Why we can't reverse climate change with 'negative emissions' technologies

October 9 2018, by Howard J. Herzog

A handful of commercial companies are testing direct air capture technology,, which takes carbon dioxide out of the air. This project in Italy will use the CO2 to ultimately produce natural gas to power vehicles. Credit: Climeworks

In a much-anticipated report, the Intergovernmental Panel on Climate

Change (IPCC) said the world will need to take dramatic and drastic steps to avoid the catastrophic effects of climate change.

Featured prominently in the report is a discussion of a range of techniques for removing carbon dioxide from the air, called Carbon Dioxide Removal (CDR) technologies or negative emissions technologies (NETs). The IPCC said the world would need to rely significantly on these techniques to avoid increasing Earth's temperatures above 1.5 degrees Celsius, or 2.7 degrees Fahrenheit, compared to pre-industrial levels.

Given that the level of greenhouse gases continues to rise and the world's efforts at lowering emissions are falling way short of targets climate scientists recommend, what contribution we can expect from NETs is becoming a critical question. Can they actually work at a big enough scale?

What are negative emissions technologies?

There is a wide range of opinion on how big an impact these techniques can have in addressing climate change. I became involved in the debate because two of the most prominent negative emissions technologies involve CO_2 capture and storage (CCS), a technology that I have been researching for almost 30 years.

Many NETs remove the CO_2 from the atmosphere biologically through photosynthesis – the simplest example being afforestation, or planting more trees. Depending on the specific technique, the carbon removed from the atmosphere may end up in soils, vegetation, the ocean, deep geological formations, or even in rocks.

NETs vary on their cost, scale (how many tons they can potentially remove from the atmosphere), technological readiness, environmental

impacts and effectiveness. Afforestation/reforestation is the only NET to have been deployed commercially though others have been tested at smaller scales. For example, there are a number of efforts to produce biochar, a charcoal made with plant matter that has a net negative carbon balance.

A recent academic paper discusses the "costs, potentials, and side-effects" of the various NETs. Afforestation/reforestation is one of the least expensive options, with a cost on the order of tens of dollars per ton of CO_2, but the scope for carbon removal is small compared to other NETs.

On the other extreme is direct air capture, which covers a range of engineered systems meant to remove CO_2 from the air. The costs of direct air capture, which has been tested at small scales, are on the order of hundreds of dollars or more per ton of CO_2, but is on the high end in terms of the potential amount of CO_2 that can be removed.

In a 2014 IPCC report, a technology called bio-energy with carbon capture and storage (BECCS) received the most attention. This entails burning plant matter, or biomass, for energy and then collecting the CO_2 emissions and pumping the gases underground. Its cost is high, but not excessive, in the range of US$100-200 per ton of CO_2 removed.

The biggest constraint on the size of its deployment relates to the availability of "low-carbon" biomass. There are carbon emissions associated with the growing, harvesting, and transporting of biomass, as well as potential carbon emissions due to land-use changes – for example, if forests are cut down in favor of other forms of biomass. These emissions must all be kept to a minimum for biomass to be "low-carbon" and for the overall scheme to result in negative emissions. Potential "low-carbon" biomass includes switchgrass or loblolly pine, as opposed to say corn, which is currently turned into liquid fuels and

acknowledged to have a high carbon footprint.

Some of the proposed NETs are highly speculative. For example, ocean fertilization is generally not considered a realistic option because its environmental impact on the ocean is probably unacceptable. Also, there are questions about how effective it would be in removing CO_2.

Negative emissions technologies

Technology or technique	Description	CO2 Removal Mechanism	CO2 Storage Medium
Afforestation/reforestation	The planting of trees to fix atmospheric carbon in biomass and soils	Biological	Soils/Vegetation
Biochar	Converting biomass to biochar and using the biochar as a soil amendment	Biological	Soils
Bioenergy with CO2 capture and storage	Removal the CO2 from the air by plants into biomass, combustion of the biomass to produce energy and CO2, which is captured	Biological	Deep Geologic Formations
Direct air capture	Removal of CO2 from ambient air by engineered systems	Physical/chemical	Deep Geologic Formations
Enhanced weathering (Mineral carbonation)	Enhancing the weathering of minerals, where CO2 in the atmosphere reacts with silicate minerals to form carbonate rocks	Geochemical	Rocks
Modified agricultural practices	Adopting agricultural practices like no-till farming to increase carbon storage in soils	Biological	Soils
Ocean (iron) fertilization	Fertilizing the ocean to increase biological activity to pull carbon from the atmosphere into the ocean	Biological	Ocean
Ocean alkalinity	Adding alkalinity to the oceans to pull carbon from the atmosphere via chemical reactions	Chemical	Ocean

Credit: Chart: The Conversation, CC-BY-ND Source: Howard Herzog, MIT

Academic takes

A 2017 study at the University of Michigan did a literature review of NETs. One the one hand, they showed that the literature was very bullish on NETs. It concluded these techniques could capture the equivalent of 37 gigatons (billion tons) of CO_2 per year at a cost of below $70 per metric ton. For comparison, the world currently emits about 38 gigatons of CO_2 a year.

However, I think this result should be taken with a large grain of salt, as they rated only one NET as established (afforestation/reforestation), three others as demonstrated (BECCS, biochar and modified agricultural practices), and the rest as speculative. In other words, these technologies have potential, but they have yet to be proven effective.

Other studies have a much harsher view of NETs. A study in Nature Climate Change from 2015 states, "There is no NET (or combination of NETs) currently available that could be implemented to meet the