Fusion Energy
Powering the XXI century

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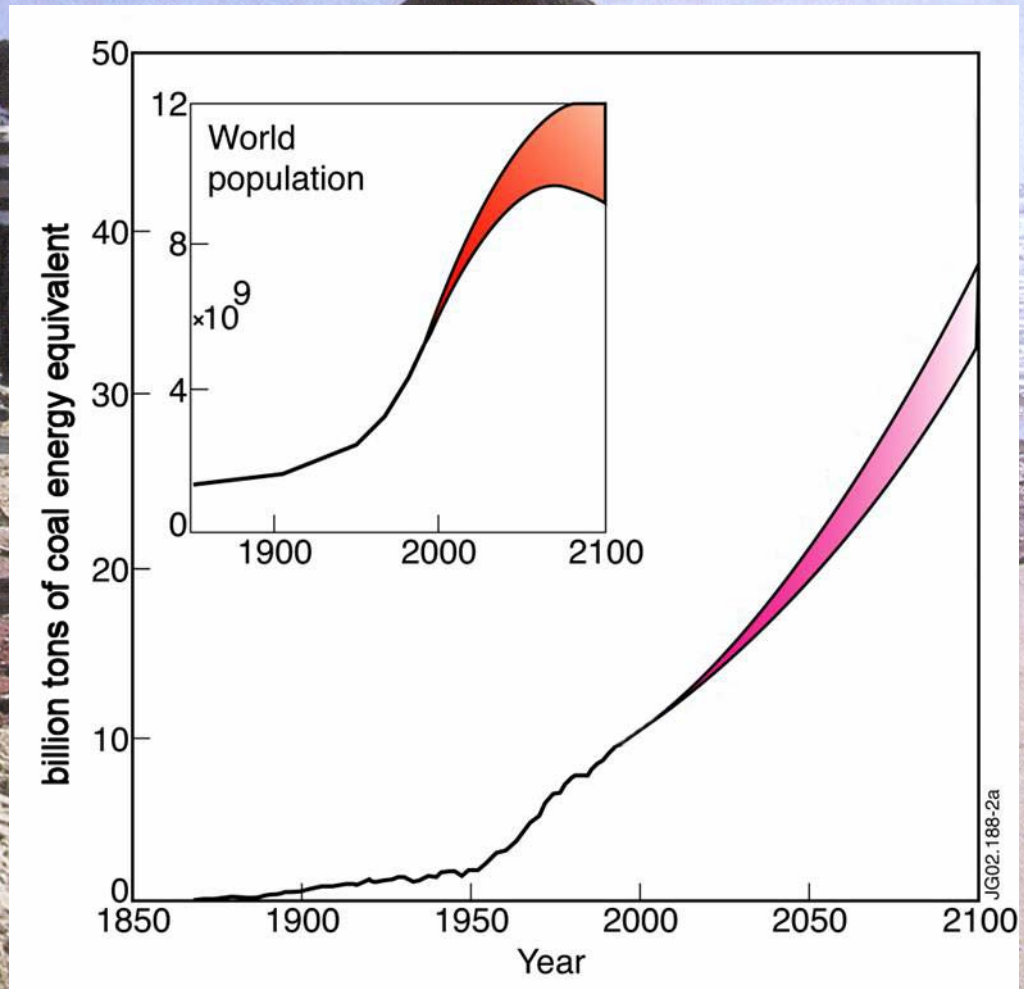
Outline

- World Energy Consumption
- Global Warming
- Advantages of Fusion energy
- Present machines close to breakeven
- ITER (Next step device)
- Summary

World Population Growth

World population and energy demand growing rapidly

Predictions suggest strong growth will continue

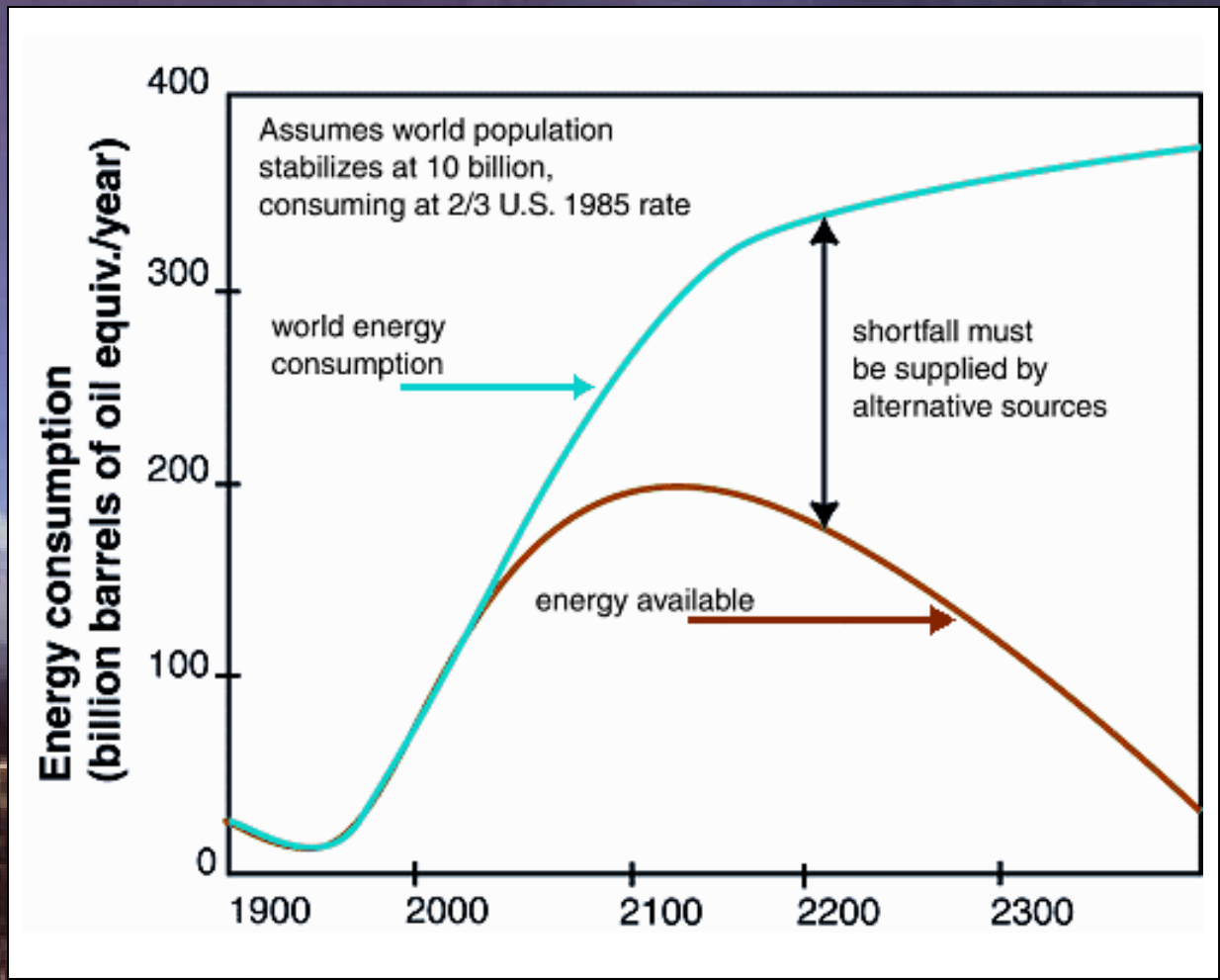


World Energy Consumption

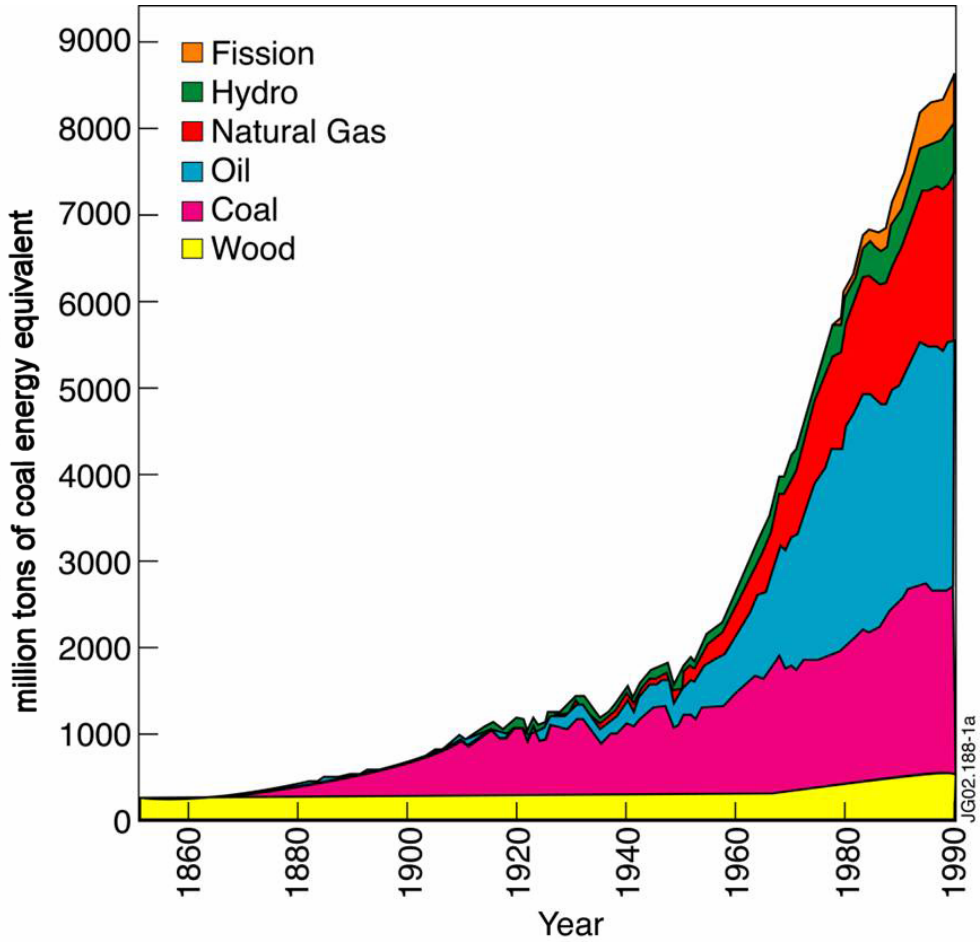
Assuming that the world population stabilises at 10 Billion

World energy consumption will exceed the current energy sources

Shortfall must be supplied by alternative sources



World Energy Consumption



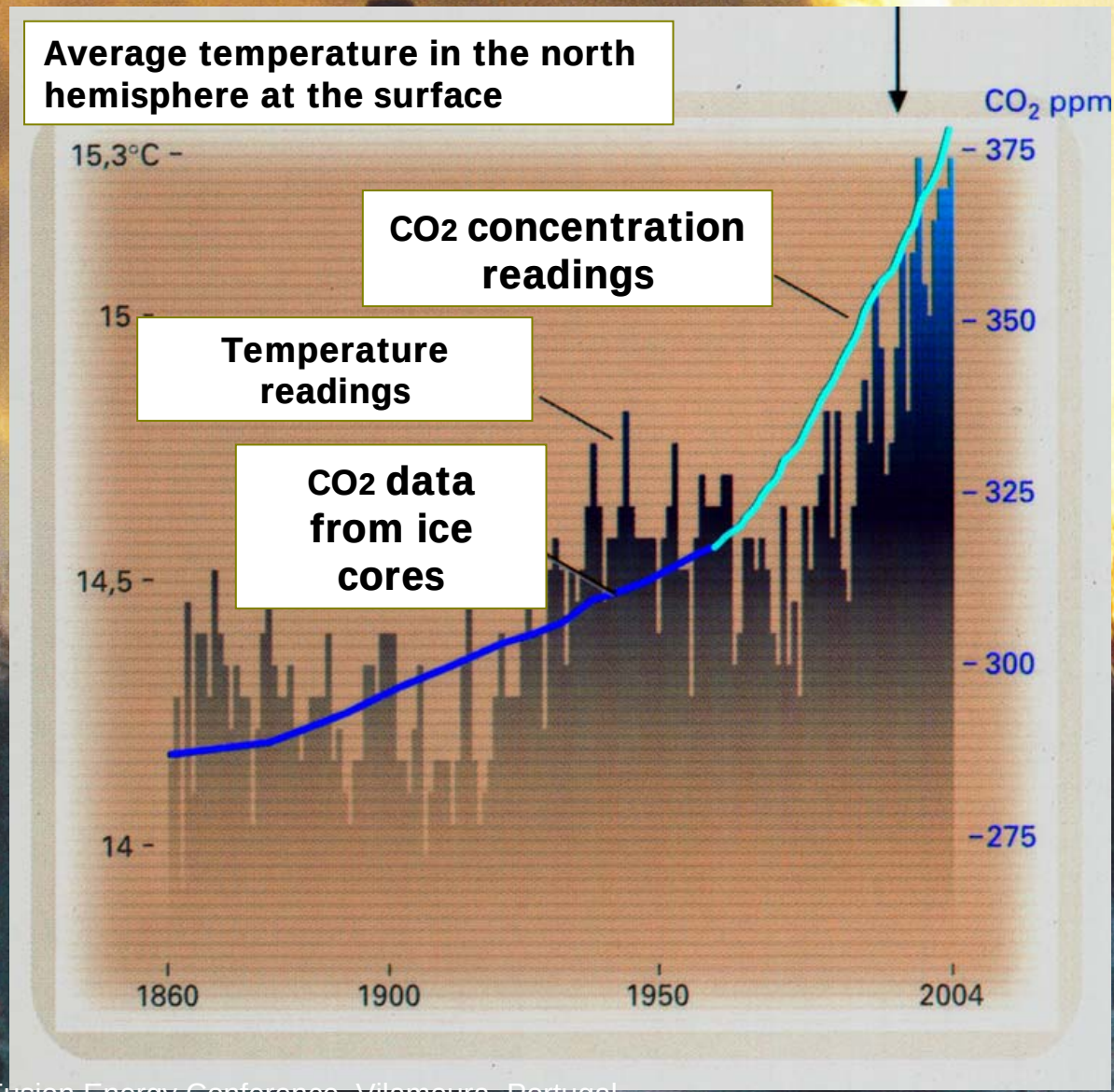
World energy consumption is dominated by the use of fossil fuels

The use of fossil fuels poses serious environmental problems due to emission of greenhouse gases to the atmosphere

Global Warming is happening

Global warming is already happening

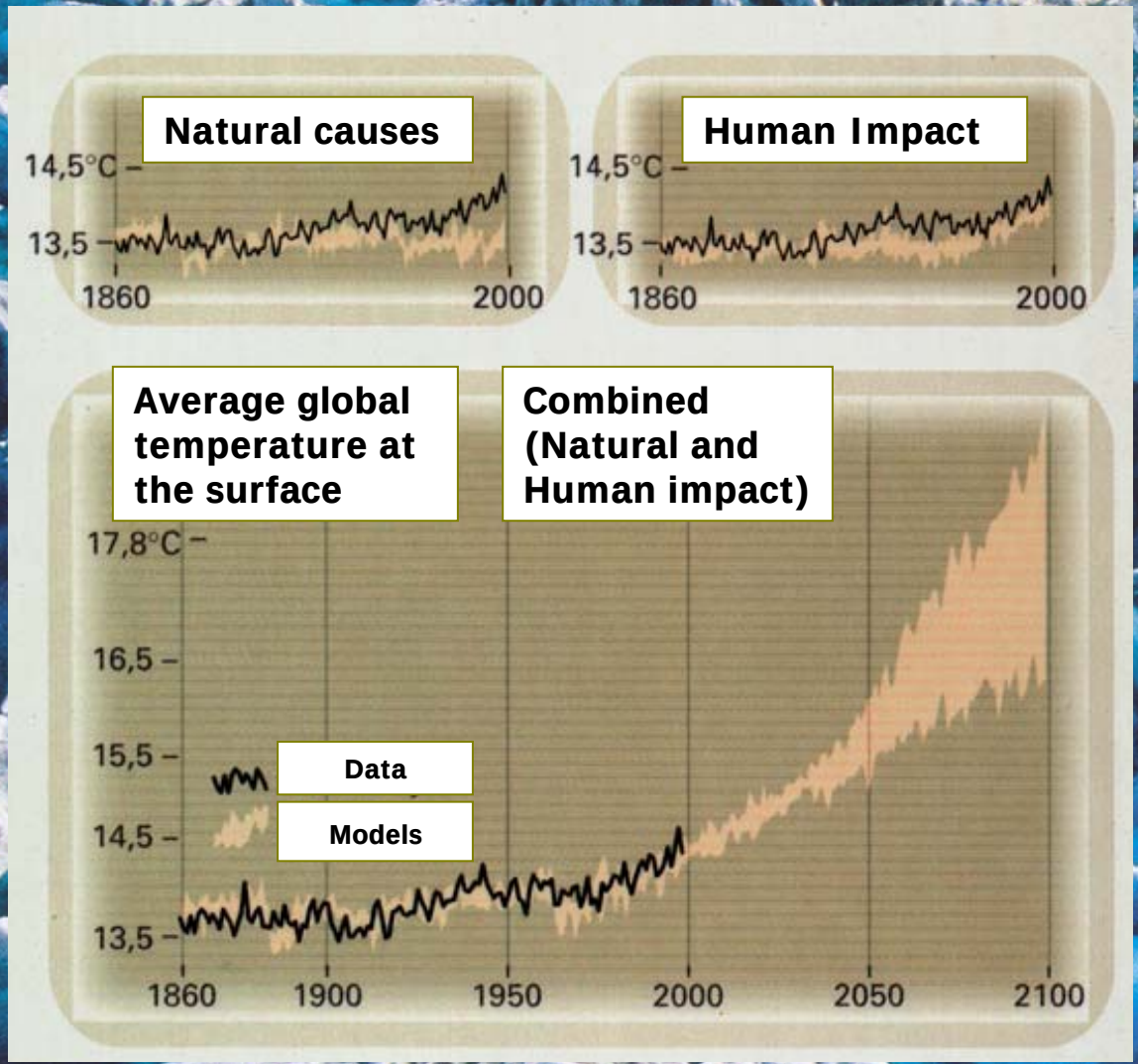
There is evidence that the main cause of recent global warming is atmospheric pollution



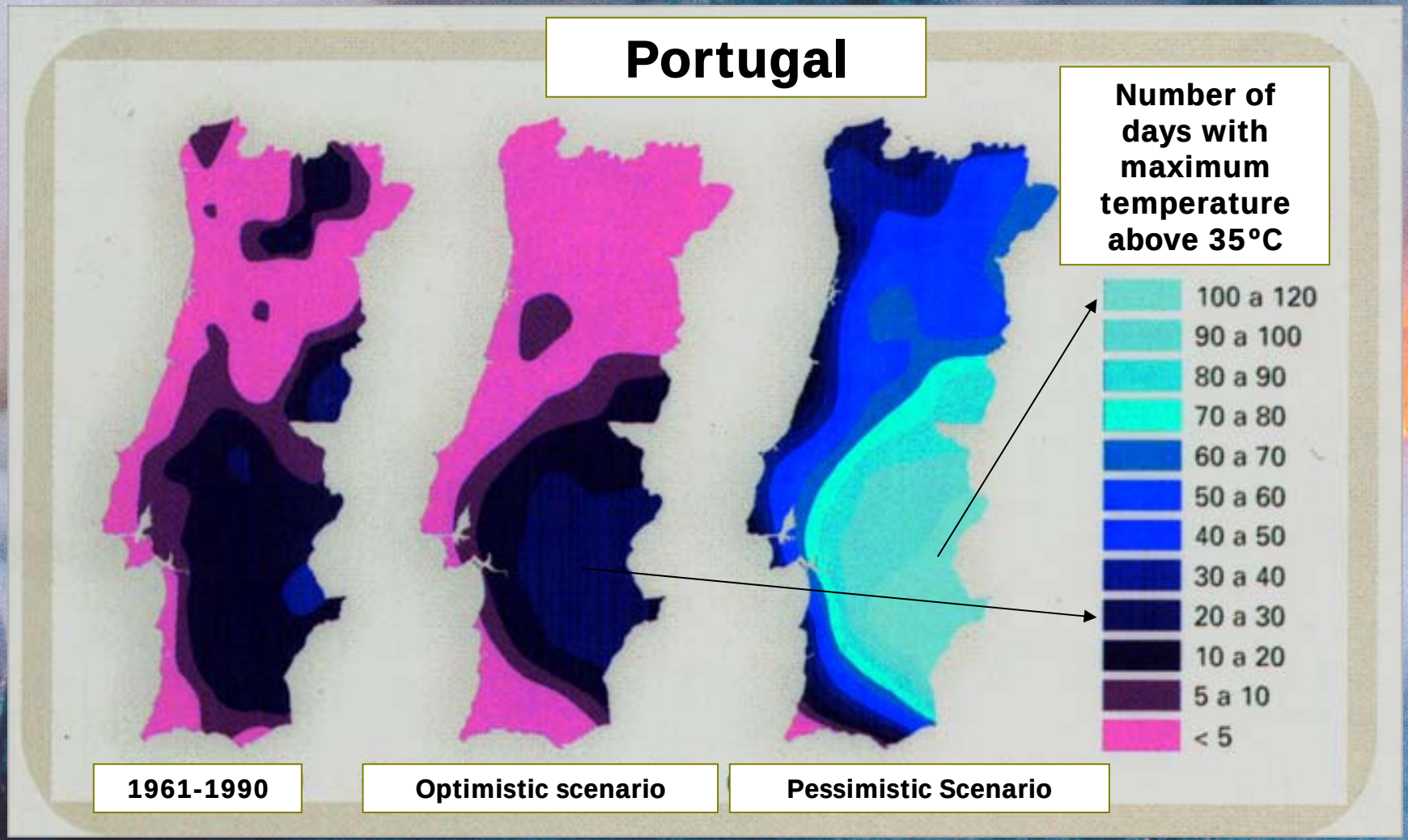
Global Warming forecast

Global temperature increases of 1-3 degrees is forecasted, depending on the global CO_2 emissions, in the next 100 years

Global temperature increases of 1-3 degrees will have a major impact on the global environment



Impact of Global Warming in 2100



Sources of Energy in XXI

Nuclear Fission (Long term, High level radioactive waste)

Fossil fuels **(Coal)** (Green house gas emissions and Global warming)

Renewables **(Solar,Wind)** (not suitable for very large energy demands peak power >>1GW)

Nuclear Fusion (Safe & low level radioactive waste, no atmospheric pollution)

Advantages of Fusion energy

Fuel abundant (available world-wide)

Deuterium available for millions of years
Lithium (to produce Tritium) available for thousands of years

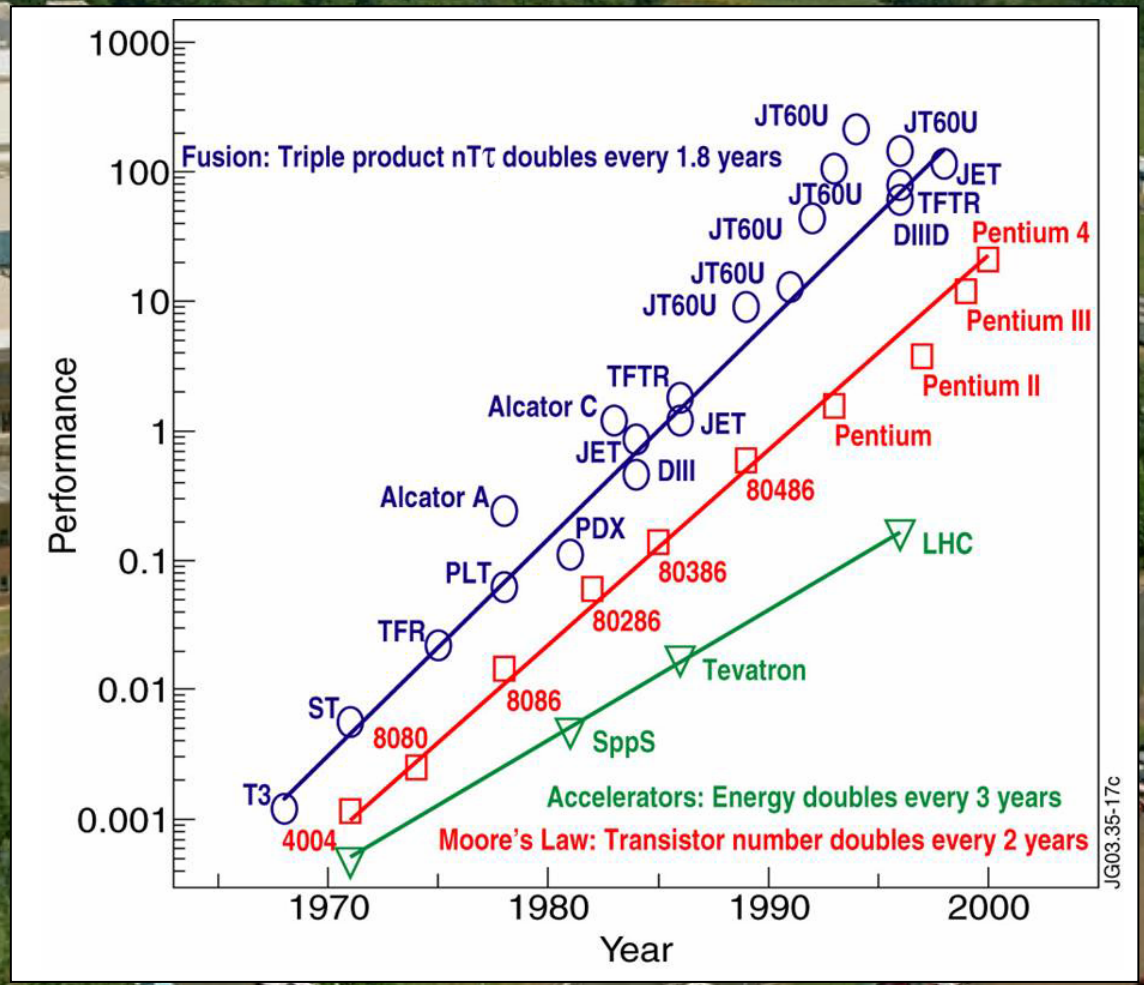
No Greenhouse gases (CO, CO_2) and no acid rain (SO_2, NO_2)

Short life radioactivity (associated with plant activation)
No need for transport of activated materials

Fusion made significant progress

Progress in fusion can be compared with the computing power and particle physics accelerator energy

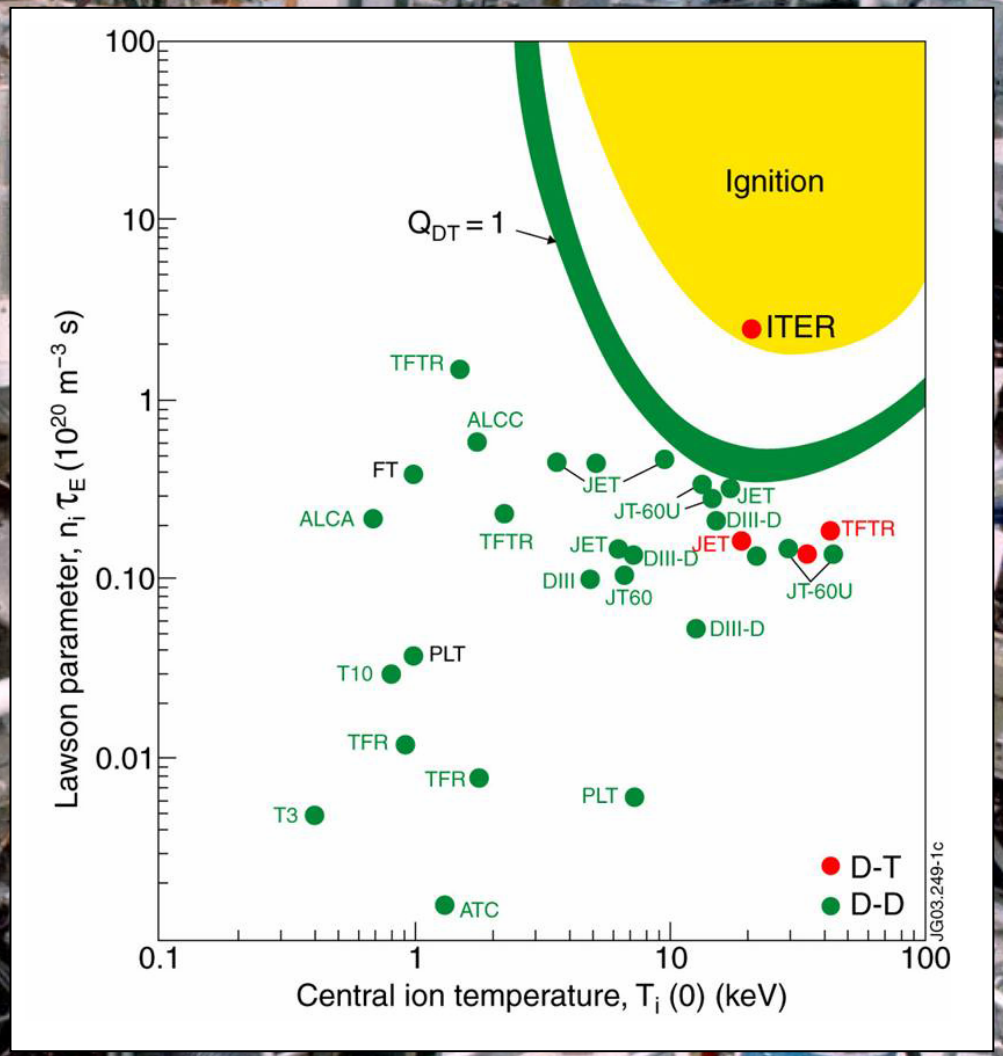
Present machines produce significant fusion power (TFTR 10MW in 1994) and (JET 16MW in 1997)



Present machines close to breakeven

Present machines are close to produce fusion energy comparable with the energy required to sustain the plasma (breakeven)

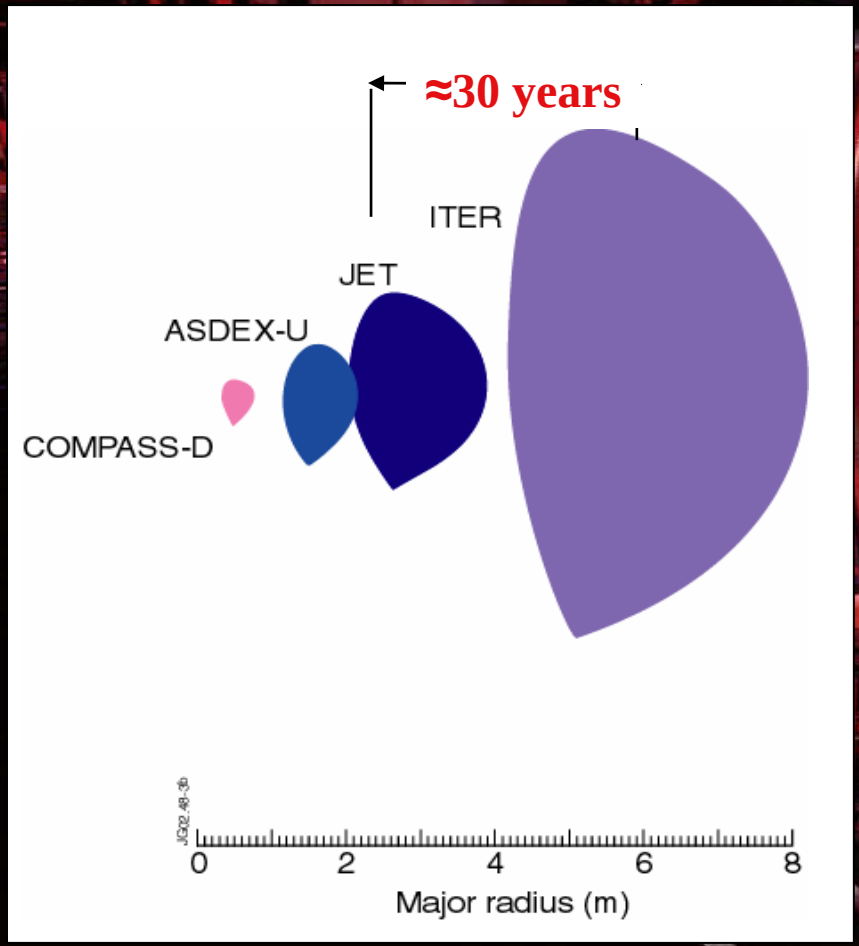
Next step devices (ITER) are expected to produce significantly more fusion energy than the energy required to sustain the plasma (close to Ignition)

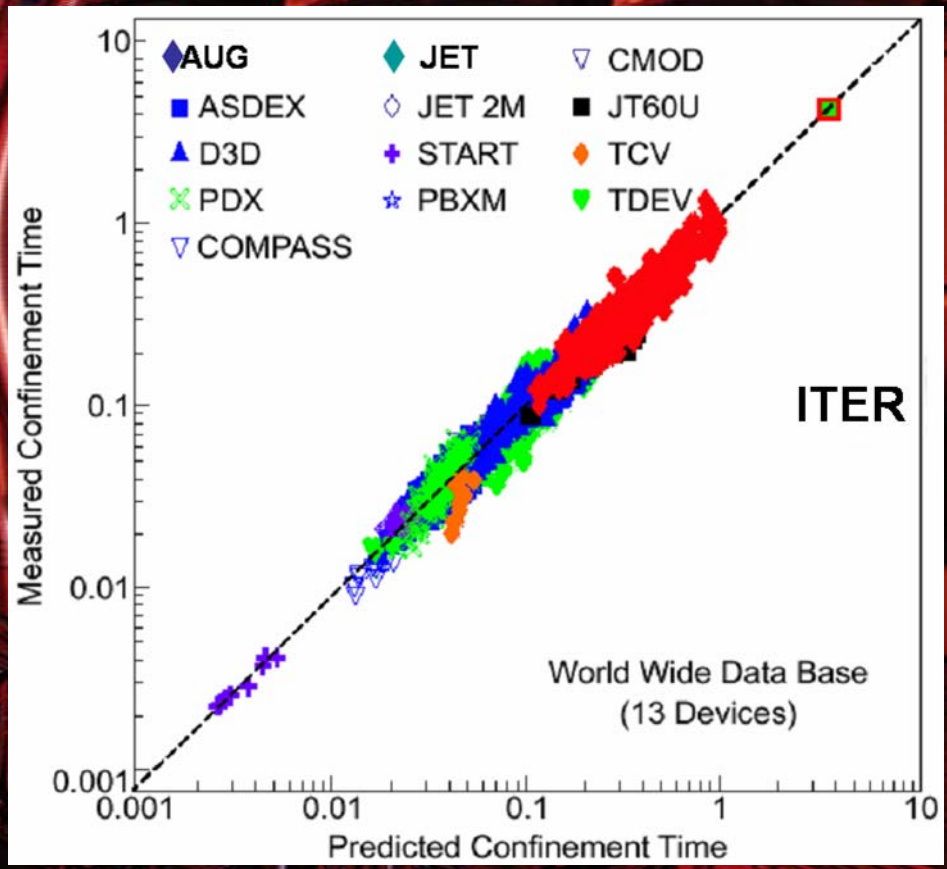


Main tokamaks around the world

Tokamak	Tore Supra (France)	Asdex-U (Germany)	Textor (Germany)	JET (European Union in the UK)	TFTR (USA) (machine closed)	DIIID (USA)	JT-60U (Japan)
Plasma Configuration	Limiter	Divertor	Limiter	Divertor	Limiter	Divertor	Divertor
Specificity	**Long Pulse**	**Tungsten Wall**	**Plasma Surface Interactions**	**Tritium Remote Handling**	**Tritium**	**Active MHD Stabilisation**	**Negative Neutral Beams**
Major radius	2.36 m	1.65 m	1.75 m	**2.96 m**	2.48 m	1.67 m	3.45 m
Toroidal field	4.5 T	4 T	2 T	3.45 T	**5.2 T**	2.2 T	4.4 T
Plasma current	1.7 MA	1.6 MA	0.65 MA	**7 MA**	2.5 MA	3.5 MA	5 MA

Next step device (ITER) close to Ignition





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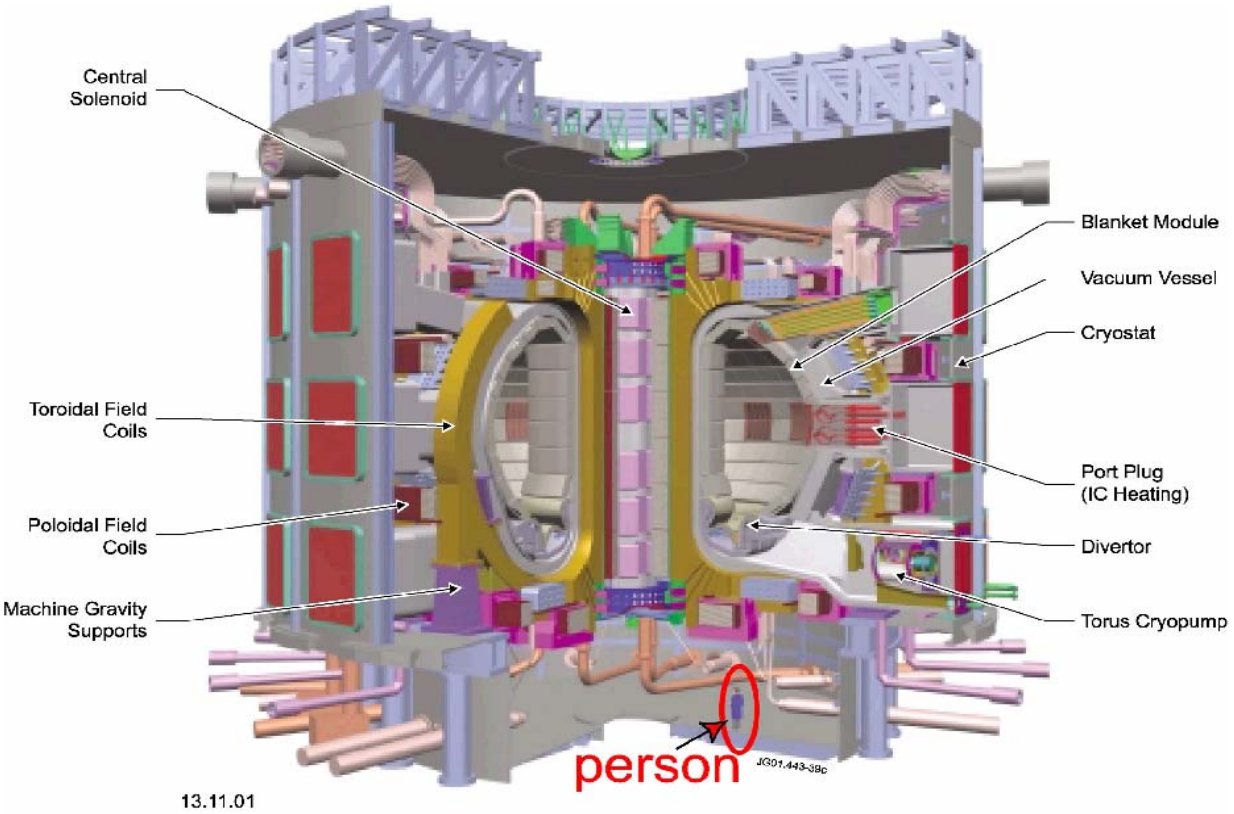
ITER (Next step device)



R (m)	6.2
a (m)	2
flat-top length (s)	**2000**
B_t (T)	5.3
I_P (MA)	15(17)
P_{fus} (MW)	**410**
P_{aux} (MW)	40-90
P_α (MW)	85
$Q(P_{fus}/P_{in})$	**10**
β_T, β_P	2.5%, 0.7

ITER will be a nuclear machine: 1.5 x 10^{20} neutrons/s

Summary

Presently 2 options exist for large scale energy production in the second half of XXI century:

- **Nuclear Fission** (Long term, High level radioactive waste)
- **Fossil fuels (Coal)** (Green house gas emissions and global warming)
- **Renewables** cannot provide a solution for the global energy problem

We need a 3rd option:

- **Nuclear Fusion** (Safe & low level radioactive waste, no atmospheric pollution)