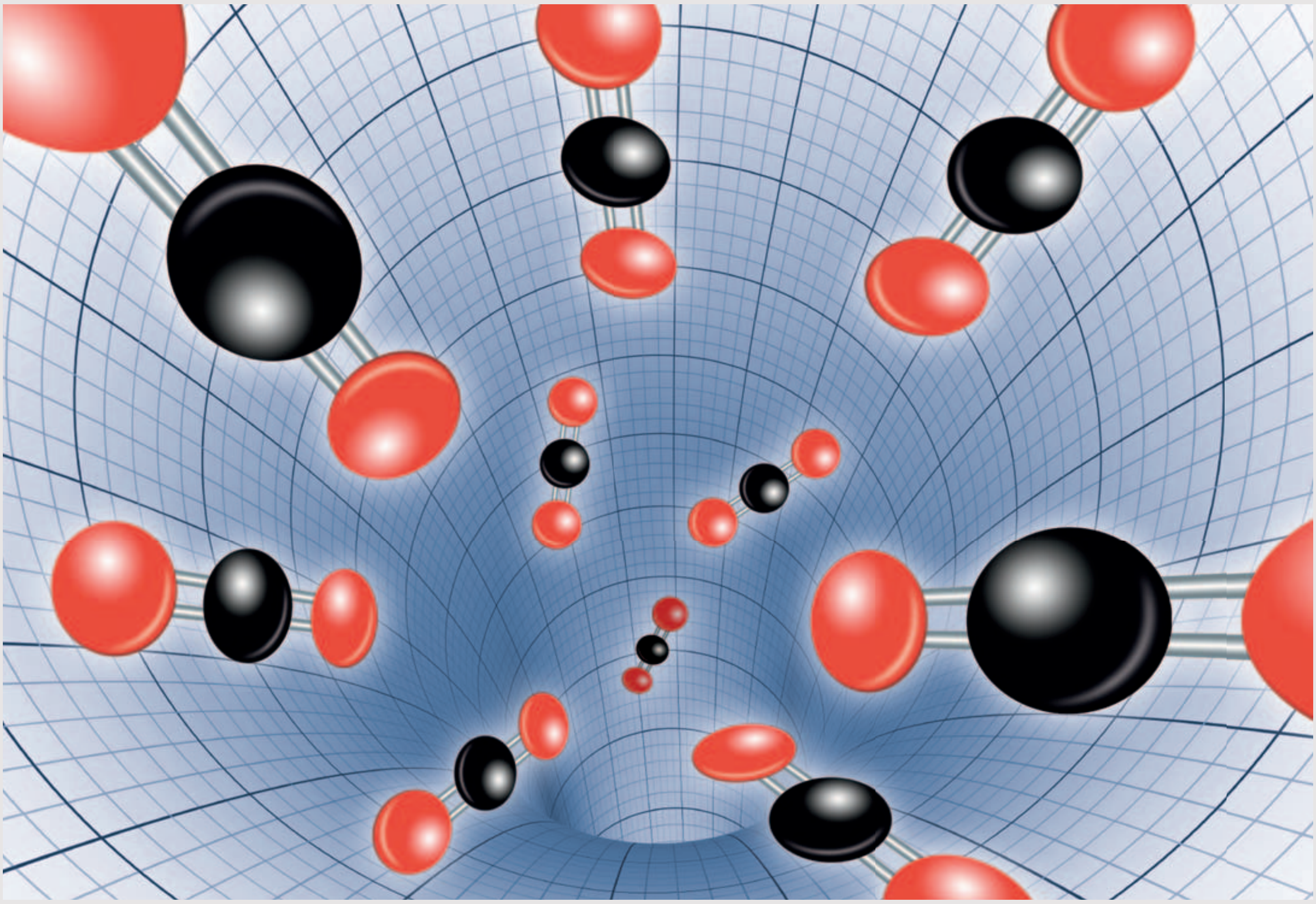
Focus



iStockphoto/James Kelly

Our options for global CO_2 drawdown

If rates of global CO_2 emissions continue to climb, ways to rapidly withdraw the gas from the atmosphere may be needed. Do we have them? **Rachel Sullivan** reports.

Despite plans and initiatives to reduce the amount of carbon dioxide being pumped into Earth's atmosphere, CO_2 emissions actually increased by 3 per cent each year from 2000 to 2007, a finding that shocked researchers and has potentially set a course for climate change beyond scientists' worst-case scenario predictions. While CO_2 is not the only greenhouse gas to consider (methane and nitrous oxides are some others), it is, as we know, the prime suspect.

'Not only has there been no reduction, emissions are growing at the upper levels of projections,' says Dr Michael Raupach, leader of the Continental Biogeochemical Cycles Research Team at CSIRO Marine and Atmospheric Research (CMAR).

'Concentrations in the atmosphere are growing rapidly, and we are nowhere near a regime where we're getting this under control,' agrees Dr Paul Fraser, leader of CSIRO's Changing Atmosphere research group at CMAR. At present, fossil fuel emissions are around 8.5 gigatonnes of carbon per year, and atmospheric concentrations are approximately 385 parts per million (ppm); pre-industrial levels were around 280 ppm.

Meanwhile forests and oceans, which naturally draw CO_2 out of the atmosphere, are becoming degraded as temperatures rise and ecosystems are affected. 'These natural sinks are not keeping pace with rapidly rising emissions,' Dr Raupach highlights.

According to Tim Flannery, Adjunct Professor in the Division of Environmental and Life Sciences at Macquarie University, 'The climate system has a more sensitive threshold for dangerous climate change than we thought, yet woefully inadequate efforts have been made to reduce emissions'.

'Assumptions about how to manage the issue [of climate change] and technology's ability to play catch-up have also been oversimplified.'

Columbia University climate scientist Dr James Hansen[1] has said that atmospheric CO_2 concentrations need to be reduced to within the range where we know the climate will remain stable and Arctic sea ice will remain intact – to around 300 ppm. According to 'Climate safety', a report recently compiled by UK-based Public Interest Research Centre,[2] and *Climate Code Red* by David Spratt and Philip Sutton, because of the delay in how the climate system responds, if we can lower atmospheric concentrations this century, then we may never receive the full level of warming we are due. The debate is still forming on that issue, but the question is how we could remove CO_2 quickly and without creating insurmountable problems for future generations.

Mechanical responses?

Few scientists believe emissions reductions on their own will be enough to prevent permanent, catastrophic climate change. Apart from decarbonising – combining energy efficiency measures, rolling out diverse and distributed renewable technologies that are cost-competitive with existing technologies, and encouraging significant behavioural change – concerted consideration and funding is now being given to both mechanical and natural options for rapidly drawing down CO_2 from the atmosphere.

But it is one thing to remove atmospheric carbon; storing it is a whole other challenge. Geosequestration, which involves the storage of captured CO_2 in deep, geologically stable strata such as saline aquifers, is one area showing some promise, although its effectiveness varies depending on the local geology, and cost is a restriction.

Biosequestration, where CO_2 is removed from the atmosphere using natural photosynthetic processes and stored in the biosphere, is another potentially more effective solution. Many of the existing mechanical means that seek to mimic the natural sequestration processes of the oceans or photosynthesis are poorly understood, or are only in early stages of development (see box). Meanwhile there are a variety of new carbon capture and storage technologies becoming available for power stations, although retrofitting old plants is proving prohibitively expensive.

Interest is turning to new technologies, including the development of smaller scale electricity plants that capture and store CO_2 released in the burning of biomass. Known as Biomass Energy with Capture and Storage (BECS), this highly regarded technology results in net negative energy emissions (that is, the creation of energy that ultimately sequesters more than it emits), although commercially viable, large-scale plants are still some years away.

'The climate system has a more sensitive threshold for dangerous climate change than we thought, yet woefully inadequate efforts have been made to reduce emissions'.

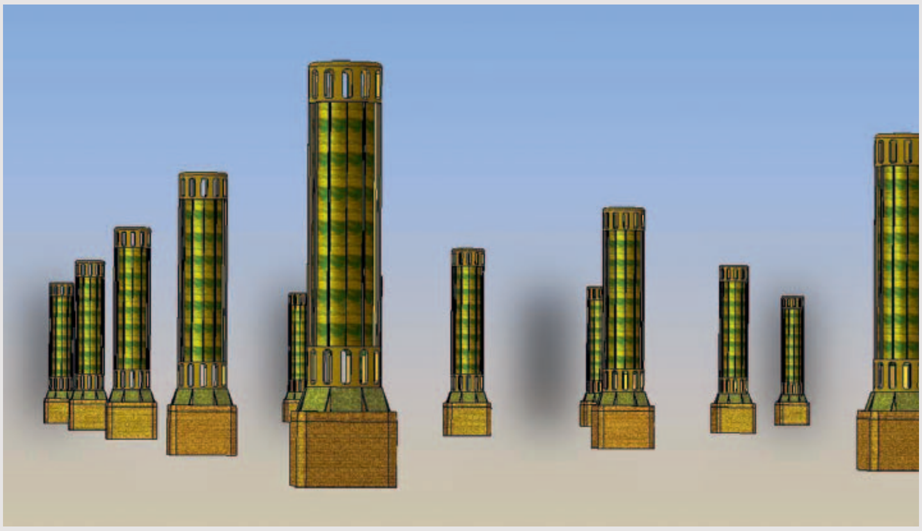
The 'holy grails' of mechanical CO_2 drawdown – commercial atmospheric air capture technologies that can be located away from the source of emissions – are also still very much in the development stages.

However, according to Dr Raupach, these 'holy grails' come with a side cost: for every emitted CO_2 molecule captured from the atmosphere away from its source, another CO_2 molecule is taken up in short-term land and ocean CO_2 sinks. As CO_2 concentrations ultimately fall, the CO_2 taken up by these sinks will be re-released into the atmosphere over years or decades. Therefore, CO_2 drawdown remote from sources of emissions needs to sequester about twice as much CO_2 as does carbon capture and storage of CO_2 before its eventual emission to the atmosphere.

Nevertheless, the search for practical mechanical solutions continues. US-based Global Research Technologies and Professor Klaus Lackner from Columbia University unveiled a proposed CO_2 capture device in mid-2007.[3] Their prototype, which has an intake vent of one square metre, uses sorbents to extract about 10 tonnes of atmospheric CO_2 each year. Scaling it up to commercial proportions, a single device measuring 10 by 10 metres could extract 1000 tonnes each year. On this scale, the inventors say one million devices, each resembling a large smokestack and located at an appropriate sequestration site, would be able to remove one billion tonnes of atmospheric CO_2 annually (that's 0.27 gigatonnes of carbon, about 3 per cent of current emissions or one year's worth of current carbon emissions growth).

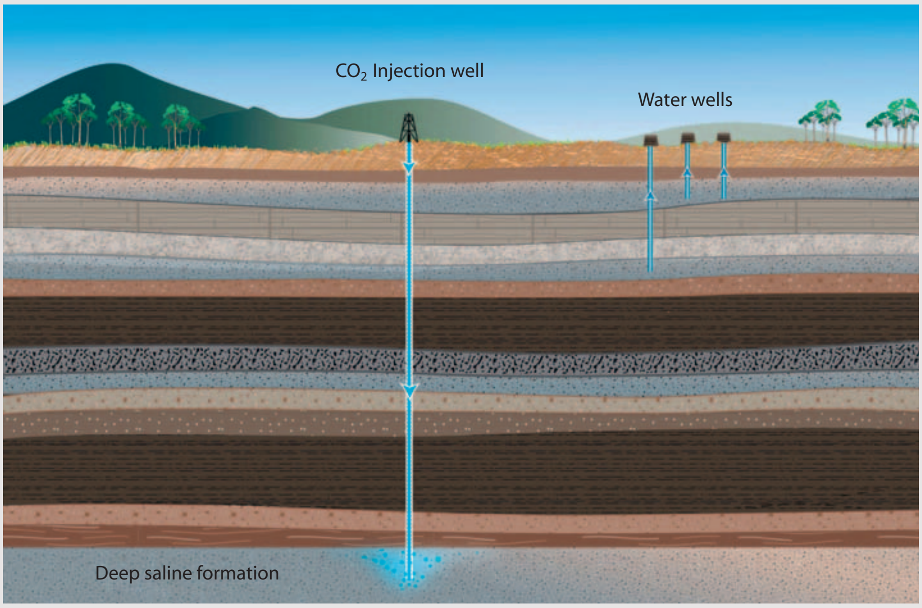
If successfully deployed around the world, this scheme would only go a small way to meeting the Stern Review's[4] demand of reducing carbon dioxide emissions by 11 billion tonnes per year by 2025 in order to maintain a stable concentration of carbon dioxide at twice pre-industrial levels. Other similar stack or 'artificial tree' projects are emerging, with the same scale issues.

Another method that has attracted global interest is ocean fertilisation. This involves sprinkling the ocean surface with trace amounts of iron or releasing other nutrients over vast areas of, say, the cold Southern Ocean, promoting blooms of phytoplankton – tiny marine



An artist's impression of carbon dioxide absorbing stacks being developed by Global Research Technologies and Columbia University. Global Research Technologies, LLC

1 http://www.columbia.edu/~jeh1/2008/TargetCO2_20080407.pdf
2 http://climatesafety.org
3 www.physorg.com/news96732819.html
4 http://www.sternreview.org.uk



There are questions about the cost and long-term effectiveness of geosequestration – storage of captured carbon dioxide in formations such as saline aquifers deep beneath the earth. CO2CRC

plants – which then soak up CO_2 during photosynthesis. When they die, they sink to the ocean's depths, along with the carbon locked in their cells where it is potentially stored for hundreds or thousands of years in marine sediments.

The problem, however, according to Australian scientists in the Antarctic Climate and Ecosystems Cooperative Research Centre's recently released position analysis[5] on ocean fertilisation and science, is that how much carbon can be captured and stored, for how long, or at what risks to ocean ecosystems is unknown. Ocean fertilisation may cause changes in marine ecosystem structure and biodiversity, and may also increase acidity and oxygen depletion and even promote the release of nitrous oxide, another greenhouse gas.

The report also says that while controlled iron fertilisation experiments have shown an increase in phytoplankton growth, and a temporary increase in drawdown of atmospheric CO_2, it is uncertain whether this would increase carbon transfer to the ocean over the long term. Meanwhile the potential for any negative impacts is expected to increase with the scale and duration of fertilisation, with grave doubts that any damaging effects could be detected in time.

'We haven't even designed measurement programmes yet to look at ecological change and the risks,' said Tom Trull, one of the report's authors. Partly as a result of the report and Australian scientists' concerns, the International Maritime Organization (IMO) recently agreed to halt fertilisation activities other than those for research, and to carefully evaluate any new activities before commencement.

Natural approaches

Professor Flannery highlights that we already have an excellent natural capture mechanism in the form of plants, which contribute to something called 'Net biome production' (the difference between what they sequester and release through respiration) – currently about 2.5 gigatonnes of carbon per year, or about 0.3 per cent of the current atmospheric CO_2 store of around 800 gigatonnes of carbon. The majority of this results from tropical rainforests, but all plants, from agricultural crops that lock away carbon in phytoliths and humus with the help of microbial life, to algae in waterways, farms or sewage treatment facilities, capture significant measurable amounts of CO_2 each year.[6] What we really need, says Professor Flannery, is to find ways of enhancing natural 'atmospheric cleansing' processes, pulling CO_2 from the atmosphere and sequestering it in the biosphere.

'To start with,' he says, 'we need better management of tropical rainforests and large-scale protection, regeneration and reafforestation programs. Eighteen per cent of all anthropogenic carbon today comes from destruction of those forests.

'Similarly, we need better rangeland management and to start investing in holistic management to boost the carbon carrying capacity of these often degraded lands.' Raising the soil carbon levels of the world's grasslands by just 2 per cent, he says, would sequester hundreds of gigatonnes of atmospheric carbon, using already well-understood technologies.

This view concurs with the work of Dr Christine Jones of the Australian Soil Carbon Accreditation Scheme (see *Ecos* 141) and some other international soil scientists, who are advocating the central role that concerted perennial grassland farming could play in significantly offsetting carbon emissions. Perennial grasses sequester carbon very faithfully.

'I believe we can double soil carbon levels with perennial croplands, with many associated benefits, and for very little cost. Increasing soil carbon by only 0.5 per cent across just 2 per cent of our agricultural areas could offset Australia's annual CO_2 emissions,' Dr Jones says.

Professor Flannery says we also need to undertake a massive research program into pyrolytic char, and how different char feedstocks interact with different soil types. Also known as biochar (see *Ecos* 146),

5 http://www.acecrc.org.au/uploaded/117/797659_23pa03fertilisation.pdf
6 http://www.sciencealert.com.au/farming-the-climate.html

The Virgin Earth Challenge

In February 2007, Virgin founder Richard Branson launched the Virgin Earth Challenge, a US$25 million prize for whoever can come up with a commercially viable method of scrubbing out anthropogenic, atmospheric greenhouse gases.

Similar in concept to other competitions, such as the Orteig Prize for crossing the Atlantic, and the Ansari X Prize for spaceflight, the prize will be awarded to the first scheme that is capable of removing 1 gigatonne of CO_2 from the atmosphere per year for 10 years.

Professor Flannery, one of the prize's judges, says that more than 18 months into the five-year competition, there has been a huge amount of interest, but so far little in the way of technologies that may be able to sequester a gigatonne per annum.

He says that as well as the main award it may yet be that one of the prize's greatest legacies is in identifying and finding ways to help companies scale-up and prove their promising technologies.

using a process known as pyrolysis, waste biomass such as crop residue or wood is heated in closed, oxygen-free conditions to produce biofuels, bioelectricity and solid 'carbon-negative' charcoal, a highly stable, inert carbon compound. It not only substantially enriches impoverished soils, but also sequesters atmospheric carbon. Proponents say that if pyrolysis of crops, forestry and other waste was in worldwide use by 2030, 9 gigatonnes of CO_2 per annum could be drawn out of the atmosphere and sequestered long term.

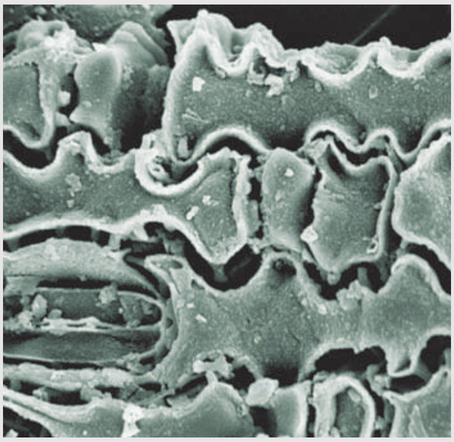
Biochar was recognised by the Garnaut Review[7] for the role it has to play in a net-negative emissions process; however, concerns remain about the effects of introducing biochar and other forms of fixed carbon into existing ecosystems. There are also considerations needed over the amounts of nitrogen that may be required to grow enough biomass stock for a significant effect, as well as the energy and logistics costs in transporting, processing and burying biochar on a large enough scale for impact.

Dr Peter Read from New Zealand's Massey University Centre for Energy Research agrees with Professor Flannery that improving land-use management, both in farming and forestry, will play an increasingly important role in atmospheric cleansing while providing larger quantities of sustainably produced food, fibre and energy.

He says that with enhanced photosynthesis taking more CO_2 out of the atmosphere, thanks to enriched soils and better management than under current land-use practices, and assuming that fixed carbon is carefully conserved in biosphere storage systems such as biochar, then on its own so-called Biosphere Carbon Stock Management (BCSM) 'has the potential to return CO_2 levels to less than 300 ppm by 2040, if pursued on an ambitious scale using currently available technologies, or those within easy reach'.

CMAR's Dr Raupach is not so convinced, however, and doesn't think terrestrial storage should be the primary method of CO_2 drawdown. He advocates focusing on reducing emissions rates and decarbonising our lives, first and foremost because it is cheaper to avoid emissions than to clean up the mess afterward, and involves less risk of environmental side effects.

'Carbon in the terrestrial biosphere is only borrowed from the atmosphere, rather than permanently stored. If a management practice is accidentally reversed or forgotten about then all of that CO_2 will be re-released,' he comments. 'It involves a permanent commitment to maintain a certain land-use practice – something that is often easier to promise than deliver over the long term.'



NSW Farmer of the Year, Nigel Kerin, in a paddock of Marombi wheat at Karuga Park, Yeoval, which was sown into perennial carbon sequestering grasses. Right: Interlocking silica phytoliths in the leaf blade of Mitchell grass. Matthew Cawood, *The Land*, Southern Cross University

The biofuel solution

Although a challenging prospect, reducing our energy dependence must be considered as part of the overall decarbonising process, says Dr Deborah O'Connell, Systems Analyst at CSIRO's Sustainable Biomass Production Project. She believes that in the meantime the booming area of biofuel production could potentially make a substantial contribution to rapid CO_2 drawdown, although it depends very much on what feedstocks and technologies are used.

'First generation biofuels in Australia are currently based on waste products, including molasses and tallow, and therefore have good greenhouse credentials. But those based on foodcrops like starch from corn, sugar and oil, compete directly with food. Second generation technologies, including pyrolysis, rely on lignocellulose inputs, that is, the woody or fibrous parts of plants that wouldn't be eaten anyway, or on algae.

'Everything from wood waste in the tip to agricultural and forestry residues has potential, although it may prove better to leave agricultural stubble to accumulate in the ground and use it to help offset CO_2.

'A better choice may be to re-examine our approach to forestry: do we want carbon forests, sinks that stay *in situ* forever and have carbon and biodiversity benefits or working forests that grow and regrow, providing high quality timber in the form of sawlogs for more sustainable construction as well as a renewable source of rapid CO_2 drawdown?'

Well-managed plantations planted on previously degraded land absorb carbon from the moment they start growing, Dr O'Connell says, rapidly accelerating until the point of canopy closure, when light and water become limited. 'Thinning the trees at various stages in the growth cycle can produce high quality sawlogs while allowing the remaining trees to keep growing – and absorbing CO_2 at an exponential rate.'

'The tradeoffs between managing forests in these ways for different products need to be closely examined.'

In August 2008, the ANU released 'The green carbon report',[8] which found that south-east Australia's natural tall wet eucalypt forests are among the most carbon dense in the world, containing up to 1200 tonnes of carbon per hectare, and averaging 640 tonnes – three times the average carbon stock of temperate forests. This suggests plantation timbers and conserved old-growth forests might help provide the combination of rapid drawdown and long-term storage necessary to significantly and permanently reduce atmospheric concentrations.

Similarly, better rangeland management and the targeted introduction of biochar from appropriate sources will not only cut atmospheric CO_2 concentrations, it will also boost soil productivity. 'And given Australia's vast area of degraded rangelands, we have a big role to play,' says Professor Flannery. Who knows – we could become the world's leading carbon farmers.

7 http://www.garnautreview.org.au
8 See http://epress.anu.edu.au/green_carbon_citation.html