon stores) into one total for the EU (3.2) and UK (3.3) with separate calculations for the two scenarios above – scenario 1 adds 19 per cent of combustion emissions, scenario 2 adds 44 per cent. The tables also compare the emissions totals with reported combustion emissions from the energy sector in the EU and UK, as appropriate. As noted, with the exception of supply-chain emissions, these emissions totals will not be included in the consuming countries' greenhouse gas reports.

**Table 2.** Overall emissions totals from the use of US-sourced wood pellets for energy in the former EU28, 2014–19

| **Imports and emissions** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** |
|---|---|---|---|---|---|---|
| Wood pellet imports (kt) | 3,890 | 4,287 | 4,902 | 5,205 | 6,139 | 6,779 |
| Combustion (kt$CO_2$) | 7,002 | 7,716 | 8,823 | 9,370 | 11,049 | 12,202 |
| Supply chain (kt$CO_2$) | 934 | 1,029 | 1,176 | 1,249 | 1,473 | 1,627 |
| **Scenario 1** | | | | | | |
| Lost forest growth and decay (kt$CO_2$) | 1,330 | 1,466 | 1,676 | 1,780 | 2,099 | 2,318 |
| **Total (kt$CO_2$)** | **9,266** | **10,211** | **11,676** | **12,399** | **14,622** | **16,147** |
| Emissions as % of EU energy emissions (not included in emissions totals) | 0.30% | 0.32% | 0.37% | 0.39% | 0.47% | 0.55% |
| **Scenario 2** | | | | | | |
| Lost forest growth and decay (kt$CO_2$) | 3,081 | 3,395 | 3,882 | 4,123 | 4,862 | 5,369 |
| **Total (kt$CO_2$)** | **11,016** | **12,140** | **13,882** | **14,742** | **17,384** | **19,198** |
| Emissions as % of EU energy emissions (not included in emissions totals) | 0.35% | 0.38% | 0.44% | 0.46% | 0.56% | 0.65% |

Source: Compiled by the authors.

**Table 3.** Overall emissions totals from the use of US-sourced wood pellets for energy in the UK, 2014–19

| Imports and emissions | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| Wood pellet imports (kt) | 2,895 | 3,528 | 4,128 | 4,266 | 4,880 | 5,484 |
| Combustion (kt$CO_2$) | 5,211 | 6,350 | 7,430 | 7,678 | 8,784 | 9,870 |
| Supply chain (kt$CO_2$) | 695 | 847 | 991 | 1,024 | 1,171 | 1,316 |
| **Scenario 1** | | | | | | |
| Lost forest growth and decay (kt$CO_2$) | 990 | 1,207 | 1,412 | 1,459 | 1,669 | 1,875 |
| **Total (kt$CO_2$)** | **6,896** | **8,404** | **9,832** | **10,161** | **11,624** | **13,062** |
| Emissions as % of UK energy emissions (not included in emissions totals) | 1.71% | 2.16% | 2.66% | 2.83% | 3.31% | 3.85% |
| **Scenario 2** | | | | | | |
| Lost forest growth and decay (kt$CO_2$) | 2,293 | 2,794 | 3,269 | 3,378 | 3,865 | 4,343 |
| **Total (kt$CO_2$)** | **8,198** | **9,991** | **11,689** | **12,080** | **13,820** | **15,529** |
| Emissions as % of UK energy emissions (not included in emissions totals) | 2.04% | 2.56% | 3.16% | 3.37% | 3.93% | 4.57% |

Source: Compiled by the authors.

Table 3 shows that taking into account emissions from combustion, the supply chain and the impact of the extraction of wood on forest carbon stores, wood pellets produced in the US, imported to the UK and burnt for energy were responsible for 13 million–16 million tonnes of $CO_2$ emissions in 2019. If included in the UK national greenhouse gas inventory, this would have added between 22 and 27 per cent to the emissions from total UK electricity generation, or 2.8–3.6 per cent to total UK greenhouse gas emissions.[64] Put another way, this volume is equivalent to the annual greenhouse gas emissions from 6 million to 7 million passenger vehicles.[65]

Since the UK is the predominant European market for US wood pellets, emissions associated with their use in the EU27 are lower: about 3.1 million–3.7 million tonnes of $CO_2$ in 2019 (the former EU28 totals in Table 2, minus the UK totals in Table 3).

**64** Office of National Statistics (ONS) (2021), *2019 UK greenhouse gas emissions, final figures*, London: ONS, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf. Total greenhouse gas emissions from power supply were 58.5 Mt$CO_2$e and total UK greenhouse gas emissions were 454.8 Mt$CO_2$e.
**65** 2018 figures, taken from BEIS (2020), 'Final UK greenhouse gas emissions national statistics: 1990 to 2018', https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2018 and Department for Transport and Driver and Vehicle Licensing Agency (2020), 'Statistical data set: Cars (VEH02)', https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars.

# 04 Projected growth of biomass energy and associated emissions in the EU and UK

**The consumption of US wood pellets in the EU and UK is likely to grow to the mid-2020s and then fall, unless new demand arises from BECCS plants and new coal-to-biomass conversions.**

This chapter discusses the possible growth of demand for biomass for energy, and specifically for wood pellets from the US, in the EU27 and the UK. It focuses mainly on the use of biomass for electricity generation, which is currently the main use of imported US wood pellets in both.

## 4.1 Projections for the EU27

### Power and heat

In April 2021 the EU agreed to increase its greenhouse gas emissions reduction target from 40 per cent to 55 per cent (based on 1990 levels) by 2030. Corresponding changes in EU policy frameworks were announced in July 2021 in the 'Fit for 55' package, including an increase in the renewable energy target from 32 per cent to 40 per cent by 2030.[66] While further growth in the use of biomass for power generation is expected to follow, its rate is projected to be lower than that of other technologies, such as solar and wind, owing to their more rapidly falling costs.

The International Energy Agency (IEA), for example, projects bioenergy (including biogas and bioliquids) power capacity in the EU growing from 37.1 GW in 2019 to 42.3 GW in 2025 – a 14 per cent increase. In its accelerated scenario, the figure is 44.1 GW in 2025, a 19 per cent increase.[67] This is a markedly slower rate of growth than for offshore wind and solar photovoltaics (PV) (both projected to more than double over the same period) and onshore wind (40 per cent increase). As the IEA observed, the increasing tendency to use technology-neutral auctions and other support mechanisms for renewable power has disadvantaged bioenergy, because of the 'generally higher generation costs for bioenergy compared with wind or utility solar PV technologies, and limited cost reduction potential for bioenergy technologies'.[68] (Bioenergy may have some additional advantage as a dispatchable power source.)

A 2020 analysis of performance against EU member states' National Renewable Energy Action Plans supports this conclusion, showing a slowing down of growth in biomass electricity since 2015.[69] In contrast, growth in biomass heat was ahead of target until 2017, when it began to slow.

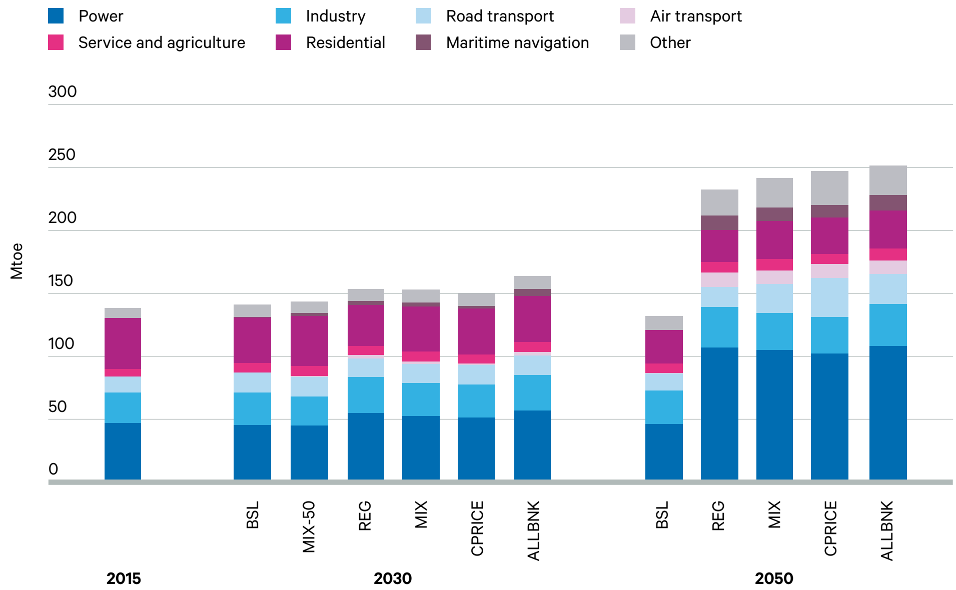
The European Commission's Communication on 'Stepping up Europe's 2030 climate ambition', published in September 2020, also supports the conclusion of limited growth in bioenergy use in the short and medium term:

> Projected increases in bioenergy use by 2030 are limited compared to today. To ensure the land use sink can continue to strengthen and improve, biomass for energy use in the EU should be produced sustainably, and environmental impacts should be minimised. To limit impact on biodiversity, the use of whole trees and food and feed crops for energy production – produced in the EU or imported – should be minimised. Any unsustainable intensification of forest harvesting for bioenergy purposes should be avoided. Instead, bioenergy production should come from better use of biomass wastes and residues and a sustainable cultivation of energy crops […][70]

**66** European Commission (2021), 'Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652', COM(2021) 557 final.
**67** International Energy Agency (IEA) (2020), 'Renewables 2020 Data Explorer', https://www.iea.org/articles/renewables-2020-data-explorer?mode=market&region=European+Union&product=Bioenergy.
**68** IEA (2020), *Renewables 2020: Analysis and forecast to 2025*, p. 110, https://iea.blob.core.windows.net/assets/1a24f1fe-c971-4c25-964a-57d0f31eb97b/Renewables_2020-PDF.pdf.
**69** European Commission/Navigant Consulting (2020), *Technical assistance in realisation of the 5th report on progress of renewable energy in the EU*.
**70** European Commission (2020), 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people', COM(2020) 562 final, p. 10, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:562:FIN.

The impact assessment accompanying the Communication foresees further long-term growth, however, including a doubling in biomass energy (of all kinds) by 2050 (compared to a sevenfold increase in other renewables).[71] This assessment projects a slight fall in residential sector use of bioenergy, but a doubling in the use for electricity production, including through BECCS (see below).[72] Figure 5 shows the scale and breakdown in bioenergy use by 2030 and 2050 under the scenarios analysed.

**Figure 5.** Use of bioenergy by sector and by scenario




Source: European Commission (2020), 'Commission Staff Working Document Impact Assessment Accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people', Part 2, p. 95.
Mtoe = million tonnes of oil equivalent. 1 mtoe = 11.63 TWh.
Scenarios – BSL: based on existing (pre-2020) 2030 targets; REG: regulatory-based measures achieving 55 per cent GHG [greenhouse gas] reductions; CPRICE, a carbon-pricing based scenario, achieving 55 per cent GHG reductions; MIX: combined approach of REG and CPRICE, achieving 55 per cent GHG reductions; MIX-50: a combined approach, achieving 50 per cent GHG reductions; ALLBNK: based on MIX and further intensifying fuel mandates for aviation and maritime sectors.

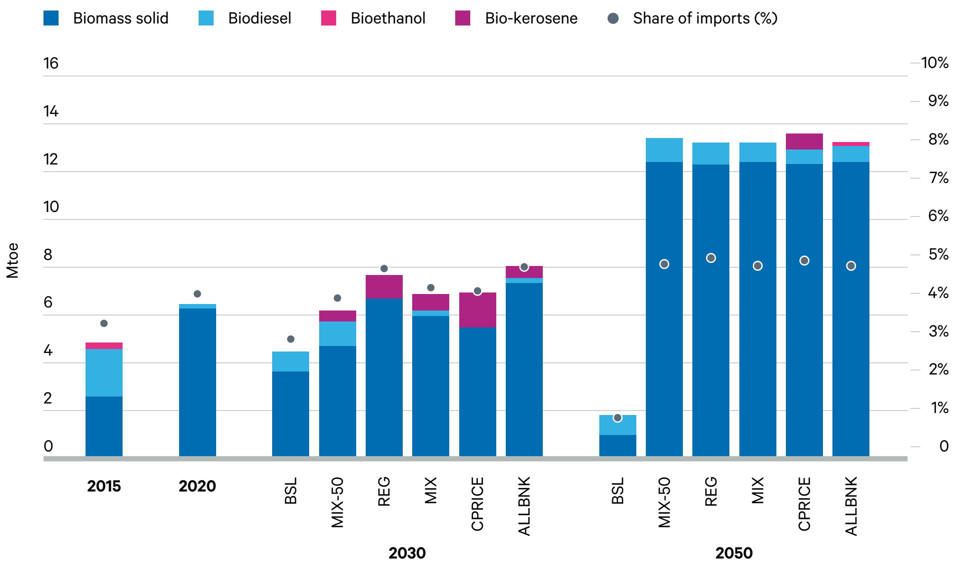
The bulk of the biomass feedstock is expected to be sourced domestically, from agricultural and forest wastes and residues, and energy crops: 'The use of harvested stemwood increases slightly compared to 2015 level while the increase in the sustainable extraction of forest residues is more pronounced.'[73] It should be noted that the projected growth in the use of energy crops is huge – representing more than a 20-fold increase between 2030 and 2050.[74] If this increase fails to take place – and existing policy frameworks do not support it – the demand for

**71** European Commission (2020), 'Commission Staff Working Document Impact Assessment Accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people' SWD(2020) 176 final, Part 1, p. 55, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020SC0176&qid=1629892827334.
**72** Ibid., Part 2, p. 95.
**73** Ibid., p. 96.
**74** Ibid., p. 103.

forest carbon could be significantly higher. If the consumption of energy crops does increase to this extent, there could be significant consequences for land-use change and emissions both in the EU and outside (if energy crop biomass is imported), with potentially severe consequences for forests.[75]

As a consequence of this increase in demand for biomass, imports increase from about 6.5 mtoe in 2020 to about 8 mtoe in 2030 (depending on scenario) and then to as much as 14 mtoe in 2050. In almost all scenarios, solid biomass accounts for 80–90 per cent of imports (see Figure 6).

**Figure 6.** Imports of bioenergy




Source: European Commission (2020), 'Commission Staff Working Document Impact Assessment Accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people'), Part 2, p. 97.
Scenarios: see notes to Figure 5.

The impact assessment does not discuss the origin of the imports, but the US seems likely to remain an important source in the short and medium term. It is the second largest wood pellet producer in the world after the EU, producing 8.6 million tonnes in 2019 (22 per cent of total world production).[76] For comparison, the next largest producers were Canada (3.0 million tonnes), Vietnam (2.5 million tonnes) and Russia (1.6 million tonnes).

In addition, the development of domestic supply faces a number of constraints, including increasing concern over the size of the EU's forest carbon sink. According to European Commission figures, the EU's LULUCF sector grew from an annual net sink of about 250 $MtCO_2e$ to more than 300 $MtCO_2e$ between 1990 and 2010. More recently, however, it has seen significant losses from the impacts of increased economic use and the adverse effects of climate change, leading to a reduction to

**75** For a longer discussion, see Dooley, K., Christoff, P. and Nicholas, K. (2018). 'Co-producing climate policy and negative emissions: Trade-offs for sustainable land-use', *Global Sustainability*, 1, E3, doi: 10.1017/sus.2018.6.
**76** FAOSTAT (2021), Forestry Production and Trade database.

263 $MtCO_2e$ by 2018.[77] While sourcing residues and wastes in place of whole trees would help to reduce the impact, policy frameworks in EU member states largely do not incentivize this. In applying sustainability criteria, they do not distinguish between categories of feedstock on the basis of their carbon payback periods, and in any case, definitions of feedstock categories cannot be relied upon to distinguish between residues and whole trees (see Chapter Two).

Industry projections for the future size of the wood pellet trade tend to support the conclusion that growth is likely to be relatively strong up to the mid-2020s, but more limited thereafter. Analysis by the FutureMetrics consultancy for Bioenergy Europe forecast that 'growth in the EU and UK in the demand for industrial wood pellets, under current policy, is expected to plateau in 2022 at about 20.3 million tonnes per year' (from just under 15 million tonnes in 2018).[78] The main sources of demand growth were expected to be the UK (from 8.2 million tonnes in 2018 to 11.2 million tonnes by 2022) and Netherlands (from 1.2 million tonnes in 2018 to 3.4 million tonnes by 2022); Denmark was expected to experience lower growth in demand (from 3.15 million tonnes in 2018 to 3.35 million tonnes by 2022) and Belgium none (its rate remaining constant at 1.05 million tonnes).

Demand for wood pellets for heating (residential and commercial) was expected to grow more slowly, from about 13.5 million tonnes in 2018 to 17.5 million tonnes in 2024.[79] This growth was accounted for mainly by Austria, Denmark, France, Germany, Italy and Sweden. With the exception of Denmark and Italy, none of those countries are large importers. Denmark is considered specifically below, in the section on key member states. Italy imports mainly from within the EU, with smaller quantities sourced from Brazil, Russia, Ukraine and the US.

There are two reasons, however, to think that future demand for biomass in the EU may be larger than these projections estimate.

## Coal-to-biomass conversions and replacements

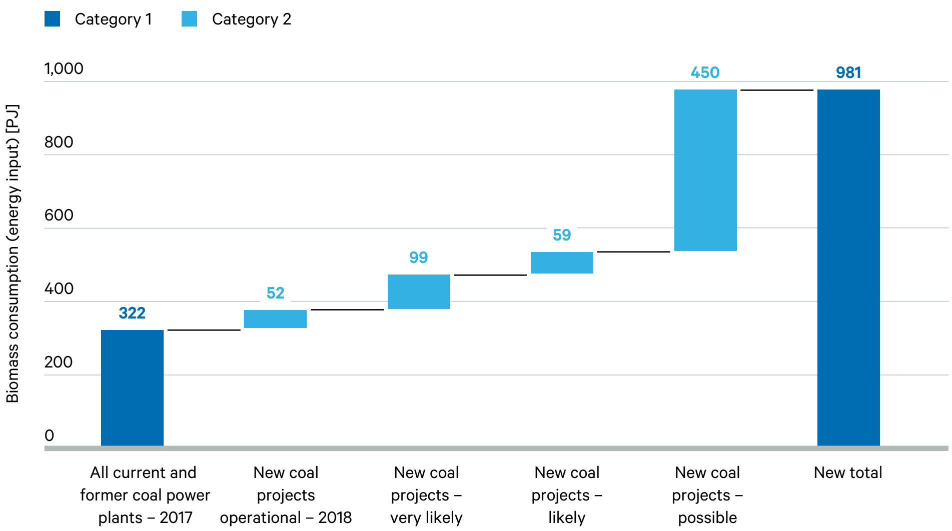
An important potential source of further demand for biomass – which is not considered explicitly in the European Commission's 2020 Communication or accompanying impact assessment – is the conversion of coal-fired power stations to biomass or their replacement by new biomass installations. An analysis by the non-governmental organization Ember in 2019 suggested that coal-to-biomass conversions carried out up to 2019 accounted for about 25 per cent of EU demand for biomass for power and heat.[80] Member states' climate strategies

**77** European Commission (2020), 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people', p. 11.
**78** Calderón and Colla (2019), *Bioenergy Europe Statistical Report 2019: Pellet*, p. 29. The FutureMetrics figures are different from Bioenergy Europe's in this report, probably because the former allocates a higher proportion of pellets used in CHP stations to industrial consumption, and less to heat, than the latter. The Bioenergy Europe figure for industrial wood pellet consumption in the EU in 2018 was 12.2 million tonnes, whereas FutureMetrics analysis reported in January 2020 suggested just under 15 million tonnes – see Strauss, W. (2020), '2020 global pellet markets outlook', *Canadian Biomass*, https://www.canadianbiomassmagazine.ca/2020-global-pellet-markets-outlook. See also following note.
**79** Bioenergy Europe figures show 16.8 million tonnes consumed for heat in 2018. See previous note.
**80** Ember (2019), 'Playing with Fire: An assessment of company plans to burn biomass in EU coal power stations', https://ember-climate.org/wp-content/uploads/2020/10/Ember-Playing-With-Fire-2019.pdf.

almost invariably include the phasing out of coal. Depending on the policy framework, it may prove more economic to convert former coal stations to biomass (possibly via an interim stage of co-firing) than to decommission them altogether, notwithstanding the worsening competitive position of biomass versus other renewable power technologies.

The Ember analysis looked at companies' proposals (up to November 2019) for future conversions and assessed the likelihood of their proceeding. Ember concluded that proposed substitutions could increase biomass consumption by up to 607 petajoules (PJ) – 14.5 mtoe/169 TWh – equivalent to about 50 per cent of current EU biomass consumption in power and heating plants. If this consumption was all supplied by wood pellets, it would require an additional 36 million tonnes of pellets per year. (By comparison, world production in 2018 totalled 39 million tonnes, while total EU27 consumption of wood pellets in 2018 was 17.8 million tonnes). In reality, the level of conversions is not likely to be that high, but even if only those conversions in the 'likely' and 'very likely' categories in the analysis go ahead, this would together account for one-quarter of the total, requiring an additional 9 million tonnes of pellets a year. (See Figure 7, which includes for comparison the output of existing coal-to-biomass conversions.)

**Figure 7.** Potential biomass consumption growth in the former EU28 due to coal-to-biomass substitutions in coal power plants, grouped by project risk




Source: Ember (2019), 'Playing with Fire: An assessment of company plans to burn biomass in EU coal power stations'.

The level of conversions may in fact be higher than the report suggests. In July 2020 Germany adopted a new Coal Exit law, which aims for the complete phase-out of coal-fired power generation by 2038. This will require the closure or conversion of 44 GW of capacity.[81] The accompanying support package of €40 billion includes support for coal-to-biomass conversion. As noted in Chapter Two, in July 2021 the European Commission proposed the extension of support for the use of forest biomass in electricity-only installations in coal-dependent regions after 2026.

## Bioenergy with carbon capture and storage (BECCS)

The other reason to expect potentially increasing demand in the future is the possible development of BECCS. This term refers to a set of technologies and processes through which the carbon emissions from burning biomass for energy are captured before release into the atmosphere and stored in underground reservoirs. If this biomass energy is assumed to be carbon-neutral (see Chapter Two), BECCS accordingly is considered to result in net negative emissions, as the accompanying carbon sequestered by biomass is permanently stored.[82] (It is not clear how negative emissions generated by countries importing biomass should be accounted for against national targets – whether in the consumer or producer country or shared between them.)

Although BECCS has yet to be demonstrated at a commercial scale, it features in the EU's forward projections for climate strategies. The impact assessment accompanying the European Commission's 2020 Communication mentions BECCS primarily as an option post-2030. (This is one of the main reasons why the amount of power generated from bioenergy increases sharply in the 2050 projections in Figure 5). It is possible, however, that BECCS projects could be developed earlier, though the first deployments appear more likely to take place outside the EU, in Norway and the UK (see Section 4.2). In Sweden, the energy company Stockholm Exergi opened a BECCS test facility at Värtan in December 2019 and aims to complete a full-scale BECCS plant by 2025.[83]

## Key member states

As noted in Chapter Three, the main EU importers of wood pellets from the US in recent years have been the UK, Belgium and Denmark, though imports to the Netherlands rose sharply in 2019. (The UK is considered separately in Section 4.2.)

**81** Appunn, K. and Wehrmann, B. (2020), 'Germany irons out last coal exit law hurdles with conversion options for younger plants', *Clean Energy Wire*, 1 July 2020, https://www.cleanenergywire.org/news/germany-irons-out-last-coal-exit-law-hurdles-conversion-options-younger-plants#:~:text=Germany%20irons%20out%20last%20coal%20exit%20law%20hurdles,passage%20of%20the%20bill%20in%20parliament%20at%20 and Wettengel, J. (2020), 'Spelling out the coal exit – Germany's phase-out plan', *Clean Energy Wire*, 3 July 2020, https://www.cleanenergywire.org/factsheets/spelling-out-coal-phase-out-germanys-exit-law-draft.
**82** For a longer discussion of BECCS, its potential and drawbacks, see Brack, D. and King, R. (2020), *Net Zero and Beyond: What Role for Bioenergy with Carbon Capture and Storage?*, Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/2020/01/net-zero-and-beyond-what-role-bioenergy-carbon-capture-and-storage.
**83** Sherrard, A. (2020), 'Stockholm Exergi sets target to be 'climate-positive' by 2025', Bioenergy International, 16 June 2020, https://bioenergyinternational.com/heat-power/stockholm-exergi-to-be-climate-positive-as-early-as-2025.

The potential development of new biomass stations, particularly coal-to-biomass conversions, mean that markets for US pellets could also emerge in other EU member states.[84]

Belgium has imported an average of 550,000 tonnes of wood pellets from the US every year since 2013. US-sourced pellets have comprised more than half of the country's total imports of wood pellets over that period. Most of this is consumed by two coal conversion plants: the Max Green power station burns 700,000–800,000 tonnes a year, all imported, and, until its closure in September 2020, the Les Awirs station burnt about 400,000 tonnes a year, just over one-third of which was imported.[85] Max Green is due to be decommissioned by 2030. The country's National Climate and Energy Plan envisages biomass-generated electricity (currently accounting for about 20 per cent of total renewable electricity in Belgium) steadily falling to 2030, while biomass-generated heat remains roughly constant, albeit falling as a proportion of total heat produced from renewables.[86] Imports of wood pellets therefore seem likely to fall.

**In July 2020 the Social and Economic Council of the Netherlands, an independent advisory board to the Dutch government, concluded that sustainably produced biomass was too scarce to use for the production of heat or electricity and that support should be withdrawn.**

Denmark has historically been one of the larger users of biomass in the EU as a proportion of total energy consumption, both for electricity and heat, particularly in CHP stations, which in recent years have gradually been converted from coal and gas to biomass. In 2019 solid biomass accounted for 19 per cent of Denmark's gross inland energy consumption, but this proportion is projected to fall slightly to 18 per cent in 2030 and to 17 per cent in 2040.[87] Biomass is expected to be used increasingly in technologies which are more difficult to electrify, such as heavy goods vehicles and shipping.[88] Overall, imports of wood pellets seem unlikely to increase significantly, but their sources may change. While the Baltic states and Russia are currently more significant suppliers to Denmark, in recent years imports from the US have increased rapidly, from 94,000 tonnes in 2016 to 623,000 tonnes in 2018 and 506,000 tonnes in 2019.

**84** This is not an exhaustive review but focuses on the main current importers of US pellets, with additional information drawn from Smith, M., Kralli, A. and Lemoine, P. (2021), 'Analysis on biomass in National Energy and Climate Plans', Trinomics/Fern, https://www.fern.org/publications-insight/analysis-on-biomass-in-national-energy-and-climate-plans-2326/#:~:text=Analysis%20on%20biomass%20in%20National%20Energy%20and%20Climate,early%202000s%20and%20has%20already%20surpassed%20projected%20levels.
**85** See ShareAction, European biomass plant database, https://shareaction.org/research-resources/european-biomass-plant-database.
**86** Government of Belgium (2019), 'Belgian Integrated National Energy and Climate Plan 2021–2030', https://www.nationalenergyclimateplan.be/en.
**87** Danish Ministry of Climate, Energy and Utilities (2019), 'Denmark's Integrated National Energy and Climate Plan', p. 158, https://kefm.dk/media/7095/denmarks-national-energy-and-climate-plan.pdf.
**88** Ibid., p. 131.

Imports of wood pellets to the Netherlands increased sharply in 2019, to 1.2 million tonnes, from an average of 350,000 tonnes over the previous two years. Most of those pellets were supplied from within the EU, but in 2019 130,000 tonnes were sourced from the US, an increase from almost nothing the previous year. Further increases in imports can be expected in the short term, as four coal plants were scheduled to start co-firing with biomass between 2018 and 2020. Three of those – with a combined maximum consumption volume of 3.3 million tonnes of pellets a year[89] – may convert fully to burning biomass. Government subsidies to support co-firing are available for a period of eight years. However, the future of biomass power in the Netherlands is unclear. In July 2020 the Social and Economic Council of the Netherlands, an independent advisory board to the Dutch government, concluded that sustainably produced biomass was too scarce to use for the production of heat or electricity and that support should be withdrawn.[90] Nevertheless, in December PBL Netherlands Environmental Assessment Agency concluded that, due to the lack of progress with developing alternative sources of renewable heat, the rapid phase-out of woody biomass for heat networks was risky.[91] In February 2021 the Dutch parliament voted to ban subsidies for future biomass plants, though this ban was not applied to existing agreements.[92] While biomass consumption for power seems likely to be in decline by 2030, the future level of demand for biomass for heat is not clear.

As examined in the 2019 Ember analysis, other potential coal-to-biomass conversions seem likely or very likely to go ahead in the Czech Republic, Finland, France, Germany, Poland, Spain and Sweden. Many of these countries have significant production of wood fuel, including wood pellets, and some are net exporters. Any increase in their consumption seems more likely to be met by increased domestic production, by imports from other EU member states (particularly the Baltic states) or by imports from Belarus, Russia and Ukraine, than by imports from the US. Any reduction in the availability of pellets from any of these sources as a result of increased domestic consumption, however, could prompt increased demand for pellets from other sources – e.g. Canada and the US – in countries such as Belgium, the Netherlands and the UK.

## Projected emissions associated with the use of US-sourced biomass in the EU27

Imports of wood pellets from the US to the EU27 totalled 1.3 million tonnes in 2019. As discussed above, further growth in demand seems likely in the Netherlands until the late 2020s at least, although demand should fall again

**89** US Foreign Agricultural Service (2019), 'The Dutch Industrial Market for Biomass', https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=The%20Dutch%20Industrial%20Market%20for%20Biomass_The%20Hague_Netherlands_2-5-2019.pdf.
**90** Janssen, D. (2020), 'The Dutch have decided: Burning biomass is not sustainable', Euractiv.com, 21 July 2020, https://www.euractiv.com/section/energy/news/the-dutch-have-decided-burning-biomass-is-not-sustainable.
**91** PBL Netherlands Environmental Assessment Agency (2020), 'Rapid phasing out of woody biobased raw materials for heat networks is risky', 18 December 2020, https://www.pbl.nl/nieuws/2020/snelle-uitfasering-houtige-biogrondstoffen-voor-warmtenetten-is-risicovol.
**92** Catanoso, J. (2021), 'Dutch to limit forest biomass subsidies, possibly signaling EU sea change', Mongabay.com, 9 March 2021, https://news.mongabay.com/2021/03/dutch-to-limit-forest-biomass-subsidies-possibly-signaling-eu-sea-change.

by 2030. Denmark and Germany may also see a rise in imports, particularly if Germany converts more coal plants to biomass. For the purpose of estimating emissions, we therefore use projected figures of 3.5 million tonnes imported in 2025 and 2.0 million tonnes in 2030.

The associated emissions are included below in Table 4. Calculated as explained in Section 3.5 and the Annex, these take into account emissions from combustion and the supply chain, forgone removals of $CO_2$ from the atmosphere due to the harvest of live trees and emissions from the decay of roots and unused logging residues left in the forest after harvest: between 1.5 million tonnes (scenario 1) and 3.6 million tonnes (scenario 2). (Some of these could change in the future. It is possible, for example, that the supply-chain emissions per weight of pellets could fall with the decarbonization of the energy used in pelletizing and transport, though these are difficult sectors to deal with. This is, however, a minor component of the total.)

**Table 4.** Projected estimates of EU27 emissions from US-sourced biomass

| Imports and emissions | 2019 | 2025 | 2030 |
|---|---|---|---|
| Wood pellet imports from US (kt) | 1,295 | 3,500 | 2,000 |
| Emissions – Scenario 1 estimate (kt$CO_2$) | 3,086 | 8,337 | 4,764 |
| Emissions – Scenario 2 estimate (kt$CO_2$) | 3,668 | 9,912 | 5,664 |

Source: Compiled by the authors.

## 4.2 Projections for the UK

As noted in Chapter Three, the UK is currently the largest global user of wood pellets, consuming about 8.5 million tonnes a year. Almost all of this is imported.

### Power generation

In the UK, government support for large-scale biomass for electricity is currently delivered through two mechanisms, the Renewables Obligation and the Contracts for Difference (CfD) scheme which has now replaced it (though operators will continue to receive support under the Renewables Obligation for 20 years; the last payments will be made in 2037). Both deliver subsidies to renewable power generators, with the funding deriving from levies placed on electricity consumers' bills.

Both schemes have been used to support coal-to-biomass conversions, as transitional mechanisms in the decarbonization of the power sector. This includes the conversion of the four units at Drax now burning biomass. As noted in Chapter Three, Drax consumes about 7 million tonnes of wood pellets a year, 4.5 million tonnes of which are sourced from the US. EPH's Lynemouth Power Station, a conversion from an old coal-fired installation, began burning biomass in June 2018. With a capacity of 420 MW, Lynemouth is expected to consume an estimated 1.4 million–1.5 million tonnes of wood pellets a year. At least 800,000 tonnes will be supplied by the US-based pellet company Enviva, under a contract signed in 2016.[93] Government support for all conversion projects is scheduled to come to an end on 31 March 2027. In November 2020 the UK government announced that future CfD auctions would exclude new coal-to-biomass conversions.[94]

Both of the government's support mechanisms have also been used to support new dedicated biomass plants. Only one of these plants – MGT Teesside Ltd's Tees Renewable Energy Plant (TeesREP) – is intended to burn wood pellets. (The others, which are much smaller, burn a variety of wood and agricultural feedstocks.) TeesREP, a new, dedicated biomass-powered CHP plant, is the largest dedicated biomass station in the world, with a capacity of 299 MW. Its CfD is due to last for 15 years from the commissioning date. Although the plant was expected to start generating in 2018, construction was delayed initially for unexplained problems, including mass redundancies among the construction workforce in the second half of 2019, and then by the coronavirus pandemic. In early February 2021, however, local media reported that the station would be commissioned within weeks following the arrival of a shipment of 50,000 tonnes of wood pellets from the US.[95] The plant's expected start date has been repeatedly delayed and at the time of publication was 18 October 2021, though this remained under review.[96]

The plant will be able to burn a large range of solid biomass feedstocks, but is expected to be supplied mainly by wood pellets. Its estimated annual consumption is at least 1.0 million – 1.2 million tonnes, plus an estimated 200,000 tonnes of wood chips, potentially supplied from local sources.[97] In 2016 MGT Teesside Ltd entered into a sourcing contract with Enviva for 1.0 million tonnes of pellets per year, to be sourced in the US.[98] A report from December 2020 suggests that MGT has agreed a 15-year supply contract with Enviva for 1.3 million tonnes per year of wood pellets.[99]

Table 5 adds these likely consumption figures together to project a potential total annual UK consumption of 11.0 million tonnes from the year in which TeesREP starts operating until the end of 2026. This represents a 33 per cent increase from 2018. Consumption of US-sourced wood pellets is projected to rise to 7.0 million tonnes a year, representing a 43 per cent increase from 2018.

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**93** Power Technology (2017), 'Lynemouth Biomass Power Station, Northumberland', https://www.power-technology.com/projects/lynemouth-biomass-power-station-northumberland.
**94** BEIS (2020), 'Contracts for Difference for Low Carbon Electricity Generation: Government response to consultation on proposed amendments to the scheme', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/983934/scps-cfd-contract-govt-response.pdf.
**95** Price, K. (2021), 'Switch-on for enormous TeesREP biomass power plant imminent – with up to 400 workers poised', *Teesside Live*, 8 February 2021, https://www.gazettelive.co.uk/news/teesside-news/switch-enormous-teesrep-biomass-power-19858247.
**96** Low Carbon Contracts Company (2021), 'CFD Register: Teesside Renewable Energy Project', https://www.lowcarboncontracts.uk/cfds/teesside-renewable-energy-project.
**97** European Commission (2015), 'State aid SA.38796 (2014/N) – United Kingdom. Teesside Dedicated Biomass CHP Project', C(2015) 168 cor, https://ec.europa.eu/competition/state_aid/cases/255393/255393_1709269_107_2.pdf.
**98** Power Technology (2015), 'Tees Renewable Energy Plant, Teesside', https://www.power-technology.com/projects/tees-renewable-plant-teesside.
**99** Argus Media (2020), 'UK's CCC advises BECCS, domestic biomass supply', 9 December 2020, https://www.argusmedia.com/en/news/2167380-uks-ccc-advises-beccs-domestic-biomass-supply.

**Table 5.** Actual 2018 and projected future consumption of wood pellets for power generation in the UK

| Source of demand | Consumption (million tonnes/year) | | | |
|---|---|---|---|---|
| | **2018, all sources** | **2026 projected, all sources** | **2018, US-sourced** | **2026 projected, US-sourced** |
| Drax | 7.1 | 7.1 | 4.5 | 4.5 |
| Lynemouth | – | 1.4 | – | 0.8 |
| TeesREP | – | 1.3 | – | 1.3 |
| Other uses, imports | 0.9 | 0.9 | 0.4 | 0.4 |
| Other uses, UK production | 0.3 | 0.3 | – | – |
| **Total** | **8.3** | **11.0** | **4.9** | **7.0** |

Source: Compiled by the authors.

The calculation assumes that consumption in Drax remains roughly constant at the 2018–19 level, while adding projected consumption figures for Lynemouth and TeesREP and an estimate of other UK uses calculated using the FAOSTAT and Eurostat data cited in Section 3.3. In reality, some domestic production may be used in the three power stations – though Drax consumed no UK-produced wood pellets in 2018–19. One industry forecast suggests that total UK consumption will reach 11.2 million tonnes (excluding use for heat) from 2020 onwards, supporting this projection.[100]

Further growth in the use of wood pellets for power generation seems highly unlikely, thanks mainly to the changes in the UK sustainability criteria for future contracts discussed in Chapter Two. Whether power generation at Drax will come to a complete end in March 2027 is, however, an open question. The withdrawal of about 7 per cent of total UK electricity capacity could have significant implications for energy security, depending on developments elsewhere in demand and new capacity.

## Other sources of demand

There are three further potential sources of demand for biomass use for energy in the UK.

First, the capacity market – the back-up mechanism ensuring security of electricity supply. Capacity providers bid, in a competitive auction, for payments to ensure they maintain enough capacity to meet demand in times of system stress. To date, most of the contracts have been won by large old coal, gas and nuclear power plants, though more recently, smaller renewable generators, interconnectors and

**100** Strauss, W. (2020), '2020 global pellet markets outlook'.

demand response systems have also been successful. Plants in receipt of other forms of government support are not eligible to compete for contracts, but Drax and Lynemouth would be able to once their existing contracts end in March 2027. The fact that the plants would have to maintain stocks of wood pellets ready to use may limit this option: wood pellets cannot be stored indefinitely as absorption of water from the atmosphere dissolves the binding agent. Nevertheless, if Drax can drive down its costs sufficiently to allow it to generate power continuously without its current levels of subsidy, participation in the capacity market may become viable.

**The UK has made much less progress in introducing renewable heat than electricity. It is currently consulting on successor schemes to the Renewable Heat Initiative, which will close to new applicants in 2021/22.**

Second, demand for wood pellets for heat. Government support for biomass heat is currently provided through the Renewable Heat Incentive (RHI). Similar to a feed-in tariff scheme, the RHI pays participants for each unit of heat generated. By September 2020 some 62 per cent of the heat generated since the start of the scheme in 2011 had derived from biomass.[101] Like the other support mechanisms examined above, sustainability criteria – including a ceiling on carbon emissions per unit of heat – apply to the biomass fuel. The threshold is currently 125 kg$CO_2$eq/MWh, stricter than existing electricity criteria, but about equal to the supply chain emissions of Drax. Like the other mechanisms, this threshold applies only to supply chain emissions; emissions from combustion are ignored. The lower emissions threshold to be introduced for future power generation does not apply to the RHI.

The UK has made much less progress in introducing renewable heat than electricity. It is currently consulting on successor schemes to the RHI, which will close to new applicants in 2021/22. While the development of extensive small-scale biomass heat sources seems unlikely (proposals issued for consultation in April 2020 favoured heat pumps and hydrogen[102]), increased use of biomass for industrial heat seems probable. Future intentions should become clearer when the UK government publishes its bioenergy strategy, expected in 2022.

The third potential source of demand is BECCS. In March 2020 the government allocated £800 million to establish CCS in at least two UK sites, one by the mid-2020s and a second by 2030. This allocation was later raised to £1 billion, with the intention of storing at least 10 Mt$CO_2$ per year by the 2030s, rising to at least 20 Mt$CO_2$ per year by 2035. In its energy white paper *Powering our Net Zero Future*, published in December 2020, the government declared its intention to review the potential application of BECCS in clean hydrogen production, power

**101** BEIS (2020), 'RHI monthly deployment data: September 2020 (Quarterly edition)', https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-september-2020-quarterly-edition.
**102** BEIS (2020), *Future support for low carbon heat*, London: BEIS, p. 27, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/888736/future-support-for-low-carbon-heat-consultation.pdf.

generation, waste management and heat for industrial processes. It observed that 'current support for electricity generation, which converted from coal to using biomass as a fuel source, expires in 2027. BECCS could provide a long-term future for this capacity.'[103] The government launched a call for evidence on greenhouse gas removal technologies and intends to publish a new biomass strategy by 2022, including establishing the role BECCS could play and reviewing feedstock sustainability criteria. In April 2021 it also issued a call for evidence on 'The Role of Biomass in Achieving Net Zero'.[104]

A report by the consultancy Ricardo Energy and Environment on the potential for BECCS, commissioned by the UK government, was published in August 2020.[105] Drawing on previous work on the likely availability of feedstock, and extrapolating from a pilot chemical absorption BECCS project under way at Drax, the study concluded that a deployment level of 500 megawatts electrical (MWe) of BECCS was feasible by 2030. This was most likely to be provided by fitting a capture plant to one of Drax's existing units. Between three and five further 500 MWe units were assumed to be capable of construction by 2040. If the Drax pilot proves successful, three of these could be the remaining biomass-fired boilers at Drax. An additional 500 MWe oxyfuel unit was assumed capable of construction by 2040. This would use a different technology for capturing the $CO_2$, but could still use biomass as fuel.

The Climate Change Committee, the government's independent advisory body on climate policy, published its recommendations for the UK's sixth carbon budget in December 2020.[106] All of the five net zero scenarios presented included BECCS, and it concluded that biomass-fired power generation should begin to include CCS technology in the late 2020s. The Committee pointed to the need to expand UK forestry and energy crop production to reduce reliance on imports. Nevertheless, volumes of imported biomass remained significant in the central scenario, plus three of the other four. As in the EU, the projection included a very large expansion in energy crop production, reaching a total area of 700,000 hectares by 2050 (central scenario), representing a more than seven-fold increase on the area in 2019.[107] However, since most UK biomass power plants were built to process wood pellets and can only burn small proportions of agricultural residues owing to their abrasive effect on the machinery when combusted, there could well be pressure from the biomass industry for wood pellet use to continue.[108]

**103** HM Government (2020), *The Energy White Paper: Powering our Net Zero Future* (CP 337), London: HM Government, p. 53, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf.
**104** BEIS (2021), 'The Role of Biomass in Achieving Net Zero – Call for Evidence', https://beisgovuk.citizenspace.com/clean-electricity/biomass-strategy-call-for-evidence/#:~:text=The%20Call%20for%20Evidence%20aims%20to%20strengthen%20the,role%20in%20our%20efforts%20to%20decarbonise%20the%20economy.
**105** Ricardo Energy and Environment for BEIS (2020), *Analysing the potential of bioenergy with carbon capture in the UK to 2050: Summary for policymakers*, London: BEIS, p. 5, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911268/potential-of-bioenergy-with-carbon-capture.pdf.
**106** Committee on Climate Change (2020), *The Sixth Carbon Budget: The UK's path to Net Zero*, London: Committee on Climate Change, https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf.
**107** The area in 2019 was 96,000 ha; having risen by 2,000 ha from 2018; Department for Environment, Food and Rural Affairs (DEFRA) (2020), *Crops Grown For Bioenergy in the UK: 2019*, London: DEFRA, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943264/nonfood-statsnotice2019-10dec20v3.pdf#:~:text=Ninety%20six%20thousand%20hectares%20of%20agricultural%20land%20was,biofuels%20%EF%82%B7%2067%20thousand%20ha%20of%20maize%201.
**108** Argus Media (2020), 'UK's CCC advises BECCS, domestic biomass supply'.

There are significant technological and financial challenges to be overcome before BECCS technology could be deployed at scale, and there are significant question marks over the extent to which it could genuinely create negative emissions. Additionally, it remains unclear whether the consuming country or the producing country would account for those negative emissions.[109] If the deployment of BECCS proceeds at scale, however, demand for wood pellets from Drax could remain largely constant after current support mechanisms end in 2027. Demand from the UK overall for wood pellets could therefore increase in the late 2020s.

## Projected emissions associated with US-sourced biomass in the UK

As set out in Table 5, UK demand for US-sourced wood pellets for power is projected to rise from 4.9 million tonnes in 2018 to 7.0 million tonnes by 2026. Uncertainty over the future development of UK renewable heat policy does not allow any conclusions to be reached about further growth of imports to feed demand for heat, including industrial processes. After 2027, demand from Lynemouth will end, while demand from Drax is likely to fall. However, this fall will not be to zero if the company is able to develop its pilot BECCS technology. If the impact of ending power generation at Drax in 2027 is too severe for UK electricity supply (or if generation continues without subsidy, perhaps in the expectation of future support for BECCS technology), consumption of US wood pellets could remain at 7.0 million tonnes in 2030. Should significant investment in BECCS go ahead, demand for wood pellets is likely to increase in the late 2020s and into the 2030s. The US remains a likely source of supply.

For the purpose of estimating emissions, we therefore use projected figures for demand for US-sourced wood pellets of 7.0 million tonnes in 2025. Two scenarios are presented for 2030. Scenario A, where Drax maintains generation only at one unit, leads to a projected consumption of 2.9 million tonnes, comprising 1.1 million tonnes at Drax, 1.3 million tonnes at TeesREP, and 0.5 million tonnes for other uses. Scenario B, which assumes that generation continues at all four units at Drax, adds an extra 3.4 million tonnes for the other three units. The associated emissions are included below in Table 6, calculated as explained in Section 3.5 and the Annex. These take into account emissions from combustion and the supply chain, forgone removals of $CO_2$ from the atmosphere due to the harvest of live trees and emissions from the decay of roots and unused logging residues left in the forest after harvest.

**109** See discussion in, e.g. EASAC (2019), *Forest bioenergy, carbon capture and storage, and carbon dioxide removal: an update*, https://easac.eu/fileadmin/PDF_s/reports_statements/Negative_Carbon/EASAC_Commentary_Forest_Bioenergy_Feb_2019_FINAL.pdf; Brack and King (2020), *Net Zero and Beyond*.

**Table 6.** Forward estimates of UK biomass emissions from US-sourced biomass

| Imports and emissions | 2019 | 2025 | 2030 |
|---|---|---|---|
| **Scenario A (one unit at Drax in 2030)** | | | |
| Wood pellet imports from US (kt) | 5,484 | 7,000 | 2,900 |
| Emissions – Scenario 1 (kt$CO_2$) | 13,062 | 16,674 | 6,908 |
| Emissions – Scenario 2 (kt$CO_2$) | 15,529 | 19,824 | 8,213 |
| **Scenario B (four units at Drax in 2030)** | | | |
| Wood pellet imports from US (kt) | 5,484 | 7,000 | 6,300 |
| Emissions – Scenario 1 (kt$CO_2$) | 13,062 | 16,674 | 15,007 |
| Emissions – Scenario 2 (kt$CO_2$) | 15,529 | 19,824 | 17,842 |

Source: Compiled by the authors.

# 05 Conclusions and recommendations

**The feedstock used in biomass plants is critical. Current sustainability criteria do not distinguish between different categories of feedstock and cannot therefore limit the impact of their use on the climate.**

Wood pellets produced in the US, imported to the UK and burnt for energy were responsible for 13 million–16 million tonnes of $CO_2$ emissions in 2019, when taking into account emissions from their combustion and their supply chain, forgone removals of $CO_2$ from the atmosphere due to the harvest of live trees and emissions from the decay of roots and unused logging residues left in the forest after harvest.

Almost none of these emissions are included in the UK's national greenhouse gas inventory; if they were, this would have added between 22 and 27 per cent to greenhouse gas emissions from UK electricity generation, or 2.8–3.6 per cent to total UK greenhouse gas emissions in 2019.[110] This volume is equivalent to the annual greenhouse gas emissions from 6 million–7 million passenger vehicles.[111]

Emissions from US-sourced biomass burnt in the UK are projected to rise to 17 million–20 million tonnes of $CO_2$ a year by 2025. This represents 4.4–5.1 per cent of the average annual greenhouse gas emissions target in the UK's fourth carbon budget (which covers the period 2023–27), making it more difficult to hit a target which the government is currently not on track to achieve in any case. While emissions are likely to fall by 2030, with the end of government support for power stations converted from coal to biomass, it could rise again thereafter if BECCS plants are developed at scale.

**110** BEIS (2020), *2019 UK greenhouse gas emissions, provisional figures*, London: BEIS, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/875485/2019_UK_greenhouse_gas_emissions_provisional_figures_statistical_release.pdf. Total $CO_2$ emissions for power supply were 57.4 $MtCO_2$.
**111** 2018 figures, taken from BEIS (2020), 'Final UK greenhouse gas emissions national statistics: 1990 to 2018' and Department for Transport and Driver and Vehicle Licensing Agency (2020), 'Statistical data set: Cars (VEH02)'.

Since the UK is the predominant European market for US wood pellets, emissions associated with their use in the EU27 are lower: about 3.1 million–3.7 million tonnes of $CO_2$ in 2019, rising to a projected 8 million–10 million tonnes by 2025 and falling back again to about 5 million–6 million tonnes in 2030. This does not take account, however, of any increase in the rate of coal-to-biomass conversions, which may follow as EU member states phase out coal use. While the main countries in which conversions are expected to take place are not large importers of US wood pellets, any constraints in domestic supply or imports from other sources could increase demand for US imports. As in the UK, the development of BECCS plants may serve further to boost demand for US wood pellets in the 2030s and 2040s.

The present scale, and likely growth, of wood pellet use in power and heat production in the UK and EU is a direct result of government subsidies. It would not have happened in the absence of financial and regulatory support.

Furthermore, as discussed in Chapter Two, because of the way in which emissions from the use of wood pellets are reported and accounted for in the land-use rather than in the energy sector in national greenhouse gas reports (and therefore in US rather than UK or EU27 reports), almost none of those emissions will be included in the data used to track progress against national targets – for example, in the UK, the five-yearly carbon budgets set under the Climate Change Act, which establishes the target of net zero emissions by 2050. (Any supply-chain emissions taking place in the UK will be included, but these represent a very small proportion of the total.)

As the IPCC and EU JRC have observed, this separation of reporting sectors obscures the real progress countries are making in meeting the targets adopted under the Paris Agreement. By treating biomass emissions as zero at the point of combustion, the system creates a significant incentive for consuming countries to burn wood for energy. Since emissions take time to be reabsorbed by forest regrowth, carbon emissions in the atmosphere will increase for a period of decades to centuries as a result, depending on the feedstock type. At the same time many policymakers in the consumer countries, as well as the wider public, will be given a false sense of optimism about their country's progress in decarbonizing its energy supply. In addition, there is no corresponding incentive for the producing countries to compensate by reducing their future emissions.

Just as importantly, the treatment of biomass as zero-carbon in policy frameworks has led governments to provide significant financial and regulatory support for the use of biomass for power and heat. While support for biomass may now be falling as other renewables increasingly out-compete it (though it may still be subsidized for coal conversions), biomass is still the dominant source of renewable heat. This support has been delivered, and seems likely to continue, with essentially no means of discriminating between feedstocks with different carbon payback periods. There is, therefore, no effective way of limiting their impact on the climate.

## Recommendations

As discussed in Chapter Two, and illustrated in both Chapter Three and the Annex, the types of biomass feedstock used have a significant impact on emissions totals. We conclude, in line with the arguments in the recent EU JRC report, that only those categories of feedstock with the lowest carbon payback periods should be eligible for financial and regulatory support. This is consistent with the Paris Agreement's aim of peaking global emissions 'as soon as possible' and reduces the chance of emissions triggering climate tipping points.

This means that eligibility for government support should be restricted to sawmill and small forest residues and wastes that would have no other commercial use and whose consumption for energy does not inhibit forest ecosystem health and vitality (e.g. by removing excessive volumes of forest residues).

Current sustainability criteria in the EU27 and UK do not take account of the real impacts of biomass feedstocks on the climate and therefore should be amended to restrict eligibility. At the same time, much tighter definitions of feedstock categories should be introduced to prevent whole trees being treated in the same way as genuine residues. The new proposals from the European Commission in July 2021 introduce the welcome principle of restricting eligibility by feedstock category, but in reality the categories that the European Commission has proposed will make virtually no difference to outcomes.

The restriction of support to feedstocks that have no other commercial use is an important element of these sourcing conditions. Sawmill residues in particular are used extensively for the manufacture of wood panels and particleboard. It is important that supplies of such residues – which are limited in volume – are not diverted to use for energy, with an accompanying pressure on the wood products industry to find other sources. A review of the supply of woody biomass from the southeastern US to the EU, published by the European Commission in 2015, concluded that, while sawmill residues were in many ways the ideal source material for pellets, US mill residues were already almost entirely utilized by the biomass energy or other industries, and there was very limited room for expansion.[112] At the time there was very little evidence of diversion of residues from wood products to energy, but the biomass energy industry has expanded significantly since that study was conducted. Periodic monitoring of feedstock use and impacts should therefore be implemented to prevent diversion.

On top of this restriction of feedstocks, additional criteria should be included to protect particular types of landscape from the extraction of biomass for energy. The European Commission's July 2021 proposal to ban biomass produced from land that was classified as primary forest at any time after 2008 is helpful, though limited. It is to be hoped that this measure is adopted.

Other features of EU sustainability criteria should also be tightened. The UK's adoption of a ceiling on supply-chain emissions of 29 kg $CO_2$eq/MWh for future contracts is welcome, as it seems likely to restrict feedstocks to

**112** Strange Olesen, A. et al. (2015), *Environmental implications of increased reliance of the EU on biomass from the South East US*, pp. 95–96, Brussels: Directorate-General for Environment, https://op.europa.eu/en/publication-detail/-/publication/8005fb30-81e9-4399-9b19-01af823fa42d/language-en.

domestically-sourced products. Similar limits should be introduced in the EU. Energy efficiency thresholds for new stations should also be increased and extended to older and smaller stations. (At present they do not apply at all to stations below 50 MW thermal input and only in full to those above 100 MW.) The European Commission's proposals do not affect these criteria. Finally, the Commission's proposal to extend support for the use of forest biomass in electricity-only installations in coal-dependent regions beyond 2026 will encourage further coal-to-biomass conversions and should be dropped.

In both the EU and UK, feedstock for BECCS plants should be subject to at least the same constraints as for other biomass plants. (The question of which feedstocks should be used for BECCS plants, and their overall impact on land use and carbon balances, is an important one but falls outside this paper's remit.)

In addition to using sustainability criteria to limit the use of biomass feedstocks, international and national reporting and accounting rules should be amended to support this objective. As discussed in Chapter Two, there is no ideal solution to the problem of double-counting or the question of whether emissions should be reported in the land-use or the energy sectors. We recommend that the IPCC review its current reporting guidelines to address this issue.

More important, however, is the question of how biomass emissions are included in accounting against national targets. Consistent with the use of sustainability criteria to limit biomass feedstocks to those with the shortest carbon payback periods, emissions from any other type of biomass used for energy should be included in full in the consuming country's greenhouse gas totals when judging progress against their national targets – for example, the UK's carbon budgets setting a trajectory to net zero emissions by 2050 or the EU's new target of a 55 per cent reduction in emissions by 2030. These emissions should also be included in full in any relevant policy frameworks, such as the EU's Emissions Trading System, which currently excludes or zero-rates emissions from biomass.

If these recommended changes to sustainability criteria are implemented fully, non-residue feedstocks would not be eligible for financial or regulatory support, but could still be used. Although their associated emissions should eventually be captured through forest regrowth, as discussed in Chapter Two, this will only take place after a period of decades or even centuries. Including their emissions in consuming countries' current totals would be an effective way of ensuring that the period during which carbon concentrations in the atmosphere are higher than they would otherwise have been is not simply ignored.

# Annex: Emissions from wood pellet use for energy

## A1. Emissions from pellet combustion

Calculations of emissions of $CO_2$ per weight of wood pellets in national reports to the UNFCCC vary. In its 2012 report, for example, the UK used the figure of 381.4 kg of carbon (1,400 kg $CO_2$) emitted per tonne of wood biomass (based on IPCC guidance from 1997),[113] whereas in its 2014 report, it used figures of 1,055 kg $CO_2$ per tonne of wood for power stations, 1,416 kg for domestic combustion and 1,767 kg for other industrial combustion.[114] The US Energy Information Administration uses the figure of 434 kg carbon (1,593 kg $CO_2$) per tonne of wood pellets.[115] Other countries report emissions per unit of energy generated rather than per weight of wood. In reality, emissions from biomass will depend on the type of feedstock, the facility in which it is burnt and several other factors.

The second Chatham House paper on biomass energy, *Woody Biomass for Power and Heat: Demand and Supply in Selected EU Member States* (2018),[116] which included this calculation for imported biomass, used the figure of 1.762 tonnes of $CO_2$ per tonne of wood pellets, based on reported emissions from Drax in 2013.

**113** Department of Energy and Climate Change (DECC) (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.
**114** UK Parliament (2016), 'Baroness Neville-Rolfe answer to Parliamentary Question HL2685', 2 November 2016, https://questions-statements.parliament.uk/written-questions/detail/2016-10-26/HL2685.
**115** See EPA (2016), *Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2014*, pp. 3–92, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014.
**116** Brack, D., Hewitt, J. and Marchand, T. M. (2018), *Woody Biomass for Power and Heat: Demand and Supply in Selected EU Member States*, Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/2018/06/woody-biomass-power-and-heat.

For the purposes of this report, we have used the average of reported consumption and emissions from Drax for the years 2013–19, which gives a conversion factor of 1.80 tonnes $CO_2$ per tonne of wood pellets (see Table 7).

**Table 7.** Consumption of and emissions of $CO_2$ from wood pellets at Drax, 2013–19

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| Total pellets (kt) | 1,596 | 3,900 | 5,893 | 6,591 | 6,756 | 7,171 | 7,051 |
| Total emissions ($ktCO_2eq$) | 2,799 | 7,150 | 10,372 | 11,836 | 12,212 | 13,019 | 12,795 |
| Emissions / pellets ($ktCO_2eq/kt$) | 1.75 | 1.83 | 1.76 | 1.80 | 1.81 | 1.82 | 1.81 |

Source: Drax Annual Reports.

Using this calculation of emissions from combustion, Table 8 sets out the $CO_2$ emissions attributable to wood pellets imported from the US and burnt for energy in the former EU28. (Figure 1 is based on these data, multiplied by 1.80).[117]

**Table 8.** Imports of US wood pellets to former EU28 and associated emissions of $CO_2$, 2014–19

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| EU28 pellet imports from US (kt) | 3,890 | 4,287 | 4,902 | 5,205 | 6,139 | 6,779 |
| Emissions ($ktCO_2$) | 7,002 | 7,716 | 8,823 | 9,370 | 11,049 | 12,202 |
| Emissions as % of EU solid biomass emissions | 1.61% | 1.71% | 1.92% | 2.01% | 2.37% | 2.53% |
| Emissions as % of EU energy emissions (not included in emissions totals) | 0.22% | 0.24% | 0.28% | 0.29% | 0.35% | 0.41% |

Source: Import figures generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do?noredirectnewsession=true.

Table 9 contains the equivalent data for US wood pellets imported to the UK and for emissions associated with consumption of US wood pellets in Drax.[118]

**117** The figures for imports are not precisely comparable with those for consumption, as pellets can be imported in one year and burnt in the next.
**118** As above.

**Table 9.** Imports of US wood pellets to UK, consumption of US wood pellets in Drax and associated emissions of $CO_2$ from combustion, 2014–19

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| UK pellet imports from US (kt) | 2,895 | 3,528 | 4,128 | 4,266 | 4,880 | 5,484 |
| Emissions ($ktCO_2$) | 5,211 | 6,350 | 7,430 | 7,678 | 8,784 | 9,870 |
| Emissions as % of UK solid biomass emissions | 32.94% | 33.77% | 40.68% | 38.12% | 39.52% | 42.29% |
| Emissions as % of UK energy emissions (not included in emissions totals) | 1.29% | 1.63% | 2.01% | 2.14% | 2.50% | 2.91% |
| Drax consumption (kt) | 2,300 | 3,135 | 3,892 | 3,996 | 4,464 | 4,613 |
| Emissions ($ktCO_2$) | 4,140 | 5,644 | 7,005 | 7,193 | 8,034 | 8,303 |

Source: Import figures generated from Eurostat data at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do?noredirectnewsession=true; Drax consumption figures from Drax annual reports.

## A2. Emissions from the supply chain

The use of biomass for energy also produces emissions from the supply chain: in this case, from the energy used in harvesting, processing and transporting wood pellets. Drax includes estimates for these in its annual reports. In 2019 50 per cent of these emissions derived from the pelletizing process, 20 per cent from shipping, 19 per cent from other transport, 8 per cent from drying the wood and about 4 per cent from cultivation, harvesting and chipping.[119] Estimates are included for these supply chain emissions per unit of electricity generated, which enables the calculation of total supply chain emissions from the wood pellets burnt for energy in each year. As Table 10 shows, the average of the supply chain figures across the six years is 0.24 tonnes $CO_2$ per tonne of pellets. (In April 2021 Drax published its supply-chain figures for 2020, showing a fall to 109 $kgCO_2eq$/MWh, though it did not provide a breakdown or explain how that reduction had been achieved.[120])

**119** Drax Group PLC (2020), *Enabling a zero carbon, lower cost energy future: Annual report and accounts 2019*, p. 43.
**120** Drax Group PLC (2021), *Driven by our purpose: Annual report and accounts 2020*, p. 53, https://www.drax.com/wp-content/uploads/2021/03/Drax_AR2020.pdf.

**Table 10.** Supply-chain emissions of $CO_2$ from the use of wood pellets in Drax, 2014–19

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| Supply chain emissions ($kgCO_2eq/MWh$) | 123 | 114 | 122 | 130 | 131 | 124 |
| Generation from biomass (TWh) | 7.9 | 11.5 | 12.7 | 13 | 13.8 | 13.7 |
| Total emissions ($ktCO_2eq$) | 970 | 1,311 | 1,549 | 1,690 | 1,808 | 1,699 |
| Emissions/pellets ($ktCO_2eq/kt$) | 0.25 | 0.22 | 0.24 | 0.25 | 0.25 | 0.24 |

Source: Drax Annual Reports.

Unlike the combustion figures, these emissions should be reported in the greenhouse gas reports of the countries in which the harvesting, processing and transport takes place. Countries are allocated shares of emissions from international transport.

## A3. Impacts of pellet production on forest carbon stocks and sequestration in the southern United States

The use of woody biomass for energy affects carbon concentrations in the atmosphere from the impacts of harvesting live trees on carbon stocks, emissions from logging and mill residues, and forgone sequestration rates in the forests from which the wood is sourced. Calculating these effects is significantly more complex than calculating emissions from combustion and the supply chain. This is in large part because publicly available data from forest inventories does not allow for directly estimating the impact of harvesting of biomass for pellets to be distinguished from harvesting for other wood products. There is, however, sufficiently detailed data available to make reasoned assumptions about how additional harvesting of biomass for pellets – above what would have occurred if pellets were not being produced – impacts forests and net emissions of $CO_2$. This assertion is based on economic analyses that show how growing demand for wood products leads to increased harvesting.[121]

The approach taken here is a partial systems analysis, focused on two major parts of a full systems analysis: the forest ecosystem carbon cycle; and the harvested wood processing by mills for pellets and other wood products. The effects of substituting wood pellets for other energy sources that would typically be the

**121** USDA Forest Service (2016), *Future of America's Forests and Rangelands*; Favero, Daigneault and Sohngen (2020), 'Forests: Carbon sequestration, biomass energy, or both?'; Buchholz, Gunn and Sharma (2021), 'When Biomass Electricity Demand Prompts Thinnings in Southern US Pine Plantations'.

target of comparative life cycle analyses are not estimated here, nor are indirect impacts of increasing harvest for pellets, such as the effects of induced land-use change on forest area, or effects on wood supply for the pulp and paper industry.

The approach aims to quantify how harvesting wood in the southern US for producing pellets for export to the UK affects the carbon stocks and stock change in the forests of the source regions for the pellet mills. To put these forest ecosystem and wood product estimates in context, the impacts of all sources used and exported were estimated, while their emissions upon combustion were also considered. The approach is focused on the cellulosic carbon and $CO_2$ emissions associated with the different sources of biomass used for pellets and the uncertainty of information about quantities of different sources used. The estimates are based on the production of pellets rather than consumption, so they may not be 100 per cent consistent with estimates from consuming countries. This is largely the result of separately compiled datasets that describe production and exports in the producing country and consumption and imports in the consuming countries.

## Approach and methods

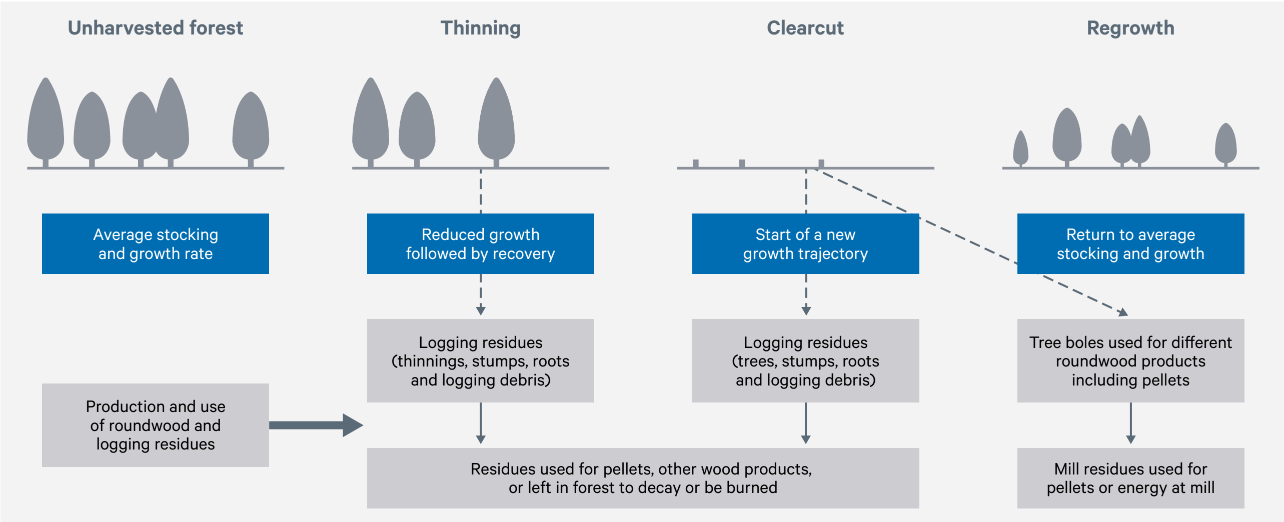
The analysis approach and methods involved the following elements:

- A set of pellet mills in the southern US that export pellets to the UK was identified, along with their assumed wood procurement areas.
- The type of source material used by each mill was also identified from available databases.
- Forest inventory data and harvest records from the USDA Forest Service were used to characterize the impact of harvesting roundwood (live trees of merchantable size) and smaller trees for pellets on the carbon stocks and stock changes in the procurement areas.
- The emissions from changes in carbon stocks were then compared with estimates of the emissions from combustion of biomass from different sources (roundwood, logging debris and mill waste).
- The proportion of the total emissions was estimated for each source category.

Combined, these estimates represent the total amount of forest-based emissions plus lost forest growth and decay of unused post-harvest debris associated with burning pellets in the UK that were sourced from the southern US.

Figure 8 below shows the flow of biomass and the associated $CO_2$ emissions and removals pathways. A forest goes through a typical management cycle beginning with an existing forest, then a thinning or stocking control treatment, then a final harvest, and finally regeneration and regrowth. When thinned or clearcut, there is a temporary reduction in growth rate (referred to here as ‘lost forest growth’) and reduced removal of $CO_2$ from the atmosphere. Harvested tree boles, logging residues and mill residues are all sources of products. Here, we separate the accounting of each so that only the proportion of these sources associated with producing pellets is counted as emissions attributed to burning pellets for energy.

**Figure 8.** Flow of biomass and associated $CO_2$ emissions and removals pathways

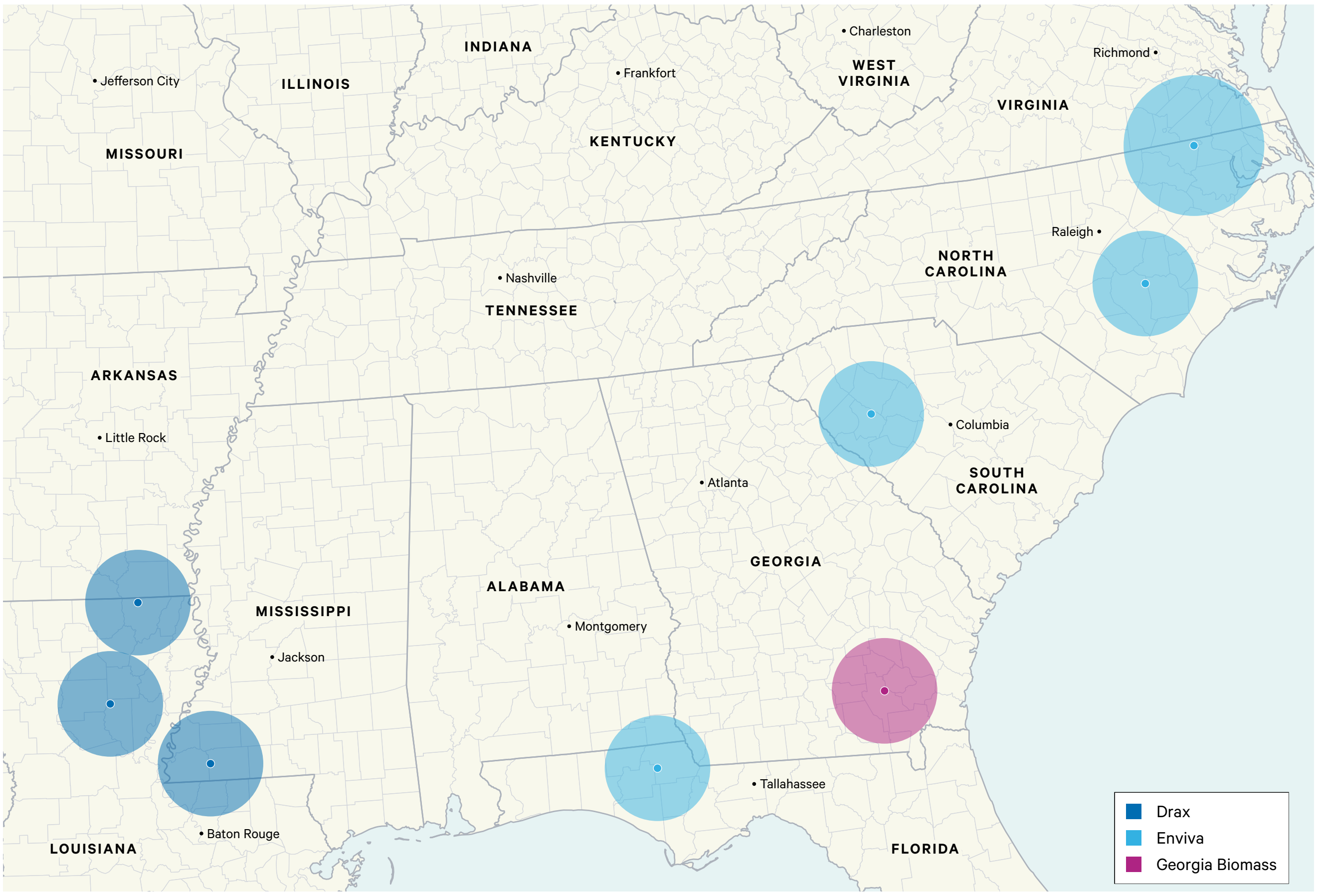



Source: Compiled by the authors.

Pellet mills in the southern US that were in operation for all of 2019 were identified from purchased data compiled by Forisk Consulting.[122] Pellet mills that were likely to export pellets to the UK were identified based on export statistics from the US International Trade Commission[123] and Eurostat[124] trade data. Based on this analysis, 10 mills were selected for further analysis. These included three operated by Drax, six operated by Enviva and one operated by Georgia Biomass (Figure 9).

**122** Forisk Consulting, LLC (2020). 'Wood Bioenergy US Database', https://forisk.com (data as at 17 April 2020).
**123** US International Trade Commission (USITC) (2020). 'USITC DataWeb', https://dataweb.usitc.gov.
**124** Eurostat (2020), 'European Union Trade Statistics', https://ec.europa.eu/eurostat/web/international-trade-in-goods/data/database.

**Figure 9.** Locations of mills analysed in this study




Source: Adapted from Southern Environmental Law Center.

Similarly to previous studies,[125] and as per common practice when assessing the procurement area for a mill, a circle with a 50-mile radius centred on each mill was used to approximate this area. The analysis assumed no overlap in the procurement areas between mills. One exception was the three Enviva mills situated close together around the North Carolina-Virginia border, near the company's Port of Chesapeake facility. In this specific example, a procurement area with a 75-mile radius was established, centred at the mid-point between the three mills.

All of the pellets produced by the three Drax-owned mills were assumed to be exported to the UK. In order to match the total quantity of pellets imported to the UK (according to UK import data) and used by Drax from all southern US mills (as shown in Table 9 above), the quantity of pellets exported from each of the remaining seven selected mills was reduced by 29.8 per cent; the adjusted figures are shown in Table 11. This accounting adjustment was necessary because

125 Buchholz, T. and Gunn, J. (2015), *Carbon Emission Estimates for Drax Biomass Powerplants in the UK Sourcing from Enviva Pellet Mills in US Southeastern Hardwoods Using the BEAC Model*, Northampton, CT: Spatial Informatics Group for Southern Environmental Law Center, https://www.southernenvironment.org/uploads/audio/2015-05-27_BEAC_calculations_SE_hardwoods.pdf; Buchholz, T., Gunn, J. and Kittler, B. (2019), *The Carbon Impacts of UK Electricity Produced by Burning Wood Pellets from Drax's Three US Mills*, Northampton, CT: Spatial Informatics Group for Southern Environmental Law Center, https://www.biomassmurder.org/docs/2019-05-27-sig-gis-the-carbon-impacts-of-uk-electricity-produced-by-burning-wood-pellets-from-drax-s-three-us-mills-english.pdf.

the data on production of pellets by the different mills in the US is not directly associated with exports from US ports to specific countries, meaning that not all of the production of pellets by most mills (except those operated by Drax) would be exported to the UK.

**Table 11.** Assumed exports to Drax Power Station in 2019

| Mill | Dry tonnes of pellets |
|---|---|
| Enviva Cottondale | 565,492 |
| Enviva Greenwood | 323,138 |
| Enviva Northampton<br>Enviva Southampton<br>Enviva Ahoskie | 1,168,214 |
| Enviva Sampson | 429,914 |
| Drax Amite | 578,000 |
| Drax La Salle | 496,000 |
| Drax Morehouse | 578,000 |
| Georgia Biomass | 474,047 |
| **Total** | **4,612,805** |

Source: Compiled by the authors, based on mill production data and export/import data.
Note: All production by the Drax-owned mills was assumed shipped to Drax Power Station. Assumed exports from the remaining mills were reduced by 29.8 per cent so that the total exported from all mills was equal to the total imported from the southern US to the Drax facility in the UK.

The main categories of source material used for wood pellets in the US are waste wood (logging residues and mill wastes) and roundwood. Logging residues are defined by the USDA Forest Service as tree limbs, tops and stumps that are typically left behind in the forest after logging operations remove the merchantable boles of live trees. Also, by definition logging residues may include trees damaged or killed in the course of logging and left behind, unmerchantable live trees such as small-diameter trees or undesirable species and live trees from pre-commercial thinning (including other intermediate harvest operations in naturally regenerated forests). There is scant evidence that pre-commercial thinning is a common practice in the southern US.[126,127] Mill wastes include sawdust and trimmings such as slabs and edgings from tree boles that are processed for various products in lumber mills. Much of this material is burnt for power in the lumber mills that produce the waste, but some of it is now being used to produce wood pellets and other composite wood products. Roundwood consists of merchantable-sized live trees that are harvested

**126** Gonzales-Benecke et al. (2011), 'A Flexible Hybrid Model of Life Cycle Carbon Balance for Loblolly Pine (Pinus taeda L.) Management Systems'; Buchholz, Gunn and Kittler (2018), 'UK wood pellet derived electricity: Carbon emission estimates from trees, thinnings and residues sourced in mixed pine-hardwood forests and pine plantations in the southeastern US'.
**127** Ricardo Energy and Environment for DECC (2016), *Use of North American woody biomass in UK electricity generation: Assessment of high carbon biomass fuel sourcing scenarios*, London: DECC, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/594046/Summary_-_Assessment_of_high_carbon_biomass_fuel_sourcing_scenarios.pdf.

for various wood products such as pulp and paper, lumber and plywood. In the southern US, roundwood is typically harvested by commercial thinning and clearcut. The wood harvested from any specific logging operation may be used for multiple products. Often the poorest quality and lowest value wood is used for pellets.

The quantities of the different sources of biomass used by each selected pellet mill in 2019 were taken from the Forisk Wood Bioenergy US Database,[128] which reports green tons of pulpwood (referred to here as roundwood), logging residues and mill residues. The Forisk data allowed for simulating individual mill contributions to exports of pellets to the UK and to Drax specifically, as well as the impacts of pellet production on the mills' supply regions. Results from individual mills were aggregated and then the exports sourced from non-Drax mills were adjusted as described earlier to match the actual imports of pellets for use by Drax in the UK.

Two adjustments to the reported amounts of source material in the Forisk database were made. First, Drax reports for 2019 suggest that about 55 per cent of all source material was from roundwood. Therefore the amount reported by Forisk for the mills that export to the UK (61 per cent) was reduced accordingly (Table 11) and considered part of a 'scenario 1' estimate of roundwood used for pellets. Second, after this first adjustment, a 'scenario 2' estimate was made for roundwood. This was because estimates reported by Forisk and by Drax are likely to be biased downward, because of a reluctance by pellet mills to acknowledge their harvesting of live trees.[129] To account for this possibility in scenario 2, 50 per cent of the total reported logging residues used for pellets was reallocated to the roundwood category (Table 12). This approach is based on the broad legal definition of logging residues, which as described earlier can include pre-commercial thinning of live trees and other non-commercial live trees that may be harvested along with merchantable trees.[130] Based on these adjustments, the estimate of roundwood used to produce pellets in the US for export to the EU and UK amounts to 55–67 per cent of the total supply of biomass from all sources.

**Table 12.** Sources of biomass used for pellets in dry tonnes of biomass

| Source | Scenario 1 | Scenario 2 |
|---|---|---|
| Roundwood | 2,537,043 | 3,083,764 |
| Logging residue | 1,093,442 | 546,721 |
| Mill residue | 982,320 | 982,320 |
| **Total** | **4,612,805** | **4,612,805** |

Source: Compiled by the authors: as reported in mill production records compiled in the US.
Note: The reported total was adjusted downward to match estimated imports from the US by Drax. The amount of roundwood reported by Forisk was also adjusted downward to match the percentage reported by Drax (55 per cent) for scenario 1. In scenario 2, one-half of the reported logging residues was shifted to the roundwood category.

**128** Forisk Consulting, LLC (2020), Wood Bioenergy US Database.
**129** Buchholz, Gunn and Kittler (2019), *The Carbon Impacts of UK Electricity Produced by Burning Wood Pellets from Drax's Three US Mills*.
**130** See also Buchholz, Gunn and Sharma (2021), 'When Biomass Electricity Demand Prompts Thinnings in Southern US Pine Plantations'.

Since there is no publicly available quantitative data on the amount of roundwood that comes from commercial thinning[131] vs final harvest, and since the type of harvest determines the impact on growth, both scenarios were further defined to help establish bounds for the impact of using roundwood on forest carbon. Scenario 1 assumed that all harvest was from commercial thinning, while scenario 2 assumed that all harvest was from final clearcut. This approach provided for a wide range of estimated impacts on forest carbon stocks and sequestration following harvest, with the actual values expected to be within those extremes.

The USDA Forest Service forest inventory database[132] was queried to estimate the characteristics of the assumed procurement areas based on the most recent forest inventories for the southern states. Inventory dates based on the time of field measurements ranged from 2012 to 2019, and the time between successive measurements varied from five to seven years among states depending on implementation schedules. Variables used in this analysis were estimated by forest type and stand origin – i.e. whether planted or artificially regenerated. Variables derived from the inventory data included: forest area; the main non-soil (biomass, dead wood, litter, and understory) carbon stocks and stock changes; harvest areas and above-ground biomass harvested; and data to calculate the proportion of total tree biomass allocated to bole, stump plus roots, and branches plus tops. The total number of inventory sample plots falling within the procurement areas associated with the 10 mills was 4,640.

The previous estimates from publicly available forest inventory data and mill surveys were used to infer the impact of pellet production on biomass stocks, carbon accumulation in the source areas and emissions from burning pellets by type of source material. To estimate the direct emissions from burning pellets sourced from roundwood, logging residues or mill residues, the average emissions figure reported by Drax for 2013–19 – 1.80 tonnes $CO_2$ per tonne of wood pellets – was used (see Section A1).

(In fact, the same figure results from converting the dry weight of the pellets to $CO_2$, assumed to be 100 per cent emitted when burnt, using the following unit conversion factors:

- One US ton = 0.907 metric tonne
- One green unit of roundwood or residue = 0.45 dry unit
- One dry metric tonne biomass = 0.49 metric tonnes carbon
- One metric tonne carbon = 3.67 metric tonnes $CO_2$
- One dry metric tonne of wood pellets = 1.8 metric tonnes of $CO_2$.)

Estimating the impact of harvesting roundwood for pellets on forest carbon accumulation required estimates of the area and biomass attributed specifically to pellet production. The supply of wood for pellets is typically integrated with the supply of wood from harvesting for other products like lumber and paper. Therefore,

**131** 'Commercial thinning' is broadly defined to include partial harvest of naturally regenerated stands in addition to thinning of plantations.
**132** Burrill, E. A. et al. (2020), *The forest inventory and analysis database: database description and user guide version 8.0 for Phase 2*, Washington, DC: USDA Forest Service, https://www.fia.fs.fed.us/library/database-documentation/current/ver80/FIADB User Guide P2_8-0.pdf.

it was necessary to assume that wood for pellets has a proportional impact on forests, according to the mass of pellets produced compared with the mass of wood harvested for all purposes. The proportion of area and biomass represented by harvesting roundwood for pellets was estimated by dividing the dry biomass of pellets from roundwood by the total biomass harvested in the procurement areas for all products, for scenarios 1 and 2 of estimated roundwood used. As described above, scenario 1 reflected reported estimates of roundwood used plus the assumption that all harvest of live trees for pellets was by thinning. Scenario 2 was defined by transferring some of the source material from the logging residue category to the roundwood category, plus assuming all harvest for pellets was done by clearcut.

The average annual forest carbon increment lost from harvesting for pellets was estimated by multiplying the area-equivalent harvested by the difference between the reduced growth from harvesting live trees and the growth that would have occurred if the trees had not been harvested, accumulated over the number of years it would take to reach the pre-harvest rate of carbon increment. These values were estimated from growth rates by age class from the forest inventory data. It assumed ages of 17.5 years for commercial thinning and 27.5 for final harvest of naturally regenerated forests, and 12.5 years for commercial thinning and 22.5 years for final harvest of planted forests.[133,134] Assumed ages of harvest were confirmed by examining forest inventory data showing harvest areas by forest age class, though the average ages of harvest may not reflect the fact that some older forests are also harvested. Calculations were carried out separately for planted and naturally regenerated forests, owing to the significant difference in average growth rates and harvest ages between the two (Table 13).

**Table 13.** Estimated number of years for the growth of a harvested forest to reach pre-harvest growth rates following thinning or clearcut, by forest type and stand origin

| | **Forest type** | | | |
|---|---|---|---|---|
| **Harvest type** | **All types** | **Loblolly-shortleaf** | **Oak-pine** | **Oak-hickory** |
| | **Natural regeneration** | | | |
| Thinning | 2½ | 3 | 2 | 2 |
| Clearcut | 7½ | 6 | 6 | 15 |
| | **Plantation** | | | |
| Thinning | 1½ | 1 | 2½ | 2 |
| Clearcut | 6 | 6 | 8 | 15 |

Source: Compiled by the authors.
Note: These estimates were calculated from analysis of harvest and growth rates by age class from forest inventory data, for the respective forest types and stand origins. Thinning is sometimes associated with faster volume growth, but available evidence indicates that there the removal of live trees causes reduced $CO_2$ uptake for a period of time (see discussion in Chapter Two).

**133** Gonzales-Benecke et al. (2011), 'A Flexible Hybrid Model of Life Cycle Carbon Balance for Loblolly Pine (Pinus taeda L.) Management Systems'; Buchholz, Gunn and Kittler (2018), 'UK wood pellet derived electricity: Carbon emission estimates from trees, thinnings and residues sourced in mixed pine-hardwood forests and pine plantations in the southeastern US'.
**134** Hoover et al. (2014), 'Quantifying Greenhouse Gas Sources and Sinks in Managed Forest Systems'.

The loss of carbon from the decay of roots and from the decay of unused logging debris in the harvested forests were also estimated for harvested roundwood attributed to increasing pellet production, using average ratios of roots and logging debris to the biomass of the harvested tree bole of 1.26 and 1.172, respectively. These ratios are based on estimates of the carbon stored in different tree parts as reported in the forest inventory database for the assumed procurement areas, using component ratio biomass equations. Logging debris used for other products besides pellets was excluded from the calculations.

All of the estimates were summarized for all mills combined using common units of carbon and $CO_2$, accounting for the proportion of all pellets produced by the mills that were shipped to the UK and used at Drax.

## Results – procurement areas and net emissions by source of material

The procurement areas around the 10 pellet mills contain 11 million hectares of forest (Table 14). About 4 million hectares are plantation forests and 7 million hectares are naturally regenerated. Loblolly-shortleaf pine is the most common forest type, with more than 4 million hectares. Of this, 61 per cent or 2.6 million hectares are planted.

**Table 14.** Area of forestland within procurement areas by forest type and stand origin (hectares)

| Stand origin | All types | Loblolly-shortleaf pine | Oak-pine | Oak-hickory | Other types |
|---|---|---|---|---|---|
| Natural regeneration | 7,119,802 | 1,662,147 | 948,479 | 1,874,467 | 2,634,709 |
| Plantation | 3,976,266 | 2,621,233 | 246,656 | 142,866 | 965,512 |
| **All origins** | **11,096,068** | **4,283,381** | **1,195,135** | **2,017,332** | **3,600,220** |

Source: Compiled by the authors.
Note: The most common forest types that supply timber are specified. Areas are unadjusted for small amounts of overlap between procurement areas.

The average annual net change in carbon stocks within the procurement areas is highest for loblolly-pine plantations at 4.72 tonnes C/ha/yr, followed closely by plantations of ‘other types’, mainly composed of longleaf-slash pine and elm-ash-cottonwood (Table 15). Naturally regenerated forests have lower carbon growth rates than plantations.

**Table 15.** Average annual net change in carbon stocks (carbon growth) of forests within procurement areas by forest type and stand origin (tonnes C/ha/year)

| Stand origin | All types | Loblolly-shortleaf pine | Oak-pine | Oak-hickory | Other types |
|---|---|---|---|---|---|
| Natural regeneration | 2.29 | 3.43 | 2.59 | 2.04 | 1.63 |
| Plantation | 4.45 | 4.72 | 2.38 | 1.50 | 4.67 |
| **All origins** | **3.06** | **4.22** | **2.55** | **2.00** | **2.45** |

Source: Compiled by the authors.

Tree harvests for all products within the procurement areas total 373,000 hectares annually, affecting 3.4 per cent of the total forest area (Table 16). Nearly two-thirds of the harvest area is plantation forest. Of the 18.5 million tonnes of biomass harvested annually for all types of wood products, about 12 per cent is harvest residues that are either left in the forests or used for timber products that can accept low-grade wood, such as pellets and particleboard. Of the total biomass harvested for all products within the procurement area, 10 per cent was attributed to pellet production in scenario 1 and 12 per cent in scenario 2.

**Table 16.** Summary of biomass harvest data within procurement areas by stand origin

| Harvest data | All forests | Natural regeneration | Plantations |
|---|---|---|---|
| Area harvested (ha/yr) | 372,626 | 141,905 | 230,721 |
| Biomass harvested (tonnes C/yr) | 18,493,140 | 8,127,292 | 10,254,466 |
| Harvest residues (tonnes C/yr) | 2,568,822 | 1,172,184 | 1,225,676 |

Source: Compiled by the authors.

## $CO_2$ emissions from different sources of biomass used for pellets burnt in Drax

As a result of this analysis, annual net emissions of $CO_2$ from pellets sourced from the southern US and burnt in Drax were estimated at between 11 million and 13 million tonnes in 2019 (Table 17). This estimate includes:

- Emissions to the atmosphere from burning the pellets (calculated from emissions reported by Drax – Section A1): 8.3 million tonnes.

— Emissions from the supply chain (calculated from emissions reported by Drax – Section A2): 1.1 million tonnes.

— Emissions from the decay of roots and unused logging residues left in the forest after harvest and forgone removals of $CO_2$ from the atmosphere due to the harvest of live trees (calculated as explained above): between 1.5 million tonnes (scenario 1) and 3.6 million tonnes (scenario 2).

**Table 17.** Net emissions in 2019 (tonnes $CO_2$) by source, from biomass used for pellets exported from the southern US to the UK for Drax, regardless of where emitted

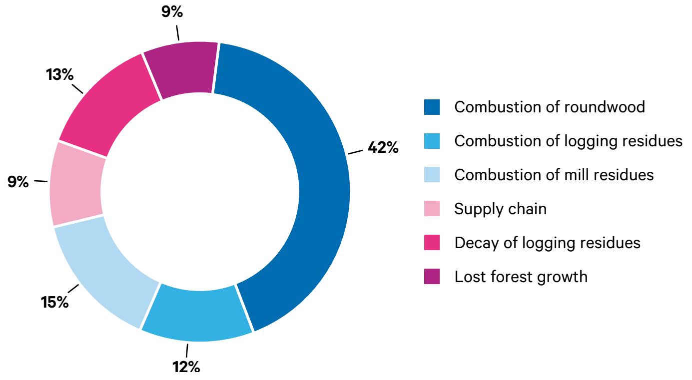
| Source | Scenario 1 | Scenario 2 |
|---|---|---|
| **Combustion emissions** | | |
| Roundwood used for pellets | 4,566,677 | 5,550,775 |
| Logging residue used for pellets | 1,968,196 | 984,098 |
| Mill residues used for pellets | 1,768,176 | 1,768,176 |
| **Supply chain emissions** | | |
| Supply chain | 1,114,334 | 1,114,334 |
| **Impact on forest carbon** | | |
| Decay of logging residues | 1,432,293 | 1,740,945 |
| Lost forest growth | 115,280 | 1,882,909 |
| **Total** | **10,964,956** | **13,041,237** |
| Additional percentage of combustion from lost forest growth and decay of residues | 19% | 44% |

Source: Compiled by authors.
Note: 'Lost forest growth' and 'decay of logging residues' represents the removal of $CO_2$ from the atmosphere that would not have occurred if the roundwood had not been harvested.

The largest difference in estimates among the source categories for scenarios 1 and 2 is for lost forest growth. This is due to the dual effects of using less roundwood and only wood from thinnings (which has a faster growth recovery) in scenario 1, compared with using more roundwood and only using wood from clearcut harvest in scenario 2. All sources considered, the actual emissions associated with burning the pellets are 19 to 44 per cent higher than combustion emissions alone when accounting for changes in the net carbon balance of the forests (decay of residues plus lost forest growth) in the procurement areas.

Of the different emission sources, the midpoint of the two scenarios suggests that the combustion of roundwood accounted for about 42 per cent of total emissions (Figure 10) and 61 per cent of the combustion emissions (Table 17) from burning pellets. Based on the amount of biomass harvested by stand origin for all products including pellets (not shown in table), 56 per cent of the roundwood used for pellets comes from forest plantations and 44 per cent from stands established by natural regeneration. The combustion of logging and mill residues, which are often cited as a main source of wood for pellets, accounted for 12–15 per cent of the total net emissions, respectively, for the midpoint of the two scenarios.

**Figure 10.** $CO_2$ emissions associated with US-sourced wood pellets burnt at Drax, 2019




Source: Compiled by the authors.

The estimate of forgone removals from lost forest growth ranges from 0.1 million to 1.9 million tonnes per year, with the midpoint of the two scenarios estimated at 9 per cent of total emissions. This large range represents the uncertainty associated with the amount of roundwood included in the reported use of forest residues, as well as the specific forest types, ages, type of harvesting (thinning or clearcut), and locations of roundwood harvested specifically for pellets. Decay of unused logging residue accounted for 1.4 million–1.7 million tonnes per year or 13 per cent of all emissions, according to the average of scenarios. Carbon accumulation rates (Table 15) were consistently estimated across the southern US and therefore do not contribute significantly to the uncertainty estimation.

The average time needed to regrow the biomass harvested for pellets varied by stand origin (plantation or natural) and whether the harvest was a thinning or final clearcut. Plantations had the shortest average regrowth periods of 5–10 years for thinning and 25–30 years for final harvest. The average of 10 years indicates that more of the supply of wood for pellets came from thinning. Because of slower growth rates, stands of natural origin would take 10–15 years to recover harvested biomass from thinning, and 40–60 years after final harvest, with an average of 25 years for thinning and final harvest combined (estimates from this analysis, not shown in table). Note that these estimates are not the same as the commonly used carbon payback period, as they do not include all elements of a full system accounting. The range of estimates is inferred from forest inventory data indicating the age and biomass stock when harvests are most common. The averages represent how long it would take the area-equivalent harvested for pellets to recover the live biomass present before the harvest based on average biomass growth rates.

## Uncertainties

As mentioned in the introduction to the Annex, numerous assumptions had to be made owing to a lack of data specific to the harvest areas that supplied the different sources of biomass for pellets and the inability to track the specific flow of biomass from the harvesting sites to the mills and through US ports that shipped to the UK. A scenario-based approach was used to illustrate some of the primary sources of uncertainty and how these affected the final results.

What follows is a summary of the main assumptions:

- Procurement areas of 50-mile radius represent actual source areas.
- Mills selected are likely to export to the UK, based on export data from US ports and import data from the UK.
- Assumed proportion of pellet production from each mill that is actually exported to the UK.
- Some of the source material labelled as 'logging residue' actually comprises harvested live trees.
- Harvesting practices range from 100 per cent thinning and partial harvest to 100 per cent clearcut.
- Forest growth rates are relatively uniform across the whole procurement region (mainly the southern US coastal plain and Piedmont region).
- Carbon emissions from lost forest growth and decomposition of logging debris are consistent with averages within the procurement areas, based on forest inventory data.
- Forest ages at time of harvest are based on averages within the source areas, according to forest inventory data and literature review.
- Harvested wood in the assumed procurement areas is proportionally allocated to pellets.
- Estimated forest emissions from pellet production are based on proportion of the total wood harvest that is used for pellets.

## About the authors

**Duncan Brack** is an associate fellow of Chatham House, an independent environmental policy analyst and an associate of Green Alliance. From 2010–12, he was special adviser at the UK Department of Energy and Climate Change. Before that he worked for Chatham House, and from 1998–2003 was head of its Sustainable Development Programme. He works mainly on impacts on global forests from the production of wood products and agricultural commodities, and national and international measures to address them.

**Dr Richard Birdsey** is a specialist in forest inventories and has pioneered development of methods to estimate carbon budgets for forest lands from forest inventory data. He retired from the US Department of Agriculture (USDA) Forest Service as a 'Distinguished Scientist' and Program Manager for global change research in the Northern Research Station. He developed the first greenhouse gas inventory of US forests, which became the model for the annual inventory of forests produced by the USDA Forest Service and the US Environmental Protection Agency. Dr Birdsey was a lead author of two Special Reports for the Intergovernmental Panel on Climate Change. He was a lead author of the first 'North American State of the Carbon Cycle' report and was also a member of the science team guiding the second report, published in 2018. He recently worked with a Forest Service team and the National Forest System to implement carbon assessments for all of the US National Forests and is currently working with the World Resources Institute and other partners to help US counties and communities include forests as part of their greenhouse gas inventories and climate change mitigation strategies.

**Dr Wayne Walker** is Associated Scientist and Director of the Carbon Program at Woodwell Climate Research Center. An ecologist and remote sensing specialist, his research focuses on monitoring the status and trends of global forests with an emphasis on understanding the role that changes in the amount and distribution of forest carbon have to play in anticipating changes in climate, as well as in mitigating climate change through natural climate solutions, including the restoration, management, and protection of forest ecosystems globally.

## Acknowledgments

Many people have been instrumental in the development of this paper. In particular, we would like to thank those who attended our workshop to discuss an early draft of the paper in January 2021, and all those who provided detailed and useful comments and feedback to the draft of the report. We are very grateful to our anonymous reviewers, to Tim Searchinger and Mike Norton, and to Dan Quiggin and Tim Benton at Chatham House for their careful interrogation of the paper and technical Annex.

The authors are grateful to James Hewitt for his support and for helpful early-stage discussions, and to Charlotte Watts at Chatham House for her patient and efficient programme management support. Thanks also to Chris Matthews for his meticulous and insightful editing of the paper, and for overseeing the production process, and to Sarah Bunney, Autumn Forecast and Ian Blenkinsop at Soapbox for their work on the design and production of the paper.

We would also like to thank Stuart Coles and Lisa Rellstab at Chatham House, Nico Muzi from the Climate and Land Use Alliance's Strategic Communications Initiative, and Edward Robinson, Alasdair MacEwen and Lorna Greenwood from the European Climate Foundation's Global Strategic Communications Council for their valuable guidance with media communications.

Thanks are due to Ember and the Southern Environmental Law Center for granting permission to reproduce figures included in this paper.

Finally, we would like to express our gratitude to the David and Lucile Packard Foundation for its financial support of this research. The views and conclusions formed and outlined in the paper are the responsibility of the author(s).

Cover image: Drax Power Station illuminated at night, Yorkshire, UK.
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ISBN 978 1 78413 493 8

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