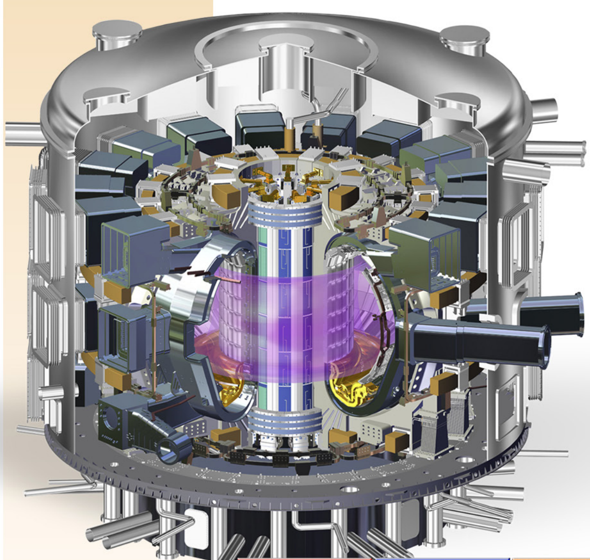
Questions and answers about fusion energy and ITER

What is fusion?

Fusion, the energy source of the sun and stars, is the most efficient process for converting mass into energy ($E = mc^2$). The fusion process is environmentally benign and does not emit gases that contribute to global warming or acid rain. Abundant fuel supplies for fusion are available that could meet the needs of the world's population for more than 10,000 years if the fusion process is harnessed successfully.

When will fusion successfully produce useable energy?

The typical U.S. home presently uses about 5,000 watts of electricity on a continuous basis. The fusion process has produced more than 10 million watts of fusion energy for about one second in laboratory test reactor experiments from 1994 to 1997. The ITER international fusion project is expected to produce 500 million watts for ~10 minutes by the year 2025. This would establish the scientific basis for a fusion power plant that could be built in the 2040s for the large-scale production of carbon-free electricity.



Why is it taking so long?

Fusion is technically very challenging. It requires temperatures of greater than 100 million degrees, fuel pressures of about 10 atmospheres, and the capability to absorb energy at power densities some three times higher than those at the surface of the sun. Fusion research has increased key fusion plasma performance parameters by a factor of 10 million over 50 years; research is now less than a factor of 10 away from producing the core of a fusion power plant.

China • European Union • India • Japan • South Korea • Russia • United States

At this stage, continued progress toward fusion energy requires large facilities in the $1–10 billion range. During previous decades when energy supplies seemed plentiful, there was little governmental interest in providing the significant funds needed for rapid progress in fusion or in any new carbon-free energy source.

Major progress toward fusion energy was made in the 1980s and 1990s as the result of large investments during the oil embargo of the 1970s. The current U.S. fusion energy program has limited funding, and no major research facility has been built in the United States for decades. However, a firm technical foundation now exists to move forward toward the demonstration of the scientific and technological feasibility of fusion energy.

How is fusion energy made on Earth?

Fusion fuel consists of hydrogen isotopes, typically deuterium and tritium. Deuterium is easily extracted from sea water. No net tritium is consumed, as the fuels used in ITER will be processed in a closed cycle in the reactor. The isotopes must be heated to temperatures of 100 million degrees Celsius, and then confined long enough for the fuel to react and produce net energy. In the magnetic confinement approach used by ITER, a tokamak – or magnetic vacuum chamber shaped like a donut – confines a low density fuel for several seconds. In inertial fusion, the fuel is compressed by radiation to very high densities and then confined for a billionth of a second by inertia during the subsequent explosion.

Could fusion reduce carbon emissions?

Fusion is a carbon-free energy source. President Obama's goal to reduce carbon emissions by some 80 percent in the next 40 years will require an Apollo Project-type approach across a broad portfolio of carbon-free energy sources, including fusion energy. While fusion would just be entering the market in 40 years, it could play an increasingly important role in sustaining carbon-free energy goals in the following decades.

Who is involved in developing fusion energy?

More than 40 nations are actively involved in fusion research. The world's largest fusion energy programs are in Europe and Japan, followed by the United States, China, Korea, the Russian Federation, and India. These nations have partnered to fund, construct, and operate ITER.

How close is fusion to producing energy?

The ITER magnetic fusion project is under construction and aims to produce 500 million watts of fusion power. The project, which involves China, the European Union, India, Japan, South Korea, Russia, and the United States, is sited in France with components contributed by all partners. The ITER project is designed to be a bridge to the first commercial fusion power plant.

The National Ignition Facility, an inertial fusion device for simulating the effects of nuclear weapons, has been constructed at Lawrence Livermore National Laboratory as part of the U.S. Nuclear Stockpile Stewardship Program. NIF has been commissioned, and a campaign to achieve ignition within several years has begun.

In both magnetic and inertial fusion, the duty cycle of fusion power production will have to be increased (from 2 percent and 0.00001 percent, respectively) to levels approaching 70 percent. Achieving this level of production largely involves extensions of technologies to heat fusion fuel and capture fusion energy more efficiently. Major research efforts are essential now to bring fusion energy to the commercial grid in the 2040s.

What happened to “cold fusion,” sonofusion, electrostatic confinement fusion, etc.?

Many methods to achieve fusion have been explored in more than 400 research devices during the past 50 years. Toroidal magnetic confinement and inertial confinement using intense radiation are the most advanced techniques for the production of significant quantities of fusion energy. Other approaches have produced microscopic quantities of fusion energy and are very unlikely to scale to commercial energy production.

Why is the cost of ITER increasing?

The cost of ITER was established in 2001. A design review conducted in 2007–08 concluded that the cost of the project had been largely underestimated, in part due to changes to the ITER machine design needed to keep up with the evolution of fusion science. In addition, the costs of many raw materials have soared since 2001.

Is ITER dangerous?

Safety. French nuclear safety regulations have been applied throughout the project's design phase and will continue to be applied during construction, operation, and decommissioning. French nuclear authorities will audit and inspect the ITER Organization in application of the regulation. The fusion reaction is intrinsically safe. If there is any disruption in the system, the plasma will cool within seconds and the reaction will simply stop. A chain reaction or an explosion is physically impossible. In a tokamak fusion device like ITER, the quantity of fuel present in the vessel at any one time is sufficient for a "burn" of only a few seconds.

Fuels. When ITER begins operation, it will first use hydrogen, then deuterium, and beginning approximately in 2026, a mix of deuterium and tritium. Tritium is a slightly radioactive element (beta-emitting), with a half life of only 12.3 years. Tritium supplies will be delivered to ITER, handled, stored, and implemented in full compliance with French Nuclear Safety regulations.

Waste. ITER will not generate any high-level, long-life waste. Because tritium will be used later in its operation, ITER will generate small quantities of: very low-level, short-life (~31 years) waste; low-level, short-life (~31 years) waste; intermediate-level, short-life (~31 years) waste; and intermediate-level, long-life (>31 years) waste.

Construction. The ITER Tokamak Building will be made of specially reinforced concrete resting on bearing pads. The structure is designed to withstand an earthquake as intense as the most severe historical earthquake, plus an increased safety margin.

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