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Going negative: Scientists explore new technologies that remove atmospheric CO2

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In his Feb. 12 State of the Union address, President Obama singled out climate change as a top priority for his second administration. "We can choose to believe that Superstorm Sandy, and the most severe drought in decades, and the worst wildfires some states have ever seen were all just a freak coincidence," he said. "Or we can choose to believe in the overwhelming judgment of science – and act before it's too late."

Four years ago, the president addressed rising global temperatures by pledging a 17 percent cut in carbon dioxide (CO2) and other greenhouse gas emissions in the United States by 2020, and an 80 percent cut by 2050. The administration has taken a number of steps to meet those goals, such as investing billions of dollars in wind, solar and other carbon-neutral energy technologies.

But reducing CO2 emissions may not be enough to curb global warming, according to scientists at Stanford University. The solution, they say, could also require developing carbon-negative technologies that remove large amounts of CO2 from the atmosphere. Their findings are summarized in a report by Stanford's Global Climate and Energy Project (GCEP).

"To achieve the targeted cuts, we would need a scenario where, by the middle of the century, the global economy is transitioning from net positive to net negative CO2 emissions," said report co-author Chris Field, a professor of biology and of environmental Earth system science at Stanford. "We need to start thinking about how to implement a negative-emissions energy strategy on a global scale."

In the GCEP report, Field and lead author Jennifer Milne describe a suite of emerging carbon-negative solutions to global warming – from bioenergy technologies to ocean sequestration. Many of the examples cited were initially presented at a negative carbon emissions workshop hosted by GCEP in 2012.

BECCS

"Net negative emissions can be achieved when more greenhouse gases are sequestered than are released into the atmosphere," explained Milne, an energy assessment analyst at GCEP. "One of the most promising net-negative technologies is BECCS, or bioenergy with carbon capture and storage."

A typical BECCS system converts woody biomass, grass and other vegetation into electricity, chemical products or fuels, such as ethanol. CO2 emissions released during the process are captured and stored. The technology can be used in power plants, paper mills, ethanol processors and other manufacturing facilities.

As a carbon-negative technology, BECCS takes advantage of the innate ability of trees, grasses and other plants to absorb atmospheric CO2 for photosynthesis. In nature, the CO2 is eventually released back into the atmosphere as the plant decays. But when vegetation is processed at a BECCS facility, the CO2 emissions are captured and prevented from re-entering the environment. The result is a net-negative reduction in atmospheric CO2.

The GCEP report identified 16 BECCS projects at various stages of development around the world. The first project was launched in 2009 by the Department of Energy at a corn ethanol production facility in

Decatur, Ill., operated by the Archer Daniel Midlands Company. Each day, about 1,000 metric tons of CO_2 emitted during ethanol fermentation are captured and stored in a sandstone formation some 7,000 feet underground. The goal of the project is to sequester 1 million metric tons of CO_2 a year – the equivalent of removing 200,000 automobiles from the road.

Approximately 60 percent of global CO_2 emissions come from power plants and other industries fueled by coal, natural gas and oil. Capturing and sequestering those emissions could play a significant role in curbing global warming. To make the process carbon negative, researchers have proposed a BECCS co-fired power plant that runs on a mixture of fossil fuel (such as coal) and vegetation (wood, grass or straw, for example). A percentage of the CO_2 emissions would come from burnt vegetation. Therefore, capturing and storing those emissions would be a net-negative process.

Estimates show that by 2050, BECCS technologies could sequester 10 billion metric tons of industrial CO_2 emissions annually worldwide. But according to the GCEP report, major technical and economic hurdles must be overcome, such as the relative inefficiency of biomass fuels and the high cost of carbon capture and storage (CCS).

Financial incentives are needed to encourage private sector investment in CCS and BECCS, said Olivia Ricci of the University of Orléans in France. "To meet ambitious climate targets, a cost-effective policy would be to implement a carbon tax and to recycle the revenues to subsidize captured emissions from biomass," Ricci said. A carbon tax would put a price on CO_2 emissions and increase the competitiveness of CCS, while an emission subsidy would encourage BECCS deployment, she added.

"We're going to be burning fossil fuels for many years to come," said

Field, who also serves as director of the Carnegie Institution Department of Global Ecology at Stanford. "BECCS is one of the only proven technologies that uses fossil fuels and actually removes CO2 from the atmosphere."

Biochar

Field and Milne also assessed the pros and cons of biochar – a carbon-negative technology based on the same principal as BECCS.

Biochar is a plant byproduct similar to charcoal that can be made from lumber waste, dried corn stalks and other plant residues. Heating vegetation slowly without oxygen – a process called pyrolysis – produces carbon-rich chunks of biochar that can be placed in the soil as fertilizer. Like BECCS, the goal is to permanently lock carbon underground instead of letting CO2 re-enter the atmosphere as the plant decomposes.

One advantage of biochar is its simplicity, the authors said. Implementing biochar technology on a global scale could result in the sequestration of billions of metric tons of carbon a year, they added.

However, long-term sequestration "would require high biochar stability," they wrote. "Estimates of biochar half-life vary greatly from 10 years to more than 100 years. The type of feedstock also contributes to stability, with wood being more stable than grasses and manure."

In addition to long-term stability, questions have been raised about the impact of biochar on soil conservation, biodiversity and water use. As an example, the authors pointed to research showing that negative effects on soil fertility can occur if the pH of the biochar and the soil are not well matched.

According to the authors, biochar systems can be net negative if the biochar is made from waste biomass, sustainably harvested crop residues or crops grown on abandoned land that has not reverted to forest. On the other hand, biochar production that relies on forest ecosystems may result in a net increase in greenhouse gas emissions, they cautioned.

Net-negative farming

Even large agricultural systems can be net negative. The GCEP report cited research by Jose Moreira of the University of Sao Paulo. Using computer models, Moreira found that from 1975 to 2007, ethanol production from sugar cane in Brazil resulted in a net-negative capture of 1.5 metric tons of CO2 per cubic meter of ethanol produced. "In this model, the system took 18 years to recoup carbon emissions, with most reductions coming from soil replenishment from root growth and replacement of gasoline with ethanol," the GCEP authors wrote. However, questions remain about the long-term effects of ethanol combustion on climate.

The report also explored the possibility of sequestering carbon in the ocean, with a particular focus on the problem of ocean acidification, which is destroying coral reefs around the world. Ocean acidification results from the increased uptake of atmospheric CO2, which causes seawater to become more acidic. The authors cited research by David Keith of Harvard University suggesting that magnesium carbonate and other minerals could be added to the ocean to reduce acidity and sequester atmospheric CO2 absorbed in seawater. Although the potential for CO2 sequestration in the ocean is large, "the associated risks to the marine environment need to be adequately assessed," the authors concluded.

Keith has also launched a startup company called Carbon Engineering that's developing industrial-scale machines – "artificial trees" – that are designed to capture CO2 directly from the air. Unlike BECCS and biochar systems, which produce electricity or fuels, mechanical "trees" do not generate power and, in fact, require natural gas to operate.

Following the 2012 negative-emissions workshop, GCEP issued an international request for proposals to develop net-negative carbon emissions technologies. The awardees will be announced later this year. Up to to $6 million could be awarded.

More information: gcep.stanford.edu/events/works … egemissions2012.html

Provided by Stanford University

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