# Researchers develop initial step toward carbon sequestration

September 21 2009, by David L. Chandler

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MIT researchers have developed designs for a new kind of coal-burning power plant, called a pressurized oxy-fuel combustion system, whose carbon-dioxide emissions are concentrated and pressurized so that they can be injected into deep geological formations. This system is a way to reduce the energy penalty that all carbon-capture systems for power plants have compared to regular fossil-fuel plants, and could thus be an enabling technology to help make carbon capture and sequestration systems (CCS) practical and affordable. While all carbon capture systems incur about a one-third reduction in plant efficiency, this system reduces that penalty.

Researchers at MIT have shown the benefits of a new approach toward eliminating carbon-dioxide ($CO_2$) emissions at coal-burning power plants.

Their system, called pressurized oxy-fuel combustion, provides a way of separating all of the carbon-dioxide emissions produced by the burning of coal, in the form of a concentrated, pressurized liquid stream. This allows for carbon dioxide sequestration: the liquid $CO_2$ stream can be injected into geological formations deep enough to prevent their escape into the atmosphere.

Finding a practical way to sequester carbon emissions is considered critical to the mitigation of climate change while continuing to use fossil fuels, which currently account for more than 80 percent of energy production in the United States and more than 90 percent worldwide. $CO_2$ emissions from fossil fuels are projected to rise by more than 50 percent worldwide by 2030.

It might seem paradoxical to reduce the carbon footprint of a coal plant by making its emissions into a more concentrated stream of carbon dioxide. But Ahmed Ghoniem, the Ronald C. Crane (1972) Professor of Mechanical Engineering and leader of the MIT team analyzing this new technology, explains: "this is the first step. Before you sequester, you have to concentrate and pressurize" the greenhouse gases. "You have to redesign the power plant so that it produces a pure stream of pressurized liquid carbon dioxide, to make it sequestration ready."

There are various approaches to carbon capture and sequestration being developed and tested, and the oxy-fuel combustion system "is one of the technologies that should be looked at," says Barbara Freese, lead author of a report on coal power by the environmental group Union of Concerned Scientists. Ghoniem says that of the approaches to oxy-fuel combustion, he and his MIT colleagues are the only academic team

examining a pressurized combustion system for carbon dioxide capture.

A paper describing the approach appeared in August in the journal Energy. The Italian energy company ENEL, the sponsor of the research, plans to build a pilot plant in Italy using the technology in the next few years.

Ghoniem explains that any system for separating and concentrating the carbon dioxide from a power plant reduces the efficiency of the plant by about a third. That means that it takes more fuel to provide the same amount of electricity. Therefore, finding ways to minimize that loss of efficiency is key to making carbon-sequestration systems commercially viable.

## Reducing the penalty

There will always be some energy penalty to such capture-enabled systems, because it requires some energy to separate gases that are mixed together, such as separating carbon dioxide from the combustion gases emerging from an air-based combustion chamber or oxygen from air for oxy-fuel combustion. As an analogy, "mixing salt and pepper is very easy, but separating them takes energy," he says. "Nobody in their right mind will jump into this and do it unless we can reduce the energy penalty and the extra cost, and only if it is mandated to reduce CO2 emissions" he says. And that's what the new process is designed to do.

Other groups have been looking into oxy-fuel combustion, in which pure oxygen is fed into the combustion chamber to produce a cleaner and more concentrated emissions stream (a mixture of oxygen and CO2 replaces ordinary air for combustion, which is nearly 79 percent nitrogen and 21 percent oxygen, thus eliminating more than three-quarters of the resulting flue gases). The focus of their studies is a system that adds one more element, putting the whole combustion chamber under pressure,

which results in a more concentrated, pressurized emissions output.

Ghoniem says even though this process uses more energy at the beginning of the combustion cycle because of the need to separate oxygen from air and pressurize it, the increased efficiency of the power cycle raises the net output of the plant and reduces the compression work needed to deliver CO2 at the requisite state for sequestration, as compared to the unpressurized carbon-capture systems; in other words, the overall energy penalty is reduced. "You have to deliver carbon dioxide at high pressure for sequestration," he points out. The system simply introduces some pressurization earlier in the process, so the output stream requires less compression at the end of the process while extracting more energy from the combustion gases.

The pressurization of the combustion system also reduces the size of the components and hence the plant, which could "reduce the footprint of needed real estate, and potentially the price of components," he says. It is expected to lead to an overall improvement of about 3 percent in net efficiency compared to an unpressurized system, and with further research and development this can probably be improved to about a 10 to 15 percent net gain from the current values, he says.

That could be key to gaining acceptance for carbon capture and sequestration (CCS) as a way to allow the continued growth of coal power while curtailing its emissions. The Union of Concerned Scientists report last year, "Coal Power in a Warming World," said: "CCS is still an emerging technology. It has the potential to substantially reduce CO2 emissions from coal plants, but it also faces many challenges."

Freese says that "the potential of this technology is there, but it needs to be demonstrated" whether it can work as expected and be economically viable. "We want to see what these actual results are before committing" to implementing such systems. Also, she added, all carbon-sequestration

plans "don't solve all the other fuel-cycle problems — all the problems associated with mining." In fact, because all such plants are inherently less efficient, "you'd need to mine more coal" for a given energy output.

The new MIT research has the potential to help narrow that gap, if it really does prove capable of reducing the efficiency penalty enough to make such plants competitive, and if the planned ENEL pilot plant in Italy based on this technology is successfully built and tested to confirm the practicality of the concept.

Ghoniem concedes that much more research is still needed for CCS technology. The three areas that need study most, he says, are systems' integration to determine the operating conditions at which the different components work together for highest efficiency; component-level research to optimize of the design of individual parts of the new system, especially the combustion chamber; and process analysis to examine the details of the physics and chemistry involved. His group has been concentrating on detailed computer simulations of the process to aid in the design of better systems.

Source: Massachusetts Institute of Technology (news : web)