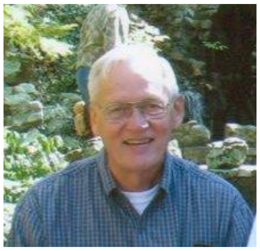
CARBON CAPTURE AND SEQUESTER (CCS)
By Gary Antonides



While there are a number of techniques that are being considered for CCS, the most popular seems to be planting trees because they absorb CO_2. To get a feeling for how much that will help, Penn State has published "How many trees are needed to take up the carbon dioxide I release every day?" by Bruce Logan, April 20, 2021. (https://iee.psu.edu/news/blog/how-many-trees-are-needed-take-carbon-dioxide-i-release-every-day#:~:text=If%20you%20add%20up%20all,7%20acres%20of%20forested%20land).

As we consume oxygen and release carbon dioxide into the air, the carbon we release comes from the food we eat. On average, we exhale about 2 pounds of CO_2 a day. And it takes about 15 trees to take up that much CO_2.

But the fossil fuels used to produce food releases a lot more carbon into the environment. Getting food to our homes or restaurants takes a lot of energy, most of which now comes from fossil fuels. Producing food requires energy for making fertilizer, plowing fields, maintaining and harvesting crops, processing, storing, and transporting the food. Adding it all up, in the US, each person needs about 375 trees to put food on the table.
To that total, add in carbon dioxide released from fossil fuels used for our other daily activities, such as driving our cars, heating and cooling our homes, and all the electricity we use. If you add up all the CO_2 released for everybody in the country, you will need about 730 trees each, or roughly 7 acres of forest.

Compare this to how much land is available. Earth's total land mass is about 36 billion acres, but about a third is uninhabitable (mostly desert and glaciers), about another third is crop land, and the final third is forested. (Developed land is actually a small percentage of the total.) So about 12 billion acres serves almost 8 billion people, about 1-1/2 acres each, or about 1/5 what would be needed if the whole world had the same life style as the US.

So, other than not using fossil fuels and growing trees, what other options will we have? Although we can't sequester and store carbon on a large scale now, it may be a major factor in the future. This is discussed in "8 Ways to Sequester Carbon to Avoid Climate Catastrophe," Ensia, Jul 19, 2017, By Mary Hoff **(**https://www.ecowatch.com/carbon-sequestration-2461971411.html)

Klaus Lackner, from Arizona State University is working on a carbon capture system that would involve 100 million semi-trailer-size boxes, each filled with a beige fabric configured to maximize surface area. Each box draws in air, and as it does, the fabric absorbs CO_2, which it later releases in concentrated form to be made into concrete or plastic or piped far underground. Though the technology is not yet operational, it's ready for a small pilot project. Lackner figures that the network of boxes could capture perhaps 40 billion tons/year at a cost of $30 per ton. Human-generated CO_2 emissions worldwide were around 45 billion tons (Gigatons, or Gt) in 2015, according to the National Oceanic and Atmospheric Administration.

Lackner is one of hundreds, if not thousands, of scientists around the world who are working on ways to remove CO_2 from the atmosphere using plants, rocks or engineered chemical reactions and storing it in soil, products such as concrete and plastic, rocks, underground reservoirs or the ocean.

Some of these "negative emissions technologies" are just unproven ideas. Others, such as the low-tech schemes like planting more forests or leaving crop residues in the field, or more high-tech negative emissions setups like the CO_2-capturing biomass fuel plant that went online last spring in Decatur, Illinois (more on this below) are already underway.

Many Approaches. Virtually all climate change experts agree that to avoid catastrophe, we must do everything we can to reduce CO_2 emissions. But an increasing number are saying we also need to actively remove CO_2 from the air in large quantities. "It's almost impossible that we could limit temperature rise to 2°C, much less 1.5°C, without some sort of negative emissions technology," said Pete Smith, from the University of Aberdeen and one of the world's leaders in climate change mitigation.

In fact, scientists from around the world recently drew up a "road map" to a future that gives us good odds of keeping warming below the 2ºC threshold. It requires completely phasing out fossil fuels, but also sequestering 0.7 Gt of CO_2 per year by 2030, 6.0 Gt by 2050, and 20 Gt by 2100.

One approach of sequestering CO_2 is not going to be enough. Lots of trees will help, but they compete with agriculture for land. Soil can't store enough, machines like the ones Lackner envisions take too much energy, and we don't have the engineering figured out yet for underground storage. Several approaches, along with some serious research and development, are needed.

Smith suggests dividing the many approaches into two categories: (1) relatively low-tech strategies that are ready to go, such as reforestation and improving agricultural practices, and (2) advanced options that need substantial research and development to become viable. Then, start doing the former right away, and start developing the others. Here is a look at some of the main approaches being considered.

Afforestation and Reforestation. The IPCC estimated that a single acre of forest can take up between 0.6 and 13 tons of CO_2 per year, depending on the kinds of trees, how old they are, the climate, etc. They figure that, worldwide, forests currently sequester on the order of 2 Gt of CO_2 per year. (This is much less than Penn State's estimate mentioned earlier, which would be about 10 Gt per year). Planting trees in new places (afforestation) and replanting deforested acreage (reforestation) could increase this by a gigaton or more, depending on species, forest management, politics, etc., and possibly genetic modification of trees and plants to improve their ability to take up and store carbon

Another way to help trees' ability to store carbon is to make long-lasting products from them—wood-frame buildings, books and so on. Using carbon-rich wood for construction, for example, along with afforestation, might store 1.3 to 14 Gt CO_2 per year, according to The Climate Institute, an Australia-based research organization.

Carbon Farming. Carbon farming uses plants to trap CO_2, using practices such as reduced tilling, planting longer-rooted crops and incorporating organic materials into the soil to encourage the trapped carbon to move into, and stay in, the soil. Currently, many agricultural soils are losing more carbon than they are sequestering. Improving plant and soil management offers a practical and almost immediate method to reduce CO_2. Research initiatives by the Advanced Research Projects Agency–Energy, a U.S. government agency, and others are aimed at improving crops' capacity to transfer carbon to the soil.

Other Vegetation. Although forests and farmland have drawn the most attention, other kinds of vegetation (grasslands, coastal vegetation, peatlands) also take up and store CO_2, and enhancing their ability to do so could help. Coastal plants, such as mangroves, seagrasses and vegetation inhabiting tidal salt marshes excel at sequestering CO_2 in vegetation, significantly more per area than terrestrial forests, according to Meredith Muth with the National Oceanic and Atmospheric Administration. That's because the oxygen-poor soil in which they grow inhibits release of CO_2 back to the atmosphere, so carbon simply builds up. With mangroves sequestering roughly 600 tons per acre; salt marshes, 400 tons; and seagrass, 160 tons, restoring lost coastal vegetation and extending coastal habitats will sequester substantial carbon and also help protect coastlines from erosion as sea levels rise.

Bioenergy & Bury. In addition to storing CO_2 in plants and soil, we can enhance sequestration by storing the carbon from plants in other ways. For example, the $208 million power plant that recently started operation in Illinois is one of several facilities that use what may be the most promising technology for removing large amounts of carbon from the air: bioenergy carbon capture and storage (BECCS). There are a number of industrial processes that can use biomass, including producing biofuels and generating electricity. The process might involve combustion, pyrolysis, or gasification of biomass, all of which produce CO_2. Rather than sending the CO_2 released into the air, BECCS captures and concentrates it, then traps it in material such as concrete or plastic or, as is the case for the Illinois plant, injects it into rock formations that trap the carbon far below Earth's surface. If the biomass used is agricultural waste, forest residue, even municipal waste, or ocean kelp, there is a net reduction of CO_2 in the air. But if the biomass is grown specifically for fuel, the net CO_2 may not be reduced, because how water, fertilizer, and land are used become factors.

Biochar. Another way to enhance plants' ability to store carbon is to partly burn materials such as logging slash or crop waste to make a carbon-rich, slow-to-decompose substance known as biochar, which can then be buried or spread on farmland. Biochar has been used for centuries to enrich soil for farming, but of late has been drawing increased attention for its ability to sequester carbon.

Fertilizing the Ocean. Plants and plantlike organisms that live in the ocean absorb immeasurable amounts of CO_2 each year. Their ability to do so is limited by the availability of iron, nitrogen and other nutrients they need. So researchers are looking at strategies for fertilizing the ocean or bringing nutrients up from the depths. A decade or so ago, companies began planning to do just that, anticipating a global carbon market that seemed likely at the time. These plans have largely remained on the drawing board, due to delays in putting a price tag on carbon, concerns over disrupting fisheries and ocean ecosystems, and high energy requirements. In addition, we don't know how much of the carbon trapped would actually stay in the ocean rather than reentering the atmosphere.

Rock Solutions. CO_2 is naturally removed from the atmosphere every day through reactions between rainwater and rocks. Some climate scientists propose enhancing this process by crushing rocks and exposing them to CO_2 in a reaction chamber or spreading them over large areas of land or ocean, increasing the surface area over which the reactions can occur. As currently imagined, these strategies are expensive and energy-intensive due to the need to transport and process large quantities of heavy material. Some also require extensive land use. Researchers are looking at using mine waste as well as refining the strategy in other ways.

Direct Air Capture and Storage. The carbon-sequestering containers from Arizona State University that were mentioned before, along with other projects such as a Climeworks' carbon-trapping facility in Switzerland, represent one of the more widely proposed greenhouse gas capture and storage technologies. Known as direct air capture and storage, this uses chemicals or solids to capture the gas from the air and store it underground or in long-lasting materials. Already used in submarines and in space vehicles, this theoretically can remove CO_2 from the air a thousand times more efficiently than plants, according to Lackner. The technology, however, is embryonic, and it is a huge energy hog.

Where to From Here? With the need to do something becoming ever more urgent, researchers are starting to take a closer look at the various technologies and putting together research agendas to advance the most promising. In May 2017, a National Academy of Sciences study panel began holding a series of meetings to identify research priorities.

But technology may not be the limiting factor in the long run. Getting carbon storage up and running is also about creating markets and/or policies that reward it. The most obvious way to do this would be to affix a price to carbon, which would provide a financial benefit for sequestering it.