Research Paper

Duncan Brack
Environment, Energy and Resources Department | February 2017

The Impacts of the Demand for Woody Biomass for Power and Heat on Climate and Forests

CHATHAM HOUSE
The Royal Institute of International Affairs

Summary

- The use of wood for electricity generation and heat in modern (non-traditional) technologies has grown rapidly in recent years, and has the potential to continue to do so.
- The EU has been, and remains, the main global source of demand, as a result of its targets for renewable energy. This demand is largely met by its own forest resources and supplemented by imports from the US, Canada and Russia.
- Countries outside the EU, including the US, China, Japan and South Korea, have the potential to increase the use of biomass (including agricultural residues as well as wood), but so far this has not taken place at scale, partly because of the falling costs of competing renewables such as solar PV and wind. However, the role of biomass as a system balancer, and its supposed ability, in combination with carbon capture and storage technology, to generate negative emissions, seem likely to keep it in contention in the future.
- Although most renewable energy policy frameworks treat biomass as though it is carbon-neutral at the point of combustion, in reality this cannot be assumed, as biomass emits more carbon per unit of energy than most fossil fuels. Only residues that would otherwise have been burnt as waste or would have been left in the forest and decayed rapidly can be considered to be carbon-neutral over the short to medium term.
- One reason for the perception of biomass as carbon-neutral is the fact that, under IPCC greenhouse gas accounting rules, its associated emissions are recorded in the land use rather than the energy sector. However, the different ways in which land use emissions are accounted for means that a proportion of the emissions from biomass may never be accounted for.
- In principle, sustainability criteria can ensure that only biomass with the lowest impact on the climate are used; the current criteria in use in some EU member states and under development in the EU, however, do not achieve this as they do not account for changes in forest carbon stock.

Woody biomass for power and heat

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

This paper summarizes the conclusions of two Chatham House research papers:

- ***Woody Biomass for Power and Heat: Global Patterns of Demand and Supply*** reviews the recent and anticipated future growth of demand for wood for electricity generation and heat in modern technologies, and identifies the likely sources of supply, in recent years and in the future.
- ***Woody Biomass for Power and Heat: Impacts on the Global Climate*** provides an overview of the debate around the impact of wood energy on greenhouse gas emissions, and reaches conclusions for policymakers on the appropriate way forward.

Introduction

In energy policy terms, wood is one form of solid biomass, which also includes agricultural crops and residues, herbaceous and energy crops, and organic waste, such as food waste or manure. Biomass-based energy is the oldest source of consumer energy known to humans, and is still the largest source of renewable energy worldwide, accounting for an estimated 8.9 per cent of world total primary energy supply in 2014.[1] Most of this is consumed in rural areas, with limited or no industrialization, for cooking and heating, usually on open fires or in simple cookstoves. Together with the use of wood charcoal, these are categorized as 'traditional' uses, and are not covered in this synthesis paper or its companion research papers.

The focus in this project is on the combustion of woody biomass to produce electricity or heat, or both, through modern, non-traditional technologies such as power stations, combined heat and power facilities, industrial processes such as pulp and paper mills, and modern biomass burners. Taken together with bioliquids (which are mainly used for transport fuel) and biogas, these forms of bioenergy are currently the largest source of modern renewable energy worldwide, accounting for an estimated 5.1 per cent of total final energy consumption in 2014. Heating for industry and

[1] *Renewables 2016: Global Status Report* (REN21, 2016), p. 28, http://www.ren21.net/status-of-renewables/global-status-report/ (accessed 13 Dec. 2016).

buildings accounts for the bulk of this; combustion for electricity is comparatively small, though it has grown rapidly in recent years.[2]

Although there are alternatives to the use of wood, including organic waste, agricultural residues and energy crops, they tend to be less energy dense, more expensive and more difficult to collect and transport. Wood – and particularly wood pellets, now the dominant solid biomass commodity traded internationally – is therefore likely to remain the biomass fuel of choice.

Demand and supply: European Union

The EU has been, and remains, the main global source of demand for wood for biomass power and heat.[3] In 2014, bioenergy (including liquid biofuels and biogas) accounted for about 10 per cent of EU gross final energy consumption and about 60 per cent of total renewable energy consumption; solid biomass, including wood, supplied about three-quarters of the total. Most of the bioenergy consumed was for heat, accounting for 88 per cent of total renewable heat consumption; biomass supplied 19 per cent of renewable electricity consumption.

Both these proportions have been rising steadily as a result of the renewable energy targets adopted for each EU member state under the 2009 Renewable Energy Directive, which set an overall target of 20 per cent of the EU's energy mix to come from renewable sources by 2020.[4] As of 2014, Germany, France, Sweden and Italy had the highest total consumption of biomass for energy (of all types, not just wood), whereas in relative terms, the largest share compared to other energy sources – in each case more than 30 per cent – was in Latvia, Finland and Sweden. Germany, the UK and Italy had the highest total generation of electricity from biomass. The UK (for electricity) and Italy (for heat) have seen the fastest growth in the use of biomass since 2009.

All forms of biomass play a significant part in the EU's ability to meet its renewable energy targets. According to the member states' National Renewable Energy Action Plans drawn up in response to the Renewable Energy Directive, bioenergy was projected to account for 12 per cent of total European energy consumption by 2020, more than half of the 20 per cent target.[5] This implies continued rapid growth between 2015 and 2020, but according to projections published by the European Commission in November 2016, accompanying the new draft Renewable Energy Directive, further significant growth beyond 2020 is not anticipated, due to the fall in price of competing renewables and anticipated improvements in energy efficiency.

[2] Except where noted, all figures in this paper are taken from International Energy Agency energy statistics, online at http://www.iea.org/statistics/statisticssearch/ (accessed 13 Dec. 2016).
[3] Except where noted, all figures in the first three paragraphs from: *Commission Staff Working Document – Impact Assessment: Sustainability of Bioenergy, Accompanying the document, Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)* (SWD (2016) 418 final, November 2016), https://ec.europa.eu/energy/sites/ener/files/documents/1_en_impact_assessment_part4_v4_418.pdf (accessed 13 Dec. 2016).
[4] *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC* (June 2009), http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN (accessed 13 Dec. 2016).
[5] Atanasiu, B. *The Role of Bioenergy in the National Renewable Energy Action Plans: A first identification of issues and uncertainties* (Institute for European Environmental Policy, 2010), http://www.ieep.eu/assets/753/bioenergy_in_NREAPs.pdf (accessed 13 Dec. 2016).

Alongside this strong demand for biomass, the EU is also a major producer of wood pellets, chips and residues, but production does not meet demand. Accordingly, it is a significant importer. In 2013 it was estimated that overall, 42 per cent of harvested EU wood was used for energy, as wood fuel (often acquired informally by households for their own use), black liquor for the pulp and paper industry and industrial roundwood (usually as chips or pellets) for power and heat generation.[6]

The EU is the largest global producer of wood pellets, its output reaching an estimated 13 million tonnes in 2014 (about half the world total); production in the EU doubled between 2009 and 2014. Consumption, however, is higher, and exports are negligible relative to consumption, so the EU is also a net importer: imports from outside the EU rose to 8 million tonnes in 2014, having more than tripled since 2009.[7] Germany is the EU's largest producer, followed by Sweden, Latvia and France; together, these four countries accounted for just under half of EU production in 2014. Within the EU, most production is destined for domestic consumption; only Latvia exported more than it consumed in 2014. The UK is far and away the EU's biggest importer, followed by Denmark and Italy. Most pellet-importing states in the EU source their pellets from other EU member states, but Belgium and the UK import more from outside the EU, mainly from the US, Canada and Russia. The Drax power station in the UK by itself accounted for more than half the total of EU imports of wood pellets, mainly from the US and Canada. Denmark and Sweden import almost all of the pellets that Russia supplies to the EU.

Projections of future EU supply potential given continued growth in demand for wood for energy are uncertain, depending on, among other factors, the future development of industries that compete for the raw material (such as pulp and paper) and the potential for increased use of wood, agricultural residues and waste wood as well as the growth of energy crops. Most projections assume a growing role for imports, particularly from North America and Russia but also potentially from non-EU Europe (e.g. Belarus, Bosnia and Ukraine) and Latin America.

Demand and supply: North America

No other government has in place the same kind of support framework for biomass energy as the EU. The US, however, has been a major user of biomass energy, mainly from wood, for years, mostly for industrial use (10 per cent of consumed energy in industry in 2013[8]). About half of this is black liquor in the pulp and paper sector; thanks partly to a tax loophole, about one-third of total world black liquor consumption takes place in the US. In 2014, only 1.5 per cent of electricity was generated from solid biomass.

[6] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *A New EU Forest Strategy: for forests and the forest-based sector* (COM(2013) 659 final, 20 September 2013), p. 8, http://eur-lex.europa.eu/resource.html?uri=cellar:21b27c38-21fb-11e3-8d1c-01aa75ed71a1.0022.01/DOC_1&format=PDF (accessed 13 Dec. 2016).
[7] All figures in this paragraph: Eurostat, *Agriculture, Forestry and Fishery Statistics* (2015 edition), http://ec.europa.eu/eurostat/documents/3217494/7158355/KS-FK-15-101-EN-N.pdf/79470e8c-abf3-43d3-8cd4-84880962cdd4 (accessed 13 Dec. 2016).
[8] *Renewable Energy Prospects: United States of America, REmap 2030* (IRENA, 2015), http://www.irena.org/remap/irena_remap_usa_report_2015.pdf (accessed 13 Dec. 2016).

While more than half of state governments have in place incentives for the production of renewable energy, these do not always cover biomass, and recent growth has been much more rapid in other renewables, particularly wind and solar. The federal government's Clean Power Plan, announced in 2015, promised to provide a new incentive for growth in biomass use (alongside other renewables), but it seems highly likely that the plan will be abandoned by the Trump administration. Future growth is, accordingly, uncertain.

The US is a major producer of wood for biomass energy, supplying both domestic and international demand. Globally, the US is the second largest producer of wood pellets (behind the EU); production climbed from 5 to 7 million tonnes between 2012 and 2014.[9] The main driver of growth has been demand from the UK; growth in exports to the UK, from 2 to 4 million tonnes between 2012 and 2014, accounts for the entire growth in US production since 2012.[10] Domestic consumption of biomass remained stable at about 3 million tonnes per year over this period.[11] Future growth seems likely to be driven by export markets, so prospects depend mainly on developments in EU energy policy.

Canada acts mainly as a supplier of wood biomass to foreign markets, particularly to the UK. Biomass energy accounts for about 10 per cent of primary energy production, mainly in industrial use; cogeneration in either pulp and paper mills or sawmills is by far the most common source. There is relatively little domestic demand. The country's plentiful supply of fossil fuels and hydroelectric power has meant there has been no reason to subsidize biomass use for electricity generation, though Ontario's decision to phase out the use of coal in power generation has led to some conversion to biomass. There has also been some growth in use for heating, particularly in small communities, but unlike many northern European countries that use biomass for heat extensively, Canada has never developed district heating networks to any significant degree, which will constrain further growth.

After the US, Canada is the world's largest exporter of biomass for energy; over 75 per cent of recent annual production of about 2 million tonnes of pellets have been exported, mainly to the EU, primarily the UK.[12] Japan, South Korea and the US are the only other large importers. Significant further expansion seems unlikely unless foreign investment becomes available: a combination of the effects of the mountain pine beetle epidemic and the rapid decline of the domestic pulp and paper industry is reducing the availability of feedstock, and the biomass energy industry receives no significant government support.

[9] Food and Agriculture Organization, *2014 Global Forest Products Facts and Figures* (FAO, 2015), http://www.fao.org/forestry/44134-01f63334f207ac6e086bfe48fe7c7e986.pdf (accessed 13 Dec. 2016).
[10] Ibid.
[11] US International Trade DataWeb, https://dataweb.usitc.gov (accessed 13 Dec. 2016).
[12] Arsenault, J., 'Canadian Pellet Industry Update' (presentation, Wood Pellet Association of Canada, July 2015), http://www.pellet.org/images/pellet/PFI-AGM.pdf (accessed 13 Dec. 2016).

Demand and supply: Asia and Australia

All of the big Asian economies are increasing their use of renewables, all have the potential to expand the use of woody biomass; but to date there are few signs of this happening to any significant degree.

In China bioenergy and waste accounted for about 7 per cent of total primary energy supply in 2014. The bulk of this was consumed in traditional forms of heating and cooking, though this use is expected to decline with increasing incomes and urbanization. Along with other renewables, modern biomass is subsidized, and annual biomass power generation has grown rapidly (from about 1 gigawatt (GW) in 2006 to 5.5 GW in 2010, with a target of 30 GW by 2020[13]), but still only supplied less than 1 per cent of electricity in 2014. Biomass supply is not well understood, and studies vary significantly in their estimates of sources, but most agree that domestically produced agricultural residues, such as straw or rice husk, are now and will remain a more significant source than wood. Pellet production is reported as about 2 million tonnes in 2013, mostly from agricultural residues.[14]

Japan increased its support for renewables after the Fukushima nuclear disaster in 2011, but the main beneficiary so far has been solar PV; in 2014, bioenergy and waste supplied just 2.5 per cent of total primary energy production, and less than 3 per cent of electricity. With very low levels of domestic production of wood pellets, Japan is currently Asia's largest pellet importer. Total volumes are small compared to the EU–North America trade, however, reaching about 250,000 tonnes in 2015, mainly from Canada, with smaller volumes from China and Vietnam.[15] Most of the imports appear destined for co-firing with coal at power plants and steel-making facilities.

While South Korea has seen many green economy initiatives in recent years, renewable energy has not yet grown significantly, though the government is supporting its future development. Use of woody biomass is very small, though biomass for heating has been supported with the distribution of small wood pellet boilers to agricultural and mountainous villages since 2009, and the deployment of horticultural greenhouse heaters since 2010.[16] Asia's largest biomass power plant opened in 2015, in Dangjin near Seoul, but it is intended to be fuelled by palm kernel shells and coal.[17] Although several wood pellet facilities have been constructed in recent years, production is well below capacity. Imports of wood pellets grew sharply between 2013 and 2015, however, reaching an estimated 1.5 million tonnes in 2015, mainly from Vietnam.[18]

[13] Zhao, X., Tan, Z., and Liu, P. (2013), 'Development goal of 30 GW for China's biomass power generation: Will it be achieved?', *Renewable and Sustainable Energy Reviews* Vol. 25, September 2013, http://www.sciencedirect.com/science/article/pii/S1364032113002591 (accessed 13 Dec. 2016).
[14] *Global Review of Dedicated Woody Biomass Plantations: Current Situation and Outlook to 2020* (produced for JOPP by RISI), February 2013, pp. 29–30, http://www.jopp.or.jp/research_project/cdm/2013/pdf/cdm2013e.pdf (accessed 13 Dec. 2016).
[15] Based on Trade Statistics of Japan online, http://www.customs.go.jp/toukei/info/index_e.htm (accessed 13 Dec. 2016).
[16] *Energy Policies of IEA Countries: The Republic of Korea, 2012 Review* (IEA, 2012), https://www.iea.org/publications/freepublications/publication/Korea2012_free.pdf, (accessed 13 Dec. 2016); Tillborg, H., *Policies for a Sustainable Energy System – South Korea* (Swedish Agency for Growth Policy Analysis, May 2014).
[17] 'Asia's largest biomass power plant operates with Valmet DNA', http://www.valmet.com/media/articles/all-articles/asias-largest-biomass-power-plant-operates-with-valmet-dna/ (accessed 13 Dec. 2016).
[18] Based on Korea Customs Service data online, http://english.customs.go.kr/kcshome/trade/TradeCommodityList.do (accessed 13 Dec. 2016).

India's large rural population is heavily dependent on wood and other natural biomass for heating and cooking, and this is expected to continue. The extensive use of wood fuel and charcoal for these purposes, alongside cattle grazing and fodder collection, has led to extensive forest degradation. The domestic wood products industry is accordingly heavily dependent on imported wood, and India is now a major global importer of wood, though not of pellets. Although the government is supporting the development of renewables, this has mainly benefited solar PV and wind; the biomass energy support programme is primarily targeting bagasse waste from sugar refineries and agricultural residues such as rice husks, coconut shells, straw and cotton stalks.

Bioenergy and waste supplied 4 per cent of Australia's total primary energy supply in 2014, with more than one-third being consumed by industry; just over 1 per cent of electricity was generated from bioenergy and waste. The main source of supply is agricultural waste, particularly bagasse, which has been extensively used by the sugar industry for more than a century, and provides an estimated 60 per cent of Australia's dedicated bioenergy capacity.[19] In 2015, the government extended support for renewables to include biomass sourced from native Australian forests, reversing an earlier policy, so it seems likely that woody biomass production will expand, but it is starting from a low base and does not seem likely to play a major role in future growth in renewables.

Supply: Rest of world

Several other countries have emerged as important suppliers of woody biomass, but almost entirely as exports. They lack domestic biomass energy industries of their own, though woody biomass may be extensively used in traditional forms of heating and cooking.

In Russia, low fossil fuel prices, a lack of government support, poor road infrastructure, and a lack of technology and skilled specialists have all limited the development of forest industries, including biomass energy. Nevertheless, significant volumes of residues are available from logging operations, and Russia is a major producer of wood pellets, with a hundred pellet plants in operation with an estimated annual capacity of 2 million tonnes.[20] The majority are located in northwest Russia, where transport infrastructure is more advanced, and where distances to Europe are shortest. This includes the Vyborgskaya mill, the largest pellet mill in the world in 2013 (whose annual capacity is almost half the national total).[21] Russia is a major supplier of biomass for energy in the EU, though its share of the EU market has declined due to higher imports from other countries, mainly the US. Concerns over the legality of Russian supplies may limit further growth, given the entry into force in 2013 of the EU Timber Regulation, designed to exclude illegally sourced timber products from the EU market.

[19] 'Bagasse and Cane Trash', *Biomass Producer*, http://biomassproducer.com.au/producing-biomass/biomass-types/crop-residue/bagasse/#.VsH4wFJfU7c (accessed 13 Dec. 2016).
[20] Pelkonen, P. et al (eds.), *Forest Bioenergy for Europe* (European Forest Institute, 2014), http://www.efi.int/files/attachments/publications/efi_wsctu_4_net.pdf (accessed 13 Dec. 2016).
[21] Dale, A., 'Wood Pellets from Russia' (presentation, Wood Pellet Association of Canada, Nov. 2013), http://www.pellet.org/images/21_-_Arnold_Dale_-_From_Russia_with_Love_2013.pdf (accessed 13 Dec. 2016).

A number of non-EU countries in Europe, including Belarus, Bosnia-Herzegovina, Norway, Switzerland and Ukraine, export wood for energy use to the EU – more as wood fuel, chips and residues than as pellets (residues and chips are more likely to be used for pulp and paper, though EU member states do consume some wood chips for energy). Although the eastern European countries have the potential for further growth, they are, like Russia, constrained by a lack of investment capital and technical capacity, poor transport infrastructure and political instability.

Vietnam has recently become a substantial exporter of wood pellets – the only one in Asia, though the scale of the trade is far smaller than that from North America to the EU. The raw material is mainly supplied by mill residues from the country's rapidly growing wood products industry, itself heavily dependent on imported timber from China, the US, New Zealand, Brazil, Cameroon and several countries in Southeast Asia. Almost all wood pellet exports are destined for Korea, with smaller volumes for Japan.

Brazil used to be seen as an important potential source of supply, but financial constraints have so far inhibited the development of pellet plants. Significant volumes of wood are used for energy, about a third as charcoal for the iron and steel industry; the rest is split between industry, agriculture and households, primarily for cooking.

Attempts have been made to develop a wood pellet export industry in South Africa, but the costs of transport, cleaning and drying, and maintenance were so high as to make the plants uneconomic. A few other African countries have in the past exported wood for energy use in the EU – mainly as chips – but not consistently or in large volumes. In recent years Indonesia, Malaysia and Thailand have all exported relatively small quantities of wood pellets, almost all to South Korea; Indonesia and Malaysia are also both exporters of wood chips and wood charcoal.

Future developments

Most analyses assuming expansion in renewable energy envisage significant growth in the use of biomass, at least to 2030 and often beyond. In 2012, for example, the International Energy Agency (IEA) estimated that as long as appropriate policies were in place by 2050, bioenergy (wood and other forms of biomass) could provide 3,100 terawatt hours (TWh) of electricity (7.5 per cent of total world electricity generation – an eight-fold increase from 2011), 22 exajoules (EJ) of final heat consumption in industry (15 per cent of the total, a tripling since 2011) and 24 EJ in the buildings sector (20 per cent of the total, though this represented a fall from 35 EJ in 2009 as inefficient traditional forms of heating were gradually replaced).[22]

As can be seen from the survey of global demand and supply earlier, these top-down estimates are not generally supported by developments to date. Even the EU, currently the main driver of biomass energy use, is projecting no further significant expansion after 2020. No other country has established a firm commitment to substantial development of the biomass energy sector, and in

[22] International Energy Agency, *Technology Roadmap: Bioenergy for Heat and Power* (IEA, 2012), http://www.iea.org/publications/freepublications/publication/2012_Bioenergy_Roadmap_2nd_Edition_WEB.pdf (accessed 13 Dec. 2016).

some countries, such as China and India, agricultural residues rather than wood seem more likely to be the main source.

One reason behind the slower than anticipated growth of biomass energy is the significant falls in the costs of competing renewable technologies, particularly solar PV and wind. While in 2014 the levelized costs of electricity from biomass were slightly lower than solar PV and roughly the same as onshore wind, biomass combustion technologies are mature, and therefore have a low cost reduction potential. The International Renewable Energy Agency (IRENA) projected a possible reduction in costs of 10–15 per cent by 2025; in contrast, it anticipated a 59 per cent fall for solar PV, and 26 per cent for onshore wind, by the same date.[23]

Biomass energy may find it easier to compete for heat supply rather than electricity, since there are fewer alternative renewable options (though improving building efficiency generally shows better value for money). Biomass energy has the advantage over solar and wind, however, of being ‘dispatchable’. Biomass power stations can be turned on or off, or can adjust their power output according to need; solar, wind and hydroelectric power are present or not, depending on the conditions. Thus biomass may come to play mainly a balancing role – though there are other options, including greater degrees of interconnection between electricity grids, and storage, either through pumped-storage hydroelectricity or batteries.

In addition, interest is growing in the combination of bioenergy with carbon capture and storage (CCS) technology (BECCS) with the aim of providing energy supply with net negative emissions. The Intergovernmental Panel on Climate Change’s (IPCC) latest (fifth) assessment report relies heavily on bioenergy for heat and power, and specifically on BECCS, in most of its scenarios of future mitigation options (see below). Despite the falling price and growing share of other forms of renewable energy, biomass thus retains some potential for future growth.

Is biomass carbon-neutral?

In the national policy frameworks of almost all the countries analysed above, biomass is classified as a source of renewable energy, benefiting from financial and regulatory support on the grounds that, like other renewables, it is a carbon-neutral energy source. However, at the point of combustion, it is of course not carbon-neutral – if biomass is burnt in the presence of oxygen, it produces carbon dioxide – and the argument is increasingly being made that its use can have negative impacts on the global climate. This classification as carbon-neutral derives from either or both of two assumptions.

The first assumption is that woody biomass emissions are part of a natural cycle in which, over time, forest growth balances the carbon emitted by burning wood for energy. In fact, since in general woody biomass is less energy dense than fossil fuels, and contains higher quantities of moisture and less hydrogen, at the point of combustion burning wood for energy usually emits

[23] International Renewable Energy Agency, *The Power to Change: Solar and Wind Cost Reduction Potential to 2025* (IRENA, 2016), http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf (accessed 13 Dec. 2016).

more greenhouse gases per unit of energy produced than fossil fuels. The volume of emissions per unit of energy actually delivered in real-world situations will also depend on the efficiency of the technology in which the fuel is burnt. Dedicated biomass plants tend to have lower efficiencies than fossil fuel plants, though this depends on the age and size of the unit. The impact on the climate will also depend on the supply-chain emissions from harvesting, collecting, processing and transport; estimates of these factors vary widely, but particularly where methane emissions from wood storage (for example from wood chips and sawdust during storage, either at the pellet mill or the power station) are taken into account, these can be very significant. Overall, while some instances of biomass energy use may result in lower lifecycle emissions than fossil fuels, in most circumstances, comparing technologies of similar ages, the use of woody biomass for energy will release higher levels of emissions than coal and considerably higher levels than gas.

The impacts on the climate will also vary, however, with the type of woody biomass used, with what would have happened to it if it had not been burnt for energy and with what happens to the forest from which it was sourced.

Biomass energy feedstocks

The harvesting of whole trees for energy will in almost all circumstances increase net carbon emissions very substantially compared to using fossil fuels, both because of the loss of future carbon sequestration from growing trees and because of the release of soil carbon consequent upon the disturbance. This is particularly true for mature trees in old-growth forests, whose rate of carbon absorption can be very high.

The use of sawmill residues for energy has lower impacts, because it involves no additional harvesting as the raw material is waste from other wood industry operations. The impact will be most positive for the climate if they are burnt on-site for energy without any associated transport or processing emissions. However, mill residues can also be used for wood products such as particleboard; if diverted instead to energy, this will raise carbon concentrations in the atmosphere. The current high levels of use of mill residues mean that this source is unlikely to provide much additional feedstock for the biomass energy industry in the future (or, if it does, it will be at the expense of other wood-based industries). Black liquor, a waste from the pulp and paper industry, can also be burnt on-site for energy and has no other use; in many ways it is the ideal feedstock for biomass energy.

The use of forest residues for energy should also imply no additional harvesting, so its impacts on net carbon emissions can be low (though whole trees can sometimes be misclassified as residues). This depends mainly on the rate at which the residues would decay and release carbon if left in the forest, which can vary substantially; if slow-decaying residues are burnt, the impact would be an increase in net carbon emissions potentially for decades. In addition, removing residues from the forest can adversely affect soil carbon and nutrient levels and tree growth rates.

Many of the models used to predict the impacts of biomass use assume that mill and forest residues are the main feedstock used for energy, and biomass pellet and energy companies tend to claim the same, though they often group ‘low-grade wood’ with ‘forest residues’, although the impact on the climate is not the same. Evidence suggests, however, that various types of roundwood are generally the main source of feedstock for large industrial pellet facilities. Forest residues are often unsuitable for use because of their high ash, dirt and alkali salt content.

Biomass and the forest carbon cycle

It is often argued that biomass emissions should be considered to be zero at the point of combustion because carbon has been absorbed during the growth of the trees, or because the timber is harvested from a sustainably managed forest, or because forest area as a whole is increasing (at least in Europe and North America). The methodology specified, for example, in the EU Renewable Energy Directive (and many national policy frameworks) for calculating emissions from biomass only considers supply-chain emissions, counting combustion emissions as zero.

These arguments are not credible. They ignore both what happens to the wood after it is harvested (emissions will be different if the wood is burnt or made into products) and the carbon sequestration forgone from harvesting the trees if left unharvested, they would have continued to grow and absorb carbon. The evidence suggests that this is true even for mature trees, which, as many studies have demonstrated, absorb carbon at a faster rate than young trees. Furthermore, even if the forest is replanted, emissions of soil carbon during harvesting may delay a forest's return to its status as a carbon sink for 10–20 years.

Another argument for a positive impact of burning woody biomass is if the forest area expands as a direct result of harvesting wood for energy, and if the additional growth exceeds the emissions from combustion of biomass. Various models have predicted that this could be the case, but it is not yet clear that this phenomenon is actually being observed. For example, timberland area in the US southeast (the main location of US wood pellet mills supplying demand in the EU) does not appear to be increasing significantly. In any case, the models that predict this often assume that old-growth forests are replaced by fast-growing plantations, which in itself leads to higher carbon emissions, together with negative impacts on biodiversity.

The carbon payback approach argues that while carbon emissions from burning woody biomass are higher than using fossil fuels, they can be absorbed by forest regrowth. The length of time this takes – the carbon payback period before which carbon emissions return to the level they would have been at if fossil fuels had been used – is of crucial importance. There are problems with this approach, but it does help to highlight the range of factors that affect the impact of biomass, and focuses attention on the very long payback periods of some feedstocks, particularly whole trees.

The many attempts that have been made to estimate carbon payback periods suggest that they vary substantially, from less than 20 years to many decades, and in some cases even centuries. As would be expected, the most positive outcomes for the climate, with very low payback periods, derive from the use of mill residues (unless they are diverted from use for wood products). If forest residues are used that would otherwise have been left to rot in the forest, the impact is complex, as their removal may cause significant negative impacts on levels of soil carbon and on rates of tree growth. The most negative impacts involve increasing harvest volumes or frequencies in already managed forests, converting natural forests into plantations or displacing wood from other uses.

It can be argued that the length of the carbon payback period does not matter as long as all emissions are eventually absorbed. This ignores, however, the potential impact in the short term on climate tipping points (a concept that is not yet proven but for which there is some evidence) and on the world's ability to meet the 1.5°C target set in the 2015 Paris Agreement, which requires greenhouse gas emissions to peak in the near term. This suggests that only biomass energy with the shortest carbon payback periods should be eligible for financial and regulatory support.

BECCS

Some have argued that interest is growing in the potential of BECCS to provide energy supply with net negative emissions. However, all of the studies that the IPCC surveyed in its latest assessment report assumed that the biomass was zero-carbon at the point of combustion – which, as discussed earlier, is not a valid assumption. In addition, the slow rate of deployment of CCS technology, and the extremely large areas of land that would be required to supply the woody biomass feedstock needed in the BECCS scenarios, render its future development at scale highly unlikely. The reliance on BECCS of so many of the climate mitigation scenarios reviewed by the IPCC is, accordingly, of major concern, potentially distracting attention from other mitigation options and encouraging decision-makers to lock themselves into high-carbon options in the short term on the assumption that the emissions thus generated can be compensated for in the long term.

Recommendations for policymakers

- In assessing the climate impact of the use of woody biomass for energy, changes in the forest carbon stock must be fully accounted for. It is not valid to claim that because trees absorb carbon as they grow, the emissions from burning them can be ignored.
- Along with changes in forest carbon stock, a full analysis of the impact on the climate of using woody biomass for energy needs to take into account the emissions from combustion (which are generally higher than those for fossil fuels) and the supply-chain emissions from harvesting, collection, processing and transport. There is still some uncertainty over some of these factors; further research would be helpful.
- The provision of financial or regulatory support to biomass energy on the grounds of its contribution to mitigating climate change needs to be limited to those feedstocks that reduce carbon emissions over the short term.
- In practice, this means that support should be restricted to sawmill residues, together with post-consumer waste. Burning slow-decaying forest residues or whole trees means that carbon emissions stay higher than if fossil fuels had been used for decades, which is a matter of considerable concern given the current rate of global warming.

Accounting for biomass carbon emissions

The second assumption that leads to the common perception that biomass energy is zero-carbon at the point of combustion, derives from the international greenhouse gas reporting and accounting frameworks established under the UN Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. In order to avoid double-counting emissions from biomass energy within both the energy sector (when the biomass is burned) and the land-use sector (when the biomass is harvested), the rules provide that emissions should be reported within the land-use sector only.

While this approach makes sense for *reporting*, it has resulted in significant gaps in the context of *accounting* – measuring emissions levels against countries' targets under the Kyoto Protocol (or, potentially, the Paris Agreement), largely deriving from the different forest management reference levels that parties have been permitted to adopt. The problem of 'missing', or unaccounted, emissions arises when a country using biomass for energy:

- Imports it from a country outside the accounting framework – such as the US, Canada or Russia, all significant exporters of woody biomass, which do not account for greenhouse gas emissions under the second commitment period of the Kyoto Protocol.

- Accounts for its biomass emissions using a historical forest management reference level that includes higher levels of biomass-related emissions than the present.

- Accounts for its biomass-related emissions using a business-as-usual forest management reference level that includes (explicitly or implicitly) anticipated emissions from biomass energy. The associated emissions built in to the projection will not count against its national target.

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

The quantity of emissions missing from the international greenhouse gas accounting framework is impossible to calculate precisely. Forest management reference level submissions do not contain sufficient information on the quantity of woody biomass projected to be used, the origins of that biomass (additional domestic forest harvests, increased use of domestic forestry residues or higher imports), and the resulting emissions. Nevertheless, it is likely to be significant.

In 2014, UNFCCC Annex I countries in aggregate emitted 985 million tonnes of carbon dioxide ($MtCO_2$) from biomass combustion, including an estimated 781 $MtCO_2$ from solid biomass. The latter figure is equivalent to 5.6 per cent of aggregate, economy-wide carbon dioxide emissions from Annex I countries in 2014, and 6 per cent of their total energy emissions. The US by itself accounts for almost 28 per cent of total Annex I solid biomass carbon emissions, while Germany, Japan and France between them account for a further 26 per cent. Neither the US nor Japan account for emissions from their land-use sectors under the Kyoto Protocol, Germany accounts against a business-as-usual projection that does not explicitly include bioenergy policies, and France uses a business-as-usual projection that includes bioenergy demand from policies up to, but not including, the 2009 EU Renewable Energy Directive. Woody biomass emissions from all these countries, therefore, have the potential to go unaccounted for.

Recommendations for policymakers

Four steps could be taken within the existing framework to reduce the potential for missing emissions:

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

If the land-use accounting rules are not reformed as suggested above, a more radical option would be to account for carbon dioxide emissions from biomass burned for energy for within the energy sector, with additional rules to avoid double-counting in the land-use sector.

Sustainability criteria

One means of avoiding, or at least ameliorating, the impacts on the climate of the use of woody biomass for energy is to apply preconditions that biomass installations are required to meet before they are eligible for the regulatory and financial support afforded to renewable energy sources. After seven years of discussions, the European Commission published proposals for sustainability criteria for solid biomass in late 2016. Many EU member states also already apply some criteria; the most detailed have been developed in Belgium, Denmark, the Netherlands and the UK.

In general these have two components: requirements for minimum levels of greenhouse gas savings compared to fossil fuels, and requirements (often called 'land criteria') relating to the legality and sustainability of forest management, usually taken from national timber procurement policies. Sometimes other criteria, such as restrictions on types of feedstock or on minimum plant energy efficiency levels, are also included. However, none of these systems includes changes in levels of forest carbon stock in their calculation of greenhouse gas savings (apart from direct land use change); though the Dutch criteria contain a requirement that the forest is managed with the aim of retaining or increasing carbon stocks in the medium or long term, and the EU proposed criteria include a requirement for the country from which the forest biomass is sourced to be a party to the Paris Agreement, which accounts for changes in carbon stock associated with biomass harvests.

A number of voluntary certification schemes have developed with the aim of including climate impacts alongside other criteria, such as sustainable forest management. The main one is the Sustainable Biomass Partnership (SBP), established in 2013 by seven major European utilities. The SBP's standard includes the need to define the supply base of the biomass, to ensure feedstock can be traced back to its source area, and a requirement that 'regional carbon stocks are maintained or increased over the medium to long term'. The standard includes a calculation of the energy and carbon balance of the biomass used for energy, but this does not include changes in forest carbon stock. Verification involves a regional approach that uses a desk-based assessment against the criteria leading to a risk rating for each indicator. Where risks are identified, appropriate mitigation measures must be defined, implemented and monitored.

These schemes' failures to account, comprehensively or at all, for changes in forest carbon stock mean they cannot be considered adequate. Effectively, these criteria permit the provision of financial and regulatory support to policy options that could increase carbon emissions in the short, medium and possibly long term. The references to forest carbon stock in the Dutch and SBP criteria are too vague. Forest carbon stock levels may stay the same or increase for reasons entirely unconnected with use for energy. The important issue is what levels they would have reached in the absence of biomass energy use. Similarly, the requirement in the proposed EU criteria for land-use sector accounting in the country of origin to take account of changes in forest carbon stock is a step in the right direction. It is still subject to the flaws identified earlier, however, and cannot take account of the full climate impact of the use of forest residues, which may be significantly underestimated in current models, given the potential effects on soil carbon levels and tree growth rates.

To date, no national biomass sustainability standards have been developed outside the EU, though the US state of Massachusetts restricts eligibility for subsidies based on net carbon accounting over a 20-year timeframe, and includes sustainability provisions such as the requirement that harvests leave sufficient woody material on the forest floor to replenish soil nutrients and protect wildlife. In addition, biomass power stations must demonstrate emissions reductions over time on the basis of lifecycle emissions analyses, including a carbon debt emissions factor, and must satisfy a minimum efficiency level.

Recommendations for policymakers

- Robust sustainability criteria need to deal both with the impact on greenhouse gas emissions of changes in forest carbon stocks and the legality and sustainability of forest management.

- One option would be for the greenhouse gas element to be underpinned by a comprehensive lifecycle analysis for each type of feedstock, including changes in the forest carbon stock alongside supply chain emissions. However, this is a complex calculation depending partly on the counterfactual (what would have happened to the wood, and the forest from which it was sourced, if it had not been used for energy?) and difficult to implement in real life.

- A more practical approach is to restrict eligibility for support to those feedstocks that are most likely to reduce net carbon emissions (or have low carbon payback periods): primarily mill residues, together with post-consumer waste. An additional element could be a requirement for a minimum level of efficiency of the unit in which the biomass is burnt.

- Policies should also ensure that subsidies do not encourage the biomass industry to divert raw material (such as mill residues) away from alternative uses (such as fibreboard), which have far lower impacts on carbon emissions.

- Alongside these emissions criteria, land criteria for legal and sustainable sourcing should be used to protect the way in which the forests are managed. Risk-based assessments of areas lacking coverage of forest certification schemes should supplement desk-based assessments with on-the-ground inspections.

Independent thinking since 1920

Chatham House, the Royal Institute of International Affairs, is an independent policy institute based in London. Our mission is to help build a sustainably secure, prosperous and just world.

ISBN 978 1 78413 194 4

This publication is printed on recycled paper.

The Royal Institute of International Affairs
Chatham House
10 St James's Square, London SW1Y 4LE
T +44 (0)20 7957 5700 F +44 (0)20 7957 5710
contact@chathamhouse.org www.chathamhouse.org

Charity Registration Number: 208223