

Algeria's In Salah field.

To date, technologies for capturing CO₂ from coal combustion have been demonstrated only in the laboratory or at most on the pilot scale, says Feeley. For coal technologies, the pilot scale ranges roughly from ½ MW to 50 MW. For the 99% of US coal-generating plants that use pulverized coal technology, CO₂ capture would take place after combustion. In recent years IGCC technology has been promoted by DOE largely for its capability to extract CO₂ prior to combustion of the synthesis gas. But IGCC is expensive, and only two plants have been built in the US, both with DOE subsidies. US utilities have announced plans to build as many as 30 others, DOE Undersecretary Bud Albright told the House Committee on Science and Technology, but many companies have been unable to obtain approval for construction because they can't assure state regulators that CO₂ capture technology will be ready and available in time.

DOE's target is to find postcombustion capture technologies that will increase the cost of electricity generation by no more than 45% from its current level, and for precombustion capture,

by no more than 20%. Edward Rubin, an engineering professor at Carnegie Mellon University, estimates that a CCS system for a 400-MW coal plant would cost between \$700 million and \$1 billion to build and operate for five years. "Despite a lot of talk and some serious commitments by a number of countries, there today is not a single large-scale CCS project at a coal plant anywhere in the world that has the full financing needed to proceed," he told the House energy committee.

Capture candidates

The leading candidate technologies for postcombustion capture today are advanced chemical solvents, sorbents, and membranes, according to Feeley. In late July DOE awarded 15 multiyear, cost-shared grants, valued at \$36 million, to support carbon capture development projects. Ranging from \$700,000 to \$5 million, the projects cover a broad range of capture approaches that also include oxygen combustion and chemical looping, which involves the use of chemical carrier particles to transport oxygen from an oxidizing reactor to a combustion chamber.

Powerspan Corp is set to begin a

demonstration next year of its aqueous ammonia capture process at a Basin Electric Power Cooperative plant in North Dakota. Powerspan estimates it will capture about 1 million tons of CO₂ a year. The company is currently testing the technology at a FirstEnergy Corp generation station in Ohio and capturing about 20 tons of CO₂ a day.

Wisconsin's We Energies is hosting a demonstration of Alstom Power Inc's chilled ammonia solvent technology at the power plant in Pleasant Prairie, treating 1% of the flue gas from a single boiler. The year-long experiment, which also involves the Electric Power Research Institute Inc, is due for completion this winter. But the project's partners say that it's already apparent that using the process will be less expensive than switching to IGCC.

Another technology approach is to burn coal in a pure oxygen environment, producing a flue gas containing a much higher concentration of CO₂. That would simplify the compression of CO₂ into a liquid state for transport to the injection site. But cheaper processes for oxygen production will need to be developed to improve the economics, Feeley says.

David Kramer

Giant telescope teams seek funding

Neither of the huge telescopes spearheaded in the US is a sure bet, but project members say that for the country to remain internationally competitive in optical astronomy, both need to get built.

Two US-led groups are planning 30-meter-class optical-IR telescopes, each with a price tag approaching \$1 billion. Neither project has yet raised enough private money to cover the full cost, and both hope for public funding. But before getting on board, NSF wants to see what priority the astronomy community places on extremely large telescopes in the next astronomy and astrophysics decadal survey, which will be completed over the next 18 months or so.

The Thirty Meter Telescope (TMT) design, an extension of the technology used in the Keck telescopes, consists of 492 1.4-meter hexagonal mirror tiles. The rival Giant Magellan Telescope's (GMT's) primary mirror would be made from seven 8.4-meter circular segments. It would have a diffraction aperture of 24.5 meters but, because of the gaps between the segments, a collecting area equivalent to a 22-meter telescope. "The two designs are sophisticated. It's very likely that we will actually get to the diffraction limit," says David Silva, director of the National Optical Astronomy Observatory, which represents the broad astronomy community's partici-

pation in the proposed telescopes. "The spatial resolution will be five times better than the *James Webb Space Telescope* [JWST], with roughly 20 times the photon collecting area."

The exciting unknown

The science capabilities of the two telescopes would be similar, and their goals would include searching for extrasolar planetary systems and biomarkers, studying black hole growth and the formation of the earliest stars and galaxies, and probing dark energy and dark matter. "You start with problems you are stuck on with the facilities you already have and outline the case for a larger facility," says Wendy Freedman, director of the observatories of the Carnegie Institution of Washington, the lead institution on the GMT. "But what's likely to be most exciting is what we cannot even imagine now."

The GMT has settled on a site in Las Campanas, Chile, while both the TMT and the 42-meter European Extremely Large Telescope have yet to choose between sites in the Southern and Northern Hemispheres—in Chile or Mauna

Kea, Hawaii, for the TMT and in Chile, Argentina, the Canary Islands, or Morocco for the EELT. Some native Hawaiians oppose further development on Mauna Kea (see PHYSICS TODAY, January 2004, page 22). "We are making as strong an attempt as we can to engage the people who have been opposed," says Michael Bolte, observatories director at the University of California (UC), which with Caltech is a founding TMT partner. "I don't know what the outcome will be, but we are working very hard to find a way forward at Mauna Kea that addresses the cultural and environmental concerns."

Because the telescopes are independent, they could all end up in Chile. "It would be nice to have one in the North, but scientifically there is not much that demands it," says Freedman. "The exception is nearer objects, and for some projects you want to cover the whole sky." Some astronomers, however, are concerned about clustering the new facilities. "I think that's a mistake," says Bruce Carney of the University of North Carolina at Chapel Hill, who attended a June workshop on public participation

The primary mirror of the Thirty Meter Telescope will be made from 492 hexagonal segments each 1.4 meters in diameter (below). The first of seven 8.4-meter mirror segments that will make up the Giant Magellan Telescope's primary mirror (right) is polished by a stressed lap, which deforms as it moves across the asymmetric surface called for in the telescope's off-axis design. (The TMT image artist rendering is courtesy of the TMT Observatory Corp.)



in the giant telescopes. For example, he adds, the giant telescopes could coordinate with the *JWST*. "That's an all-sky instrument, and it seems foolish to throw away a third or more of the sky. You become the myopic astronomer."

Government participation?

For both the TMT and the GMT, going forward depends on amassing more money. The Gordon and Betty Moore Foundation has pledged \$200 million to the TMT, on condition that UC and Caltech each raise an additional \$50 million (see *PHYSICS TODAY*, March 2008, page 20). A consortium of Canadian universities is the third partner in the project, and Japan is considering signing on. The GMT's partners—eight US institutions and Australia, with South Korea poised to join—each aim to contribute \$60 million; Houston businessman George Mitchell is one donor to the project. For the US-led projects, raising money for operations is harder than for construction, whereas the opposite is true for the EELT because of member nations' dues to the parent European Southern Observatory.

A 50% share in an extremely large telescope was the top-ranked ground-based priority in the last US decadal survey. The US could get equivalent ac-

cess through quarter shares in both the TMT and the GMT, but many astronomers doubt the US would spring for two. Indeed, they worry that participation in even one giant telescope may be out of reach. Others, though, note that before any 8- or 10-meter telescopes were built, many people believed only one was affordable; today there are a dozen.

"I do think it's feasible [for the US government] to join both at the 25% level," says Freedman. "There are many advantages to having two large telescopes." And, with the EELT in the works, says the Carnegie Institution's Patrick McCarthy, who heads the GMT's science advisory committee, "If we want to maintain anything like parity—it will still be stretching to get that—both [the GMT and the TMT] projects need to succeed."

But Carney cautions that a balance is needed between the new diffraction-limited telescopes and still serviceable smaller facilities. "There is not enough talk about better instruments for existing telescopes," he says. At this point, says Wayne Van Citters, a senior adviser in NSF's mathematics and physical sciences directorate, "NSF has to await the outcome of the decadal survey before making up its mind. We've

told the community that many different paths might be possible."

It's not just for the money that the US-led teams want their government on board. "You can draw on the brain power of a much larger group of people," says Silva. Adds Freedman, "It would be dreadful to go back to a time when telescopes are in the hands of a small group of private institutions and the general population doesn't have access to them."

Toni Feder

O'Riordan takes VP reins at AIP

This month ocean scientist Catherine O'Riordan becomes the new vice president of the Physics Resources Center at the American Institute of Physics. In that post, she will direct AIP's statistical research, history, education, media and government relations, magazines, and industrial outreach programs that serve 10 member societies, the public, and the corporate sector. The magazines division produces *PHYSICS TODAY*. O'Riordan replaces former physics professor James Stith, who announced his retirement earlier this year following 10 years at AIP.

O'Riordan, who holds a doctorate in civil engineering from Stanford University and specializes in environmental fluid mechanics, was director of science development and education at the Consortium for Ocean Leadership, a nonprofit organization that represents



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