Frequently Asked Questions

Fusion energy

Below are questions that we are often asked about fusion power, mainly by sixth-form students, and our answers. If you have a question to ask, please use this form and we will reply as soon as possible.

How is the plasma contained?

A helical magnetic field of typically a few Tesla at the centre is sufficient to provide good insulation from the material surfaces and to balance the plasma pressure. This allows the low density of the plasma to be heated to the very high temperatures required for fusion. The combination of very high temperature and low density leads to a plasma pressure comparable to atmospheric pressure.
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How are the very high temperatures achieved?

The magnetic field provides insulation some 40 times better than loft insulation and is up to ten times thicker. With such good insulation, the application of high power (in the megawatt range) leads to very high temperatures, above 100 million degrees Celsius.
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Why are toroidal devices used?

The effect of the magnetic field is to confine the charged plasma particles by applying a force that opposes the motion across the field. There is no such force in the direction parallel to the magnetic field so, if the magnetic field lines were to connect the ends of a linear device, for instance, particles would be able to escape rapidly to the ends. In a toroidal device, the particles primarily spiral along the field lines, travelling around the machine typically a million times before escaping.
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How do charged particles escape from the magnetic field?

Although the forces applied to the charged particles are such as to prevent them moving to the plasma edge, the effect of collisions and turbulence is to lead to a random walk of particles, reaching the plasma edge in around one second.
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What are the dominant costs foreseen in a fusion power plant?

As you might expect in a magnetic confinement system, the largest cost item is anticipated to be the superconducting magnets. The next largest cost is anticipated to be the buildings needed to house the plant. These two items together are estimated to make up more than half of the cost of a fusion power plant. There is the expectation that the cost of superconducting magnets will reduce with time.
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Are the fuel costs significant?

The fusion energy obtained from each kg of fuel is very high (ten million times higher than from fossil fuels) so the fuel costs are a very small part of the expected costs. Using present costs, the fuel would contribute much less than 1% to the cost of electricity.
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How is deuterium obtained from water?

The conventional method of concentrating deuterium in water uses isotopic exchange in hydrogen sulphide gas, although more advanced techniques are being developed. Separation of different isotopes of hydrogen can also be done using gas chromatography and cryogenic distillation, which use the differences in physical properties to separate the isotopes.
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Where is lithium found?

Lithium is a light alkali metal found in several different minerals, such as spodumene. It can also be extracted from brines and clays, Natural deposits are particularly found in South America. It is presently widely used in batteries.
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Is any use made of advances in superconductors?

Most experimental devices do not use superconducting magnets since the required experimental plasmas, lasting less than one minute, can be achieved without the additional complexity. Those experiments that do use superconducting magnets have so far relied on conventional technology.
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Is the depletion of water significant?

Deuterium represents approximately 0.015% of hydrogen in water. Even so, there is enough deuterium to generate present levels of energy consumption for billions of years. Depletion of water is not an issue.
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Is the atmospheric pollution due to helium significant?

Because of the large amount of energy produced per unit mass of fuel, the production of helium is rather low, ten million times less than the CO_2 production of an equivalent fossil fuel power plant. If the whole world's energy requirements were met by fusion, the helium production would still be small compared to the present helium production of around 25,000 tonnes per year.
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What is the power input to the fusion reactor used for?

The best existing experiments need as much power to heat the plasma as they produce in fusion power. In a power plant, which would be larger, the fusion power would be around 20 to 30 times higher than the heating power.
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How is electrical energy created from the reactors (heat)?

In a future power plant, it is envisaged that the heat from a fusion power plant would generate electricity in just the same way as existing power plants, in which the heat is used to raise steam, driving turbines. The possibility of

using the plasma energy more directly has been considered but does not seem practical.
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Are there any negative safety or environmental implications of a fusion reactor?

It is an intrinsic property of fusion that enables power plants to be designed that are inherently safe with low environmental impact. Extensive studies over the last decade have shown that no internally-generated accident could result in the need to evacuate public from outside the site, and that the waste products from fusion power will not be a burden for future generations.
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Do you think that fusion is a viable energy resource for the 21st century?

Fusion provides one of the few options for future baseload electricity generation and it is essential that we develop it, along with other sources, particularly renewables. We cannot reliably predict the future, but the trends towards less polluting energy sources are clear and we must do our best to establish ways of electricity production that are consistent with those trends.
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How much energy could you get from a litre of water compared with a litre of petrol?

One litre of ordinary water contains enough deuterium to provide the energy content (when fused with tritium) of more than 500 litres of petrol.

What is the calculation that shows, in terms of binding energies, that 17.6 MeV of energy is released per colliding D-T pair, and why is it split 14.1/3.5 between the neutron and the alpha particle?

The masses of the particles concerned, in terms of the proton mass are:

D	1.99900
T	2.99371
alpha	3.97260
neutron	1.00138

The gain is that the alpha is more tightly bound. The net energy gain is mc^2, where the mass difference is 0.01873 proton masses. This gives 17.6 MeV (or 2.8×10^{-12} J) per reaction. In order to conserve momentum, the heavier alpha particle must take a smaller part of the energy (smaller by the ratio of alpha to neutron mass, that is 1:4).
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Could fusion be powered by other hydrogen isotopes or other light elements?

Yes. We concentrate on fusion of deuterons and tritons for energy production as it is the easiest way we know of getting a net energy gain. We have also investigated D-D and D-^{3}He. Other reactions are demonstrated in the sun, for instance p-p, D-p, ^{3}He-^{3}He. There are a large number of possible fusion reactions, other than D-T, that produce energy. However, their usefulness in a terrestrial power source remains to be demonstrated.
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How much fuel would a fusion power plant consume in a day?

A large power station generating 1,500 megawatts of electricity would consume approximately 600 grammes of tritium and 400 grammes of deuterium each day.
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Can the economic cost of fusion's environmental impact be estimated, including the costs of constructing and dismantling the power plant?

Yes, estimates are made using the method developed by the EU's ExternE project. This considers the total environmental impact of power production, from the original extraction of materials, through to the operation and subsequent recycling/dismantling of the facility. This is done by associating a cost to everything from CO_2 emissions to accidents at work. The conclusions in published work have been very favourable, with fusion estimated to be considerably less harmful than conventional oil, coal, and gas.
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When can we expect electricity generated from fusion to be available?

Experimental fusion machines have now produced fusion powers of more than ten megawatts. A new machine under construction, called ITER, will be capable of producing 500 megawatts of fusion power. ITER is expected to start operating in the early 2020s. Although it will be on the scale needed for a power station, there will still be technological issues to address to produce steady, reliable electricity, so it is anticipated that a prototype power station will be needed after ITER. Electricity generation is expected in 30 to 40 years, depending on funding and technical progress.
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