IEA Bioenergy

Bio-CCS and Bio-CCU

Climate change mitigation and extended use of biomass raw material

Summary Series

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What is Bio-CCS?

The term Bio-CCS describes concepts that combine biomass use with carbon capture and permanent underground storage (CCS). As opposed to fossil CCS, which at best only decreases the amount of CO_2 entering the atmosphere, Bio-CCS has the potential to provide net removal of CO_2 from the atmosphere. By binding atmospheric carbon during growth of biomass and subsequently capturing CO_2 from the biomass conversion process for permanent storage in geological formations, carbon is extracted from the carbon cycle, while at the same time avoiding fossil energy use (and associated CO_2 emissions). In order for Bio-CCS to provide net negative emissions, it is essential that the biomass production and use is sustainable. Bio-CCS can thus remove historic CO_2 emissions from the atmosphere and offset CO_2 emissions from sectors more challenging to decarbonize.

What is carbon capture and utilization (CCU)?

Carbon Capture and Utilization refers to the use of pure CO_2 or CO_2-containing gas mixtures as a feedstock to produce fuels, chemicals and materials. When fuels, chemicals and materials are produced using low-carbon energy sources, these products could displace their fossil counterparts and thus reduce net carbon emissions to the atmosphere.

The CO_2 molecule has little energy potential and the conversion of CO_2 into fuels or chemicals is highly energy-intensive. Consequently, the effectiveness of the CCU system as a climate mitigation option depends strongly on two conditions:

- Whether the energy input for CO_2 conversion originates from low-carbon or fossil sources;
- Whether the CO_2 utilized as feedstock comes from a fossil or atmospheric source.

In traditional, fossil resource based processes, carbon and energy originate from the same (fossil) source. CCU enables different inputs for energy (e.g. electricity) and carbon (CO_2). Here, carbon originating from the atmosphere (mixture of biogenic and fossil), captured either through direct air capture or from conversion of sustainable biomass, is defined as atmospheric carbon.

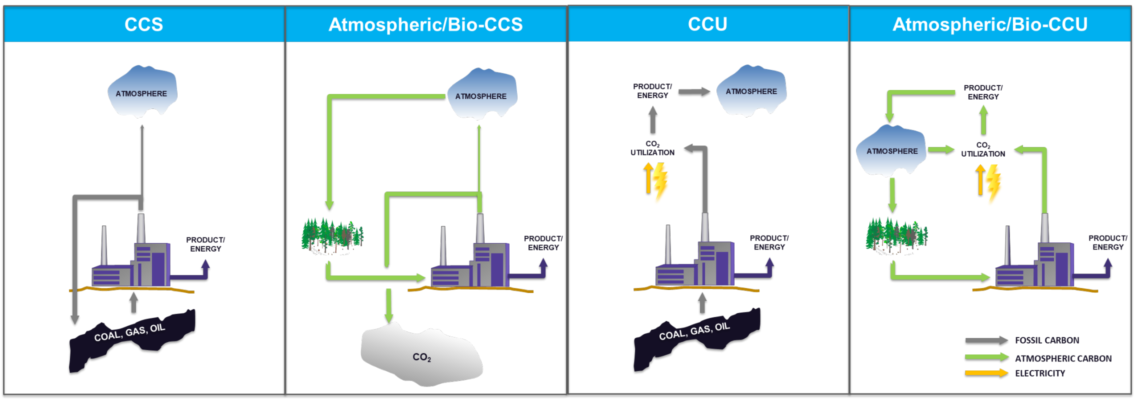

Figure 1 Conceptual comparison of carbon flows in fossil and biomass based CCU and CCS.

CCS, CCU and climate impact

Bio-CCS can provide permanent removal of CO_2 from the atmosphere. Bio-CCU, on the other hand, can be climate neutral at best, because the carbon is released at the end of the product life. For CCU to be able to offer very low emission solutions as a climate mitigation measure there are two essential requirements:

- Low-carbon/carbon neutral energy input for CO_2 conversion
- Carbon/CO_2 used as feedstock needs to be atmospheric

Unless these two prerequisites are met, fossil CO_2 will eventually reach the atmosphere, either from fossil energy for the conversion of CO_2 to products or when releasing fossil CO_2 contained in the CCU product at the end of its lifetime. In order to have a substantial direct climate impact, the delay in emission of CO_2 should be at least in the magnitude of centuries (>100 years). The climate impact mechanism of most CCU concepts is systemic in nature, and depends on the carbon intensity of the energy input to the concept. From a systemic perspective, CCU only has a positive climate impact if it enables a higher amount of low carbon input (solar, wind, etc.) to the energy system compared to an energy system without CCU. The challenge with CCU as a climate mitigation measure is the low cyclic efficiency, making use of electricity less efficient than with direct electrification. From a climate perspective, the most important applications of Bio-CCS and Bio-CCU identified in this project are:

- Indirect electrification of sectors otherwise difficult to decarbonize (when the electricity sector on average already has a low carbon intensity).
- Boosting the output of biomass based processes, such as gasification, fermentation or anaerobic digestion with renewable electricity (sustainable resources are a limiting factor with current global biomass use, and boosting the conversion would in theory double or triple the amount of bio-product per unit resource).
- Applications where high concentration CO_2 is captured and stored simultaneously with product generation (energy, hydrocarbon, material etc.).

Between May 2016 and January 2018 a Special Project of IEA Bioenergy organized four specific workshops concentrated on various aspects around Bio-CCS and Bio-CCU. Workshop summaries are available at: http://task41project5.ieabioenergy.com/iea-publications/