# Biomass: Carbon sink or carbon sinner?


## Executive Summary

This report summarises the results of research carried out by AEA for the Environment Agency on greenhouse gas (GHG) emissions from producing and using biomass to generate electricity and heat compared with using coal and gas. It also discusses the policy implications. The research shows that:

*GHG emissions from energy generated using biomass are generally, but not always, less than from fossil fuels.*
For example, using short rotation coppice chips to generate electricity can produce 35 to 85 per cent less emissions, whereas using straw can, in some cases, produce over 35 per cent more, than a combined cycle gas turbine power station per unit of energy delivered.

*How a fuel is produced has a major impact on emissions.*
Transporting fuels over long distances and excessive use of nitrogen fertilisers can reduce the emissions savings made by the same fuel by between 15 and 50 per cent compared to best practice.

*Land use change can negate any emission savings.*
Using formerly fallow land to grow bioenergy crops can reduce emission savings from a fuel by up to 10 per cent. Planting on permanent grassland is worse, with emissions savings significantly reduced and in some cases reversed.

*Energy conversion efficiency is an important factor in reducing emissions*
Factoring the efficiency of converting the energy stored in the fuel to electricity and heat into the life cycle analysis results in an even greater range of emissions savings. Efficiency standards already exist for many energy conversion technologies, but these will need to be improved.

*Emission reductions of several million tonnes of greenhouse gases per year could be achieved by following good practice*
Based on current market projections, we estimate that by 2020 the emission of greenhouse gases equivalent to several million tonnes of carbon dioxide per year could be avoided if good practice in fuel production, processing and transport, and energy conversion efficiency were to be followed.

*By 2030, biomass electricity will need to be produced using good practice to avoid emitting more GHG emissions per unit than the average for the electricity grid indicated to be necessary by the Committee on Climate Change*
In the short term, improvements in energy conversion efficiency and lifecycle emissions from biomass fuels will help to reduce emissions. However by 2030 some fuels will be at risk of becoming redundant. While innovation may help to deliver good practice for biomass plant built in the future, the infrastructure the UK is developing now will form a major component of the country’s generating capacity in 2030. It is difficult, if not impossible in some cases, to retrofit a combined heat and power (CHP) system, which makes it

imperative that biomass plants – like all other new power stations – are designed to utilise heat from the outset. If they are not, and if the plants cannot be retro-fitted, operators risk being left with stranded assets within 20 years.

*Co-firing biomass is a good short term measure to reduce emissions, but unless carbon capture and storage can be deployed and preferably the heat utilised, it does not have a long term role*
Just as for dedicated biomass plant, by 2030 the carbon intensity of the electricity grid will mean that even with co-firing of biomass, coal-fired power stations will have to have carbon capture and storage operational. There should also be a strong presumption in favour of combined heat and power for new plant.

The Environment Agency believes that the biomass heat and power sector can play a key role in helping the UK meet its renewable energy and greenhouse gas commitments. To deliver this, however, the sector needs to use sustainable feedstocks and maximise greenhouse gas emission reductions. We therefore recommend:

1. The Renewables Obligation, the Renewable Heat Incentive and other relevant policies should provide greater incentives for CHP and heat only plants than for electricity only as currently.
2. Mandatory reporting on greenhouse gas emissions by generators receiving public support through the Renewables Obligation and the Renewable Heat Incentive.
3. Development of mandatory minimum standards for the greenhouse gas savings achieved by biomass fuels used to generate heat and power.
4. A review of energy conversion efficiency in biomass heat and power generation to ensure current standards are adequate in ambition and scope.
5. Further research to understand which technologies and production methods will produce the most renewable energy and least GHG emissions from a given amount of biomass.

## 1. Introduction

The Environment Agency is committed to supporting the development of a sustainable, low carbon biomass heat and power sector that plays a major role in delivering the UK's energy needs by 2020.

To facilitate this, we have worked with Defra, AEA and North Energy to develop the Biomass Environmental Assessment Tool ($BEAT_2$). $BEAT_2$ is now available free at www.biomassenergycentre.org.uk/BEAT and is being used by biomass project developers to calculate and minimise greenhouse gas emissions and to identify wider environmental issues.

This report is based on research carried out by AEA for the Environment Agency[1], which used $BEAT_2$ to investigate the levels of greenhouse gas emissions from different methods of producing biomass heat and power in the

[1] AEA (2009) *Maximising the greenhouse gas emission reductions from biomass used to generate heat and power* Technical Report for the Environment Agency

UK. The report is divided into two sections. The first summarises the key findings of the research, the second discusses the policy implications.

## 2. Research results

### *2.1 Greenhouse gas emissions from energy generated using biomass are generally, but not always, lower than those from fossil fuels*

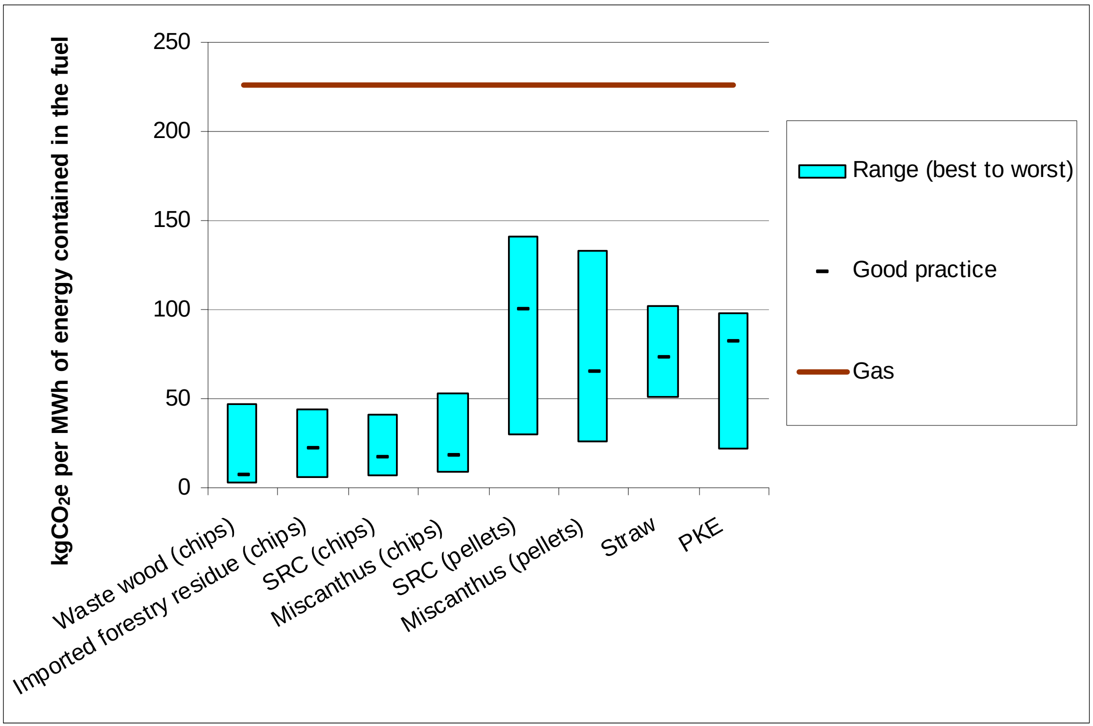
Using biomass to generate heat, power or both simultaneously generally reduces emissions of greenhouse gases compared to fossil fuel generation. However emissions vary widely between different fuels and for the same fuel depending on whether good practice is followed. If certain land use changes occur, these can negate any savings made. The following sections build up the full picture.

### *2.2 How a fuel is produced has a major impact on emissions*

How a fuel is produced, transported and processed has a significant impact on lifecycle emissions. Transporting fuels over long distances and excessive use of nitrogen fertilisers can reduce the emissions savings made by the same fuel compared to natural gas by between 15 and 50 per cent.

Figure 1 shows greenhouse gas emissions in equivalent carbon dioxide ($CO_2e$) from producing different biomass fuels before they are converted into useful heat and electricity, compared with the carbon dioxide ($CO_2$) in natural gas, per unit of calorific energy in the fuels. On this score, biomass fuels generally measure well compared with gas, though there is considerable variation between different fuels and practices.

**Figure 1: Greenhouse gas emissions from producing different biomass fuels, best to worst practice**



### *2.3 Energy conversion efficiency is an important factor in saving emissions*

When the efficiency of converting the energy in the fuel into heat and electricity delivered is factored in, the overall emissions savings are generally less compared with gas and the variation is greater, because biomass plant is often less efficient than a modern gas-fired power station.

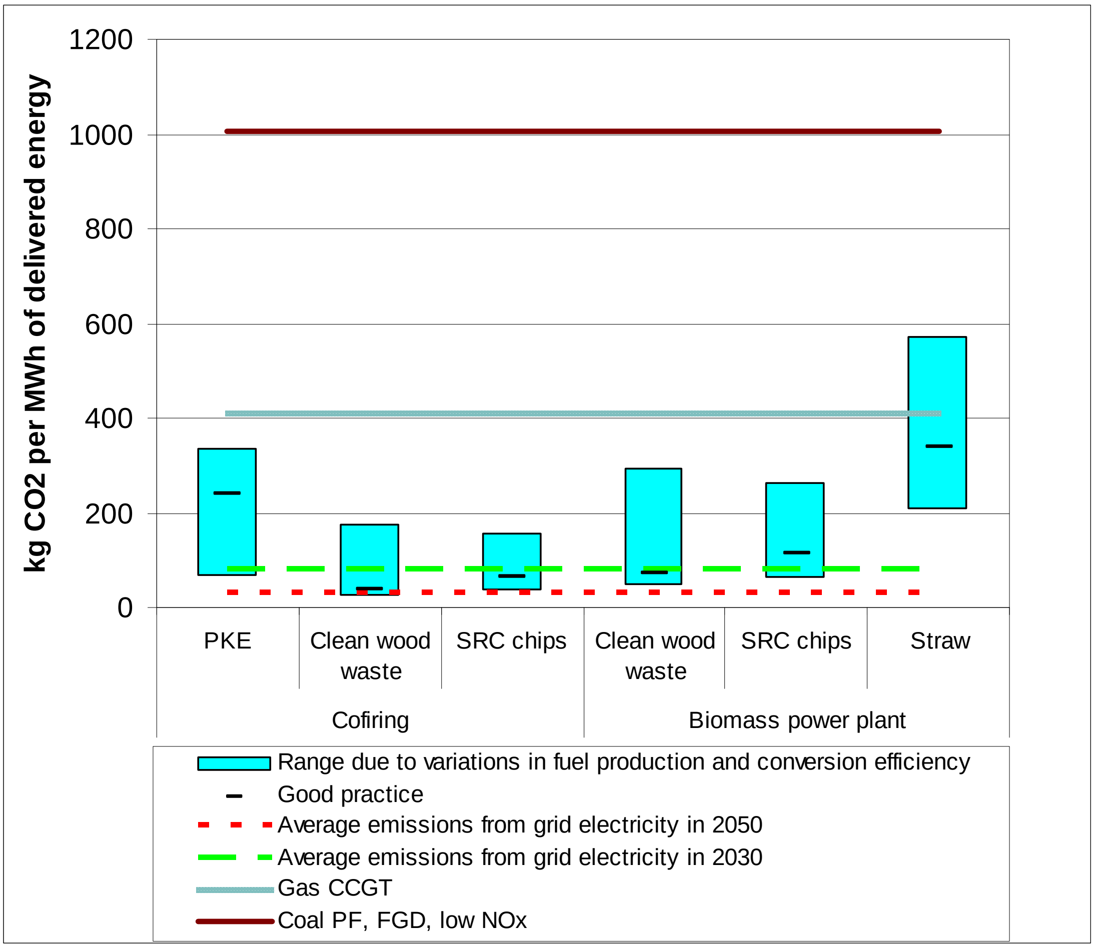
Figures 2 and 3 show the range of greenhouse gas emissions produced over the whole lifecycle of a number of biomass fuels; from growth of a crop or production of a by-product, through transport, processing and conversion to energy. Co-firing and stand-alone biomass plant are compared to coal and gas fired electricity generation in figure 2, while domestic biomass boilers are compared with a gas equivalent in figure 3.

The ranges shown are the result of expert judgements about a number of the values used in the $BEAT_2$ model. Best and worst practice represent extreme but feasible values for factors such as the distance a fuel is transported. Good practice represents a high level of performance considered to be within the capabilities of plants operating today.

In their advice to Government on future carbon budgets, the Committee on Climate Change indicated that the carbon intensity of electricity production should fall from the current level of 550 $kgCO_2$ per million watt hours (MWh) to 80 $kgCO_2$ per MWh by 2030 and 30 $kgCO_2$ per MWh by 2050. These figures are plotted for comparison on Figure 2 because of the long lifetimes of power generation facilities. The heat sector will have to follow a similar trajectory, albeit over a longer time period as current options are more limited.

The range in energy conversion efficiency shown in figure 2 only reflects changes in the efficiency with which electricity is generated. It does not include the use of heat through a combined heat and power (CHP) system.

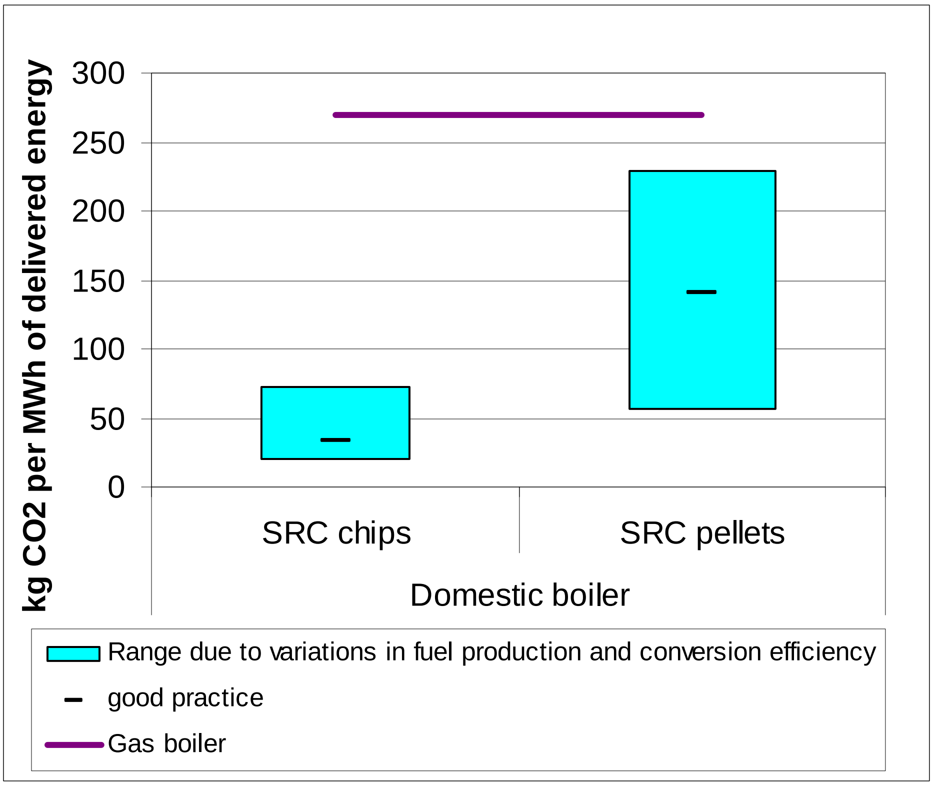
**Figure 2: Greenhouse gas emissions from producing and using different biomass fuels to generate electricity, best to worst practice**




**Key:**

| | |
|---|---|
| PKE | Palm kernel expeller |
| SRC | Short rotation coppice |
| CCGT | Combined cycle gas turbine |
| PF/FGD | Pulverised fuel with Flue Gas Desulphurisation and technology to lower emissions of oxides of nitrogen |

**Figure 3: Greenhouse gas emissions from producing and using biomass fuels in domestic boilers, best to worst practice**



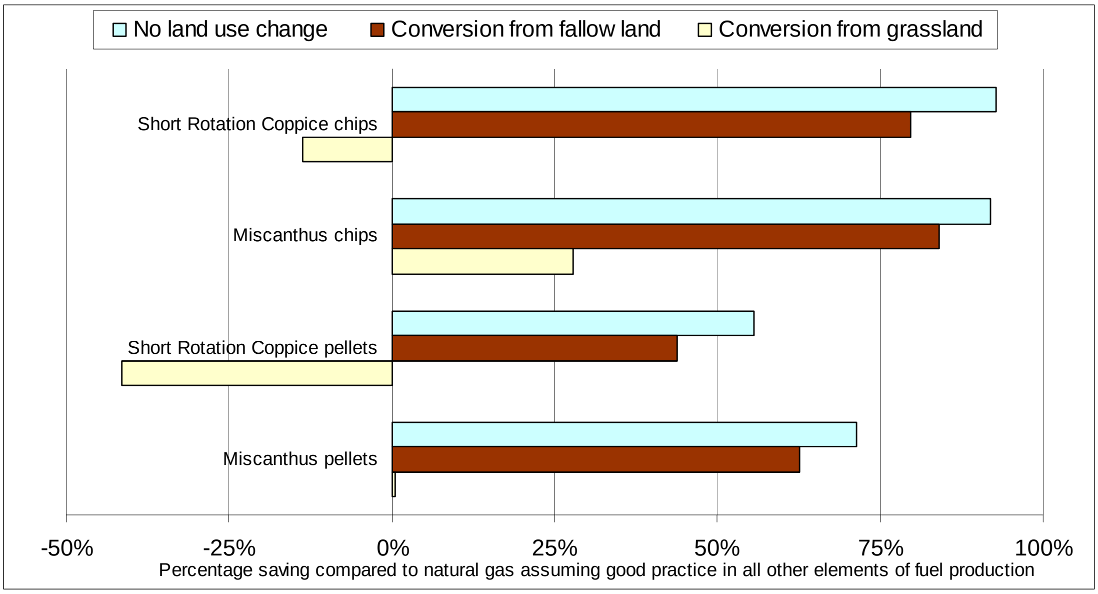

**Key:**
SRC Short rotation coppice

***2.4 Land use change can negate any emission savings***

Where biomass originates from energy crops, land use becomes an important factor in a fuel's greenhouse gas emissions. Using formerly fallow land to grow bioenergy crops can reduce emission savings from a fuel by up to 10 per cent. Planting on permanent grassland is worse, with emissions savings significantly reduced and in some cases reversed. This is shown in Figure 4, which averages emissions due to land use change over a 20 year period: the lifetime of a typical energy crop plantation.

There is no evidence that energy crops are currently being planted directly on permanent grassland in the UK, although anecdotal evidence suggests this is an issue elsewhere. However, if demand for land to produce energy crops rises and leads to the displacement of other crops, the indirect effect may be to shift production of these crops onto permanent grassland, causing the same problem.

**Figure 4: The impact of direct land use change on emission reductions**




### *2.5 Emission reductions of several million tonnes of greenhouse gases per year could be achieved by following good practice*

Figure 5 illustrates what impact moving from poor to good practice in fuel production and energy conversion efficiency could have. It takes a notional 250MW biomass plant located in the UK and assumes that it generates only electricity, at 27 per cent efficiency, using wood chip imported from Canada or the eastern United States.

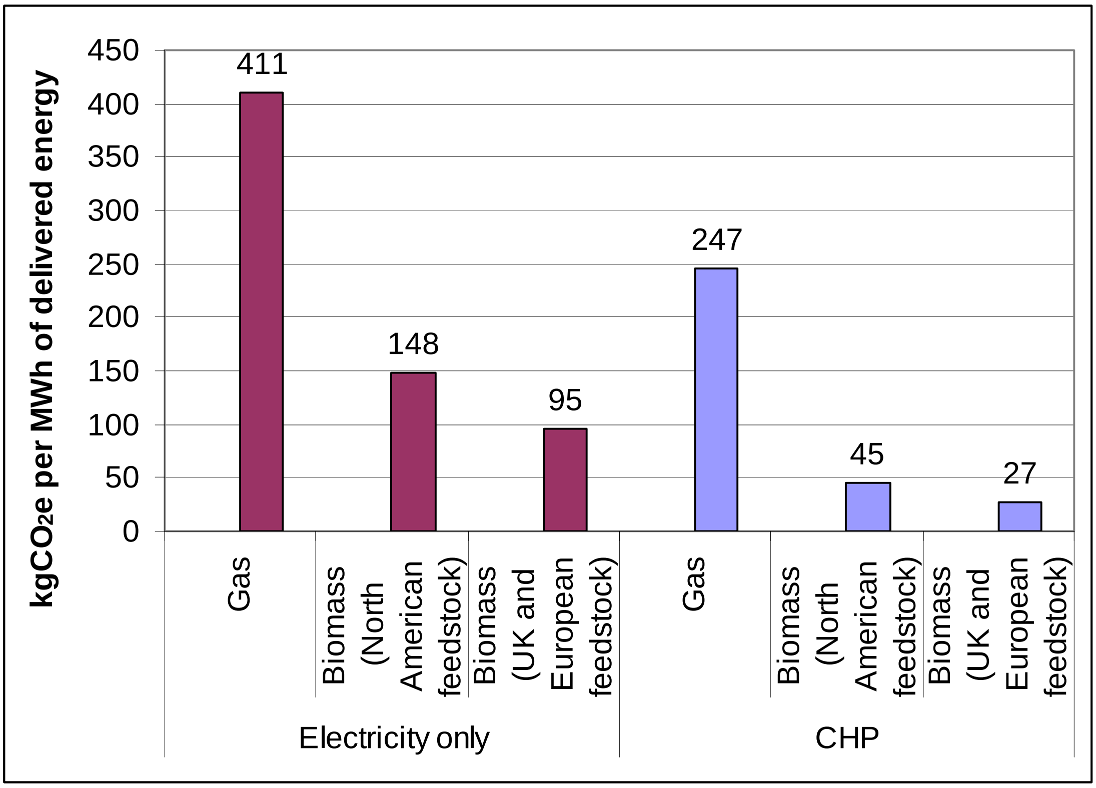
To move this plant from poor to good practice would require: using the heat generated during electricity production, which would bring its energy conversion efficiency up to 80 per cent; ensuring all the heat produced was utilised; and importing 75 per cent of its fuel from the Baltic states, with 25 per cent derived from UK sources.

Switching from gas to biomass results in impressive reductions in emissions per MWh of delivered energy. Switching from a biomass plant that generates just electricity to one that also utilises heat again reduces emissions substantially. Improving the 'carbon efficiency' of the biomass feedstock still results in large savings but these are smaller relative to the other two options.

This highlights the urgent need to ensure that new biomass (and fossil fuel) plant is designed to produce usable heat from the outset. But it also shows that even in a plant that has already been designed to generate only electricity, good practice in biomass fuel production could reduce emissions significantly.

Although estimates of the amount and type of biomass generation likely to be available by 2020 are uncertain, around 80 million MWh (80 terawatt hours or TWh) is likely to be needed. This would meet the share of the UK's renewable energy target envisaged for biomass, which would be about 30 per cent of the UK's renewable heat and electricity requirement. If the majority of

**Figure 5: Comparison of emissions from biomass and gas-fired power stations**




this generation was in the form of electricity generated using poor practice feedstocks, moving to good practice would save over 3Mt$CO_2$e (million tonnes of carbon dioxide equivalent) per year by 2020. If, in addition, 75 per cent of future electricity generation capacity was converted to CHP, total savings would be over 4Mt$CO_2$e per year. This would make a useful contribution to the reduction in UK emissions of 95 or 160Mt$CO_2$e (depending on the outcome of international negotiations) between 2008 and 2020 recommended by the Committee on Climate Change.

### *2.6 By 2030, biomass energy will need to be produced using good practice to avoid emitting more GHG emissions than the average for electricity produced for the grid*

In the short term, improvements in energy conversion efficiency and lifecycle emissions from biomass fuels will help to reduce emissions. However by 2030 some fuels will be at risk of becoming redundant. Biomass plants generating only electricity, a number of which are currently in development, cannot have a long-term future in the UK's energy mix as they are not able to produce sufficiently low carbon energy. The only way electricity production from biomass can keep within the Committee on Climate Change's recommended trajectory is if the heat generated at the same time is put to domestic or industrial use.

While innovation may help to deliver good practice for biomass plant built in the future, the infrastructure being developed in the UK now will form a major component of the country's generating capacity in 2030. It is difficult, if not impossible in some cases, to retrofit a CHP system, which makes it imperative that biomass plants – like all other new power stations – are designed to utilise heat from the outset. If they are not, and if the plants cannot be retro-fitted, operators risk being left with stranded assets within 20 years.

### *2.7 Co-firing biomass is a good short term measure to reduce emissions, but unless carbon capture and storage can be deployed and the heat utilised, it does not have a long term role*

Large coal-fired power stations tend to have higher energy conversion efficiencies than smaller biomass-fired electricity generation plant. They also tend to co-fire biomass fuels with lower lifecycle greenhouse gas emissions. However, even including co-fired biomass, their overall greenhouse gas emissions are very high. The Committee on Climate Change, which advises the UK Government on greenhouse gas targets and budgets, has recommended that new coal fired power stations should only be built on the clear expectation that they will have carbon capture and storage operational by the early 2020s. There should also be a strong presumption in favour of CHP for new plant.

## 3. Policy Implications

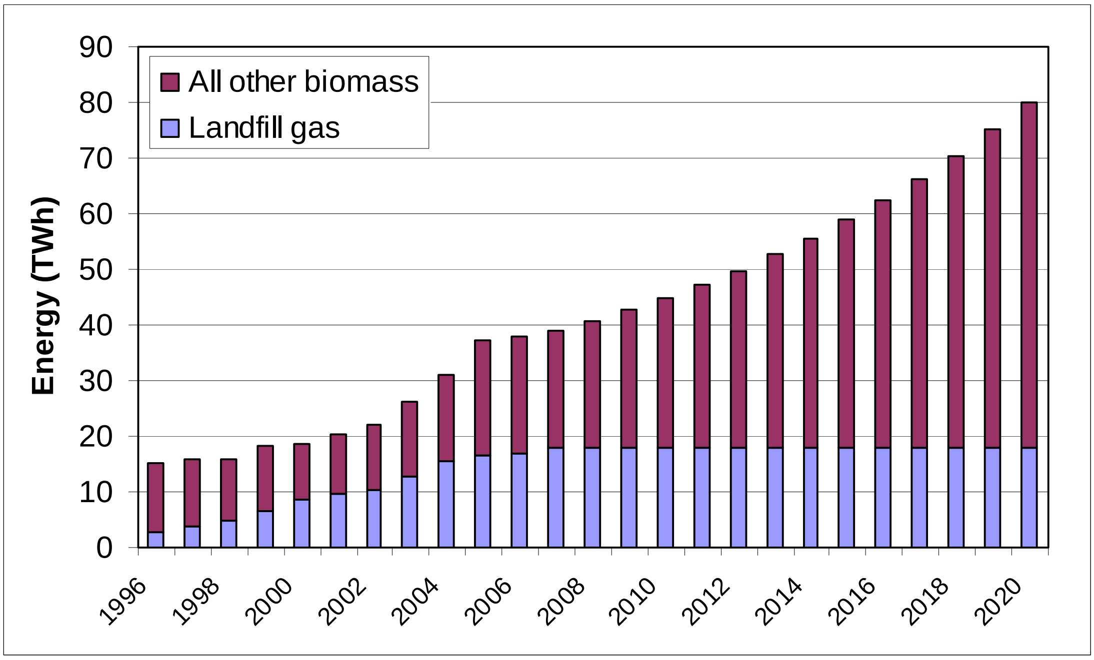
### *3.1 The policy framework*

Biomass heat and power is expected to play a key role in meeting the UK's target of generating 15 per cent of its energy from renewable sources by 2020. The Government's Renewable Energy Strategy suggests that around 30 per cent of renewable heat and electricity (not including transport fuels) will need to come from biomass to help achieve this target. This is around 80TWh, which compares to generation of 39TWh in 2007, almost half of which came from electricity generated using landfill gas.

Figure 6 shows that the biomass sector will need to achieve an annual growth rate of nearly 9 per cent over the next ten years to generate 80TWh of energy by 2020. With biodegradable waste being increasingly diverted from landfill, the contribution from the landfill gas sector can be expected to plateau or even decline. Although higher rates of growth than this have been achieved, this was due almost entirely to increases in co-firing. Further increases from this source are likely to be limited by technical and policy considerations, meaning that the rate of growth of dedicated biomass energy generation needs to increase significantly from the very low rates seen in recent years.

If Government policy is correctly aligned then such rates of growth are possible. For example electricity generation from wind increased by an average of over 25 per cent per year between 1996 and 2007. However the long planning and construction time needed for large biomass plants means that much of the capacity needed to achieve this target is either already being planned or will be very soon. These investments in infrastructure and supply chains will still have a considerable influence on energy generation in 2030 and beyond.

**Figure 6: Energy generated from biomass in the UK (1996 to 2007) and generation required to meet the 2020 target (from 2008 onwards)**




Sources: Committee on Climate Change (2008), Digest of UK Energy Statistics (2008)

The biomass heat and power sector should therefore aim to maximise greenhouse gas emission reductions from the outset. The relevant support instruments – the Renewables Obligation and the Renewable Heat Incentive – need to be designed to favour low carbon biomass energy generation. Developers must understand what is being asked of them and be equipped with the tools they need to calculate their greenhouse gas emissions and improve their performance.

**Recommendation: The Renewables Obligation, the Renewable Heat Incentive and other relevant policies should ensure that combined heat and power and heat only plants are built rather than electricity only, as is currently the case.**

### *3.2 Greenhouse gas reporting*

The Renewables Obligation will require basic sustainability reporting by biomass generators from April 2009, but the level of information required will not be sufficient to calculate accurate greenhouse gas emissions savings. The Environment Agency is therefore currently using $BEAT_2$ to develop a greenhouse gas reporting tool capable of calculating emissions savings in a similar way to the Renewable Transport Fuel Obligation's carbon calculator. We believe that, as a matter of urgency, generators should be required to use this tool to report on emissions when they apply for Renewables Obligation Certificates. A similar approach should be taken for large generators under the Renewable Heat Incentive. This would provide accurate data on emission savings from biomass generators in the UK with minimal cost and effort.

**Recommendation: Mandatory reporting on greenhouse gas emissions by generators receiving public support through the Renewables Obligation and the Renewable Heat Incentive should be introduced.**

### *3.3 A minimum standard?*

Given the very demanding trajectory that the Committee on Climate Change has recommended for emissions from the electricity sector, and the equally urgent need to reduce emissions from heat, it may be justified in the future to introduce a minimum lifecycle emissions standard for biomass heat and power generators. This standard could be set in terms of $kgCO_2e$ per MWh and meeting it would become a precondition for support via the Renewables Obligation and the Renewable Heat Incentive. A similar approach is already used for biofuels, where the variability in emissions is considerably larger.

A minimum standard may be appropriate and achievable for larger scale generators, such as those applying for Renewable Obligation Certificates, but would be more difficult for smaller scale units. A large number of small-scale generators, however, will have a significant impact on emissions and would therefore need to be covered by an equivalent scheme. This could be achieved through a scheme that applies to biomass fuel suppliers rather than generators. The Environment Agency would be happy to work with other interested organisations to help develop greenhouse gas and wider sustainability quality standards for this market.

**Recommendation: Mandatory minimum standards for the greenhouse gas savings achieved by fuels used to generate heat and power should be developed.**

### *3.4 Standards for energy conversion efficiency*

Emissions from the production of fuels are one part of the problem: poor energy conversion efficiency is another. As efficiency standards already exist for many energy conversion technologies, we believe it would be simpler to improve these than to include energy conversion efficiency in a life cycle greenhouse gas emissions standard.

There are a variety of standards for different generator types and scales, but it is not clear whether these standards are sufficiently demanding for all parts of the market. Anecdotally, there is evidence of inefficient boilers being installed in the UK, but no data exists to prove this. Investments made in infrastructure now will have an impact on the UK's GHG emissions for many decades to come, reinforcing the urgency of addressing this issue.

**Recommendation: A review of energy conversion efficiency in biomass heat and power generation should be carried out to ensure current standards are adequate in ambition and scope.**

### *3.5 Making the best use of biomass*

Biomass is ultimately a limited resource with many competing uses in the heat, power, transport and materials sectors. This makes it even more important to ensure that each tonne of fuel produces the best return in terms of greenhouse gas emission savings.

We believe that a more strategic approach needs to be taken to biomass to ensure it is put to its most efficient use. The Environment Agency is therefore conducting further research into the lifecycle greenhouse gas emissions from a range of uses of biomass to inform this debate. The outputs from this work will include a hierarchy setting out the energy conversion technologies that produce the greatest savings in greenhouse gases per tonne of biomass used. The aim is for this hierarchy to be applied to regional assessments of biomass resources to help provide strategic direction to policies designed to encourage bioenergy generation. The Environment Agency would be happy to work with other interested organisations on this important issue.

**Recommendation: Further research needs to be carried out to understand which uses of limited biomass resources will maximise renewable energy generation and greenhouse gas emission reductions.**

**Environment Agency, April 2009**