CARBON SEQUESTRATION

Neil F Curtis
Emeritus Professor of Chemistry
Victoria University of Wellington

The climate change debacle continues. TheIPCC4 report has been released. Its conclusions are that it is now highly probable that anthropomorphic greenhouse gas release is going to cause major climactic problems (though the chronic deniers remain unconvinced). Politicians, including even the US and Australian administrations, reluctantly accept that there may be something to this inconvenient truth. Their response, however, has been in rhetoric rather than in effective measures to curb the rate of increase in greenhouse gas production, let alone decrease it. The major problem is carbon dioxide emissions and their major source is burning coal. Continued growth of the US (and Australian) economies is dependent on expanded coal-fired electricity generation and all projections are for steadily increasing coal use. China and India also project massive increases in coal use in their efforts to raise the living standards of their people. China alone plans to build over 500 coal fueled power stations over the next ten years. Each tonne of coal burned produces about 3 tonnes of carbon dioxide and a typical 1 GW power station produces about 6 million tonnes of carbon dioxide per year.

No conceivable combination of nuclear and renewable electricity generation can substitute for coal in the major polluting countries in the near future - if the growth scenario continues unabated. For the major emitters of carbon dioxide stopping burning coal is just not a politically acceptable option.

The solution proposed by politicians in these countries is carbon sequestration. This, they assert, will enable increasing burning of coal, but somehow make the carbon dioxide go away. Relevant questions are:

Is it possible to burn coal and somehow collect the resulting carbon dioxide?

Is it possible to prevent this carbon dioxide **ever** getting into the atmosphere?

Can this be done at a politically acceptable cost?

Is it possible to burn coal and somehow collect the resulting carbon dioxide?

It is, in principle, technically possible to do this. There are currently two possible processes. Both use established technologies.

The simplest method is to burn the coal, as at present, and then extract the carbon dioxide from the exhaust stream. At present carbon dioxide is extracted

from natural gas (such as from the Kapuni or Maui fields) by scrubbing with amines, such as ethanolamine. The process works well to reduce carbon dioxide levels from the up to 50% found in natural gas down to the 2% level acceptable in a gas supply. The process could *probably* be developed to remove the majority (85 –95%) of the carbon dioxide from the exhaust stream from coal burning but this will be more complicated (and expensive in both capital expenditure and running costs).

A variant is to burn the coal in oxygen, or oxygen enhanced air. Separation of the carbon dioxide from the flue gas is the easier, but combustion temperatures are higher, leading to corrosion problems, and the prior separation of the oxygen from the air requires additional plant and operating costs.

The second method is to gasify the coal, essentially by heating with air and steam and then to catalytically reform the resulting gas mixture to a mixture of hydrogen and carbon dioxide. The carbon dioxide is then scrubbed from the mixture and the hydrogen burned to generate electricity, or used to fuel hydrogen powered cars, if that technology can be made acceptable. This process uses established technology, but is again expensive in both capital expenditure and running costs.

Is it possible to prevent the collected carbon dioxide ever getting into the atmosphere?

These carbon dioxide collection processes, and any others likely to be developed, would result in the collection of millions of tonnes per year of carbon dioxide gas, which has to be continuously disposed of - permanently.

The only currently practical repositories for such large amounts of carbon dioxide are underground. The obvious choices are depleted gasfields and oilfields. These are generally regions of porous rock capped by a dome of impervious strata. They have contained gas for millions of years and should be able to contain carbon dioxide indefinitely. Carbon dioxide is currently injected into depleting oilfields to help extract the last of the oil, so the injection technology is well established. This technology has been in use for 10 years at the Sleiper gasfield in Norway, where 1 M tonne/year of carbon dioxide is buried. It is also in use in Algeria.

Such structures will generally contain water, often saline. Carbon dioxide is injected through a well at 80×10^5 Pascal. Below 800 metres depth carbon dioxide exists as a supercritical fluid with a density of 700 kg m^3. It therefore displaces the water downwards and is contained by the dome. However, unlike oil, carbon dioxide is appreciably soluble in water under these conditions, so if the water is contiguous with a larger aquifer then migrating water could carry carbon dioxide out of the containment zone and so potentially release it.

Other underground structures could be similarly used. The requirements are similar; a region of porous rock with an impervious cap, generally of a dome shaped structure, so the carbon dioxide cannot migrate to a fractured-rock region from which it could diffuse to the surface.

Such structures in the past have generally had no commercial significance, so have been little investigated, and their locations and properties are largely unknown. Any proposed underground storage system would need to be very thoroughly researched before it could be trusted for permanent disposal. This investigation would be comparable in cost to that of a new gas field, which is very expensive.

The carbon dioxide has to be piped to the disposal oilfield, so this approach is feasible only when the coal is burned relatively close to a depleted gas or oilfield, and many regions do not have suitable sites. Depleted oilfields in the US would be able to contain all the carbon dioxide produced by power generation in the US for a period of years, so would provide only a breathing space while other solutions are developed.

Carbon dioxide is absorbed by coal in deep seams, which could not subsequently be mined. The potential capacity is uncertain. Another disposal method that has been suggested is injection into the bottom of deep ocean basins. It is not obvious why it would stay there indefinitely.

Can carbon dioxide be sequestered at a politically acceptable cost?

It is unlikely that it would be economic to retrofit any existing coal-fired power station with exhaust gas carbon dioxide capture, so existing plants would continue to emit carbon dioxide for their economic life. Incorporating the technology into all new power stations would be possible. The simpler exhaust gas extraction process, which is as yet unproven, would add to the cost of the station, and would consume appreciable energy, making the electricity produced more expensive. The coal gasification route is an established technology, but would greatly increase the cost of a new power station, and be energy-expensive to operate. It would probably be economic only for extremely large power stations.

Estimates of the cost range from US$25 – US$50 per tonne of carbon dioxide, of which 80% is the cost of capture, with a resulting increase in cost of electricity in the range 40 – 85%.

These increased costs would have to be balanced against any carbon emission-charging regime. In a free market economy carbon sequestration would be adopted only if cheaper, so the carbon price would have to be set at a level which made capture and sequestration economic. This would have implications for transport and many other industries.

Carbon dioxide capture would be practical only for large point sources such as power stations, steel works and cement works. It would be costly to implement and practical only where suitable burial sites are available. Such burial sites would have to guarantee permanent disposal, not just for the few thousand years required for a nuclear waste disposal site. The most likely leaks would be from wells into the stratum, which would have to be very carefully sealed and the field monitored indefinitely. Some legacy!

Conclusions

Coal use will continue to increase and there is no political will to stop it.
The growth scenario in both the industrialized and developing world will see the increasing rates of increase of carbon dioxide emissions.

Carbon dioxide sequestration is our present best hope for minimizing climate change.

If coal use is to be reduced the development of renewable energy sources and methods of minimization of energy use are essential. Research with these objectives should be of the highest priority. There is little evidence of the political will to adequately enhance this research.

For more detail, see Steve Furnival, Physics World, September 2006, p24, or chapters 3 and 5 of the IPCC4 report at www.ipcc.ch.