Stephen Stretton, *Environmentalists for Nuclear Energy*

The Contribution Of Nuclear Energy to Our Future Energy Mix

About EFN

An international non-profit organisation based in Paris

Supported by James Lovelock CH FRS

www.ecolo.org

"For complete factual information about energy and the environment"

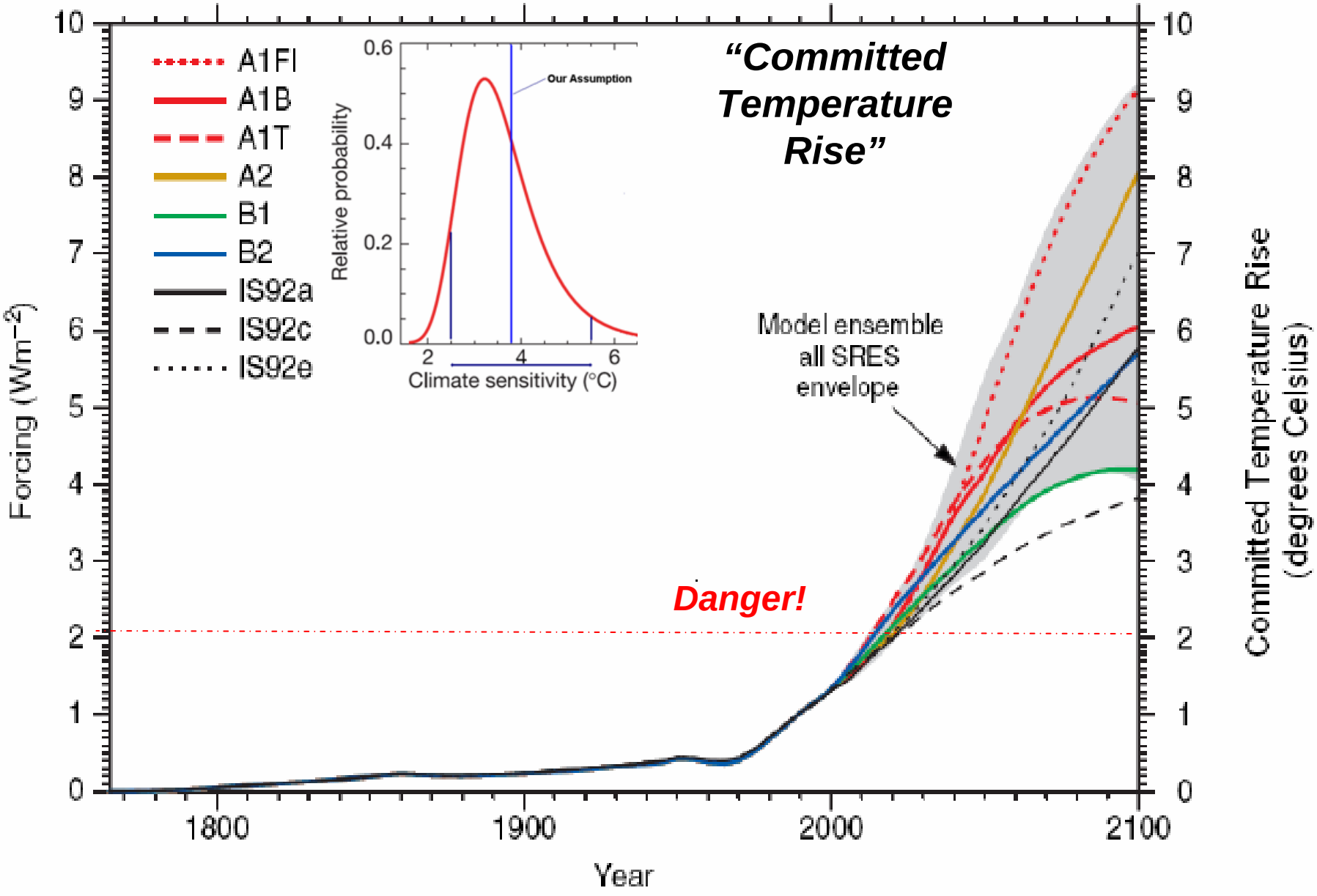
Contents

- The Big Picture
- Nuclear – Key features
- The Nuclear Contribution
- Addressing CSD Criticisms
- Finance and Economics
- Conclusions

The Big Picture: *A Finite Planet*

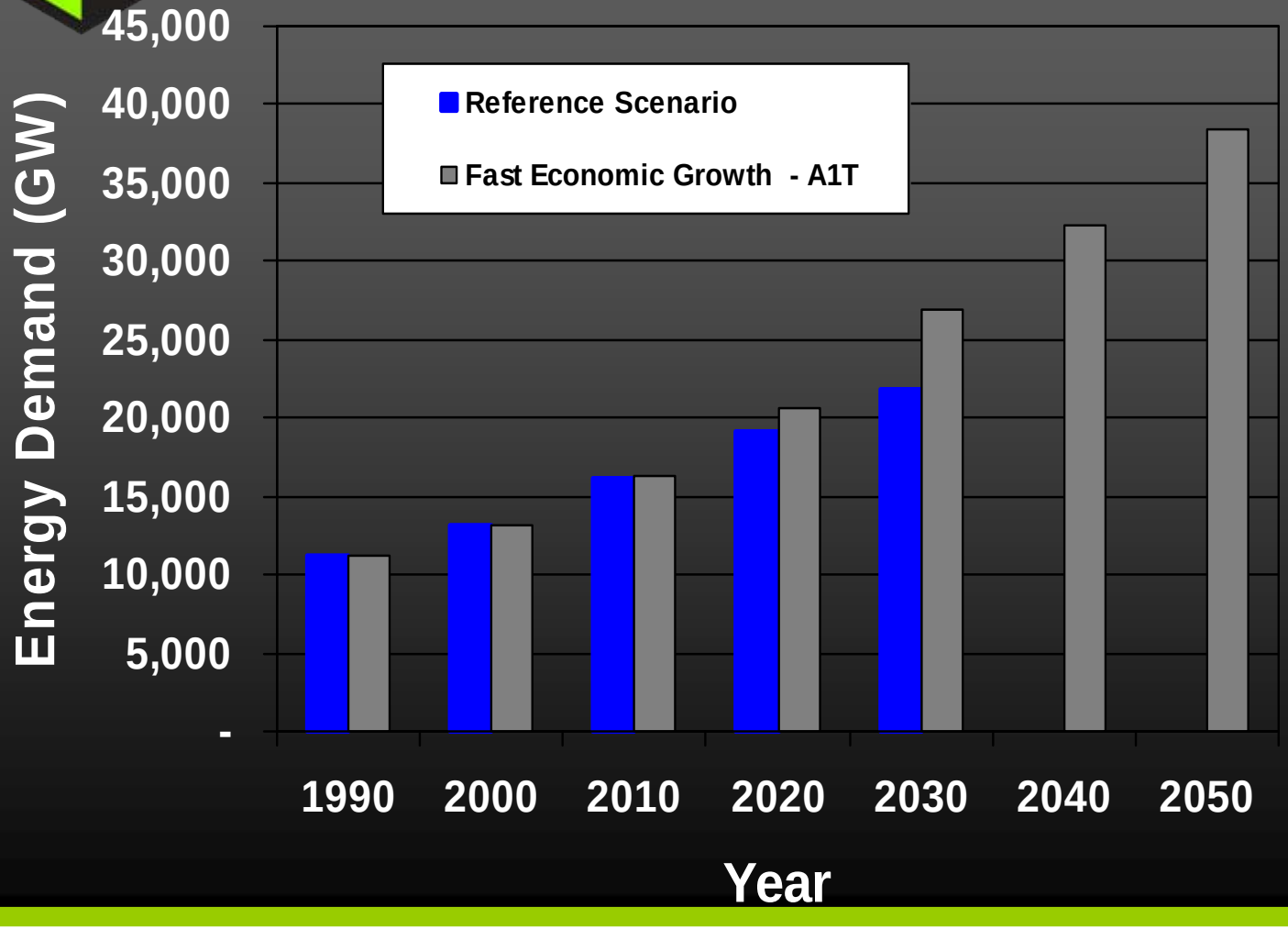
- The Pace of Global Change
- World Energy Demand
- Sustainable Level of Emissions
- Conclusions for Britain

Shallow/deep oceans mix: *7 billion* tonnes CO2/yr
Total GHGs *now* *50 billion* tonnes CO2eq /yr
(About half CO2 from fossil fuel burning)



Assumes that temperature rises by 3.7degrees Celsius with a greenhouse gas concentration equivalent to 550ppm CO2 (doubling of pre-industrial levels)

Primary World Energy demand will double by 2050 and triple by 2100

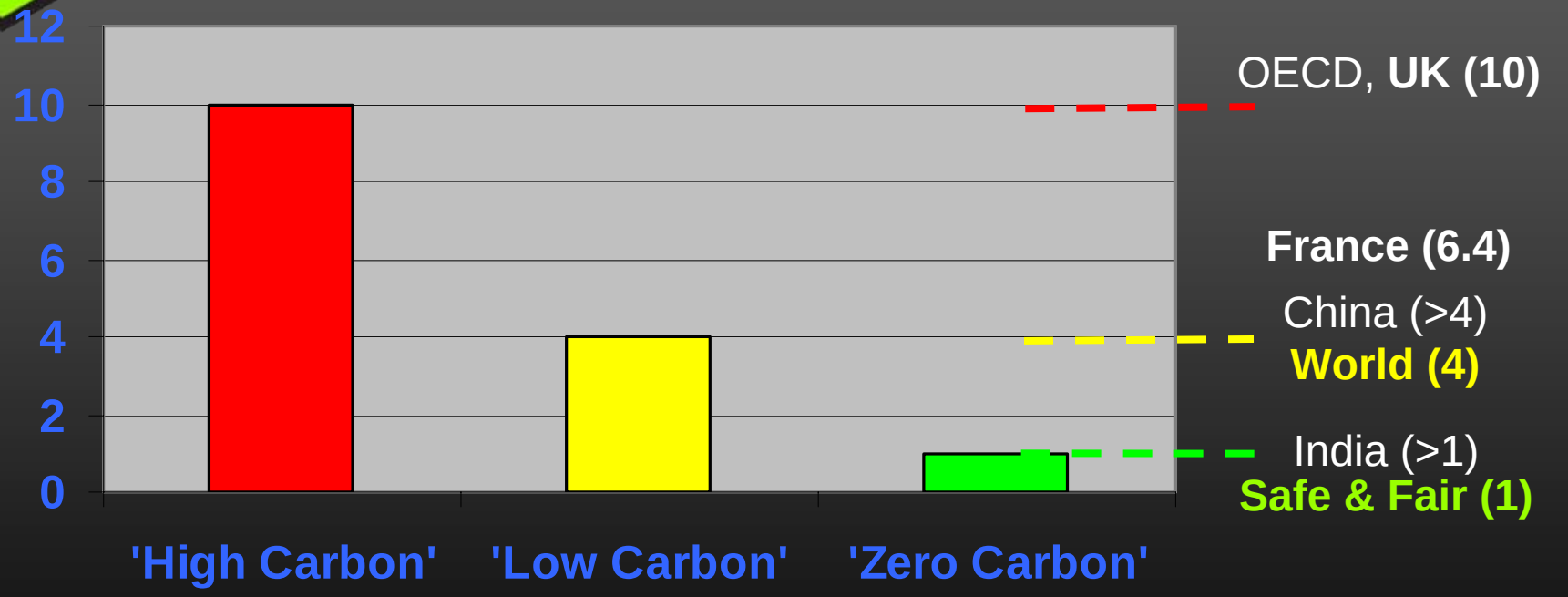


* In agreement with the recommendations from the Royal Academy of Engineers

Sources: Reference Scenario, IEA (2004) World Energy Outlook; A1T Scenario IEA (2003) Energy to 2050

Objective - Zero Carbon

Fossil fuel CO2 only (tonnes CO2 per person per annum)



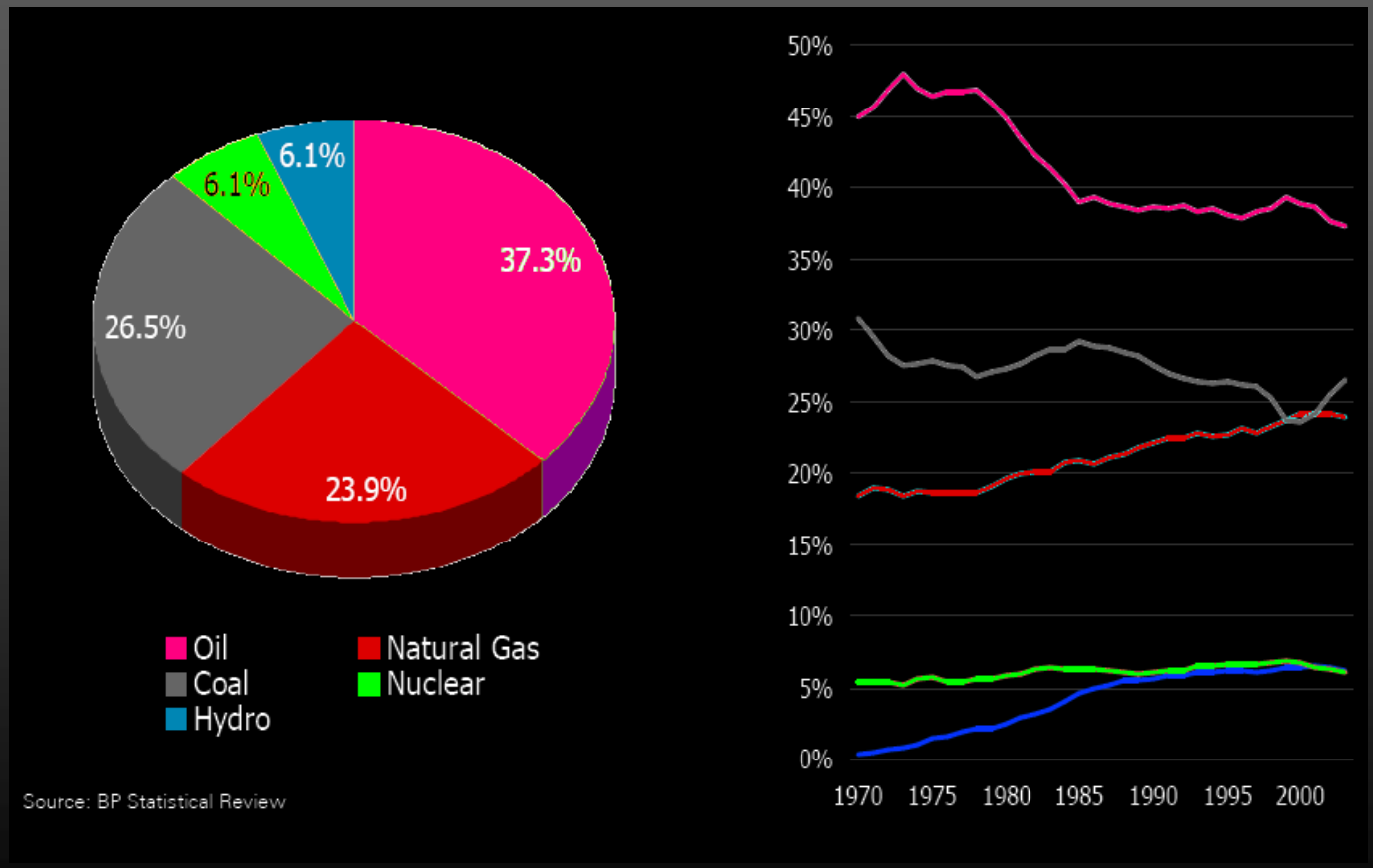
Conclusions

- Human activity is now swamping natural processes.
- Policies & Technologies must:
  - Solve the problem
  - Be attractive at the national scale
- With energy demand expected to double by 2050 energy supply is key.
  - Need scalable technologies which are cheaper than fossil fuels

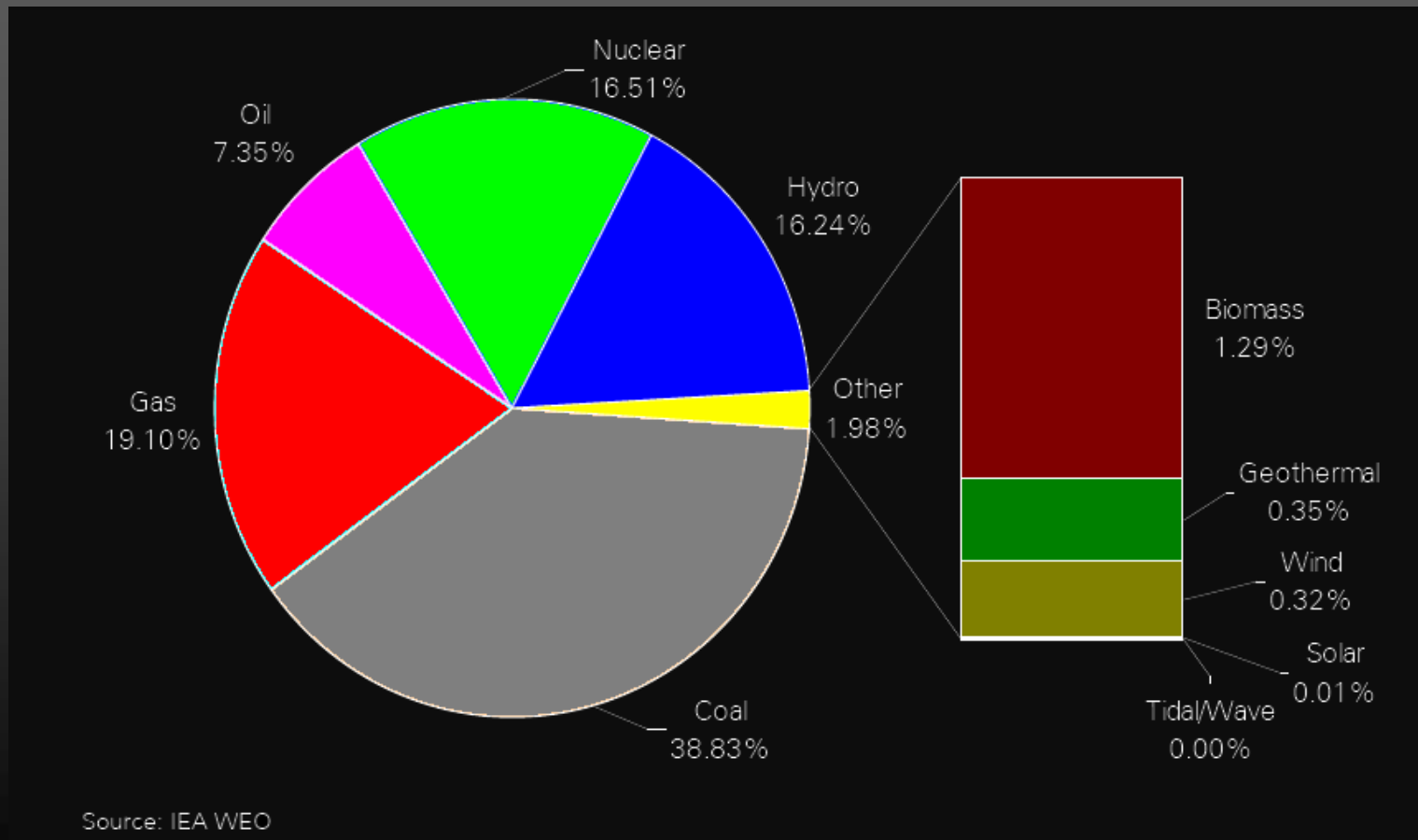
Nuclear – Key Features

- Already used on a large scale
- High Energy Density
- ‘Zero Carbon’
- Always On

Nuclear provides 6% of Primary Energy



Nuclear provides 16% of World Electricity



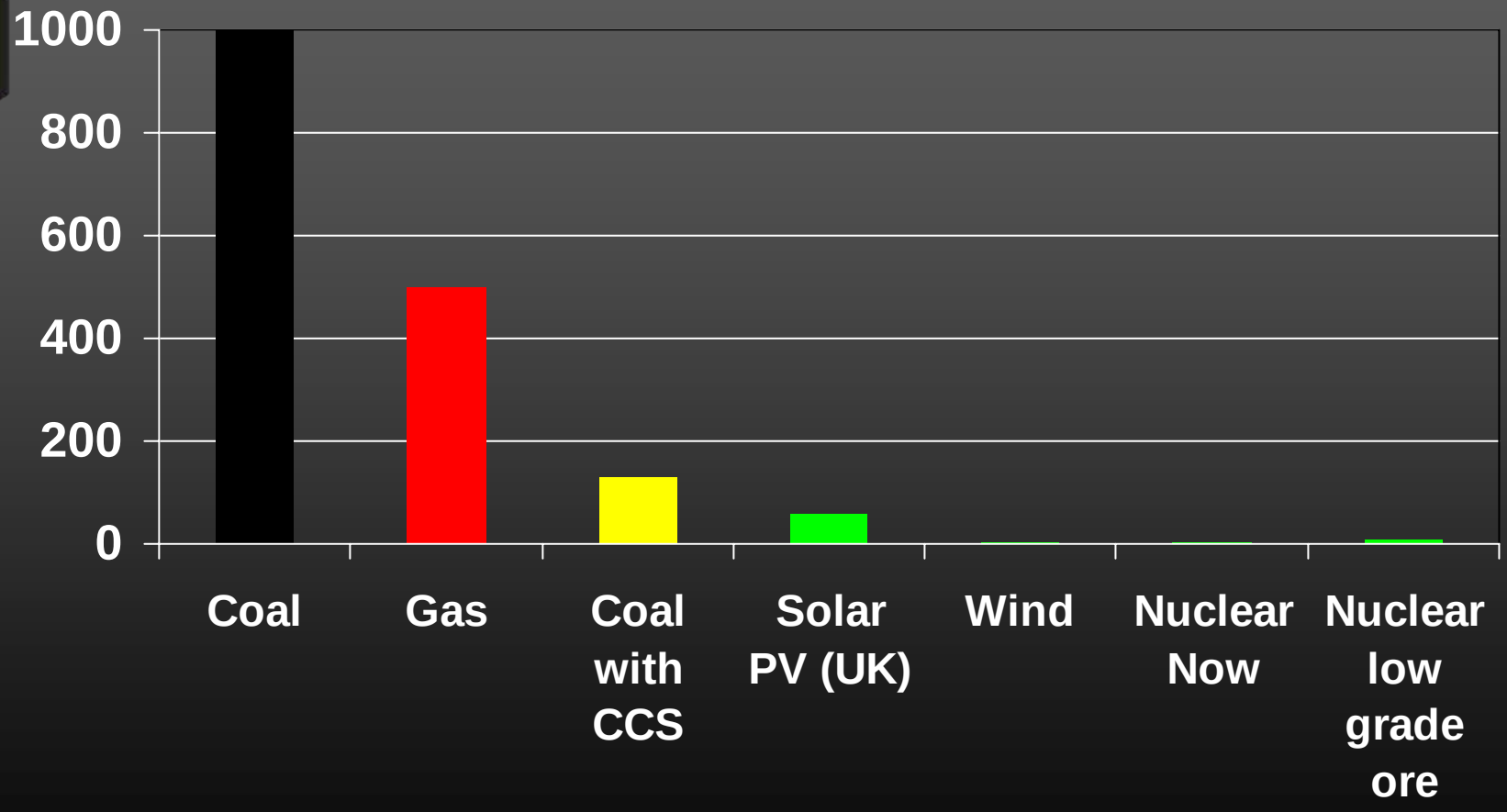
High Density

1GW = 1000 x 1MW

Cost £1bn = 1000 x £1m

‘Zero Carbon’ Electricity

Lifecycle gCO2e per kWh



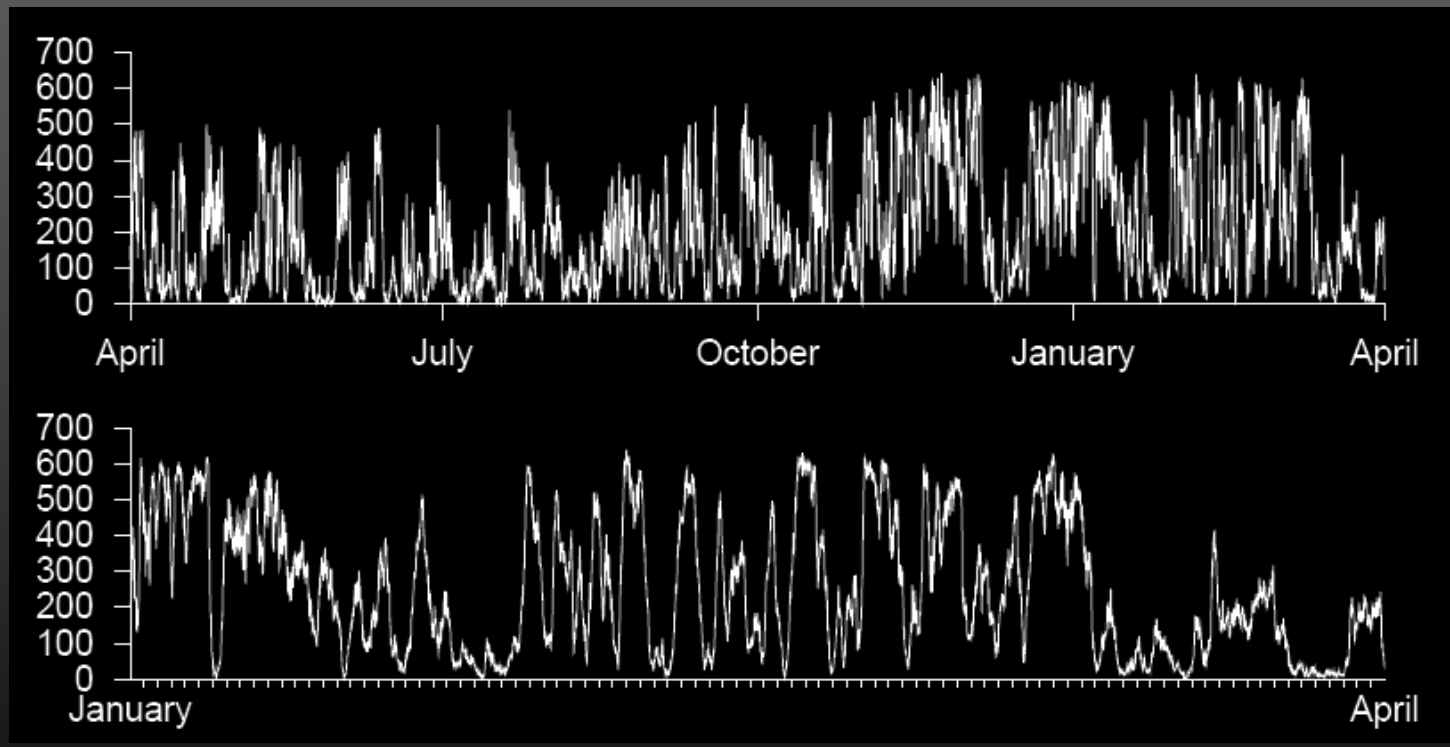
Parliamentary Office of Science and Technology Note 268: http://www.parliament.uk/documents/upload/postpn268.pdf

Nuclear is Always On

- It's doesn't rely on weather, or imports from unstable regions of the world
- However it’s not as flexible as the use of fossil fuels.
- Baseload power

Either the wind blows or it doesn't

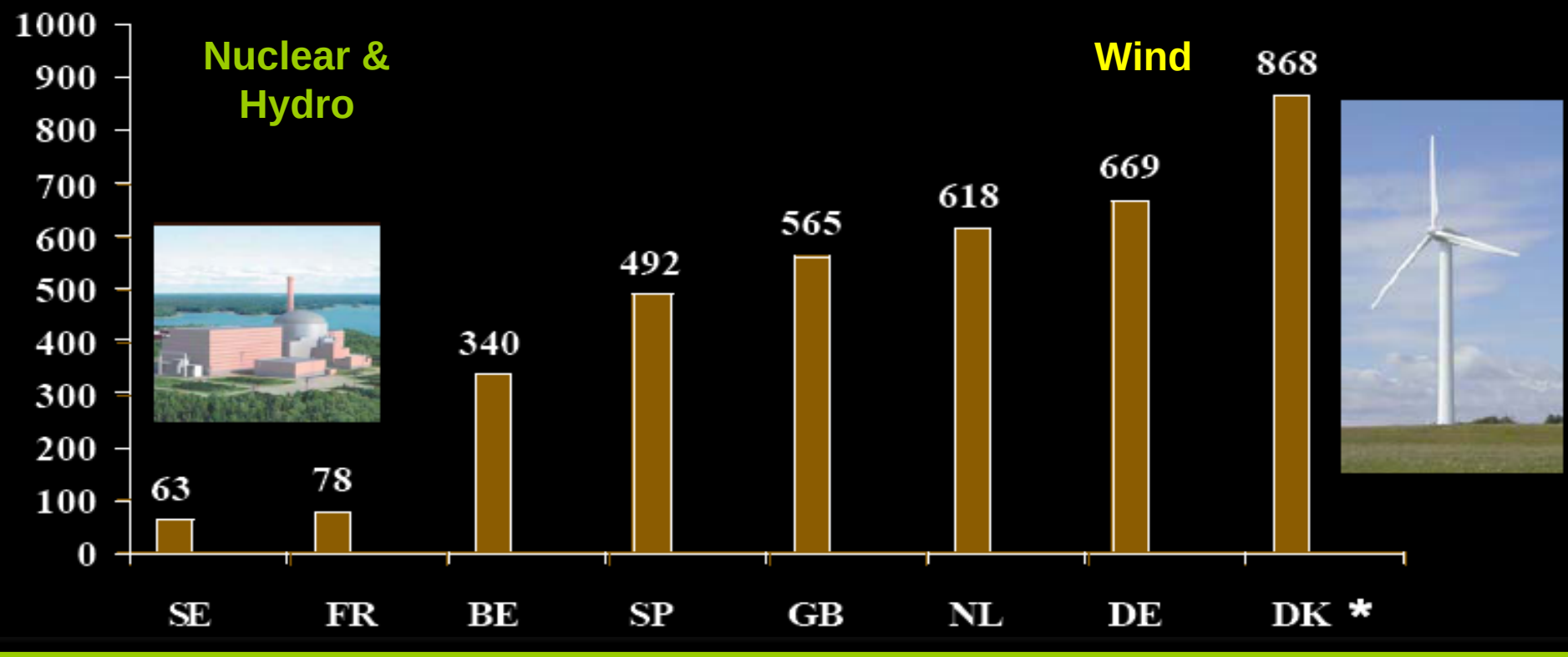
(Wind energy for whole of the Republic of Ireland)



Total output, in MW, of all windfarms of the Republic of Ireland, from April 2006 to April 2007 (top), and from January 2007 to April 2007 (bottom). www.withouthotair.com from www.eirgrid.com

Nuclear Matters

CO2 Emissions from Electricity by Country (gCO2/kWh)



Features of Modern Reactors

(e.g. Westinghouse AP1000
European PWR, Canadian ACR)

- **Modularity & 'Passive' safety (AP1000, ACR)**
- Quick construction
- Compact
- Constructors take price risk
- Inexpensive decommissioning
- Reduced fuel consumption
- Much less waste
- Price competitive with gas

**Sustained investment can create a global 'backstop' technology.
Cheap, modular, mass produced reactors for China and US.**

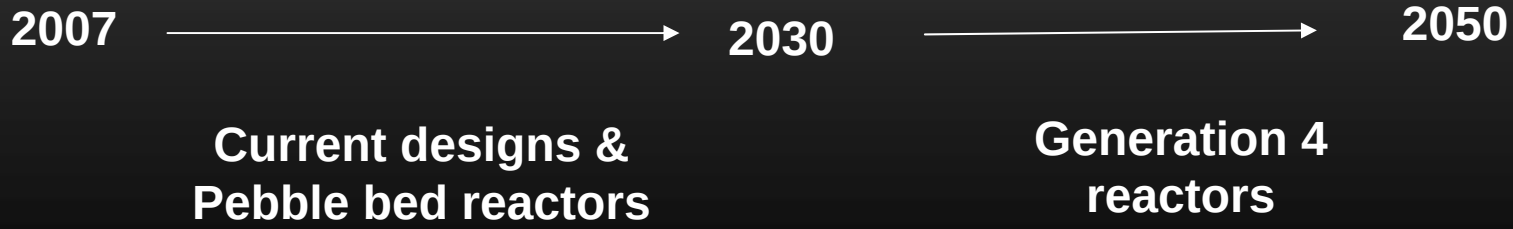
Image: AP1000 © Westinghouse 2005

The Nuclear Contribution in UK

- Uranium
- Available Sites
- Public Acceptability
- Skills

Uranium

- Uranium is as common as Tin in the crust
- 70 years worth at current rates, 3 times more inferred.
- 2 billion tonnes of Uranium in seawater
- Generation 4 fast reactors will get 40 times more energy out!

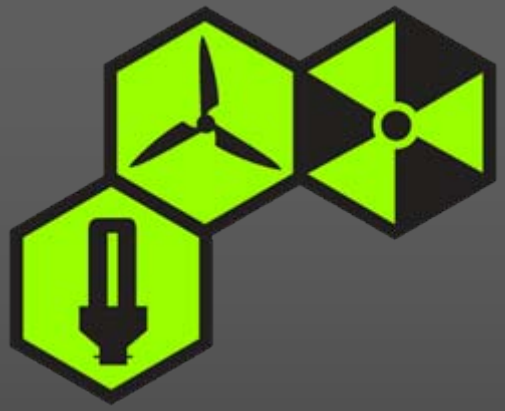


Skills

- Main constraint for the UK.
- Need to train many more engineers over next decade (more concentration on maths & science)
- Compete in global market for skills

Public Acceptability

- Nuclear is low risk but is not perceived as such
- Nuclear needs to become a ‘normal’ technology
- Social sustainability requires wide public debate and reliable and neutral information



Available Sites

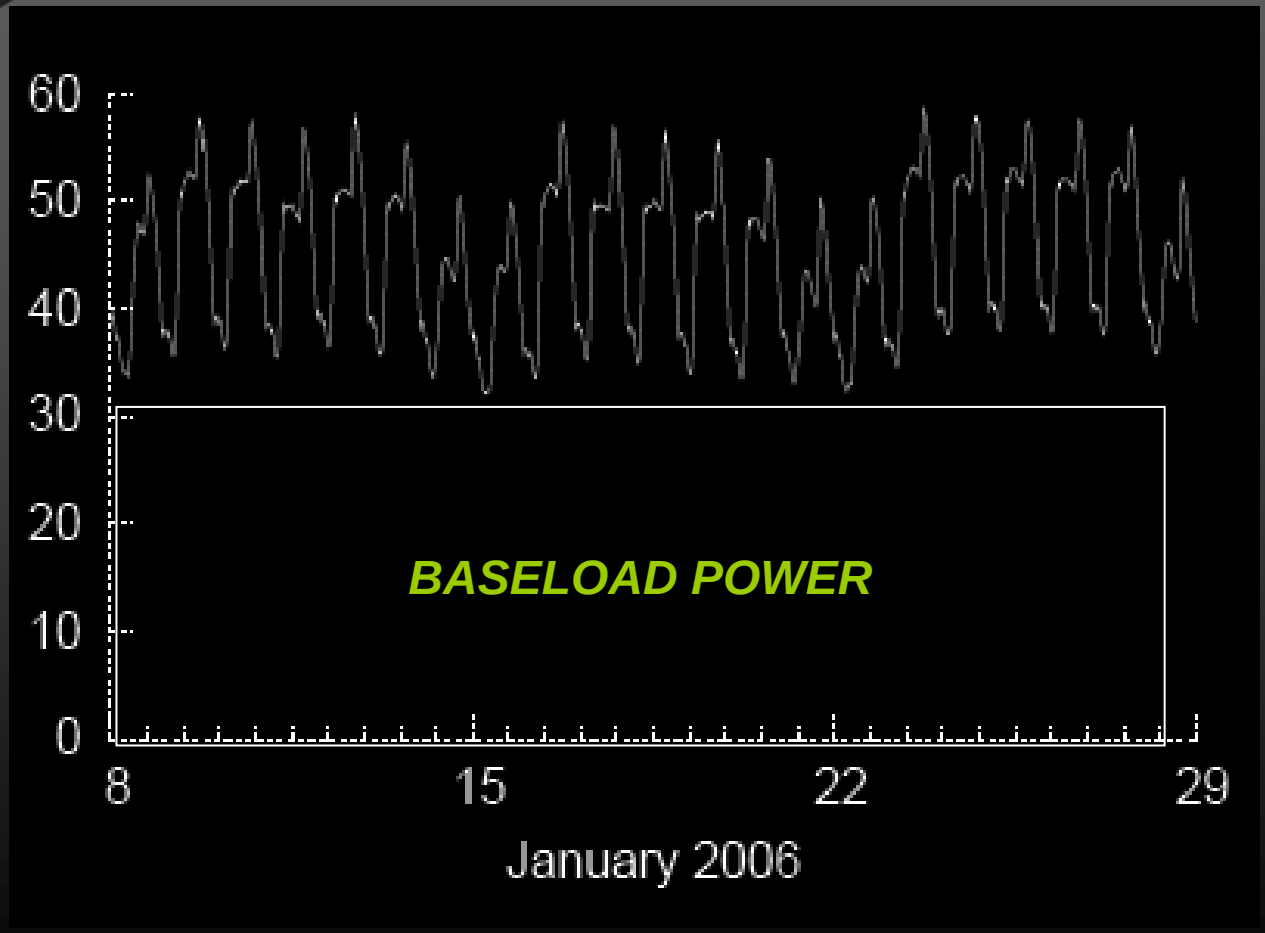
- Some nuclear reactors (first few) can be based at existing sites.
- Up to 5 units per site?
- New sites needed for larger expansion (coastal erosion/sea level issues)
- Must involve full public consultation

How Much?

Demand in Winter (GigaWatts)

10GW plans;

Initial 30GW program?



Commission for Sustainable Development Criticisms

1. it centralizes energy supply
2. the problem of long term waste has not been solved
3. it might be impossible to deny nuclear technology to less stable countries if the UK nuclear industry is expanding
4. it undermines measures to reduce energy efficiency,
5. there are risks in construction cost which would be borne by the taxpayer

All Non-Carbon Energy is Electricity

Renewables clean but intermittant, depending on when the sun shines or the wind blows!

Nuclear clean and is always on

Carbon Capture and Storage is flexible, but there's still 15 % that is released!

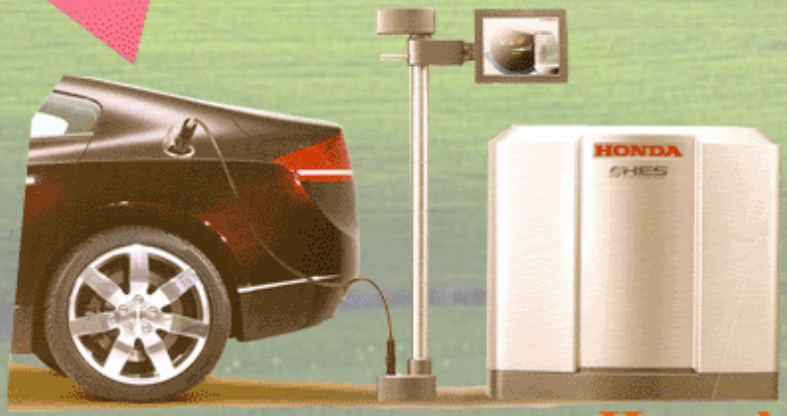
To solve the Carbon Problem, we will need to decarbonise not just the electricity sector, but also Transport and Home Heating

Decarbonise car sector

Need Storage!

3 Limitations on renewables:

1) Physical-Land area and available sites,
2) Planning and Aesthetic
3) Central grid cannot cope



Household storage buffer

Stage 1:

Regional nuclear power stations provide reliable baseload power. There is excess supply at night. This encourages the use of electric cars because the fuel then is essentially free.

It does not require a redesign of the grid and can be achieved cheaply using the current infrastructure.

Low carbon power is required for environmental reasons and reliable power is required because people want to use their car even when there is no wind.

Cars can use the latest generation batteries, hydrogen and/or fuel cells

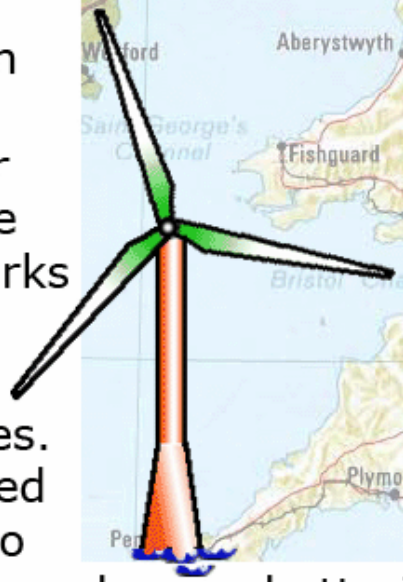
Stage 2:

Once the electric car economy is set up, this has the advantage of INCREASING the renewable consumption with:

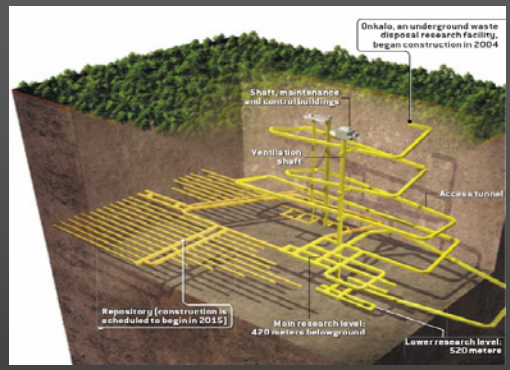
A) Decentralised power without redesigning the grid since a battery works as a storage buffer.

B) Offshore wind can recharge spare batteries.

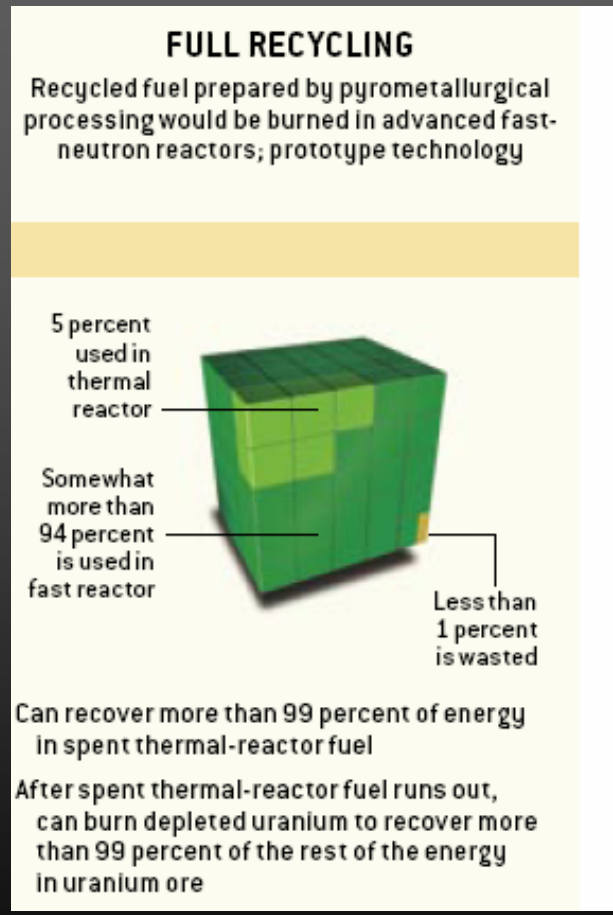
C) Technology developed here can be exported to 3rd world, African solar recharges batteries using HVDC or produces hydrogen



Waste / Spent Fuel



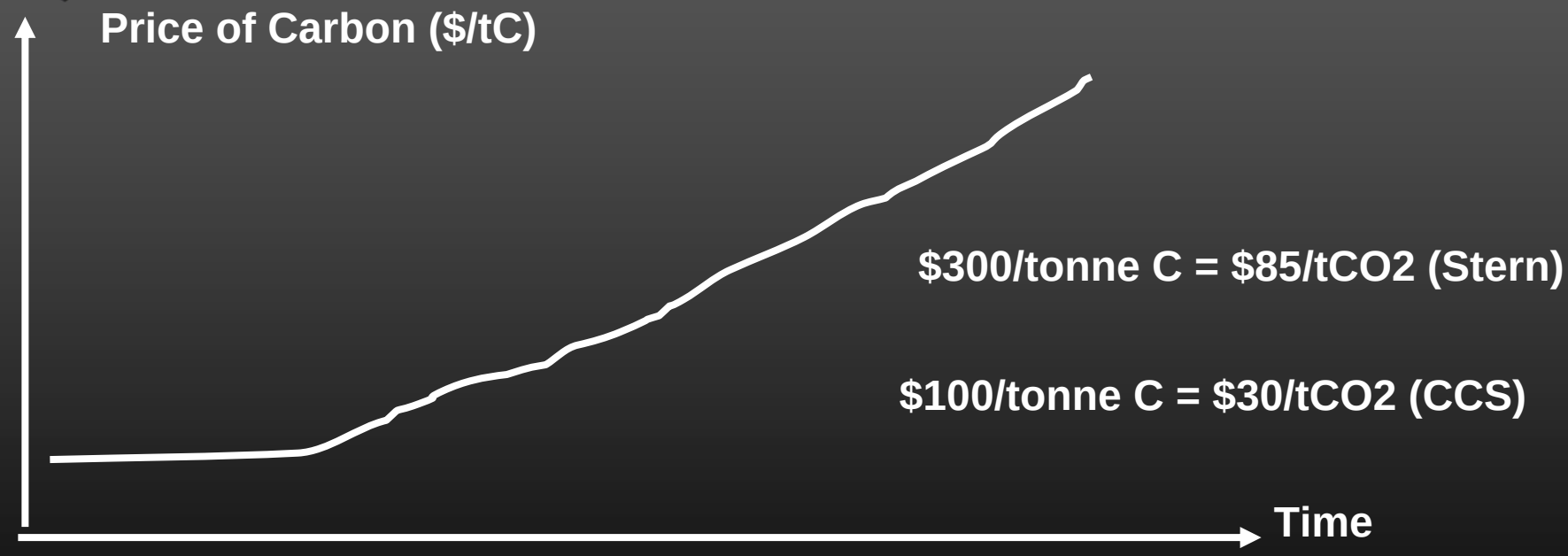
- 1/3 -2/3 of UK is suitable for storing waste (clay or granite or salt domes)
- Political/social issues, dealt with by separate agency (Corum)
- In the future, spent fuel may be 99% recycled - very high energy content



Proliferation?

- Different countries have different power needs.
- What are the real proliferation drivers?
- Britain has a nuclear infrastructure already
- Arguably it makes little difference to global proliferation if we have a larger rather than smaller nuclear industry?
- Nuclear weapons are different matter. (many countries have one without the other).

How to encourage energy efficiency
A steadily increasing price of carbon



Use Carbon as a source of governement revenue – aiding both energy efficiency and non-carbon energy

Different Types of Risk

Electricity Price Risk – needs addressing

Operational Risk, decommissioning, spent fuel – not the government's responsibility

Costs must be carried by investor; decommissioning liabilities must be bankruptcy-remote

Response to CSD Criticisms

1. it centralizes energy supply
   - Britain is a densely populated country. Transmission losses are small. Decentralised energy is not significant, and in any case Electric cars will promote it.
2. it undermines measures to reduce energy efficiency,
   - Not if in conjunction with systemic economic measures such as a carbon tax
3. it might be impossible to deny nuclear technology to less stable countries if the UK nuclear industry is expanding
   - Questionable
4. the problem of long term waste has not been solved
   - This is now an entirely independent process, Corum.
5. there are risks in construction cost which would be borne by the taxpayer
   - Should not happen. Some constructors have offered fixed-price contracts.

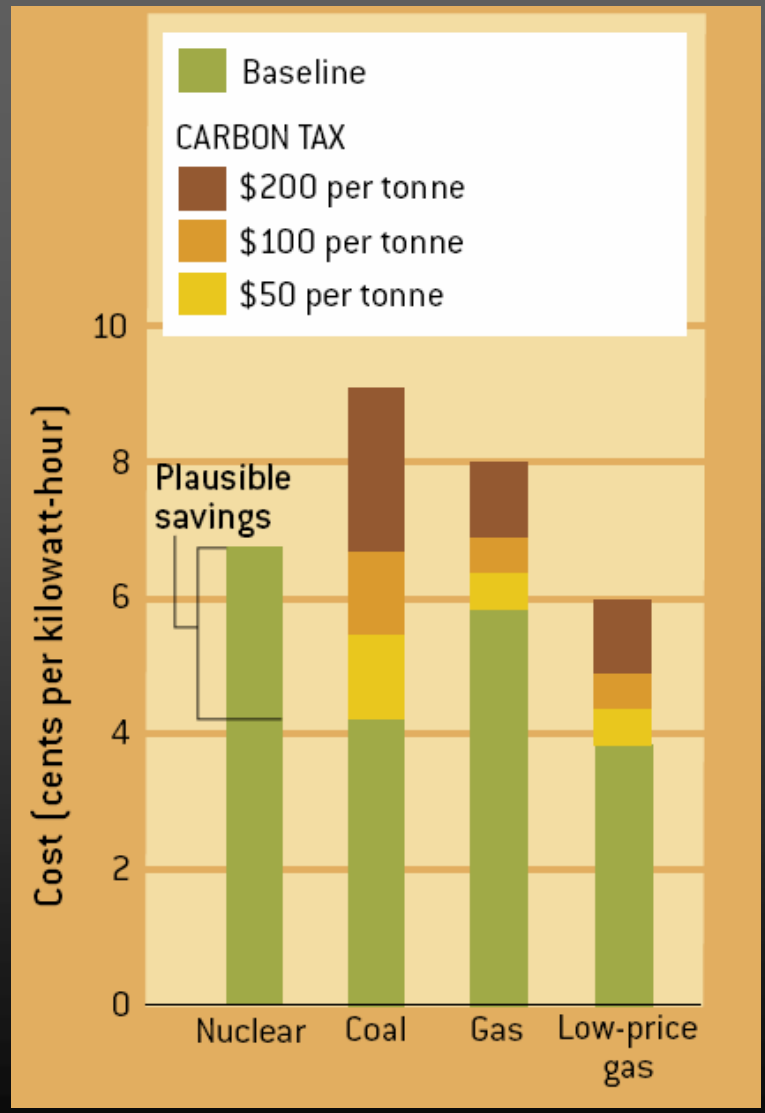
Economics, Finance and Government Policy

- Cost per kWh
- French Experience
- Capital Cost
- Electricity Prices
- Finance

Cost / kWh
MIT Study

Main drivers:

- *Economies of Scale*
- *Financing Costs*



The French Experience

- Major building program 1970s – 1990s.
- Now 80% of electricity is generated by nuclear.
- Realised economies of scale by using one design.
- Often with duplicate units on same site.
- **France now has the lowest electricity prices in Europe.**
- **Electricity is a major export good.**

Capital Cost

Potentially very low:

AP1000 "Overnight Capital Cost: $1bn-$1.1bn per GWe for a twin-unit plant, after the first several AP1000 plants have been constructed"

Round numbers for UK:

- £1bn/GW for large programme
- More for first-of-series

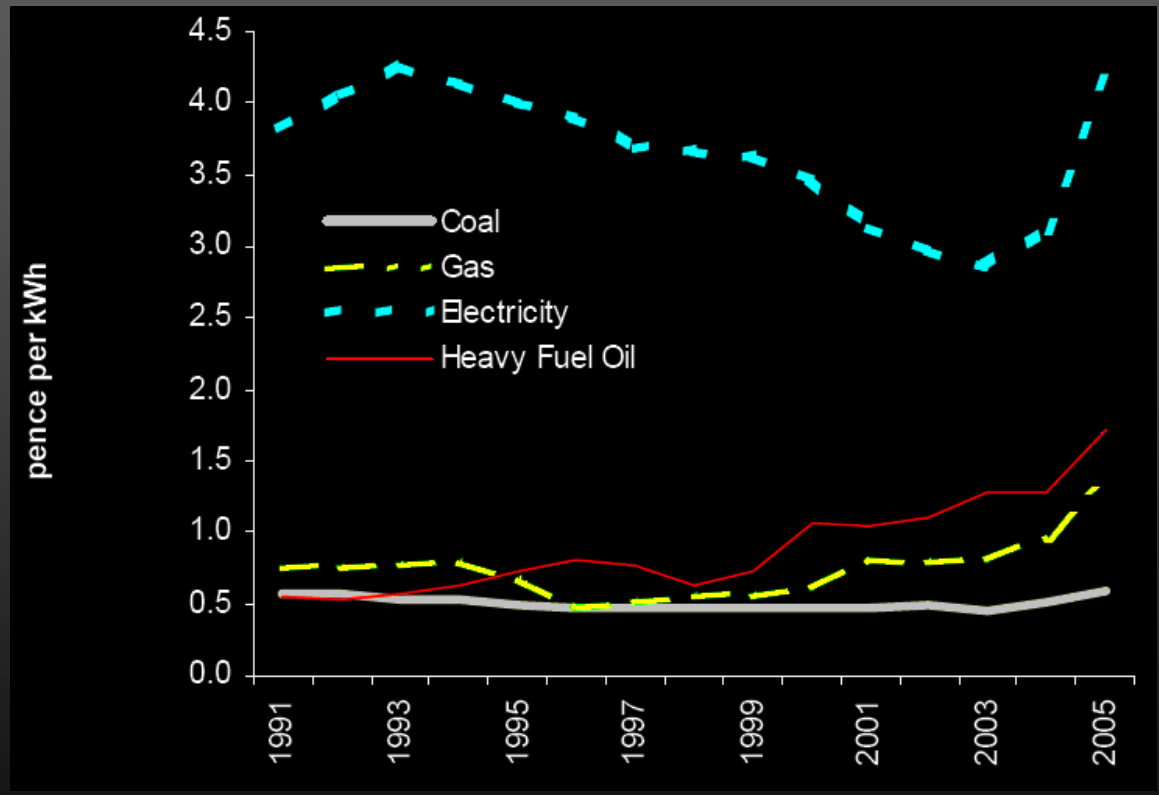
Electricity Price Risk – needs addressing

- Unless there is a carbon tax, the economic decision to invest is marginal.
- Financial risks are too high due to the uncertain nature of the electricity and carbon price.
- Banks will demand high interest rates

Finance: Price of Electricity and Gas are Highly Correlated

- The gas price determines the electricity price, and so they move together

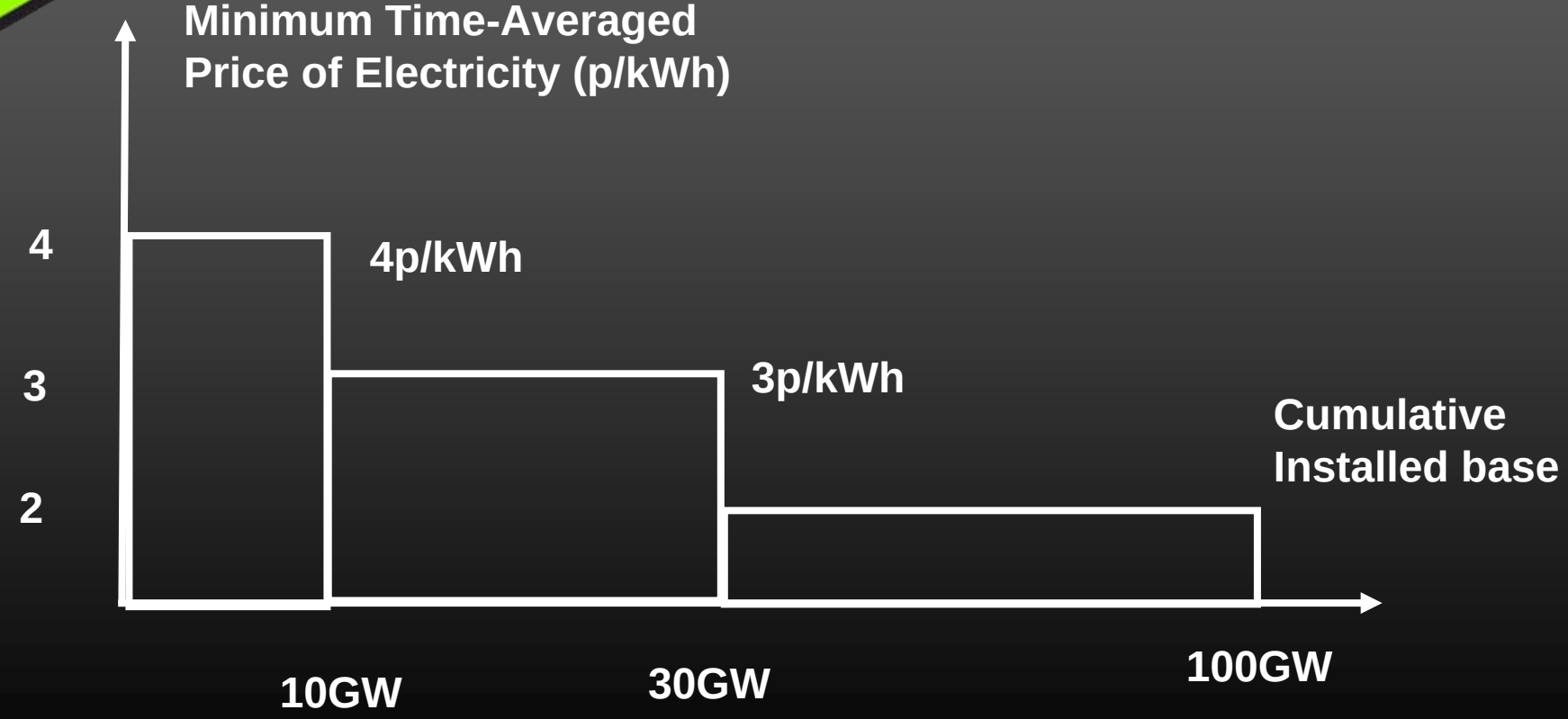
- **Good for gas electricity providers, bad for everyone else.**



Financing new investment

- Liberalised markets do not suit long term capital intensive investment.
- They suit gas producers since their cost and revenues move together.
- Difficult to coordinate rapid, large scale investment without some additional government intervention.
- Use Electricity price risk mitigation?

How to encourage investment
Minimum electricity prices for non-carbon electricity



A Plan to Achieve Zero Carbon

- Overall Capacity requirements
  - Low Cost Renewable Contribution (Low Cost)
  - (Carbon Capture and Storage used too)
- Cost
- Benefits
- Overall Summary

Renewable Capacity (excl. tidal) can generate only 11% of total UK energy

Energy Source	Max Capacity (GW)*
Hydro	0.6
Waste (Residues; Municipal; Landfill gas)	3.8
Wind (Onshore)	6.5
Wind (Offshore)***	11.4
Solar (Photovoltaic Cells)	0.1
Wave / Tidal	3.8 / 0.4
Total UK Renewable Capacity**	**25**
UK Final Energy Demand	**230**
Maximum Renewable Contribution	***11%***

*Interdepartmental Analysts Group estimation of maximum capacity available at less than 7p/kWh (current price 2-3p/kWh).
Apart from hydro figures from RCEP study (all large opportunities already used; small scale hydro adds <0.1GW).
**Energy Crops Excluded for Environmental Reasons (Land Area, Indirect emissions).
***Offshore wind *included* but note that large rotating objects interfere with UK coastal radar.

The 'Zero Carbon' Society - *How to Achieve a 90% reduction in emissions*

	Energy (GW)	Emissions Intensity* (t CO2/ GW)	Total Emissions (Mt CO2 / year)
Baseline	230		590
Future: *Reductions in Use*	*70*		
Nuclear**	100	0.15	14
Renewables***	25	0.15	4
Coal-Gas with (partial) Sequestration#	20	0.50	10
Oil for essential uses ##	15	2.00	30
Total	160	0.95	58

Reduction in CO_2 Emissions: 90%

Total Cost of 100GW Nuclear

- Approximate Cost ~ £4bn per year over 25 years.
- Small compared to NHS spending £70bn+ per year
- Financed in private sector if efficient price risk mitigation used

Benefits of this Plan

a) Hydrocarbon independence
b) Low Cost Energy
c) Massive reduction in CO_2 emissions.
   - Setting an example
   - Developing better ways of living

Zero Carbon Economy

Trains

Nuclear Power

Electric Cars

Heat Pumps

Summary

- Need to Act Rapidly
- Coordinate international program to roll out standardised, modular reactors.
- Minimum electricity prices to target investment
- Steadily increasing Carbon tax or cost of permits
- Try Carbon Capture too!
- Rest of the economy will adjust!

References

IPCC (2001 & 2007)

MIT (2003) *The Future of Nuclear Power, An Interdisciplinary MIT study,* MIT Press, Cambridge, MA

Comby, B. (2006), *Environmentalists for Nuclear Energy*

Lovelock, J (2006) *The Revenge of Gaia*, Penguin, London

Nuttall, W. J. (2005), *Nuclear Renaissance*, IOP Publishing

Royal Commission on Environmental Pollution (2000) *Energy - The Changing Climate*

Sceffer, M; Cox, Pet Al. (2006) *Positive Feedback between global warming and atmospheric CO2*

Contact Me

Stephen Stretton

stephen@ecolo.org

Environmentalists for *Nuclear Energy*

http://www.ecolo.org

UK Policy Site:

http://www.zcarb.org.uk