Reduce, Remove, Recycle:

Clarifying the Overlap between Carbon Removal and CCUS

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ICRLP Working Paper No. 2
December 2020

INSTITUTE *for* CARBON REMOVAL
LAW AND POLICY

Summary

The complicated relationship between carbon removal and carbon capture with utilization or storage (CCUS) causes confusion in climate policy conversations. Two questions about CCUS technologies and related direct air capture (DAC) technologies help cut through this confusion: where did the carbon come from, and where did it go? Asking these questions refocuses the discussion away from vexing technological categories and toward the different roles that these approaches can play in climate policy—namely, carbon removal, carbon recycling, and emissions reductions. Carbon dioxide captured directly from the atmosphere ("air carbon") or captured from the combustion or fermenting of biomass ("biocarbon") can be used for carbon removal or carbon recycling, depending on whether it ends up in geological storage or long-lived products or in short-lived products. "Fossil CCUS" can reduce emissions relative to fossil fuels without CCUS, provided that the captured carbon dioxide ends up in geological storage or long-lived products, but it cannot remove or recycle carbon. These relationships are depicted graphically in the last section of the paper. There are also many ways of reducing emissions and removing carbon without DAC or CCUS, but these are outside the scope of this paper.

Published December 2020 by the Institute for Carbon Removal Law and Policy at American University.

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The views expressed in this working paper are the authors' and do not necessarily reflect the views of their organizations.

Suggested Citation

Morrow, D.R. & Thompson, M.S. 2020. "Reduce, Remove, Recycle: Clarifying the Overlap between Carbon Removal and CCUS," Working Paper No. 2, Institute for Carbon Removal Law and Policy, American University, Washington, DC.

Introduction

Ask ten people what role "carbon capture" should play in addressing climate change, and you will likely get a dozen different answers, in part because the term "carbon capture" gets used in so many ways. It sometimes refers only to technologies that capture carbon dioxide from large point-sources, sometimes only to technologies that scrub carbon dioxide from the ambient air, and sometimes to both. This terminological confusion not only makes it harder to understand one another in important climate policy conversations, but it leads people to run together different technologies that could play very different roles in climate policy.

Of the various problems this causes, one important problem concerns the relationship between carbon removal and a set of technologies known as carbon capture and sequestration (CCS) or, more broadly, carbon capture with utilization and storage (CCUS). Carbon removal involves capturing carbon dioxide (CO_2) from the ambient atmosphere and sequestering it or storing it for a long time. CCUS involves capturing carbon dioxide from a large point-source, such as a power plant or steel factory, and either using the captured carbon to make new products or sequestering it in geological formations. Sometimes people keep these categories separate, despite the fact that some approaches to carbon removal use CCUS technologies. Sometimes people run the two categories together, despite the fact that some uses of CCUS do not amount to carbon removal and many approaches to carbon removal do not use CCUS. To make matters worse, direct air capture (DAC) technologies bear a strong family resemblance to CCUS technologies because both involve captured gaseous carbon dioxide, but DAC is often excluded from the category of CCUS because it captures carbon from the ambient air.

To cut through this confusion, we suggest worrying less about technological categories and focusing instead on two simple questions: Where does the carbon come from, and where does it go? These questions help distinguish different roles that different approaches can play in climate policy.

In focusing on DAC and CCUS, we deliberately exclude other approaches to carbon removal, such as ecosystem restoration and enhanced weathering, which use very different methods to capture or store carbon.[1] These are less often confused with CCUS and so are less in need of clarification.

Three sources of carbon

To understand various roles that DAC and CCUS can play, it is worth distinguishing three kinds of carbon, based on where the carbon comes from.

AIR CARBON	Air carbon is carbon dioxide that has been captured from the atmosphere using direct air capture technology.
BIOCARBON	Biocarbon is carbon dioxide produced by burning or fermenting grasses, trees, or other plants, which had absorbed the carbon from the air through photosynthesis.
FOSSIL CARBON	Fossil carbon includes carbon dioxide produced by burning fossil fuels, including coal, oil, and natural gas.

Figure 1 illustrates the pathways that lead to each kind of captured carbon. Note that air carbon and biocarbon are both derived from atmospheric carbon dioxide, whereas fossil carbon comes from carbon that had been buried underground.

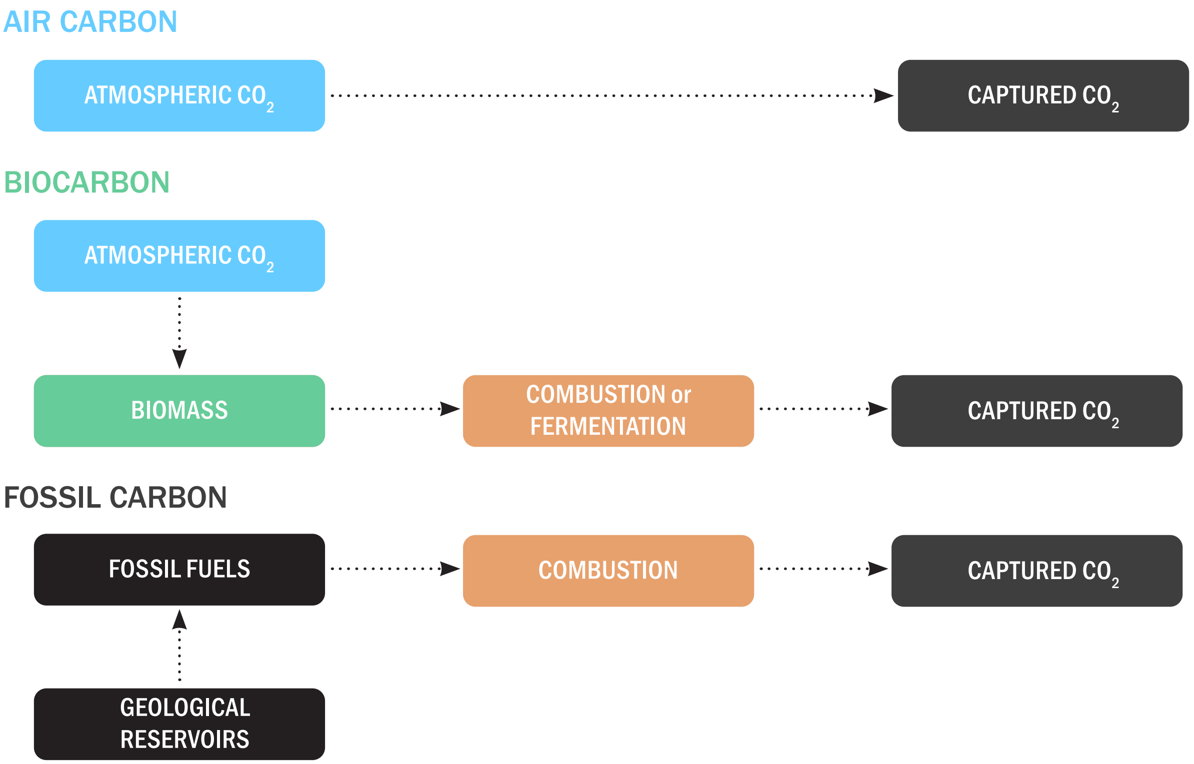


Figure 1. For the purposes of understanding the various roles that DAC and CCUS can play in climate policy, it is important to distinguish different sources of captured carbon.

Three places carbon can go

Carbon captured with DAC or CCUS can end up in three different places.

GEOLOGICAL STORAGE	Captured carbon can be sequestered in geological reservoirs. Most existing carbon capture operations with geological storage inject carbon dioxide into appropriate sedimentary rock formations, such as depleted oil and gas wells or deep saline aquifers, where non-porous cap rocks trap the carbon dioxide underground. A more recent approach injects carbon dioxide into basalt, where it reacts with the basalt to form solid minerals. Barring leaks from sedimentary formations through geological faults or leaky wellbores, geological storage is effectively permanent.
LONG-LIVED PRODUCTS	Captured carbon can be used to manufacture long-lived products, such as cement or durable polymers. While any sharp line between long-lived and short-lived products is somewhat arbitrary, a recent report from the US National Academy of Sciences classifies products as long-lived if their production results in carbon being kept out of the atmosphere for at least 100 years.[2]
SHORT-LIVED PRODUCTS	Captured carbon can be used to manufacture short-lived products, such as synthetic fuels or short-lived industrial chemicals. Again following the National Academy of Sciences report, any product whose use results in the re-emission of carbon dioxide in less than 100 years counts as a short-lived product.

Note that carbon captured by other means, such as ecosystem restoration or enhanced weathering, can end up in other places, such as stored in soils and biomass or dissolved in the ocean as bicarbonate. The categories in this working paper apply only to carbon captured with DAC or CCUS.

Three roles in climate policy

DAC and CCUS can serve three different roles in climate policy, depending on where the carbon comes from and where it goes: removing carbon from the atmosphere, recycling carbon that is already in the atmosphere, and reducing the amount of carbon released into the atmosphere.

Carbon removal

Carbon removal, sometimes called carbon dioxide removal (CDR) or negative emissions, is the process of taking carbon dioxide out of the atmosphere and sequestering it or storing it for a long time. Carbon removal could be used to draw down remaining "legacy carbon" after the end of the fossil fuel era. It could also be used to clean up emissions from harder-to-abate sectors, such as heavy industry, while societies figure out how to decarbonize those sectors.[3] While carbon removal cannot eliminate the need to cut emissions, it appears to be a necessary supplement to emissions reductions if the world is to meet ambitious climate goals.[4]

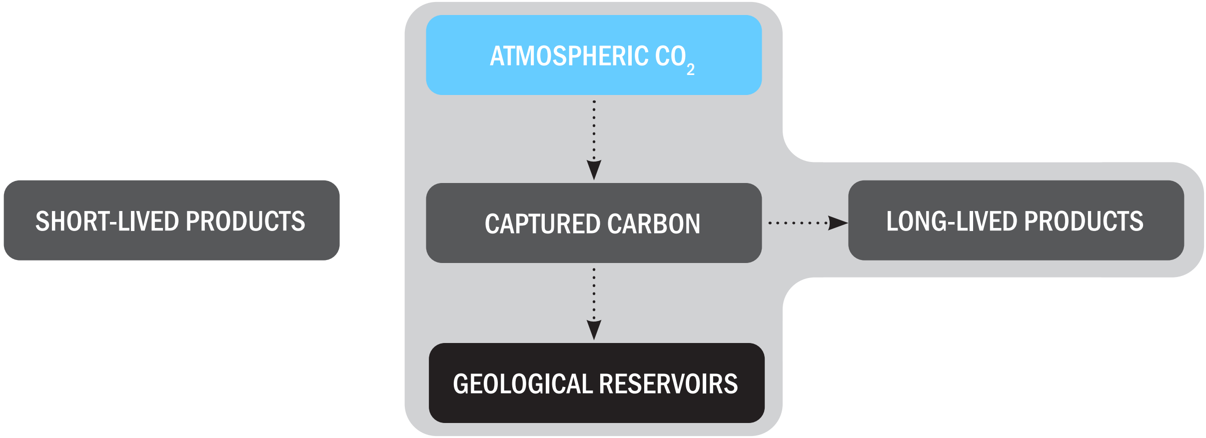


Figure 2. Carbon removal requires moving carbon dioxide from the atmosphere into long-lived products or geological reservoirs. This can be done using air carbon or biocarbon, but not fossil carbon. Short-lived products cannot be used to achieve carbon removal, regardless of the source of the carbon.

Carbon recycling

Carbon recycling involves taking carbon dioxide from the atmosphere and putting it to use in a way that returns carbon dioxide to the atmosphere within less than a century. Synthetic fuels made from air carbon offer a salient example: carbon dioxide is captured using direct air capture technology and then converted into fuel. When the fuel is burned, the carbon is released back into the atmosphere as carbon dioxide. It can then be recaptured to make more fuel.

While carbon recycling does not directly *reduce* carbon dioxide levels, it does not *add* to the amount of carbon dioxide in the atmosphere over the long run. Furthermore, if carbon recycling displaces fossil fuels, it can indirectly contribute to climate change mitigation by preventing the emission of carbon that is currently buried in geological reservoirs.

Short-lived products made from fossil carbon do not count as carbon recycling because the captured carbon dioxide had previously been safely underground, not in the atmosphere.

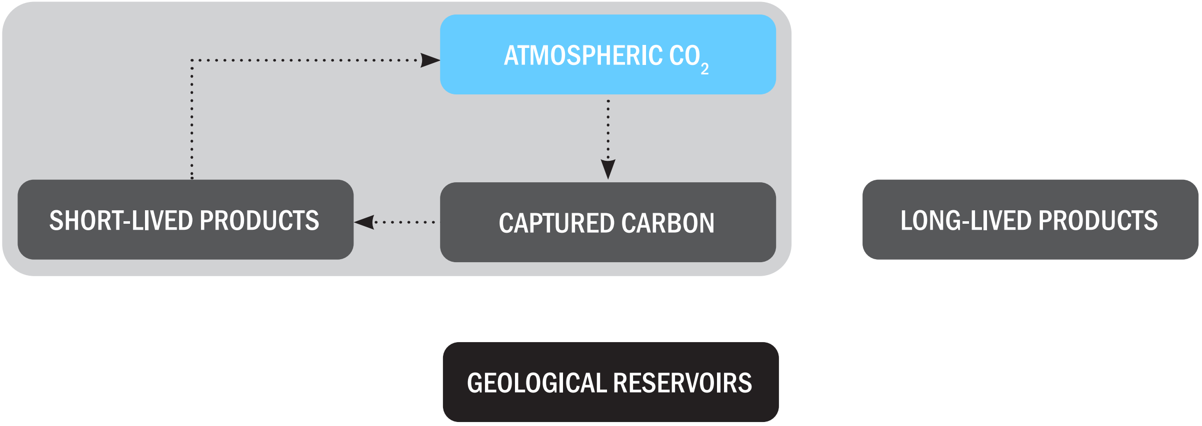


Figure 3. Carbon recycling involves converting carbon dioxide from the atmosphere into short-lived products, whose use re-emits that carbon into the atmosphere. In the long run, this does not directly increase or decrease atmospheric concentrations of carbon dioxide, although it can indirectly contribute to mitigating climate change if it displaces fossil fuel use.

Emissions reductions

Fossil CCUS that embeds the captured carbon in long-lived products or puts it into geological storage reduces carbon dioxide emissions, at least when compared to fossil fuels without CCUS or fossil CCUS that embeds the capture carbon in short-lived products. In effect, fossil CCUS creates a closed loop between geological reservoirs of carbon, preventing the fossil carbon from reaching the atmosphere.

Since most carbon capture technologies cannot capture 100 percent of a plant's carbon dioxide emissions, however, almost all fossil CCUS still involves some carbon dioxide emissions. Furthermore, because the CCUS technology itself uses energy, a fossil fueled power plant fitted with CCUS would need to burn more coal or gas to provide the same amount of electricity to the grid, leading to an increase in fossil fuel extraction compared to a plant without CCUS. Still, CCUS could help mitigate climate change by reducing carbon dioxide emissions, especially in places or industries where fossil fuels cannot easily be replaced by clean energy.

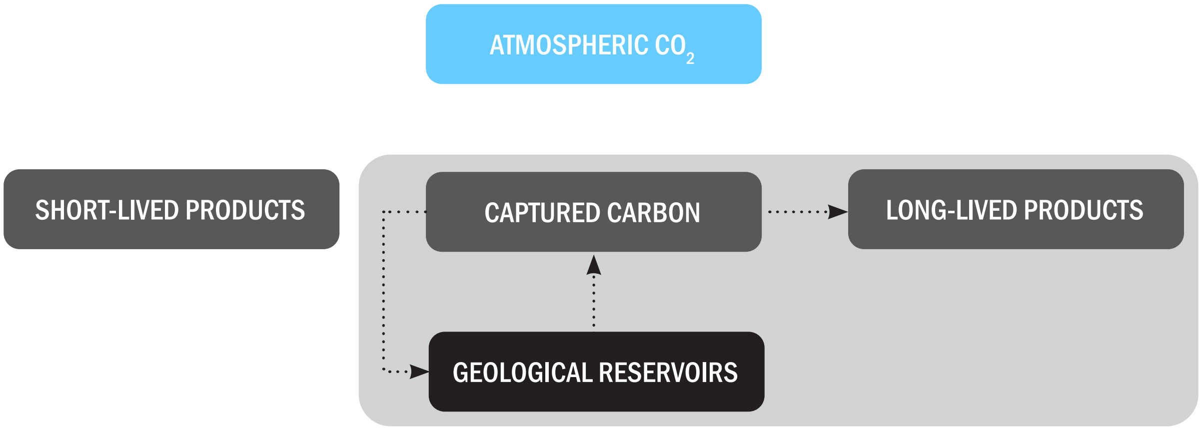


Figure 4. Fossil CCUS can reduce emissions, relative to fossil fuel use without carbon capture, if the carbon produced by burning fossil fuels is embedded in long-lived products or put into geological storage. Note that embedding captured fossil carbon in short-lived products does not reduce emissions.

Other ways of using captured carbon

Other approaches to using or storing captured carbon sometimes get lumped in with the previous approaches, but they differ in important ways.

First, fossil CCUS that embeds the captured carbon in short-lived products neither removes carbon, recycles carbon, or reduces carbon emissions. It merely delays the emission of fossil carbon into the atmosphere, as illustrated in Figure 5.

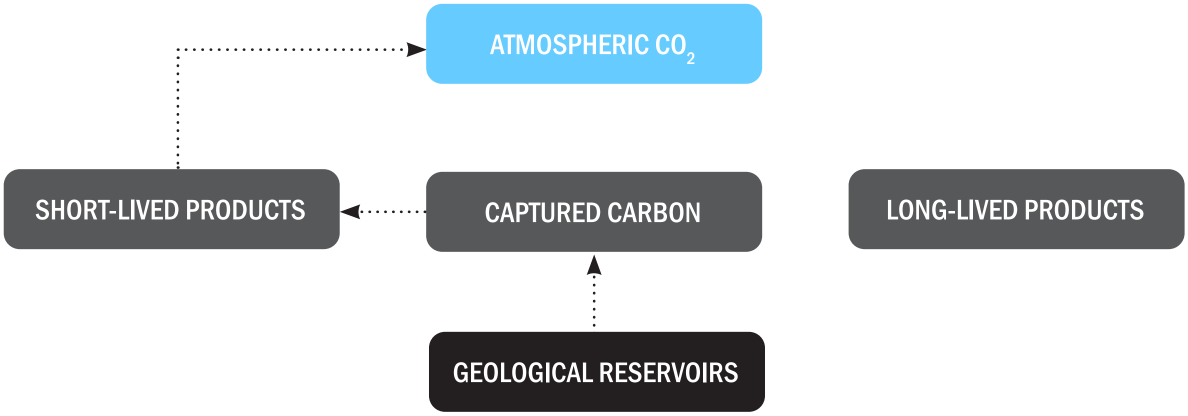
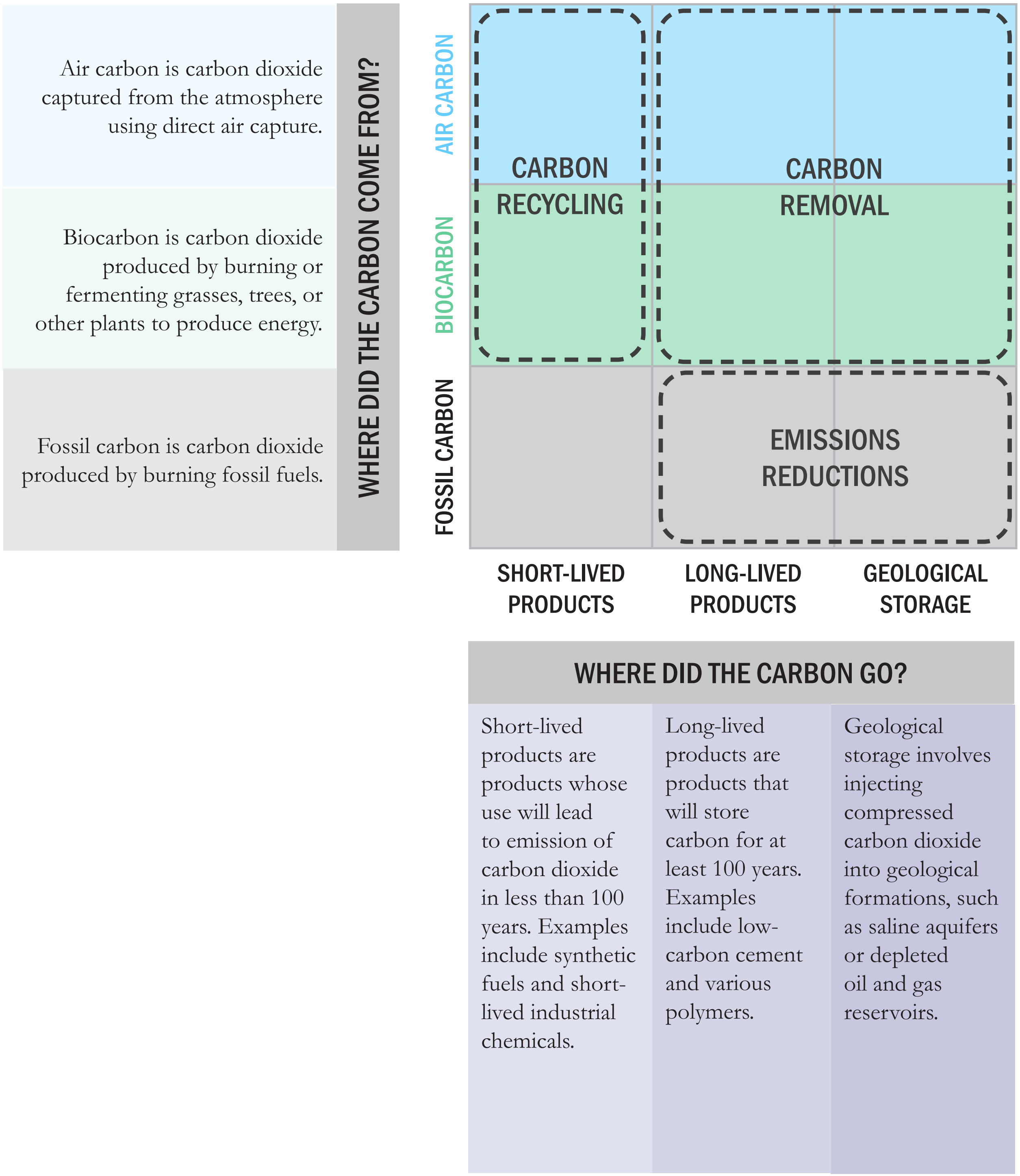


Figure 5. When fossil CCUS is used to produce short-lived products, the captured carbon is soon emitted to the atmosphere. This use of fossil CCUS neither reduces emissions nor removes carbon dioxide from the atmosphere.

Second, using captured carbon for enhanced oil recovery (EOR) has provoked intense controversy. EOR involves injecting captured carbon into oil and gas reservoirs to increase fossil fuel production from those reservoirs. Technically, EOR involves geological storage of captured carbon, since the injected carbon remains trapped underground. To the extent that EOR increases fossil fuel production, however, the emissions from those extra fossil fuels partly or entirely eliminate any climate benefit from injecting the captured carbon underground. Therefore, although EOR can have net-negative lifecycle emissions under specific circumstances,[5] it is not safe to assume that EOR involves carbon removal or emissions reductions once all relevant sequestrations and emissions are taken into account. Furthermore, EOR with fossil carbon never counts as carbon removal.

What can DAC and CCUS do?

To understand the roles that DAC and CCUS can play in climate policy, we suggest worrying less about technological categories and focus instead on where the captured carbon comes from and where the carbon goes, as shown below.



Air carbon is carbon dioxide captured from the atmosphere using direct air capture.

Biocarbon is carbon dioxide produced by burning or fermenting grasses, trees, or other plants to produce energy.

Fossil carbon is carbon dioxide produced by burning fossil fuels.

Short-lived products are products whose use will lead to emission of carbon dioxide in less than 100 years. Examples include synthetic fuels and short-lived industrial chemicals.

Long-lived products are products that will store carbon for at least 100 years. Examples include low-carbon cement and various polymers.

Geological storage involves injecting compressed carbon dioxide into geological formations, such as saline aquifers or depleted oil and gas reservoirs.

Notes

1. For a brief introduction to carbon removal, see: Institute for Carbon Removal Law and Policy, *Explainer: Carbon Removal* (Washington, DC: American University, 2020), https://carbonremoval.info/explainer. For a more detailed introduction, see: Royal Society, *Greenhouse Gas Removal* (London: Royal Society, 2018), https://royalsociety.org/greenhouse-gas-removal

2. See: National Academies of Sciences, Engineering, and Medicine, *Gaseous Carbon Waste Streams Utilization: Status and Research Needs* (Washington, DC: National Academies Press, 2019), https://doi.org/10.17226/25232. The report's glossary specifies 100 years of storage as the division between short-lived and long-lived products.

3. The question of what role(s) carbon removal should play in climate policy is itself hotly debated, with some arguing that (most kinds of) carbon removal should only be used for carbon drawdown and others arguing that it should be used to help reach net-zero emissions more quickly by offsetting emissions from harder-to-abate sectors. A report from the U.S. National Academy of Sciences recommends using it for both purposes. See: National Academies of Science, Engineering, and Medicine, *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda* (Washington, D.C.: National Academies Press, 2019), https://doi.org/10.17226/25259

4. On the importance of carbon removal in meeting ambitious climate policy targets, such as those established by the Paris Agreement, see: IPCC, *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* (Intergovernmental Panel on Climate Change, 2018), https://ipcc.ch/sr15

5. For a discussion of the conditions that would have to be met for enhanced oil recovery to sequester more carbon than is emitted by the increase in fossil fuel production, see: Christophe McGlade, "Can CO2-EOR really provide carbon-negative oil?" International Energy Agency, April 11, 2019, https://www.iea.org/commentaries/can-co2-eor-really-provide-carbon-negative-oil