energy technologies institute

www.eti.co.uk

SPRU Nuclear Waste Seminar – 27th and 28th March 2017

SMRs in the context of waste and spent fuel management

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ETI10 TEN YEARS OF INNOVATION 2007 – 2017

Presentation Structure

Structure:

- The Energy Technologies Institute - what do we do?
- Scenario modelling around an affordable energy system transition
- Nuclear in a UK low carbon 2050 energy system
- Importance of investor confidence in nuclear power projects
- Potential schedule for deployment of a UK LWR SMR
- Potential implications regarding waste and spent fuel from moving to an advanced reactor technology
- Conclusions

Introduction to the ETI organisation

- 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

Department for Business, Energy & Industrial Strategy

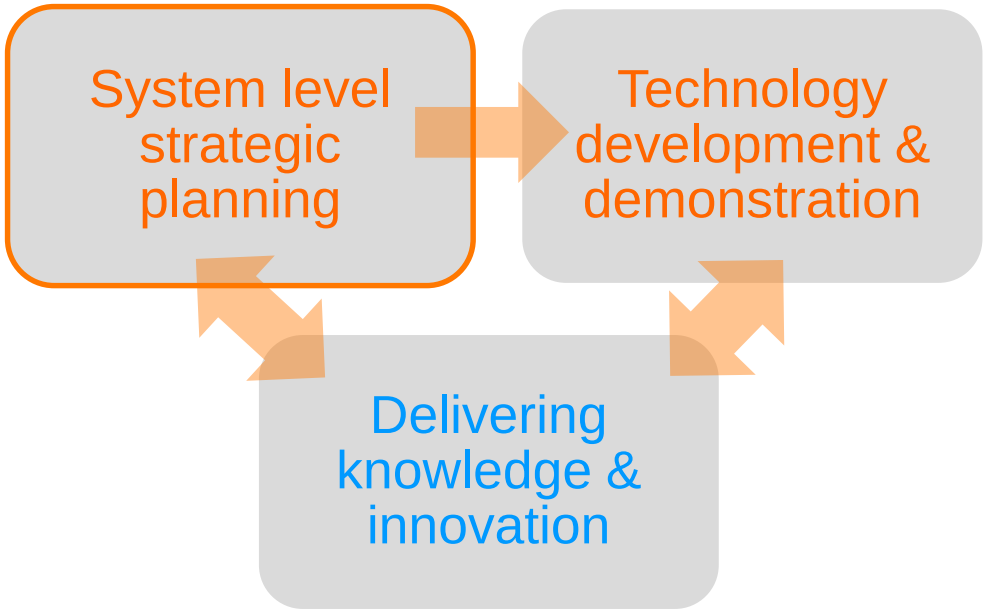
EPSRC Pioneering research and skills

Innovate UK

ETI programme associate

HITACHI Inspire the Next

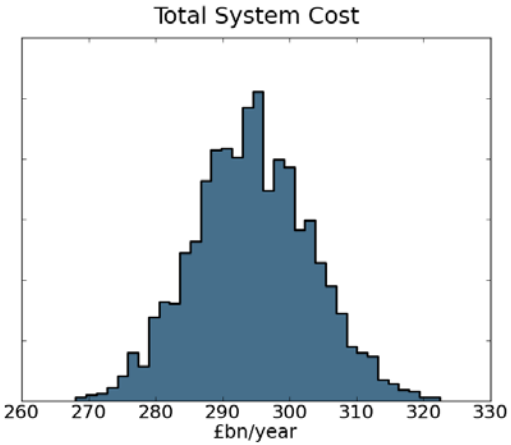
What does the ETI do?

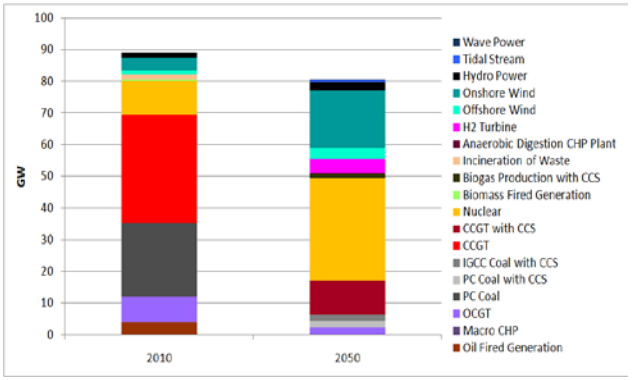


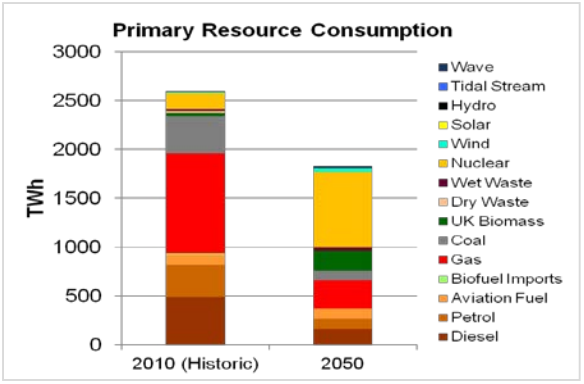
ESME – The ETI's system design tool

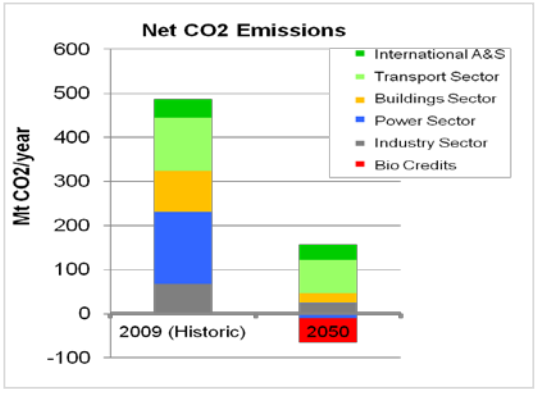
Integrating power, heat, transport and infrastructure providing national / regional system designs

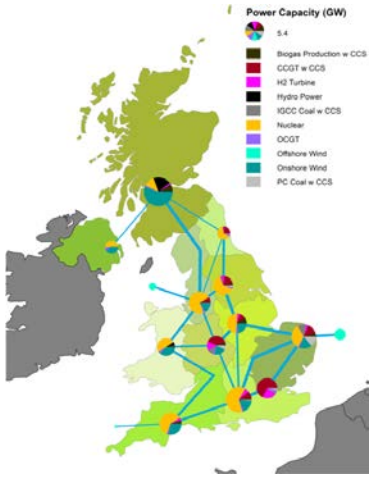
ESME
Energy System Modelling Environment

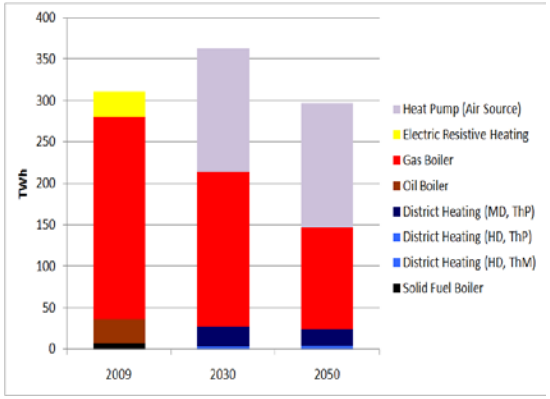












ESME example outputs

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

10 YEARS TO PREPARE for a low carbon transition

New nuclear plants can form a major part of an affordable low carbon transition

with potential roles for both large nuclear and small modular reactors (SMRs)

Large reactors are best suited for baseload electricity production

analysis indicates an **upper capacity limit** in England & Wales to 2050 from site availability of

35 GWe

Actual deployment will be influenced by a number of factors and could be lower. Alongside large nuclear, SMRs may be less cost effective for baseload electricity production

SMR's could fulfil an additional role in a UK low carbon energy system by delivering combined heat and power

a major contribution to the decarbonisation of energy use in buildings

but deployment depends on availability of district heating infrastructure

SMR's offer more flexibility with deployment locations that could deliver heat into cities via hot water pipelines up to

30 km in length

Assessed deployment capacity of at least **21 GWe** limit could be higher

Total nuclear contribution in the 2050 energy mix could be around 50 GWe; SMRs contributing nuclear capacity above 40 GWe will require flexibility in power delivery to aid balancing of the grid

Future nuclear technologies will only be deployed if there is a market need

and these technologies provide the most cost effective solution

A decision is required now

10 years

whether to begin 10 years of enabling activities leading to a final investment decision for a first commercially operated UK SMR

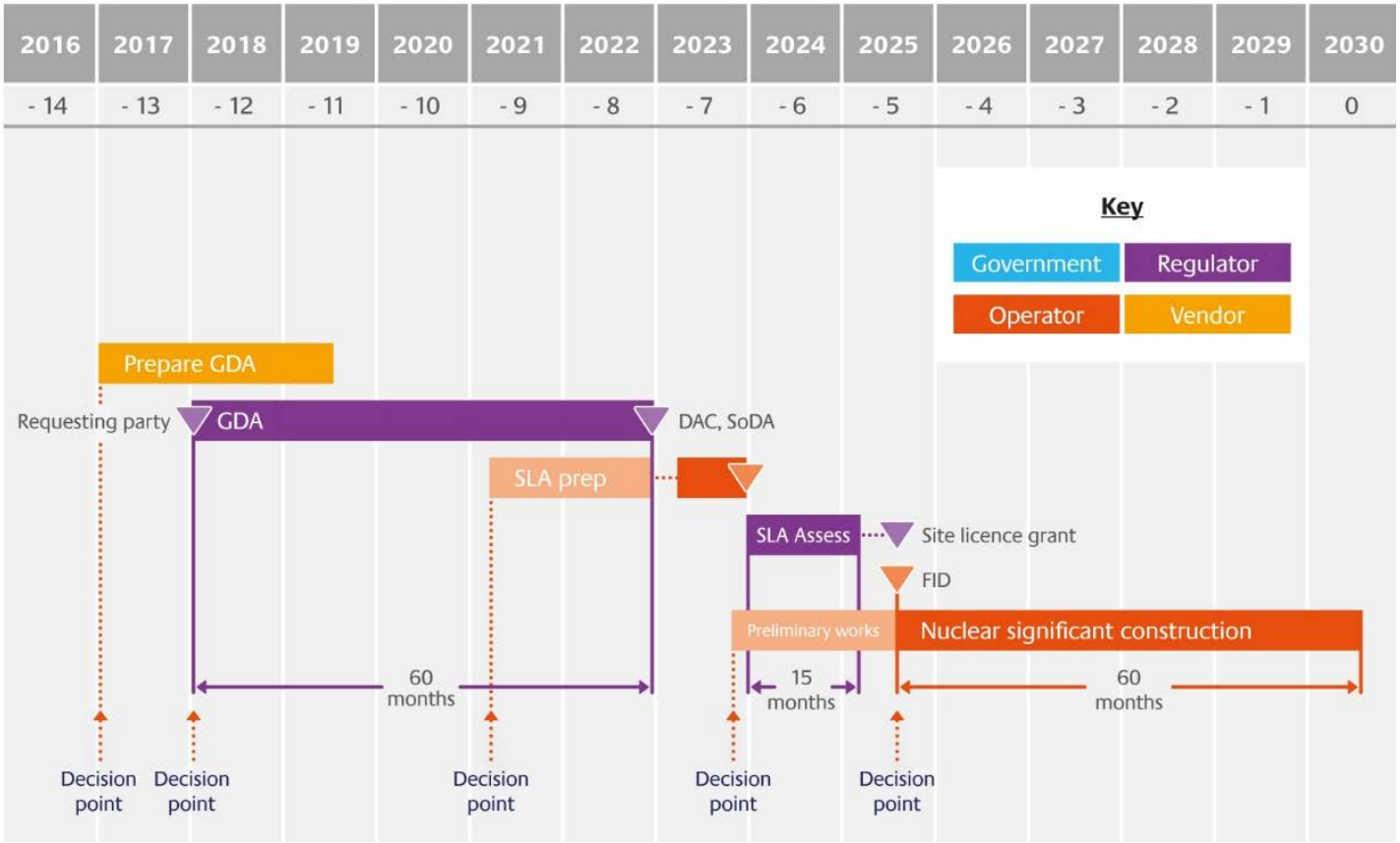
earliest operational date around **2030**

A strategic approach to reactor siting together with public consultation

will be important in determining the extent of deployment of both large nuclear and SMR's

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

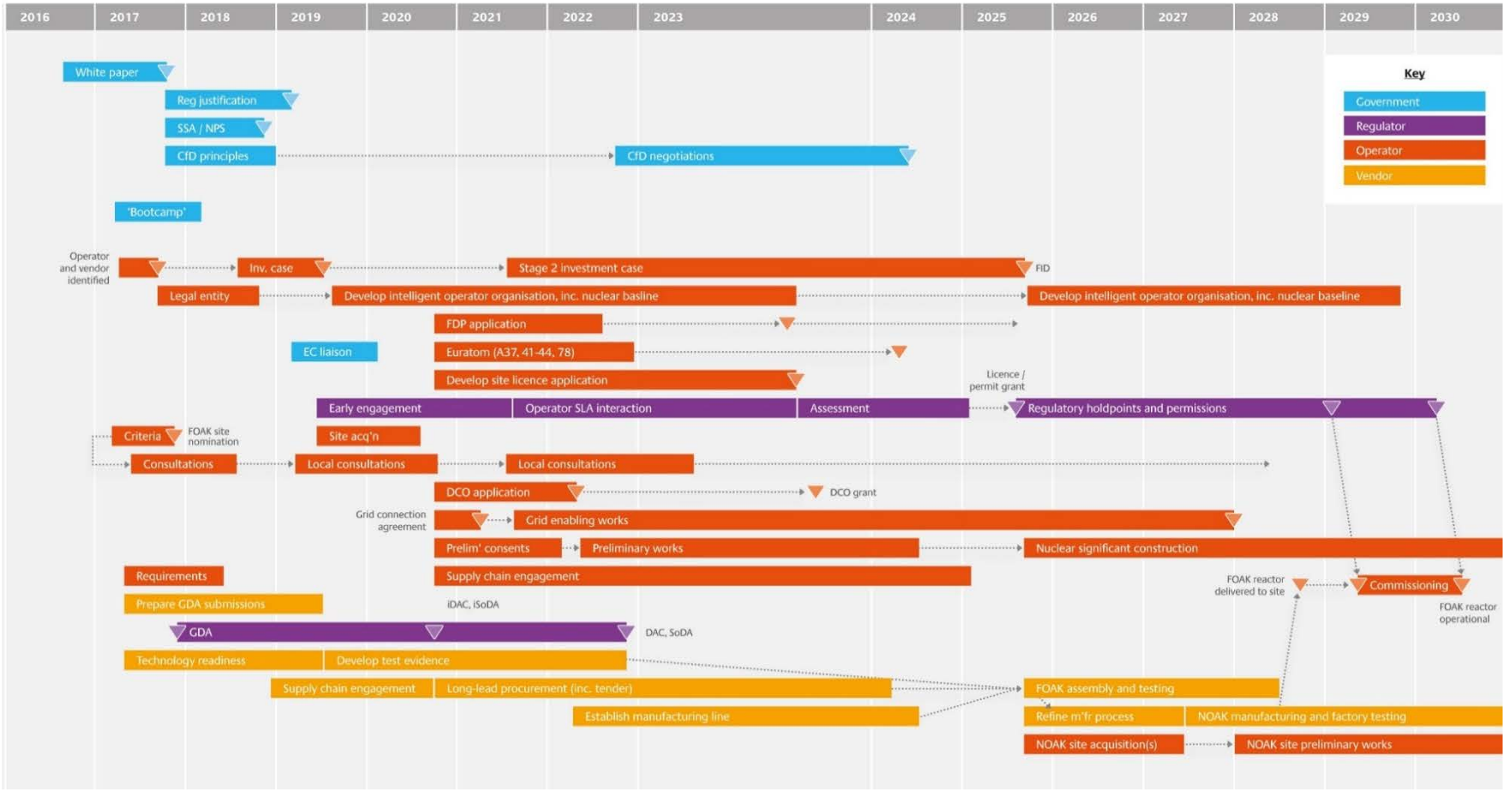
The Critical Path Of A 2030 Schedule For A UK LWR SMR



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 Potential UK FOAK Operations By 2030



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

Preparing for deployment of a UK SMR by 2030 – ETI nuclear insights (2)

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

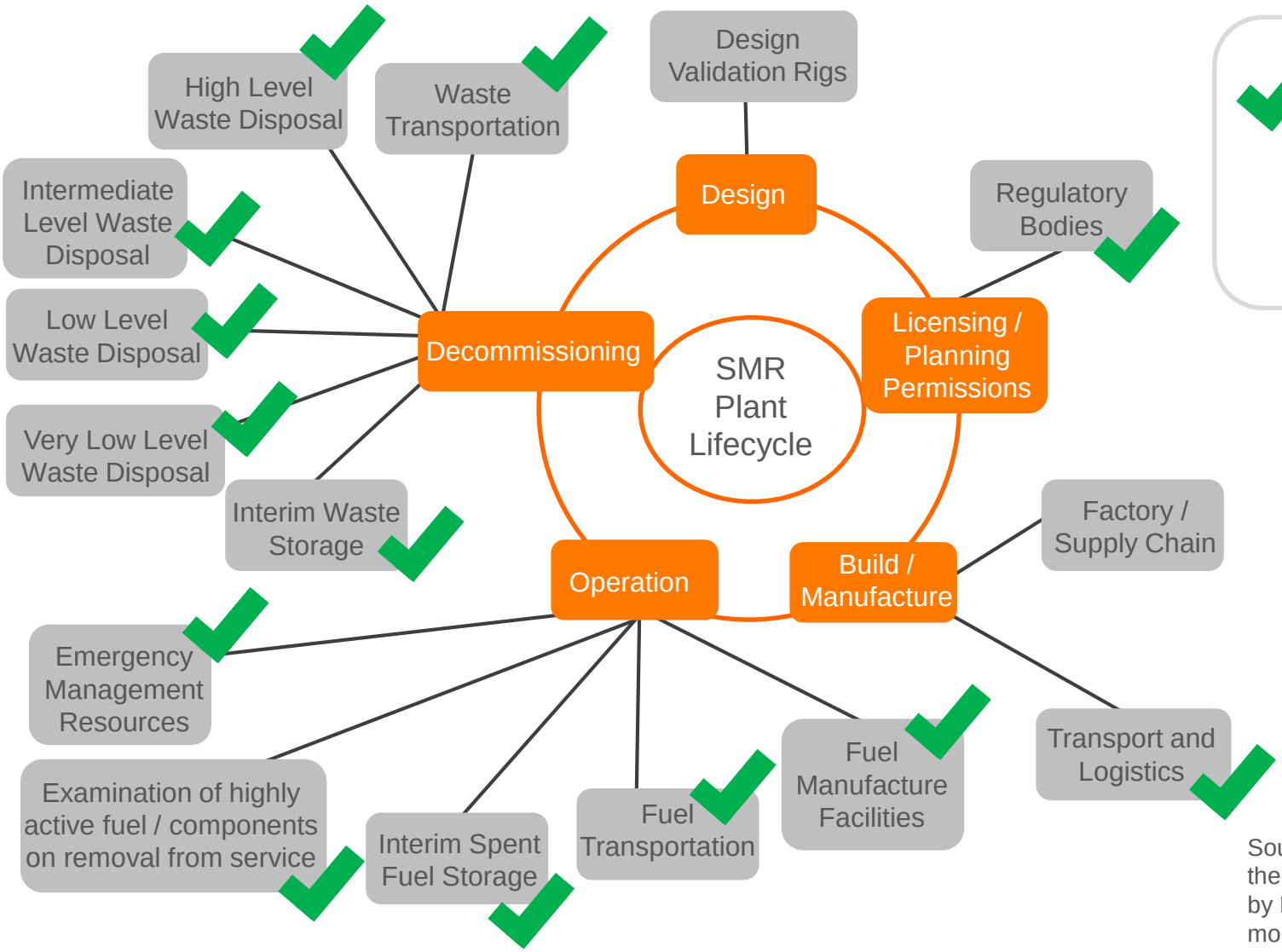
Waste and Spent Fuel Management

Must be considered within the economic and technical life cycle of a nuclear power project because of:

- Legal requirements for developers to prepare and update technical and economic plans subject to scrutiny by the independent Nuclear Liabilities Funding Assurance Board
- Uncertainties regarding waste and decommissioning economic and technical solutions will impact the pace and scale of investor confidence
- Waste disposal is frequently identified as a principal stakeholder concern in new nuclear power projects

How might waste and spent fuel management be different for an advanced non-LWR technology?

SMR Plant Life Cycle – LER Designs



As for large reactors

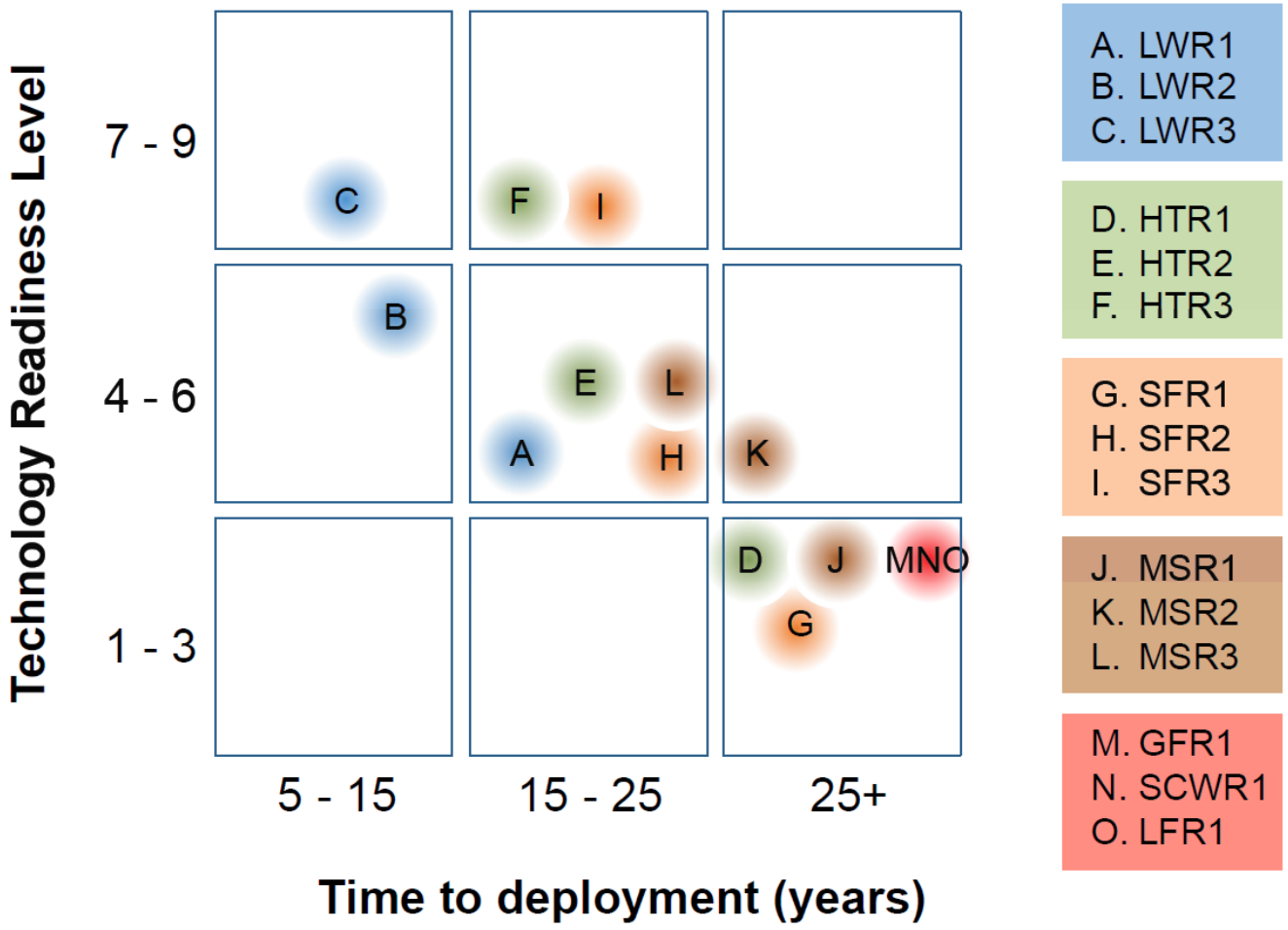
Further work required as suggested by the ETI

Source: core diagram from the ETI's ANT project report by Mott MacDonald with modifications by the ETI

Generation IV Advanced Reactor Types

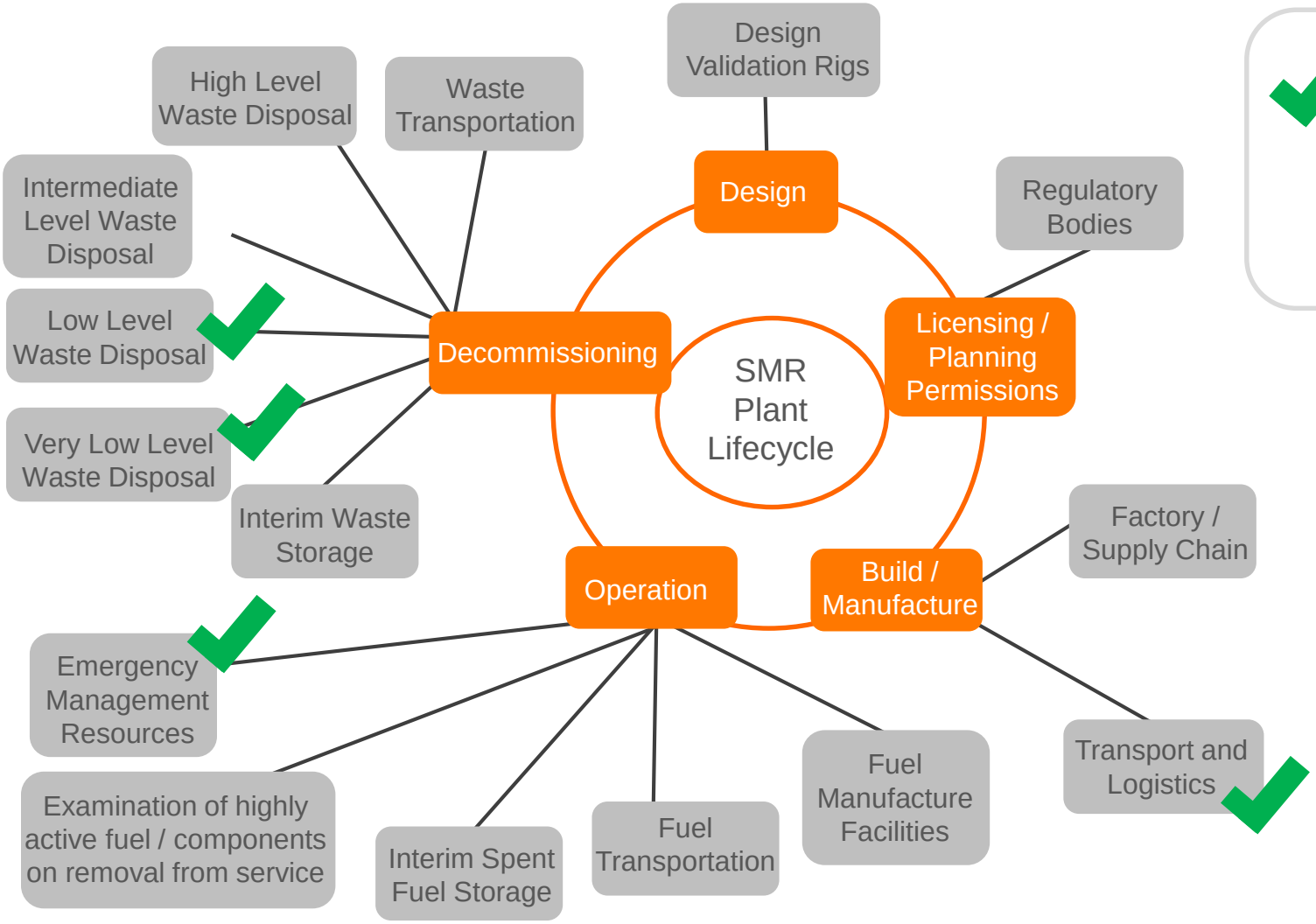
Technology Group	Abbreviation	Neutron Spectrum
Very high temperature gas reactors	VHTR	Thermal
Molten salt reactor	MSR	Thermal
Supercritical water cooled reactors	SCWR	Thermal
Gas cooled fast reactor	GFR	Fast
Sodium cooled fast reactors	SFR	Fast
Lead cooled fast reactors	LFR	Fast

NNL View of SMR Technology Readiness Levels



Source: NNL presentation at the London Nuclear Power Symposium 24th October 2016

SMR Plant Life Cycle – Advanced Technologies (non LWR Designs)



As for large reactors

Further work required as suggested by the ETI

Conclusions

- Economics of SMRs still relatively uncertain
  - Development schedule and cost
  - Capital cost and construction duration
  - Emergence of developers and operators prepared to invest
  - Necessary investor confidence to bring forward commercial projects
- If the economics of LWR SMRs deliver early investor confidence:
  - A pre-commercial technology demonstrator may not be necessary
  - The waste and spent fuel technical and commercial solutions are similar to current UK power reactor projects
  - Early investor confidence could support UK LWR SMR deployment by 2030
- If the economics of non-LWR advanced (SMR) technologies promise a step improvement:
  - A pre-commercial technology demonstrator may still be necessary
  - Regulatory capability and capacity to be developed to assess the design
  - Engineering and commercial solutions need to be developed for waste and spent fuel management and disposal for non-LWR advanced technologies
  - Rate of progress limited by investor confidence (vendor, developer, supply chain)
  - Challenging to envisage commercial deployment (operations) before 2035

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