Frequently Asked Questions

In this section, we provide answers to the most frequently asked questions about the ITER Project.

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Fusion and the ITER Project

What is ITER?
What questions will be answered by ITER that have not already been answered by research to date?
Is there consensus in the scientific community about the ITER Project?
What has been accomplished in 60 years of tokamak research?
What are the advantages of ITER compared to the alternative approaches under development such as the Wendelstein 7-X stellarator in Germany, and the inertial fusion programs in the US and France?
What is the ITER model for collaboration and cooperation?

ITER schedule

When will ITER be operational?
When will the first giant ITER components travel along the ITER Itinerary?
Is ITER running behind schedule?
What are the Members doing to address the project's difficulties/schedule delays?
We hear the project is delayed. Are the ITER Members prepared to contribute additional budget?
Is there any danger that ITER will experience start-up difficulties as, for example, the LHC had with its array of magnets?

ITER cost

How is ITER financed?
How much is France contributing as Host?
Why have ITER costs risen?
Do we really know how much ITER will cost?
Is it worth spending billions on fusion or would the money be better spent in improving renewables like solar, wind and geothermal?
Are there risks of further cost increase?

Economic Benefits

Has ITER resulted in any positive economic benefits locally? Is ITER creating jobs?

ITER power amplification

I read that ITER's goal is $Q \geq 10$? What does that mean?
Q—also called "fusion gain"—measures the ratio between the power produced by the fusion reactions, and the external heating power that must be injected in a tokamak to sustain the reactions.

Let's review how ITER will create the conditions for fusion inside its vacuum chamber.

- Fuel is injected in gaseous form into the vacuum vessel (the gas weighs only a few grams and fills the entire volume of the tokamak);
- Electricity flowing through the electromagnets, particularly the central solenoid, produces a voltage across the gas;

- This voltage rips electrons from the fuel atoms, turning them into charged particles (ions). This new state of matter is called a plasma;
- The changing magnetic fields that are used to control the plasma produce a heating effect (*read about "ohmic heating"* ***here***). But in order to obtain the temperatures approaching 150,000,000 °C that are needed for deuterium-tritium fusion, three sources of **external heating** must be applied from outside of the tokamak;
- The megawatts of heating power injected by these external systems is part of the ratio measured by Q, which compares input heating power to output fusion power.

In ITER, the programmatic goal, Q≥10, signifies delivering ten times more power (500 MW) than that which is delivered by the heating systems (50 MW).

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Is Q ≥ 10 significant?

Very. Breakeven, which corresponds to Q=1, is the moment when the total fusion power produced during a plasma pulse equals the power injected into the systems that heat the plasma. This has never been achieved in a fusion device; the **current record** worldwide is held by the European tokamak JET (UK), which succeeded in generating a Q of 0.67 in the 1990s. ITER is the machine that has been designed to do it, which explains the participation of so many nations—who run domestic fusion programs at home—in the international collaboration surrounding the project.

ITER's Q value of ≥10 makes it a first-of-kind machine and a unique scientific device.

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What is a burning plasma?

The fusion between the nuclei of the hydrogen isotopes deuterium (D) and tritium (T) produces one helium nucleus, also called an "alpha particle," and one neutron.

The helium nucleus, which carries 20 percent of the energy produced by the fusion reaction, is electrically charged and remains confined by the magnetic fields of the tokamak (whereas the neutron escapes). The heating provided by these alpha particles contributes to maintaining the temperature of the plasma and decreases the need for external heating. When heating by the helium nuclei ("alpha heating") is dominant (over 50 percent) the plasma is said to be a "burning plasma."

This is a state of matter that has never been produced in a controlled manner on Earth.

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Will ITER be the first burning plasma device in the world?

Yes, it will, and there is a large worldwide consensus around the necessity of building such a device. Achieving a burning plasma in which at least 50 percent of the energy to drive the fusion reaction is generated internally through the alpha particles is an essential last step in the 70-year quest to control fusion reactions in a magnetic fusion device.

At Q = 5, approximately 50 percent of the plasma heating is contributed by the alpha particles. At Q = 10 (ITER), this percentage rises to 66 percent. At Q=20 alpha heating represents 80 percent.

The primary motivation behind the design of ITER is to provide Members scientists with the opportunity to study, and better understand, a burning plasma. The knowledge acquired in ITER will help scientists and engineers design the commercial fusion-generated electricity plants of the future. As a research device, ITER will be equipped with far more diagnostics and other research components than the commercial facilities that will follow.

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How did the ITER designers choose the specific value of Q ≥ 10?

Accounting for the size of ITER's vacuum vessel and the strength of the confining magnetic field (5.3 Tesla), the ITER plasma (830 cubic metres) can carry a current of up to 15 megaamperes.

Under these conditions, an input thermal power of 50 megawatts is needed to bring the hydrogen plasma in the vessel to about 150 million degrees Celsius. This temperature in turn translates to a high enough velocity, among a sufficient population of hydrogen nuclei, to induce fusion at a rate that will produce at least 500 megawatts of thermal power output.

Why not design ITER for a Q of 30, or 50? The answer is clear: expense. For tokamaks, size matters: if all other parameters are equal, larger size means greater Q. In simple terms, increasing Q would require an increase in the major radius or in the magnetic field strength. Either approach would have increased the cost of the device unnecessarily, whereas the achievement of Q ≥ 10 is sufficient to allow the primary scientific and technology **goals** of the project to be satisfied.

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And a related question: Why not design ITER to produce electricity?

This would also have required an increase in cost with no great benefit to the goals of the project. ITER is an experimental device designed to operate with a wide range of plasma conditions in order to develop a deeper understanding of the physics of burning plasmas, and to allow the exploration of optimum parameters for plasma operation in a power plant. The addition of the systems required to convert fusion power to high temperature steam to drive an electricity generator would not have been cost-effective, since the pattern of experimental operation of a tokamak such as ITER will allow for very limited generation of electricity.

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What is the difference between plasma energy breakeven and engineering breakeven?

Plasma energy breakeven is the moment when the efficiency of the fusion reaction reaches Q = 1 (*please see explanations on "Q" in the preceding paragraphs*); that is, when the total fusion power produced during a plasma pulse equals the power injected into the systems that heat the plasma. This important scientific goal—never before achieved—is the "*raison d'être*" for the scale of ITER and the design of many of its key technological systems (superconducting magnets, external heating, blanket, divertor, etc.).

Engineering breakeven would take into consideration all of the plants systems—and not just external heating systems—in the evaluation of the input/output power balance of an electricity-producing fusion power plant. Commercial fusion plants will be designed based on a power balance that accounts for the entire facility: the electricity output, sent to the industrial grid, compared to the electricity consumed by the facility itself—not only in tokamak heating, but also in secondary systems such as the electricity used to power the electromagnets, cool the cryogenics plant, and run diagnostics and control systems.

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What is the status of construction workers?

Some say that ITER construction will rely on migrant workers who are poorly paid and precariously housed. Is this true?
Doesn't ITER have a specific legal status ?
What hiring regimes apply?
How are the construction companies chosen?
How many levels of subcontractors are permitted?
How many workers are expected on the ITER worksite in the years to come? What percentage will come from outside of France?
I've heard that foreign workers on the ITER site are only paid EUR 300 per month. Is this true?
What controls are carried out by the French authorities on site working conditions?
Several construction companies have reported the late payment of invoices. What is the situation?
What are the plans for housing thousands of people involved with ITER construction and assembly works?
Will infrastructure modifications be necessary to absorb the increase in traffic flow around the ITER site?

ITER licensing procedure

Becoming an "Installation Nucléaire de Base" in France
What regulatory steps remain?

ITER and the environment

What kind of nuclear waste will be produced by ITER, and in what quantity?
What arrangements are foreseen for radioactive waste generated by ITER during operation and decommissioning?
What effect will ITER operation have on local electricity and water supplies?

ITER safety

Is the energy stored in a 100-million-degree plasma dangerously large?
What would be the danger of an earthquake occurring near ITER, or a double disaster like earthquake and flooding?
What about malevolent acts?
Could ITER explode?
Could a Fukushima-type catastrophe occur at ITER?
What about the issue of nuclear decay heat that was so serious at Fukushima?
ITER will be built near a site with other nuclear installations. What is the additional risk due to the presence of more than one installation?
What will be the total amount of tritium stored on site? What are the procedures foreseen to confine and control the stock?
Where do all the neutrons go?

What procedures are foreseen to avoid any loss of tritium, mostly during the first tests (incomplete fusion)?
What would be the effect on the population near ITER of potential accidental radioactive releases in the environment, including tritium?
Can you declare fusion is really safe, while it uses huge amount of tritium, generates strong neutrons, and brings about huge amount of radiological waste?
Is there any possibility that fusion opens a new way for the production of mass destruction weapons?
What measures are in place for occupational safety?

Disruptions : Everything you wanted to know

What are disruptions?
What are the consequences of disruptions?
Will ITER be able to withstand disruptions?
What disruption mitigation system is planned for ITER?

Fusion as a sustainable energy source

Why has fusion science developed much more slowly than fission science, which provided commercial reactors just a few years after its inception?
Will commercial fusion be available early enough to contribute to the energy transition needed to fight climate change and to replace fossil fuels?
If successful, when would fusion be able to add power to the grid? What steps would be required after ITER?
How much power would a fusion reactor be able to deliver and at what cost? Would it be competitive?
Will fusion run out of fuel?
Is the concept of tritium breeding sufficiently robust to start the ITER Project?
I recently read that there was a shortage of helium in the world and this was unlikely to improve as stocks are used up. How will this affect plans for the fusion superconducting magnets?
What are the benefits of pursuing fusion as compared to next-generation nuclear fission reactors?

Reliability of materials

Is it really possible to find materials which can cope with strong fusion neutrons?
How often will the ITER first wall need to be replaced during operation?
What are the procedures to dispose of the irradiated material contained in the first wall? Have safety risks been taken into account?
Is there any risk of damage in case of loss of superconductivity in the ITER superconducting magnets?