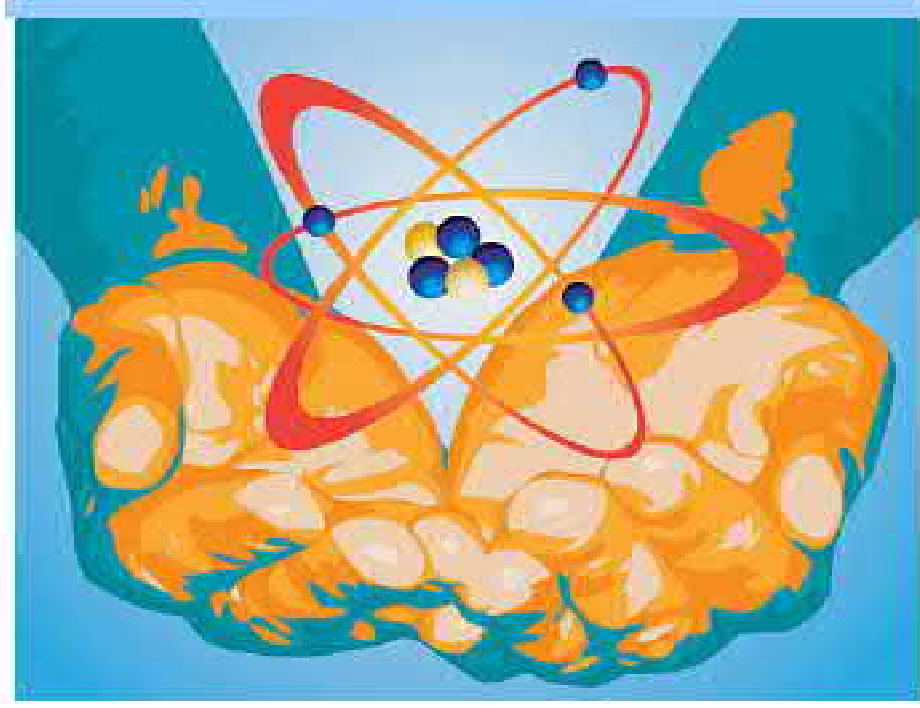
ITER: the nuclear fusion project

ITER is a €15 billion, 35-year project to build an experimental thermonuclear fusion reactor, which could serve as a basis for a future, larger scale demonstration power source and, after that, commercial power plants.
Reactor construction started in 2010 and is planned to be completed by around 2019. Experiments will be carried out over the following 20 years, with dismantlement planned for the final five years.
This is the world's largest scientific partnership with its members being the EU, Russia, USA, China, South Korea, Japan and India.
The EU will pay 45.5% of the construction costs with 9.1% to be paid by each of the other partners. France, host of the project site, will contribute 20% of the EU costs. During the operations phase costs will be divided differently, with the EU share at 34%.
The predecessor scientific project ("JET") has achieved fusion for short periods, providing information for the much larger ITER reactor.
Planned costs have escalated, causing a financing problem. This particularly relates to EU funding needed of €1.3 billion in 2012/13. The Commission has made a proposal but the EP and Council have not yet agreed.
Given the unknowns (technical and financial) there can be no guarantee that ITER will succeed. If it is successful, when and at what cost may also be significantly different from current plans. The prize however is the potential of cheap and clean energy for up to an estimated 50% of our needs.



In this briefing:

Context

Plentiful cheap energy produced in an environmentally friendly way could theoretically be produced by nuclear fusion.

However it has often been said that fusion is the power of the future and always will be. This is because of technical difficulties to achieve controlled fusion and, once achieved, to scale up and create a commercially viable production (electricity generating) power centre.

A short history

The project - the International Therm onuclear Experimental Reactor (ITER) - aims to demonstrate the scientific and technical feasibility of controlled nuclear fusion to produce energy. The ITER Organisation has been tasked to construct, commission, operate, and later permanently shut down the experimental facilities. It should also promote fusion energy to the public.

This initiative for nuclear fusion began following a US-Soviet summit meeting in 1985. The EU (Euratom) joined the US and Russia in the project in 1986.

The ITER Council approved the design of a fusion reactor in June 1998. A new design was developed and approved in 2001. Then, in 2006, the seven partners in the project (the EU, Russia, Japan, China, India, South

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Korea and the United States) agreed to its funding and adopted a 35-year international agreement. This agreement foresees ten years for construction, twenty for operation and five years for closure. The seven parties represent half of the world's population.

The ITER site

Source: ITER.

In June 2005 it was agreed to base it at Cadarache in southern France (near Marseille), The 42-hectare site was prepared from 2007 and completed in 2009. In 2010 work started on excavating the reactor site and in August 2011 concrete pouring began for the reactor building. Assembly of the reactor itself is planned to start in 2015, with completion in 2018. It is hoped that this, the world's largest and most advanced experimental fusion reactor, will be switched on in 2019.

Concern has been expressed with ITER being built in a seismic area and therefore potentially having a "nuclear accident" like Fukushima, The experts say that this is not possible:

- Nuclear fusion is very different from nuclear fission.
- The fusion chamber would turn itself off automatically in case of a problem so a runaway reaction is not possible.
- There is little fuel in the reactor vessel.

Fusion for energy (F4E), created under the Euratom Treaty, is the EU's managing organisation for ITER. It is responsible for the preparation and coordination of the design, research and development and fabrication of most of the high-technology components. F4E was established in April 2007 for a period of 35 years and is located in Barcelona, Spain.

JET: paving the way for ITER

The Joint European Torus (JET), sited in the UK, is the world's largest fusion device and holds the world record for fusion power. The organisation has a thousand scientists and engineers. Knowledge gained from JET is to be used at ITER, its successor in the development of fusion power.

JET routinely initiates nuclear fusion at a rate far in excess of that of the sun. However, this lasts only for seconds. Though too small to produce meaningful amounts of electricity, it is a prototype for the bigger and potentially commercial ITER.

JET's management currently hopes that in five years it may reach a point where the amount of energy produced will equal that put in. Its best result in this was in 1997 when, for two seconds, 16 megawatts of output was achieved for 25 megawatts of input. For commercial use there would need to be a near constant ten times power output gain.

Major technical problems to be overcome are:

- Finding a material for the tiles in the fusion reactor that can withstand the neutron bombardment arising from fusion. The interior of the larger of the JET's two fusion machines ("tokamaks") was recently retiled (5 000 carbon tiles replaced by beryllium and tungsten tiles at a cost of €100 million), necessitating an 18-month shut down.
- Plasma turbulence: the primary magnetic field varies, causing turbulence in the plasma. This is balanced by the plasma's own magnetic field but since this is inconsistent it causes the system to break down. This means that the reactor is constantly starting and

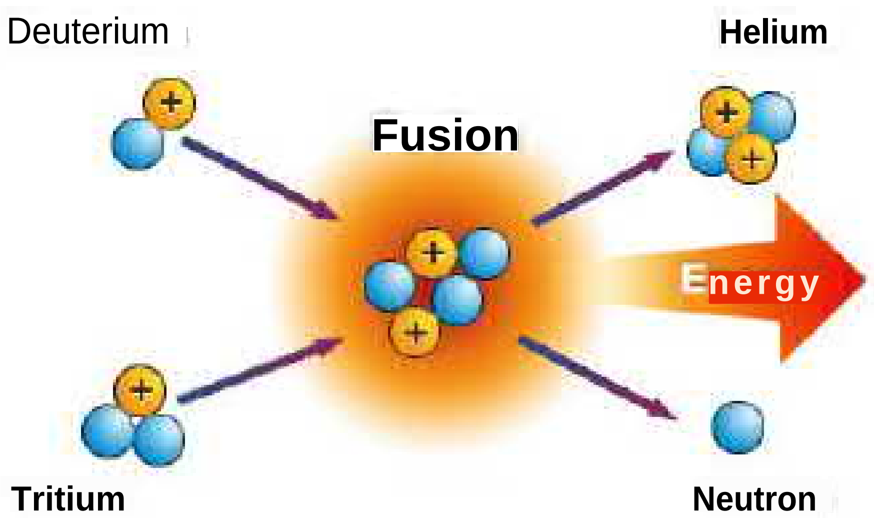
stopping, which is not acceptable for a commercial power station.

The inside of the JET tokamak, showing the tiles

Source: EFDA-JET

ITER:simple technical details

Atoms can be joined together ('fusion') using very high pressures and temperatures. This is what happens in our sun. To achieve this on earth gases need to be heated ten times hotter than the sun, to 150 million degrees Celsius. In these conditions gas becomes plasma, which is a high-energy state of matter.



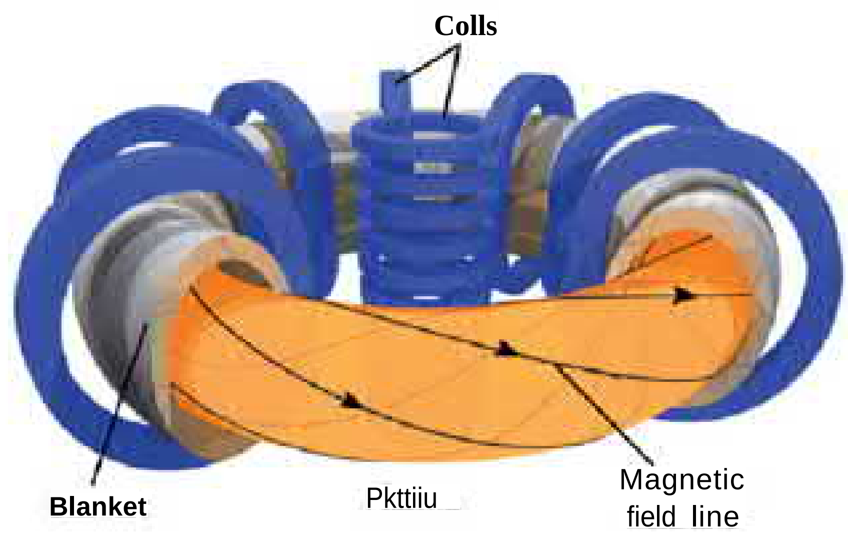
Two isotopes of hydrogen (deuterium and tritium) are used since they fuse most easily. When enough deuterium-tritium plasma is held for long enough at a high enough temperature and pressure, fusion occurs.

Deuterium, the principal fuel, can be extracted from water. Tritium is produced during the fusion reaction through contact with lithium. Fusion produces helium, a neutron and a lot of energy. No carbon dioxide is released.

The neutrons produced through fusion make the reactor chamber radioactive. However, the quantity and life of the radioactive waste should be limited, certainly in relation to current fission nuclear energy generation.

This whole process is to be carried out in a specially designed, vessel. Invented by the Russians in the 1950s, this is called a 'tokamak'[1]: a torus (doughnut)-shaped magnetic chamber. The magnets provide shielding, which minimises heat loss.

The doughnut-shaped chamber



Source: EFDA

No fusion machines - since the first machine constructed in the 1950s - have produced meaningful amounts of electricity so far, although megawatts of power have been produced for a few seconds.

There are other independent, on going projects to achieve fusion using different designs.

The next steps

Plasma experiments at ITER are planned to begin in 2019. A fusion reaction to produce 500 megawatts of output power for 50 megawatts of input power is planned by 2026/27.

ITER will be about twice as big as the JET reactors. It should have pulses 20 times as long (400 seconds), with the aim to produce around 30 times the power (500 MW against 16 MW) during individual runs lasting up to

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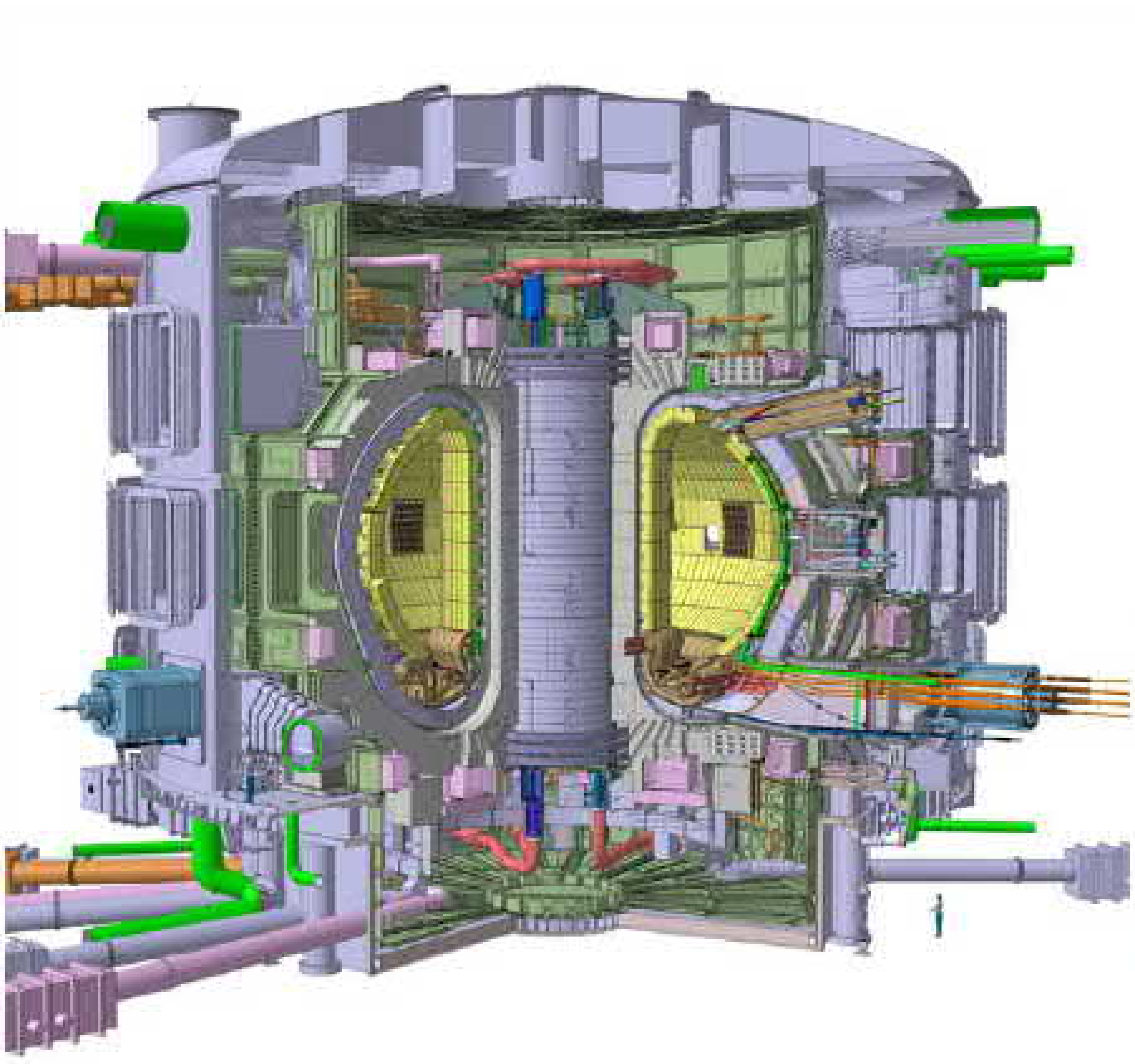
50 minutes. ITER aims to demonstrate the commercial viability of fusion.

The ITER design



Source: F4E

Success with the ITER should be followed by a commercial demonstration fusion power plant. The ITER partners are expected to build their own fusion reactors based on the demonstration model.

The European Commission's (EC) director of research in nuclear energy has said that the earliest date for a commercial fusion reactor would be 2040. Elsewhere, a demonstration plant has been indicated as likely by 2040, with estimates that fusion could produce 20% to 25% or 50% of our energy needs by 2100.

The budget

Costs

Three cost phases have been identified: construction, operation and dismantling.

In 2001, total **construction** costs were estimated at around €5.9 billion. By the time of formal agreement and the establishment of the funding package in 2006, the cost estimate was €10 billion.

Cost increases have arisen through:

- Materials (steel, concrete and copper) rising up to three times faster than inflation.
- The setting up of F4E at a cost of €650 million and greater complexity for the project's management (there were only three partners in 2001).
- Design changes reflecting the fact that fusion science continues to develop.

The ITER construction cost was agreed with a maximum ceiling of €13 billion in July 2010 by the ITER Council. The EC and EU ministers have expressed support for ITER. The latter have said they expect credible, contained and reasonable costs, a realistic timetable and good management.

ITER's Director General (the equivalent of the Chief Executive Officer) has said that cost containment is very important. Cost savings are to be achieved through reductions in construction costs and some contingency provisions along with simplification, such as the management structure. Cuts of around €600 million have been mentioned.

Operating costs were estimated in 2006 at €3 billion for the 20 years.

The **deactivation and decommissioning** phases (2037-2042) have planned costs of €281 **million and** €530 **million (in** 2001 values).

Financing

ITER is financed by its members. F4E manages the EUs contribution to ITER. Switzerland, as a Euratom associated state, is a full member of F4E, and contributes to the EUs share of funding.

For the **construction** phase (2007-2019), the EUs contribution is 45.5% (capped at €6.6 billion) of the cost with the French contribution being approximately 20% of

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the EU's share. The other parties will each contribute about 9.1%,

ITER parties' contributions

Source: F4E

Contributions by the partners are both financial and 'in-kind' (components, equipment materials and other goods as well as seconded staff). Indeed, 90% of contributions will be in this latter form.

The cost sharing in the operations phase (2019-2037) will be EU 34%, Japan and the United States 13% each and China, India, Korea, and Russia 10% each.

EU problems

The existing inter-institutional agreement between the EU Council and the European Parliament defines the multiannual financial framework (MFF) until 2013. This MFF included financing for ITER of €2.7 billion. It therefore needs to be modified if the EU contribution is to reflect ITER's latest, higher cost calculations.

The EC has made proposals for how to cover a funding shortfall of approximately €1.3 billion, which is needed for 2012-13. It has suggested using unspent funds and other sources from the EU budget.

As co-budgetary authority the EP must approve and ensure the financing of ITER as well as its proper budgetary discharge. However, it has so far not agreed with the EC's propositions.

Funding for ITER will likely be a key point of discussion as Council and Parliament finalise the 2014-2020 MFF.

Members have noted that they have insufficient powers to scrutinise the project. The Greens / EFA have been the most critical of the project, wanting green energy and energy saving investments instead. A group of French physicists, including a Nobel Prize winner, have called ITER a catastrophe.

Main references

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3. European research in action - ITER fusion energy for the world, EC, DG Research.
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