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Optimising Fusion's Contribution to Economically Efficient Climate Change Mitigation

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Background

Until very recently:

- Most decision-makers were ignorant of fusion, or had little confidence that viable fusion power was possible.
- Many decision-makers could see no urgent need – or perhaps no need at all - for fusion.

The results were:

- Severe funding constraints.
- ‘Sequential’ conceptions of fusion development – even in ‘Fast Track’ scenarios.

But this is changing!

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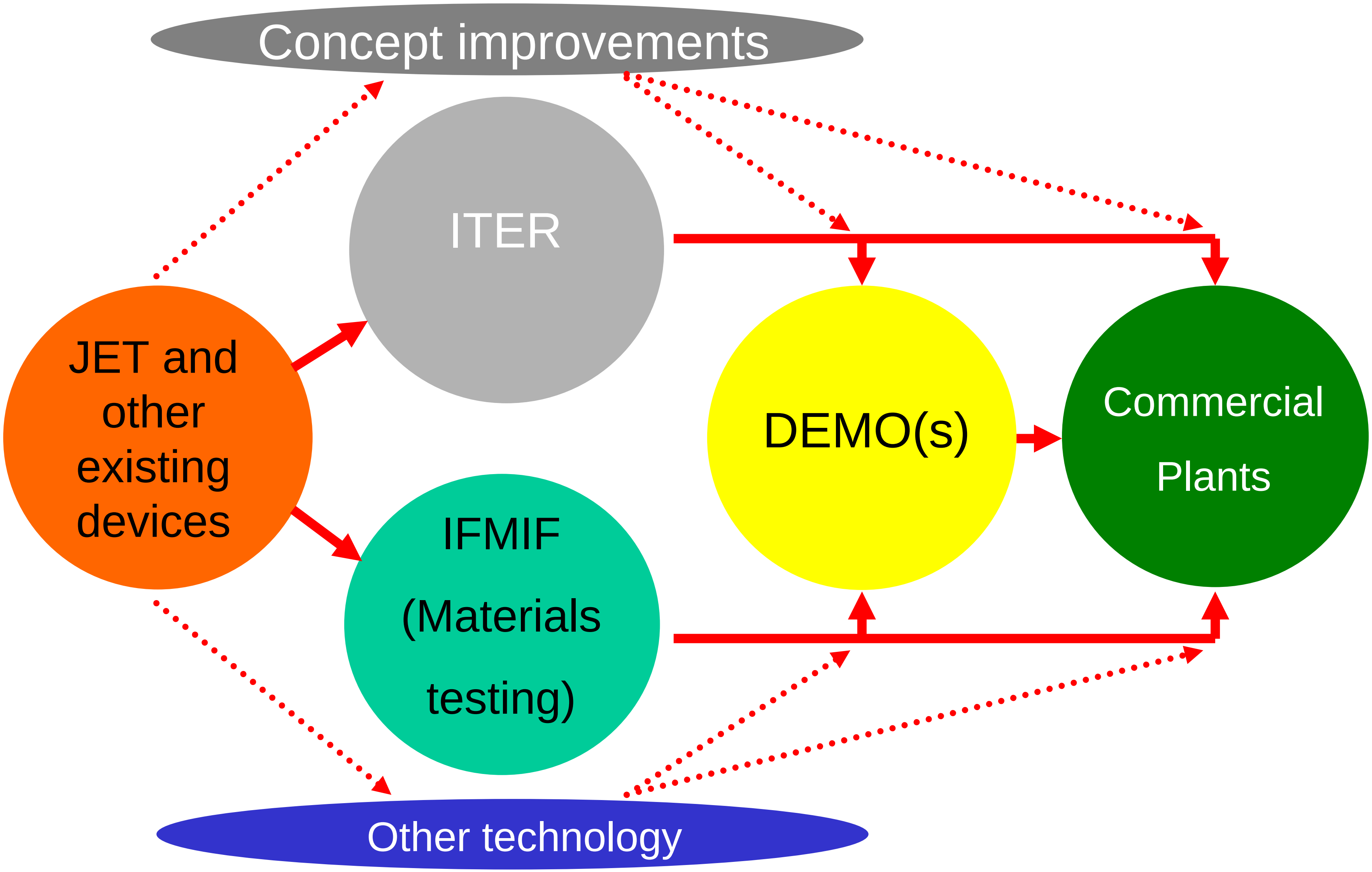
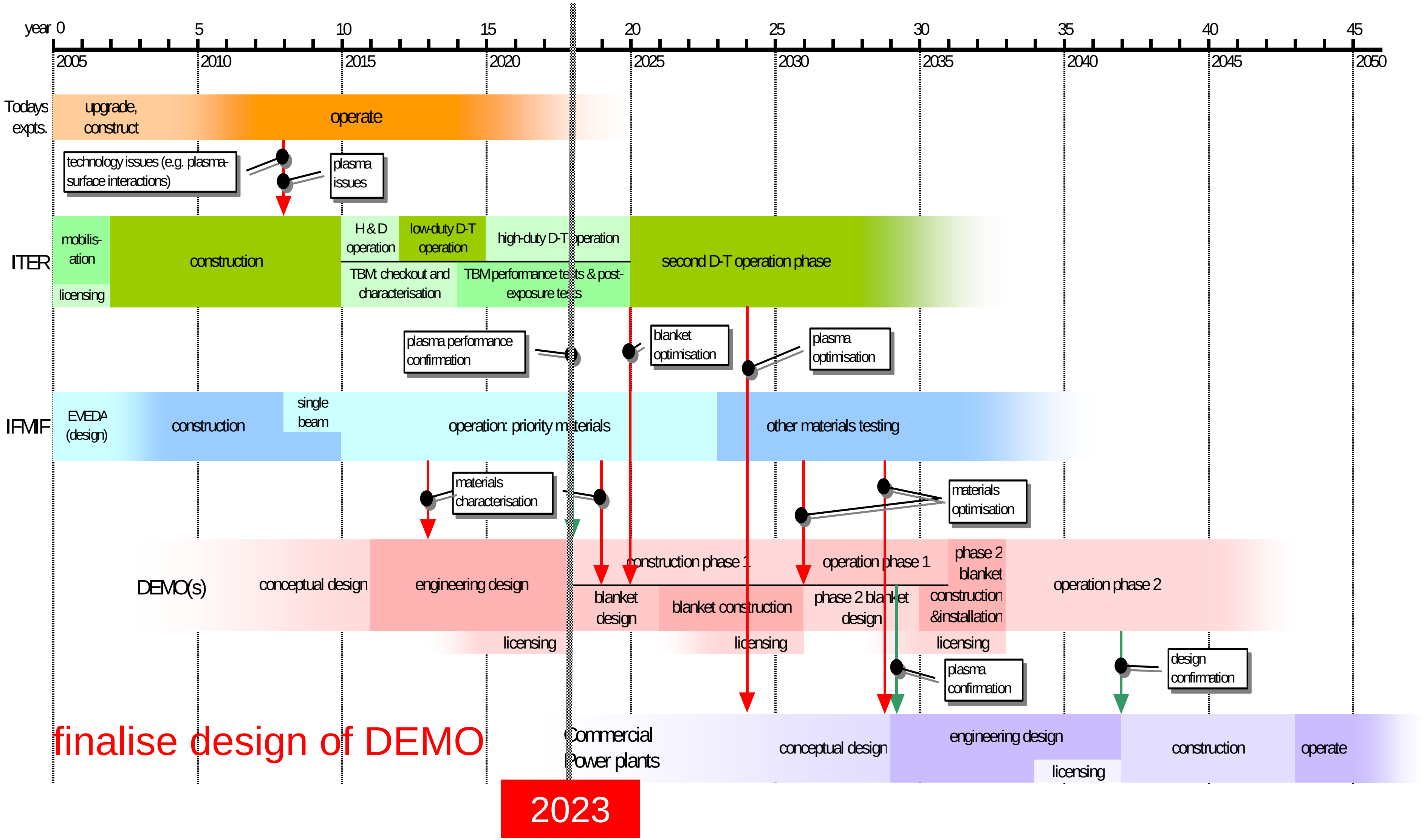
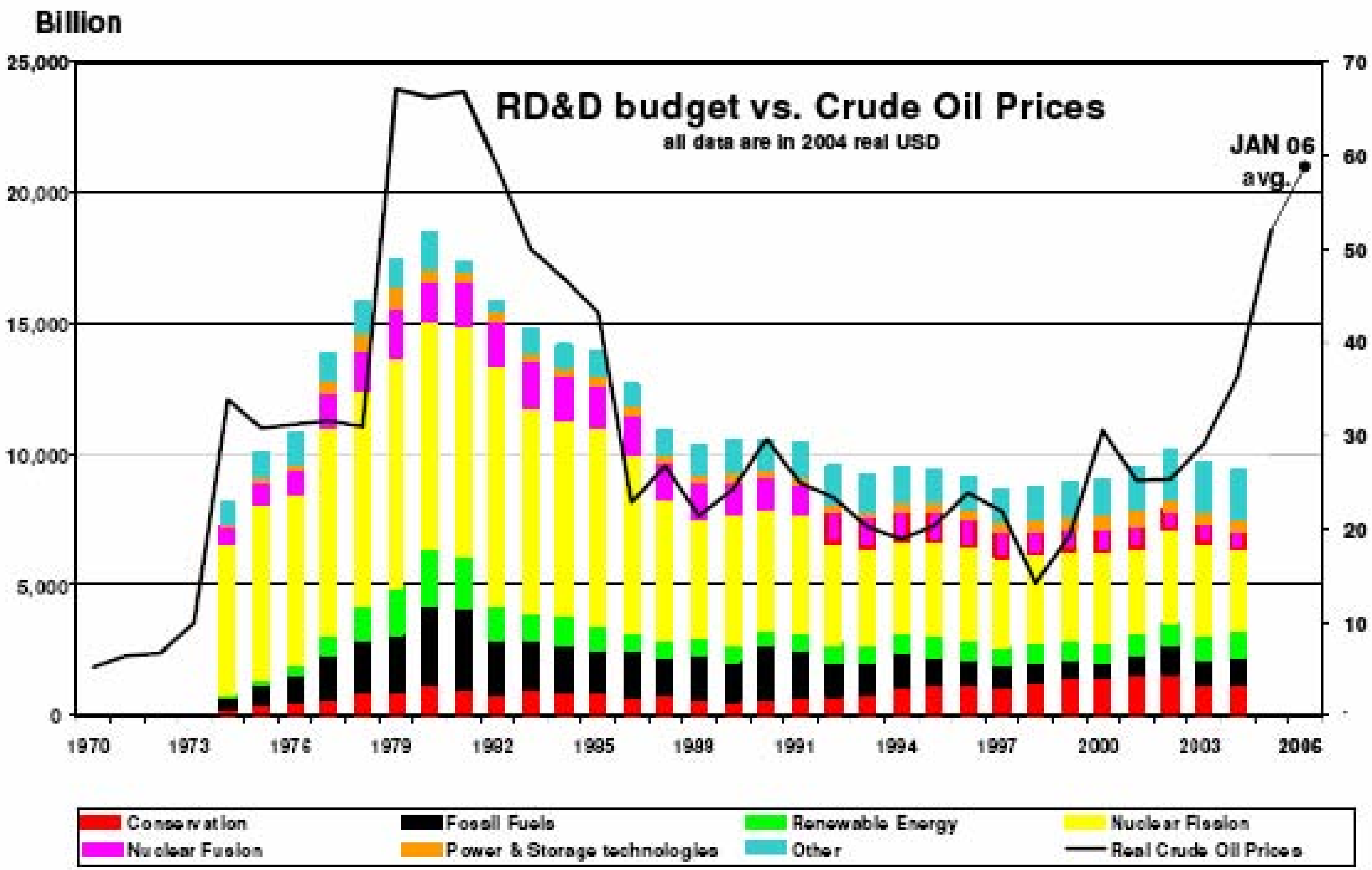
‘Sequential’ Fast Track Strategy



A ‘Funding-Constrained’ ‘Sequential’ Fast Track

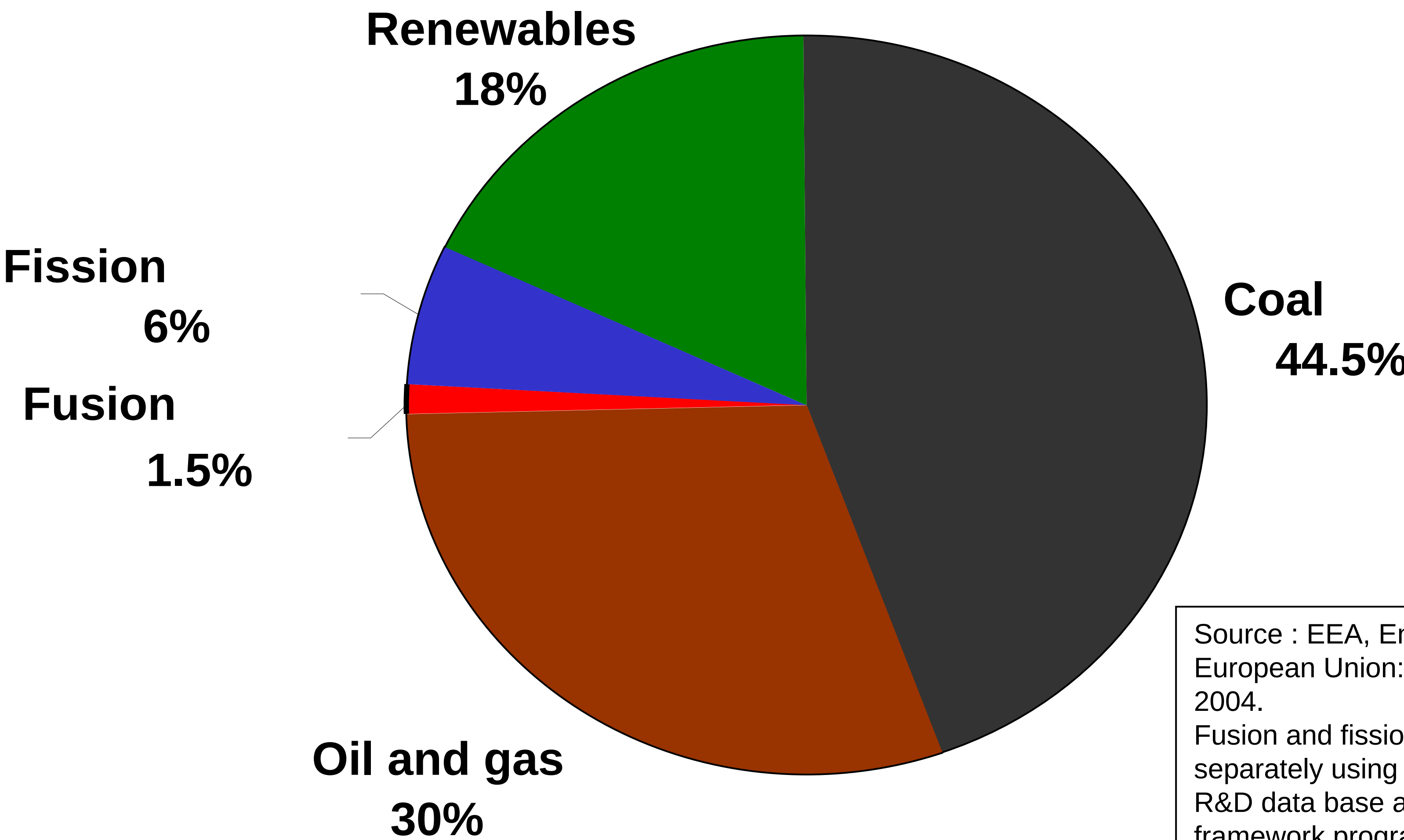


Public sector energy research spending



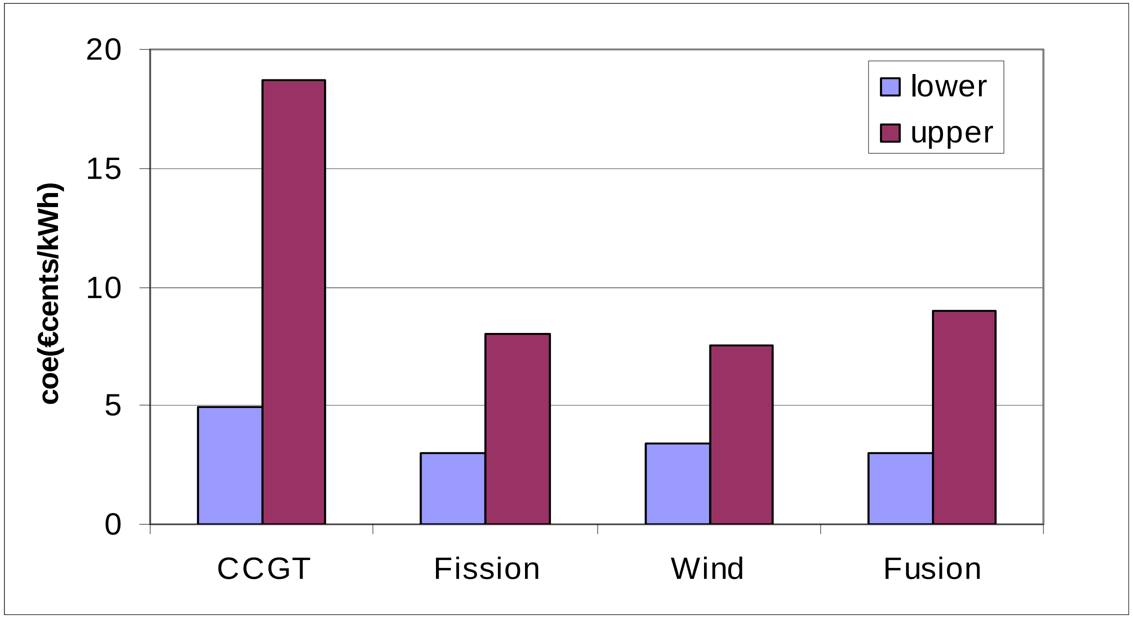
Source: IEA

Energy subsidies and R&D in the EU~ 30 Billion Euro (per year)



Source : EEA, Energy subsidies in the European Union: A brief overview, 2004.
Fusion and fission are displayed separately using the IEA government-R&D data base and EURATOM 6th framework programme data

The fusion economics produced by these ‘funding-constrained sequential’ fast tracks is typically:



- Large uncertainties inherent in projections.
- **Projections include no carbon tax or emissions trading**.

[Wind is near term technology but no standby or storage costs.]

Source: “Projected Costs of Generating Electricity” IEA,
1998 Update, PPCS

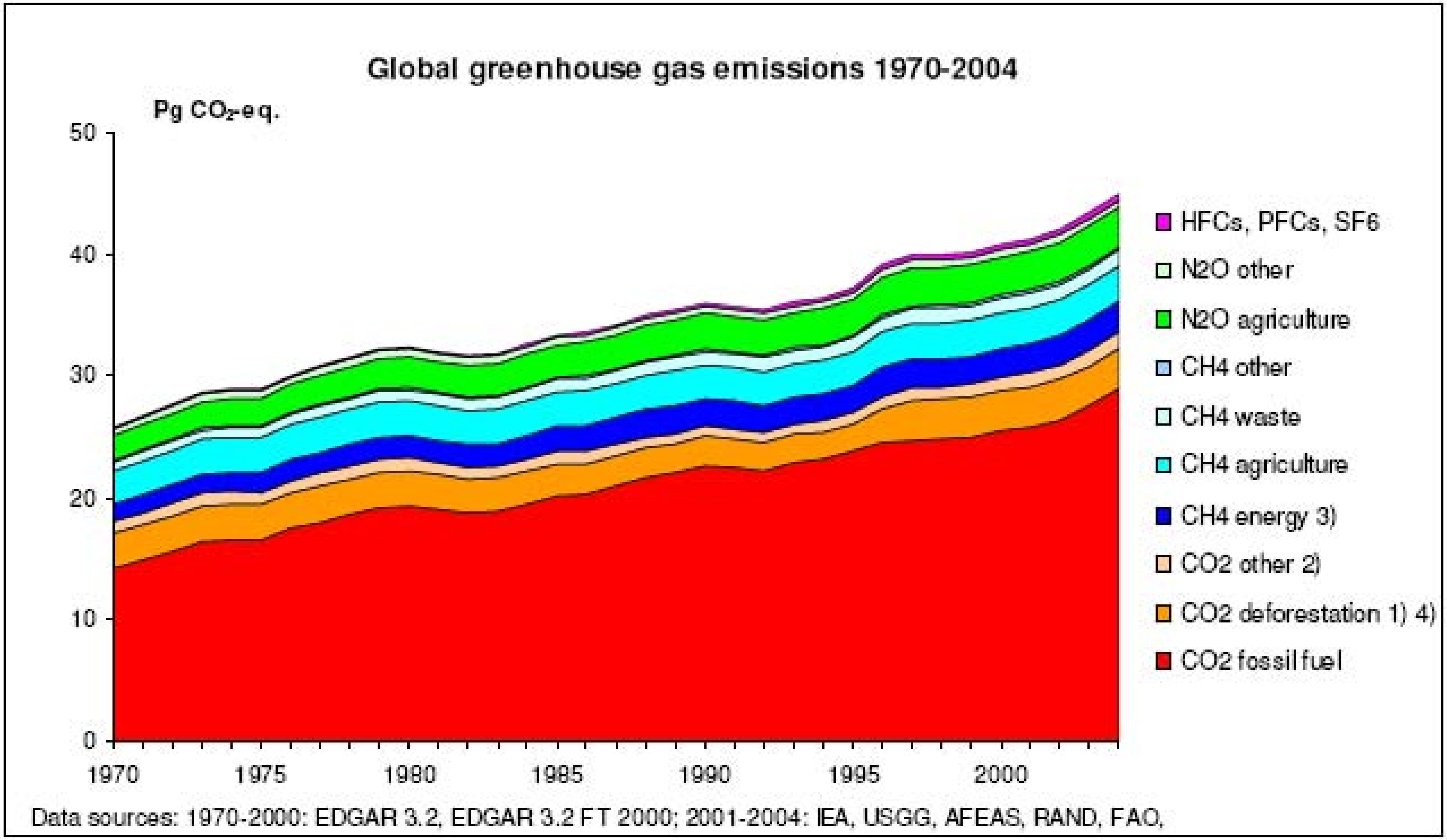
But everything is changing!

- The ITER Treaty, and the Broader Approach agreement, have removed much uncertainty relating to the near-term steps of fusion development.

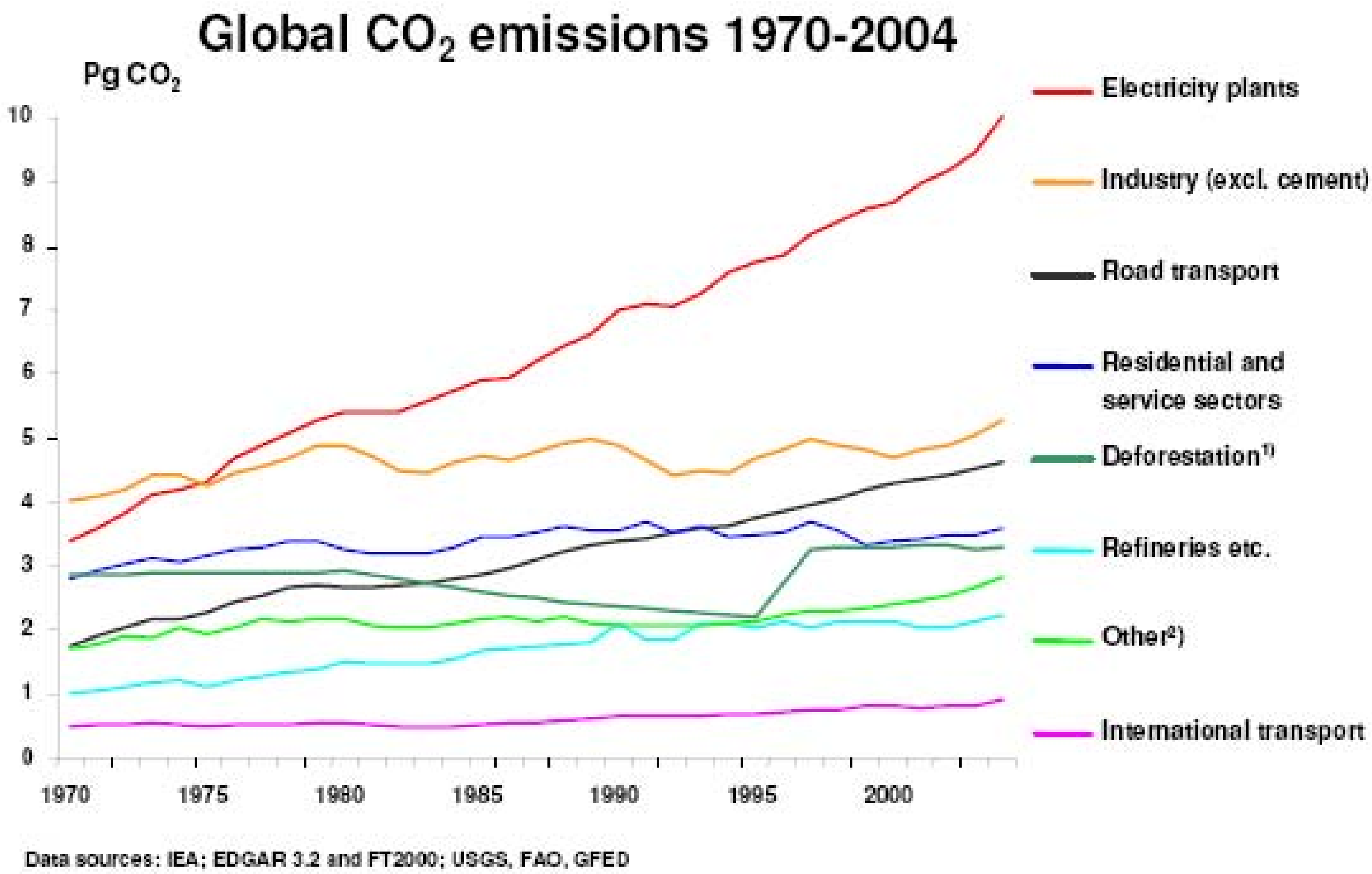
- Concerns over Energy Security have increased markedly.

- Recent (2007) publications by the IPCC and the Stern Review have removed most of the uncertainties about the reality, causes, speed and costs of climate change.

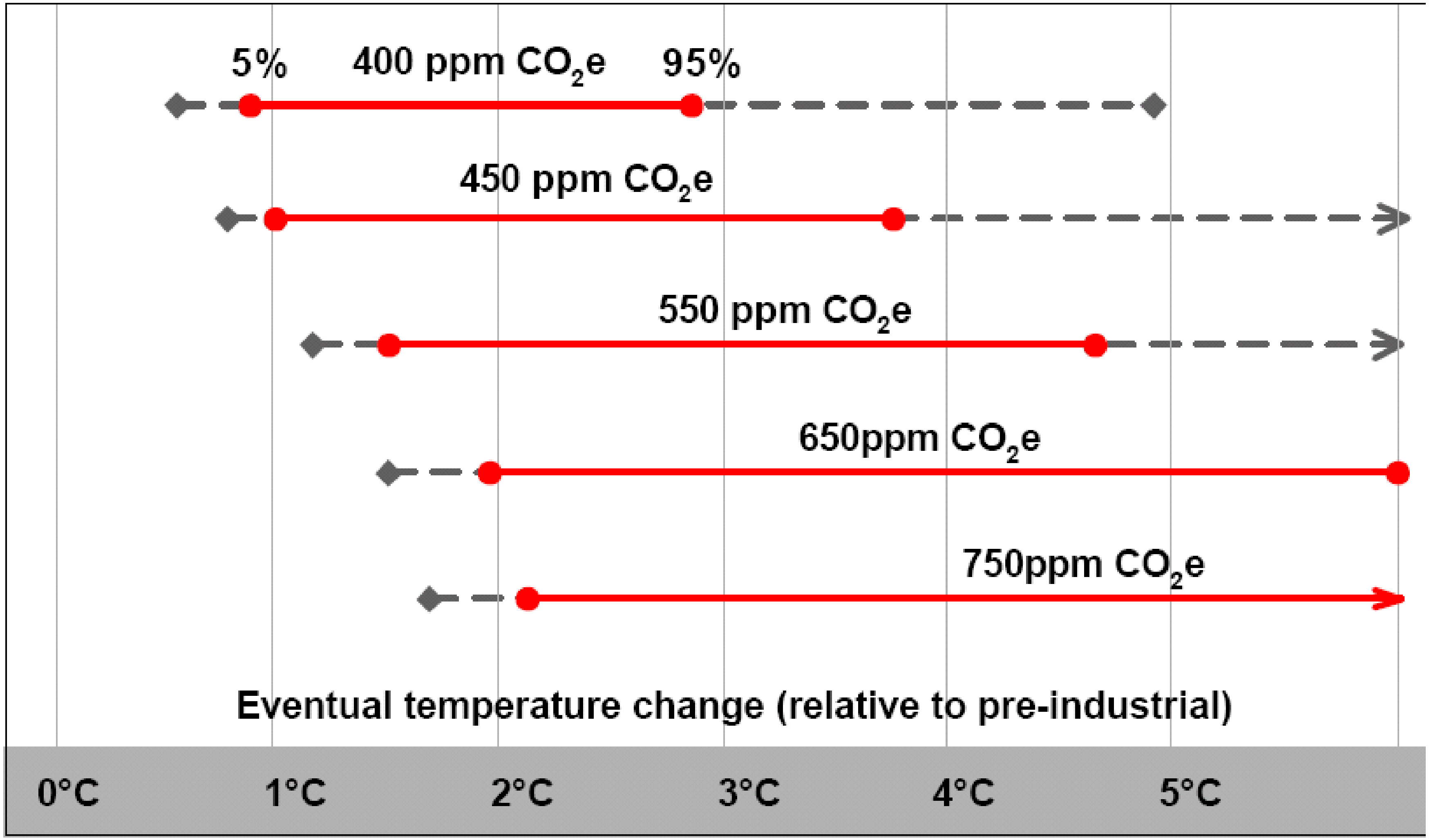
Greenhouse gas emissions



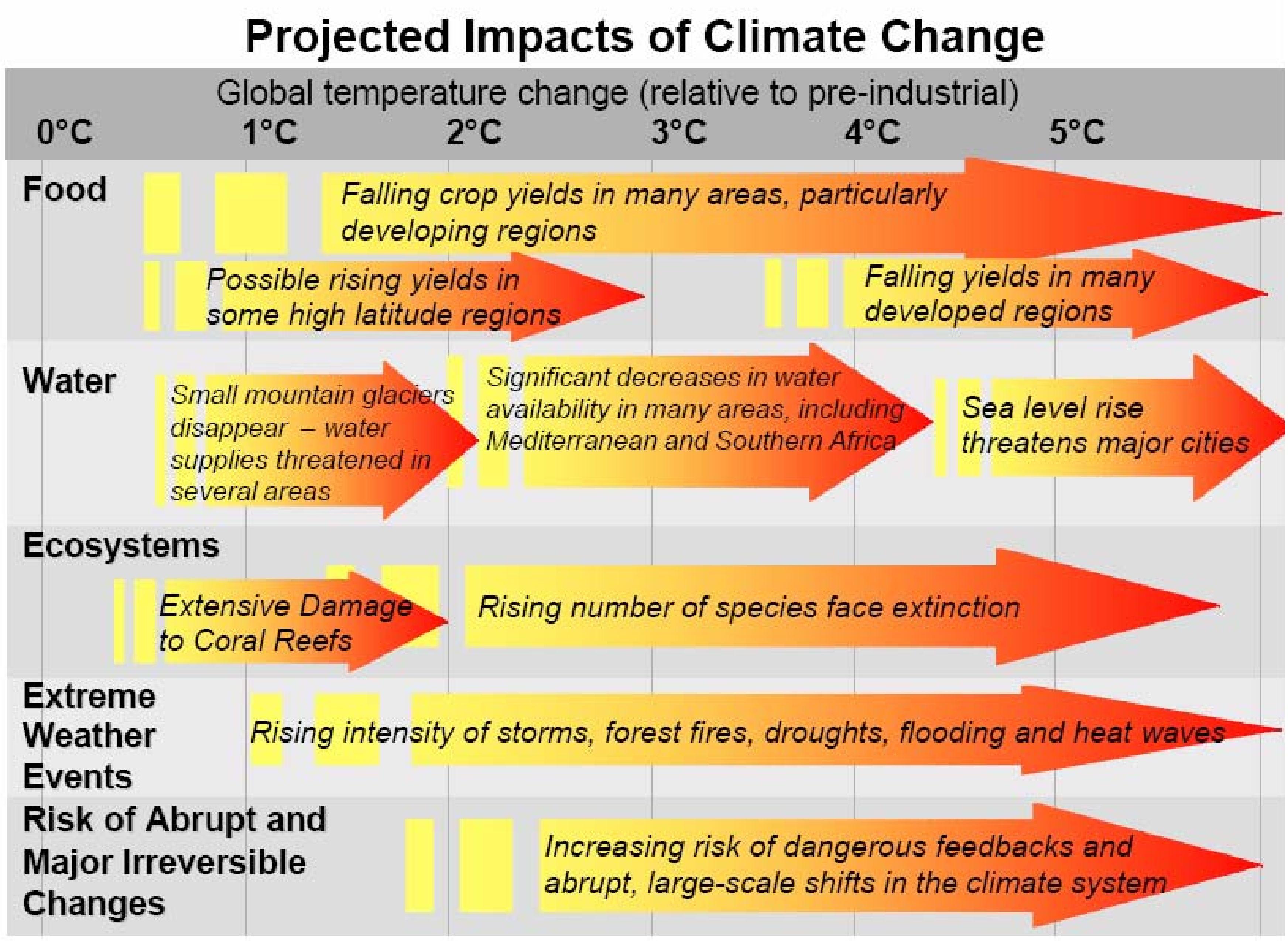
Carbon dioxide emissions



Stabilisation and Commitment to Warming

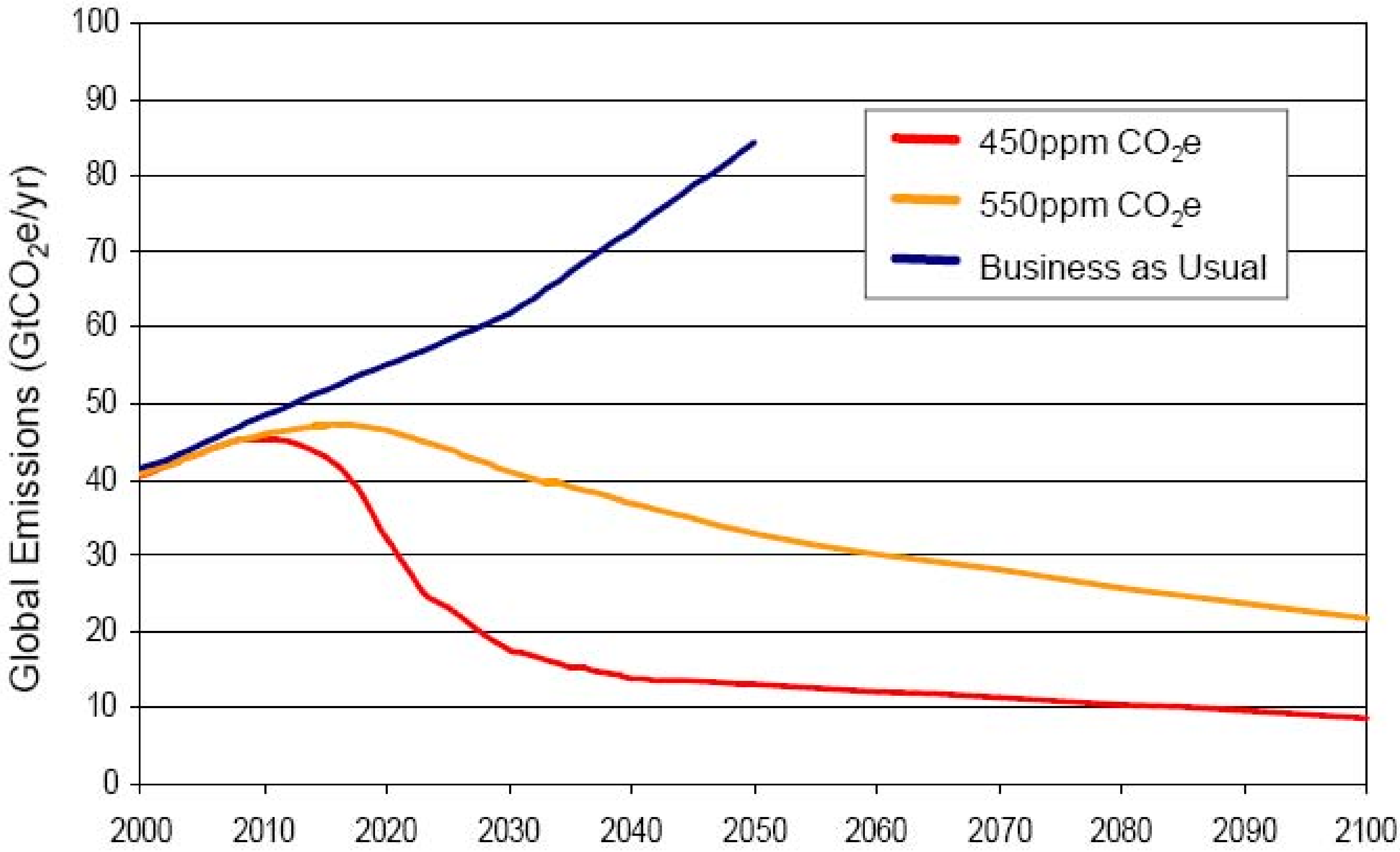


Source: Stern Review



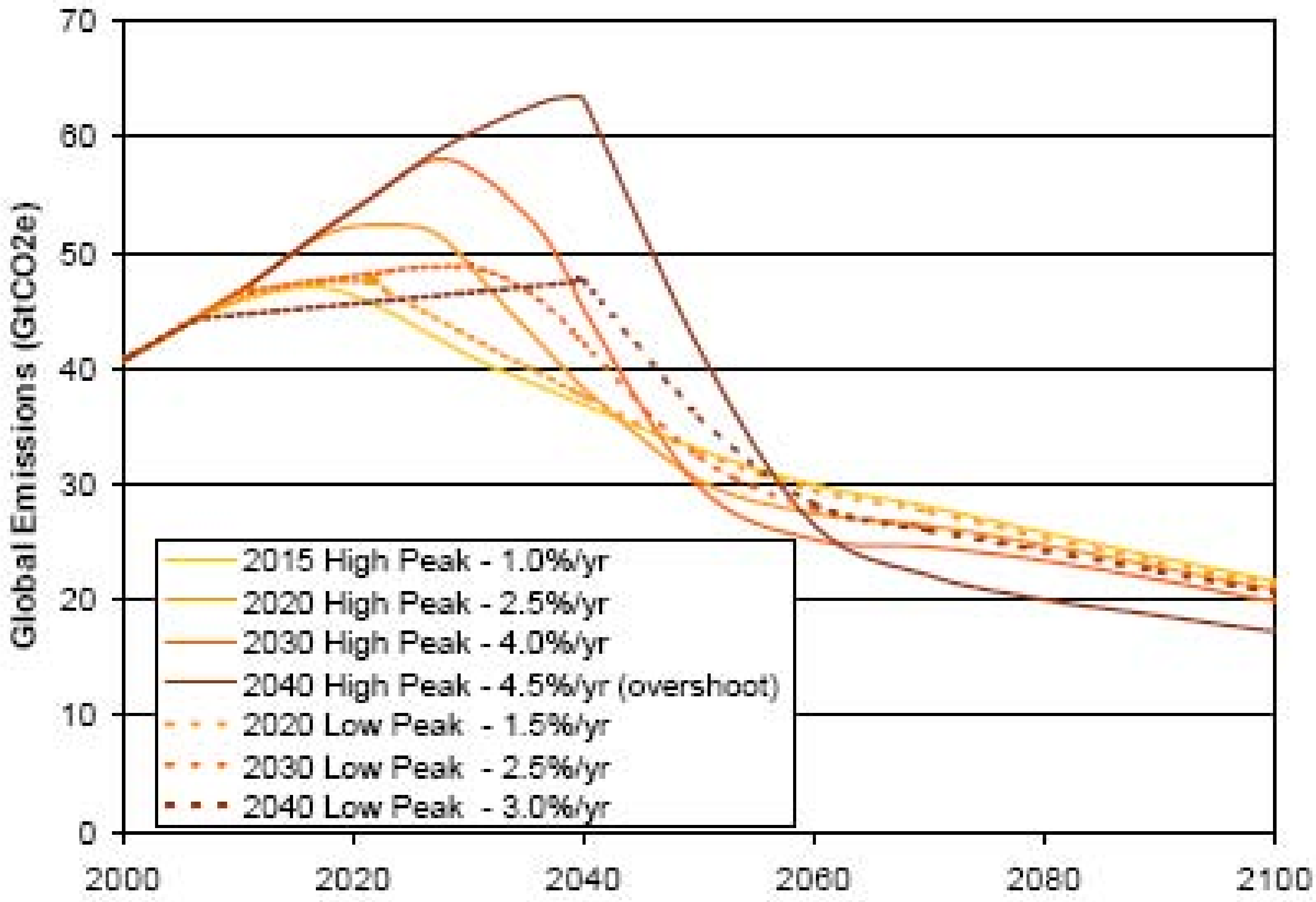
Source: Stern Review

Emissions Paths to Stabilisation



Source: Stern Review

Illustrative emission paths to stabilise at 550ppm CO2e



Source: Stern Review

Economics of mitigating climate change

- The Stern Review (by the former Vice-President and Chief Economist of the World Bank) found that **the costs of climate change are far higher than the costs of measures that would mitigate it.**

- **This review recommended that investment in energy R&D should *at least* double.** [Priorities: PV, biofuel, **fusion**, materials science.]

- These points were prefigured by our own work.

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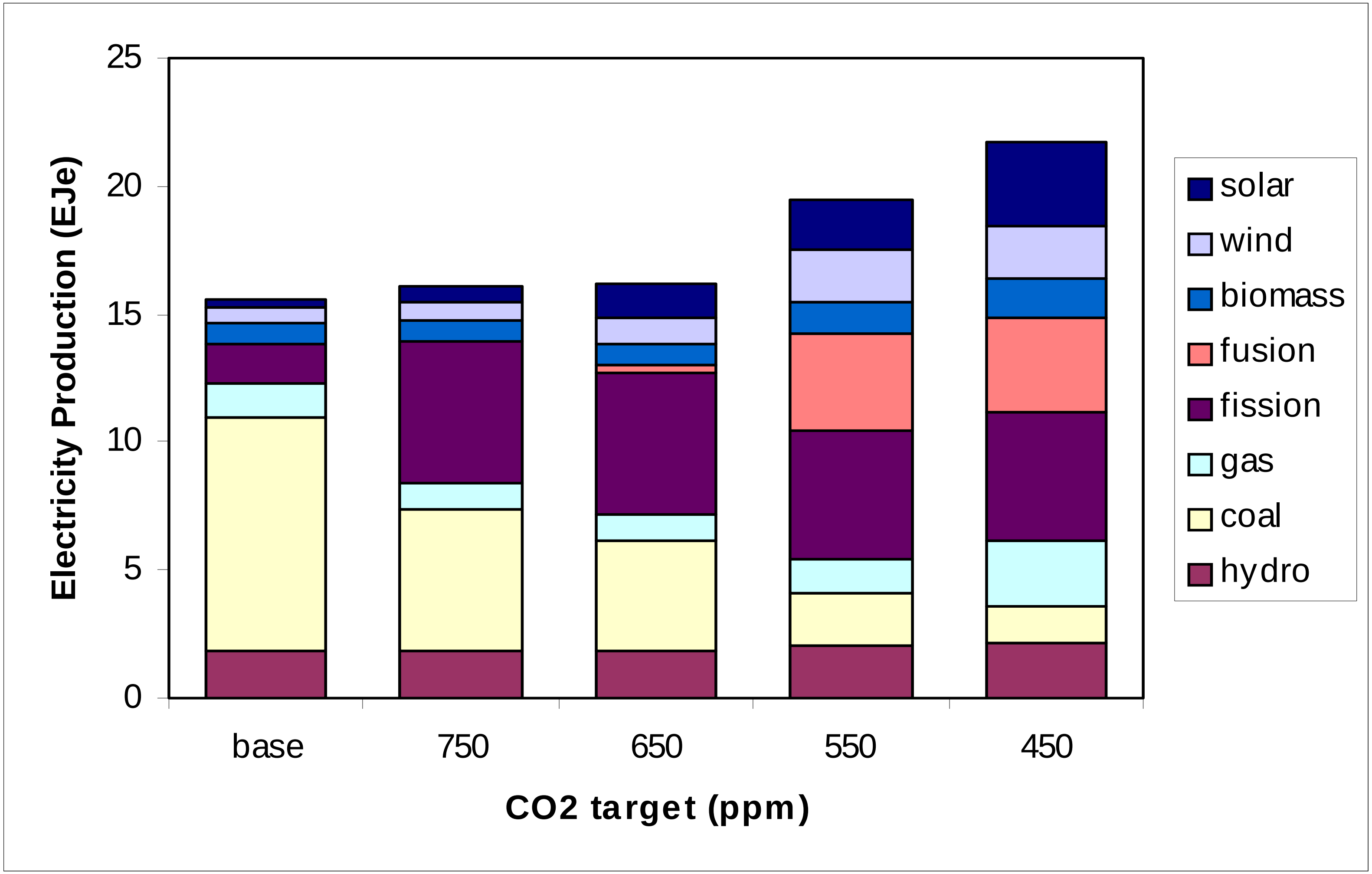
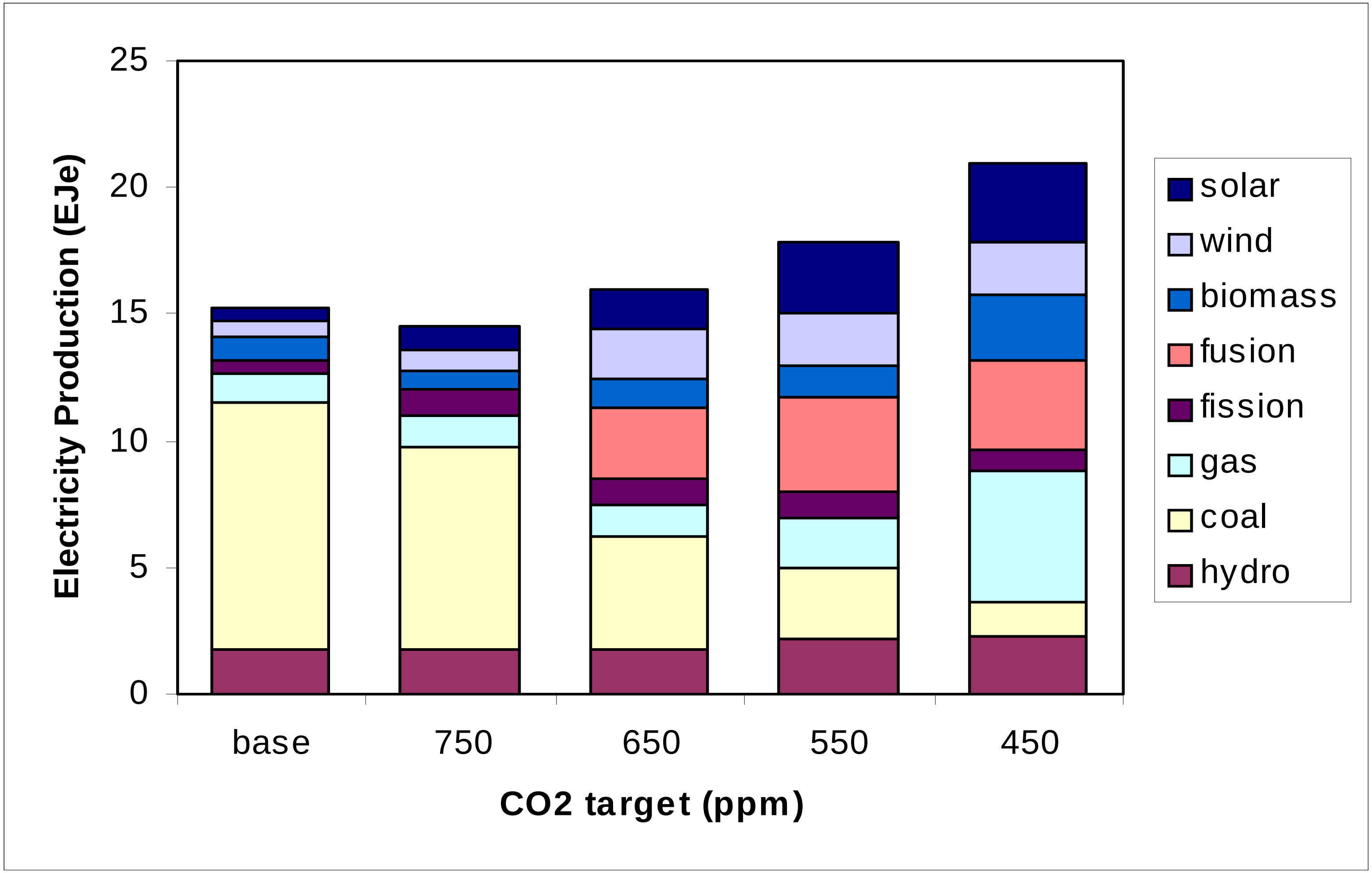
CO2-constrained European energy/environment/economic scenarios (2100)

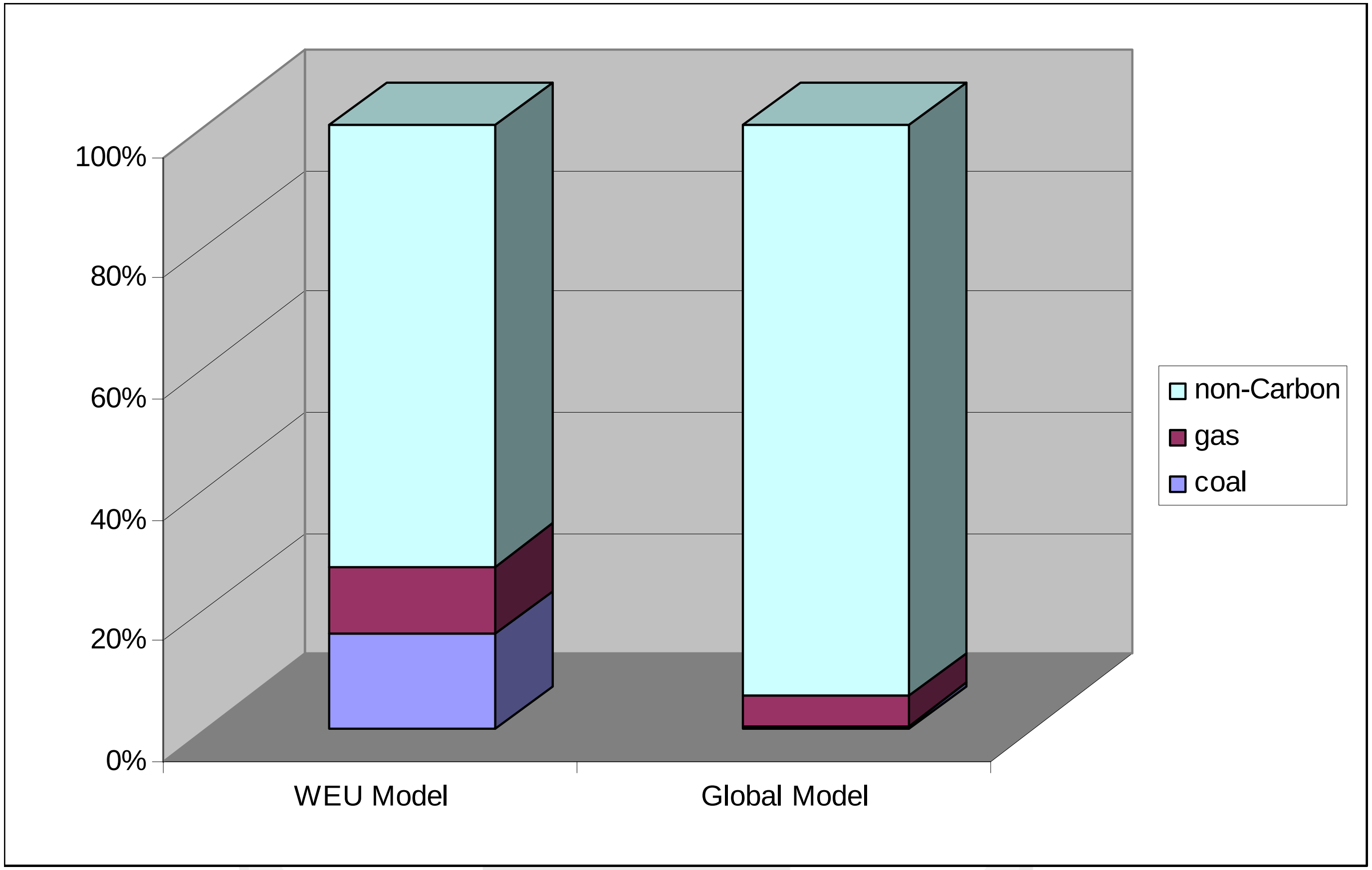


With an artificial constraint on fission



Fusion could capture no more of the market, because <u>on the assumptions made at that time (1997)</u>, it could not be deployed fast enough.

More recent (preliminary) modelling



The fraction of Western European electricity projected to be supplied in 2100 by non-carbon technologies when placed in the global context, compared to the earlier modelling of Western Europe alone. [550 ppm case.]

Implications of Scenario Modelling

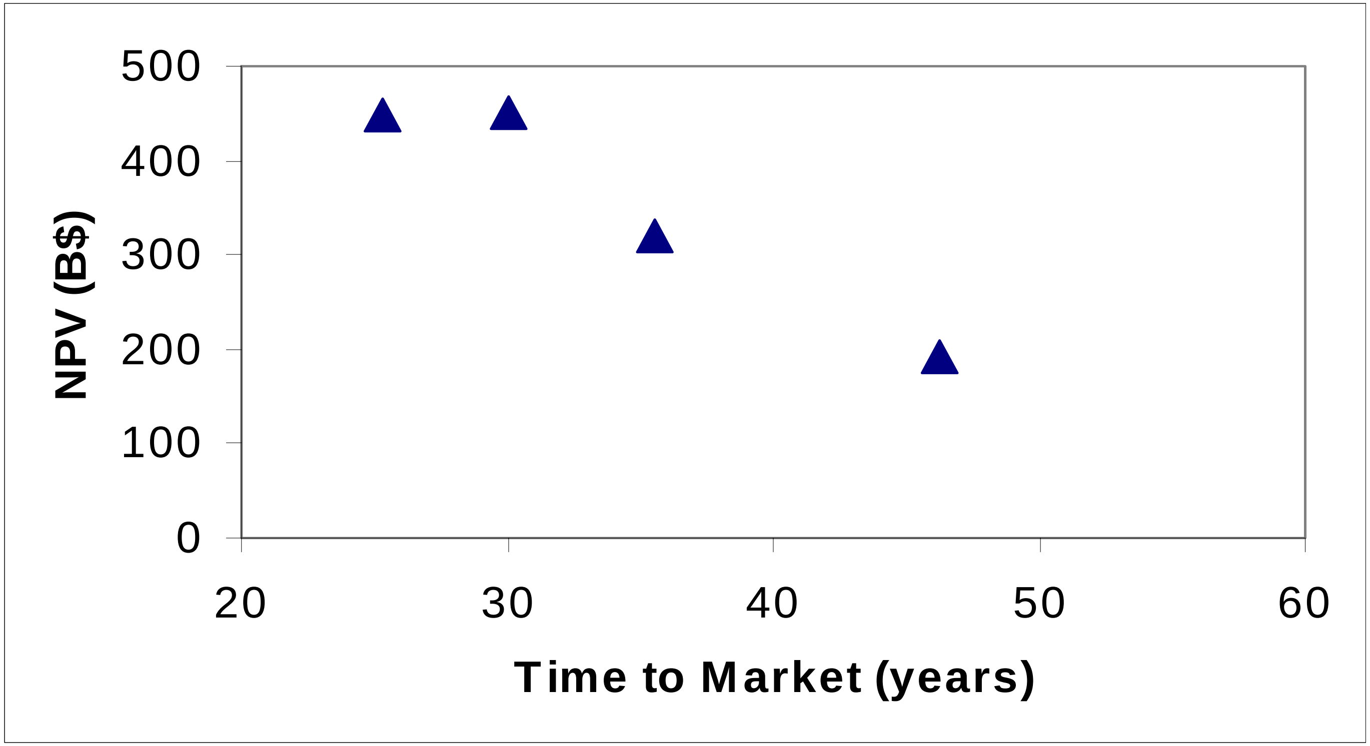
- **Fusion is not forced into the scenarios: it is pulled in by the cost – minimising machinery of the model.**

- **Since each scenario has the lowest (discounted) cost subject to the constraints, satisfying the demand without fusion is more expensive.**

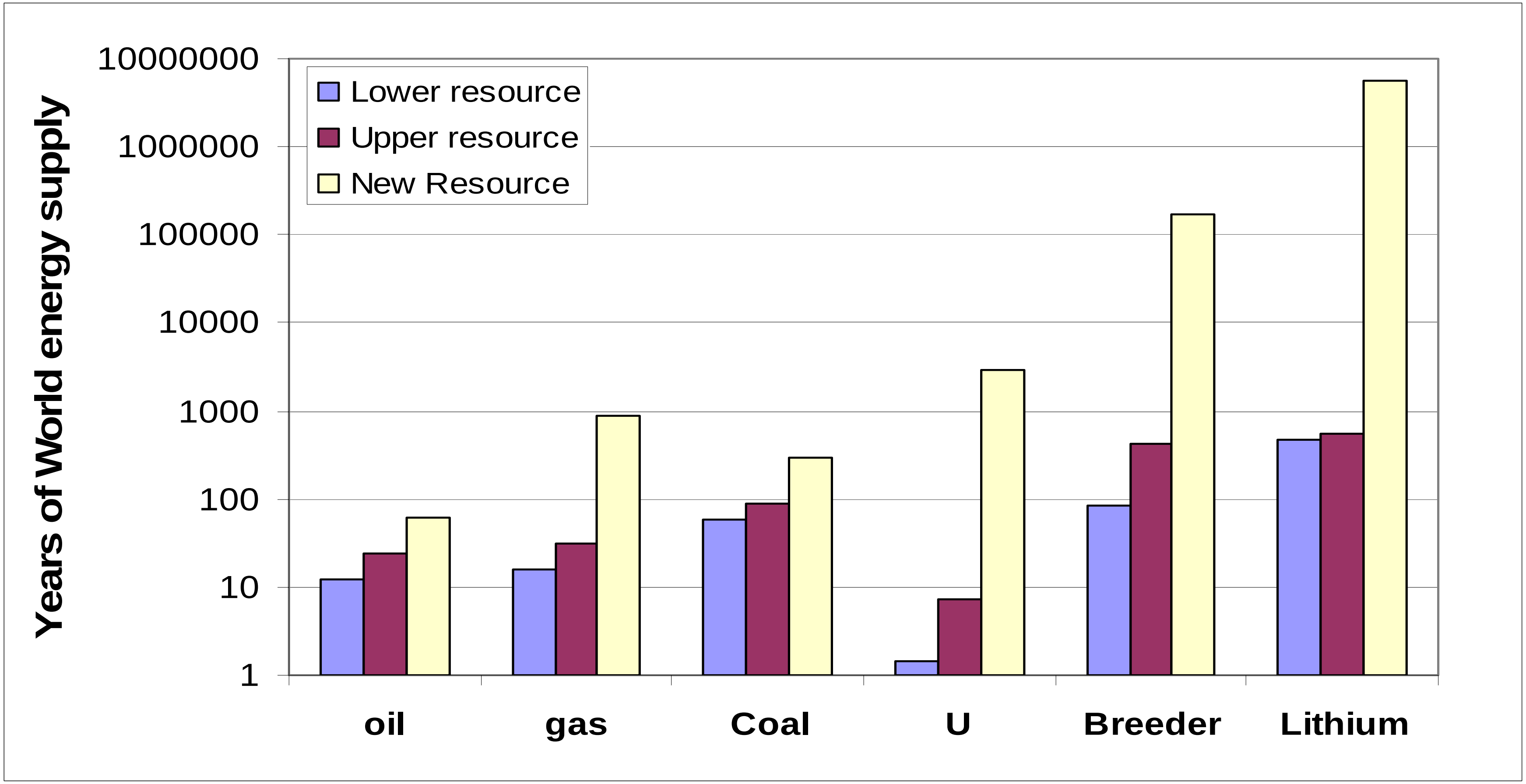
- **The sums involved are huge, dwarfing the costs of fusion development, so it is much cheaper to develop and deploy fusion than not to develop it.**

Economic value of developing fusion

- Map out different fusion development and implementation programmes with cost estimates, and estimates of failure probabilities at each stage. Find Net Present Value by discounting all costs and benefits to present day.
- Economic value is substantially positive in all but the most pessimistic scenarios.
- Economic value is highest for early deployment.



Energy Security (1): Ultimate Fuel Resources for Different Energy Systems



[Solar provides a large resource also.]

Source: WEC, BP, USGS, WNA

Energy security (2)

- **Fusion contributes positively to both energy security and climate change mitigation.**

- **For other forms of energy, there can be conflicts between these two aims: national/regional energy security imperatives may inhibit the most cost-effective, ‘globalised’, deployment of climate-change-mitigating energy technologies.**
- **E.g. (a) Europe massively supplied by efficient Algerian solar power? (b) Countries (e.g. Australia. Poland) with large coal supplies will not wish to phase out their use of these. Etc.**

Strategic conclusions

- **It has become reasonable to plan on the assumption that the world will be eager for <u>early</u> clean, secure, energy supplies with <u>internal costs in a reasonable</u> range.**

- **Higher levels of fusion development funding – say, doubling - would be economically justified, and could be used to break the 'sequential' assumption.**

- **An earlier first generation of fusion power stations, with reduced targets for economic performance, would be economically justified, and this may be the economically optimal scenario.**

A broader programme

Conventional ways to *marginally* accelerate, and reduce the risks of, fusion development:

- Several IFMIFs
- Several DEMOs
- Component Test Facilities
- ITER-satellite devices, etc.

This would be closer to the way that fission was developed.

A non-sequential programme

An early <u>DEMO could begin construction in ten years, with relaxed requirements</u> such as:

- Plasma performance similar to ITER, and moderate power density.
- Long pulse operation, if steady-state is not available early.
- A near-term, less efficient, blanket concept.
- A reduced lifetime-fluence target for the blanket structural steel.

'Learning by doing' – bring Industry's experience into play as soon as possible.

An early first generation of power plants could be based directly on such ideas. Given the likely energy/climate situation at that time, this would be economically acceptable.

There are risks, but only risks of losing some money. The risks and costs are small compared to those of climate change.

This development concept can be pursued <u>*in addition*</u> to the standard model of development.

This would be closer to the way that flight was developed.

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Pulsed fusion power plants

Long pulse (about ten hours) fusion power, with energy storage to produce steady net electric power.

- Near-term plasma physics
- Economic penalty is only about 20% - mainly from measures taken to reduce effects of fatigue
- Device size is automatically larger (for fixed net electric output), so:
  - Easier maintenance
  - Reduced load on divertor
  - Reduced neutron flux

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Summary

A new atmosphere:

- climate change;
- energy security;
- fusion confidence;

Suggests a radical change to fusion development planning

- Reduced target performance
- Earlier DEMOs and power plants

Economic considerations suggest that this may be the optimal way for fusion to contribute to climate-change-mitigation

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Supplementary slides

Supplementary slides

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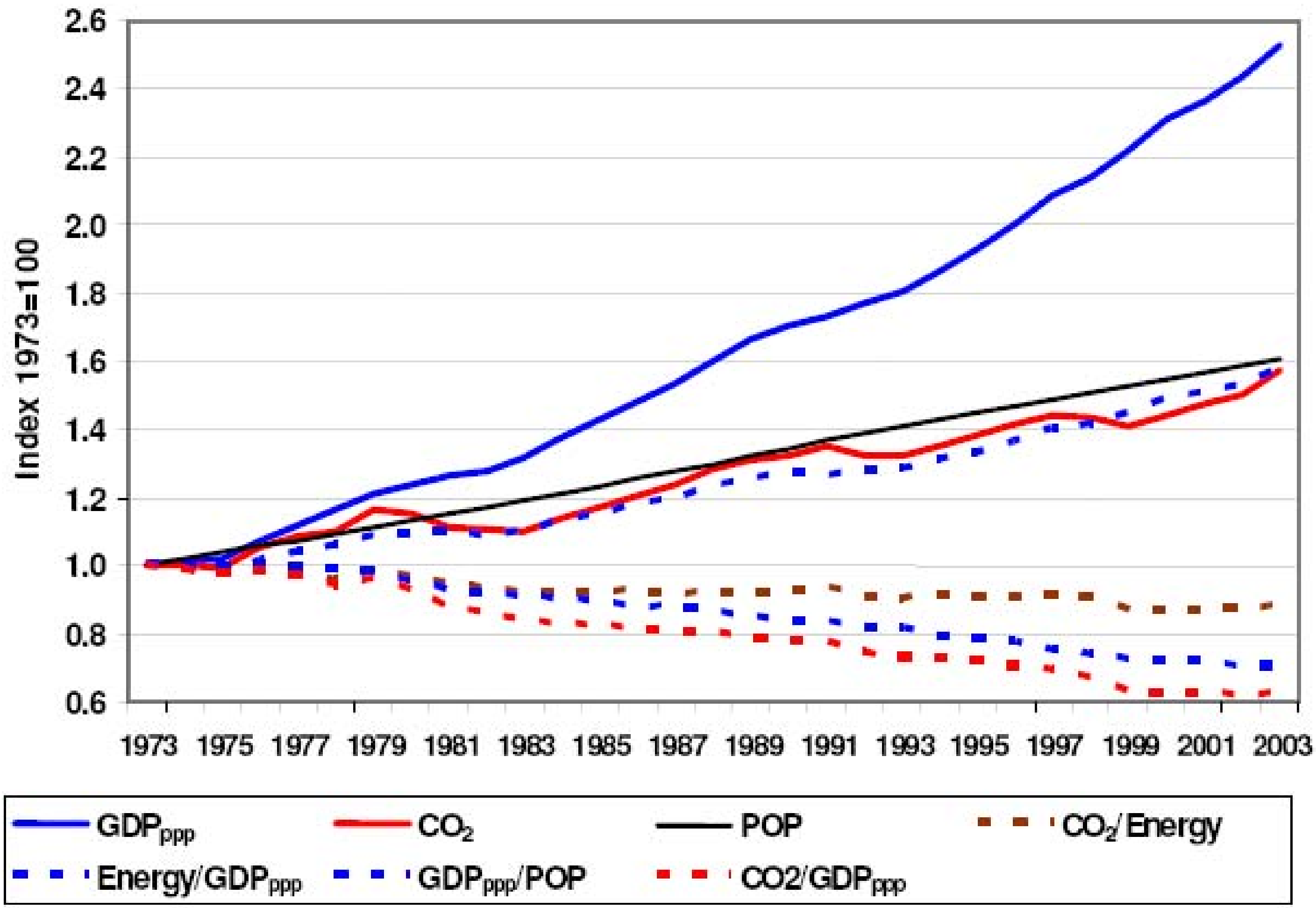
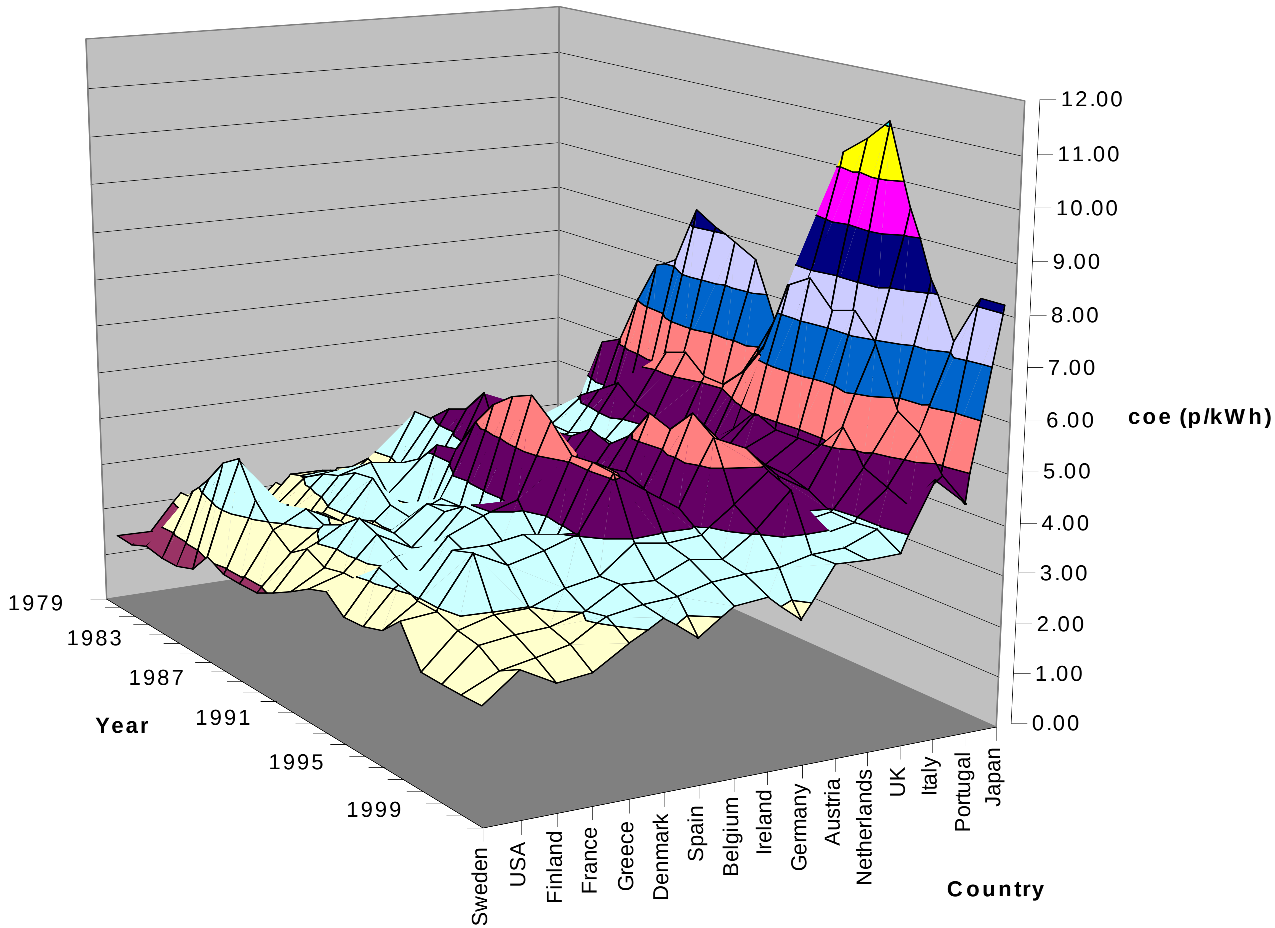
The 'Kowa identity'



What is the cost target for a new energy source?

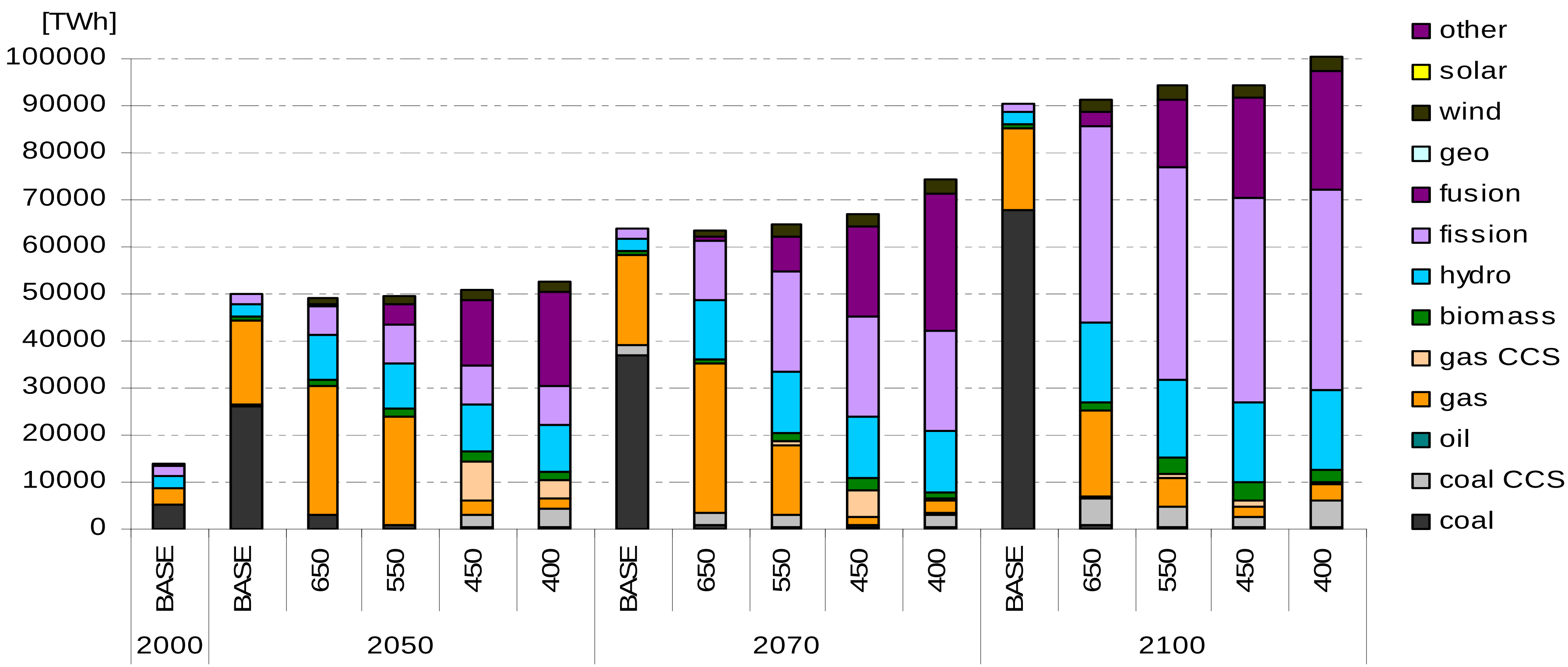
World industrial electricity prices (taxes excluded) in p/kWh

[1p = UK£0.01]



Also: carbon emission trading, etc.!

Scenario modelling under development (world)



Scenario modelling under development (Europe)