ITER Project

ITER ("The Way" in Latin) is one of the most ambitious energy projects in the world today.

In southern France, 35 nations are collaborating to build the world's largest tokamak, a magnetic fusion device that has been designed to prove the feasibility of fusion as a large-scale and carbon-free source of energy based on the same principle that powers our Sun and stars.

The experimental campaign that will be carried out at ITER is crucial to advancing fusion science and preparing the way for the fusion power plants of tomorrow.

ITER will be the first fusion device to produce **net energy**. ITER will be the first fusion device to maintain fusion for long periods of time. And ITER will be the first fusion device to test the integrated technologies, materials, and physics regimes necessary for the commercial production of fusion-based electricity.

Thousands of engineers and scientists have contributed to the design of ITER since the idea for an international joint experiment in fusion was first launched in 1985. The ITER Members—**China, the European Union, India, Japan, Korea, Russia and the United States**—are now engaged in a 35-year collaboration to build and operate the ITER experimental device, and together bring fusion to the point where a demonstration fusion reactor can be designed.

What will ITER do?

The amount of fusion energy a tokamak is capable of producing is a direct result of the number of fusion reactions taking place in its core. Scientists know that the larger the vessel, the larger the volume of the plasma ... and therefore the greater the potential for fusion energy.

With ten times the plasma volume of the largest machine operating today, the ITER Tokamak will be a unique experimental tool, capable of longer plasmas and better confinement. The machine has been designed specifically to:

1) Produce 500 MW of fusion power
The world record for fusion power is held by the European tokamak JET. In 1997, JET produced 16 MW of fusion power from a total input power of 24 MW (Q=0.67). ITER is designed to produce a ten-fold return on energy (Q=10), or **500 MW** of fusion power from 50 MW of input power. ITER will not capture the energy it produces as electricity, but—as first of all fusion experiments in history to produce net energy gain—it will prepare the way for the machine that can.

2) Demonstrate the integrated operation of technologies for a fusion power plant
ITER will bridge the gap between today's smaller-scale experimental fusion devices and the demonstration fusion power plants of the future. Scientists will be able to study plasmas under conditions similar to those expected in a future power plant and test technologies such as heating, control, diagnostics, cryogenics and remote maintenance.

3) Achieve a deuterium-tritium plasma in which the reaction is sustained through internal heating
Fusion research today is at the threshold of exploring a "burning plasma"—one in which the heat

from the fusion reaction is confined within the plasma efficiently enough for the reaction to be sustained for a long duration. Scientists are confident that the plasmas in ITER will not only produce much more fusion energy, but will remain stable for longer periods of time.

4) Test tritium breeding
One of the missions for the later stages of ITER operation is to demonstrate the feasibility of producing tritium within the vacuum vessel. The world supply of tritium (used with deuterium to fuel the fusion reaction) is not sufficient to cover the needs of future power plants. ITER will provide a unique opportunity to test mockup in-vessel tritium breeding blankets in a real fusion environment.

5) Demonstrate the safety characteristics of a fusion device
ITER achieved an important landmark in fusion history when, in 2012, the ITER Organization was licensed as a nuclear operator in France based on the rigorous and impartial examination of its safety files. One of the primary goals of ITER operation is to demonstrate the control of the plasma and the fusion reactions with negligible consequences to the environment.

What is fusion?

Fusion is the energy source of the Sun and stars. In the tremendous heat and gravity at the core of these stellar bodies, hydrogen nuclei collide, fuse into heavier helium atoms and release tremendous amounts of energy in the process.

Twentieth-century fusion science identified the most efficient fusion reaction in the laboratory setting to be the reaction between two hydrogen isotopes, deuterium (D) and tritium (T). The DT fusion reaction produces the highest energy gain at the "lowest" temperatures.

Three conditions must be fulfilled to achieve fusion in a laboratory: very high temperature (on the order of 150,000,000° Celsius); sufficient plasma particle density (to increase the likelihood that collisions do occur); and sufficient confinement time (to hold the plasma, which has a propensity to expand, within a defined volume).

At extreme temperatures, electrons are separated from nuclei and a gas becomes a plasma—often referred to as the fourth state of matter. Fusion plasmas provide the environment in which light elements can fuse and yield energy.

In a tokamak device, powerful magnetic fields are used to confine and control the plasma.

What is tokamak?

Power plants today rely either on fossil fuels, nuclear fission, or renewable sources like wind or water. Whatever the energy source, the plants generate electricity by converting mechanical power, such as the rotation of a turbine, into electrical power. In a coal-fired steam station, the combustion of coal turns water into steam and the steam in turn drives turbine generators to produce electricity.

The **tokamak** is an experimental machine designed to harness the energy of fusion. Inside a tokamak, the energy produced through the fusion of atoms is absorbed as heat in the walls of the vessel. Just like a conventional power plant, a fusion power plant will use this heat to produce steam and then electricity by way of turbines and generators.

The heart of a tokamak is its doughnut-shaped vacuum chamber. Inside, under the influence of extreme heat and pressure, gaseous hydrogen fuel becomes a plasma—the very environment in which hydrogen atoms can be brought to fuse and yield energy. The charged particles of the plasma can be shaped and controlled by the massive magnetic coils placed around the vessel; physicists use this important property to confine the hot plasma away from the vessel walls. The term "tokamak" comes to us from a Russian acronym that stands for "toroidal chamber with magnetic coils."

First developed by Soviet research in the late 1960s, the tokamak has been adopted around the world as the most promising configuration of magnetic fusion device. ITER will be the world's largest tokamak—twice the size of the largest machine currently in operation, with ten times the plasma chamber volume.

Who is participating?

The ITER Project is a globe-spanning collaboration of 35 nations.

The ITER Members **China**, the **European Union**, **India**, **Japan**, **Korea**, **Russia** and the **United States** have combined resources to conquer one of the greatest frontiers in science—reproducing on Earth the boundless energy that fuels the Sun and the stars.

As signatories to the ITER Agreement, concluded in 2006, the seven Members will share of the cost of project construction, operation and decommissioning. They'll also share the experimental results and any intellectual property generated by the operation phase.

Europe is responsible for the largest portion of construction costs (45.6 percent); the remainder is shared equally by China, India, Japan, Korea, Russia and the US (9.1 percent each). The Members deliver very little monetary contribution to the project: instead, nine-tenths of contributions will be delivered to the ITER Organization in the form of completed components, systems or buildings.

Taken together, the ITER Members represent three continents, over 40 languages, half of the world's population and 85 percent of global gross domestic product. Literally thousands of people are working toward the success of ITER.

The ITER Organization has also concluded non-Member technical cooperation agreements with Australia (through the Australian Nuclear Science and Technology Organisation, ANSTO, in 2016) and Kazakhstan (through Kazakhstan's National Nuclear Centre in 2017), as well as over 40 Cooperation Agreements with international organizations, national laboratories, universities and schools.

As the scientific installation rises on a 42-hectare (100 acre) site in southern France, fabrication activities for the ITER machine and systems are underway all over the globe. According to a carefully planned timetable, completed components will be shipped over a period of five years, beginning in 2014, to the ITER site for integration into the plant.

When will experiments begin?

That will be the first time the machine is powered on, and the first act of ITER's multi-decade operational program.

On a cleared, 42-hectare site in the south of France, building has been underway since 2010. The ground support structure and the seismic foundations of the ITER Tokamak are in place and work is underway on the Tokamak Complex—a suite of three buildings that will house the fusion experiments. Auxiliary plant buildings such as the ITER cryoplant, the radio frequency heating building, and facilities for cooling water, power conversion, and power supply are under construction.

As soon as access to the Tokamak Building is possible, scientists and engineers will progressively assemble, integrate, and test the ITER fusion device. Commissioning will ensue to verify that all systems function together and to prepare the ITER machine for operation.

The successful integration and assembly of over one million components (ten million parts), built in the ITER Members' factories around the world and delivered to the ITER site constitutes a tremendous logistics and engineering challenge. The assembly workforce, both at ITER and in the Domestic Agencies, will reach 2,000 people at the height of assembly activities. In the ITER offices around the world, the exact sequence of assembly events has been carefully orchestrated and coordinated. The first large components were delivered to the ITER site in 2015.

In November 2017, the project passed the halfway mark to First Plasma.

ITER Timeline

2005: Decision to site the project in France
2006: Signature of the ITER Agreement
2007: Formal creation of the ITER Organization
2007-2009: Land clearing and levelling
2010-2014: Ground support structure and seismic foundations for the Tokamak
2012: Nuclear licensing milestone: ITER becomes a Basic Nuclear Installation under French law
2014-2021: Construction of the Tokamak Building (access for assembly activities in 2019)
2010-2021: Construction of the ITER plant and auxiliary buildings for First Plasma
2008-2021: Manufacturing of principal First Plasma components
2015-2021: Largest components are transported along the ITER Itinerary
2018-2025: Assembly phase I
2024-2025: Integrated commissioning phase (commissioning by system starts several years earlier)
Dec 2025: First Plasma
2035: Deuterium-Tritium Operation begins

ITER MEMBERS

As signatories to the ITER Agreement, the ITER Members China, the European Union, India, Japan, Korea, Russia and the United States will share of the cost of project construction, operation and decommissioning, and also share in the experimental results and any intellectual property generated by the project. Twenty years of collaborative research experiments are planned on the machine.

Europe is responsible for the largest portion of construction costs (45.6 percent); the remainder is shared equally by China, India, Japan, Korea, Russia and the US (9.1 percent each). The Members contribute very little monetary contribution to the project: instead, nine-tenths of contributions will be delivered to the ITER Organization in the form of completed components, systems or buildings. In this way, the scientific and industrial fabric in each Member is prepared for the step after ITER—the conception and realization of the type of prototype fusion reactor that will demonstrate industrial-scale fusion electricity within this half of the century. For all Members, the potential benefits of participation are significant: by contributing a portion of the project's costs, Members benefit from 100 percent of the scientific results.