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ITER: How it works

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It's simple – in principle, at least. Take two forms (isotopes) of hydrogen, squash them together, and you get a helium atom and a very energetic subatomic particle called a neutron.

The product of the reaction is a fraction lighter than its atomic ingredients, and by Einstein's famous equation $E = mc^2$ that tiny loss of mass results in a colossal release of energy. Harness that release in an efficient way and the world's energy needs are solved.

The problem is that the atomic ingredients of fusion, like all nuclei, repel each other.

In the core of the sun, huge gravitational pressure allows fusion to take place at temperatures of around 15 million °C. In fusion machines, temperatures to achieve fusion need to be much higher – above 150 million °C.

No materials on Earth could withstand direct contact with such temperatures. To achieve fusion, therefore, ITER will use a device called a tokamak, which holds the reacting plasma away from the furnace's walls with intense magnetic fields.

The aim is for ITER to generate 500 megawatts of fusion power. This would pave the way for a demonstration power plant, called DEMO, in which fusion power will produce steam and – by way of turbines – up to 1000 megawatts of net electrical power. That's equivalent to a power plant that could supply about half a million British homes.

Fuelled by water

The most efficient fusion reaction is that between two forms (isotopes) of hydrogen: deuterium and tritium.

While deuterium can be extracted from seawater in virtually boundless quantities, the worldwide supply of tritium is limited, estimated at only 20 kilograms.

Future fusion power plants will have to produce their own tritium. They will use "tritium breeding modules" made from lithium, which turns into tritium when bombarded by neutrons from the fusion reaction. Lithium is a light metal, as abundant as lead.

ITER will test experimental tritium breeding modules.

Catch a star

How can ITER handle matter 10 times as hot as the core of the sun? By trapping it inside a strong magnetic field.

Magnetic fusion machines of various shapes and arrangements were developed in several countries as early as 1950. But the breakthrough occurred in 1968 in the Soviet Union, when researchers were for the first time able to achieve remarkably high temperature levels and plasma confinement time – two key criteria for fusion.

The secret of their success was a revolutionary doughnut-shaped magnetic confinement device called a tokamak, developed at the Kurchatov Institute, Moscow.

From this time on, the tokamak became the dominant concept in fusion research.

Environmental impact

The terrific heat generated by fusion will be absorbed using 3 million cubic metres of water per year, about a fifth of the total transported by the local Verdon river.

Tritium releases are predicted to be 100 times lower than the regulatory limit.

Fusion reactions produce no long-lived waste. Low-level radioactive waste will result from the activation of some of the machine's components. All waste materials will be treated, packaged and stored on site.

In all, 39 protected or rare species will benefit from measures on the 180-hectare ITER site. Two areas have been fenced off to protect the Occitan cricket, two species of butterfly, woodlark nesting sites and rare orchids.

Of the 2.5 million cubic metres of earth and rock moved to level the ITER platform, over two-thirds were reused on site.

Read more: *ITER: The way to a benign and limitless new energy source*