UNIVERSITY OF CAMBRIDGE

Transformative Change in Energy
How can Nuclear beat Gas?

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Agenda

1. What would be transformative?

2. Gas and Nuclear cost comparisons;
3. How can the cost of current nuclear become competitive?

4. Developing nuclear as the ‘go to’ carbon-free energy source:
   - Advanced systems v LWR developments?

What would Transformation look like?

- **UK electricity shares:**
  - Nuclear 19% Renewables 11%
  - Coal 39% Gas 28%

Dukes Chapter 5.July 2013

- Situation is mirrored globally where
  - Fossil fuels generate 68% of electricity, nuclear 12% - renewables etc. 20%;

2011 figures in: IEA World Energy Outlook 2013

- **Transformation** of energy supplies means:
  - 50% increase in share of electricity, by 2040; 3,500 GW to >5,000GW
  - Replacing almost all fossil fuels by low-carbon energy – **Renewable & Nuclear**

IEA World Energy Outlook 2013

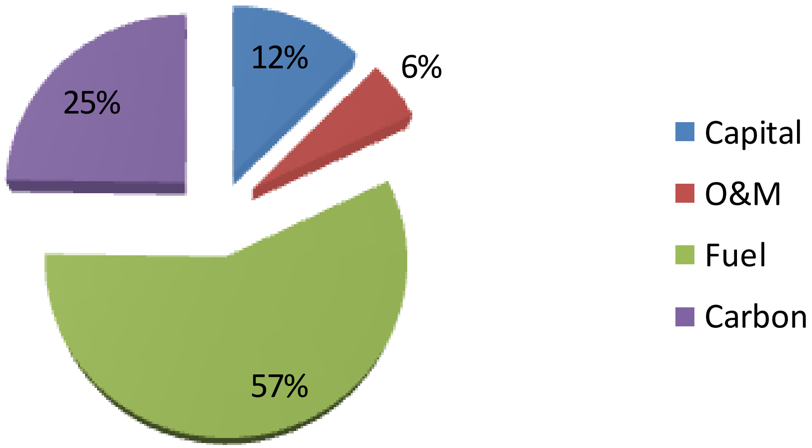
Competing with Gas – Price: £80 or £70/MWh

- CCGT is attractive because of low capital costs and efficiency >50%;
- Cost of generation is dominated by fuel cost, but also carbon price/taxes;
- DECC central assumption is gas cost rise in real terms – from 63 to 74p/therm;
- Generation cost forecast to be £94/MWh in 2020, but could be as low as £70/MWh – low gas, or low carbon prices

Effect of Gas Price & Carbon Floor

Gas		Low	Mid	High
2013				
Gas	p/therm	54.1	63.6	73.2
Electricity	£/MWh	72.7	**80.0**	87.4
ex carbon price	£/MWh	54.7	62.6	69.4
2020				
Gas	p/therm	42.2	73.8	100.5
Electricity	£/MWh	69.5	93.9	114.4
ex carbon price	£/MWh	45.5	69.9	90.4

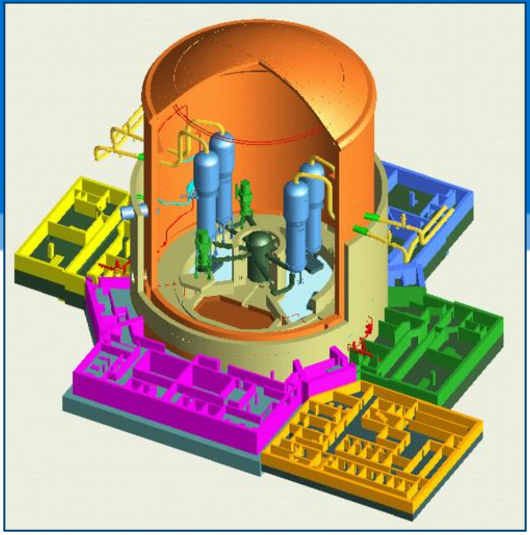
New CCGT Investment 2013



Electricity price: £80/MWh

DECC Electricity Generating Costs 2013

Nuclear Costs in the UK



- **2006 Energy Review** suggested mature new nuclear could be built in 5-6 years with unit overnight capital costs ~£1,200/kWe
- When **inflated** to current values (2013) overnight capital costs: £1,600/kWe,

  or, with project interest: £2,162/kWe

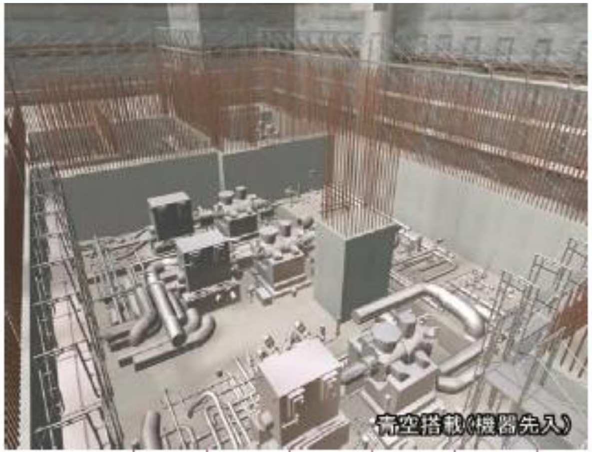
  would require a life-time levelised price of: **£70/MWh** @ 9% project discount rate

- Press reports that **Hinkley C** (£16.5bn), which includes significant first-of-class costs, will have overnight capital costs of: ~£3,300/kWe (£3,000/kWe)

  adding project interest over a 9-10 year build period: £5,150/kWe

  requires unit generation prices of: **£92.5/MWh** (£86.5/MWh)

Japanese Nuclear Construction Practice



Scaled SMR
£7,500/kWe

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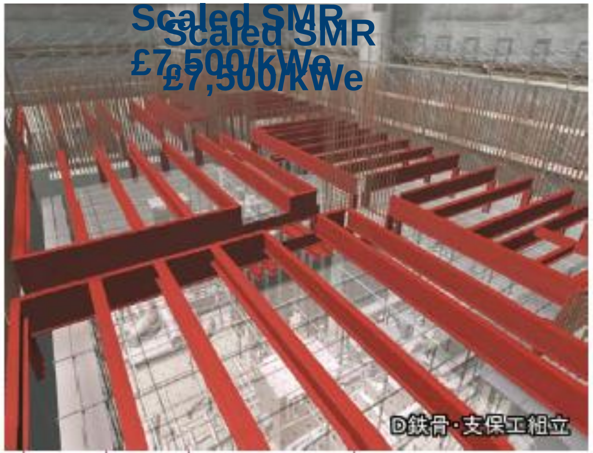
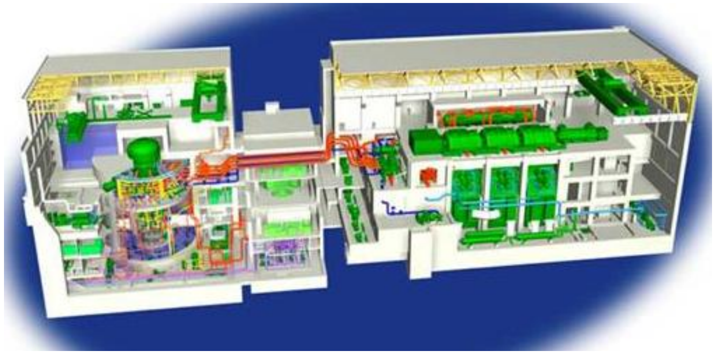


Scope for Cost & Price Improvement?

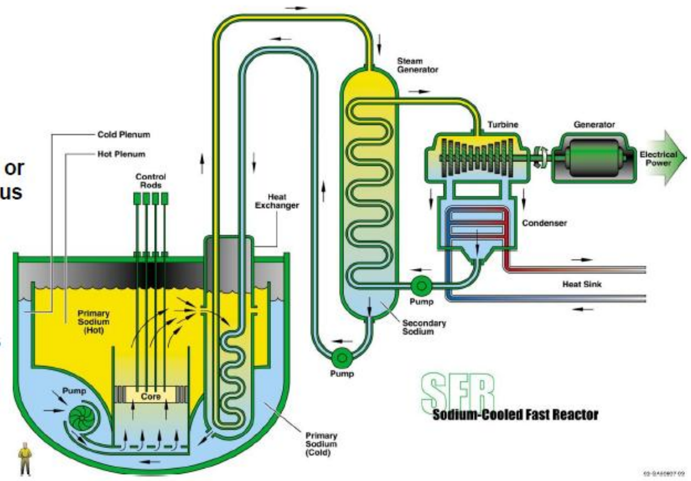
- Investment cost - **EPR** from £92.5/MWh
  - First of class capital costs ~10% removed £86.5/MWh
  - Construction schedule from 10 → 8 years? £80/MWh
- **Re-financing** post construction could reduced required 'Strike price' by ~15% in the range £70-75/MWh

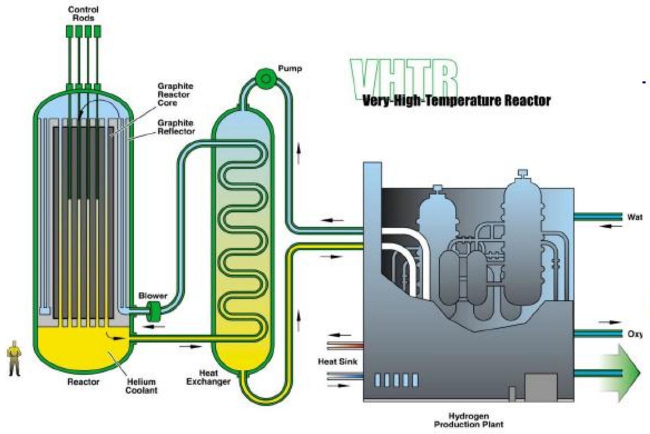


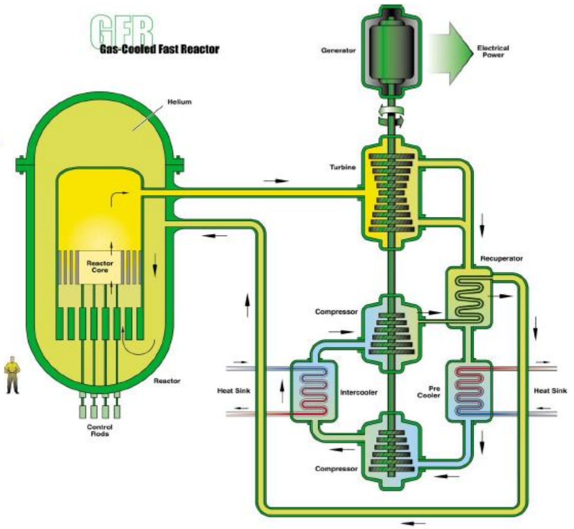
- Competition from lower cost designs **ABWR** – perhaps 20% cheaper

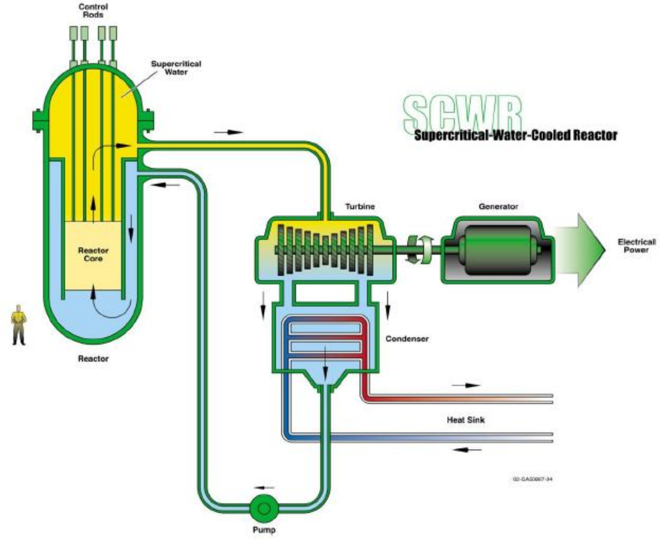
'Strike price' in the range £65-72/MWh

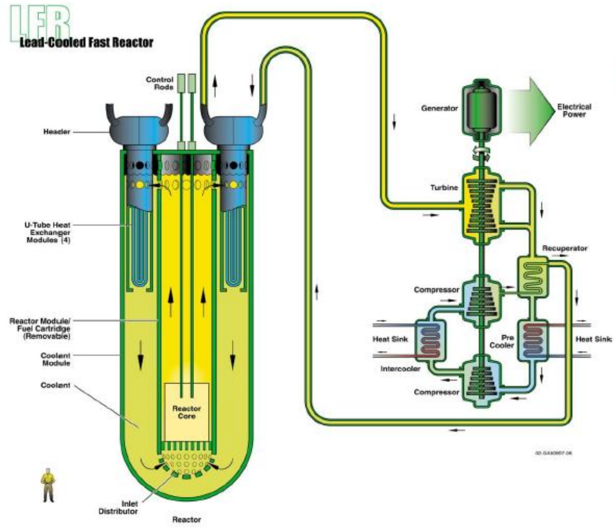
Advanced Systems

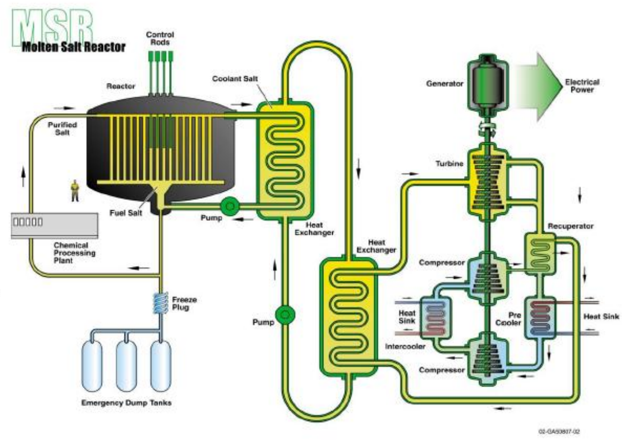












Advanced Systems – Variety of Attributes

Gen IV Goals	Sustainability Fuel Utilisation	Safety & Reliability	Economics/ Efficiency	Proliferation & Security
Sodium Fast R	Yes	? Low Press	No	No requires reprocessing
Lead Fast R	Yes	? Low Press	Perhaps but materials	No requires reprocessing
Gas Fast R	Yes	No	Yes but materials	No requires reprocessing
V High TR	No	No unless small	Yes but materials	No different
Super Critical WR	No	No	No	No different
Molten Salt R	Yes if Fast spectrum	? Low Press	Yes but materials	Yes – but novel processing

Gen IV ARs v LWRs by 'Anon'

	LWRs	ARs	
Safety	Green	Amber	Like for like comparisons yet to be done
Economic Competitiveness	Amber	Amber	Economics of nuclear dominated by capital cost, not operating costs – AR costs unproven
Waste Production	Amber	Amber	While LWR efficiency is low, nuclear waste volumes of both are small. Some ARs have larger volumes of graphite cladding.
Waste Disposal Cost	Amber	Amber	Both LWRs and ARs can burn full range of trans-uranics at competitive rates – both requiring reprocessing developments
Waste Burning	Green	Green	RLWR can burn nuclear waste like FRs
Water Supply	Green	Green	No real difference for any power cycle – water not normally an issue, unless in desert
Proliferation	Green	Red	ARs - reprocessing leads to proliferation issues

LWRs more mature & will provide nuclear energy for next 50 years

Reactor Development Potential - LWR

1. Large reactors **higher performance/better safety** :
   - Modelling & conservatism,
   - High conductivity fuels – nitride & silicides
   - Improved fuel cladding – coated zircalloy, steels, silicon carbide
2. **Small simplified reactors** – shorter construction, less capital, lower costs;
3. **Breeding** of more fuel than used – Thorium Breeder LWR;
4. **Burning** of long-lived **nuclear waste –** Reduced Moderation LWR.

mPower SMR

Transformative Future for Nuclear?

- Drivers are:
  - **Economics** – which are set by oil and gas supply & prices;
  - **Resource depletion** – plenty of uranium for at least the next 50 years;
  - **Proliferation** – reprocessing is the key issue, whether LWR or Advanced Reactors;
  - **Climate Change** → wide-scale application of low-carbon energy generation.
- Priorities for development are:
  - **First:** to build on & develop the **success of LWRs** with lower costs, for the massive expansion of low carbon energy, during the **next 25 years**;
  - **Second:** to select one or two of most **promising Gen IV** reactors for medium term development and demonstration – probably by means of international collaborative projects – with aim of **commercial construction before 2050**.
- **Global nuclear** from 370GW → 1,500GW by 2040. '**electricity of choice'.**

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