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Negative emissions tech: can more trees, carbon capture or biochar solve our CO2

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As CO2 levels rise, controversial techniques including carbon capture and storage, enhanced weathering and reforestation may be solutions

Reforestation is the least controversial negative emissions technology - but a substantial amount of good quality land is needed. Photograph: Jenny Bonner/Getty Images

In the 2015 Paris climate agreement, 195 nations committed to limit global warming to two degrees above pre-industrial levels. But some, like Eelco Rohling, professor of ocean and climate change at the Australian National University's research school of earth sciences, now argue that this target cannot be achieved unless ways to remove huge amounts of carbon dioxide from the atmosphere are found, and emissions are slashed.

This is where negative emissions technologies come in. The term covers everything from reforestation projects to seeding the stratosphere with sulphates or fertilising the ocean with iron fillings.

It's controversial - not least because of the chequered history of geoengineering-type projects, but also because of concerns it will grant governments and industry a licence to continue with business as usual. But many argue we no longer have a choice.

"Most things are not applied yet on larger scales but we have a pretty good feeling of things that will work and we can quantify roughly how much carbon we should be able to remove from the atmosphere with them," says Rohling.

The scale of the task is staggering, says Dr Pep Canadell, from the global carbon project at CSIRO.

"The models are basically asking for removing carbon dioxide from the atmosphere which will be equivalent of one-quarter of all carbon emissions at present," he says.

This amounts to about 10 billion tonnes of carbon dioxide removed from the atmosphere and disposed of each year.

The least controversial method of doing this is deceptively simple: plant more trees. "We have lost a lot of density of carbon in the landscapes because of deforestation and degradation. We have depleted carbon in the soils in all the problem areas of the world," Canadell says. "What are the opportunities to bring some of this carbon back?"

Again, the scale of reforestation efforts needed to make a dent in atmospheric carbon dioxide is substantial.

"We would need as many as three Indias worth of land globally - and good quality land, not marginal land," Canadell says. Reforestation also needs enough water, and needs to be done in such a way that it enriches the soil and ecosystems, not deplete them.

The fact that so many soils are carbon-depleted by intensive agriculture offers a way to tackle two environment challenges at the same time. Biochar is a form of charcoal produced by heating plant material in the absence of oxygen. Agricultural waste, which would otherwise be a major source of greenhouse gas emissions if burnt, could instead be turned into a biochar - a process that produces more energy than it consumes - and the biochar could then be used to enrich agricultural soils with carbon. Research suggests that biochars not only boost crop yields, but could lock away carbon for several thousand years.

Another approach designed to lock away carbon while also helping depleted soils is enhanced weathering.

Olivine refers to a group of silicate minerals that react with carbon dioxide to form other compounds. Enhanced weathering aims to amplify this chemical interaction by mining huge quantities of olivine - which is widespread and relatively abundant - and pulverising it to maximise its exposure to the air, then spreading it over areas such as agricultural fields to add carbon to the soils.

Rohling believes enhanced weathering is very promising, but it does have some significant downsides.

"It's not one of the most expensive approaches but it does require large-scale mining, which we do for everything else anyway," he says. The mining would also consume significant amounts of energy, which reduces the efficiency of the process by up to one-third.

The oceans are of particular interest for negative emissions because of their enormous capacity for carbon dioxide. One proposal is to fertilise the oceans with powdered iron or olivine. This boost in important nutrients leads to an increase in phytoplankton which, when it dies, decomposes and sinks to the seafloor, taking the carbon with it.

This phenomenon occurred naturally during recent ice ages, Rohling says, when the Southern Ocean was fertilised with dust from South America and Australia. But any project that attempted to alter the biochemistry and ecology of the oceans would very quickly run foul of international conventions, and rightly so.

"The law of the sea would forbid you from dumping things that will affect the environmental chemistry or ecology, and that's exactly what you want to do," he says.

As atmospheric carbon dioxide rises above 400 parts per million (ppm) for the first time in human history, there's even talk of direct capture of carbon dioxide, using huge versions of the atmospheric scrubbers that remove carbon dioxide from the air on board spacecraft.

Canadell's strongest bet is on carbon capture and storage, but instead of sucking it out of the air, he wants to see every facility that produces carbon dioxide equipped with technology to capture it at the release point.

"Anything that can be attached to any plants that are emitting carbon, either it's a full power plant, a bioenergy burning biomass to produce electricity or carbon capture storage that is associated to industrial processes which release carbon," he says. The captured carbon can then be disposed of deep underground in abandoned oil and gas wells, saline aquifers, or in the kind of geology that locks it away chemically.

While not strictly a negative emissions technology, he argues that as long as we continue to emit carbon dioxide, we cannot hope to remain below two degrees of warming unless we find a way to capture it.

Whatever the choice of negative emissions technology, Rohling says we are running out of time to study and implement them responsibly. He's worried that at the first big global climate change disaster, governments will respond with a knee-jerk embracing of whatever negative emissions technologies they can, regardless of whether scientists have adequately explored the consequences.

"We need to start preparing so we know what we're talking about when we need it," he says.