Progress in fusion research

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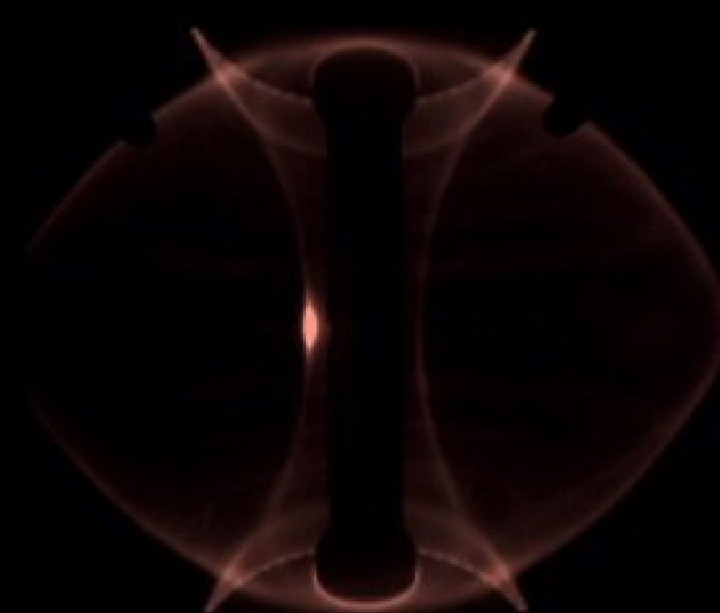


JET has produced a world record 16 megawatts of fusion power using deuterium and tritium fuel, around 70% of the heating power put into the plasma itself. Today's tokamaks have high auxiliary power requirements to run the heating systems and energise the magnetic coils. However, research into reducing these requirements – notably through the use of superconducting magnets – is underway. The next large international experiment, ITER, should produce about as much fusion power as the electricity required to run the entire plant.

CCFE is part of a worldwide research programme to show that fusion is viable. ITER will demonstrate the physics of controlling a power plant-scale fusion plasma. The challenge now is to develop the technology and engineering of tokamaks to capture fusion neutrons and produce electricity. This will prove fusion not only works as an experiment, but works economically on the scale of a power plant.

Bringing the power source of the stars down to Earth could give us low-carbon electricity for millennia to come.

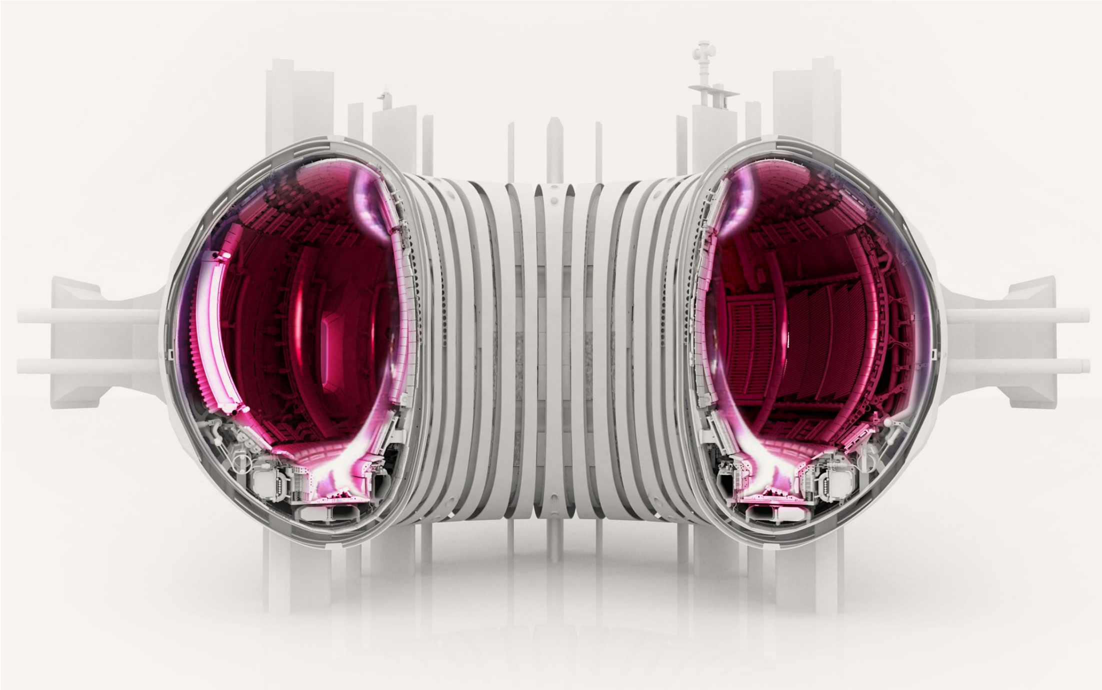
Nuclear fusion is one of the most promising options for generating the cleaner energy the world badly needs. CCFE scientists and engineers are developing the technology to bring fusion electricity to the grid.

What is nuclear fusion?

Fusion is the process that takes place in the heart of stars and provides the power that drives the universe. When light nuclei fuse to form a heavier nucleus, they release bursts of energy. This is the opposite of nuclear fission – the reaction that is used in nuclear power stations today – in which energy is released when a nucleus splits apart to form smaller nuclei.

To produce energy from fusion here on Earth, a combination of hydrogen gases – deuterium and tritium – are heated to very high temperatures (over 100 million degrees Celsius). The gas becomes a plasma and the nuclei combine to form a helium nucleus and a neutron, with a tiny fraction of the mass converted into 'fusion' energy. A plasma with millions of these reactions every second can provide a huge amount of energy from very small amounts of fuel.

One way to control the intensely hot plasma is to use powerful magnets. The most advanced device for this is the 'tokamak', a Russian word for a ring-shaped magnetic chamber. CCFE's goal is to develop fusion reactors using the tokamak concept.



Advantages of fusion power

With increasing concerns over climate change and finite supplies of fossil fuels, we need new, better ways to meet our growing demand for energy. The benefits of fusion power make it an extremely attractive option:

- ***No carbon emissions.*** The only by-products of fusion reactions are small amounts of helium, an inert gas which can be safely released without harming the environment.
- ***Abundant fuels.*** Deuterium can be extracted from water and tritium will be produced inside the power station from lithium, an element abundant in the earth's crust and seawater. Even with widespread adoption of fusion power stations, these fuel supplies would last for many thousands of years.
- ***Energy efficiency.*** One kilogram of fusion fuel could provide the same amount of energy as 10 million kilograms of fossil fuel. A 1 Gigawatt fusion power station will need less than one tonne of fuel during a year's operation.
  - ***Less radioactive waste than fission.*** There is no radioactive waste by-product from the fusion reaction. Only reactor components become radioactive; the level of activity depends on the structural materials used. Research is being carried out on suitable materials to minimise decay times as much as possible.
  - ***Safety***. A large-scale nuclear accident is not possible in a fusion reactor. The amounts of fuel used in fusion devices are very small (about the weight of a postage stamp at any or

time). Furthermore, as the fusion process is difficult to start and keep going, there is no risk of a runaway reaction which could lead to a meltdown.

- ***Reliable power***. Fusion power plants will be designed to produce a continuous supply of large amounts of electricity. Once established in the market, costs are predicted to be broadly similar to other energy sources.

Fusion in the UK

The United Kingdom's fusion research programme is based at Culham Centre for Fusion Energy (CCFE) in Oxfordshire, the fusion research arm of the UK Atomic Energy Authority. The research is funded by the **Engineering and Physical Sciences Research Council** and by the European Union under the Euratom treaty.

The UK contributes to fusion research in two main ways:

Its own fusion programme, centred on the **MAST (Mega Amp Spherical Tokamak) Upgrade** device. MAST Upgrade builds on the success of the original MAST tokamak (2000-2013) with major new capabilities in areas such as plasma stability and exhaust. The UK programme is also contributing to preparations for the international ITER project, and research on plasma physics and fusion materials and technology

Operating JET – the Joint European Torus, the world's largest tokamak and Europe's flagship experiment. JET is situated at Culham, where CCFE operates it **on behalf of fusion researchers around Europe** via a contract between the European Commission and the United Kingdom Atomic Energy Authority.

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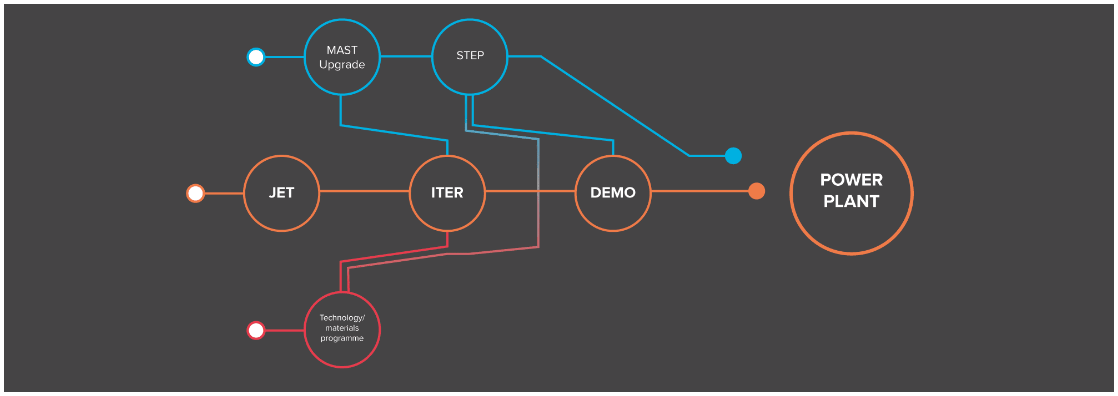
The next steps

European fusion research is following a roadmap to achieve power generation around the middle of this century.



Beyond JET, the programme focusses on four main projects:

- **ITER** – a large multinational tokamak that is being built in the south of France. ITER will aim to produce 500 megawatts of fusion power and will be an important step towards demonstrating the viability of fusion on a commercial scale.
  - A parallel technology programme to develop and test robust materials that can withstanc the harsh environment expected inside a fusion power plant.

- DEMO – the EU's demonstration power station design – which aims to supply fusion electricity to the grid around 2050. There are also power plant design programmes being developed in several areas of the world including China, S Korea and Japan. These will be followed by the first generation of commercial fusion power stations.
  - **STEP** – a new UK power plant design activity based on the compact 'spherical tokamak' reactor concept, which aims to deliver net electric power output on a timescale of 2040.