

UK coalition gears up to demonstrate commercial viability of fusion energy

The government is aiming to build a prototype plant in the next two decades.

The UK plans to build a prototype fusion plant by the early 2040s that can put electricity on the grid and demonstrates that fusion energy is commercially viable. Researchers with the Spherical Tokamak for Energy Production (STEP) hope to produce about 100 MW of net electricity with the new plant, sustain the amount of tritium needed to spur fusion reactions, and show that the plant can be maintained over time, says Paul Methven, CEO of UK Industrial Fusion Solutions, a private entity established by the UK government that is responsible for the delivery of STEP. The goals are “massively ambitious,” he says, “but just about doable.”

The idea that fusion energy is “getting closer to commercialization started with the UK going out for a site and creating the STEP program,” says Stephen Dean, the president of Fusion Power Associates, a research and advocacy organization that disseminates fusion-development information. In doing so, he says, the UK took the lead on the spherical tokamak.

Achieving the STEP milestones will position the UK to be at the forefront of fusion energy, says Methven. It will also create thousands of jobs, he says. UK Industrial Fusion Solutions will work with the UK Atomic Energy Authority, private companies, and other partners to deliver the plant.

The STEP team released the initial concept design in August. Magnetic fields within the spherical tokamak will confine a plasma of deuterium and tritium and heat it to more than 100 million degrees Celsius to spur nuclear reactions and produce energy. The tokamak will measure about 10 meters in diameter. In comparison, ITER, the international fusion-reaction prototype under construction in France, has a diameter of 19.4 meters (see *PHYSICS TODAY*, August 2023, page 18). STEP’s small size should help keep down construction costs, but it also leads to increased stress on the materials, including

the confinement wall, says Christopher Holland, a research scientist at the Center for Energy Research at the University of California, San Diego.

So far, the UK government has invested £300 million (about \$390 million) into STEP, but it’s too early to know how large the tab will grow. The facility will be located at the West Burton site of a former coal station in Nottinghamshire. (The last UK coal plant, at Ratcliffe-on-Soar, closed in late September.) Ash cleanup and other preparations are underway, says Methven. Construction is to begin around 2030.

Navigating the roadblocks

“The first challenge is to get to the burning plasma,” says Steven Cowley, director of the Princeton Plasma Physics Laboratory. That’s when energy released in fusion reactions heats the plasma faster than it cools, and the reactions become self-sustaining. Fusion from magnetic confinement has never produced more energy than is inputted.

Neutrons released during fusion reactions damage the tokamak walls. Methods are still needed to fix damage to the confinement walls without being exposed to the extremely radioactive environment, says Cowley. Robots may be used to conduct remote maintenance.

Tritium production presents another hurdle for researchers. Nuclear fusion fuel typically consists of a 50-50 blend

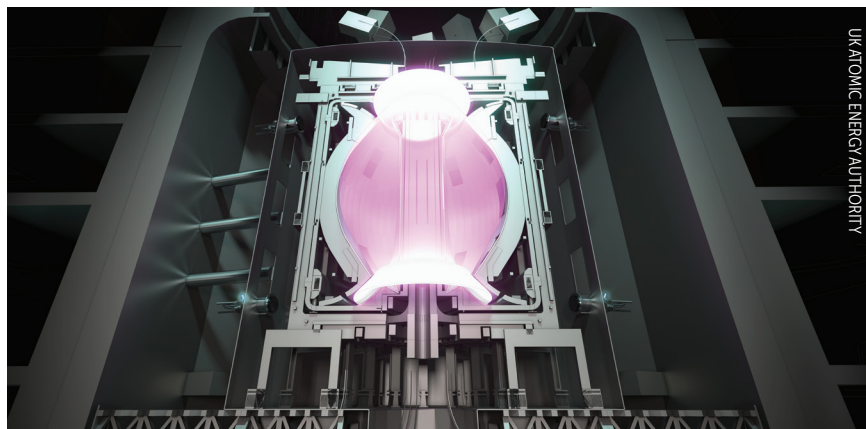


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PAUL METHVEN, the CEO of UK Industrial Fusion Solutions, leads the development of the UK’s first prototype fusion power plant.

of deuterium and tritium. The latter exists naturally only in trace amounts and has a half-life of about 12 years, so breeding and stockpiling is difficult, says Holland.

STEP builds on advances in fusion around the world: Lawrence Livermore National Laboratory achieved ignition at the National Ignition Facility through a different approach to fusion (see “National Ignition Facility surpasses long-awaited fusion milestone,” *PHYSICS TODAY* online, 13 December 2022). MIT developed low-cost high-temperature superconducting magnets in 2021 that reached a magnetic field of 20 tesla, high enough to be used in a fusion reactor. A few months later, researchers at the Experimental Advanced Superconducting Tokamak in China obtained a steady-state plasma at 70 million °C that lasted more than 17 minutes; the previous record of 6.5 minutes at the same



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THE UK ATOMIC ENERGY AUTHORITY released designs for a spherical tokamak to be completed by the early 2040s.

temperature was achieved in 2003 by France's Tore Supra tokamak.

Entities around the world are working on putting fusion energy on the grid. In the private sector, for example, Commonwealth Fusion Systems in Massachusetts plans to focus on energy production in the 2030s with a high-field tokamak. Helical Fusion in Japan is constructing a stellarator—another magnetic confine-

ment approach—to produce energy in about a decade. Others are also making progress (see “Investments in privately funded fusion ventures grow,” *PHYSICS TODAY* online, 13 October 2020). In the public sector, EUROfusion, a consortium of European fusion research institutes, plans to demonstrate net-energy production in the coming decades.

“There are several horses in the race,

but no one is sure who is in the lead or even when they will finish,” says Dennis Whyte, a fusion researcher at MIT. He says that STEP's purpose “is not just to have a successful device on the grid but to build a fusion industry and the platform for the supply chain. STEP researchers are making a commitment to take on all the challenges.”

Hannah H. Means

UCSD institute will tackle fusion engineering problems

Researchers collaborate with colleagues at national labs, companies, and universities in efforts to make nuclear fusion a viable source of clean energy.

At a fusion technology workshop at the University of California, San Diego (UCSD), in September 2023, participants asked themselves, “Is fusion a big enough program here that it should have its own institute?” recalls Javier Garay, the associate dean for research at the university's engineering school. “We decided yes.”

Barely a year later, on 8 October, UCSD launched the Fusion Engineering Institute to focus on gaps in technology for fusion reactors, strengthen relationships with other universities and labs, and increase the number of fusion researchers. The institute, for which Garay is the founding director, is funded by the Department of Energy, UCSD's engineering school, and private industry; institute officials declined to provide numbers.

The institute's researchers hope to spur progress toward the long-elusive goal of harnessing nuclear fusion to produce clean energy. The two main approaches are magnetic confinement, achieved with tokamaks and stellarators, and inertial confinement, which uses lasers. Both methods heat a plasma to kick-start the fusion of hydrogen nuclei.

To be commercially viable, the process has to produce more energy than is used to create it and then steadily produce electricity. A short burst of net energy was first achieved in 2022 by the National Ignition Facility at Lawrence Livermore National Laboratory (see

“National Ignition Facility surpasses long-awaited fusion milestone,” *PHYSICS TODAY* online, 13 December 2022).

Developing materials that can withstand heat and damage from nuclear reactions and designing methods to remotely maintain fusion reactors are high priorities at the new institute. Researchers will focus on engineering issues in materials science, laser technologies, robotics, and diagnostics to help facilitate the conversion of fusion energy into usable electricity. Already, says Garay, UCSD students work with scientists at the nearby DIII-D National Fusion Facility, which is operated by General Atomics for DOE and houses a tokamak.

Researchers will collaborate with the San Diego Supercomputer Center to

integrate AI into research efforts. For example, AI will improve laser target tracking and placement for inertial confinement schemes, says Farhat Beg, co-director of the new institute.

As the institute matures, Garay says, he hopes to double the number of PhD students working on fusion topics from the current 30–40. UCSD undergraduates and researchers from other universities will also have opportunities to work with the institute. Researchers from those universities, national labs, and private industries will help inform the UCSD fusion curriculum, present guest lectures, and direct joint research projects. In addition, UCSD is looking to hire two fusion engineering faculty members.

Hannah H. Means



LASER INTERFEROMETRY is used to probe the density and other properties of deuterium plasmas in Farhat Beg's lab at the University of California, San Diego. The lab now works with the university's Fusion Engineering Institute.