Let Big Oil save the World

By Tom Williamson

Wind-powered artificial trees in the North Sea could capture excess carbon dioxide in the air and store it in the pore spaces of depleted oil and gas reservoirs.

Courtesy: Institution of Mechanical Engineers

In 1859, the year in which Charles Darwin published *The Origin of Species*, a second Victorian scientist, the Irish-born John Tyndall, made another great scientific advance. He demonstrated that while nitrogen and oxygen, the two chief gases in our planet's atmosphere, were transparent to radiant heat, two minor constituents of air, 'aqueous vapour' (water vapour) and 'carbonic acid' (carbon dioxide) absorbed heat radiation strongly.

Tyndall made more accurate measurements in the following year. In 1861 he concluded that past changes in the abundance of such gases - later rather misleadingly called greenhouse gases - 'may have produced all the mutations of climate which the researches of geologists reveal.'

So, although Tyndall didn't spell it out himself, it's been clear since the 1860s that the stones' record of past climate change may warn us of what might happen if we fool around with the greenhouse gases in the atmosphere. This was one of the points I made in the 1977 Science Museum climate change exhibition. One display showed that a sizeable part of Britain would lie underwater if rising greenhouse gas emissions caused all the world's ice sheets to melt.

And sea level rise will be only one of threats posed by future greenhouse gas emissions, if we continue business as usual. Average global temperatures will also rise – recent studies suggest that temperatures would already be five degrees higher by 2100 [1] – and they would continue to rise. Although Asian countries like Pakistan and Bangladesh might suffer increased monsoon flooding, spreading aridity in two broad latitudinal belts would devastate global agriculture. The oceans will become acidic, killing corals and other marine organisms and the Earth would experience another great mass extinction of species. All in all an apocalyptic scenario,

So what is the outlook for emissions of the most important greenhouse gas, carbon dioxide, in the twenty-first century? So far all efforts to curb growing emissions have failed and levels of the gas in the atmosphere, as measured at Mauna Loa observatory in Hawaii, have risen from around 335 parts per million in 1976 to around 392 parts per million in 2010.

And carbon emissions are likely to continue to grow. Despite impressive efforts to curb its burgeoning population and to develop alternative energy sources, China, the largest current emitter, will rely on a growing fleet of coal-fired power stations for most of its rapidly increasing electricity demand over the next twenty years. In 2007, in large part as a result of its burning of coal, mostly its own and mostly for power generation, China released about six gigatonnes of carbon dioxide into the atmosphere (about twenty percent of the world total energy-related carbon emissions). This is projected to increase to around twelve gigatonnes in 2030, about thirty percent of projected global energy-related carbon emissions.[2]

India, too, is planning new coal-fired power stations that will hugely increase its carbon emissions. The Indian Ministry of Power plans nine Ultra-Mega Power Projects that will collectively emit about 9 gigatonnes of carbon dioxide over planned life of 35 years. And such new coal-burning projects aren't confined to China, India and other non-OECD countries. In the US alone, corporations intend to build about 145 gigawatts of new coal-fired energy capacity by 2030.[3]

All these new coal-burning plants make nonsense of claims that the world is moving to a low-carbon economy. In fact we're heading straight for an apocalypse.

So what can we do?

Old industrial nations like Britain and the US and now also new ones like China have created the problem by taking carbon from inside the earth and burning it. We could solve the problem by removing the extra carbon dioxide from the air and putting it underground.

We could store it within the pore spaces of stones. Throughout the world various underground formations, in particular sandstones and limestones saturated with saline groundwater, have the potential to store carbon dioxide gas. At depths below about one kilometre the weight of rock above causes the gas to 'magically' transform to a supercritical phase occupying only about three per cent of its ordinary volume. As long as there is a suitable impermeable cap rock above, wet porous stone can therefore trap enormous quantities of carbon dioxide . The supercritical carbon dioxide dissolves in the saline pore water and slowly sinks downwards in the stone storage reservoir. Total global storage capacity has been estimated to be around twelve thousand gigatonnes of carbon dioxide.

Several projects have demonstrated the feasibility of injecting carbon dioxide into deep formations of stone. For example more than more then ten million tonnes of carbon dioxide have been stored in an offshore sandstone formation beneath the North Sea (Sleipner), and more than eighteen million tonnes in a dolomite storage reservoir beneath Saskatchewan in Canada.

So how can unwanted carbon dioxide be sequestered and transported to injection points above such storage reservoirs? Suppliers of coal and coal-based electricity, their livelihoods and profits at risk in a carbon-constrained world, have quickly grasped that these deep geological reservoirs offer them a potential life-support system. They have therefore created the CCS (Carbon Capture and Storage) narrative. This is the claim that coal-burning power stations can be 'fitted with CCS technology'. In other words the stations' output of carbon dioxide will be captured, pressurised and then piped to the injection points above the storage reservoirs.

These wealthy coal and energy corporations have successfully promoted the CCS narrative to governments, academics, journalists, and the Intergovernmental Panel on Climate Change (IPCC). As a result governments worldwide are planning to spend more than twenty billion US dollars worth of our taxpayers cash on rolling out CCS schemes over the next twenty years. To further such projects, a Global CCS Institute [4] was formed in 2009, based in Canberra, Australia, and funded by the government of Australia, the world's leading coal exporter.

Geological accident means that some countries are in a better position than others to capture carbon dioxide from power stations and pipe it to stone storage reservoirs. The UK, for example, has plentiful storage reservoirs beneath the North Sea, including exhausted oil and gas fields that come complete with reusable production platforms and pipelines to land terminals. But other nations, in particular the crucially important coal-burners, China and India, aren't so lucky. Indeed, most of the world's nations have not yet even commissioned their geological surveys to conduct detailed national surveys of carbon dioxide storage capacity in relation to nearby fossil fuelled power plants.

Overall, therefore, the energy penalties incurred by plants fitted with CCS, the problems of matching emission sources with suitable storage reservoirs, the vast costs and practical and legal difficulties in completing pipelines from power stations to injection points above tested local storage reservoirs create formidable obstacles to the rapid deployment of CCS technology. There is therefore a serious risk that CCS won't significantly reduce projected global carbon emissions by 2030.

But we're not doomed yet.

There's another, more logical, way of getting the world's excess carbon dioxide into those deep beds of stone. It should be called ACS (air capture and storage) because ease of storage is one of its great advantages over CCS, but it's misleadingly called 'air capture' or 'artificial trees'. As Daniel Sarewitz, of Arizona State University, and Richard Nelson, of Columbia University, pointed out in a seminal paper published in *Nature* [5] air capture is the logical response to global warming in that unlike other climate change strategies it directly addresses the chief cause of the problem. It doesn't require vast changes in human behaviour and because it is a form of climate mitigation [6] rather than a geoengineering solution, it doesn't suffer from the risks associated with other technical fixes.

How does air capture work? Just as trees capture carbon dioxide by absorbing it an an aqueous solution passing through their leaves, so artificial trees would capture the gas by means of sorbent solutions passing through artificial leaves. The feasibility of the technology has already been demonstrated on a small scale [7], for example by David Keith's group based at the University of Calgary in Canada, Klaus Lackner's group based at Columbia University in the USA, two other American groups based at the Palo Alto Research Center and the Brooklyn National Laboratory, and two Swiss groups, based at the Swiss Federal Institute of Technology, Zurich and the Paul Scherrer Institute, Viligen.

Although extracting carbon dioxide from air demands more energy than capturing it from power station emissions, such extra costs could be offset by the savings due to air capture's many advantages over CCS. With air capture there's no need to construct vastly expensive pipeline networks as 'artificial forests' powered by zero-carbon energy sources like wind turbines or solar power could be sited above the world's most efficient and leak-proof stone reservoirs.

For example the UK Institution of Mechanical Engineers has suggested that artificial forests could be located above the North Sea storage reservoirs. [8] Wind turbines could supply the power and there would be no shortage of seawater for use in the carbon dioxide extraction process.

If technologies of this kind could be developed and deployed on a sufficiently large scale, Klaus Lackner has found that long term costs of air capture could drop as low as 30 dollars per tonne of carbon dioxide captured. [6]

But how to we get from here to there? In 2010 air capture technology has yet to be demonstrated on an industrial scale. Convincing politicians, climate scientists and journalists of the urgency of deploying air capture won't be enough. We need to mobilise the powerful technological and lobbying capabilities of the big oil companies. These include not only the six oil supermajors - ExxonMobil, BP, Shell, Chevron, ConocoPhillips and Total - but state-owned oil and gas companies like the Norwegian Statoil ASA and the Canadian Encana Corporation.

Why should Big Oil be interested in artificial trees? One reason, of course, would be to promote its green image and enable it to claim that future deployment of air capture would allow it to carry on business as usual. But there's another argument, which I believe really could motivate the oil companies to put serious cash into the development of air capture technologies. It revolves around the use of EOR - enhanced oil recovery.

EOR is a well-established technology in which carbon dioxide or other gases are pumped into depleted oil reservoirs to recover more oil. With global oil reserves dwindling and peak oil threatening, oil companies are keen to deploy EOR in as many exhausted oil and gas fields as possible. They are therefore desperate for pure carbon dioxide, which is currently costly for them because it has to be first produced and then brought in along expensive pipelines. The oil companies currently envisage that CCS projects will supply an increasing proportion of their carbon dioxide requirements. [8]

But not all EOR projects will be able to draw on carbon dioxide from CCS power stations. And what if the CCS projects and infrastructure fail to develop as projected? Since rapid expansion of EOR is critical for its future, Big Oil could find itself in a highly embarrassing situation.

If oil companies invest now in the the development of air capture on an industrial scale they could avoid being caught off guard in this way. Wind or solar-powered artificial trees deployed above depleted oil reservoirs could solve their carbon dioxide supply problems at one stroke.

Initially the oil companies might wish to get together with visionary governments, global engineering corporations and national institutes like the UK Institution of Mechanical Engineers to fund a Global Air Capture Institute. In conjunction with the Global CCS Institute, the new institute would need to conduct two urgent and simultaneous projects. The first would involve the preparation of global geological surveys of possible carbon dioxide storage reservoirs, with particular emphasis on offshore sites with potential for 'growing' artificial forests as envisaged by the Institution of Mechanical Engineers. At the same time they would need to fund the scaling up of air capture technology to an industrial scale and thereby demonstrate the reliability and economic feasibility of the technology.

Assuming that the outcomes of these two projects are satisfactory, after their completion, perhaps around the year 2020, we can envisage two possible scenarios. If by this time CCS has proved effective enough to supply a sizeable proportion of the oil companies' carbon dioxide needs and is significantly reducing projected global carbon emissions, air capture might remain predominantly linked with EOR. The technology would enable oil companies to extend EOR to depleted reservoirs beyond the reach of carbon dioxide supply networks, and make modest contributions to global climate change mitigation.

But if by 2020 CCS has failed to develop and it's obvious that cumulative greenhouse gas emissions have created a threat that demands the (long overdue) declaration of total war on anthropogenic global warming, air capture technology will be mature enough to step into the breach. Wind-powered artificial forests offshore and solar-powered ones in suitable desert locations could soak up the world's excess carbon dioxide, giving countries like China, the USA and India time to replace their ageing coal-fired energy capacity with zero-carbon alternatives.

1. https://westcoastclimateequity.sslpowered.com/westcoastclimateequity.org/wp-content/themes/studiopress/images/HadleyClimateModelTemp.pdf

2. http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2010).pdf

3. http://www.americanprogress.org/issues/2007/05/coal_report.html

4. http://www.globalccsinstitute.com/

5. Nature 456, 871-872, 18 December 2008.

6. The Institution of Mechanical Engineeers classes air capture as an example of geo-engineering. But that's because its members are engineers and they want a piece of the action. In fact, as Klaus Lackner and other pioneers of air capture have made clear, the process is a form of climate mitigation. Since the climate problem is chiefly caused by the addition of too many carbon dioxide molecules to the atmosphere, in climate mitigation it matters not a whit whether we remove a given molecule before it leaves a power station, as in CCS, or after, as in air capture..

7. Klaus Lackner, Scientific American, June 2010.

8. http://www.imeche.org/Libraries/Key_Themes/IMechEGeoengineeringReport.sflb.ashx

9. http://www.adv-res.com/pdf/v4ARI%20CCS-CO2-EOR%20whitepaper%20FINAL%204-2-10.pdf