



UK SMR

Oct 2020

Alan Woods





Agenda

01 Introduction / Background

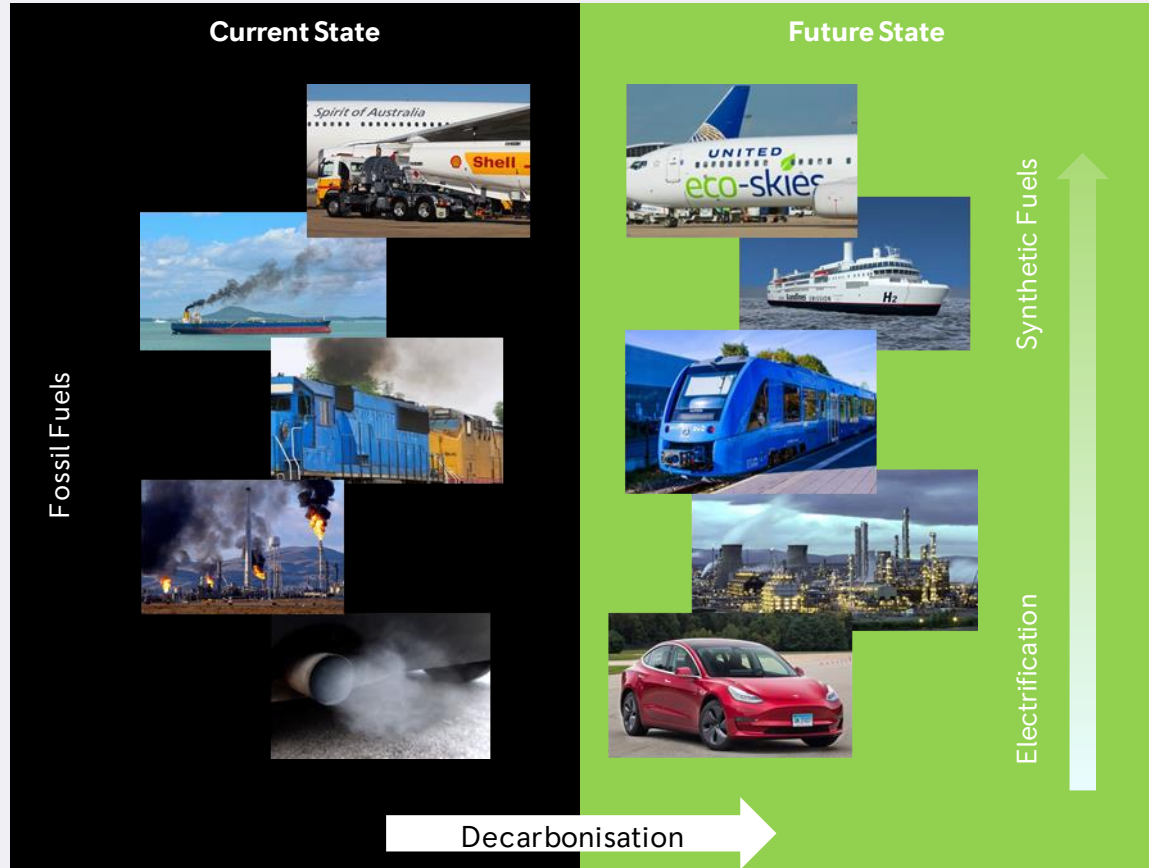
02 Overview of SMR plant

03 Economics

Context – changing energy systems

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

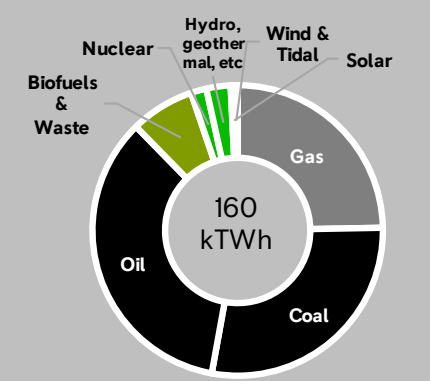
Electricity will be the central pillar for future industrial activity



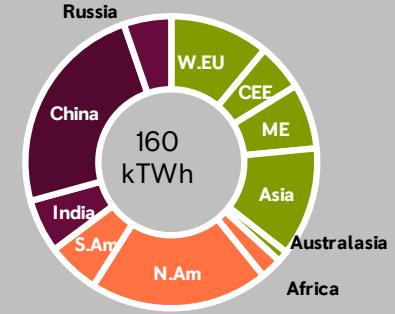
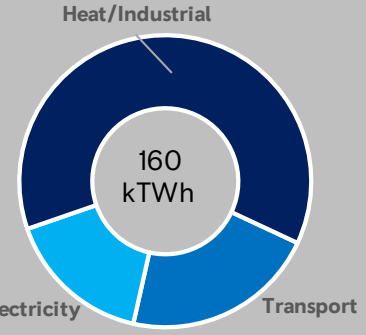


The addressable market is driven by a combination of geographical reach and extent of decarbonisation

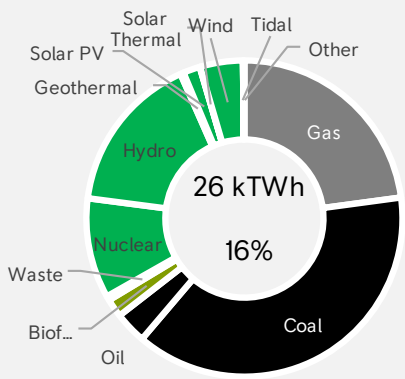
Excludes energy growth



Only 13% global energy is low carbon



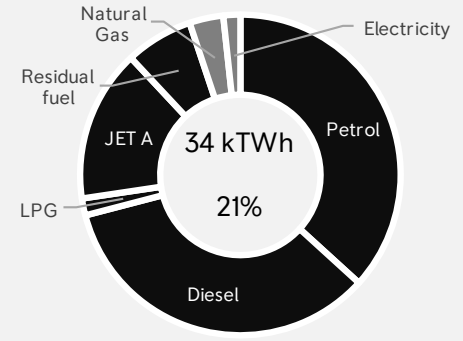
~48% of the world is addressable



- 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

Clean applications

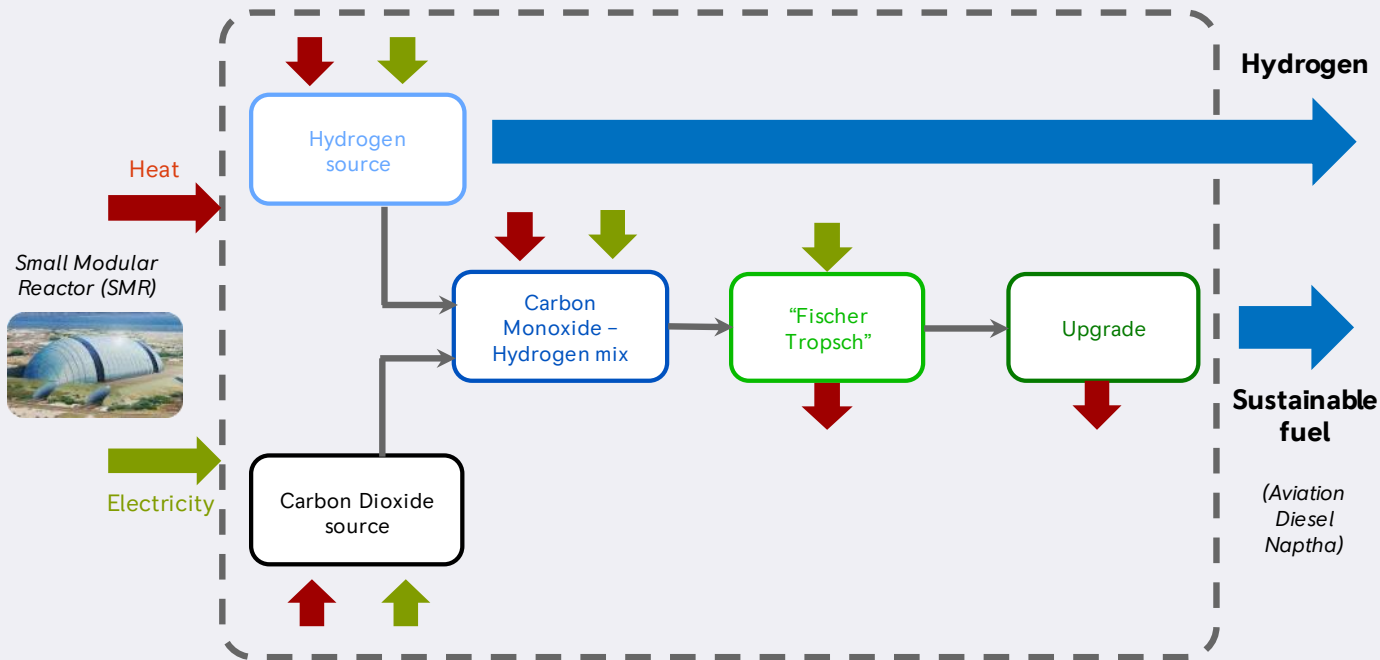
We need all sources of clean energy to decarbonise

Nuclear can play a vital role BUT NOT AT ANY COST

SMRs are perfectly suited to many of these applications

Fossil Fuel source	→		Hybridisation Lower emissions due to efficiency improvements	Primary fuel based
<u>Clean generation sources</u>	→		Electrification Carbon free power generation source dependent	<ul style="list-style-type: none">Heat potentialTransport for lower power & energy missions
<u>Clean electricity and / or heat</u>	→		Sustainable fuels Carbon neutral due to generation technology but still emitting	<ul style="list-style-type: none">Transport for higher power & energy missions
	→		Hydrogen Carbon free depending on generation technology	<ul style="list-style-type: none">Peak powerHeatTransport 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





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)

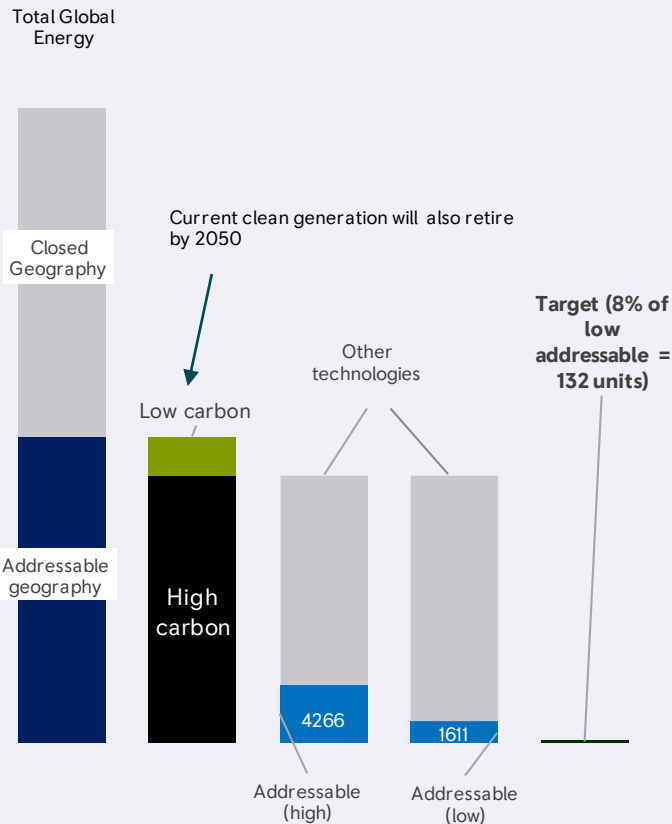


SMR Market in business case

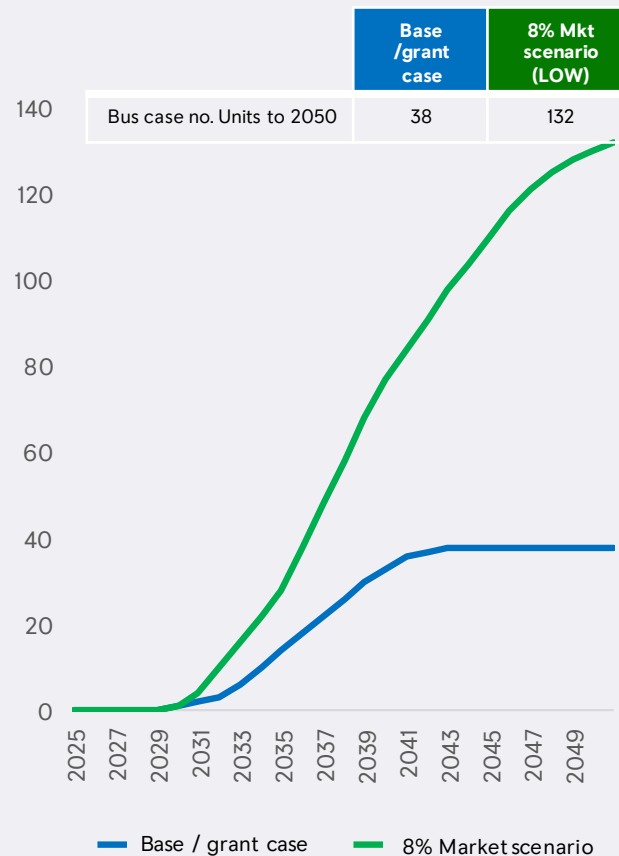
Base / Grant case (derived 2017) assumes:

- 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.



Cumulative Units in Service





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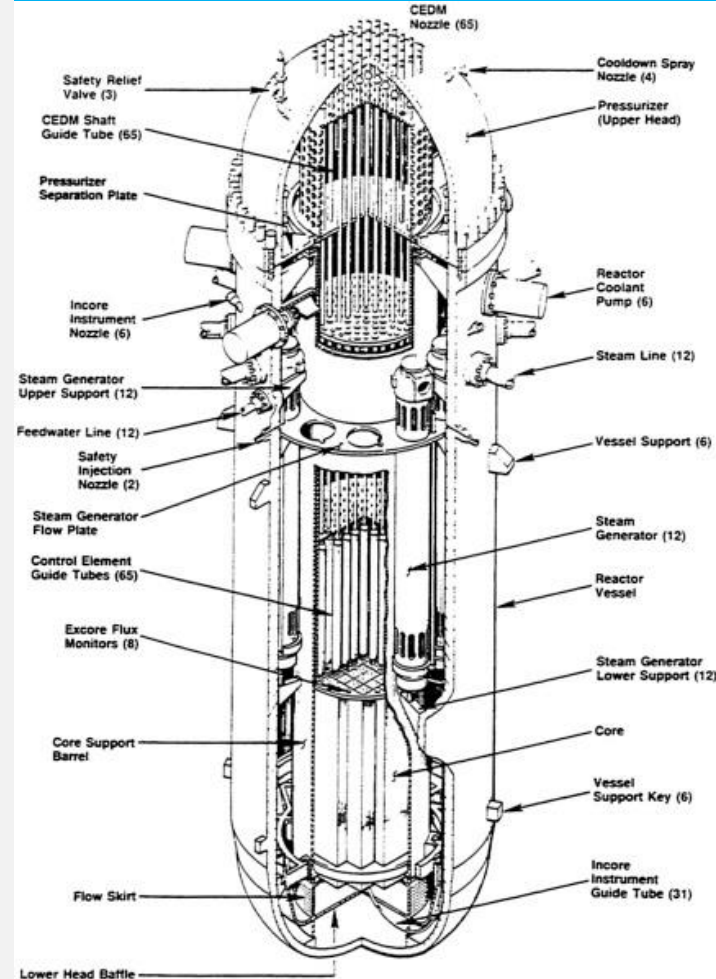
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SMRs have been around for a while, so why now?

- 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**mall 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

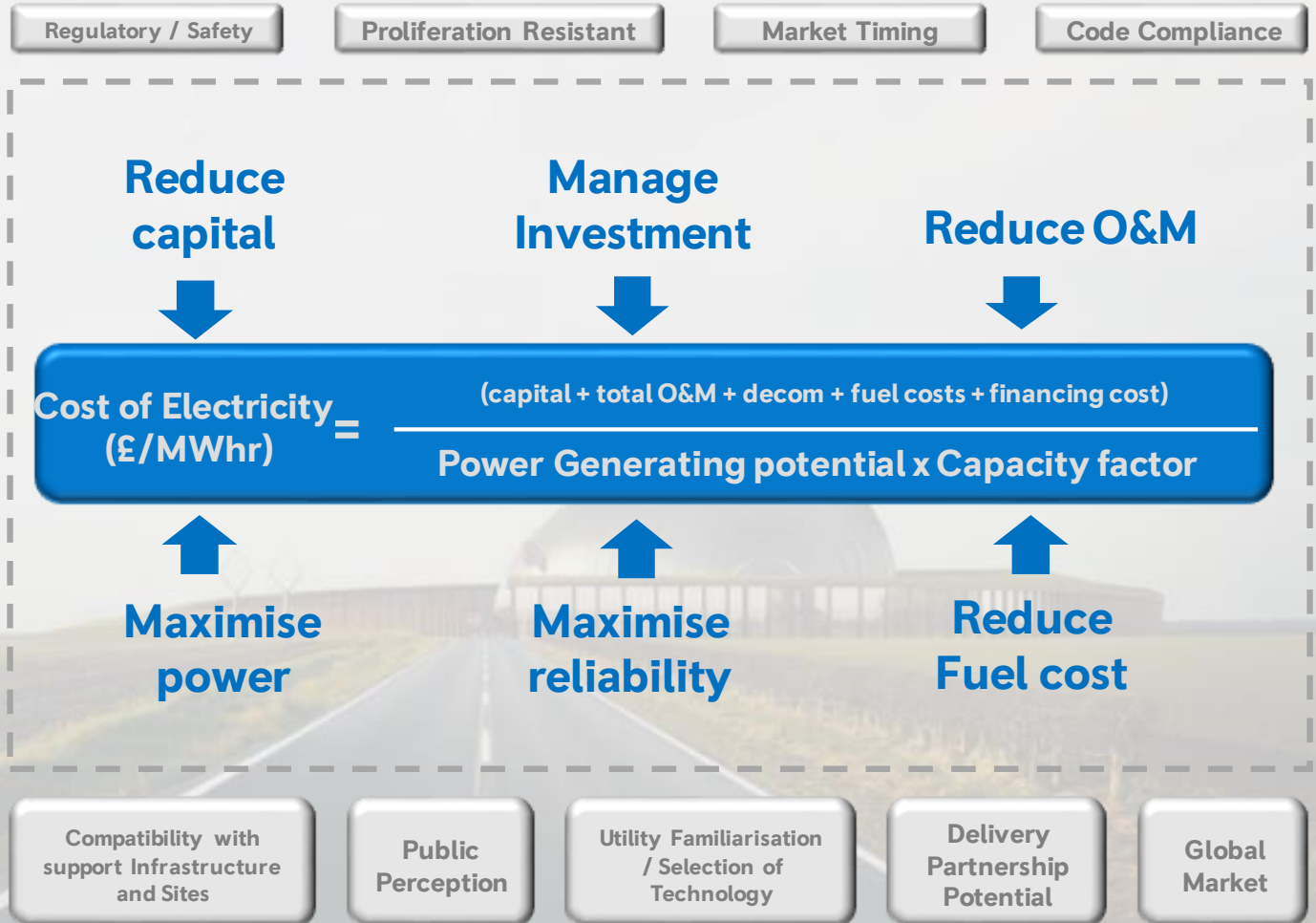
Rolls-Royce, Stone & Webster, UKAEA SIR Reactor (1990's)





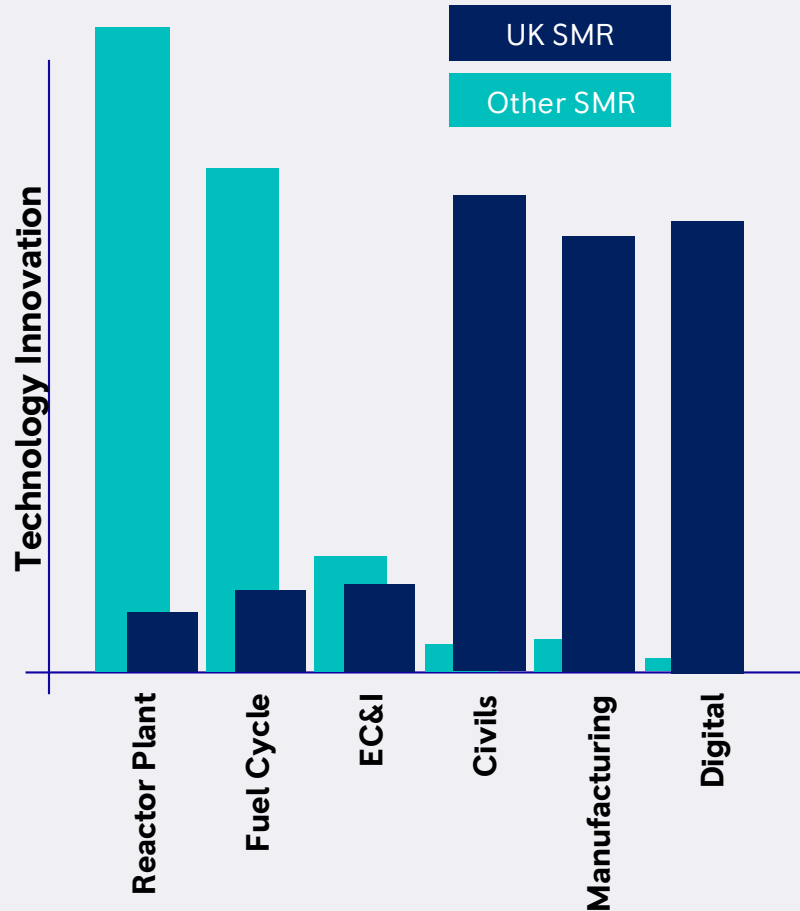
Power station design:

The principle of lowest LCOE is the primary requirement





Technology and Innovation Where it Adds Value



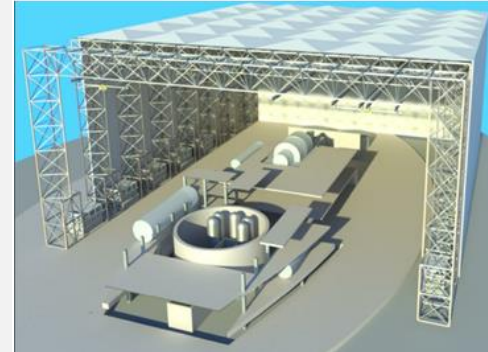
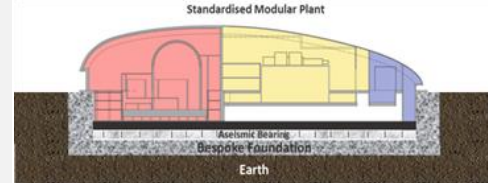
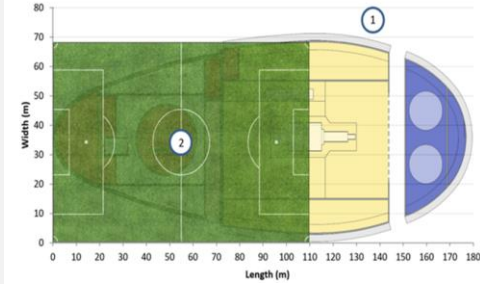
- Reactor Plant
 - Conventional reactor system
 - Proven materials
 - Conventional temperatures
- Fuel Cycle
 - Standard fuel
 - Minimal geometric change
- EC&I
 - Digital I&C
- Civils
 - Aggressively modularised civils
 - Off-site construction & build certainty
- Manufacturing
 - Modular manufacture
 - 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 / approach overview:

400 – 450 MWe 3 Loop PWR

Industry-Standard UO2 Fuel

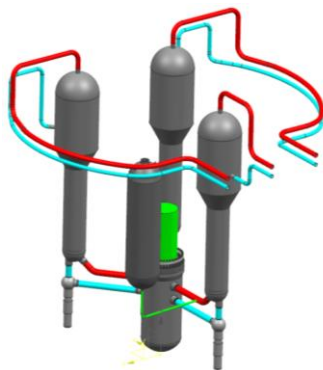
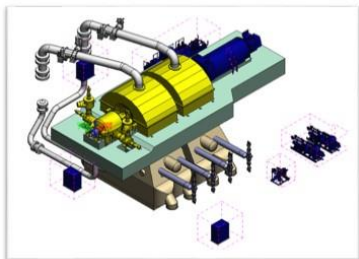
Compatible with Existing Infrastructure

Designed for Road Transport

Passive Safety Systems

Maintenance and Operations Access

Cost reduction - standardisation



Build time reduction - Modular Manufacture

Nuclear Island

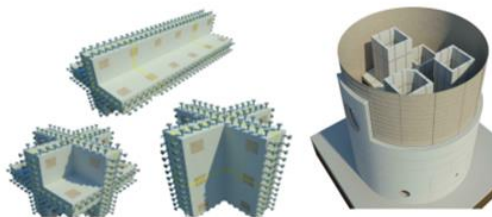


BOP & systems

Factory testing and commissioning

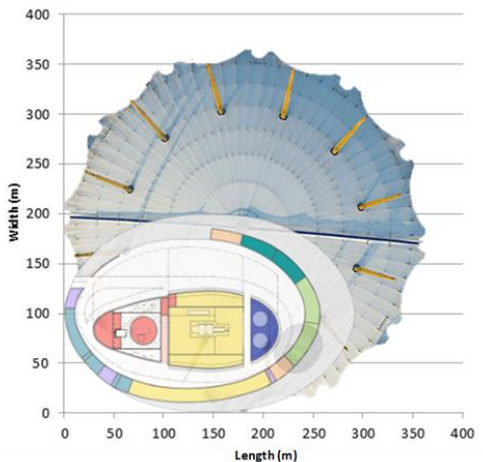
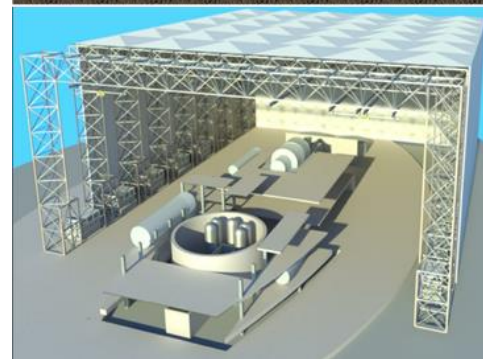
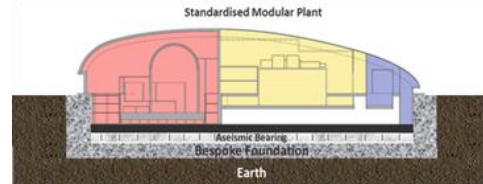


Civil construction



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

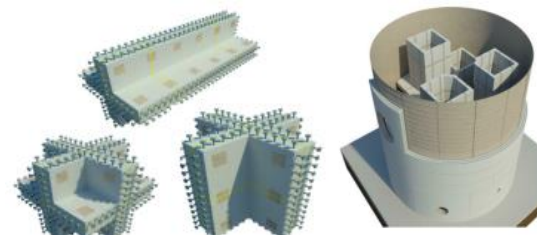
Nuclear Island



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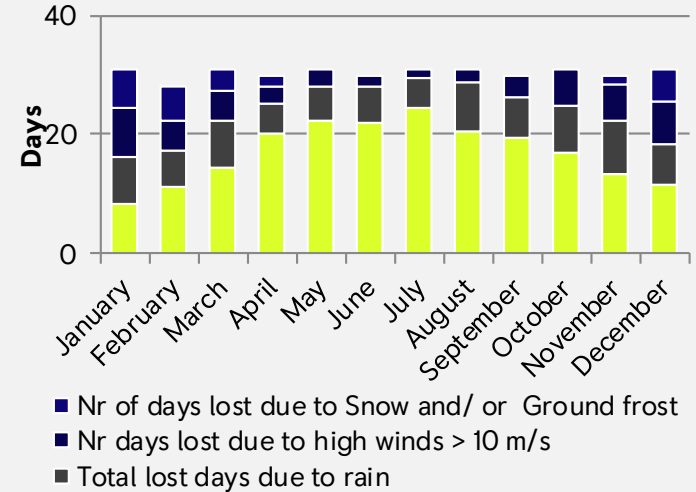
The Site Assembly Facility can provide major benefits in certainty of costs and schedule

- 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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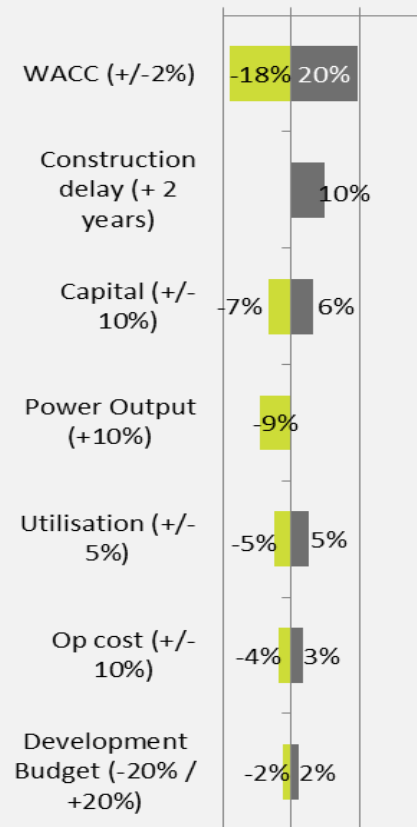


The electricity economics are dominated by certainty which can bring cheaper financing

- 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

LCOE sensitivity assessment

-20% 0% 20% 40%

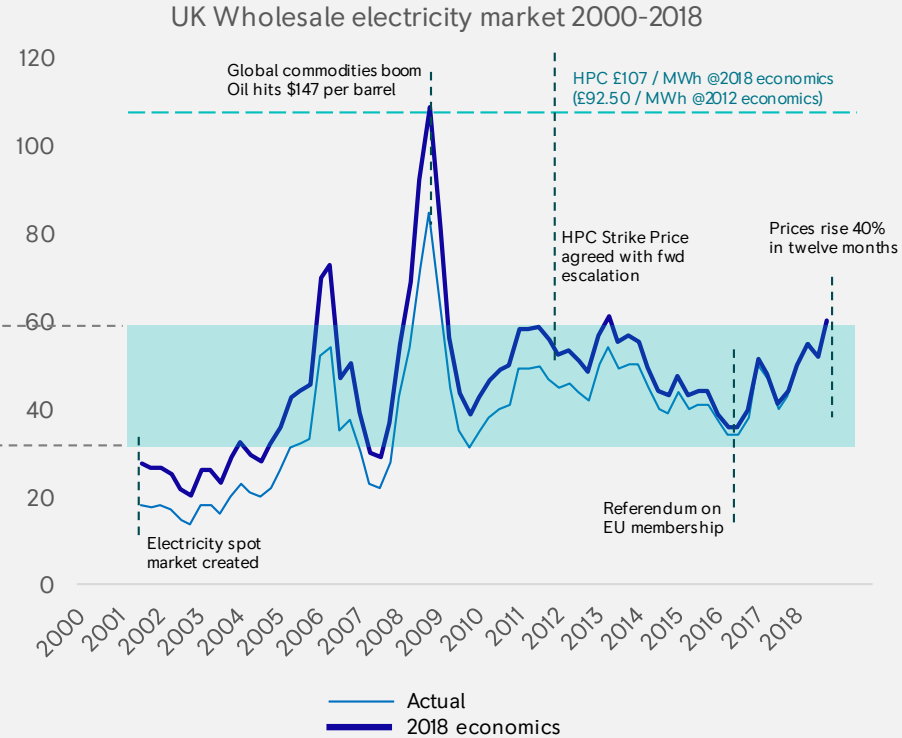
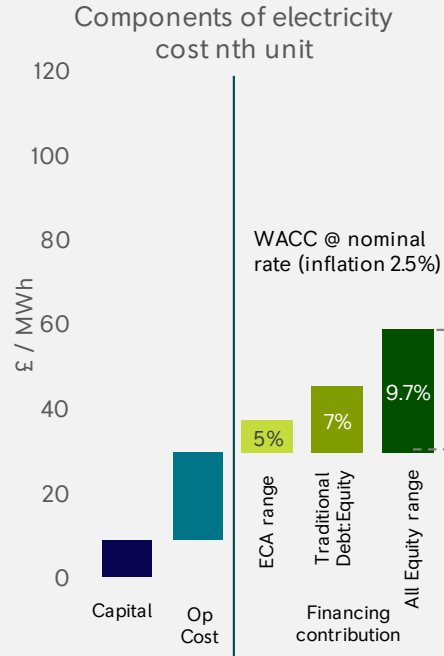




Electricity Market pricing

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



UK SMR

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JACOBS



NATIONAL NUCLEAR
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