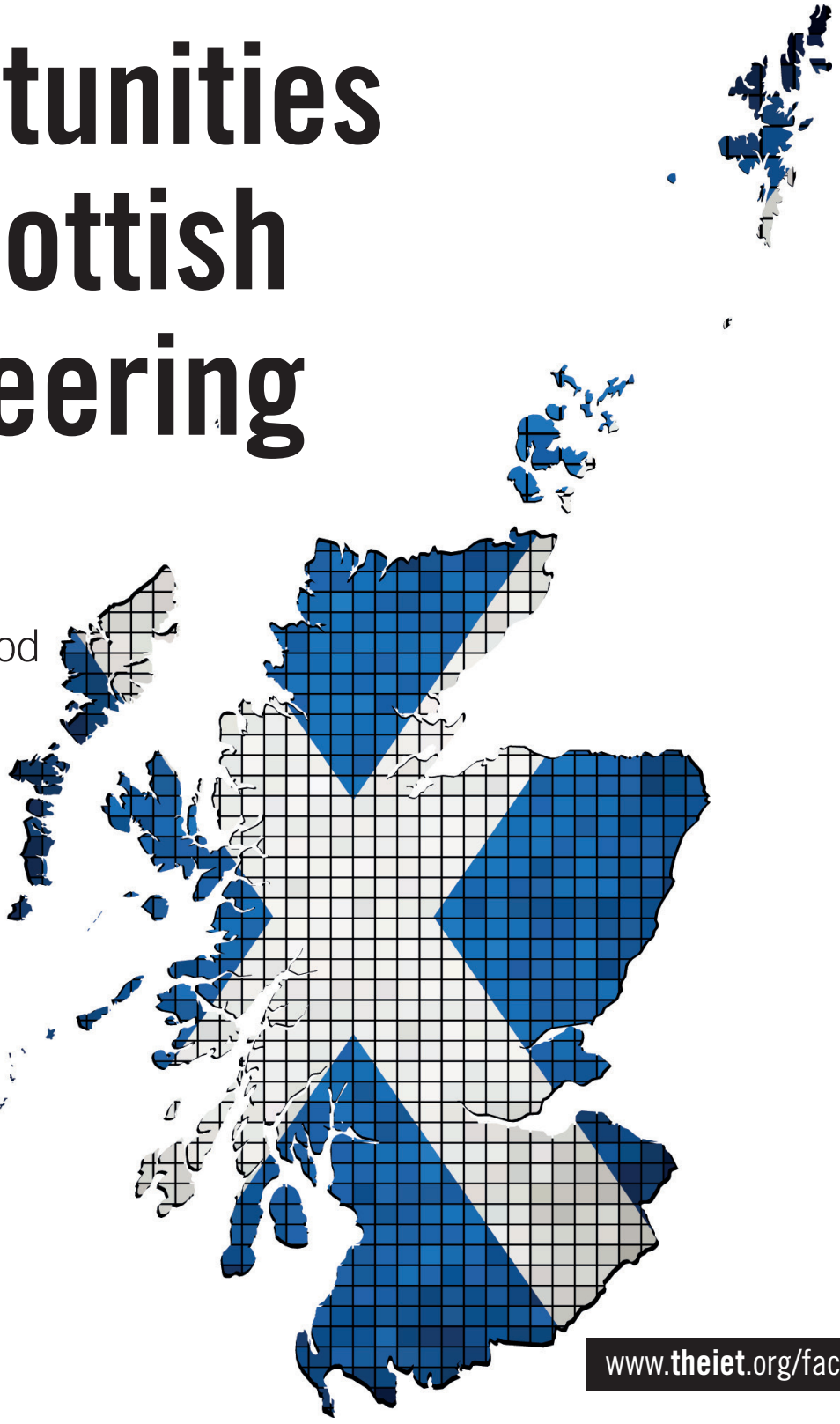
The Institution of Engineering and Technology

Civil Nuclear Power **Opportunities for Scottish Engineering**



An Engineering Policy Group Scotland Holyrood Briefing given at the Scottish Parliament on 25th November 2015

www.theiet.org/factfiles

The Engineering Policy Group Scotland

With a combined membership of 40,000 Scottish engineers and scientists, the Engineering Policy Group Scotland (EPGS) acts as a two way link between the professions and government in Scotland. It aims to provide feedback into government thinking and proactively raise matters of relevance with government.

The EPGS comprises senior members from across Scottish industry academia and professional organisations.

The leadership is provided by a core group of senior professional Engineers and Scientists from key professional bodies in Scotland

The information given in this document represents the outcome from an event organised by EPGS. It does not necessarily represent the definitive subject views of the participating organistations listed above.

As engineering and technology become increasingly interdisciplinary, global and inclusive, Professional Bodies reflect that progression and welcome involvement from, and communication between, all sectors of science, engineering and technology.

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- policy@theiet.org

Civil nuclear power - opportunities for Scottish engineering?

The Engineering Policy Group Scotland (EPGS) provided a briefing on "Civil nuclear power - opportunities for Scottish engineering?" which took place on Wednesday 25th November 2015, at the Scottish Parliament, in Committee Room 3. This event was hosted and chaired by Iain Gray MSP. The presentations provided by the speakers are set out on pages 5-10 of this briefing.

Dr Graeme West from the Department of Electronic and Electrical Engineering at the University of Strathclyde and Professor William Nuttall, Professor of Energy at the Open University, were the guest speakers and PowerPoint presentations delivered at the event are reproduced in this booklet.

The first presentation from Graeme West focused on nuclear power generation in Scotland.

Aspects covered included the following:

- the history of nuclear power in Scotland;
- the relative contributions of energy generation by fuel type in Scotland;
- prospects for the two remaining Scottish nuclear plants in terms of both the current policy of the Scottish Government and also in relation to extensions to the life of these power stations and;
- other related issues such as waste, decommissioning and the energy "quadrilemma" (decarbonisation, affordability, security of supply and social acceptability).

William Nuttall then expanded the scope of the event by:

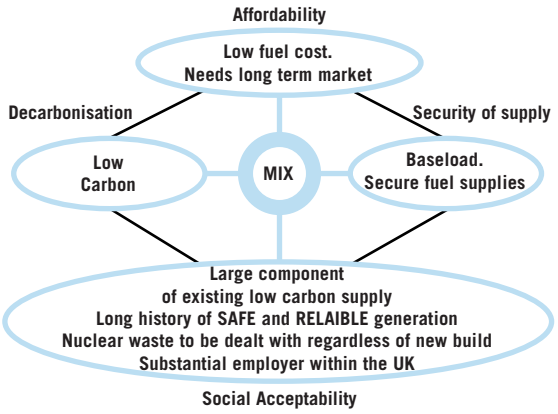
- outlining the situation for new nuclear power generation in the rest of the UK, in particular the multi-billion expansion plans for England and Wales;
- discussing broader developments in the wider nuclear arena including EU energy goals; and
- highlighting some of the latest ideas within the field (e.g. small nuclear reactors) which others noted might offer alternate development routes in Scotland.

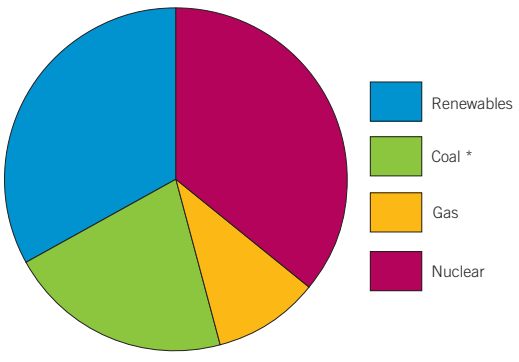
Plant	Type	Present capacity (MWe Net)	First power	Expected Shutdown
Wylfa1	Magnox	490	1971	Dec 2015
Dungerness B 1&2	AGR	2 x 520	1983, 1984	2028
Hartlepool 1&2	AGR	595, 585	1983, 1984	2024
Heysham I 1&2	AGR	580, 575	1983, 1984	2019
Heysham II 1&2	AGR	2 x 610	1988	2023
Hinkley Point B 1&2	AGR	475, 470	1976	2023
Hunterston B 1&2	AGR	475, 485	1976, 1977	2023
Torness 1&2	AGR	590, 595	1988, 1989	2023
Sizewell B	PWT	1198	1995	2035
Total: 16 units	**9373 MWe**			

Data: WNA Country Profile UK Nov 2015

At present power generation in Scotland is at a critical juncture. In the same week as world leaders met in Paris to consider the vital necessity of promoting low carbon energy sources, some facts which emerged at this briefing, included the following:

- in 2013 48% of gross electricity consumption in Scotland was generated by two ageing nuclear power stations, both of which are near the end of their planned operational lives;
- the enormous expansion in civil nuclear power generation south of the border presents Scottish engineering firms with considerable opportunities; and
- the high up-front costs of building nuclear power plants and the lengthy de-commissioning processes present particular challenges.





* Coal includes a small quantity of non-renewable waste

Source: Scottish Government 2013

After 40 minutes of presentations, the two speakers were joined by Derek Elder (Chairman of EPGS); Chic Brodie MSP (SNP); and Alex Johnstone MSP (Scottish Conservative). This panel, chaired by Iain Gray MSP, (Labour) fielded questions from the audience. Other MSPs who took part in the audience discussion included: Elaine Murray, Nigel Don and Christian Allard.

The lengthy discussion period allowed audience members to consider several aspects of power generation in Scotland. These included:

- the practicality of current Scottish Government policy which is targeting 100% of gross electricity consumption from renewable generation;
- that Scotland currently exports around 28% of electricity generated to the rest of the UK;
- while gas is better than other fossil fuels in relation to carbon emissions, “decarbonising” electricity generation probably means the elimination of fossil fuels;
- the impending closure of the coal fired Longannet station will have a dramatic effect by removing around 20% of capacity;
- the volatility of present arrangements as illustrated by the recent “emergency” purchase of 200 MW of power at very high cost when renewable supplies were temporarily unobtainable;
- continued disquiet on the implications of nuclear power both in relation to security and long term disposal;
- the difficulties of maintaining national energy security;
- the job opportunities for a skilled Scottish engineering work force; and
- the challenges around grid access, capacity and stability as a consequence of the changing mix of power generation.

Civil Nuclear Power
Opportunities for Scottish Engineering

Scottish Parliament, 25th November 2015

Nuclear Power in Scotland

Dr. Graeme West
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Department of Electronic and Electrical Engineering
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Overview of presentation

- Brief History
- Current & Future Nuclear
  - Lifetime Extension of plants
  - Scottish Government's position
- Waste and decommissioning
- Opportunities for Scottish Jobs
- The Energy "Quadrilemma"

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Nuclear Electricity in Scotland

Nuclear Power generated...

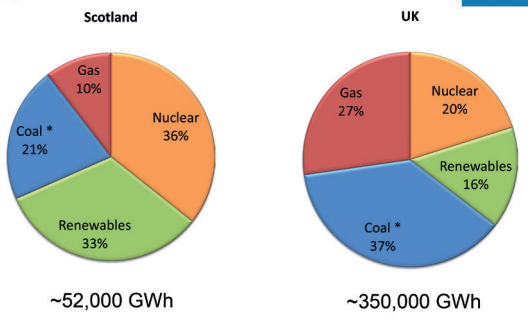
48.4%

...of gross electricity consumption in 2013.

Gross consumption is generation – net exports

3

Electricity Generation by Fuel
2013



*Coal includes a small quantity of non-renewable wastes
Source: http://www.gov.scot/Topics/Statistics/Browse/Business/Energy/EIS2015data

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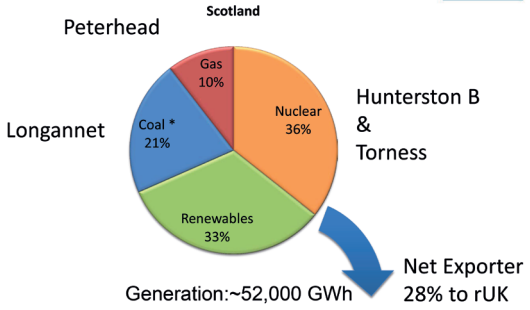
Electricity Generation by Station
2013



*Coal includes a small quantity of non-renewable wastes
Source: http://www.gov.scot/Topics/Statistics/Browse/Business/Energy/EIS2015data

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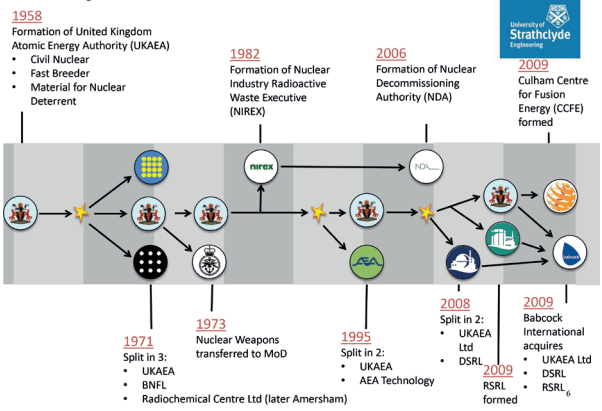
History of Nuclear in UK



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Dounreay

Fast Breeders

Dounreay Materials Test Reactor (DMTR)

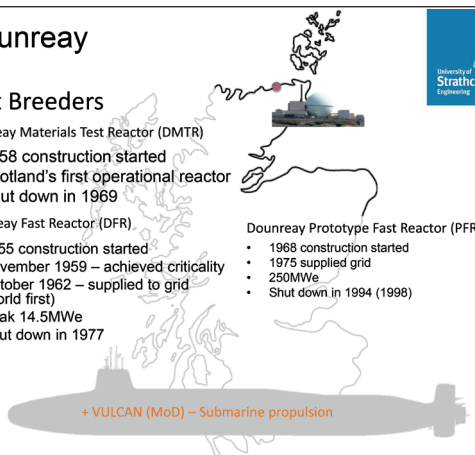
- 1958 construction started
- Scotland's first operational reactor
- Shut down in 1969

Dounreay Fast Reactor (DFR)

- 1955 construction started
- November 1959 – achieved criticality
- October 1962 – supplied to grid (world first)
- Peak 14.5MWe
- Shut down in 1977

Dounreay Prototype Fast Reactor (PFR)

- 1968 construction started
- 1975 supplied grid
- 250MWe
- Shut down in 1994 (1998)



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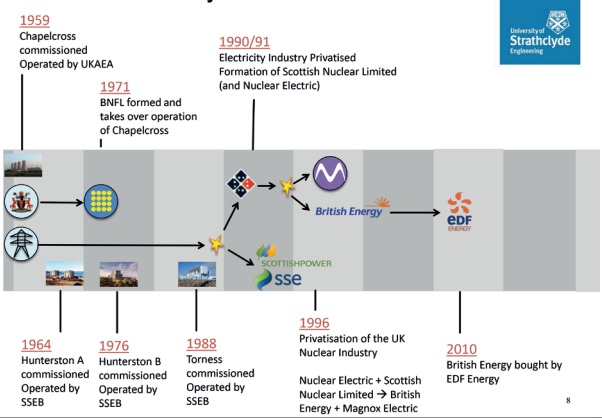
Nuclear Electricity Generation in Scotland



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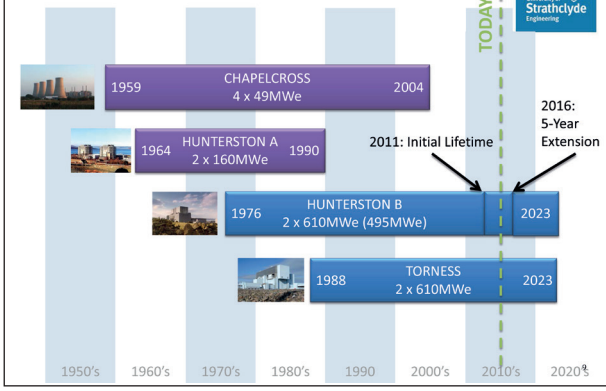
Scotland's Power Stations

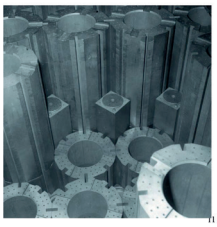


Future of Civil Nuclear Power in Scotland

- January 2008: Scottish Parliament narrowly voted to reject the building of new nuclear power stations
- Scottish Government's stated position:
  - No to new nuclear build (consent required from Scottish Ministers under Section 36 of the Electricity Act 1989)
  - Will not oppose the application for lifetime extensions for Hunterston B and Torness
- It is highly likely that EDF will look to extend the operation of Torness for (at least) another 5 years

Lifetime Extension

- Advanced Gas Cooled Reactor
  - Graphite Moderated
  - CO_2 Cooled
- Most probable life limiting factor is the graphite core
  - Cannot be replaced
- Exposure to radiation causes the graphite to age
  - Dimensional change
  - Weight loss



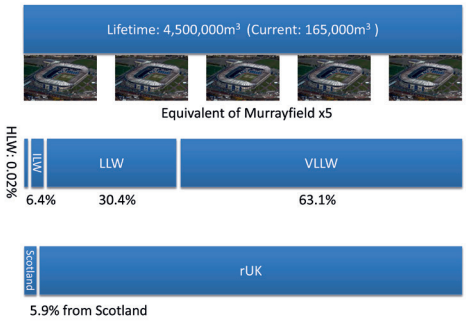
Safety Case

- 6-Leg "Safety Case" made to Office of Nuclear Regulation (ONR)
  - Core Component Condition Assessment
  - Damage Tolerance Assessment
  - Monitoring
  - Inspections
  - Plant Modifications
  - Nuclear Safety Consequences

Nuclear waste & spent fuel

- High Level Waste (HLW)
  - High levels of radioactivity & require cooling before disposal
  - Stored as liquid or as glass blocks
- Intermediate Level Waste (ILW)
  - High levels of radioactivity but no requirement for cooling considerations
  - Stored in tanks/drums/vaults with concrete shielding
- Low Level Waste (LLW) & Very Low Level Waste (VLLW)
  - >90% of all UK waste
  - <0.1% of radioactivity
  - Low level repository
  - Some to landfill sites
- Nuclear Materials
  - Plutonium & Uranium
  - Resource, not waste - stored

Current Volumes of Waste

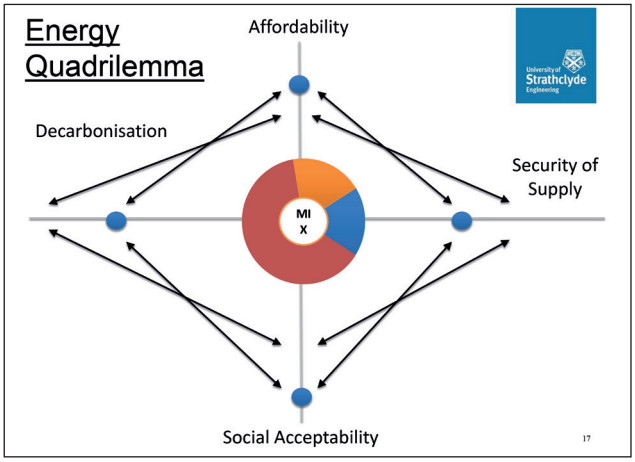


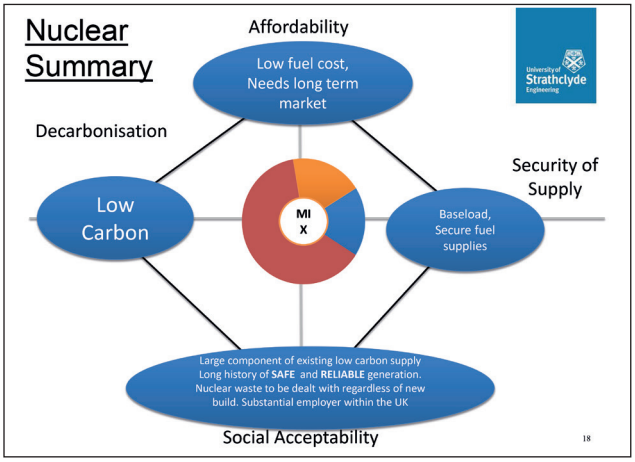
Policy and New Build

- Existing waste needs to be dealt with regardless of new build
  - Scotland: Near surface storage
  - rUK: Deep Geological Disposal
- Does not include new build estimates
  - Hinkley Point C to be included in 2016 figures
  - Funded Decommissioning Programme (FDP) will contribute to the costs of dealing with waste

Job Opportunities in Civil Nuclear?

- Existing stations
- Decommissioning & waste disposal
- New build
- Supply chain
  - Broader engineering skills
- Research
- Nuclear Power is challenging
  - Unique problems drive innovation
- Significant number of jobs located near or at the facilities
- Local economy benefits


Energy Quadrilemma
Affordability
Decarbonisation
Security of Supply
MIX
Social Acceptability
17


Nuclear Summary
Affordability
Low fuel cost, Needs long term market
Decarbonisation
Security of Supply
Low Carbon
MIX
Baseload, Secure fuel supplies
Large component of existing low carbon supply
Long history of SAFE and RELIABLE generation.
Nuclear waste to be dealt with regardless of new build. Substantial employer within the UK
Social Acceptability
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Thank you for listening
Disclaimer: The opinions and comments expressed in this presentation are mine alone
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The Open University

Civil Nuclear Power Opportunities for Scottish Engineering

Scottish Parliament 25 November 2015

Nuclear Developments: UK, EU and Globally

William J Nuttall
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Structure

- UK Nuclear
- UK Policy: The Journey to New Build
- Nuclear Power in EU Energy Policy
- Selling Electricity vs Selling Technology
- Small Modular Reactors
- Civil Nuclear Marine
- New Research Reactor

2

UK Nuclear: The Fleet

Plant	Type	Present capacity (MWe net)	First power	Expected shutdown
Wylfa 1	Magnox	490	1971	Dec 2015
Dungeness B 1&2	AGR	2 x 520	1983 & 1985	2028
Hartlepool 1&2	AGR	595, 585	1983 & 1984	2024
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Sizewell B	PWR	1198	1995	2035
Total: 16 units		9373 MWe		

Most AGR units are running at significantly less than original or design capacity

3

Table and Data: WNA Country Profile UK November 2015

UK Nuclear: New Build
Plans and Proposals

Proponent	Site	Locality	Type	Capacity (MWe gross)	Construction start	Start-up
EDF Energy[1]	Hinkley Point C-1	Somerset	EPR	1670		2023
	Hinkley Point C-2		EPR	1670		2024
EDF Energy[1]	Sizewell C-1	Suffolk	EPR	1670?		?
	Sizewell C-2		EPR	1670?		?
Horizon	Wylfa Newydd 1	Wales	ABWR	1380		2025
Horizon	Wylfa Newydd 2	Wales	ABWR	1380		2025
Horizon	Oldbury B-1	Gloucestershire	ABWR	1380		late 2020s
Horizon	Oldbury B-2	Gloucestershire	ABWR	1380		late 2020s
NuGeneration	Moorside 1	Cumbria	AP1000	1135		2024
NuGeneration	Moorside 2		AP1000	1135		?
NuGeneration	Moorside 3		AP1000	1135		?
China General Nuclear	Bradwell B-1	Essex	Hualong One	1150		
China General Nuclear	Bradwell B-2*		Hualong One	1150		
Total planned & proposed	13 units *			17,900 MWe		
GE Hitachi	*Sellafield*	*Cumbria*	*2 x PRISM*	*2 x 311*		
Candu Energy	*Sellafield*	*Cumbria*	*2 x Candu EC6*	*2 x 740*		

Proposed total new build capacity: 18,000 MWe approx. (excluding Pu disposition technologies).

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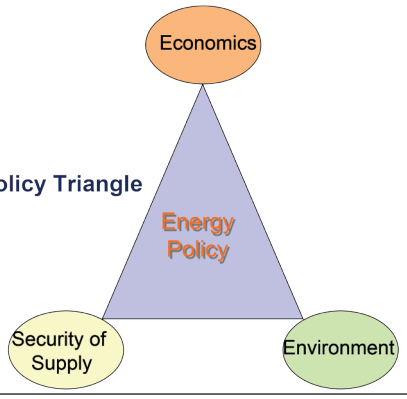
Table and Data: WNA Country Report UK November 2015

Policy Journey to New Build



Energy Policy Triangle

5

Nuclear Energy Security

Uranium yellowcake is easily transported and stored for UK energy policy it is regarded as 'domestic'.

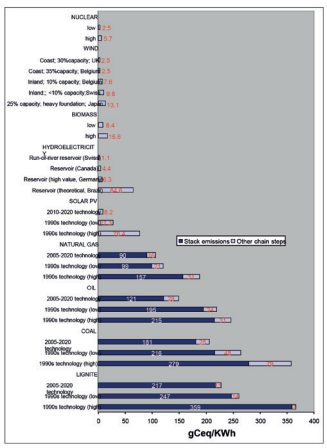
6

Environment
What about CO_2?

Source:

Spadaro et al. (2000), *"Greenhouse Gas Emissions of Electricity Generation Chains" IAEA bulletin*, vol. 42, No. 2, Vienna, Austria.

Nuclear Power is low carbon



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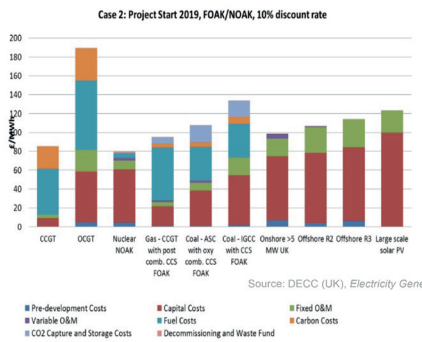
Cost of Nuclear Power

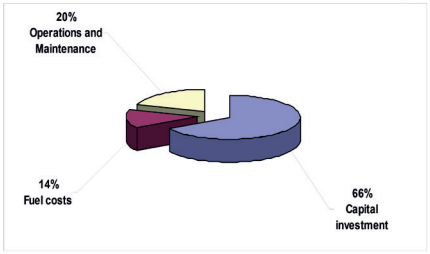


Source: DECC (UK), *Electricity Generation Costs 2013*

Levelised cost estimates for projects starting in 2019 assuming a 10% discount rate. Assumes n^{th} of a kind (NOAK) status has been achieved by Nuclear Power

8

Nuclear New Build Lifetime Costs



Breakdown of lifetime costs of a nuclear power plant.
Capital investment is the most significant factor in the economics of nuclear power.

Source: DTI *Energy Review – A Report*, chart A1, page 175, cm6887, (July 2006). Available at: http://www.berr.gov.uk/files/file39525.pdf
Discount Rate assumption 10% real post tax

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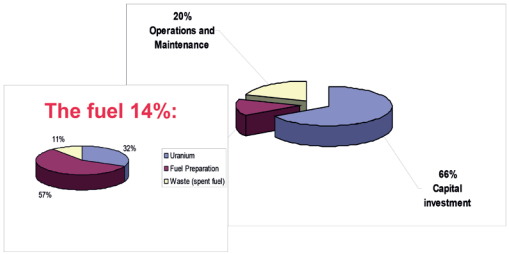
Uranium a minor cost



The fuel 14%:

Note: typically decommissioning costs are less than 1% of ongoing operating costs (10% discount rate assumed).

Ref: *Nuclear Power in the OECD*, IEA (2001)

Raw uranium costs are only a minor part (about 5%) of the total costs, this is in contrast to fossil fuel power generation where equivalent fuel costs are approximately 70%.

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Costs … and Economic Risks

The fundamental economic risks of nuclear power are:

- High cost of capital
- Overrun of construction phase
- Future electricity prices
- Changes of safety or environmental regulation during planning and construction
- Political risk and public acceptance problems
- Risk of a low carbon price
- Poor plant reliability in operational phase

Blue font denotes risks occurring before first operations

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Economic 'Non-Risks'

For nuclear power the following factors are relatively minor:

- **Decommissioning costs** (40-60 years in the future)
- **Fuel costs** (raw U_3O_8 is only a few % of total costs)
- **Geopolitical risks** (fuel is easily stored and is regarded as "domestic" for energy security)

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EU Energy Policy: *EU 20:20:20 by 2020*

Binding EU targets affecting electricity:

- **20% of total energy consumed to be supplied from renewables by 2020**
- **20% reduction in greenhouse gas emissions by 2020.**
- **In addition there is a non-binding target to reduce primary energy use by 20%**

See: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/80 and http://ec.europa.eu/energy/energy_policy/

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EU Policy to 2030 *a major victory for Britain?*

Member state binding 40% greenhouse gas emissions reduction by 2030 (c.f.1990). ½ the effort within the EU-wide ETS and ½ in the non-ETS sectors, with national, but tradable targets.
27% percent of total energy consumed to come from renewables in 2030 (today 14%). Only binding on EU as a whole.
An increase of 27% in energy efficiency with an aim to increase to 30% (2020 review). The 27% figure is indicative and compares to 2030 projections based on current consumption and technology.

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Nuclear Research in Europe

In 2012, and at the request of the European Council, the European Commission supported an independent review of EU nuclear fission research and training. The exercise was to inform *Horizon 2020*.

I was one of eight experts inside the process

http://www.eesc.europa.eu/?i=portal.en.events-and-activities-symposium-on-nuclear-fission

Selling Electricity vs Selling Technology

Prospects for Nuclear Engineering are mainly shaped by two types of policy:

- Energy Policy – here the product is electricity for local use and the issues are those of the energy policy triangle.
- Technology Policy – here the product is technology to be sold both domestically and globally.
- Technology Policy links to research policy, industrial policy, skills policy, export policy and much more.
- Over the last 10 years much progress has been made in both energy policy and technology policy in the UK. Together these measures have sought to favour UK nuclear technology expansion

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Growing British Interest in SMRs

Two of my favourite new UK reactor ideas:

1. Civil Nuclear Marine Propulsion – a variant on a UK Small SMR?

Note UK interest in early 1960s including a refrigerated cargo ship with thanks to Joe Frater, Cambridge Univ. MPhil 2012

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Second Idea: New Research Reactor

- Noting that the US 1950s Atoms for Peace programme led to the ultra-safe General Atomics TRIGA Reactor
- I see a case for a new ultra-secure equivalent to serve global needs in medical isotope production, materials testing and training
- An Ultra-Proliferation Resistant Research Reactor could be developed by the UK possibly in partnership with another country.
- The first of a kind should be constructed in the UK with a view to global technology export.

British Designed Research Reactors: Dido and Pluto at AERE Harwell, Oxfordshire 1957-1990.
Technology exported to Australia, Denmark and Germany

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Thank you

My thanks go out to all my research collaborators and to the sources of third party material.

Responsibility for all comments and opinions is mine alone

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