# Negative emissions

## The role of negative emissions in meeting net zero

**Every year National Grid Electricity System Operator (ESO) produces the Future Energy Scenarios (FES). These scenarios explore the uncertainty surrounding the future of energy; including the challenge of meeting net zero and the impact of this on future energy supply and demand.**

**Archie Corliss, one of the ESO's Strategic Insight Leads, considers the importance of sources of negative emissions in meeting the UK's net zero target. For FES 2021 we are considering a broader range of negative emissions technologies with more variation between the net zero scenarios, including the use of direct air capture of carbon dioxide displacing some bioenergy with carbon capture and storage and the potential for increased use of natural climate solutions.**

Meeting net zero will require wholesale change across the economy. Different sectors will face their own challenges to achieve this. In our future energy scenario modelling we explore the extent to which different sectors can be decarbonised. Whilst heat and road transport are assumed to be able to be completely decarbonised completely by 2050, there are other areas where this is not the case. We expect there to be some residual emissions from industry, for example industrial processes that involve certain chemical reactions. We also expect to see some residual emissions from areas which continue to use fossil fuels with carbon capture and storage, which, while it could capture up to 96% of the carbon emitted from these processes, would still result in some carbon dioxide being released into the atmosphere.

*Table 1: FES 2020 greenhouse gas emissions by category and scenario today and in 2050*

| $MtCO_2$ equivalent | 2019 | CT 2050 | ST 2050 | LW 2050 | SP 2050 |
|---|---|---|---|---|---|
| Heat for buildings | 87 | 0 | 0 | 0 | 78 |
| Electricity before BECCS | 57 | 3 | 2 | 2 | 30 |
| BECCS in power sector | 0 | -52 | -49 | -61 | 0 |
| Industry | 102 | 4 | 4 | 4 | 55 |
| Road transport | 113 | 0 | 0 | 0 | 16 |
| Hydrogen production | 0 | 0 | -1 | 0 | 0 |
| Other | 121 | 45 | 45 | 45 | 79 |
| **Total** | **480** | **0** | **0** | **-10** | **258** |

Included in the 'Other' category in Table 1 are non-energy areas that are some of the most challenging to decarbonise and where carbon emissions are likely to continue. These include aviation, shipping, agriculture (including land use change), waste[1] and F-gases[2]. The Sixth Carbon Budget from the Committee on Climate Change explores many of these aspects in greater detail.

If not all sectors can reach zero emissions, then to offset this will require negative emissions of some form. This is discussed at the start of our System View chapter in FES 2020, with detailed emissions pathways included in tab SV.2b of our Data Workbook.

[1] Emissions from waste include those associated with landfill, energy from waste plants, wastewater treatment sites and anaerobic digestion plants

[2] Fluorinated gases (F-gases) are released in very small volumes relative to other greenhouse gases but can have a global warming potential up to 26,000 times greater than carbon dioxide and are produced particularly by the refrigeration sector.

## What do we mean by negative emissions?

'Negative emissions' refers to any way that greenhouse gases can be removed from the atmosphere. These fall into two main categories: natural climate solutions and negative emissions technologies.

Natural climate solutions are those such as tree planting or peatland restoration. Trees absorb carbon dioxide as they grow and so planting a significant number of additional trees helps to reduce the carbon dioxide in the atmosphere. Reforestation is planting trees again in areas where trees have previously been removed, while afforestation is the process of planting trees and forests in areas that have so far not had trees.

Negative emissions technologies are those that directly remove carbon from the atmosphere, the two main ones we will consider here are Biomass Energy Carbon Capture and Storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS). Neither of these are currently operating at scale in the UK, although there are demonstration projects operating in other countries[3].

Coupling bioenergy with carbon capture and storage to capture the $CO_2$ produced on combustion means that the process, known as BECCS, delivers negative emissions. Trees naturally pull $CO_2$ out of the atmosphere (absorbing it during photosynthesis). This results in carbon being stored in forests, vegetation and in the soil. While the burning of fossil fuels releases carbon that has been 'trapped' underground for many millions of years; when we burn sustainably sourced wood or other bioenergy crops, the $CO_2$ they emit can be offset by the $CO_2$ they have absorbed over their life, resulting in net zero emissions. Biomass can be burned in a power plant to generate electricity, or biomethane can be reformed to produce hydrogen. Combining these processes with carbon capture and storage technology to trap and store recently absorbed $CO_2$ can then result in negative emissions.

DACCS is technology which captures carbon dioxide directly from the air using a chemical process. It is in the early stages of technology development and offers a potential solution to offsetting residual fossil fuel emissions. It could be deployed in modular units and scaled up rapidly once the technology is proven. It is, however, a highly energy intensive process. Removing 5 $MtCO_2e$ is estimated to require 1.8TWh of electricity and 8 TWh of hydrogen[4]. It may be possible to use waste heat to meet some of the energy demand required by this process to reduce reliance on electricity. However, in general it is a technology that is only appropriate to deploy at scale once the power generation sector has been decarbonised or if it can be supplied directly by renewable electricity.

## What did we assume in FES 2020?

Our Future Energy Scenarios are based on an extensive annual engagement cycle with a range of industry stakeholders and experts. This includes our FES Bridging the Gap programme, which last year specifically focused on bioenergy. Within our FES 2020 scenarios we considered a range of outcomes for the availability of bioenergy feedstocks. The low case used in Steady Progression assumed limited UK policy support and poor global governance, leaving supply levels largely the same as today. The medium case used for Consumer Transformation and System Transformation assumed UK policy support enables domestic production to increase. Strategically managed land use and waste products led to around 211 TWh of bioresource, the majority domestically produced. In the high case scenario, used in Leading the Way, a favourable global context for sustainable biomass production was assumed. The UK was assumed to be an early mover in the developing global import market, resulting in access to around 275 TWh of bioresources (domestic and imported) by 2050.

Bioenergy resources were assumed to be used in a variety of sectors, including in industry, aviation, shipping and road transport, amongst others, but in the net zero scenarios the largest single use of bioresources was for power generation from BECCS, with between 7.8 and 9.6 GW of generation installed in 2050 in the net

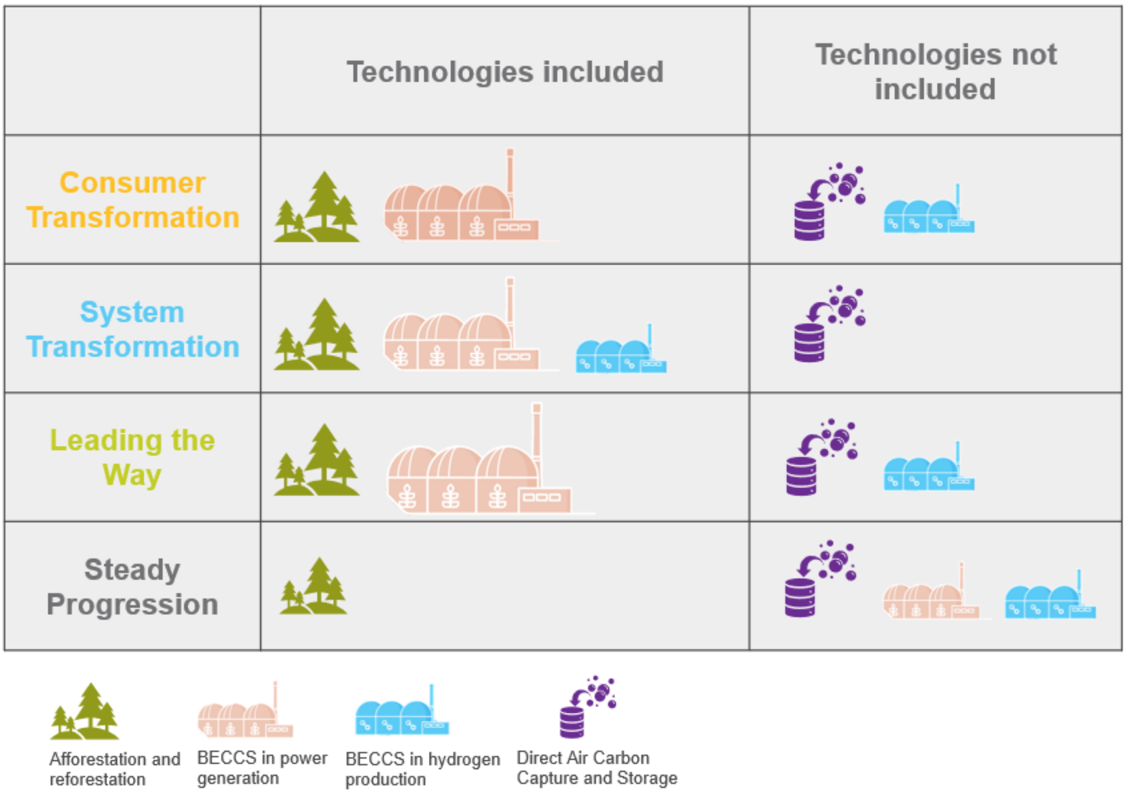
[3] Store&Go, Italy https://www.storeandgo.info/demonstration-sites/italy/
https://www.climeworks.com/co2-removal
[4] CCC Sixth Carbon Budget

zero scenarios, absorbing 49-61 $MTCO_2$ from the atmosphere each year. The high demand for bioresources for power generation limited their potential use in other sectors.

In System Transformation some bioenergy resources were also used to produce hydrogen, with biomethane displacing some natural gas use for this. When combined with CCS this also offered an alternative source of negative emissions.

Due to the uncertain and immature nature of direct air carbon capture technology we did not include it within FES 2020 as a source of negative emissions. All net zero scenarios did include some level of afforestation and reforestation however. Emissions associated with these natural climate solutions were captured within our assumptions on land use, land use change and forestry (LULUCF) which we based on work done by the Committee on Climate Change.

*Figure 1: Negative emissions technologies in FES 2020*




## Potential issues with reliance on bioenergy solutions for negative emissions

Not all biomass use can be considered carbon neutral and, if it is not, then this limits the scope to use this for negative emissions. For biomass feedstocks to be considered carbon neutral they need to meet sustainability criteria, and not all biomass in use today will meet this. Furthermore, while emissions from biomass combustion can be considered carbon neutral over an appropriate time period, high use of biofuels could increase emissions in the short term. This is because while combustion releases large amounts of carbon dioxide into the atmosphere, the trees planted take a number of years to grow to a point where they have absorbed the equivalent of these emissions. This issue can be mitigated by using faster growing variants of biomass such as miscanthus or other rapidly growing energy crops rather than forestry biomass with species of trees which take a long time to reach maturity. This does, however, place a limit on the scalability of forest biomass between now and the net zero target date of 2050.

There are also other considerations around the sustainability of bioresources, including the potential impact on the carbon sequestration of soils where they are grown, and the emissions associated with processing and transporting them from where they are grown to where they are needed. These emissions need to be captured in the lifecycle carbon assessment of bioresources. Today, emissions associated with processing and transport of biomass to UK biomass electricity generation plant can represent between 90-150 $kgCO_2$/MWh electricity generated, depending on the source of the biomass. In future this figure will be affected by decarbonisation of the transport sector. Carbon emissions associated with international imports of biomass would be affected by the pace of decarbonisation of international shipping which is likely to be slower than that of domestic road and rail transport.

Beyond this, availability of bioresources is affected by competition between different land uses. Land needed to grow energy crops for bioresources could alternatively be used for food production or afforestation (or reforestation if the land was formerly forested). These different uses all have different trade-offs, and demand for each will be affected factors explored in our ‘level of societal change’ axis in our scenario framework. For example, land needed for food production could vary depending on the people’s diets and the level of domestically produced food. Energy crops could also be used in hard to decarbonise sectors such as the aviation sector rather than being used for negative emissions. One avenue to decarbonise aviation would be to increase the use of biodiesel or biokerosene produced from energy crops. Alternatively, carbon neutral synthetic fuels could be produced from carbon captured from bioenergy generation. There are a wide range of competing resource uses for bioenergy in future as well as a range of potential sources of supply that we need to explore in our modelling.

How much bioresource we could source domestically, and the degree of import dependency is also important, as while the UK may be able to import bioresources as part of a global market, for the world to reach net zero any level of imports would need to be sustainable. The UK’s potential for future carbon storage in depleted North Sea oil and gas fields could lead to other countries exporting bioresources to the UK to be used in negative emission processes.

## Our emerging thinking for FES 2021

Within FES 2021 we intend to build on the feedback we have received from stakeholders to adjust our assumptions in this area. We will split out our assumptions on bioresource use into a more granular level, showing the use of different forms of bioresource including wood pellets, energy crops and waste.

Stakeholders have told us that negative emissions are important, with some sectors having not alternative options to decarbonise, but that sustainability of bioresources and biodiversity issues need to be considered. We also received feedback that the import of bioresources should be minimised and the range of import level in our scenarios should not be increased further.

We propose to diversify the sources of negative emissions we are using, with less reliance on BECCS (especially from the power sector) in some of the scenarios. This could be supplemented by lower residual emissions in some scenarios, and increased ambition for natural climate solutions. For negative emissions technologies there will be greater use of DACCS in some scenarios, while in System Transformation we expect to increase the use of bioresources to produce hydrogen as an alternative to BECCS power generation.

The potential use of DACCS reduces the reliance on bioresources for negative emissions. Unlike BECCS, which requires large amounts of land to grow the biomass feedstock, DACCS would have a relatively small land footprint, limited to the physical extent of the plant. They are flexible when it comes to location, so could be sited to take advantage of available low-cost energy and/or access to $CO_2$ storage capacity. It will, however, increase electricity demands further. Careful consideration will need to be given to the operation of this technology – if it is able to operate flexibility it could help integrate higher penetrations of variable renewable generation into the electricity generation mix. However, if it operates constantly to maximise negative emissions it will prove more challenging to integrate. When considering the viability of this technology we also need to consider the economic operation of the technology and the potential limiting factors to its growth.

We are keen to hear more from stakeholders about your views on different aspects of our FES modelling. If you are interested in sharing your thoughts on negative emissions and our modelling for FES 2021 please email us at Box.FES@nationalgrideso.com.