UK SMR

Oct 2020

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Agenda

01 Introduction / Background

02 Overview of SMR plant

03 Economics

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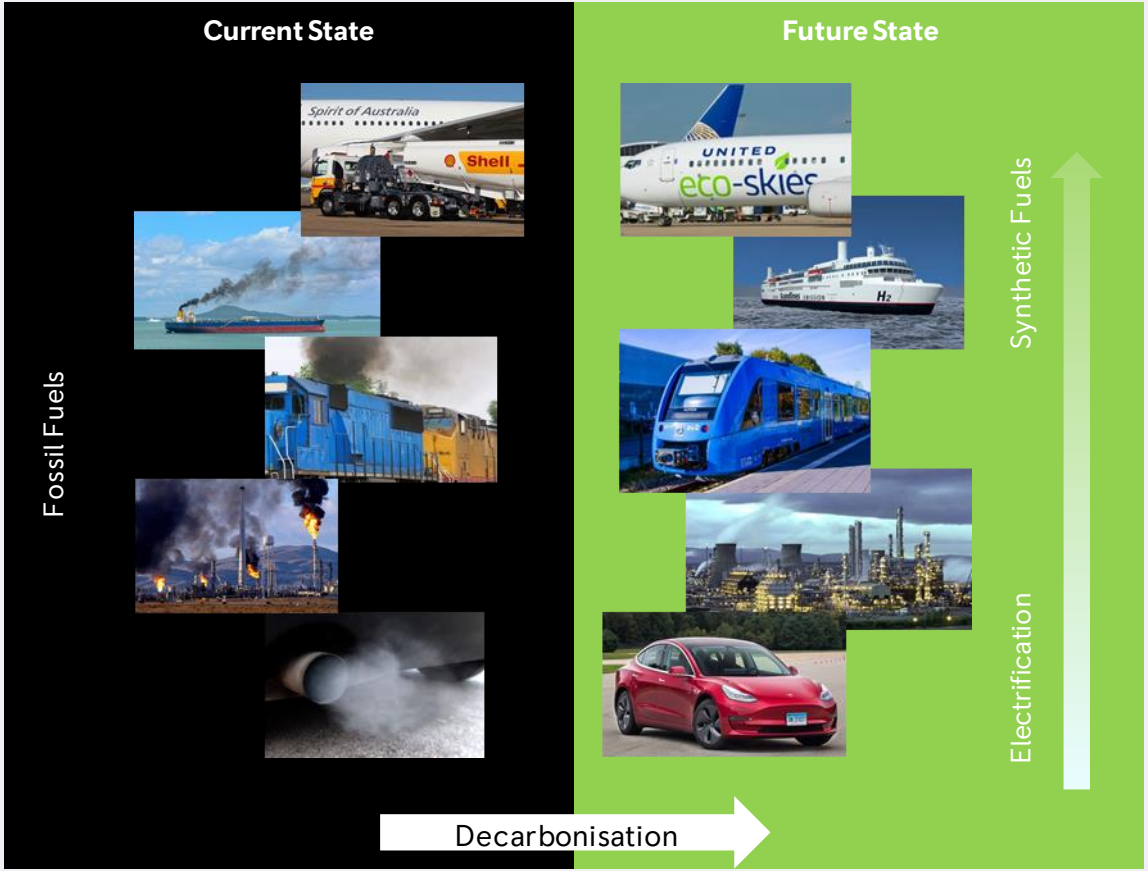
Context – changing energy systems

Demand for clean electricity will increase – driven by global development, population growth and decarbonisation of heat and transportation.

Electricity will be the central pillar for future industrial activity



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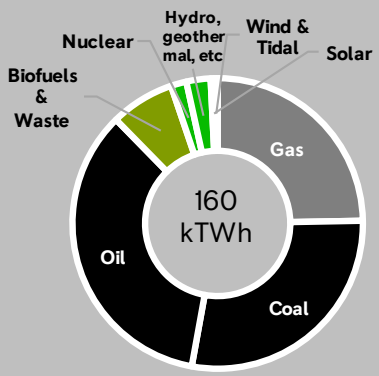
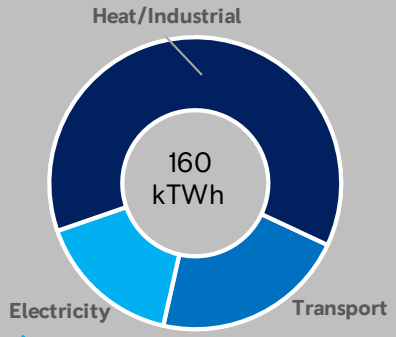
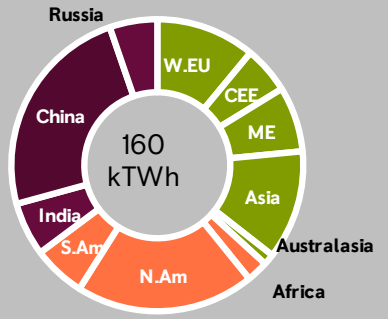
The addressable market is driven by a combination of geographical reach and extent of decarbonisation

Excludes energy growth

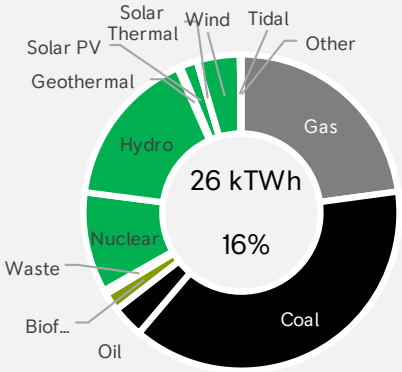


Only 13% global energy is low carbon





~48% of the world is addressable



- 64% is carbon intensive
- Nuclear is 10% today, most retired by 2050
- Low cost nuclear (LCN) can contribute through replacing share of fossil generation:

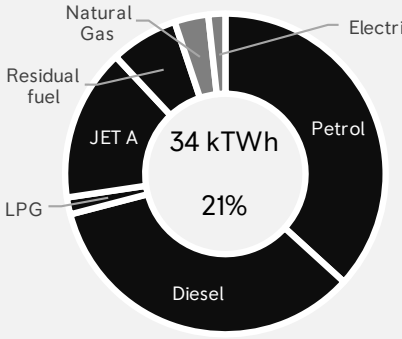
- **Low – convert 20% current fossil fuel to LCN**
- **High – convert 50% current fossil fuel to LCN**

- Virtually all heat / industrial is carbon intensive
- Low cost nuclear can contribute:

- **Low scenario – 5%**
- **High scenario – 10%**

No. SMRs for each scenario		
	High	Low
Heat/Ind	1760	880
Transport	1357	271
Electricity	1,148	459
Total	**4,266**	**1,611**

Cum mkt value (£Tn)	**£6.4**	**£2.4**
Mkt p.a. 2050 (£Bn)	**£320**	**£120**



- 98% is carbon intensive
- Electricity from low cost nuclear (LCN) can be the source for e-fuels, Hydrogen, direct electric

- **Low – convert 10% current fossil fuel to LCN**
- **High – convert 40% current fossil fuel to LCN**

There are a number of mechanisms available to decarbonise today across heat and transport

We need all sources of clean energy to decarbonise

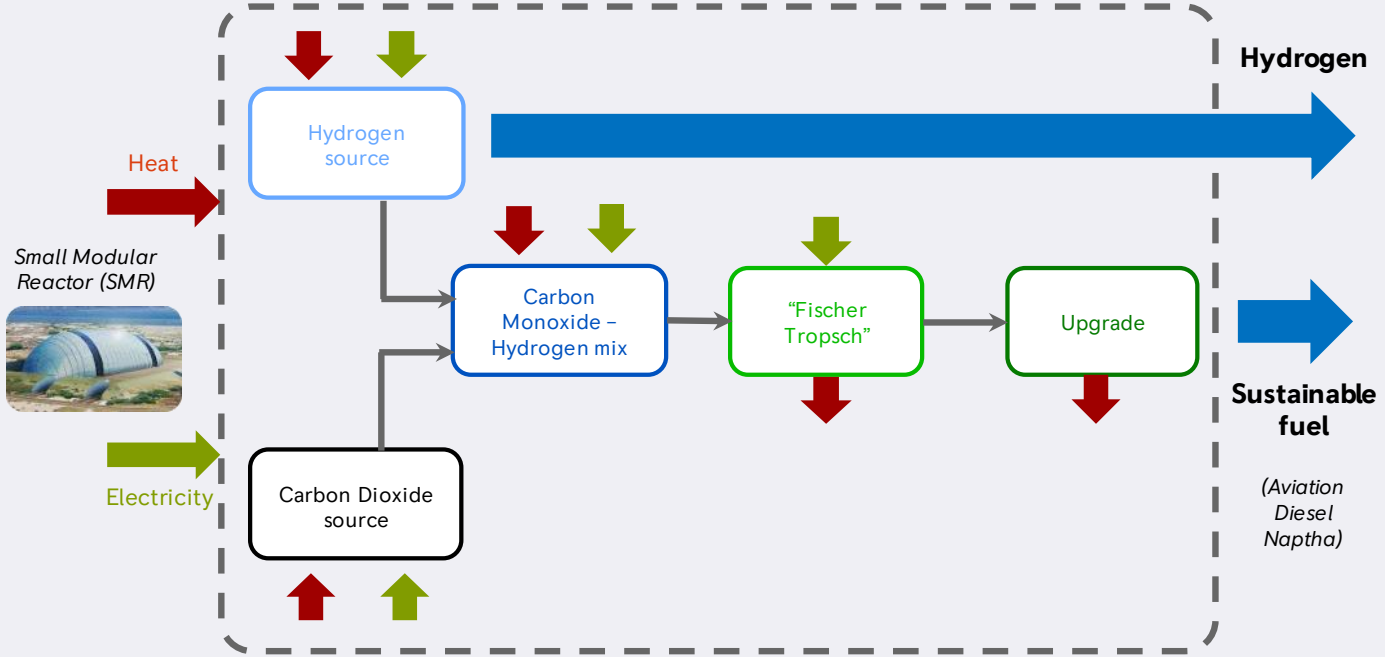
Nuclear can play a vital role BUT NOT AT ANY COST

SMRs are perfectly suited to many of these applications

Clean applications

	Fossil Fuel source	→		**Hybridisation** Lower emissions due to efficiency improvements	**Primary fuel based**
→	**Clean generation sources**	→		**Electrification** Carbon free power generation source dependent	• Heat potential • Transport for lower power & energy missions
→	**Clean electricity and / or heat**	→		**Sustainable fuels** Carbon neutral due to generation technology but still emitting	• Transport for higher power & energy missions
		→		**Hydrogen** Carbon free depending on generation technology	• Peak power • Heat • Transport for all power & energy missions

Sustainable fuels and hydrogen economy need significant clean power and present a further market opportunity beyond pure grid power



- A constant supply of energy (electricity) is much better economically to avoid large storage costs in the form of hydrogen
- More installed capacity of intermittent power sources will be required to enable parallel storage and use of hydrogen and carbon inputs
- The process for generating synthetic fuel / hydrogen must source power from clean sources
- Sources of power with waste heat can help optimise the process
- Many of the process steps produce waste heat that can aid process efficiency

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SMRs can be key to green hydrogen production where large amounts of baseload power are needed

Cost of electricity is a key driver

Single SMR

440MWe
3.5TWh / p.a. electricity

Electrolysis plant

87 m Kg hydrogen p.a.

Store for Peak Power	Heat	Transport

Heat for 240,000 domestic homes

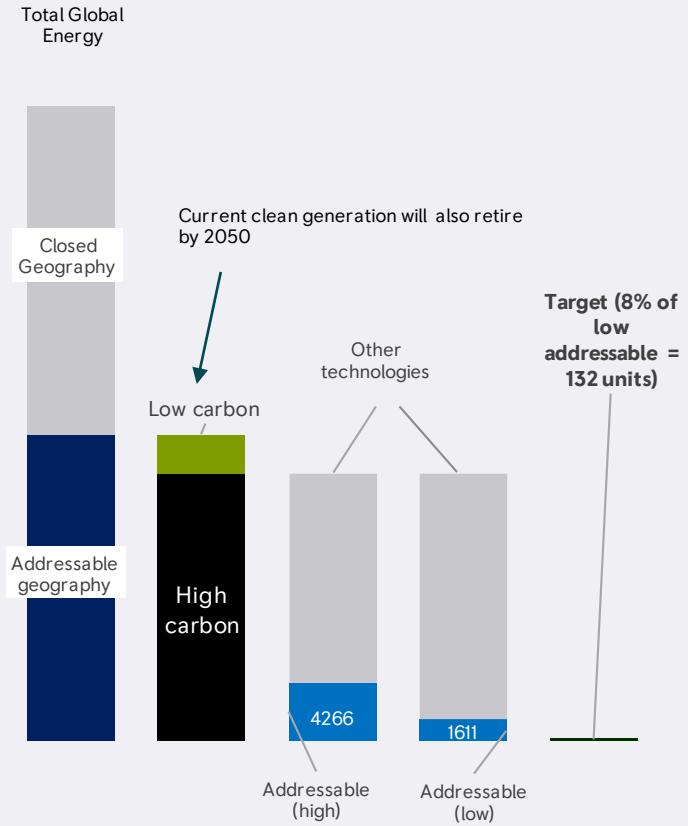
~4% UK HGV market (Based on Fuel cell)

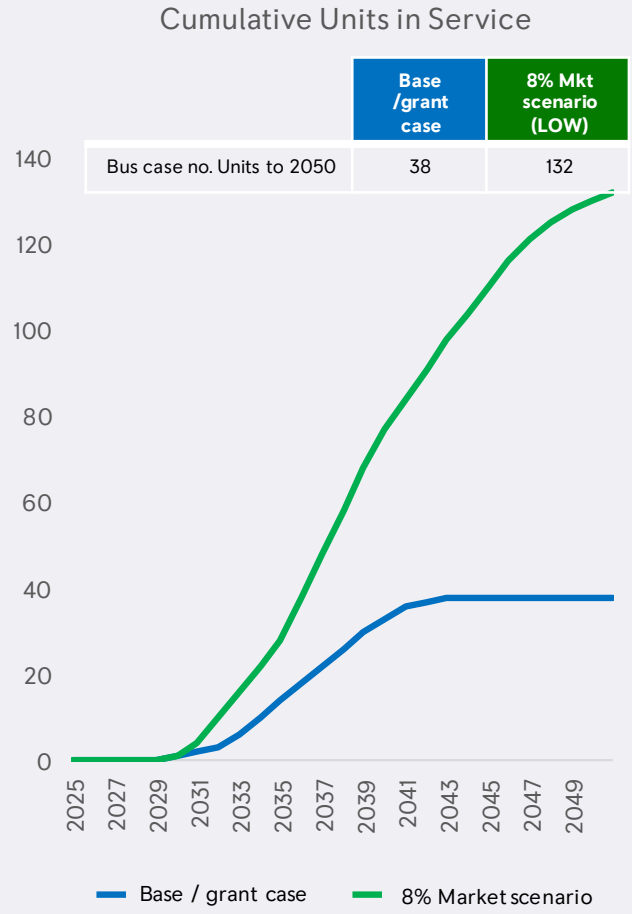
SMR Market in business case

Base / Grant case (derived 2017) assumes:

- 16 units (7 GWe) in UK
- 22 units (9 GWe) Internationally

8% market share scenario accounts for a winnable market position within an increased low-carbon electricity demand driven by power, heat and transport.





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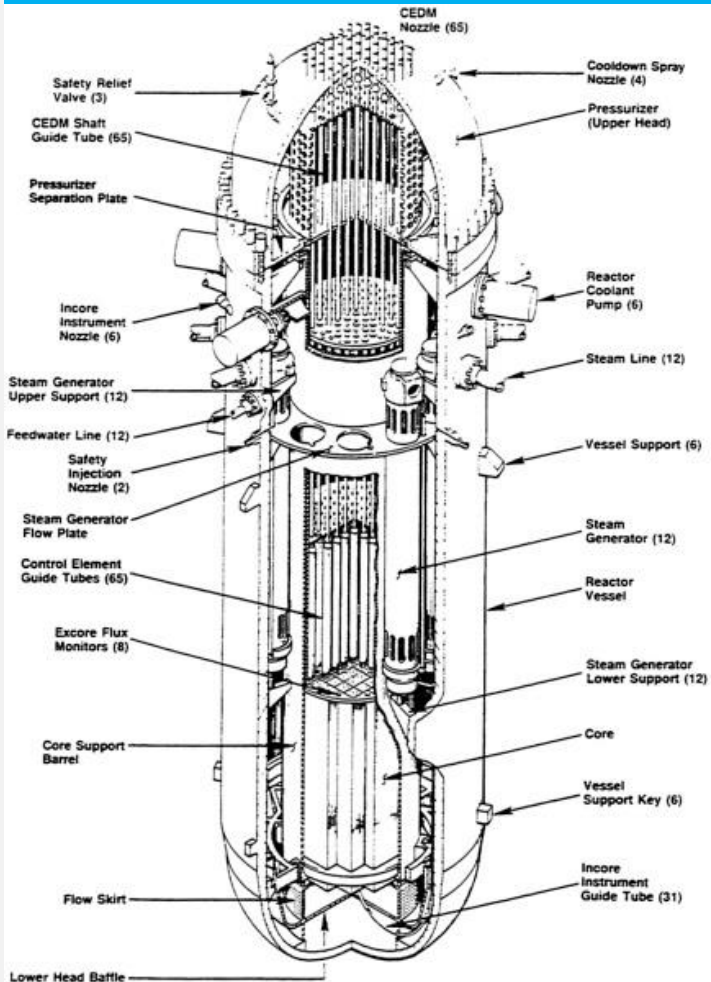
SMRs have been around for a while, so why now?

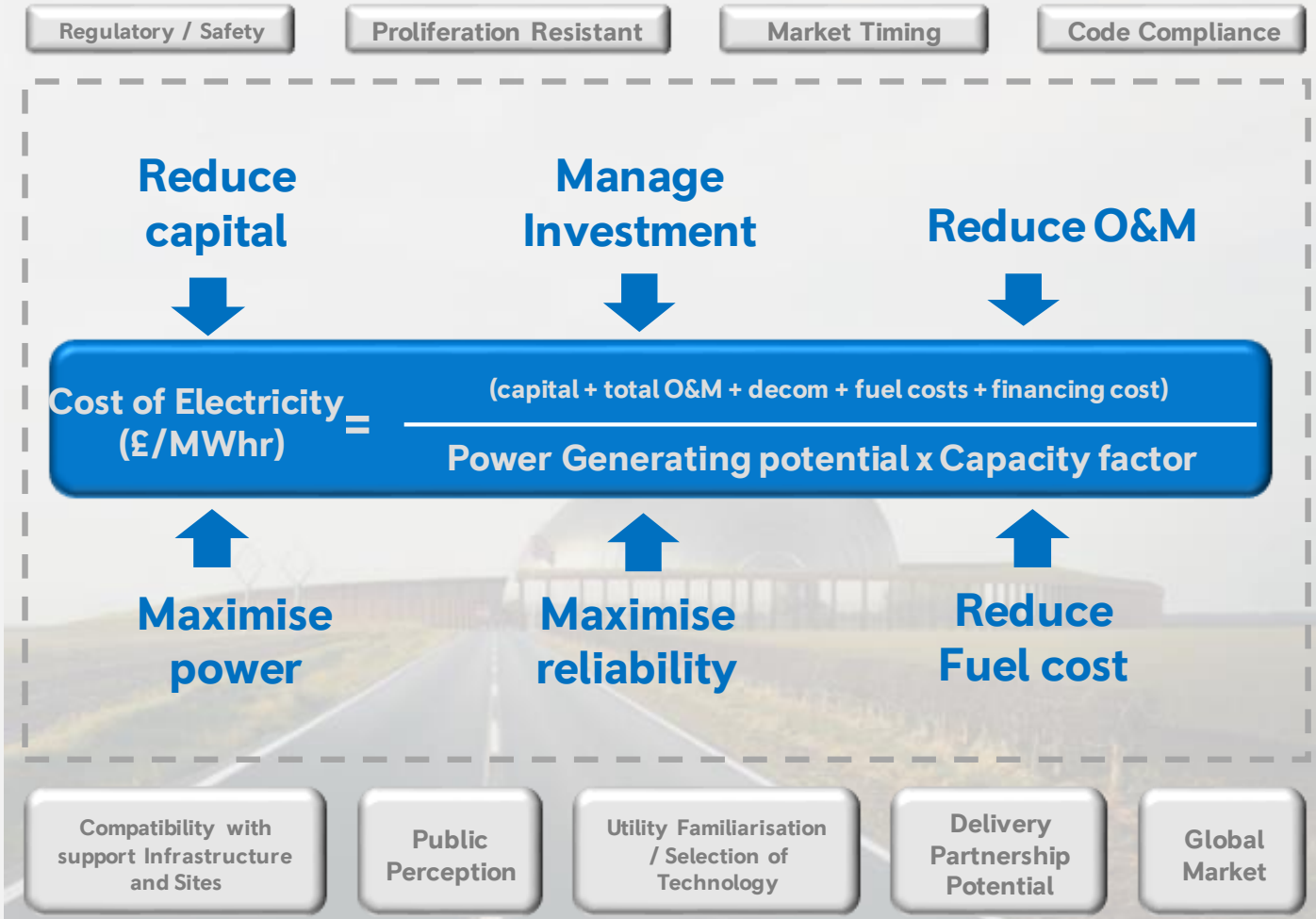
- The UK designed an SMR in the late 1980's early 1990's
- Large reactors can be unaffordable to some governments and private utilities
- **S**maller physical size important to reduce capital, and risk
- **M**odularisation is about manufacturability not building huge 1-off structures
- It needs to be about a Power Station not just a **R**eactor

Rolls-Royce, Stone & Webster, UKAEA SIR Reactor (1990's)

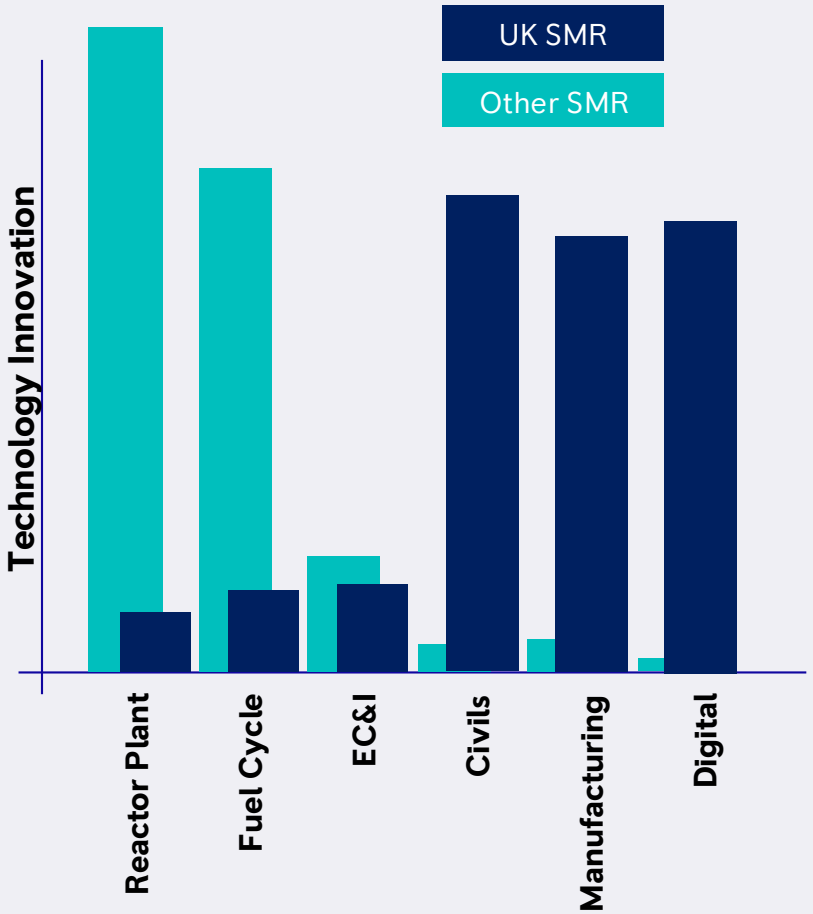


Power station design:

The principle of lowest LCOE is the primary requirement



Technology and Innovation Where it Adds Value

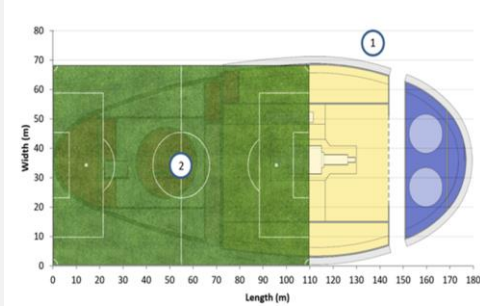


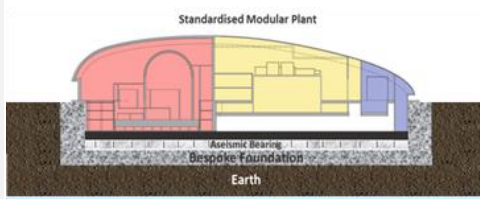
- Reactor Plant
  - Conventional reactor system
  - Proven materials
  - Conventional temperatures
- Fuel Cycle
  - Standard fuel
  - Minimal geometric change
- EC&I
  - Digital I&C
- Civils
  - Aggressively modularised civils
  - Off-site construction & build certainty
- Manufacturing
  - Modular manufacture
  - Flowline methods
- Digital
  - Substantial digitisation
  - Advanced analytics

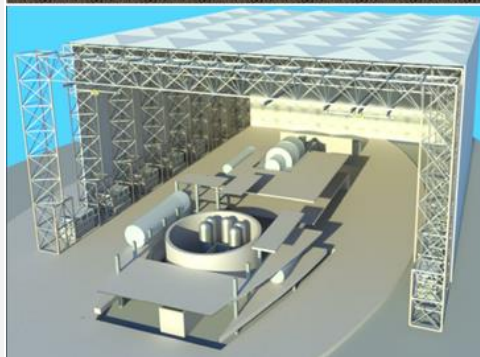
Innovation for benefit not for technology sake to reduce:

Capital Construction period Risk

- **Power station** design NOT just nuclear reactor
- Smaller in physical size and power output (440MWe)
- Designed for all aspects of **lifecycle**
- **Seismic raft** to standardise all plant modules
- **Short construction** period, lower levels of site activity
- **Site canopy** to improve efficiency / remove weather risk from construction schedule
- **Commercial separation of** ground construction







Our design / appraoch overview:

400 – 450 MWe 3 Loop PWR

Industry-Standard UO2 Fuel

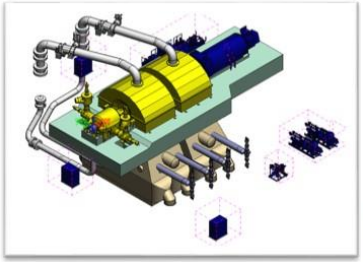
Compatible with Existing Infrastructure

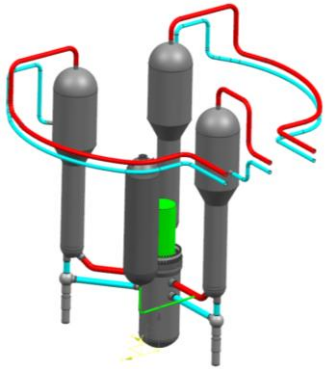
Designed for Road Transport

Passive Safety Systems

Maintenance and Operations Access

Cost reduction - standardisation



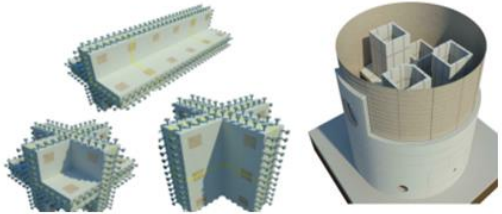


Build time reduction - Modular Manufacture

Nuclear Island

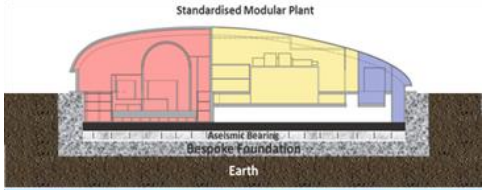
BOP & systems

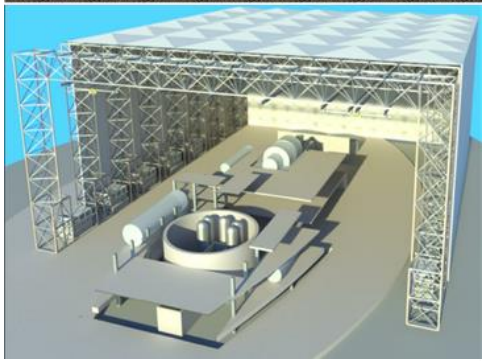
Civil construction

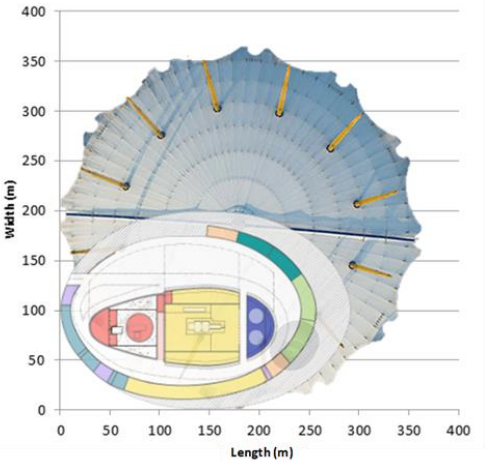


Benefits or learner of amplified through a shift from site construction to factory module construction

Risk reduction







Modularisation is a solution to reduce cost, schedule and risk, not a design

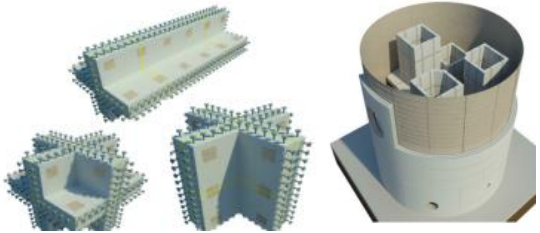
Modularisation approach must deliver benefit

- **Whole plant modularisation**
- **85%-95%** plant factory fabricated (site dependent)
- **Standardisation** of product, module sizes and interfaces – improve learner effect
- **Production line** approach to module manufacture
- Modules sized to **reduce factory capital**
- **Commercial / commodity** products
- **Use of digital twin** – design for maintenance

Nuclear Island

BOP & systems

Civil construction



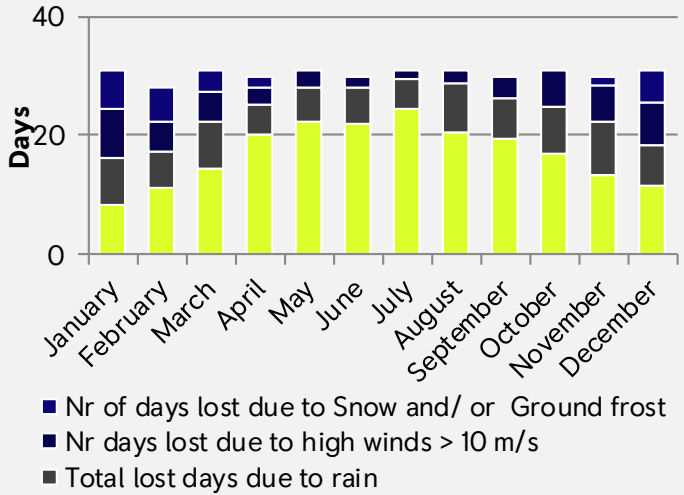
Benefits or learner of amplified through a shift from site construction to factory module construction

The Site Assembly Facility can provide major benefits in certainty of costs and schedule

- Removing the impact of weather:
  - Potential lost days over 4 year construction period ~641 days
  - Equates to ~£867M of deferred spend resulting
  - Avoids potential extension of programme of ~18 to 24 months
  - Overspend from non-re-deployable costs

- The removal of this risk will enable:
  - **Certainty on a baseline plan with shorter schedule and lower cost**
  - **Lower premiums on cost of borrowing**
  - **Lower LCOE**

Average weather assessment at Wylfa - September 201



A fleet approach can realise further savings to operators

- Rolls-Royce has extensive experience in Aerospace and Marine in monitoring customer assets to optimise performance
- All units can be monitored against the performance of other units and normalised for age and environmental factors
- Central Ops centre analysis will
  - Optimise performance across the fleet
  - Minimise downtime / increase capacity factor
  - Provide early insights into future demands during maintenance schedules
- Sharing of engineering capability across the fleet

Digitally connected units

Centrally monitoring Ops centre

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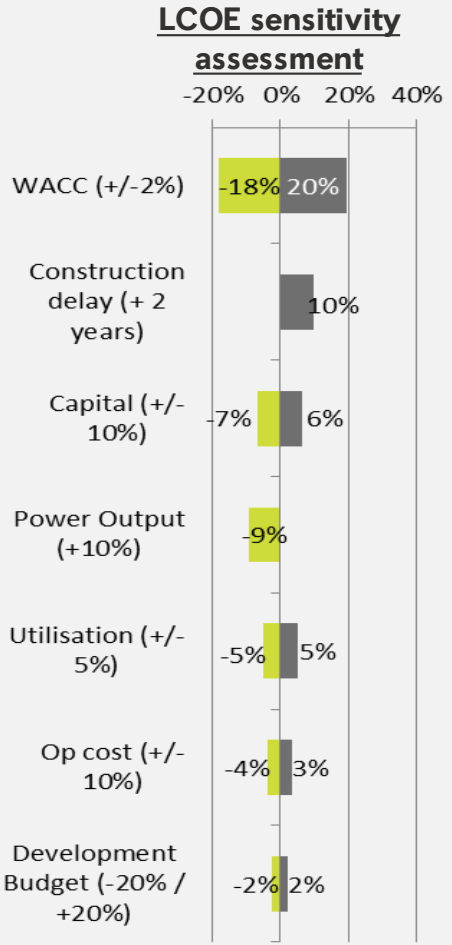
The electricity economics are dominated by certainty which can bring cheaper financing

- Cost of financing is the biggest sensitivity
- Function of:
  - Capital
  - Risk (or perceived risk)
  - Time to construct
- Maximise power for no additional capital
- Reduction of maintenance periods
- Digital twin and associated technologies to:
  - Maximise capacity factor
  - Reduce operational costs
- Development aimed at innovation for benefit



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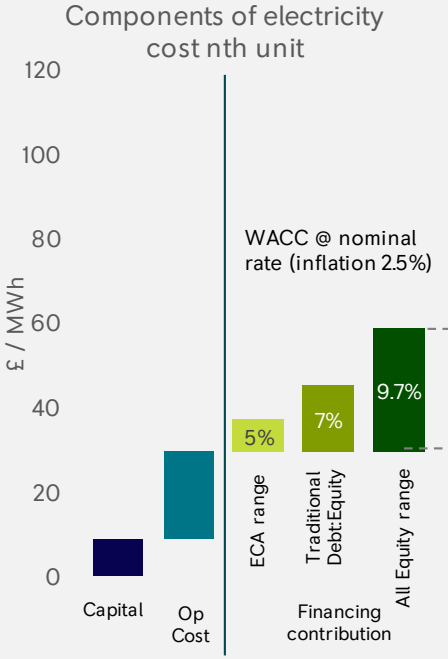
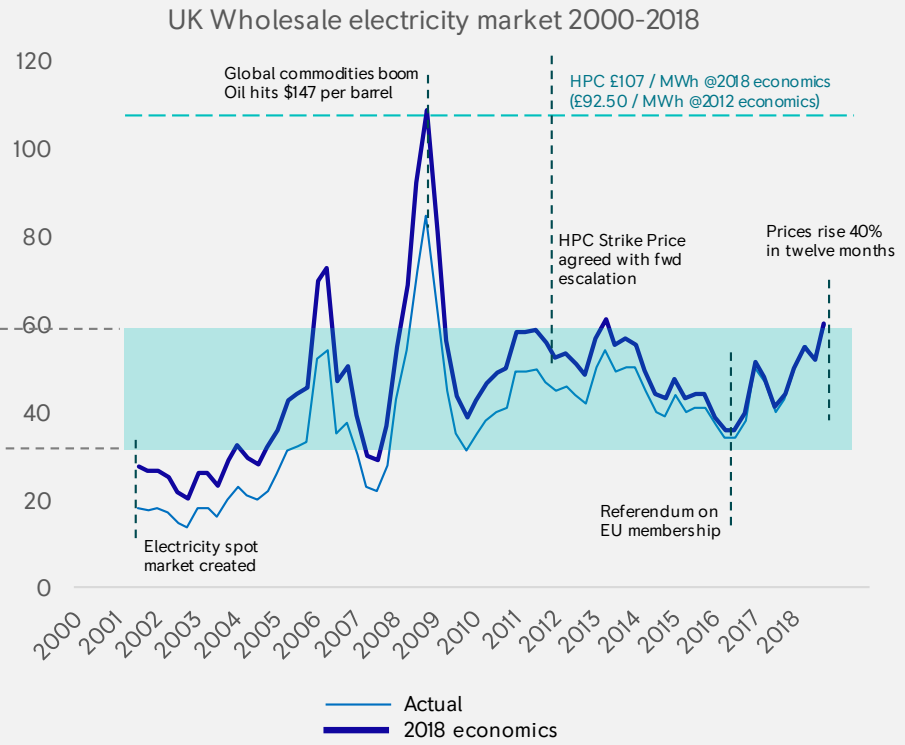
Electricity Market pricing

Electricity price is volatile and heavily linked to Oil Price

SMR electricity generation economics is detached from oil price and brings long term certainty





- SMRs provide clean, dispatchable electricity at scale
- Price of electricity from an SMR heavily dependent on financing cost of the plant but provides long term price certainty
- Operating costs of an SMR are fixed, with little variation or external influence

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