Supergen Bioenergy | SUSTAINABLE BIOENERGY SYSTEMS FOR OUR LOW-CARBON FUTURE

Public engagement theme 1

Is bioenergy carbon neutral?

In summer 2022, as part of the Supergen Bioenergy Hub public engagement strategy, a media literature review was conducted to explore the public debate around biomass energy in the UK. A number of themes were identified in the review.

The following questions and areas of debate arose concerning the theme of biomass energy and its **carbon or climate impact**. This is arguably the most important theme of bioenergy since a primary reason for using bioenergy is to substitute fossil fuel energy to reduce carbon dioxide emissions and support climate change mitigation. Each question or area of debate is addressed with a short scientific answer or response.

When is bioenergy carbon neutral?

Carbon dioxide (CO_2) is released during the 'life-cycle' of using biomass material for bioenergy, this means it the harvesting, transporting, processing, and burning, or combustion, of biomass to generate energy. The generated bioenergy is considered carbon neutral when that CO_2 released during this life-cycle process is balanced by CO_2 absorption, from new biomass material. CO_2 can be absorbed by both above-ground biomass (e.g tree material), and below-ground biomass (e.g root matter). The time taken for a biomass resource to re-absorb the CO_2 that is released during combustion is referred to as the 'carbon payback' period. Forests and bioenergy crops can be managed to minimize the life-cycle carbon emissions of bioenergy and promote a balance between these emissions and the absorption of CO_2.

Isn't the 'carbon payback' period of biomass long because trees take many years to grow?

Some bioenergy crops - such as fast-growing grasses and trees - are harvested every year or several years, and so the payback period on these forms of bioenergy can be relatively short. The carbon payback period of commercial forestry trees is longer, although at the forest-scale, there can be a continuous cycle between harvest of biomass for bioenergy and CO_2 absorption in new biomass material, to ensure that the total forest biomass is constant, or even growing.

When is bioenergy carbon positive?

Bioenergy is carbon positive when the CO_2 released from the life-cycle process of generating bioenergy outweighs the CO_2 absorbed by the growth of new biomass material. There are several ways this could happen.

Bioenergy could be carbon positive if insufficient CO_2 is absorbed by new biomass material, for example, if biomass is harvested from a land area which is permanently changed and therefore does not absorb further CO_2, such as the result of urbanisation. Bioenergy may also be carbon positive if the life-cycle of generating bioenergy results in high CO_2 emissions. For example, if a bioenergy crop is grown on land where the soil has a high content of carbon, with the disturbance to the soil of growing the bioenergy crop risking the release of this carbon. If fertilizer is used on a biomass crop (which leads to emissions of nitrous oxide, another greenhouse gas), or if there are large emissions from the biomass transport and processing, this could also lead to bioenergy with a carbon positive balance.

Biomass is often referred to as 'low carbon' in comparison to fossil fuel energy which it is used to replace. This reflects a positive carbon balance from the life-cycle of the bioenergy, but one which is smaller in comparison to the carbon balance of the fossil fuel energy, such as coal, and therefore resulting in a reduction in greenhouse gas emissions.

When is bioenergy carbon negative?

Bioenergy is carbon negative when the carbon released from the life-cycle process of generating bioenergy is outweighed by the CO_2 absorbed, by the growth of new biomass material. There are two ways in which this can be achieved.

Firstly, biomass material absorbs CO_2 not only into 'above-ground' material (e.g tree growth), but also 'below-ground' material (e.g roots). Whilst the above-ground biomass is harvested and combusted, the below-ground is not, and this storage of CO_2 in the soils can support an overall carbon negative balance of bioenergy. The second way bioenergy can be carbon negative is when the CO_2 released from the combustion of biomass material is prevented from entering the atmosphere and put into a form of storage, such as geological (underground) storage. The technology Bioenergy with Carbon Capture and Storage (BECCS) combines bioenergy with the capture and storage of the CO_2 emissions of biomass combustion. It is promising in climate scenarios because of the potential to achieve a carbon negative balance.

Is the type of biomass material relevant to carbon balances?

Some biomass feedstocks can have better carbon balances than others. Typically, using arable food crops for bioenergy, such as corn ethanol in the US, will result in greater life-cycle emissions than using dedicated bioenergy crops - fast-growing grasses and trees grown specifically for bioenergy – which typically require fewer inputs such as fertilizers and which can lead to greater below-ground carbon storage.

Can biomass be worse than coal?

The 'stack' emissions - the CO_2 emissions through the power station chimney - of biomass and coal combustion are similar. However, to compare the carbon balance of coal and biomass requires considering the life-cycle carbon impact of bioenergy, as discussed above.

The growth of new biomass material will reduce the carbon impact of the bioenergy compared to coal, since coal resources do not have this ability to absorb CO_2. However, if there is no new biomass material, such as because of a change in the use of the land, or if new growth is minimal and there are large life-cycle carbon emissions, such as through disturbance of soils high in carbon content, then it is possible that bioenergy would have life-cycle emissions comparable to, or even worse than, coal. Regulatory frameworks for biomass energy seek to prevent this scenario through requiring that carbon stocks (e.g forests) are protected.

Can forests provide biomass material whilst continuing to sequester carbon?

Forests can provide biomass material for bioenergy and continue to capture CO_2 if there is an increase in the total forest area, the total forest biomass material, or below-ground carbon stored in the soil. A number of countries manage their forests to provide biomass material and grow at the same time, including many European countries such as Sweden and the Baltic countries.

Is it better to leave trees to grow and accumulate carbon than to cut them?

This depends on what the cut biomass is used for. Where biomass is used to replace fossil fuels, such as in a biofuel, this can achieve a reduction in CO_2 which would not be achieved if the biomass was not harvested and used.

Forests can be managed to promote growth and therefore also absorb CO_2, such as by the removal of some of the trees to control tree density and to remove weak trees (known as ‘thinning’), reducing competition for resources. This management is required in some forests to reduce the risk of severe wildfire events, which can lead to large losses of trees and stored carbon.

From a carbon balance perspective, CO_2 absorption is typically highest in the early stages of tree growth, and so a continuous cycle between the harvest and re-planting of trees can be an efficient way of absorbing CO_2 in biomass material. There may be other reasons to leave trees to grow longer, such as to support biodiversity.

What is the carbon impact if biomass resources are not used?

This depends on the management practice of these resources. Some biomass resources from forestry, farm, or municipal sources may end up generating CO_2 emissions if they are disposed of and not utilised for energy, such as via landfill, ‘open-pile’ burning or decomposition on the ground. Much of the biomass material used for bioenergy is low-value wood or residues (e.g sawdust or chippings), which may result in CO_2 in this way.

What about ‘indirect land-use change’?

The life-cycle emissions of bioenergy sometime consider whether using land for bioenergy, such as a bioenergy crop, has stopped that land being used for another purpose, such as

food-based agriculture, and whether this leads to land conversion for that other land use elsewhere, which may result in increased CO_2 emissions. This is called 'indirect land-use change'. This is a difficult and controversial topic because it is not clear that the bioenergy should be responsible for these indirect emissions: that other land-use change may have happened anyway, and there are multiple competing uses for land, of which bioenergy is only one.

How is bioenergy treated in policy making?

Policymakers introduce policy and regulatory frameworks aimed at promoting the generation of bioenergy with a low carbon balance.

The UK government considers biomass combustion to be carbon neutral, providing certain criteria are met in relation to greenhouse gas emission reduction compared to a fossil fuel energy source, and criteria which ensure that the carbon stock of forests, wetlands, and peatlands are protected (BEIS, 2021; Committee on Climate Change, 2018).

Biomass combustion for bioenergy is considered carbon neutral in reporting frameworks for the United Nations Framework Convention on Climate Change (UNFCCC). The frameworks do report changes in the land carbon stocks as a result of bioenergy, which could be either positive or negative, as discussed above.

Summary

Whether bioenergy is carbon neutral, or low-carbon compared to the alternative it is measured against, depends on its life-cycle, which includes both sources of greenhouse gases and CO_2 absorption in new biomass growth. Management practices, land-use contexts, and the type of biomass material used will all influence this balance.