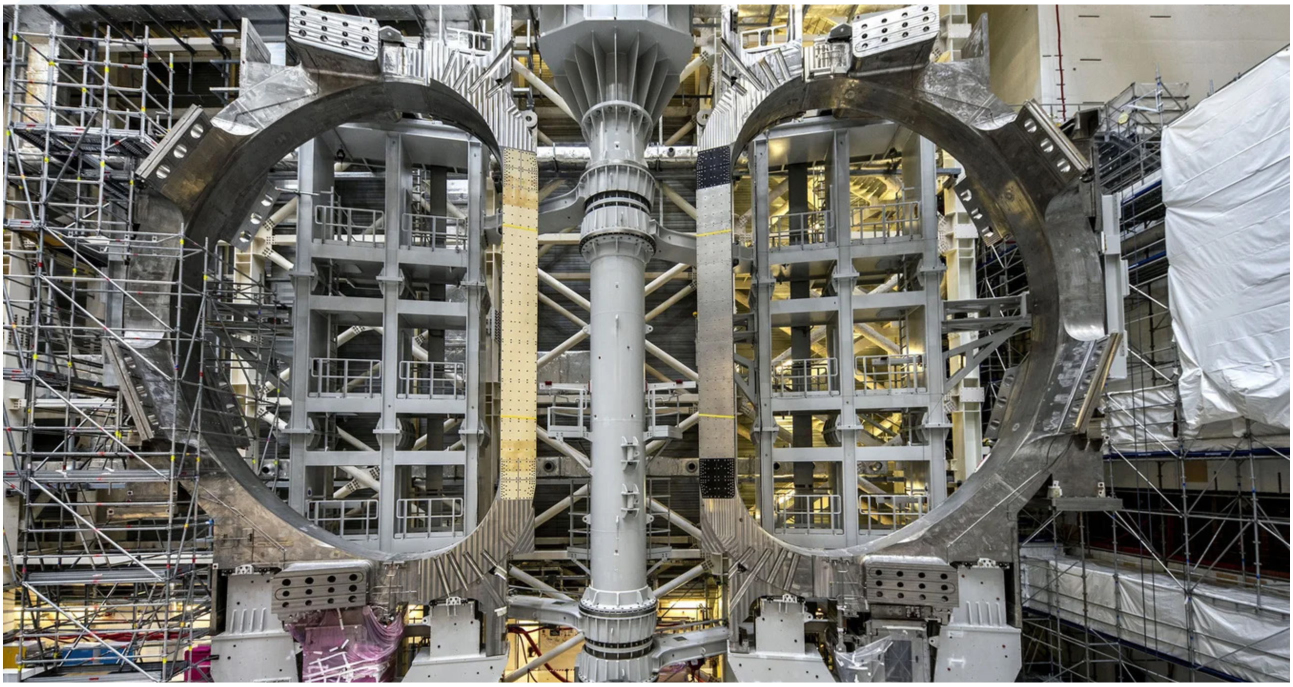
Fusion – the energy source of the future?

By Fredrik Lundberg



Construction of the International Thermonuclear Experimental Reactor (ITER) is underway at a site in southern France. Photo: ITER Organization.

The ambition to reproduce the process in the sun, releasing nuclear energy by fusing atomic nuclei, has prompted decades of research, but still only been successful in creating uncontrolled destruction in fusion weapons.

There are two main ways of attempting to control nuclear fusion, magnetic fusion and laser fusion. Both have failed for several decades.

Magnetic fusion research began around 1950, as part of nuclear weapons research in the UK, the Soviet Union and the USA.

In recent decades, most fusion research has focused on the construction of a single reactor, known as ITER, which is being built at the Cadarache facility in France and was initiated in **1985** by presidents Reagan, Gorbachev and Mitterrand. It has suffered numerous delays and soaring costs, increasing by several hundred, maybe a thousand percent, from the original budget.

ITER is now expected[1] to be fully operational by **2039. It will not, even then, demonstrate "ignition", i.e. continuous fusion operation. It will not produce electricity or other useful energy. It is unlikely to have solved the main technical problems for fusion reactor design, let alone the economics.**

1 https://www.nature.com/articles/d41586-024-02247-2

It is a long process to turn a successful experiment into a working reactor that generates electricity. Even if that is achieved, that electricity must also be produced at a reasonable cost. As modern electricity generation is done by wind power and solar plants without thermal conversion system it is hard to imagine that any conversion system based och heat released by nuclear fusion will ever be able to compete economically.

Research into laser fusion began around 1960. In the most successful and most publicised experiment at the National Ignition Facility (NIF), at Lawrence Livermore Nuclear Weapons Laboratory in California, the facility was reported to have supplied more energy than was put into the process, in other words it generated more heat than the energy delivered by the laser beams.

But this ignores the fact that it takes an enormous amount of energy to power the 192 lasers in a facility the size of a football stadium.

"The reaction needs to be at least 100 times as effective as NIF's laser shot on 5 December 2022. Although the energy that NIF produced within the capsule exceeded the laser energy aimed at it, the amount falls well short of the energy it took to fire the lasers, which draw about 300 MJ of energy from the grid for every shot."[2]

In both magnetic and laser fusion, 80 percent of the fusion energy comes from extremely energetic neutrons. When they strike surrounding materials they form various radioactive isotopes and create an intensely radioactive environment that is dangerous for humans and the environment in the short term – up to a few years or decades – if there is a leak or if access is needed to the reactor for maintenance. However, unlike conventional nuclear fission, nuclear fusion does not produce long-lived waste.

Another radioactive hazard comes from the fact that half of the fuel used for fusion is tritium (super-heavy hydrogen), which is highly radioactive. Steps must be taken to prevent its release into the environment.

One of the many hurdles that fusion must overcome is that the 150-million-degree plasma exhibits many instabilities, some of which are of an explosive nature and could cause major damage to the reactor and contribute to the risk of a release. The reactor has many expensive and sensitive components, including liquid helium cooling systems that need to be kept at -269 degrees C.

The consensus of most experts is that no form of fusion, even if technically successful, can help replace fossil fuels in time to save the climate, i.e. before 2050. The IPCC 6th assessment report does not even mention it. Thousands of the best scientists and engineers have spent seven decades and thousands of billions of dollars trying to solve the problem, so far without success.

ITER has an opaque funding structure, with members providing a portion of their contributions "in kind" – as components rather than funding. This makes it difficult to assess the actual costs. In 2016, the US Department of Energy estimated the total cost at $65 billion. With delays and inflation, it is clearly much more today.

2 https://spectrum.ieee.org/national-ignition-facility-impractical

Investments of this size can only be made by large nation states, or many nations together. One consequence is that so-called fusion start-ups have no chance of delivering a commercial product for decades. Private fusion research is a form of pyramid scheme, where the first "investor" can only make money by selling on their stake, if they do so quickly enough. If fusion is ever to take off, it must largely be achieved through government, perhaps multinational, funding.

This all comes at the expense of research, development and deployment of technologies that already work reliably but can be improved, such as solar, wind, energy storage and efficient energy use, or which have a reasonable chance of working within a reasonable time frame, such as wave power.

The bleak prospects of the ITER reactor, once hailed as the future source of non-fossil energy were summarised in a 2023 Scientific American article on the topic saying:

"With each passing decade, this record-breaking monument to big international science looks less and less like a cathedral – and more like a mausoleum." [3]

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3 https://www.scientificamerican.com/article/worlds-largest-fusion-project-is-in-big-trouble-new-documents-reveal/

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