The 9th International Conference on Greenhouse Gas Control Technologies (GHGT-9), organized by MIT in collaboration with the IEA Greenhouse Gas R&D Programme (IEA GHG), with sponsorship from the U.S. Department of Energy, is taking place this week in Washington, D.C. It features several MIT papers on greenhouse gas control and reduction.

A quicker, easier way to make coal cleaner

Nancy Stauffer
MIT Energy Initiative

Construction of new coal-fired power plants in the United States is in danger of coming to a standstill, partly due to the high cost of the requirement — whether existing or anticipated — to capture all emissions of carbon dioxide, an important greenhouse gas. But an MIT analysis suggests an intermediate step that could get construction moving again, allowing the nation to fend off growing electricity shortages using our most-abundant, least-expensive fuel while also reducing emissions.

Instead of capturing all of its CO2 emissions, plants could capture a significant fraction of those emissions with less costly changes in plant design and operation, the MIT analysis shows.

"Our approach — 'partial capture' — can get CO2 emissions from coal-burning plants down to emissions levels of natural-gas power plants," said Ashleigh Hildebrand, a graduate student in chemical engineering and the Technology and Policy Program. "Policies such as California's Emissions Performance Standards could be met by coal plants using partial capture rather than having to rely solely on natural gas, which is increasingly imported and subject to high and volatile prices."

Hildebrand will present her findings on Nov. 18 at the 9th International Conference on Greenhouse Gas Control Technologies in Washington, D.C. Her co-author is Howard J. Herzog, principal research engineer at the MIT Energy Initiative and chair of the conference organizing committee.

The United States is facing a pressing need for more power plants that run essentially all the time. Renewable sources aren't suited to the task, nuclear plants can't be built quickly enough, and expanded reliance on natural gas raises price and energy-security concerns. Coal, which now supplies more than half of all U.S. electricity, seems the best option.

But as several states have started to regulate CO2 emissions, and others are expected to follow suit, some of the luster has come off coal. Amid the uncertainty, no one wants to be the "first mover" on building a new coal plant incorporating carbon capture and storage (CCS). Depending on the type of plant, carbon capture alone can increase the initial capital cost by 30 to 60 percent and decrease plant efficiency so that the cost per kilowatt-hour rises. That high cost would reduce a plant's economic competitiveness, meaning it might be called on to run on a limited basis, or not at all. Plus, CCS hasn't been proved at full scale, so no one knows exactly what to expect.

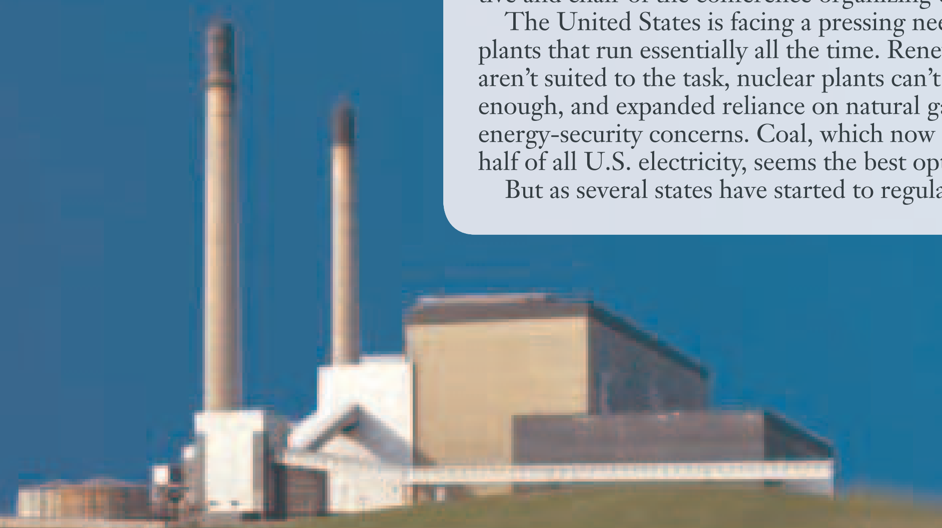
In Herzog's view, the call for full carbon capture is "a policy of inaction, a policy that won't move forward either new coal plants or the CCS technology." Partial capture could be a viable intermediate step.

The push for full capture (defined as 90 percent of total plant emissions) is in part economic: Everyone assumed that 90 percent capture would — due to economies of scale — yield the lowest cost per ton of CO2 removed. Anything less than 90 percent would mean a higher per-ton cost.

To investigate that assumption, Hildebrand and Herzog modeled the technological changes and costs involved in capturing fractions ranging from zero to 90 percent. The model takes into account technological breakpoints. For example, carbon capture is achieved by a series of devices that absorb CO2, release it and compress it. Full capture may require two or more parallel series.

The model confirms that the cost per ton of CO2 removed declines as the number of captured tons increases. Not surprisingly, when the second series is added, cost per ton goes up, but it then quickly levels off. Cost per ton is thus roughly the same at, say, 60 percent capture as it is at 90 percent capture. Since there are no economies of scale to be gained by going to 90 percent, companies can remove less — and significantly reduce their initial capital investment as well as the drop in efficiency once the plant is running.

The researchers conclude that as a near-term measure, partial capture looks promising. New coal plants with lower CO2 emissions would generate much-needed electricity while also demonstrating carbon capture and providing a setting for testing CO2 storage — steps that will accelerate the large-scale deployment of full capture in the future.



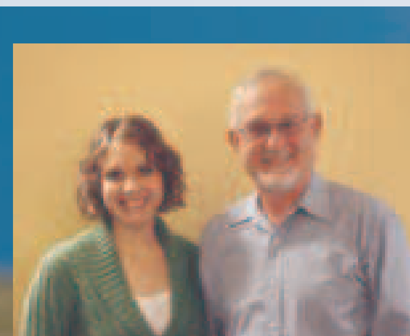


PHOTO / **RAMYA SANKAR**

MIT's Ashleigh Hildebrand and Howard Herzog are working toward a more ecofriendly option for coal power plants.

Burying the greenhouse gas

New tool could aid safe underground storage of CO2

Deborah Halber
Civil and Environmental Engineering

To prevent global warming, researchers and policymakers are exploring a variety of options to significantly cut the amount of carbon dioxide that reaches the atmosphere. One possible approach involves capturing greenhouse gases such as carbon dioxide at the source — an electric power plant, for example — and then injecting them underground.

While theoretically promising, the technique has never been tested in a full-scale industrial operation. But now MIT engineers have come up with a new software tool to determine how much CO2 can be sequestered safely in geological formations.

The work will be reported Nov. 18 at the 9th International Conference on Greenhouse Gas Control Technologies (GHGT-9), to be held Nov. 16-20 in Washington, D.C.

According to the 2007 MIT study, "The Future of Coal," and other sources, capturing CO2 at coal-burning power plants and storing it in deep geological basins will mitigate its negative effects on the atmosphere.

However, injecting too much CO2 could create or enlarge underground faults that may become conduits for CO2 to travel back up to the atmosphere, said Ruben Juanes, assistant professor of civil and environmental engineering (CEE) and one of the authors of the work. "Our model is a simple, effective way to calculate how much CO2 a basin can store safely. It is the first to look at large scales and take into account the effects of flow dynamics on the stored CO2," he said.

Already Juanes and co-author CEE graduate student Michael L. Szulczewski have applied their model to the Fox Hills Sandstone in the Powder River basin straddling Montana and Wyoming. They found that the formation would hold around 5 gigatons of CO2 — more than half of all the CO2 emitted by the United States each year.

A geological basin is a large underground bowl between 100 and 1,000 kilometers wide and 5,000 kilometers deep that has filled over millennia with layers of sand, fine-grained clays and other sediments that are eventually consolidated into porous rock. Some of the layers contain brine and are called deep saline aquifers. CO2 would be injected into the aquifers through wells.

The MIT model predicts how much a plume of CO2 will migrate from its injection well and the path it is likely to take due to underground slopes and groundwater flow.

"A lot of people have done studies at small scales," Szulczewski said. "If we're going to offset emissions, however, we're going to inject a lot of CO2 into the subsurface. This requires thinking at the basin scale."

"Despite the fact that our model applies at the basin scale, it is very simple. Using only pen and paper, you take geological parameters such as porosity, temperature and pressure to calculate storage capacity," Szulczewski said. "Other methods suffer from major shortcomings of accuracy, complexity or scale."

Juanes studies a phenomenon called capillary trapping, through which CO2, liquefied by the pressure of the Earth, is trapped as small blobs in the briny water (picture bubbles of oil in vinegar). The CO2 dispersed throughout the basin's structural pores eventually dissolves and reacts with reservoir rocks to precipitate out into harmless carbonate minerals.

CO2 has been sequestered in small pilot projects in Norway, Algeria and elsewhere. In 2004, 1,600 tons of CO2 were injected into high-permeability brine-bearing sandstone of the Frio formation 1,500 meters beneath the Gulf coast of Texas. Current proposals call for injecting billions of tons within the continental United States.