BURNT OFFERING
The biomess of biomass

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About the author

After graduating in chemistry, Martin Livermore worked for Unilever, Dalgety and DuPont for 27 years in a range of technical jobs in the food and agriculture sector, in the UK, South Africa and the Netherlands. He set up his own consultancy business in 2001, working with national and international trade associations and major companies on a range of science communications issues, while developing particular interests in the biotechnology and energy sectors. He was director of the Scientific Alliance from 2006 until 2018, working to encourage a rational, evidence-based approach to major policy issues.

Executive summary

EU climate change policy currently includes targets for the use of renewable energy to reduce carbon dioxide emissions. The most visible of these are for wind and solar, but in some countries biomass is the greatest single source of energy in this category.

The use of biomass is counterintuitive, since substituting wood for coal for electricity generation, for example, releases more carbon dioxide, in addition to the extra energy used to harvest, process, dry and transport the wood pellets that are the preferred form of use. Only by continuous replanting of trees can the carbon dioxide emitted nominally be reabsorbed, and then only over a period of several decades.

Drax, one of the largest thermal power stations in Europe,* was originally a modern coal-fired generator. Government policy has made it uneconomic to continue operating in this mode, so the company is now well down the road to generating primarily using biomass. In practice, this means wood pellets, mainly imported from the southern states of the USA.

Drax was due, in the company's words, to have 'saved its 50 millionth tonne of carbon' by the end of 2018. In reality, this 'saved' carbon equates to 183.5 million tonnes of carbon dioxide emitted into the atmosphere. This can be reabsorbed by planting more trees, but it will take some decades for the net emissions to be zero. In the meantime, the IPCC is recommending drastic reductions in global emissions by 2030, with net emissions effectively zero by 2050, in a global environment in which major emerging economies are becoming increasingly, rather than less, reliant on coal to provide the energy for economic growth.

The guaranteed price paid to Drax for biomass-generated electricity under the Contract for Difference (CfD) scheme is £106 per MWh. Even allowing for inflation, this is higher than the much-criticised £92.50 per MWh strike price (2012 prices) agreed for the Hinkley Point C nuclear power station. And while Hinkley will generate electricity with zero carbon dioxide emissions, Drax produces more carbon dioxide per unit of electricity than it did when coal-fired.

The situation with biomass reinforces the case for any rational policy to reduce global net carbon dioxide emissions to be independent of technology or geography.

* Only Belchatow in Poland and Neurath in Germany have a higher capacity, and these are both fuelled by lignite.

1 Introduction

Wood has been used by humankind as a source of energy for millennia. By the time of the Industrial Revolution, it was still the primary source of heating, although industrial processes such as milling were mainly powered by wind and water. As well as its central role as a fuel, wood was one of the main materials for building houses and making carts, furniture and a wide range of domestic utensils and tools. Not surprisingly, this resulted in the clearing of large areas of boreal forest and the creation of the 'traditional' landscapes we value so much today.

In the late 18th century, this situation began to change rapidly, as coal displaced wood and, to some extent, other traditional sources of energy, first in the United Kingdom and then gradually in other countries: the almost unbelievable changes that have occurred over the last two and a half centuries in the industrialised world have been fuelled by coal and, more recently, by gas and oil. Without fossil fuels, sophisticated modern civilisations would not have been able to develop.

Because areas cleared of trees have usually become established as farmland, woodland has not always been regenerated, although there are exceptions, such as the formerly industrial state of New Hampshire, which is now densely wooded. Many other regions are also more wooded than we might at first expect. In surprising fact, according to Forestry Commission statistics, in 2017 woodland covered 13.1% of total UK land area, compared with less than 5% a century ago, while in England alone 10% of land area is wooded, the highest proportion since the 14th century.[1]

In the industrialised world, our reduced dependency on wood has had a number of benefits, including this expansion of forests and the associated improvements to drainage, soil stability and wildlife habitat. On the other hand, billions of people in poorer countries across the world, mainly in Asia, Africa and South America, continue to live a subsistence lifestyle, dependent on wood as a primary source of energy, and without the benefits of electricity. The majority have to gather wood for cooking every day, although many governments are expanding electricity networks so that people can avoid both the chore of collecting wood and the dangerous levels of air pollution from open fires.

Meanwhile, wood burning is enjoying a renaissance in the Western world, partly via increasing use of modern domestic heating stoves (which are increasingly being seen as a significant source of particulate air pollution),[2] but more particularly as a key part of government policy aimed at reducing carbon dioxide emissions from electricity generation (and in the longer term, heating). This report looks at the objectives, drivers and rationale for this policy in comparison to alternative approaches.

2 Current energy policy in the EU

EU energy policy has evolved over time, but in essence is a concerted attempt to drastically reduce carbon dioxide emissions over the first half of the 21st century. In this respect, the EU is very much in the lead of global action to mitigate climate change.

Member states were set individual emissions reduction targets under the 2020 climate and energy package, which was agreed in 2007 and passed into law in 2009.[3] Although the primary purpose was ostensibly to cut greenhouse gas emissions (relative to a 1990 baseline), the package actually set three goals for 2020, the so-called 20:20:20 targets:

- a 20% reduction in greenhouse gas emissions

- 20% of EU energy to come from renewables
- a 20% improvement in energy efficiency.

A range of further national policies and incentives have been introduced in order for member states to meet their individual targets and contribute to the overall EU ones. The UK, as has been its wont in other areas, chose to go further than the EU package: in a fit of enthusiasm, it passed the Climate Change Act in 2008,[4] so becoming the first country to set itself legally-binding emissions reduction targets. The current end target in the legislation is an 80% reduction by 2050, although the Act allows this to be modified.

The important point is that the EU Council and Commission, swayed by the arguments of the powerful green lobby, chose not simply to set the overall emissions reduction target, but to mandate the way it should be achieved, thus potentially preventing players in the energy market from meeting targets in the most efficient way possible. Since saving energy in the first place is the easiest way to reduce overall consumption and hence emissions, it is arguable that the target for 20% greater energy efficiency is a sensible one, even though it is almost certain that savings of this magnitude would have been achieved under a policy regime that called for emissions reductions to be achieved in the most cost-effective way, without specifying specific methodology. However, the target for renewable energy is entirely political and ideological, and is having very significant consequences. One of these is a large increase in the use of biofuels. Bioethanol and biodiesel for road transport are the fuels most in the public eye, but the elephant in the room is biomass (wood and other energy crops), mostly used to generate electricity.

Biomass burning is deemed to be an acceptable way to generate renewable energy and does, on the surface at least, have a role to play as part of the overall range of renewables technologies. To summarise the options:

- Wind energy is one of the most developed and widely exploited renewable technologies. However, as wind is a diffuse energy source and highly variable (with wind turbine power output varying with the cube of the wind speed), it is necessarily intermittent. It is not possible to provide a stable, on-demand supply of electricity from wind alone, even on a region-wide network, however much nominal capacity is installed.[†]
- Solar energy is also used to generate electricity, and photovoltaic panels have become more efficient and considerably less expensive in recent years. In favourable climates, concentrated solar energy can be used to generate electricity thermally. In both cases, intermittency is inevitable, however, although in a more predictable way than for wind. Solar and wind energy may at times complement each other, but at other times neither may produce useful amounts of electricity.
- Tidal and wave energy can be used to generate power, but in practice are severely limited in potential and are likely never to make more than a niche contribution. To date, the need for equipment that can both harvest wave energy and survive storms has precluded the development of viable systems.
- To complement the intermittency of wind and solar energy, despatchable technologies are needed. Hydroelectric power is both renewable and despatchable, although

[†] This remains the case until an economic and efficient way to store and release vast quantities of electrical energy can be developed. This has to be capable of supplying country-wide grids on demand for many hours (and potentially days).

it can only make a significant contribution in particular geographies and can only generate when there is sufficient head of water available.

- Biomass is the only technology classified as renewable that is potentially more practical but, all other considerations apart, the supply of biomass is only sufficient to supply a proportion of global demand.

Under a more rational policy regime, the aim would have been to achieve emissions targets flexibly and at lowest economic cost. All forms of generation would have competed on a level (albeit rigged) playing field. Biomass use would have increased if the economics were right, but it is equally possible that nuclear would have become the major tool to reduce carbon dioxide emissions. We are where we are, but we should at least consider the realities and alternatives. After all, the road to hell is paved with good intentions.

3 The economics and public subsidy of biomass

Many economists would prefer to see a flat-rate 'carbon tax' levied to incentivise the efficient cutting of emissions. Energy efficiency would be the initial route of choice, making the headline 20% energy efficiency target unnecessary. Beyond that, if different energy sources were subject to the same tax regime (unrelated to emissions targets) and unsubsidised, market forces would do their work.

In some cases, burning wood would make good sense, particularly for off-grid generation of heat and electricity when a continuous supply of low-grade timber was available locally. However, under the current policy regime, wood is deemed to be a fuel that is preferred to gas or nuclear when burnt on a large scale – to generate electricity – which inevitably means shipping from relatively distant sources.

Small-scale scale use of renewable energy is incentivised in various ways in the UK, as in other countries. In the case of solar panels, used to generate electricity, this is via feed-in tariffs. Small-scale use of biomass, however, is primarily for heating, and subsidy is provided via a separate system, the Renewable Heat Incentive (RHI). In the UK currently, domestic biomass boilers and stoves receive 6.74p/kWh under the RHI.[‡] Commercial users are subsidised from a similar but separate RHI scheme. On a larger scale, the primary tool in the UK has been the Renewables Obligation (RO), which more recently changed to a so-called 'Contract for Difference' (CfD) mechanism. The CfD scheme sets a price that the generator will receive for every unit of electricity, whatever the wholesale price.

4 Current biomass use

According to Eurostat, biomass and waste accounted for 64% of all primary renewable energy production in the EU in 2016. Although wind and solar energy are both more obvious and have a higher public profile because of the nature of the generating equipment, this dominance of biomass seems set to continue.

A recent report from Chatham House provides a good summary of the current situation in the EU:[5]

> In 2016, energy from solid biomass (mainly wood) accounted for about 7.5 per cent of EU gross final energy consumption and about 44 per cent of total renewable energy

‡ Ofgem figures.

consumption. Most of the biomass consumed was for heat, accounting for 78 per cent of total consumption of renewable heating and cooling; biomass supplied about 10 per cent of total generation of renewable electricity.

To put that in a different perspective, Eurostat figures show that in 2016, 94.1 million tonnes of oil equivalent (Mtoe)[§] of wood were used for energy production in the EU, compared with 26.0 Mtoe for wind and 13.4 for solar.

5 Carbon dioxide and methane: sustainability issues

The rationale for replacing fossil fuels with wood and other forms of biomass is that doing so reduces emissions. The European Commission has made recommendations for biofuel sustainability criteria, although these are non-binding:

- forbid the use of biomass from land converted from forest, and other high-carbon stock areas, as well as highly biodiverse areas
- ensure that biofuels emit at least 35%[‖] less greenhouse gases over their lifecycle (cultivation, processing, transport, etc.) than fossil fuels
- favour national biofuels support schemes for highly efficient installations
- encourage the monitoring of the origin of all biomass consumed in the EU to ensure its sustainability.

The 2005 EU biomass action plan showed estimates of the volume of home-produced biomass available.[6] These estimates, which are summarised in Table 1, do not include contributions from Romania and Bulgaria, neither of which was a member state at the time.

Table 1: Estimates of potential biomass availability in the EU.

<table>
<tr><th></th><th>Actual</th><th colspan="3">Potential</th></tr>
<tr><th></th><th>2003 (Mtoe)</th><th>2010 (Mtoe)</th><th>2020 (Mtoe)</th><th>2030 (Mtoe)</th></tr>
<tr><td>Wood direct from forest (increment and residues)</td><td rowspan="2">67</td><td>43</td><td>39–45</td><td>39–72</td></tr>
<tr><td>Organic wastes, wood industry residues, agricultural and food processing residues, manure</td><td>100</td><td>100</td><td>102</td></tr>
<tr><td>Energy crops from agriculture</td><td>2</td><td>43–46</td><td>76–94</td><td>102–142</td></tr>
<tr><td>TOTAL</td><td>69</td><td>186–189</td><td>215–239</td><td>243–316</td></tr>
</table>

Clearly, large amounts of domestically-produced biomass are potentially available to meet the EU targets, although the reality in the case of large-scale electricity generation seems somewhat different. Drax, one of the largest thermal power stations in the EU, imports most of its biomass in the form of wood pellets from the southern states of the USA (see case study below).

§ Mtoe, or million tonnes of oil equivalent, is a widely-used unit of comparison for different fuels.

‖ For new installations this amount rises to 50% in 2017 and 60% in 2018.

But more important overall is the fact that burning biomass releases carbon dioxide – much more so than burning gas, for example – and harvesting crops or felling trees releases methane from disturbed soil. Since these are both greenhouse gases, the short-term impact of using biomass as a fuel source is to boost the radiative forcing that, all things being equal, leads to higher average global temperatures. Why then, has biomass become the largest slice of the renewable energy pie?

The answer is that, since biomass is, by its nature, renewable, planting more crops or trees to replace those harvested and burnt absorbs carbon dioxide from the atmosphere and leads to an overall carbon-neutral fuel cycle. In other words, over a long enough timescale, burning biomass reduces net emissions. While this is factually correct, it is not a given that this is an effective, efficient or sustainable way to reduce emissions to meet the ambitious targets set.

6 Alternative realities

Ignoring the rest of the available renewable energy technologies for now, let's think about alternatives to using biomass for heating and electricity generation. The two main factors in favour of biomass are that there is a large –but limited – supply available every year and that, unlike all other primary sources of renewable energy, it can be used as and when needed, supplying reliable heating and despatchable electricity. But, to set against this, there are a number of downsides. In particular:

- a lower energy density than coal, oil or LNG
- greater emissions of CO_2 per unit of energy extracted
- emissions of particulates (PM2.5)
- greater processing (drying, chipping etc) and transport costs
- additional release of methane due to soil disturbance
- the extended period needed to recapture emitted CO_2.

Let's assume in the first case that coal-fired power stations are replaced by ones burning wood (ignoring other sources of biomass for simplicity). To generate a unit of electricity, wood will release more carbon dioxide than coal, the most carbon-rich of the fossil fuels. If wood were to replace gas, the increase in carbon dioxide emissions would be even greater. The premise on which wood-burning is favoured as a way to 'reduce' emissions is that the net amount of carbon dioxide released into the atmosphere is reduced (relative to coal-firing) over a period of time because more trees are planted to absorb carbon dioxide as they grow.

The most obvious alternative to this would be to continue burning coal while planting trees at a rate equivalent to that needed to replace biomass with the same thermal energy content. This, of course, would not be infinitely sustainable because of the supply of suitable land is limited. Nevertheless, if the proposed transition from coal and gas is to take place over a few decades, as seems reasonable, this alternative route seems entirely feasible.

There are many areas in which trees will grow but which are not suitable for arable farming. There may be some competition with livestock grazing on upland areas (primarily sheep and goats), but large tracts of land are too wet, too arid, too steep or have too cool a climate for agriculture. Although it is difficult to put a definitive number on the land still available, we can assume that a significant area could be (re-)forested, particularly in areas of North America where farming is not intensive. When considering emissions of carbon dioxide in the context of climate change mitigation policy, it is the global figure that is important rather than where emissions occur; if there is insufficient land for planting trees in Europe, land in the USA or elsewhere can just as easily fit the bill.

Another alternative would be to use gas instead of coal to generate electricity. If combined with planting of trees, as for option one, this would reduce emissions still further. Over a longer period of time, converting to nuclear energy would be even more beneficial.

7 Emissions patterns: with and without biomass use

According to the most recent IPCC special report on restricting global warming to 1.5°C above the nominal pre-industrial level,[7]

> Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems (*high confidence*). These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options (*medium confidence*).

This report led to headlines such as 'We have 12 years to limit climate change catastrophe, warns UN' (the Guardian) and 'Final call to save the world from "climate catastrophe"' (BBC). The report is clear that drastic action is needed by 2030 (the reason for the 12 years in the headline above) and that net emissions should effectively be zero by 2050.

To see how extraordinary this demand is, it is necessary to look at how carbon dioxide emissions have changed in recent years. Despite the implementation of the UN Framework Convention on Climate Change, the Kyoto Protocol, the EU's own climate change and energy policy and the more recent Paris agreement, the trend of global emissions is still upwards (Figure 1), although there was a brief pause in 2015 and 2016, after growth in Asia slowed significantly. Recent reports suggest that emissions growth recommenced in 2017.

And as Figure 2 shows, although the USA and EU seem to have made modest reductions in their overall carbon dioxide emissions, nearly all other countries – China most particularly – have increased theirs. EU renewable energy use over coming decades will make a rather insubstantial difference to the global picture; whatever targets EU governments may set, it is the global picture that is important, and which will drive domestic policy.

Expect, then, more pressure to change the way in which energy is produced and the way in which it is used.[¶] And since burning biomass for electricity generation and heating has distinct advantages over intermittent solar or wind energy, its use is highly likely to increase.

But does this make any sense in emissions reduction terms? Burning biomass undoubtedly releases more carbon dioxide than using fossil fuels. Figures given on the website of Volker Quashning, a professor of renewable energy,[8] are reproduced in Table 2. Natural gas – widely used as the primary source of domestic heat – emits not much more than half the amount of carbon dioxide that coal does, on a thermal equivalent basis. Wood, on the other hand, leads to higher emissions of carbon dioxide per unit of energy generated than any form of coal.

¶ Through campaigns like that of the 'Extinction Rebellion' group. What will actually happen will be a balance between what activists demand and what is politically acceptable to voters. The limits of acceding to activists are shown by the situation in France, where the *Gilets Jaunes* movement grew out of mass protests against the large hikes in diesel prices introduced by the government as part of its energy and climate change policy.

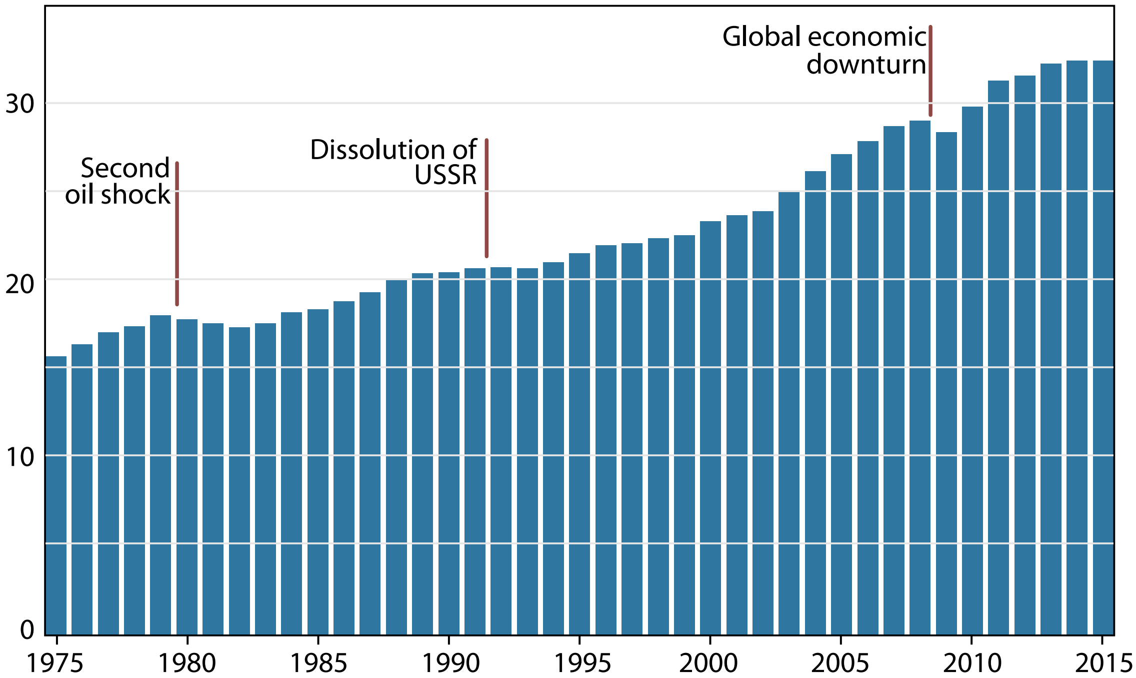

Figure 1: Global energy-related carbon dioxide emissions
Source: International Energy Association

Table 2: Carbon dioxide emissions for different sources of energy.

Energy source	Emissions ($kg\ CO_2/GJ$)
Wood	109.6
Lignite	101.2
Hard coal	94.6
Natural gas	56.1

The reason that wood is still used for industrial energy generation is that the EU claims that biomass is a zero-carbon fuel. This convenient fiction is based on the idea that most of the emissions will be sucked out of the atmosphere as new trees grow, and thus only the emissions associated with producing and shipping the wood pellets need to be included in the carbon balance. Of course, this is only true over a timescale of several decades: the release of carbon dioxide from burning pellets is immediate, but recapturing it by planting more trees takes as long as the trees need to reach the same maturity as those harvested - perhaps several decades. The carbon dioxide released each year may be gradually recaptured in subsequent years, but there is also the addition of new emissions in those subsequent years too. So, biomass used now will certainly lead to higher real net emissions by 2030 than if coal had been used. Logically, it also means that wood burning should cease by 2025 if it is not to push the 2050 figure higher as well.

For the sake of argument, consider the effect of generating 1 GWh of electricity from wood pellets (ignoring the additional emissions associated with importing from the USA or

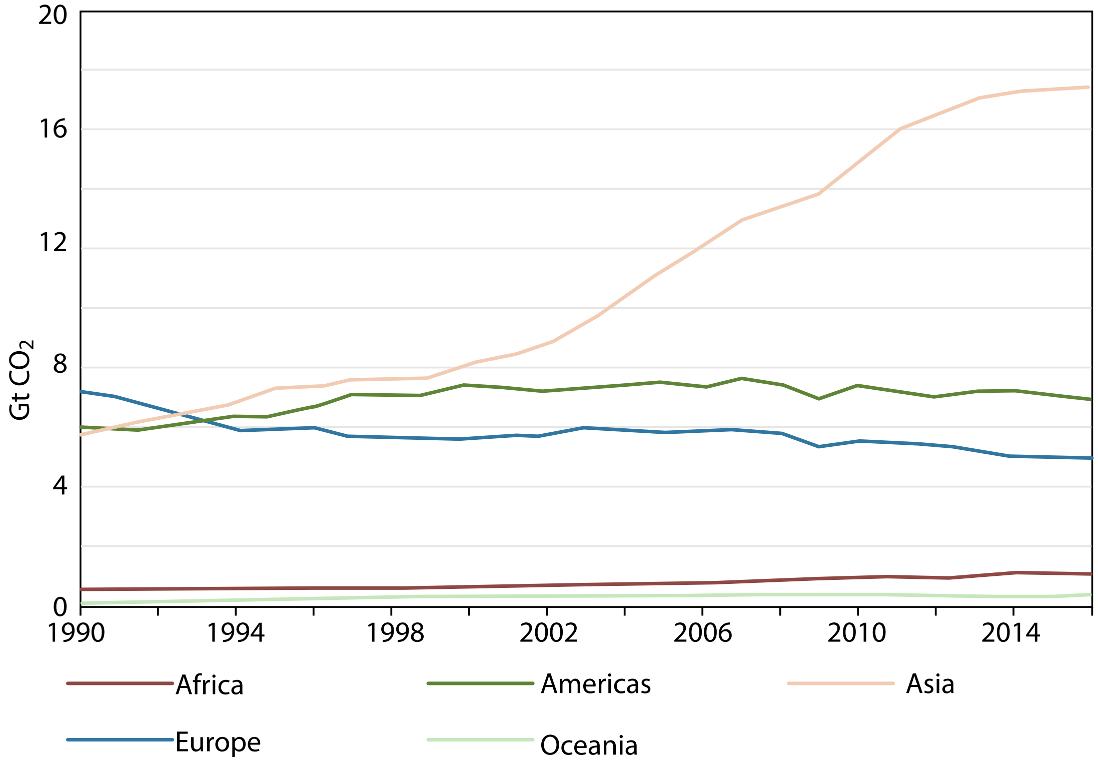

Figure 2: Carbon dioxide emissions from fossil fuels, by region
Source: International Energy Association

elsewhere for now). Using the figures in Table 2, it can be shown that generating a gigawatt hour of electricity from wood rather than coal releases an additional 54.5 tonnes of carbon dioxide.** This assumes that wood- and coal-fired generators run at the same efficiency and so is a best-case scenario.

Government figures show that 336 TWh of electricity were generated in the UK in 2017.[9] If 10% (33.6 TWh or 33,600 GWh) of this were to be generated by switching from coal to biomass, an additional 1.8 million tonnes of carbon dioxide would be emitted annually. In the scheme of things, this is trivial, with government figures†† showing total carbon dioxide emissions in 2016 to have been 379 million tonnes. Nevertheless, burning biomass leads to a net *increase* in carbon dioxide emissions. Not only this, but it comes at a net cost (see Section 8).

8 Case study – Drax

In June 2016, Drax issued a press release announcing the imminent achievement of a milestone in its conversion away from coal: the saving of its 20 millionth tonne of carbon. The expectation was that the 50 millionth tonne of carbon would have been saved after only

** The emissions quoted previously are for emissions of 109.6 kgCO_2/GJ for wood, and 94.6 kgCO_2/GJ for hard coal. So emissions per unit of heat released are 16% higher for wood than for coal. 1 GWh is equivalent to 3,600 gigajoules. Thus, the extra CO_2 released in $94.6 \times 3{,}600 \times 0.16$ kg = 54.5 tonnes

†† Department for Business, Energy and Industrial Strategy.

another two and a half years; that is, about as this report is being written. This and further information in this section is from the Drax website.[10]

In its 2017 sustainability report, the company claims an 86% saving of greenhouse gas emissions compared to the average figure for coal: 36 gCO_2/MJ for Drax biomass compared to the official UK government benchmark figure of 256.94 gCO_2/MJ for coal. Savings of 64% are also claimed over burning gas. The same source says that the company emitted 20.1 million tonnes of carbon from burning coal in 2013. By 2017, this figure had reduced to 6.2 Mt, while emissions from biomass burning rose to 11.8 Mt (overall electricity generation had fallen from 28 to 21.2 TWh over this period). This enabled the company to claim that the emissions per gigawatt hour of electricity had fallen from 736 tonnes to 297 tonnes between 2013 and 2017.

These figures are only true because, to quote from the report:

> The emissions data do not take into account the CO_2 that has been absorbed from the atmosphere during the growth of feedstocks which are used to manufacture the biomass pellets used at Drax to generate electricity.
>
> The biogenic CO_2 emissions resulting from power generation are counted as zero in official reporting to both UK authorities and under the EU ETS as the use of sustainable biomass is considered to be carbon neutral at the point of combustion. This methodology originates from the United Nations Framework Convention on Climate Change (UNFCCC).

In practice, the total emissions associated with burning wood pellets are significantly higher than for burning the coal required to release an equivalent amount of energy. The 'saving' is only accomplished once a corresponding amount of carbon dioxide has been absorbed by growing additional biomass. If we assume that by now, on the basis of the figures from Drax, 50 million tonnes of carbon emissions have been 'saved' by burning biomass rather than coal, we can estimate the actual additional emissions that are generated over the years the biomass has been burned.

A tonne of carbon is equivalent to 3.67 tonnes of carbon dioxide, so the claim is that emission of 183.5 million tonnes of carbon dioxide have been averted over the current lifetime of the generator's biomass burners. In reality, we have seen earlier that burning wood emits 16% more carbon dioxide than coal per unit of electricity generated. The *additional* carbon dioxide emitted over the period biomass was burned can thus be calculated as 29.4 million tonnes, in addition to emissions associated with harvesting, drying, processing and transport. To claim that such a practice *reduces* emissions by 86%, we have to find a timescale over which 213 million tonnes of carbon dioxide have been recaptured. This will be a matter of decades rather than years, so it makes no sense to claim that emissions are being reduced in the present day.

The use of biomass to replace coal comes at a cost to the UK consumer. The first two biomass units at Drax are subsidised under the Renewables Obligation.[‡‡] Under the scheme, Renewable Obligation Certificates (ROCs) are granted to electricity suppliers to demonstrate compliance with the statutory target to supply a set proportion of that electricity from renewable sources. These ROCs are either bought with the green electricity or from other suppliers who have an excess (those who have a higher proportion of renewable electricity in their supply mix than they are obliged to provide). Suppliers failing to meet their Renewable Obligation are fined, with the fines being redistributed to suppliers in proportion to

‡‡ Unavailable for new capacity since 2017.

the ROCs they have provided to Ofgem. The value of an ROC is in the range of £45–50/MWh, which covers the amount of the fine otherwise incurred, plus the expected share of fines to be redistributed. The sum received from sale of excess ROCs is declared as income.

In 2017, total ROC payments declared by Drax were £626.7 million (with £258.9 million being intra-group sales).[11] This means that the net payment received by the group under this scheme was £367.8 million. The third biomass-fuelled generation unit, not being eligible under the ROC scheme at the time it was approved, receives taxpayer subsidies via the CfD scheme, under which it is guaranteed a 'strike price' of £106/MWh (as of the end of 2017). Under this scheme, the company received £248.2 million in 2017, being the difference between the wholesale value of the energy and the value at the agreed strike price.

Total subsidies paid to Drax under the two schemes during 2017 therefore amounts to £616 million. In other words, the largest user of biomass in the UK received £616 million more from consumers in 2017 than would be necessary if wholesale electricity market pricing had been used, while emitting rather more carbon dioxide than it did as a coal-fired generator. This cost will increase further – along with emissions – now that conversion of the fourth generating unit to biomass burning has been completed. Drax has announced that this unit is eligible for subsidy under the Renewable Obligation scheme, the company having agreed with government a cap to ROC support across the power station as a whole (250,000 ROCs) rather than for individual generating units.

The fourth unit was already equipped for co-firing, so full conversion was at a lower cost than for the previous three. It is expected to operate mainly at times of higher demand. Even so, the annual subsidy paid to Drax is now likely to be in in the order of three-quarters of a billion pounds. To complete the picture, Drax has two remaining coal-fired generating units. The company intends to convert these to gas (combined cycle gas turbines), with a capacity of up to 3.6 GW, to eliminate coal firing by 2025.

To put this in perspective, the controversial construction of Hinkley Point C nuclear power station was agreed only after the strike price was set at £92.50/MWh, at 2012 prices. This was widely condemned as being too high and, in particular, being higher than the price for at least on-shore wind energy. Ignoring for now the oversimplification of the pricing issue by considering only spot prices rather than system-wide costs, industrial-scale burning of biomass has been encouraged, with little public controversy, even though it costs more in public subsidy than nuclear. Note also that, while Hinkley Point C will provide a reliable supply of electricity with zero carbon dioxide emissions, Drax will push more carbon dioxide into the atmosphere when burning subsidised wood pellets than it did when operating on coal.

9 Summary and conclusions

The current prosperity of the developed world is built on a ready supply of affordable energy generated from fossil fuels – coal, oil and gas – nuclear fission and (in some places) hydroelectricity. Current climate change mitigation policy in the EU dictates that 20% of energy should come from renewable resources, and in future even more. While solar and wind farms are the most visible of the technologies used, some countries (the UK and Denmark in particular) are using biomass (primarily wood) as a major source of energy.

In the absence of government policy incentives, wood as a fuel is mainly used in the developing world in lieu of better sources of energy. As such, it contributes very significantly to the burden of ill health in poor countries by causing both indoor and outdoor air pollution.

However, its attraction to policymakers in the industrialised world is its apparent sustainability, since trees felled can be replanted and used in their turn some time hence. The argument that this, over time, is a worthwhile way of reducing overall emissions has been sufficient for biomass burning to become a key component of energy generation.

Emissions from burning wood are higher than for coal, partly because it has a lower energy density per unit carbon content, and partly because of the energy expended in harvesting, processing, drying and transporting wood pellets, the preferred form of delivery. Depending on what trees are planted to replace those harvested, the degree of soil disturbance, the environment in which they are grown and their maturity at harvest, it will take at best several decades to recapture the carbon dioxide emitted by burning wood in the first place.

The cost of this process, assuming the experience with Drax to be typical, is higher than the price due to be paid for electricity from Hinkley Point C nuclear power station, which has been widely thought to be unnecessarily high. If we accept the argument that burning biomass reduces carbon dioxide emissions in the long term, then this is a rather expensive way to achieve this end. In the shorter term, it seems to be an expensive way of increasing emissions in comparison to burning coal.

A more rational policy would be to price carbon dioxide emissions and allow the most efficient technology to be used to minimise them. Results could include, for example, continuing to burn coal in the medium term while planting greater areas of trees to fix carbon dioxide, or a programme of investment in new nuclear generating stations.

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11. Drax annual report 2018 (https://www.drax.com/investors/results-reports-agm/.)

About the Global Warming Policy Foundation

The Global Warming Policy Foundation is an all-party and non-party think tank and a registered educational charity which, while openminded on the contested science of global warming, is deeply concerned about the costs and other implications of many of the policies currently being advocated.

Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policy makers, journalists and the interested public. The GWPF is funded overwhelmingly by voluntary donations from a number of private individuals and charitable trusts. In order to make clear its complete independence, it does not accept gifts from either energy companies or anyone with a significant interest in an energy company.

GWPF REPORTS

1	Montford	The Climategate Inquiries
2	Ridley	The Shale Gas Shock
3	Hughes	The Myth of Green Jobs
4	McKitrick	What Is Wrong With the IPCC?
5	Booker	The BBC and Climate Change
6	Montford	Nullius in Verba: The Royal Society and Climate Change
7	Goklany	Global Warming Policies Might Be Bad for Your Health
8	Hughes	Why Is Wind Power So Expensive?
9	Lilley	What Is Wrong With Stern?
10	Whitehouse	The Global Warming Standstill
11	Khandekar	The Global Warming-Extreme Weather Link
12	Lewis and Crok	Oversensitive
13	Lewis and Crok	A Sensitive Matter
14	Montford and Shade	Climate Control: Brainwashing in Schools
15	De Lange and Carter	Sea-level Change: Living with Uncertainty
16	Montford	Unintended Consequences of Climate Change Policy
17	Lewin	Hubert Lamb and the Transformation of Climate Science
18	Goklany	Carbon Dioxide: The Good News
19	Adams	The Truth About China
20	Laframboise	Peer Review: Why Scepticism is Essential
21	Constable	Energy Intensive Users: Climate Policy Casualties
22	Lilley	£300 Billion: The Cost of the Climate Change Act
23	Humlum	The State of the Climate in 2016
24	Curry et al.	Assumptions, Policy Implications and the Scientific Method
25	Hughes	The Bottomless Pit: The Economics of CCS
26	Tsonis	The Little Boy: El Niño and Natural Climate Change
27	Darwall	The Anti-development Bank
28	Booker	Global Warming: A Case Study in Groupthink
29	Crockford	The State of the Polar Bear Report 2017
30	Humlum	State of the Climate 2017
31	Darwall	The Climate Change Act at Ten
32	Crockford	The State of the Polar Bear Report 2018
33	Svensmark	Force Majeure: The Sun's Role in Climate Change
34	Humlum	State of the Climate 2018
35	Peiser (ed)	The Impact of Wind Energy on Wildlife and the Environment
36	Montford	Green Killing Machines
37	Livermore	Burnt Offering: The Biomess of Biomass

For further information about the Global Warming Policy Foundation, please visit our website at www.thegwpf.org.
The GWPF is a registered charity, number 1131448.