The discussions in Manaus underscored just how many nagging details remain to be worked out. Hardware for controlling and dispersing the CO_2 must be designed and manufactured. Researchers must decide the best way to ship CO_2 to the site. Should they buy it from Carboman, the Manaus supplier that puts the fizz in the hot city's Coca-Cola, or tap a cheaper source on the other side of the country and ship it up the Amazon River? Should they upgrade the treacherous 34-kilometer dirt road to the site, or find a special vehicle able to haul 15 tons of gas on the difficult last leg of the journey? Lapola had recently test-driven a truck that might work: a modified mobile missile launcher made in the Czech Republic.

Construction at the site should get underway by the middle of next year, Lapola says. So far, he has raised about $4 million in grants from the Inter-American Development Bank and two Brazilian agencies, nearly enough to run the two-plot startup phase of the experiment, but he will need tens of millions of dollars more to expand to eight plots for another decade, as planned. Much of the money will go to CO_2, Lapola says: With the gas constantly escaping into the sky and surrounding forest, each treatment plot will need about 3.7 metric tons of CO_2 per day, or about 1350 tons a year, at up to $1000 a ton. The 2-year startup phase of the experiment has budgeted $1.3 million for the gas alone.

Results should start coming in 6 months after AmazonFACE begins, Lapola says, but it will take years for some effects of higher CO_2 levels to become apparent. Richard Norby, a U.S. biologist from Oak Ridge National Laboratory in Tennessee and veteran FACE researcher who was at the Manaus meeting, says the results might dash hopes that the Amazon forest will provide the longed-for carbon sponge.

Norby's own experiment on a sweetgum plantation in Tennessee and studies in other forests have shown that trees exposed to elevated CO_2 initially grow faster and sequester more carbon. But sometimes the beneficial effect abates within a few years, for reasons not yet clear. Norby says he expects a similar result in the Amazon. Like many other researchers, he thinks that a lack of phosphorus—a critical plant nutrient—in most Amazon soils will limit tree growth there, no matter how much CO_2 is present in the air. In the long term, he told his colleagues on the drive from the research site to Manaus, "I don't expect the extra carbon will do didley in this system." ■

Daniel Grossman is a science journalist specializing in climate change, in collaboration with the Pulitzer Center on Crisis Reporting.

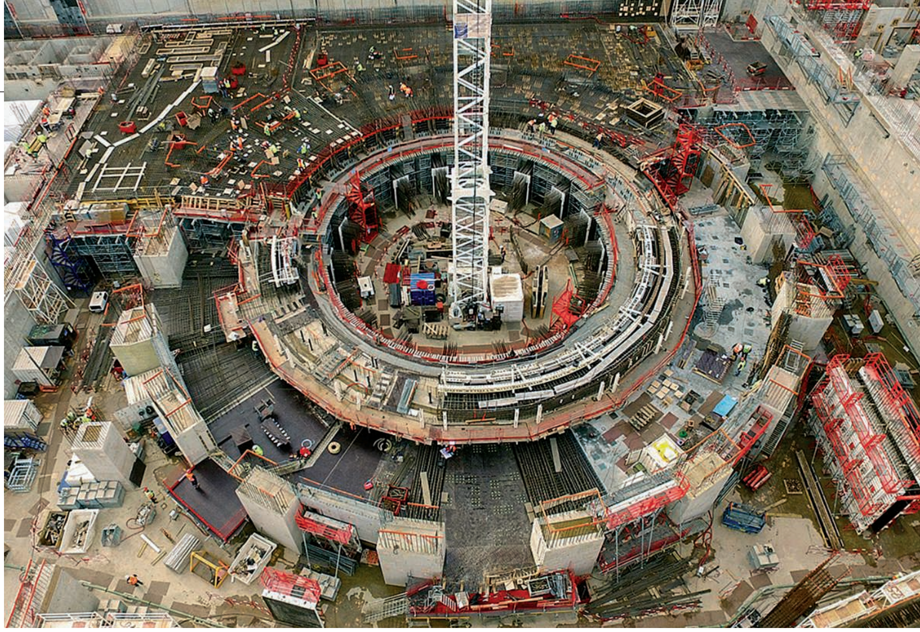


PHOTO: ITER COLLABORATIVE/EJF RICHE

FUSION ENERGY

More delays for ITER, as partners balk at costs

Review warns that new timeline could still be too optimistic

By **Daniel Clery** *and* **Adrian Cho**

It wasn't the pat on the back that ITER officials were looking for. Last week, an independent review committee delivered a report that was supposed to confirm that ITER, the troubled international fusion experiment under construction in Cadarache, France, finally has come up with a reliable construction schedule and cost estimate. But the report says only that the new date for first operations—2025, 5 years later than the previous official target—is the earliest possible date and could slip. And it underscores the challenge of ITER's ballooning budget. To start running by 2025, ITER managers have asked for an extra €4.6 billion, which they are unlikely to receive. As a result, the report says, ITER's ultimate goal—producing a "burning plasma" reaction of deuterium and tritium nuclei that sustains itself mostly with its own heat—will be delayed from 2032 until 2035 at the earliest.

ITER officials say the report confirms that the project is finally on the right track. "There is now a credible estimate of the schedule and cost envelope with respect to the financial capabilities of all the members," says ITER Director-General Bernard Bigot. "All the pieces are in place to make a decision" on enacting the plan. But others say that the new schedule is implausibly optimistic. "It's all fiction," says one expert who requested anonymity to protect his connections to the project. "As the report very carefully lays out, there are umpteen assumptions that aren't going to happen."

Dreamed up in the 1980s, ITER aims to show that deriving energy from nuclear fusion is feasible. Specifically, it aims to produce a burning plasma, trapped in an intense magnetic field, that will generate 10 times more energy than it consumes. In France, the project site is finally taking shape, as workers erect the massive facility's buildings and install the first components shipped from member states. About 40% of the work needed for first operations is done.

But delays and cost overruns have plagued ITER from the beginning. When the project partners—China, the European Union, India, Japan, Russia, South Korea, and the United States—signed the construction agreement in 2006, ITER was supposed to be finished this year for about $11 billion. The actual cost, impossible to calculate exactly because members contribute mostly parts rather than cash and use different accounting systems, could be three times as high.

ITER's woes stem from two sources, experts say. First, its design was far from complete when the agreement was signed. In fact, the report says, it's still not complete. Second, the ITER agreement established a weak central organization with little power to direct the project. Those management deficiencies were laid bare in a February 2014 review that called for 11 reforms, including the appointment of a new director-general and the completion of a realistic "baseline"

The foundations of ITER's reactor pit take shape in Cadarache, France.

construction schedule and cost estimate. Last November the ITER organization presented that new baseline—called the updated long-term schedule (ULTS)—to the ITER Council of representatives from the member states, and the council requested the independent review. The ULTS itself has never been made public, researchers say, but the panel report gives the bottom line.

The 14-member review panel, headed by Albrecht Wagner, former chief of the DESY particle physics lab in Hamburg, Germany, praised Bigot, a French nuclear physicist with extensive management experience in industry and government, for greatly improving ITER's management. The changes have "led to a substantial improvement in project performance, a high degree of motivation, and considerable progress during the past 12 months," the report says.

However, the report also suggests that the new schedule falls short of providing a true, reliable baseline. "[T]his is a success-oriented schedule with no contingency," the report says. "If any of the major risks that the [ITER organization] has identified materializes, then the [first plasma] date will almost certainly slip by some degree." The reviewers do not give a "probable" date for when ITER might actually start, notes the expert with connections to the project, who estimates it at 2028 or 2029. "The answer is so devastating that if they came out and said it in public, they might lose [the support of] the European Union," he says.

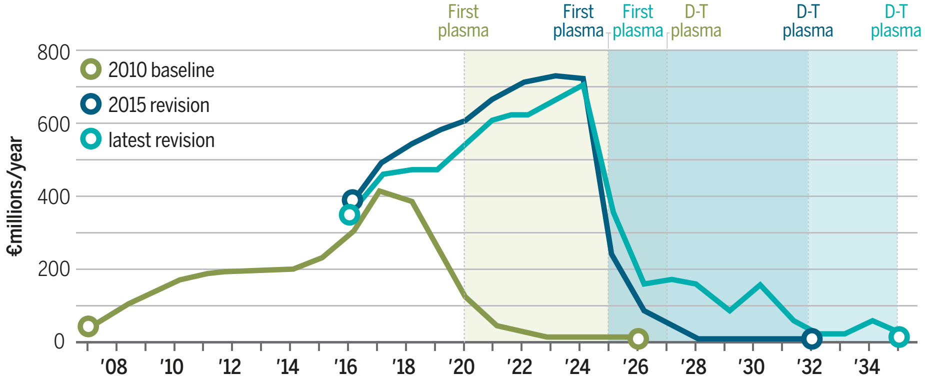
The biggest assumption behind the schedule is that members will provide an extra €4.6 billion ($5.2 billion) between now and 2025. That money would enable the ITER organization to hire many more engineers, technicians, and skilled workers to assemble the parts that the members provide. It would also enable the ITER organization to develop a reserve fund for contingencies. However, the ITER Council made it clear at its last meeting in November 2015 that the cash would not be forthcoming. In particular, representatives of the European Union—which, as host, bears 45% of the financial burden—noted that the European Parliament has fixed spending on ITER through 2020, and it cannot be increased.

Since then, the ITER organization has been trying to figure out how to keep to the schedule at a lower annual cost, adjusting it even as reviewers were analyzing it. One option would be to delay the construction of some components that won't be needed in the experiment's early years, when it will run on just hydrogen or deuterium. Neither substance can support a burning plasma, so the start of runs to achieve one would have to wait an extra 3.5 years, until 2035, the report estimates. That date "is so far off that it's more like an idea," says Stephen Dean, president of Fusion Power Associates, a nonprofit foundation in Gaithersburg, Maryland, that advocates for fusion development.

The review panel calls for the formulation of a real baseline by November. Reaching consensus on the schedule may be difficult, Dean warns, because ITER members have divergent priorities. Whereas the European Union frets over annual costs, Japan and South Korea worry about keeping the schedule for burning plasma, he says. That's because they're already planning ITER's successors, "demo" power plants that would generate electricity. To build one by 2050, they need the ITER data as soon as possible. "From the beginning of the process the Asian countries wanted to get to [deuterium-tritium] burning as fast as possible," Dean says. "They are not going to be happy to hear that the date for D-T burning is as far away as 2035." ■

ITER's evolving budget: More, later

Compared with ITER's 2010 "baseline," the schedule presented last November pushes first operations back 5 years. And to limit peak spending, ITER officials would now delay the key deuterium-tritium (D-T) runs to 2035.



DATA: ITER

RENEWABLE ENERGY

A reboot for wave energy

U.K. engineers and funders take stock of failures as they design new prototypes

By **Erik Stokstad**

In the remote Orkney archipelago off Scotland's northern coast, workers have hauled a 180-meter-long metallic sea monster onto a pier and are dismantling it. For several years, the snakelike machine floated 2 kilometers offshore, tethered to the seabed. As it undulated in the waves, fluid was forced through the sleek beast's hydraulic motors, generating up to 750 kilowatts of power, which was sent to shore via submarine cable. Now, its guts and joints are being dissected and examined for wear. "It's like an autopsy," says Tim Hurst, director of Wave Energy Scotland (WES) in Inverness, a funding program in the economic development agency that now owns the machine.

The wave energy prototype worked, but its test run ended ignominiously, amid investors' fears about its durability and slow pace of development. Fated for the scrap heap, it is a symbol of recent setbacks in the wave energy sector here. The machine's builder, Pelamis Wave Power, was the first company to feed electricity generated by a floating wave device into a national grid. But in late 2014, the Edinburgh-based company failed after investors pulled out. A year later, the other leading U.K. wave power company, Aquamarine Power in Edinburgh, went belly-up for the same reason.

Now, the Scottish government is going back to the drawing board. In December 2014, it created WES to fund cross-cutting research on wave energy and to improve technology transfer. And a new crop of companies is counting on novel, and often more-compact, designs to rescue the nascent industry. "There's quite a change going on," says Neil Kermode, managing director of the European Marine Energy Centre in Orkney, which tests wave and tidal devices. The renewed efforts, he adds, are crucial to ensuring that the United Kingdom becomes an exporter of wave energy technology.

Buffeted by strong waves and tides, the U.K. coastline is a rich resource and natural test bed for ocean energy. Efforts to harness