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INDEPENDENT STRATEGIC ANALYSIS OF AUSTRALIA'S GLOBAL INTERESTS

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Atmospheric Carbon Drawdown – A Global Imperative

Christopher Johns
Research Analyst,
Northern and Rural Australia Research Programme

Key Points

- To achieve the global warming targets set by the Paris climate change conference it will be necessary to actively remove and store greenhouse gas currently in the atmosphere.
- The capture and storage of carbon will be key to reducing future greenhouse gas emissions.
- The storage of greenhouse gas underground is a promising solution but there are still capability gaps to be filled before its large-scale implementation can be achieved.
- Large quantities of greenhouse gas can be stored in the oceans but the cost may be prohibitive and environmental consequences are unknown.
- Restoring and improving our agricultural soils will permanently sequester carbon and improve soil health and productivity.
- It is unlikely and, indeed, possibly unadvisable that only one carbon sequestration solution be employed. A varied and tailored approach is likely to produce the most productive and the most resilient overall solution.

Summary

There exists a strong and growing body of scientific research evidence that supports the belief that to achieve the targets set by the Paris climate change conference, greenhouse gas must be actively removed from the atmosphere and stored. Carbon capture and storage technology will also have a key role in reducing future greenhouse gas emissions. There is a range of storage options. Storage underground is technologically and

financially feasible but gaps in capability still exit and implementation time may be significant. It may be possible to store large volumes of carbon in the ocean; however, this will require very large sums of capital investment in infrastructure and may have unforeseen, adverse environmental consequences. Carbon sequestration from revegetation and plantation programs can provide a significant but shorter-term contribution to atmospheric greenhouse gas reduction. Actively increasing soil carbon can make a significant contribution to the reduction of greenhouse gases currently in the atmosphere while improving the quality and productivity of our agricultural soils.

Analysis

Since the beginning of the Industrial Revolution, humans have caused more than 2000 gigatons of carbon dioxide (CO_2) to be emitted into the atmosphere principally through the burning of wood and fossil fuels. This blanket of greenhouse gas (GHG) causes the climate change we are experiencing today. The imperative is to stop the emissions and to draw down carbon from the atmosphere. If nothing changes, climate impacts such as weather extremes, wildfires and rising sea levels will intensify.

In an address to the Royal Society in 2016, Lord Nicholas Stern, the former Chief Economist to the World Bank and current chair of the Grantham Research Institute on Climate Change and the Environment at the London School of Economics, stressed the importance of 'negative GHG emissions' if global temperatures are to be stabilised. Negative emissions, put very simply, are the active removal of GHG currently in the atmosphere because of the burning of fossil fuels and other human activities. Many scientists believe that the reduction of future GHG emissions alone will not achieve the target set by the Paris climate change conference of restricting global warming to two degrees above pre-industrial levels. The quantities of GHG already in the atmosphere are beyond that point and we must, therefore, lower that amount. Negative emissions are also an important mitigation, as some industrial sectors are unlikely to achieve the appropriate emission reductions in the short or medium term and compensatory reductions will be required in other areas.

It is also widely assessed that carbon capture and storage, or sequestration technology will be key to stabilising global temperature. This is the process of capturing waste CO_2 from large sources, such as fossil fuel power plants, transporting it to a storage site, and depositing it where it will not enter the atmosphere. Ten countries, collectively responsible for approximately one third of global annual emissions, explicitly refer to carbon capture and storage in their 'intended nationally determined contributions' submitted prior to the Paris Climate Change Conference.

To be successful, both negative emissions and carbon capture and storage rely on the long-term or permanent storage of GHG. The options for long term storage on the scale necessary to meet global warming target, however, are limited. This paper provides an outline of some of the options and some analysis of their feasibility.

Carbon sequestration is the general term used for the capture and long-term storage of carbon dioxide. Capture can occur at the point of emission (e.g. from power plants) or through natural processes (such as photosynthesis), which remove carbon dioxide from the earth's atmosphere and which can be enhanced by appropriate management practices. Sequestration methods include:

- storing carbon in underground geological formations (geosequestration);
- subjecting carbon to chemical reactions to form inorganic carbonates (mineral carbonation).
- storing carbon in the ocean (ocean sequestration);
- enhancing the storage of carbon in forests and other vegetation (plant sequestration); and

- restoring and enhancing the storage of carbon in soil (soil sequestration).

Geosequestration

Geosequestration is the injection and storage of greenhouse gases underground. The most suitable sites are deep geological formations, such as depleted oil and natural gas fields, or deep natural reservoirs filled with salt water referred to as saline aquifers. Geosequestration is part of the three-component scheme of carbon capture and storage (CCS), which involves:

- capture of CO_2 either before or after combustion of the fuel
- transport of the captured CO_2 to the site of storage, and
- injection and storage of the CO_2.

This scheme seeks to reduce to near-zero the greenhouse gas emissions of fossil fuel burning in power generation and CO_2 production from other industrial processes such as cement manufacturing and purification of natural gas. It is predominantly aimed at mitigating emissions of CO_2, but geosequestration may also prove to be applicable to other greenhouse gases, particularly methane. The concept of CCS may also be applied to other long-term storage options (see ocean sequestration and mineral sequestration below). Of the storage options, however, geosequestration is thought to be the most promising due to higher confidence in the longevity of storage, the large capacity of potential storage sites and a generally greater understanding of the mechanisms of storage.

Fig 1. The Chevron, Gorgon carbon dioxide geosequestration project on Barrow Island is the largest, commercial carbon dioxide injection project in the world.
Source: www.dmp.we.gov.au .

Mineral sequestration

Mineral sequestration (sometimes referred to as mineral carbonation) involves reaction of CO_2 with metal oxides that are present in common, naturally occurring silicate rocks. This process mimics natural weathering phenomena, and results in natural carbonate products that are stable on a geological time scale. There are sufficient reserves of magnesium and calcium silicate deposits to fix the CO_2 that could be produced from all fossil fuel resources. Though the weathering of CO_2 into carbonates does not require energy, the natural reaction is slow; hence as a storage option the process must be greatly accelerated through energy-intensive preparation of the reactants. The technology is still in the development stage and is not yet ready for implementation; however, studies indicate that a power plant that captures CO_2 and employs mineral carbonation would need 60 to 180 per cent more energy than an equivalent power plant without the capture and conversion process.

Ocean Sequestration

A carbon sink is anything that absorbs more carbon than it releases as CO_2. Forests, wetlands, soils and the ocean are the most important natural carbon sinks. The ocean represents the largest carbon store on earth. Prior to the industrial revolution, it contained 60 times as much carbon as the atmosphere and 20 times as much carbon as the land vegetation and soil. The ocean has been a significant sink for manmade CO_2 emissions of similar magnitude to the land sink but, as with the land sink, the ocean sink will decrease in strength. Increasing CO_2 concentration in the upper layer of the oceans is also causing ocean acidification with potentially severe consequences for marine organisms and ecosystems. CO_2 dissolves in seawater by combining with carbonate ions, but the number of these ions is limited and, as their concentration decreases, this will limit the rate at which CO_2 is taken up by the ocean. A possible slow-down in ocean circulation may also reduce the ocean sink capacity. In addition to the dissolution process, plant plankton in the surface layers perform photosynthesis and incorporates CO_2 into biological material but, as with terrestrial photosynthesis, there comes a saturation point where other factors restrict further photosynthesis.

It has been proposed to bypass the natural ocean CO_2 uptake mechanism and inject CO_2 directly into the deep ocean to utilise its enormous storage capacity. Models suggest that CO_2 injected into the deep ocean would remain isolated from the atmosphere for several centuries, but on the millennial time scale it would recycle into the atmosphere. Considerable uncertainties exist in our understanding of deep ocean chemistry and biology and the potential adverse impacts on ocean ecosystems. In addition, despite many years of theoretical work and small-scale experiments, the feasibility of ocean storage has not been demonstrated and the technologies for deep ocean CO_2 transport and dispersal are yet to be developed.

Another possible way to enhance the ocean carbon sink that has been proposed involves large scale ocean fertilisation with iron to stimulate phytoplankton (microscopic marine plants) growth and photosynthesis. This is one of several ambitious geo-engineering schemes that involve high uncertainty and risk but may provide quick and effective means to halt or significantly slow the rate of climate change.

Plant Sequestration

Plants use the energy of sunlight to convert CO_2 from the atmosphere to carbohydrates for their growth and maintenance, via the process of photosynthesis. Natural terrestrial biological sinks for CO_2 already sequester about one third of CO_2 emissions from fossil fuel combustion. These natural sinks are a transient response to higher atmospheric CO_2 concentration, which enhances the rate of photosynthesis. The uptake of CO_2 by vegetation will decrease with time as plants grow to their full capacity and become limited by other resources such as nutrients, and regrowth potential in previously cleared or sparsely vegetated areas is fulfilled. Biological storage could be enhanced through agricultural and forestry practices and revegetation, but the capacity is limited and longevity of storage depends on the final fate of the timber or plant material. Carbon sequestration from revegetation and plantation programs, however, could provide a significant shorter-term contribution to climate change mitigation.

Soil Sequestration

It is estimated that soils contain between 700 gigatonnes (Gt, 10^9 tonnes) and 3000 Gt of carbon, or more than three times the amount of carbon stored in the atmosphere as CO_2. Most agricultural soils, however, have lost 50 to 70 per cent of the original soil organic carbon pool that was present in the natural ecosystem prior to clearing and cultivation. When forests are converted to agricultural land, the soil carbon content decreases. This happens because organic matter in the soil decomposes following the disturbance while, at the same time, less carbon enters the soil because the clearance has reduced the biomass above ground, and practices such as stubble burning will reduce it even more. Agricultural usages such as grazing, harvesting and tillage also tend to reduce soil carbon, as does increased erosion that often results.

Given the enormous carbon storage capacity of soils, it has been suggested that with appropriate changes in management practices, soil could represent a significant sink for atmospheric CO_2. Managing agricultural soils to increase their organic carbon content can also improve soil health and productivity by adding essential nutrients and increasing water-holding capacity.

Management practices that can retain or increase the carbon content of soils include low-tillage or no tillage, use of manures and compost, conversion of monoculture systems to diverse systems, crop rotations and winter cover crop, and establishing perennial vegetation on steep slopes. These practices primarily affect the amount of labile carbon in the soil, or carbon with relatively high turnover time (less than 5 years). Labile carbon is released to the atmosphere as carbon dioxide through decomposition and microbial activity. The potential increase in storage through such methods is limited by soil type, which determines the carbon-holding capacity, and climate, which determines the rate of decomposition. Soil microbial activity increases with soil moisture and temperature, and increasing average temperatures due to climate change may be expected to increase the turnover rate of labile carbon in soils.

An alternative and promising approach, which is the subject of much current research, is the use of 'biochar' to increase the soil carbon sink. Biochar is a type of charcoal that results from heating organic materials such as crop residue, wood chips, municipal waste or manure in an oxygen-limited environment (a process known as 'pyrolysis'). This can occur in a dedicated facility that harnesses the resultant 'bioenergy' to produce electricity, and the biochar residue can be returned to the soil. As a more generally applicable process, biochar can be produced through replacement of conventional slash and burn practices with 'slash and char', where complete burning is inhibited, for example by dampening the fire with earth. Biochar is chemically stable and the carbon can remain in the soil for hundreds to thousands of years.

The properties of biochar will differ depending on the source of material used in its production and the conditions of pyrolysis. For example, different feedstocks (manure, wood waste, etc) will result in different nutrient levels and chemical stability of the resulting biochar. Different pyrolysis temperatures will affect the capacity of the biochar to adsorb or mop up toxic substances and help to rehabilitate contaminated sites, or to increase the water holding capacity of the soil.

The net agronomic benefits of biochar are still being investigated. Biochar production removes agricultural waste that may otherwise be returned to the soil as labile carbon and returns it instead as biochar. The relative impacts of this process are not yet well understood, but it is thought that biochar has the potential to significantly increase crop yields and improve soil health.

Conclusion

It is unlikely and, indeed, possibly unadvisable that only one carbon sequestration solution be employed. A varied and tailored approach is likely to produce the most productive and the most resilient overall solution. Highly technological solutions may be the most appropriate actions in some circumstances, these solutions, however, are still evolving and can be expensive, impractical and may have unforeseen consequences. Under-researched or solutions with unknow environmental impacts, obviously should be avoided when effective and safer options exist. The restoration and improvement of soil carbon in global agricultural regions presents a possible double positive solution. It has the potential to reduce and store GHG and improve our ability to feed the growing would population.

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80 Birdwood Parade, Dalkeith WA 6009, Australia.
Tel: +61 8 9389 9831 Fax: +61 8 9389 8803
E-mail: info@futuredirections.org.au Web: www.futuredirections.org.au