Sink or are we 'Swimming' in our future?

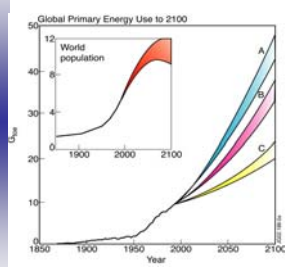
Chris Carpenter

Head of Public Affairs

UKAEA Culham Division

EURATOM/UKAEA Fusion Association

Energy Demand



World population and energy demand are growing rapidly, and predictions suggest strong growth will continue

Even with energy saving measures, there will be an expanding need for energy

But how can it be delivered without making global warming worse?

THE WORLD NEEDS MORE/CLEANER ENERGY

- World need for power will increase

Present annual consumption per person

eg	USA	-	12.5 TCE (tons of coal equivalent)
	W Europe	-	6.0 TCE
	China	-	1.4 TCE
	India	-	0.7 TCE

Expect/hope ⇒ at least 3 TCE, while populations rising

- IEA expects world energy need to double by 2045

ALTERNATIVE ENERGY SOURCES Fossil fuels

- finite resources
- global warming (CO_2)
- pollution*
- security of supply?

Sequestration possible - but expensive

**7.4 million-person-years lost annually in China from air pollution-related health problems - pollution cost estimated at $54B pa*

ALTERNATIVE ENERGY SOURCES Renewables

- must develop, but could not provide a major fraction of world-need (mostly intermittent: energy storage and/or major back-up power sources essential if fraction becomes large)

ALTERNATIVE ENERGY SOURCES Nuclear fission

- long-lived radioactive waste
- potential for proliferation
- public not convinced it's safe

Politically possible?

ALTERNATIVE ENERGY SOURCES Fusion

Fusion **is the process that produces energy in the core of the Sun and stars.**

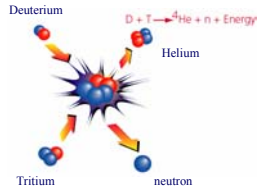
The temperature of the centre of the Sun **is 15 million °C. At this temperature** hydrogen **nuclei fuse to give** Helium and Energy. **The energy sustains life on Earth via sunlight.**

WHAT IS FUSION?

To make it work on Earth we use deuterium-tritium **and need at least** 100 million °C

We use a "magnetic bottle" called a tokamak **to keep the hot plasma away from the wall**

The challenge **is to make an effective "magnetic bottle" and a robust container**



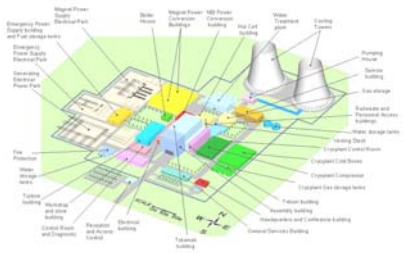
WHAT IS FUSION?

Compare:
burning fossil fuel (oil, coal), **wood or gas**
1 GW **for one day**
needs 10,000 tons of fossil fuel **= 10 train loads of coal**

With:
burning deuterium and tritium
1 GW **for one day**
needs 1 kg of deuterium* + tritium**

** extracted from (sea) water*
*** bred by: neutron + lithium (very abundant) → tritium + helium*

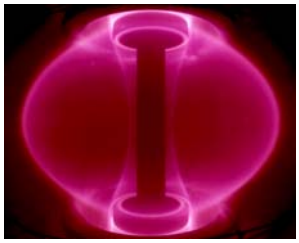
What would a fusion power plant look like?



How can we achieve Fusion on Earth?

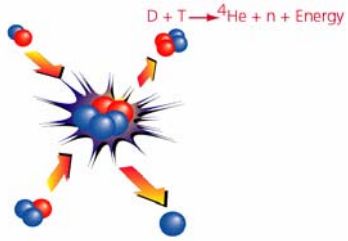
Requires:
Plasma at 100 million °C, at a high enough density and for a sufficient time for fusion to occur

Research concentrates on using the magnetic bottle approach, with the principal focus on the 'TOKAMAK'.



Plasma in the START magnetic confinement device at Culham, Oxfordshire

Fusion Reaction



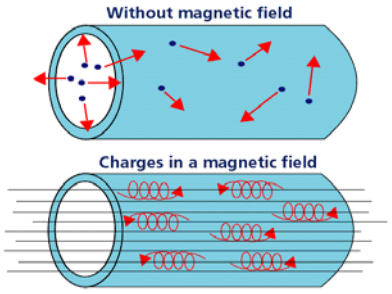
In a Fusion Power Plant Deuterium would fuse with Tritium to release Energy, Helium and a Neutron

Plasmas are used to make fusion

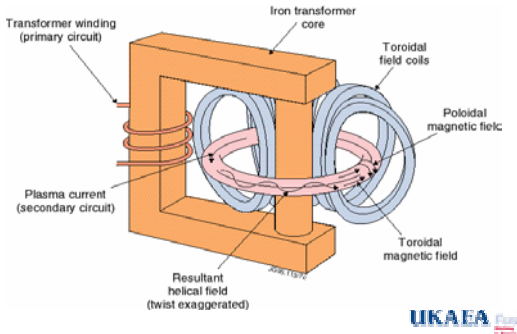
A plasma is an ionised gas - a mixture of positive ions and negative electrons

Plasmas are the fourth state of matter obtained at temperatures exceeding 10,000 degrees Centigrade

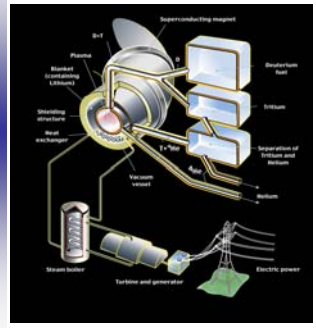
Magnetic Bottles (1)



Magnetic Bottles (2)



A Fusion Powerplant

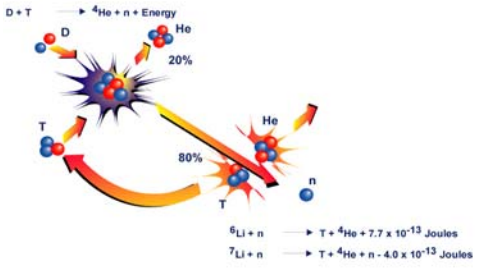


Lithium blanket captures energetic neutrons from the fusion process and serves two purposes.

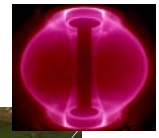
Boils water in a heat exchanger to produce steam to drive a generator.

The Lithium and neutron react to produce Tritium, one of the primary fuels in the fusion process.

Fusion How it works



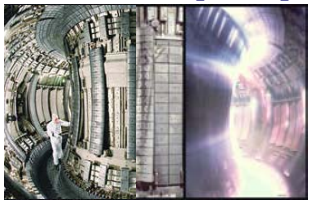
Culham Site with the JET



JET

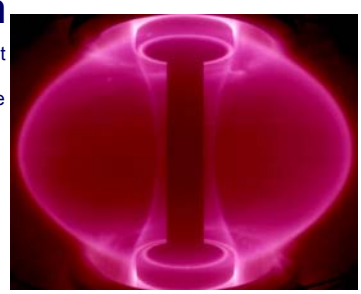
ST Plasma

JOINT EUROPEAN TORUS (JET)

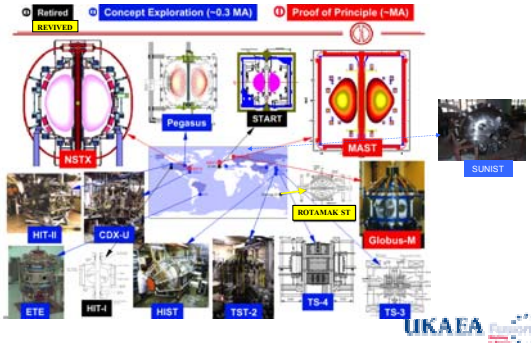


Worlds first hot ST Plasma

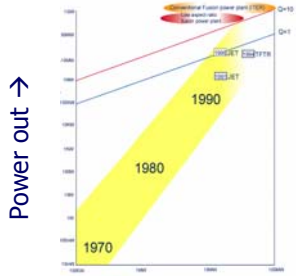
START operated at Culham from 1991 to 1998 during time other fusion programmes followed the UKs lead by building their own STs



World ST Programme



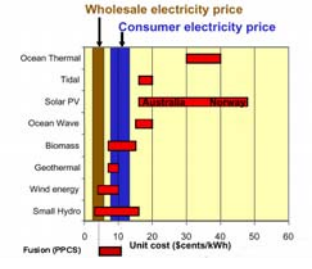
Progress



FUSION ADVANTAGES

- unlimited fuel
- no CO_2 or air pollution
- major accidents impossible
- no radioactive “ash” and no long-lived radioactive waste
- good chance of working at a competitive “internal” cost (and essentially zero “external” cost [impact on health, climate])
- meets a need

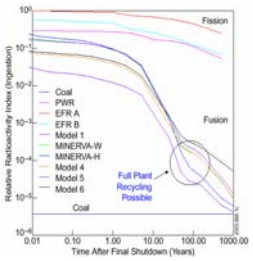
COST COMPARISONS

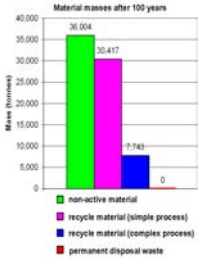


Results from Shell Renewables + Fusion Power Plant Conceptual Studies

RADIOACTIVITY

No equivalent of core of fission reactor + no actinides (long-lifetimes)





NEXT STEP FOR FUSION

- Construct ITER (International Tokamak Experimental Reactor)

  ⇒ energy out = 10× energy in

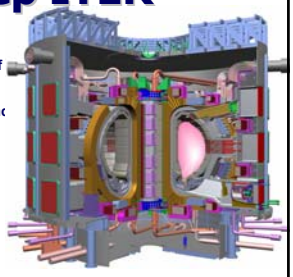
  ⇒ "burning" plasma

  Project involves Europe, Japan, USA, Russia, China, S Korea.

  Close to approval (for construction in France or Japan)

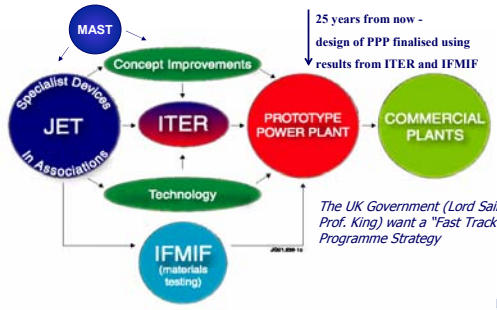
The Next Step ITER

- **Aim is to demonstrate integrated physics and engineering on the scale of a power station**
- **Key ITER technologies fabricated and tested by industry.**
- **4.5 Billion Euro construction cost**
- **Europe, Japan, Russia, US, China, South Korea.**
- **Candidate sites in France and Japan**
- **Decision soon**



Fast Track ~25 years

(Fusion Electricity a reality in our lifetimes ⇒)



The UK Government (Lord Sainsbury, Prof. King) want a "Fast Track" Fusion Programme Strategy