With climate catastrophe looming, experts say world also needs carbon removal solutions

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Elisabeth Gilmore compares the world's urgent need to find alternatives to remove excess carbon dioxide from the air to a family bank balance

depleted by a shopping spree.

While the world's carbon budget isn't completely overdrawn, said Gilmore, a visiting professor at Rutgers University and associate professor at Canada's Carleton University, "we're really, really close."

The globe is on track to exceed the carbon budget set by world leaders in Paris in 2015. Now the world can no longer rely solely on slashing emissions to lower the excess carbon dioxide and avoid catastrophic consequences, the United Nations Intergovernmental Panel on Climate Change concluded in a series of reports over the past year.

Fortunately, the climate panel's April report highlighted a number of strategies for removing excess carbon that are being used or studied around the world. Some are as natural as planting more trees. Others rely on cutting-edge machine technologies to do things like vacuuming carbon dioxide out of the air.

"Really great innovations are happening," said Angela Anderson, director of industrial innovation and carbon removal for the World Resources Institute.

Seeing the opportunities laid out in the report gives researchers hope for a potential pathway to keep the global average temperature increase to no more than 1.5 degrees Celsius and meet the world's catastrophe-averting carbon budget.

"By carefully using carbon dioxide removal, we can buy ourselves a little more time and space," said Gilmore, an author on the panel's report released in February.

Yet while carbon removal may be necessary to keep the world from continuing to see rising temperatures and all their harmful effects, the

strategy could pose a risk if it serves as a "distraction from the real task at hand—getting off fossil fuels," said Michael Mann, a climatologist at Penn State University and author of "The New Climate War."

Mann has his own analogy to describe the world's relationship with carbon emissions, noting that carbon removal "simply cannot be done at the scale necessary to make a substantial dent in our carbon emissions as long as we remain dependent on fossil fuels." Attempting to do so, he said, would be like trying to empty the water from a sinking boat with a paper cup before plugging the hole in the bottom.

But whether the goal is akin to saving the boat or the family's finances, the world needs to work together on a full suite of alternatives to try to stay within its temperature targets, said Ben Wilinsky, director of partnerships and innovation for the Arbor Day Foundation. The nonprofit supports reforestation projects in dozens of countries.

"The reality of climate change," he said, "is if there was one solution or one approach, we wouldn't be in this problem to begin with."

While research continues, here's a look at the climate panel's findings on the alternatives for carbon removal, with additional information from Microsoft and the World Resources Institute:

Planting trees, restoring forests, improved forest management

People have been planting trees long before their benefits at storing carbon were understood. "Everyone understands tree planting and everyone loves it," said the Arbor Day Foundation's Wilinsky.

Benefits: These methods improve biodiversity; provide employment and

renewable wood products; cycle nutrients; and create more resilient systems.

Drawbacks: Forests have to be actively managed to protect carbon storage. Wildfires fueled by the already warming climate could destroy trees and release their carbon into the atmosphere. Invasive insects and hurricanes also are wreaking havoc on trees, and reversing their carbon removal. If planting isn't targeted to areas that have been deforested, it could mean land lost for food production.

Biochar: Charcoal created by burning natural materials

Burning organic materials, like those gathered from thinning forests and agricultural waste, in a low-oxygen environment creates a kind of charcoal that can be used as a soil additive or fertilizer. In a report for the state of California, the Lawrence Livermore National Laboratory concluded biomass-based carbon removal has the greatest potential over the next decade, given its costs and capacity.

Benefits: Increased crop yields; reduced non-carbon dioxide emissions from soil; drought resilience.

Drawbacks: Fine particles released by the burning or eroded from the soil by wind or water could create human health concerns or negate some carbon removal. If the materials used aren't sustainably harvested, biodiversity could suffer.

Direct air capture with carbon storage

At its most basic level, a machine sucks carbon dioxide out of the air, splits it and stores the carbon either deep underground or in materials

that offer long-term storage, such as concrete. Nineteen facilities are already operating worldwide, and Occidental Petroleum Corp. has announced plans to build the world's largest in the Southwestern U.S. This month, the U.S. Department of Energy announced it will provide $14 million to the University of Illinois, Battelle Memorial Institute and two other organizations for design studies for additional direct air capture projects.

Benefits: Microsoft, in a public report on its own efforts, stated direct air capture could hold carbon for thousands of years without the same risk of accidental release of some of the nature-based solutions. Some designs produce water.

Drawbacks: Increased energy and water use. Microsoft also found the technologies are still in "in very short supply and unaffordable for many companies, costing hundreds to thousands of dollars per ton."

Bioenergy with carbon capture and storage

In another idea being debated, organic materials, such as those gathered through tree trimming and thinning or left over from food production, are burned for power or fuel while capturing and storing carbon.

Benefits: This method may produce fewer air pollutants than open burning or fossil fuel production, while providing energy. Models show benefits to using leftovers from harvesting increased income for farmers and have the potential to enhance biodiversity.

Drawbacks: At large scale, it could require a lot of additional land and water use to grow crops. Unsustainable harvesting of materials could lead to biodiversity loss.

Soil carbon sequestration

This method is one of several that illustrate the potential for agriculture to remove and store carbon. Soil naturally contains carbon. These alternatives, still in development, rely on protecting farm soils to hold carbon and seeking ways to enhance the soil's ability to hold more carbon, such as the planting of perennial crops.

Benefits: Improved soil quality, resilience and agricultural productivity.

Drawbacks: Presents risks of increased nitrous oxide emissions due to higher levels of organic nitrogen and carbon release if the soil is returned to more active tilling.

Peatland and coastal wetland restoration

Wetlands such as coastal marshes and peatlands store vast amounts of carbon. Conserving, protecting and restoring them could provide another natural alternative.

Benefits: Enhances local employment; increases fishing productivity; improves biodiversity and soil carbon storage and the filtering of nutrients.

Drawbacks: Carbon could be lost to the atmosphere during droughts or other disturbances. While hydrated wetlands store more carbon, they release more methane, another greenhouse gas.

'Blue carbon' in seagrass beds, mangroves, salt marshes

Coastal wetlands such as seagrass beds, mangroves and salt marshes are

considered "blue carbon" ecosystems because they capture carbon dioxide and move the carbon to the soil where it can be stored. Preserving and restoring these types of wetlands could enhance the storage capabilities.

Benefits: Protecting these wetlands contributes to coastal protection against erosion and rising sea levels while increasing biodiversity. It can also reduce upper ocean acidification that occurs when carbon dioxide dissolves in seawater, making it more difficult for coral and other marine organisms to form their shells and skeletons.

Drawbacks: Wetlands that are degraded or lost release most of their stored carbon back into the atmosphere. Risks the build up of contaminants in sediments and organisms that live there. Carbon storage could be negated by efforts to reclaim land for other purposes.

Enhanced weathering

Rock weathering occurs when carbon dioxide breaks down rocks and is trapped in the soil. Enhanced weathering involves pulverizing mineral-rich rocks and spreading them on soils or in ocean and coastal environments to encourage chemical reactions that trap the carbon dioxide. The climate panel reported this proposal hasn't yet been demonstrated at large scale.

Benefits: Plants will grow better in soil enriched by carbon. The process also reduces erosion and soil pH levels, which generally improve plant growth.

Drawbacks: Mining the rocks required, and the resulting dust from spreading the crushed rock on the soil, could produce harmful effects.