energy technologies institute

www.eti.co.uk

Preparing For The Deployment Of A UK SMR By 2030

Presentation At The Small Modular Reactor UK Summit - 19th October 2016

Mike Middleton – Strategy Manager for Nuclear

Presentation Structure

Introduction to the ETI

- The Energy Technologies Institute - what do we do?
- An affordable energy system transition
- Nuclear in a UK low carbon 2050 energy system

The ETI's recent projects and analysis –

- SMR Deployment Enablers Project – delivered by Decision Analysis Services
- Alternative Nuclear Technologies Study Phase 3 – delivered by Mott MacDonald
- Power Plant Siting Study Phase 3 – delivered by Atkins

Integrated analysis and conclusions

Introduction to the ETI organisation

energy technologies institute

- The ETI is a public-private partnership between global energy and engineering companies and the UK Government.
- Targeted development, demonstration and de-risking of new technologies for affordable and secure energy
- Shared risk

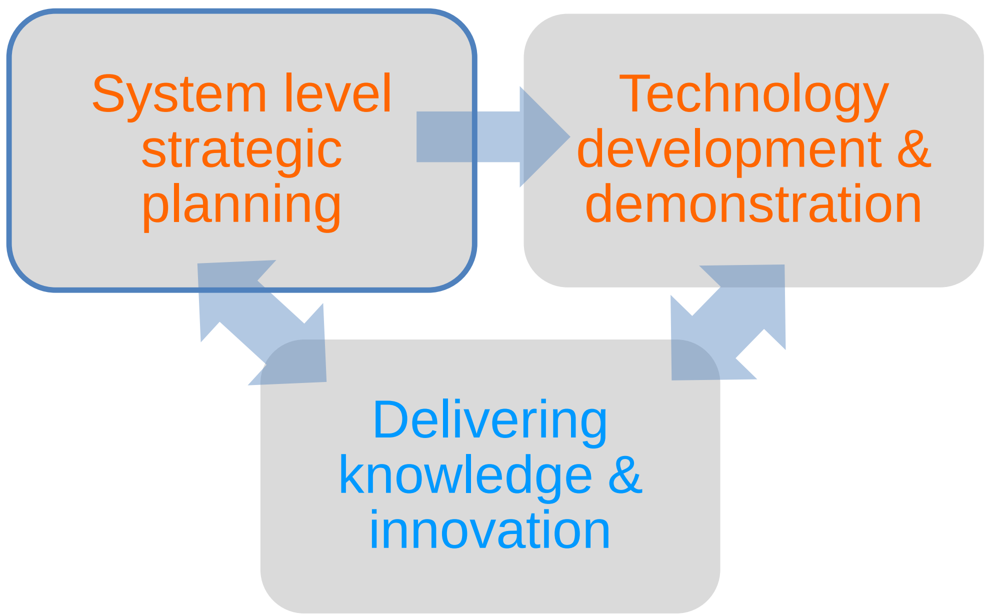
ETI members

- bp
- CATERPILLAR®
- EDF ENERGY
- Rolls-Royce
- Shell
- Department for Business, Energy & Industrial Strategy
- EPSRC Pioneering research and skills
- Innovate UK Technology Strategy Board

ETI programme associate

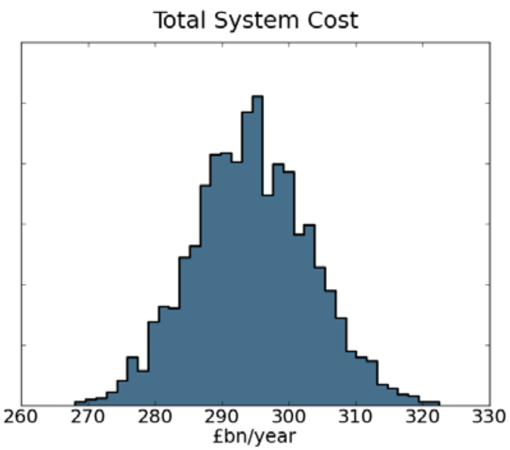
- HITACHI Inspire the Next

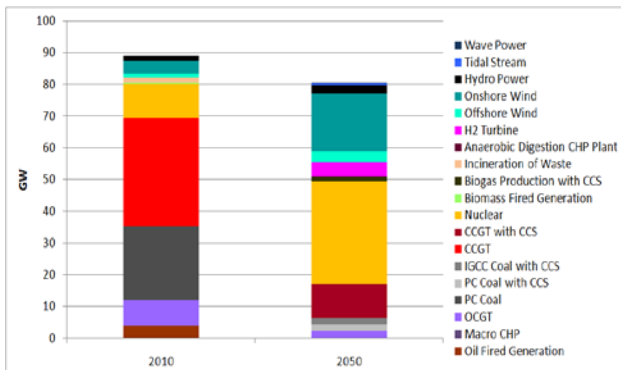
What does the ETI do?

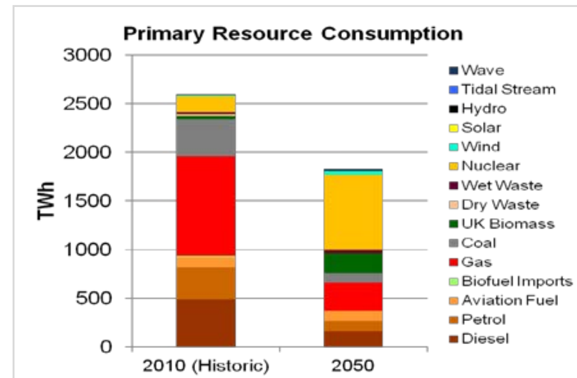


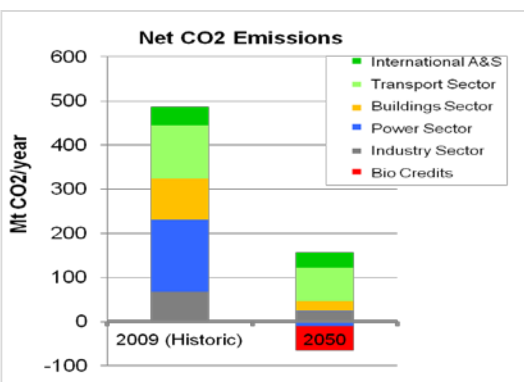
ESME – The ETI’s system design tool

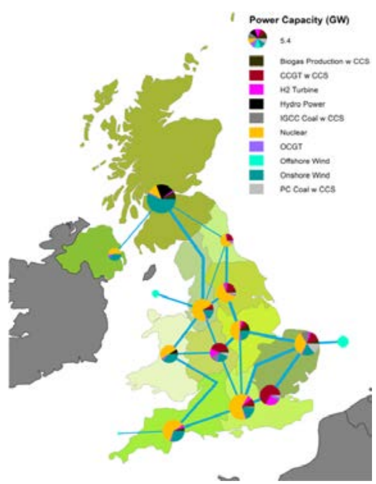
Integrating power, heat, transport and infrastructure providing national / regional system designs

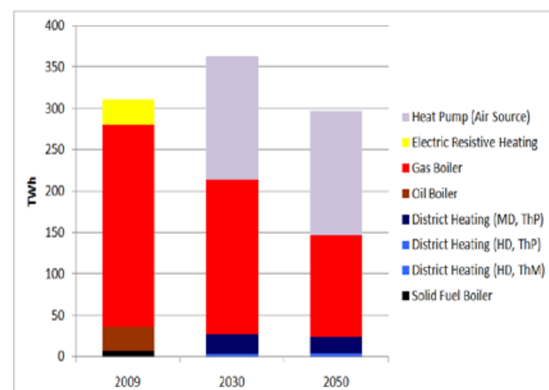






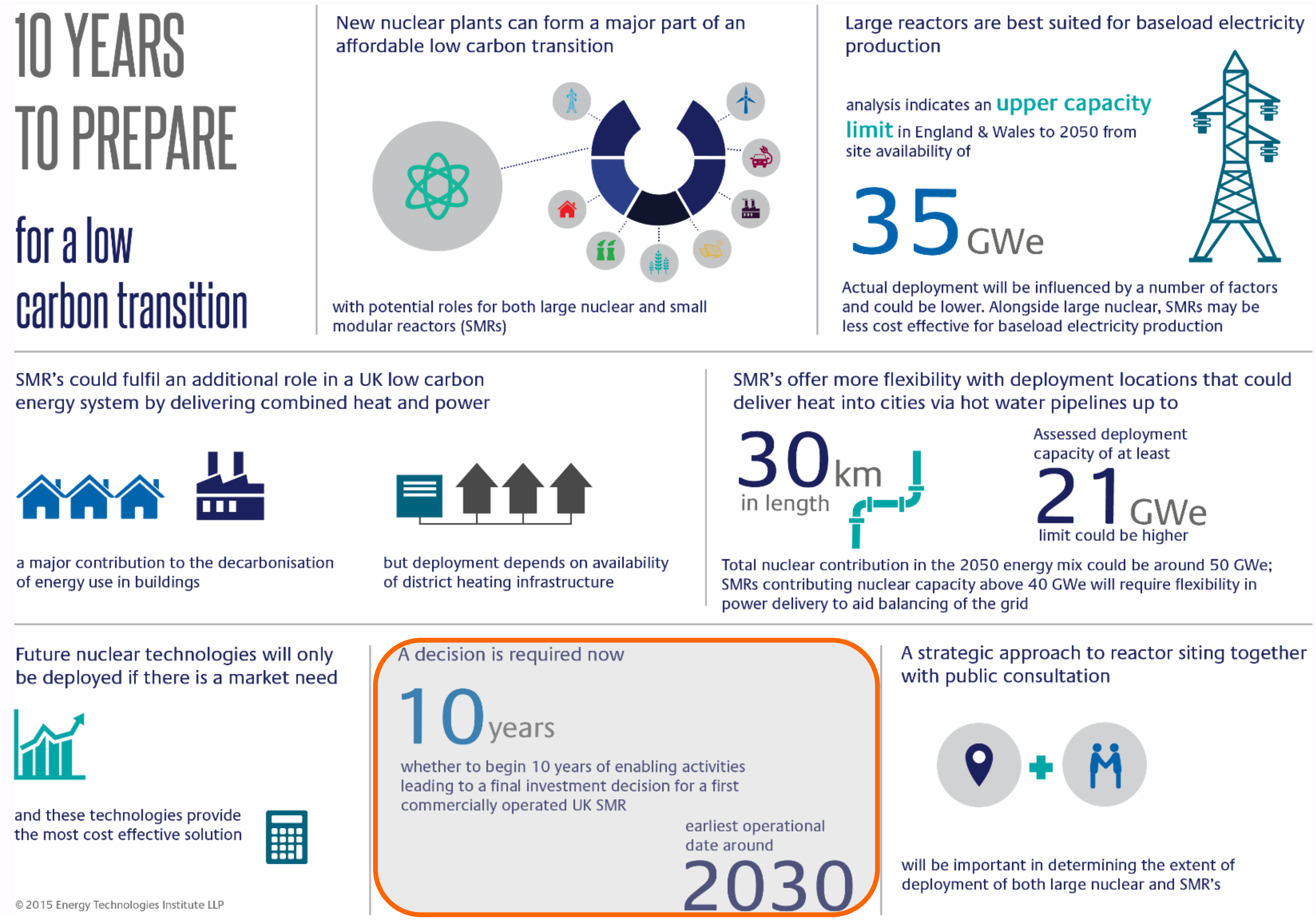






ESME example outputs

Conclusions from published ETI insights (1) – role for nuclear in a low carbon energy system



http://www.eti.co.uk/the-role-for-nuclear-within-a-low-carbon-energy-system/

Further ETI Projects Relevant To UK SMRs

What are the enabling activities in the first five years of an SMR programme necessary to support potential operations of a first UK SMR by 2030?

- SMR Deployment Enablers Project

What are the design, cost and operational implications of committing to a plant which is CHP ready when built? What are the potential cooling system choices and economic impacts if unconstrained access to cooling water becomes more difficult?

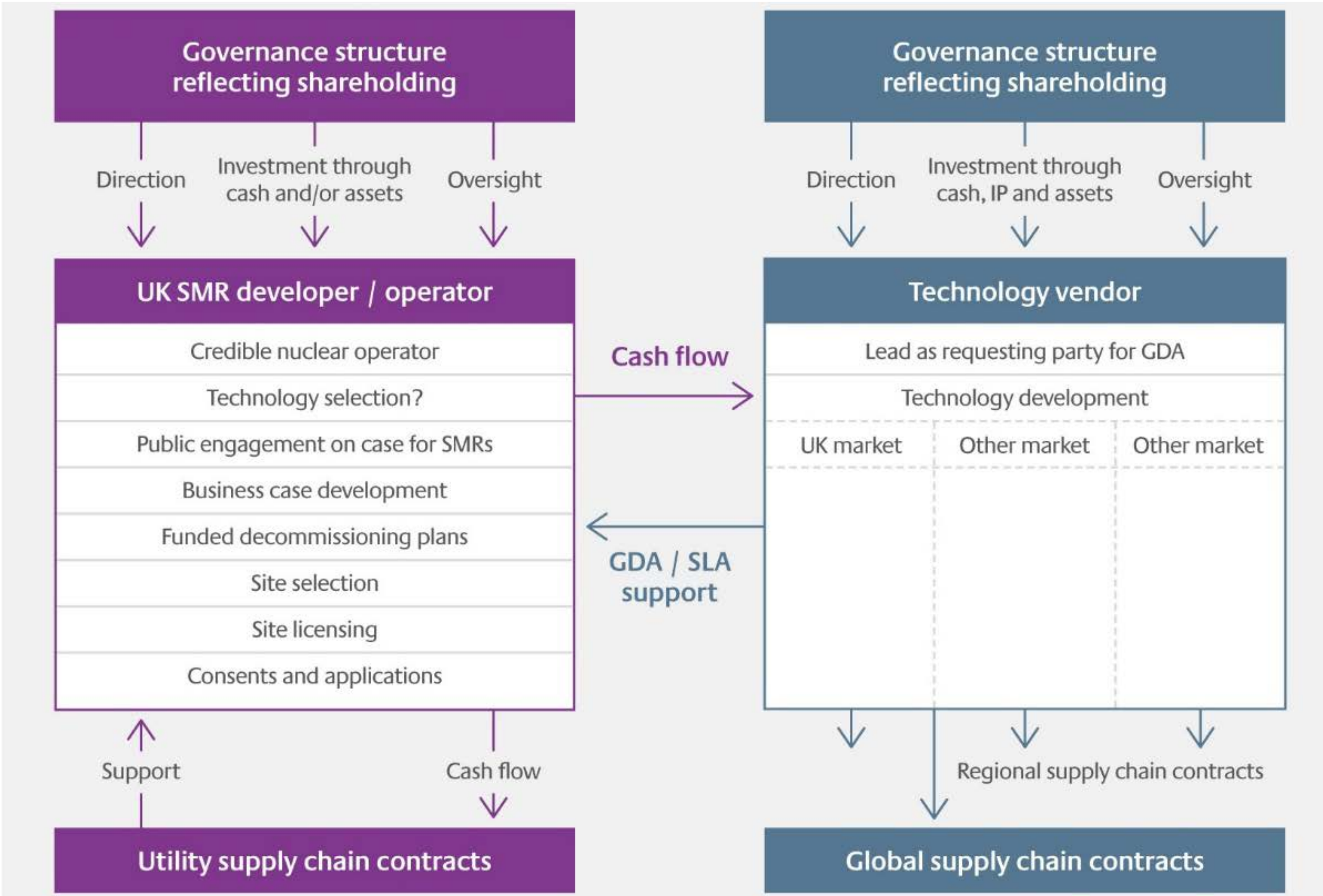
- System Requirements For Alternative Nuclear Technologies Phase 3

What is the range of locations suitable for early SMR deployment and is there an obvious front runner for a First Of A Kind (FOAK) SMR site?

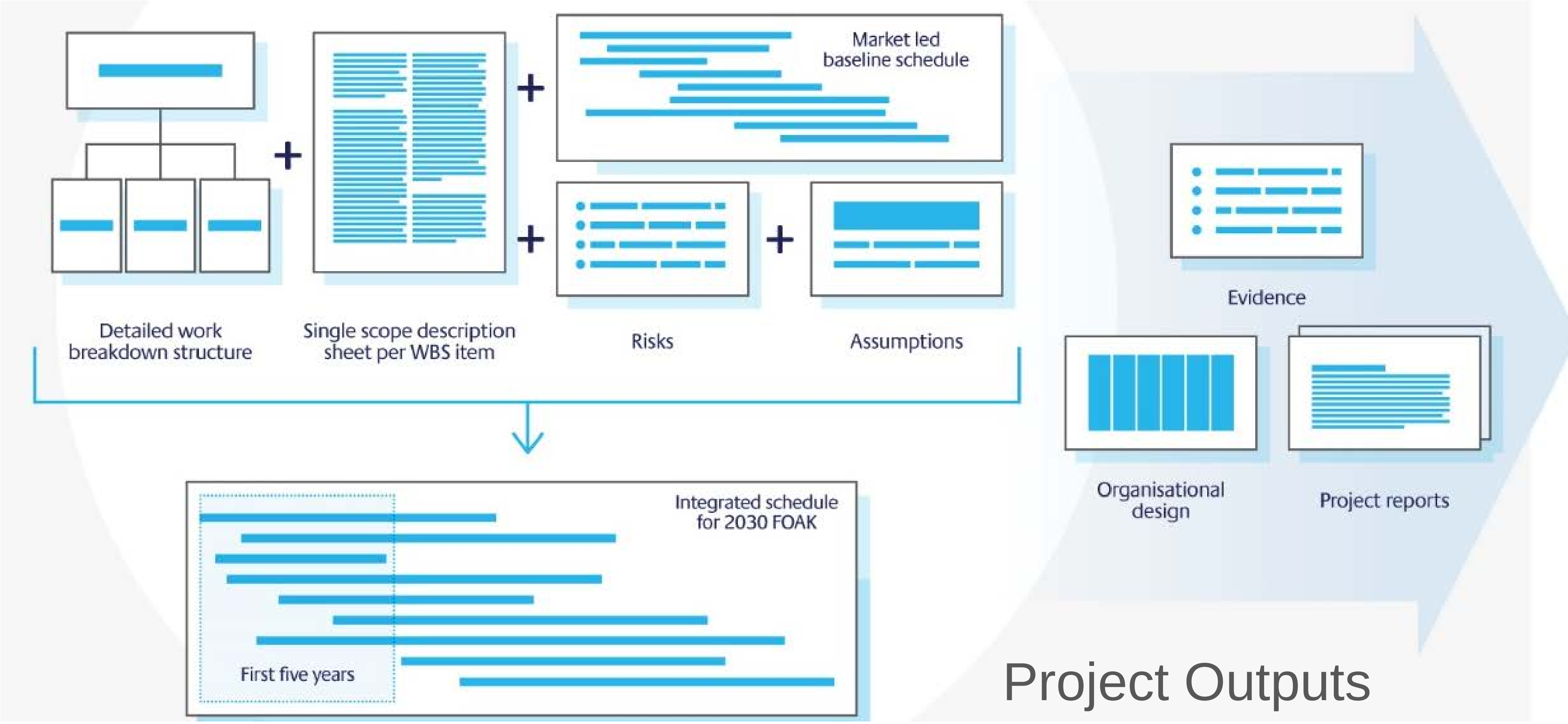
- Power Plant Siting Study Phase 3

Key Elements Of A UK SMR Development Programme

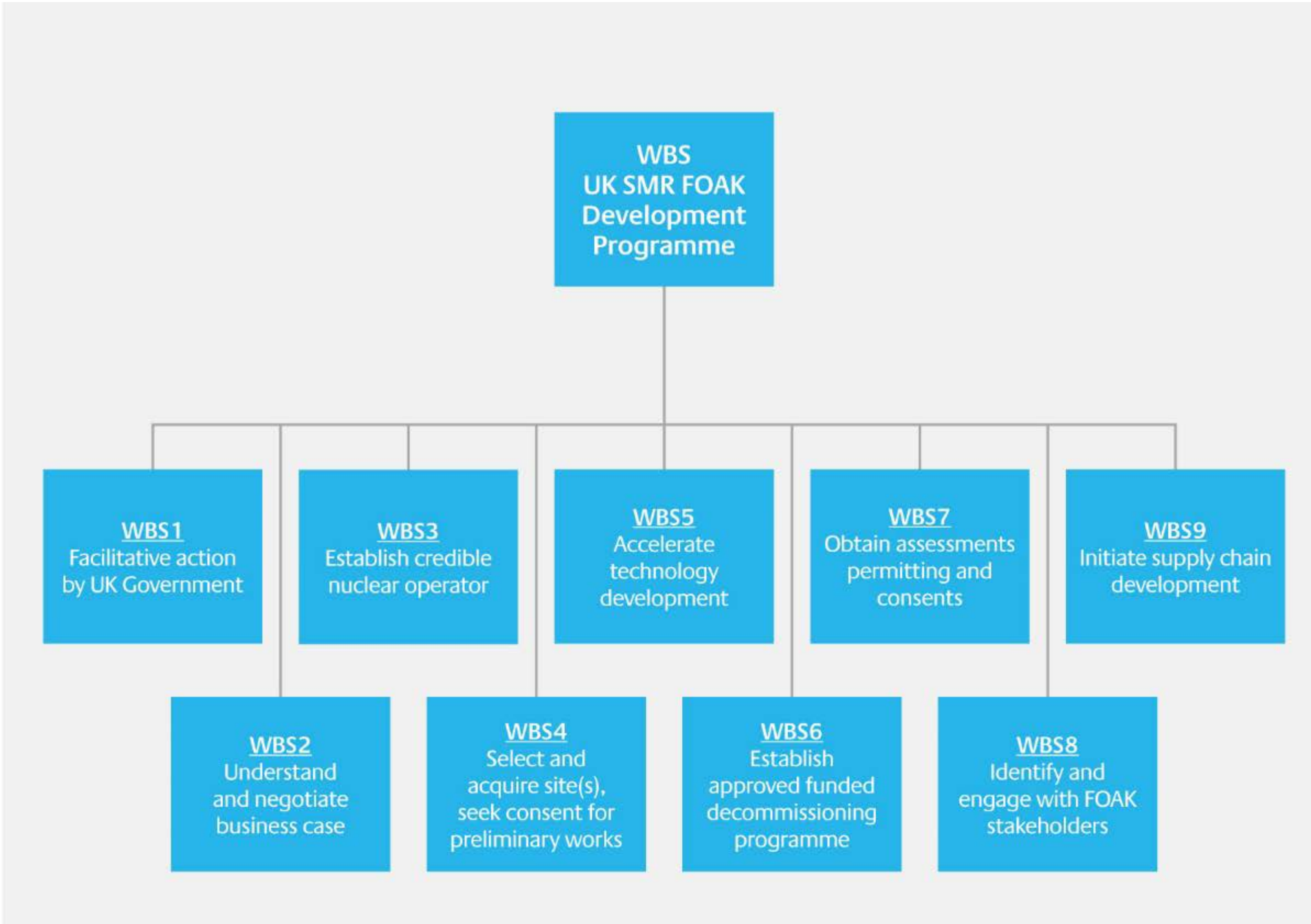
Developer And Vendor – Typical Relationship From UK GW Reactor New Build Projects



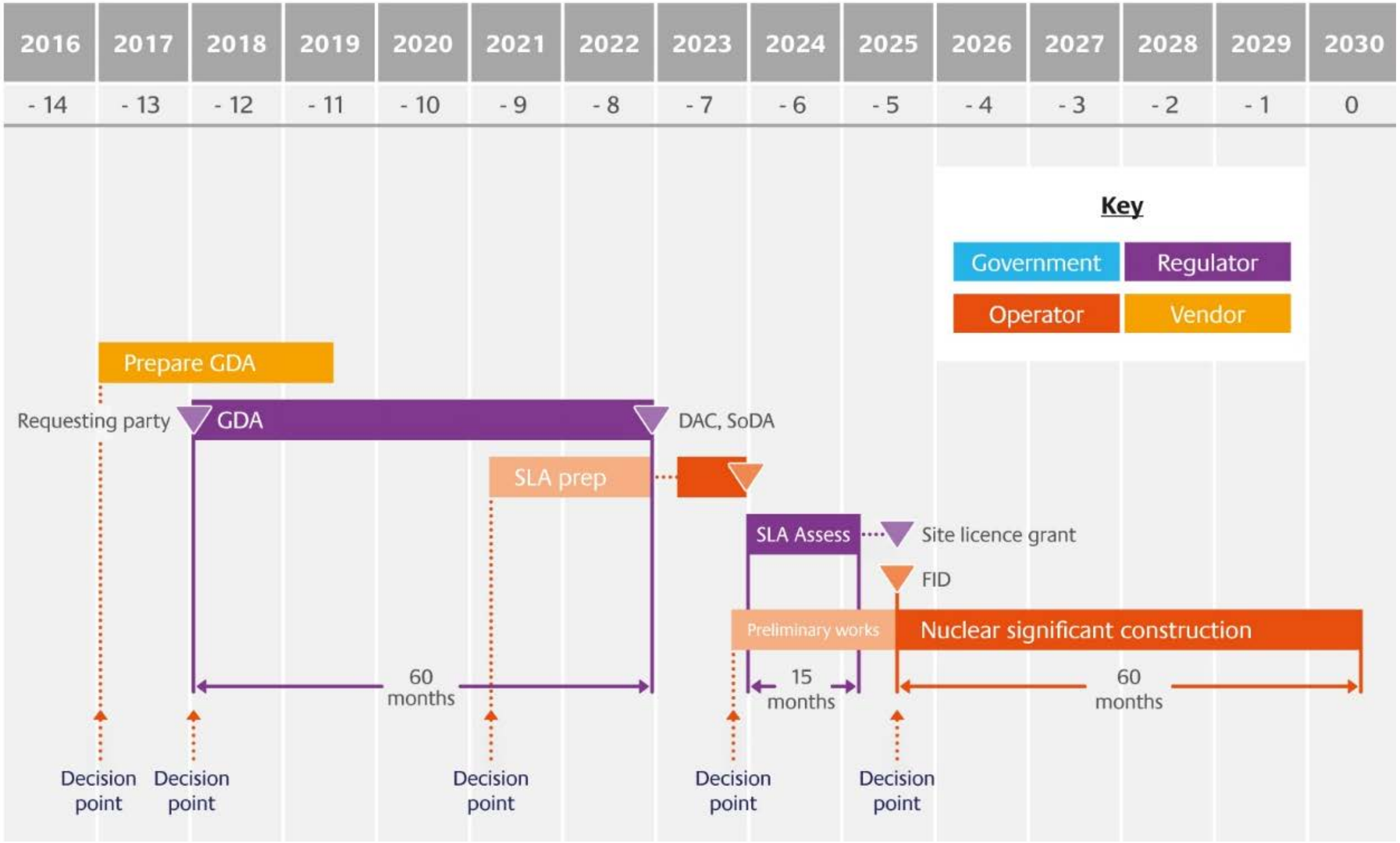
Systematic Application Of Project Tools



Work Breakdown Structure In SDE Analysis



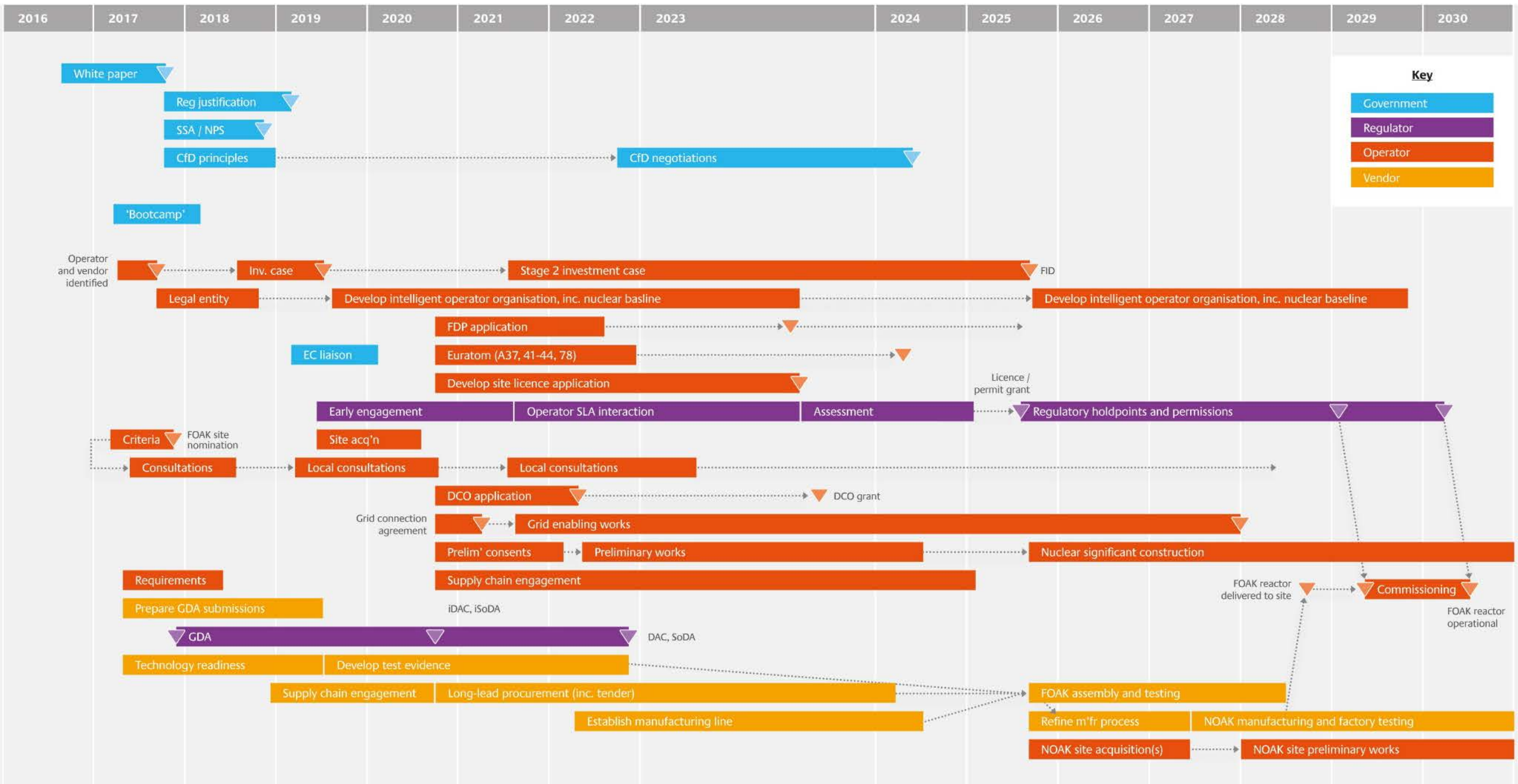
The Critical Path Of A 2030 Schedule



Key dates & assumptions (durations):

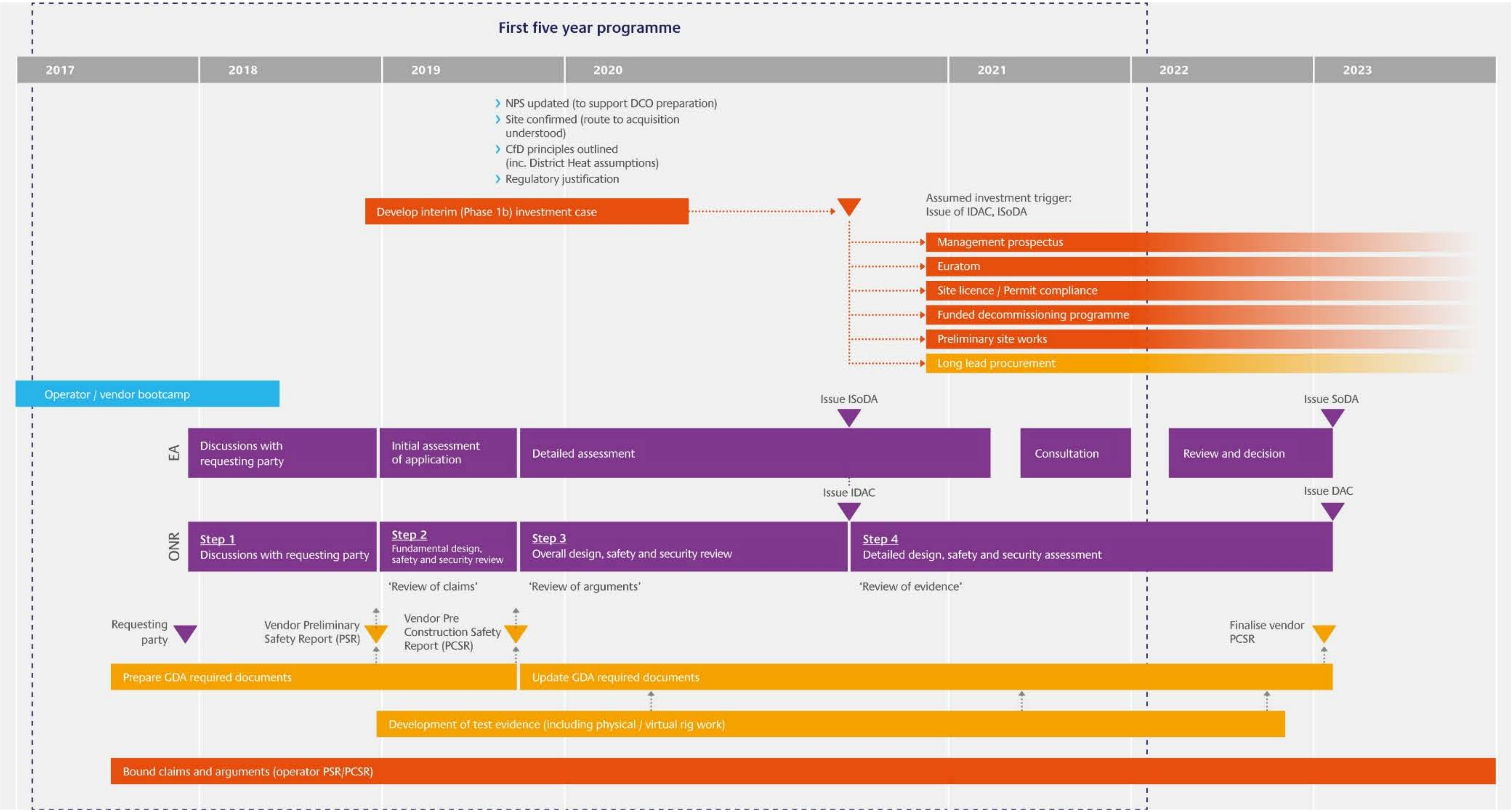
- GDA starts end 2017 (5 years)
- Site licensing preparations from early 2021 (4 and a half years)
- Site preliminary end 2023 (21 months)
- FID 2025 followed by nuclear construction and commissioning (5 years)

Integrated Schedule Leading To FOAK Operations By 2030



With UK Government Facilitation of enabling activities, vendor and developer activities can proceed in parallel - facilitation enables deployment acceleration

Enabling Activities In The First 5 Years



Services Required From A UK SMR

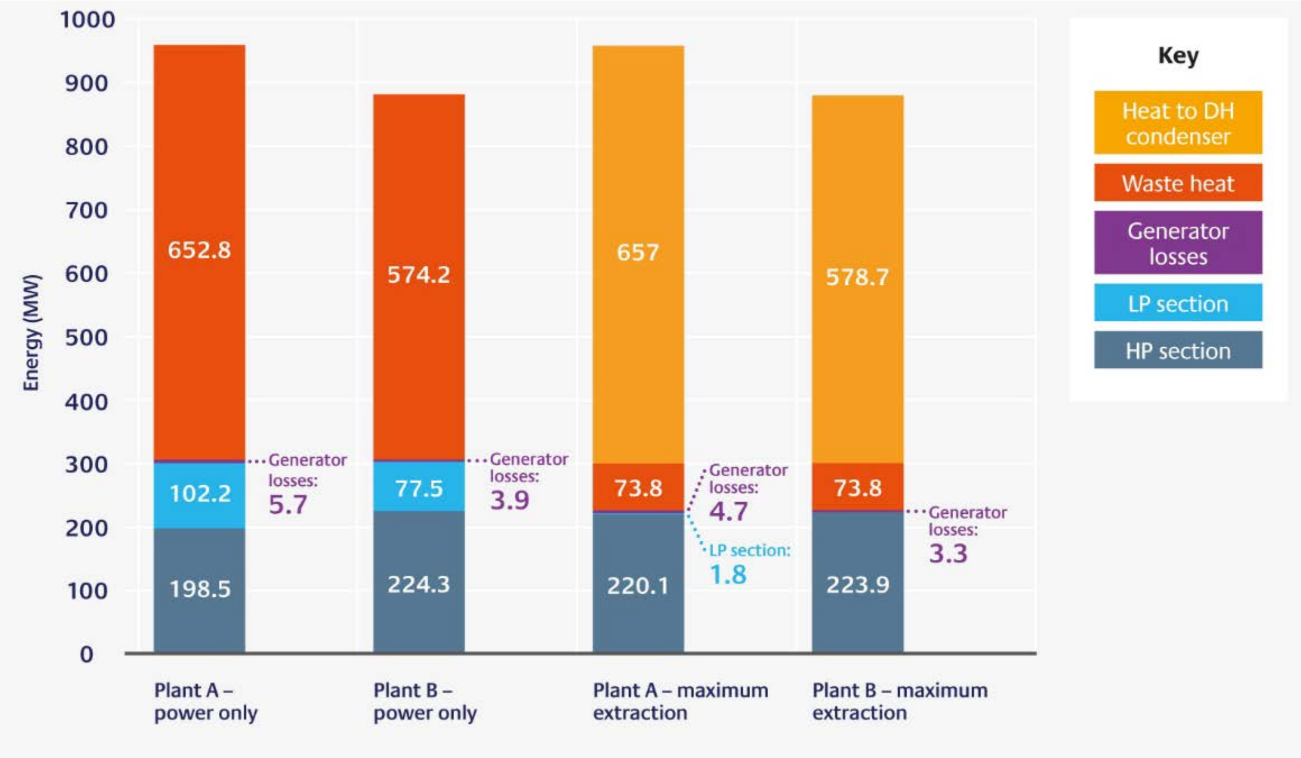
Large reactors optimal here

		Baseload	Flexible	Extra-flex
	Electricity only SMR power plant	Baseload power (continuous full power operation between outages)	Operated with daily shaped power profile when required to help balance the grid	(Slightly) reduced baseload power with extra storage & surge capacity
	Combined Heat & Power (CHP) plant	As above but with heat	As above but with heat	As above but with heat

Power, heat and flexibility

SMRs optimal here

SMRs For CHP – Analysis Of Impact Of Module Size and Thermal Efficiency



Results scaled for same electricity output (300 MWe) when operated in power only mode

System design and cost estimation used to compare heat extraction from:
A - smaller, reactor module and secondary steam system with lower thermal efficiency, against
B - larger reactor module and secondary steam system with higher thermal efficiency

Conclusions

- An SMR with relatively lower thermal efficiency produces more heat
- An SMR selected for cost effectiveness for power will still be cost effective for CHP

CHP – Comparison With Earlier Work and Impact On Internal Rate of Return

		ANT1&2 (power only)	ANT1&2 (CHP)	ANT 3 Plant A (CHP)	ANT 3 Plant B (CHP)
Model	Gross electrical efficiency in power-only mode	37%	37%	31.4%	34.4%
	CHP CAPEX increment - £/kW$_e$ (net)	-	£200	£544	£529
	CHP OPEX increment - £/kW$_e$ p/a (net)	-	£5	£4	£4
	Scenario 1: Base electricity-only plant CAPEX = ~£4,700 (indicative cost scenario from Phases 1& 2)				
	Model output – internal rate of return	7.7%	11%	11.2%	10.6%
	Scenario 2: Base electricity-only plant CAPEX = ~£3,600 (target cost from Phases 1 and 2)				
	Model output – internal rate of return	10.1%	13.7%	13.7%	13.0%

Scenarios from previous modelling work reported earlier:

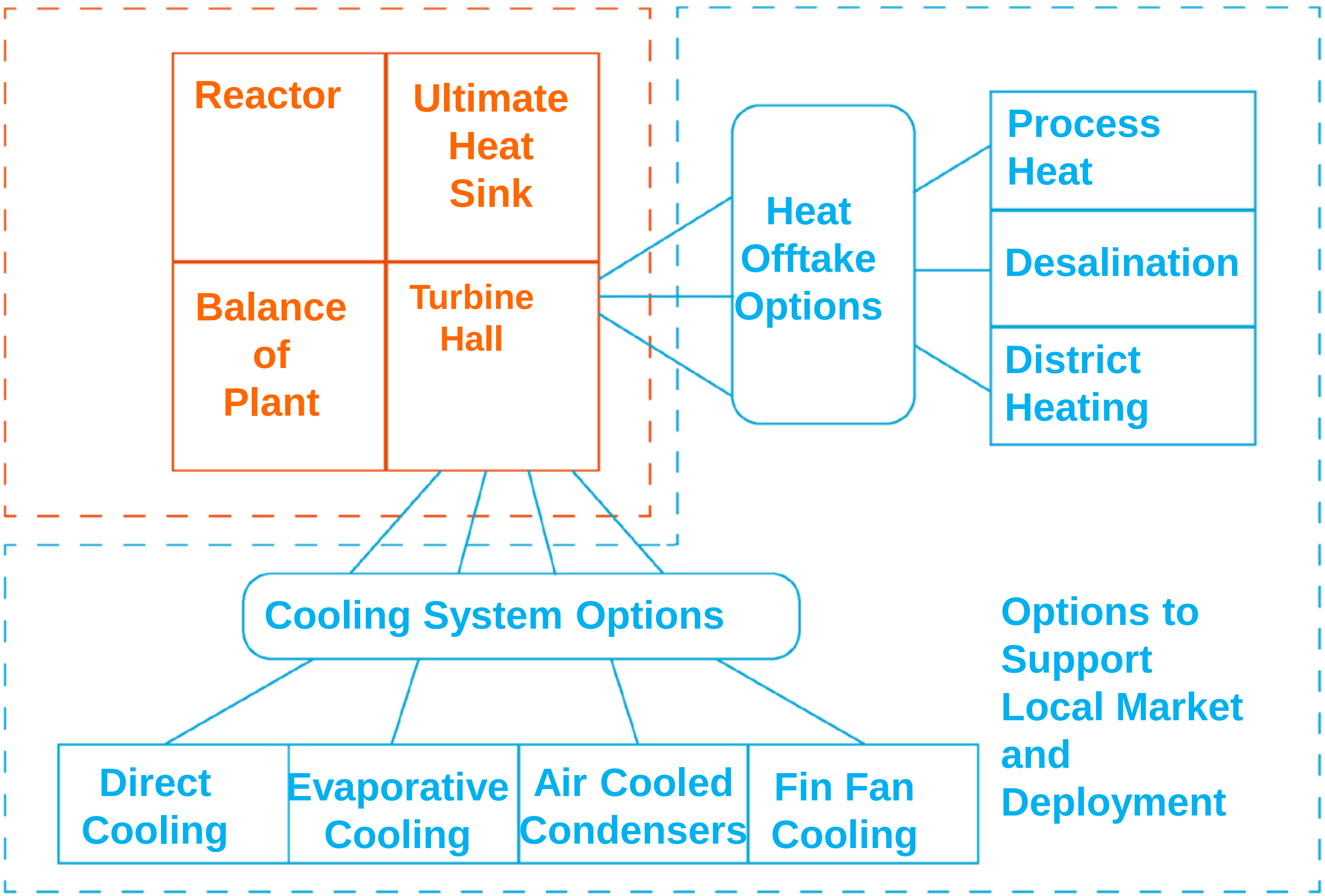
1. Indicative NOAK CAPEX of around £4,700/Mw$_e$
2. Competitive baseload CAPEX target of £3,600/Mw$_e$

Conclusions:

- SMR economics more favourable as CHP plants compared with electricity only
- Details within analysis have changed from earlier work, but conclusions have not
- Economic differences between plants A and B are small when modified for CHP

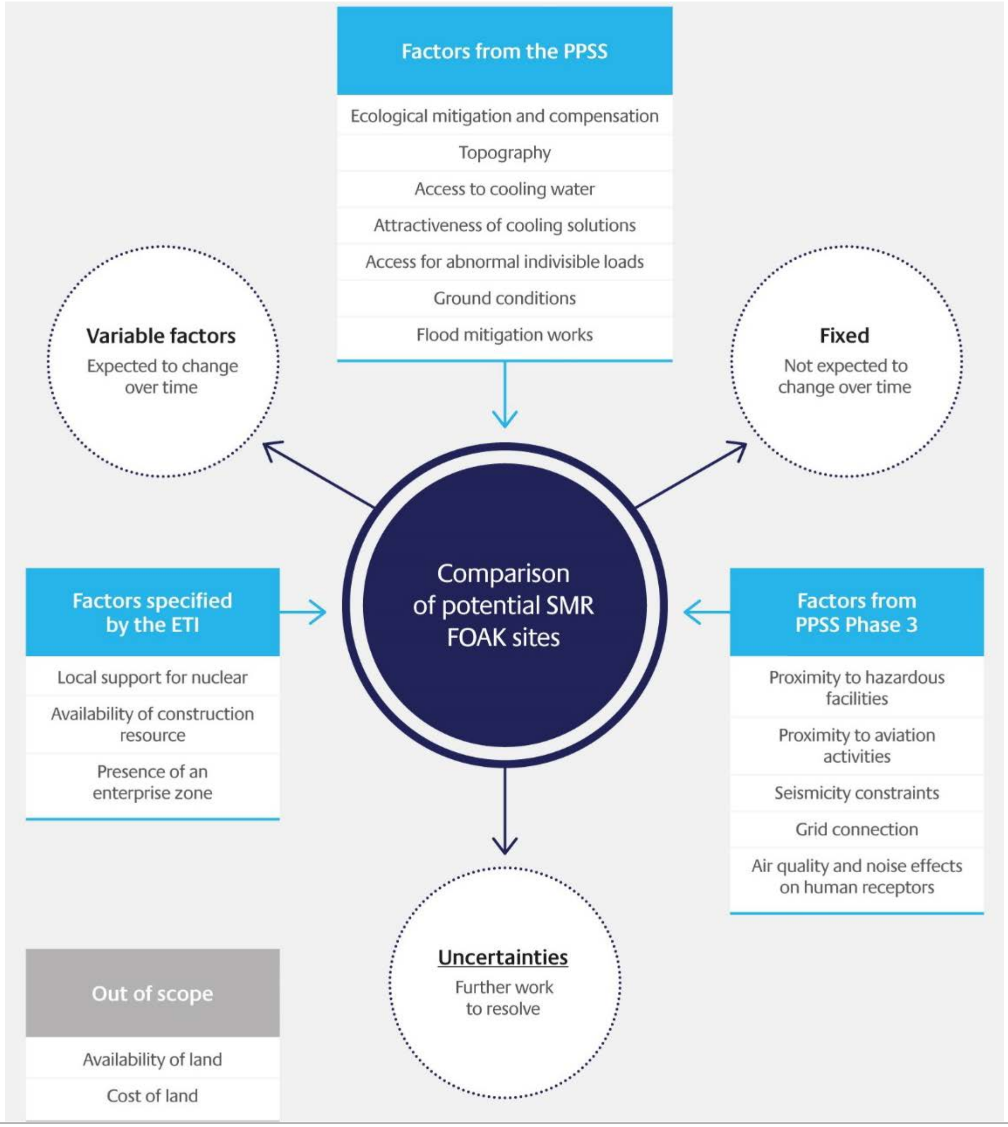
Exploiting The Economies Of Multiples – UK GDA and Coping With Variants

Standardise To Exploit Economies of Multiples



Scope of Design To Be Assessed Through Generic Design Assessment

Comparison Of Potential Early SMR Sites Using Ranking Factors



Conclusions - Preparing for deployment of a UK SMR by 2030

A credible integrated schedule for a UK SMR operating by 2030

depends on early investor confidence

The Government has a crucial role to play

in delivering a policy framework which supports SMR deployment and encourages investor confidence

If SMRs are to become an integral part of a 2050 UK energy system, deployment should address future system requirements including

power

heat

flexibility

SMR factory production can accelerate cost reduction

UK SMRs designed and deployed as "CHP ready"

Extra costs are small and potential future revenue large

UK SMRs should be designed for a range of cooling systems

including air cooled condensers

There is economic benefit in deploying SMRs as CHP to energise district heating networks; this depends on district heating roll out

There is a range of sites suitable for early UK SMR deployment

Including options for the UK first of a kind site

http://www.eti.co.uk/insights/preparing-for-deployment-of-a-uk-small-modular-reactor-by-2030

Registered Office
Energy Technologies Institute
Holywell Building
Holywell Park
Loughborough
LE11 3UZ

For all general enquiries telephone the ETI on 01509 202020.

For more information about the ETI visit www.eti.co.uk

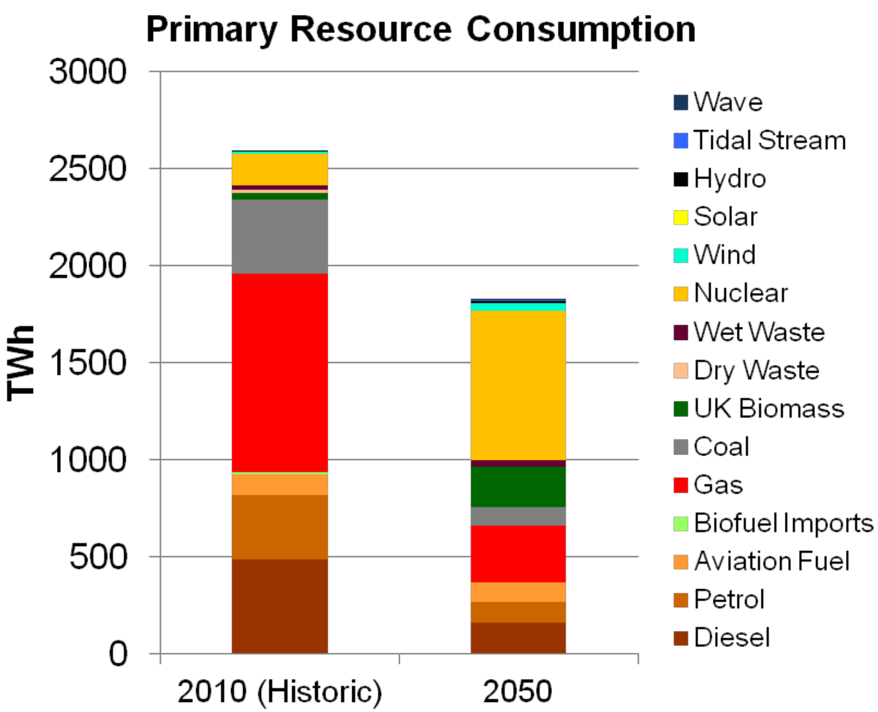
For the latest ETI news and announcements email info@eti.co.uk

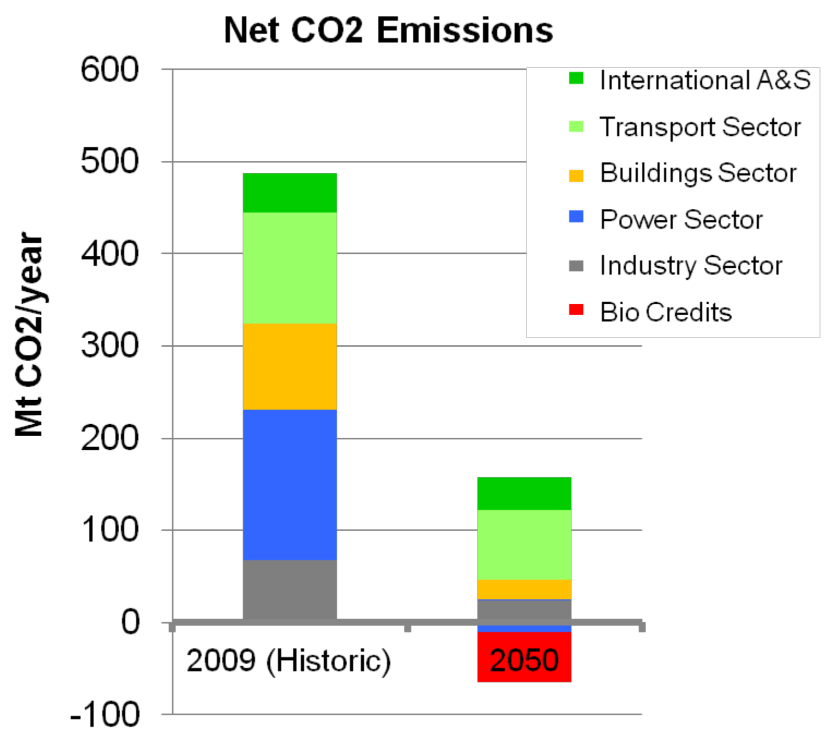
The ETI can also be followed on Twitter @the_ETI

Back Up Slides

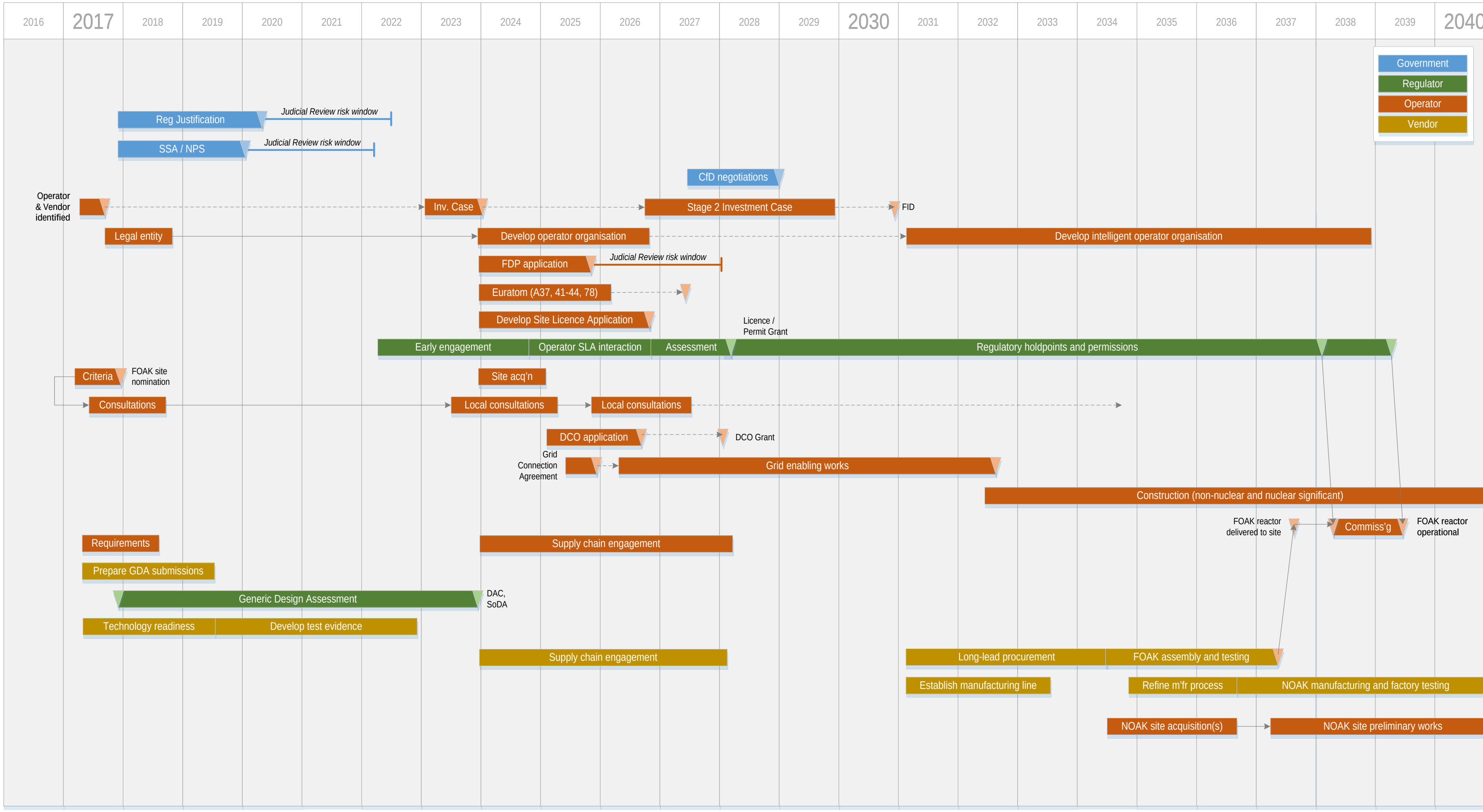
Priorities for the UK energy system

Efficiency (inc. Smart), Nuclear, CCS, Bioenergy, Offshore Wind and Gases are immediate development priorities



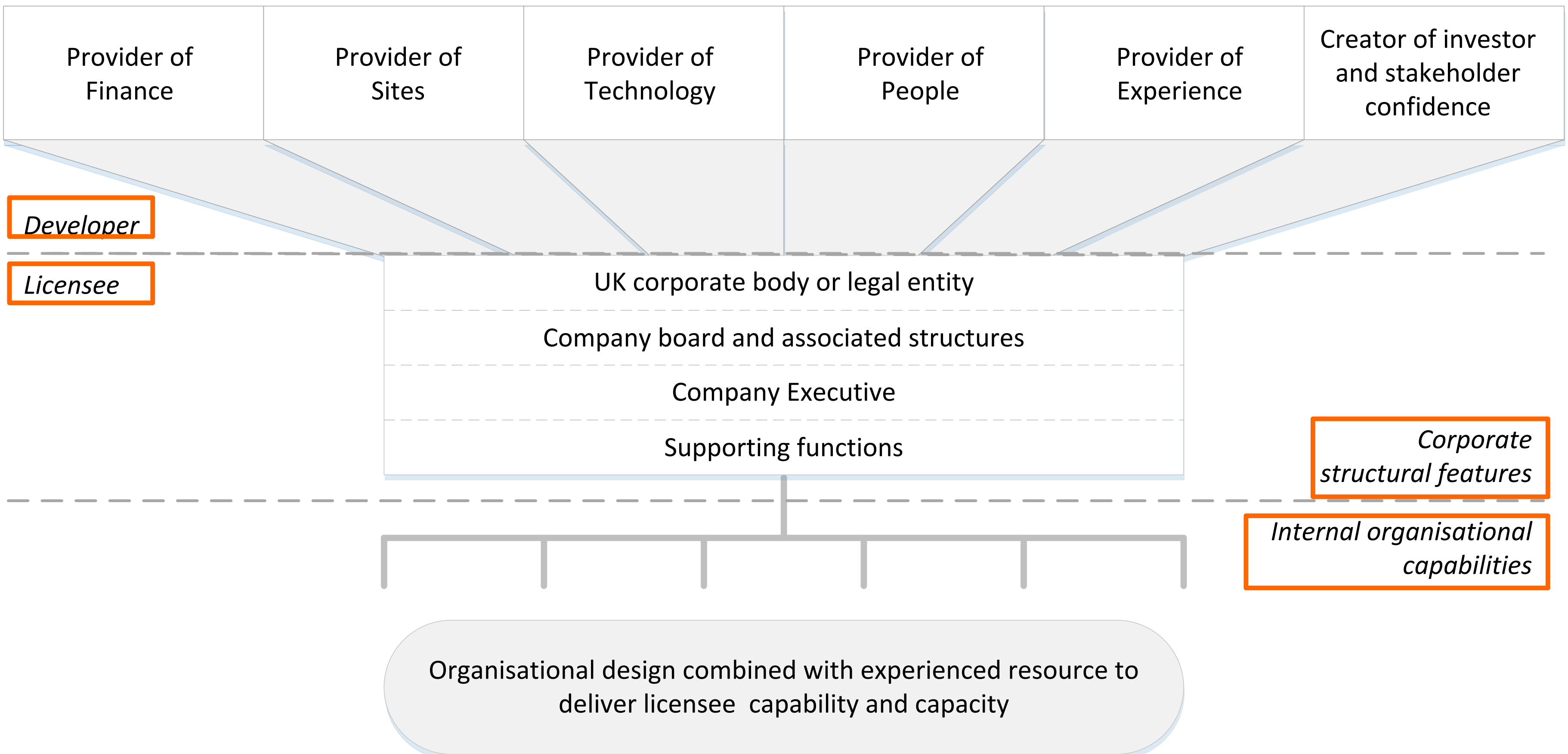


Market led Schedule – First Operations 2040?



Breadth and scale of the challenge – look beyond technology/GDA to the necessary speed and sequence of activities order to achieve success

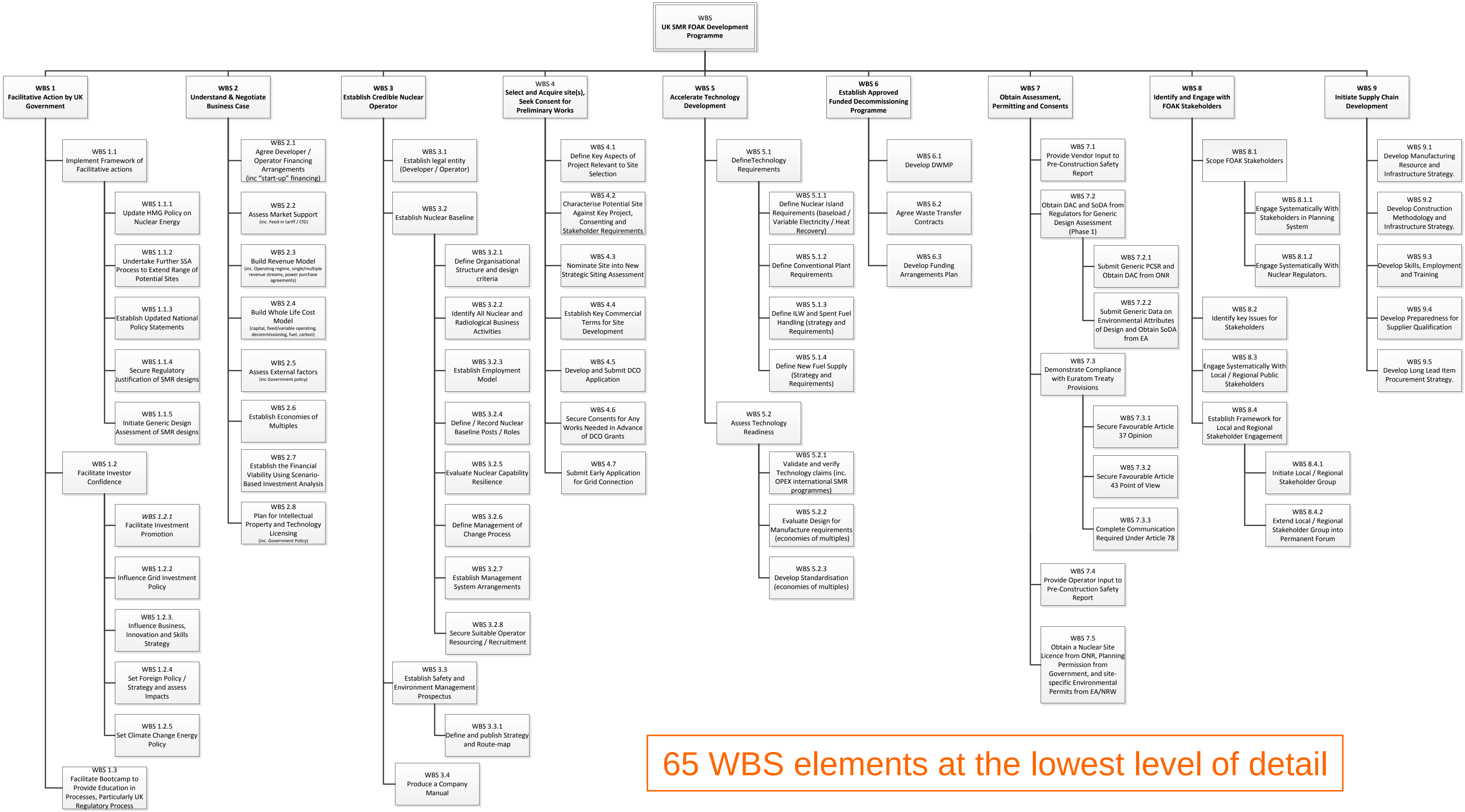
Licensing Preparations From Around 2021



Options regarding relationship between developer and the SMR operating organisation (licensee)

- wholly owned - share in a Joint Venture operating organisation - operation under contract
- Could take 4 to 5 years if a new start up Licensee; faster for an existing mature organisation

Work Breakdown Structure In Detail



Economic Impact Of Air Cooling Condensers – Electricity Only and CHP

	Assumes 12C dry ambient temperature	Electricity-only (Plant A)			CHP (Plant A)		
		Cooling Tower (ECT)	Cooling Tower + ACC (unconstrained)	ACC only (unconstrained)	Cooling Tower (ECT)	Cooling Tower + ACC (unconstrained)	ACC only (unconstrained)
Model	Max. net power output – MW_e	47.7	48.2	48.2	34.1	33.9	33.9
	CAPEX increment - £/kW_e (net)	£0	£347	£169	£544	£886	£708
	OPEX increment - £/kW_e p/a (net)	£0	£10	£7	£4	£15	£12
	Scenario 1: Base electricity-only plant CAPEX = ~£4,700 (indicative cost scenario from Phases 1& 2)						
	Model output – internal rate of return	7.7%	7.1%	7.4%	11.2%	10.4%	10.7%
	Scenario 2: Base electricity-only plant CAPEX = ~£3,600 (target cost from Phases 1 and 2)						
	Model output – internal rate of return	10.1%	9.1%	9.6%	13.7%	12.6%	13.1%

ANT project assumption that sufficient water always available for reactor cooling should normal systems be degraded or unavailable

Conclusions:

- Evaporative cooling towers more economically favourable than air condenser cooling
- For inland applications delivering CHP, still financially attractive if ACC addition needed later
- Incremental CAPEX for CHP readiness £10/kWe - costs small but potential future revenues large