This *Economist* article shows that carbon capture is doable, but expensive, therefore a revenue generation component is needed to offset costs. SETF's EmeraldCarbon approach produces recycled products that are marketable and allow carbon capture to carry its own weight.

Carbon capture and storage

A shiny new pipe dream

Capturing the carbon dioxide from power stations is not hard. But it is expensive. A new project in Norway aims to make it cheaper

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AS Helene Boksle, one of Norway's favorite singers hit the high notes at the Mongstad oil refinery on May 7th, the wall behind her slid open. It revealed, to the prime minister and other dignitaries present, an enormous tangle of shiny metal pipes. These are part of the world's largest and newest experimental facility for capturing carbon dioxide.

Such capture is the first part of a three-stage process known as carbon capture and storage (CCS) that many people hope will help deal with the problem of man-made climate change. The other two are piping the captured gas towards a place underground where the rocks will trap it, and then actually trapping it there. If the world is to continue burning fossil fuels while avoiding the

consequences, then it will need a lot of CCS. There is no other good way to keep the CO_2 emitted by power stations, and also by processes such as iron- and cement-making, out of the atmosphere. To stop global warming of more than 2°C—a widely agreed safe limit—carbon-dioxide emissions must be halved by 2050. According to the International Energy Agency, an intergovernmental body that monitors these matters, CCS would be the cheapest way to manage about a fifth of that reduction. To do this, the agency reckons, requires the building of 100 capture facilities by 2020 and 3,000 by 2050. Which is a problem, because at the moment there are only eight, none of which is attached to a power station? Another 28, mostly in North America, are under construction or planned. But some are likely to be cancelled—as happened on May 1st to a project in Alberta. CCS is thus having difficulty reaching escape velocity.

That is not because it is hard. Since 1996, for example, Statoil, Norway's largest oil company has captured and stored the CO_2 which forms part of the natural gas extracted from the Sleipner field in the North Sea. Rather, the process consumes a lot of power that would not otherwise have to be generated—which is ironic, and also makes it expensive. Hence the need for experiments like those at Mongstad, to try to improve and cheapen it.

Burying bad news

The most common capture technologies involve running the gas to be processed through a solution of amines or ammonium carbonate. These react with CO_2 to form soluble chemicals called carbamates and bicarbonates. The remainder of the exhaust (mostly nitrogen) can then be vented safely to the atmosphere. The carbon-rich solution, meanwhile, is treated in a separate vessel to release its burden of CO_2, which can then be piped away and stored, and the amines or ammonium carbonate thus liberated recycled.

All of which is fine and dandy except that, if rigged to the average coal-fired power station, this process might use a quarter of the energy the plant produces. According to Howard Herzog, a chemical engineer at the Massachusetts Institute of Technology who has made a study of the matter, that implies a cost of between $50 and $100 per tonne of carbon stored. Carbon dioxide can sometimes be sold to oil companies for injection into partially depleted wells, in order to force more petroleum out of them. For that use it fetches at most $40 a tonne. But much CO_2 is not produced near depleted oil wells—and anyway, the price would surely drop if CCS became widespread. In one way or another, then, the technology will need to be subsidized if it is ever to become important.

There was a rush of interest in CCS in the late 2000s, including $3 billion for it in America's stimulus package of 2009. But many projects are now being cancelled. Either the developers have lost confidence in government commitments to support them or their costs have turned out higher than expected. Mongstad—a billion-dollar development owned jointly by the Norwegian government and three oil companies, Statoil, Shell and Sasol of South Africa—is a rare exception that has actually opened. Hence the hoopla.

The facility itself consists of two capture plants fitted with more than 4,000 instruments to monitor what is going on, and with a total capacity of 80,000 tonnes of carbon a year. These plants are connected to the exhaust flues of the refinery and also to a nearby gas-fired power station. That lets operators experiment with different flow rates and carbon-dioxide concentrations, which can be tweaked to be anything from 3.5% to 14% (roughly equivalent to those from a coal-fired power station).

The operators will also experiment with the capture technology itself. At one of the two plants Aker Clean Carbon, a Norwegian firm, will have 14 months to try out a new amine solution. At the other Alstom, a French concern, has 18 months to test the ammonium-carbonate process.

Amine- and ammonium-carbonate-based CCS are not, however, the only ways to do things. Two other techniques, called gasification and oxy-combustion, work by reacting coal with pure oxygen rather than air, and thus produce exhausts that require little treatment before burial. The former uses coal, oxygen and steam to produce burnable hydrogen. The latter burns coal directly. Purifying oxygen and raising steam, however, both consume energy. And gasification also requires bespoke plants. Unlike the other processes it cannot be retrofitted to existing power stations.

The upshot is that there is no free lunch. If people are serious about carbon capture and storage, they will have to pay for it. The best that facilities like Mongstad can do is make the meal as cheap as possible.