The Potential for Nuclear Energy in the UK Beyond 2025

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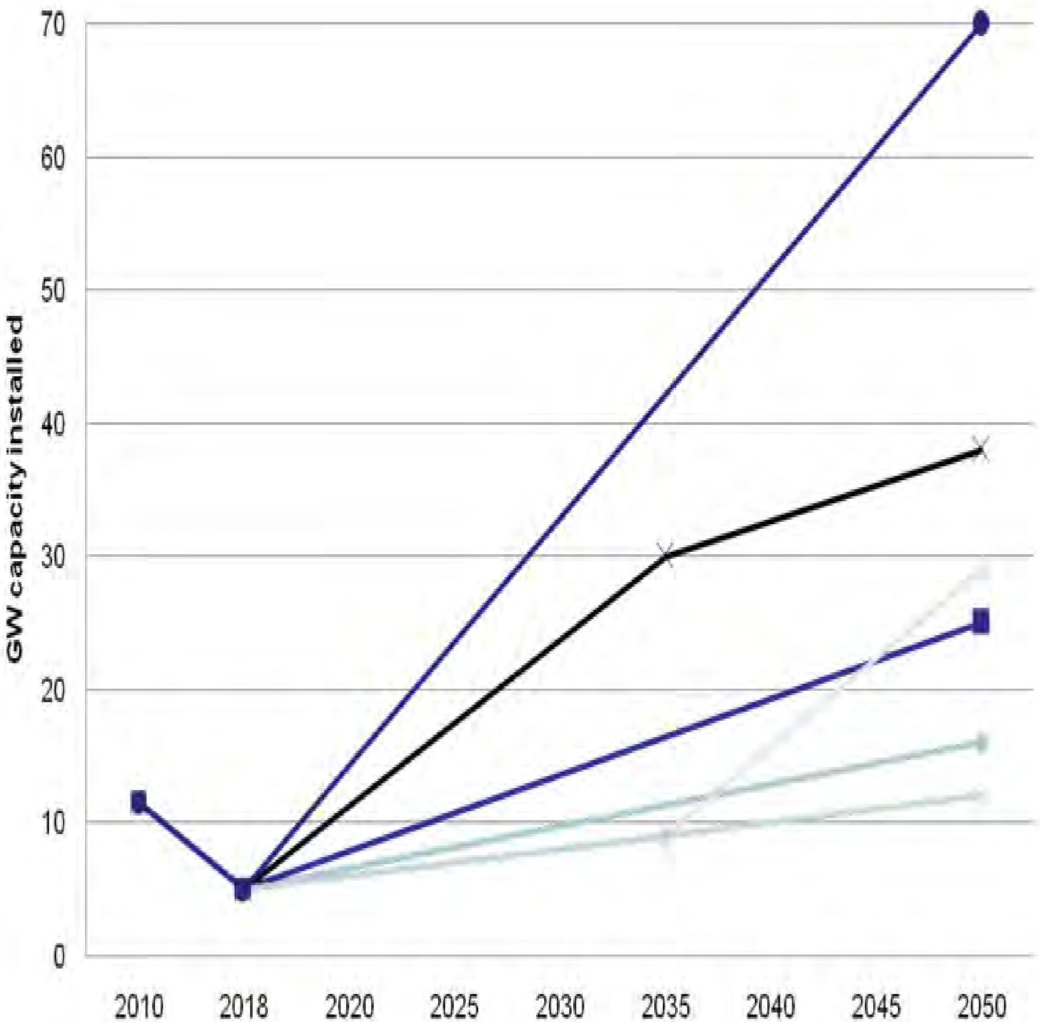
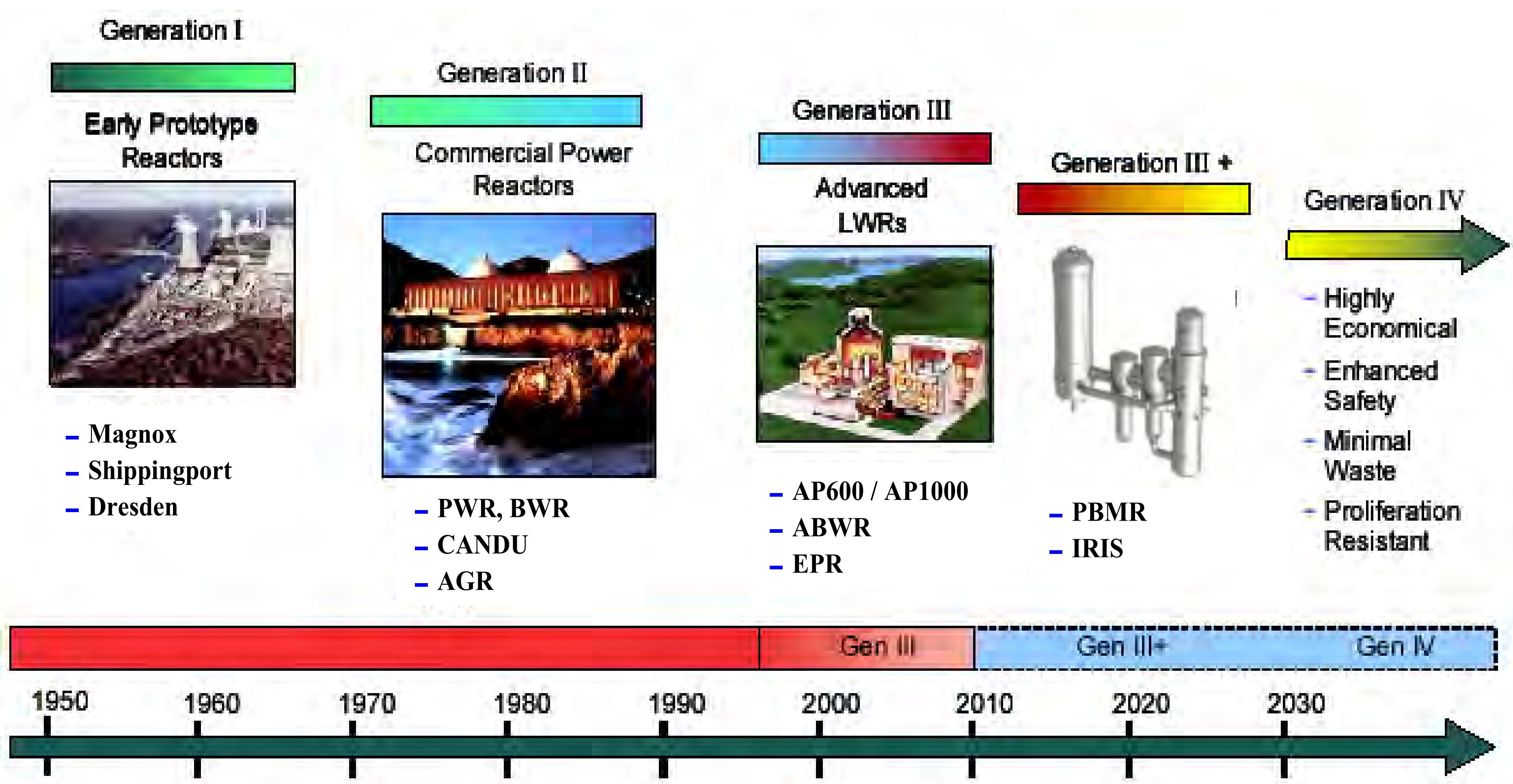
Scenarios for UK deployment



DECC Energy 2050

- Legally binding 80% emission reduction by 2050
- Low carbon generation for:
  - Electricity
  - All transportation
  - Domestic and Industrial Heat, Light & Power
- Electricity grid grows from ~85 GWe to ~300GWe
- Generation sources ~ 33% renewables, CCS and nuclear

"Generations" of Nuclear Plants



Generation IV Systems

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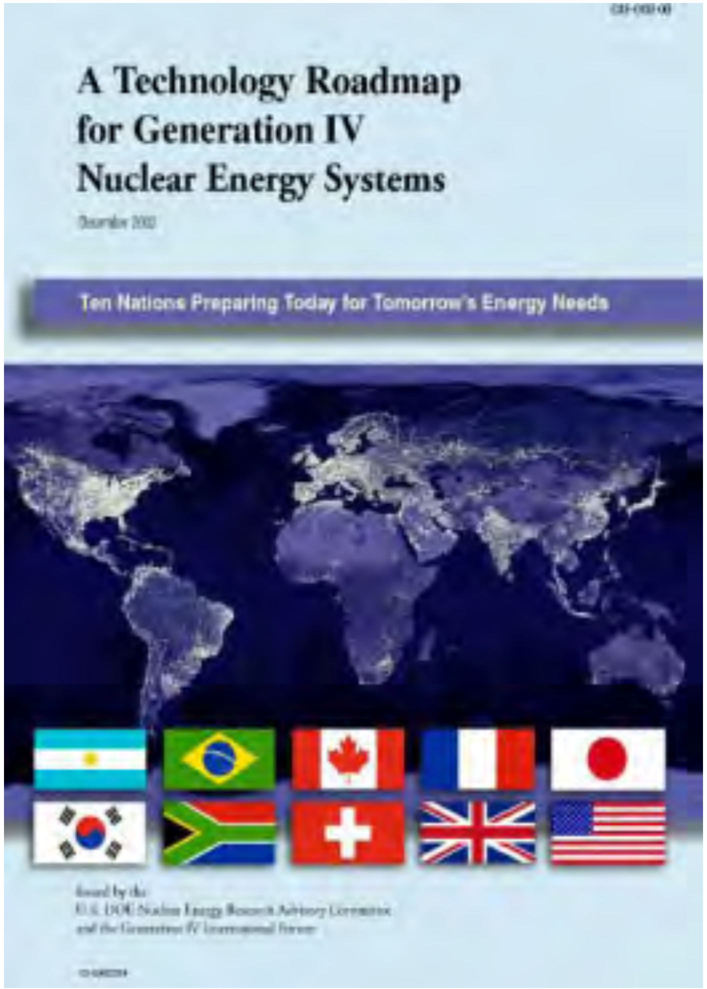
- Gas-Cooled Fast Reactor (GFR)
- Lead-Cooled Fast Reactor (LFR)
- Molten Salt Reactor (MSR)
- Sodium-Cooled Fast Reactor (SFR)
- Supercritical Water-Cooled Reactor (SCWR)
- Very-High-Temperature Reactor (VHTR)



Sodium-cooled Fast Reactors

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JOYO

MONJU

DFR

PFR

PHENIX

EBR-II

SUPER PHENIX

Other Advanced Reactor Systems

- Gen III+ Systems:
  - Integral PWRs
  - High Temp Gas-Cooled Rectors

- Examples include:
  - GE-Hitachi PRISM (FR)
  - B&W mPower (PWR)
  - NuScale (PWR)
  - Holtec (PWR)
  - ANTARES (HTR)
  - Hyperion (FR)
  - Molten Salt Reactors
  - Th fuelled based systems

SMR Reactors

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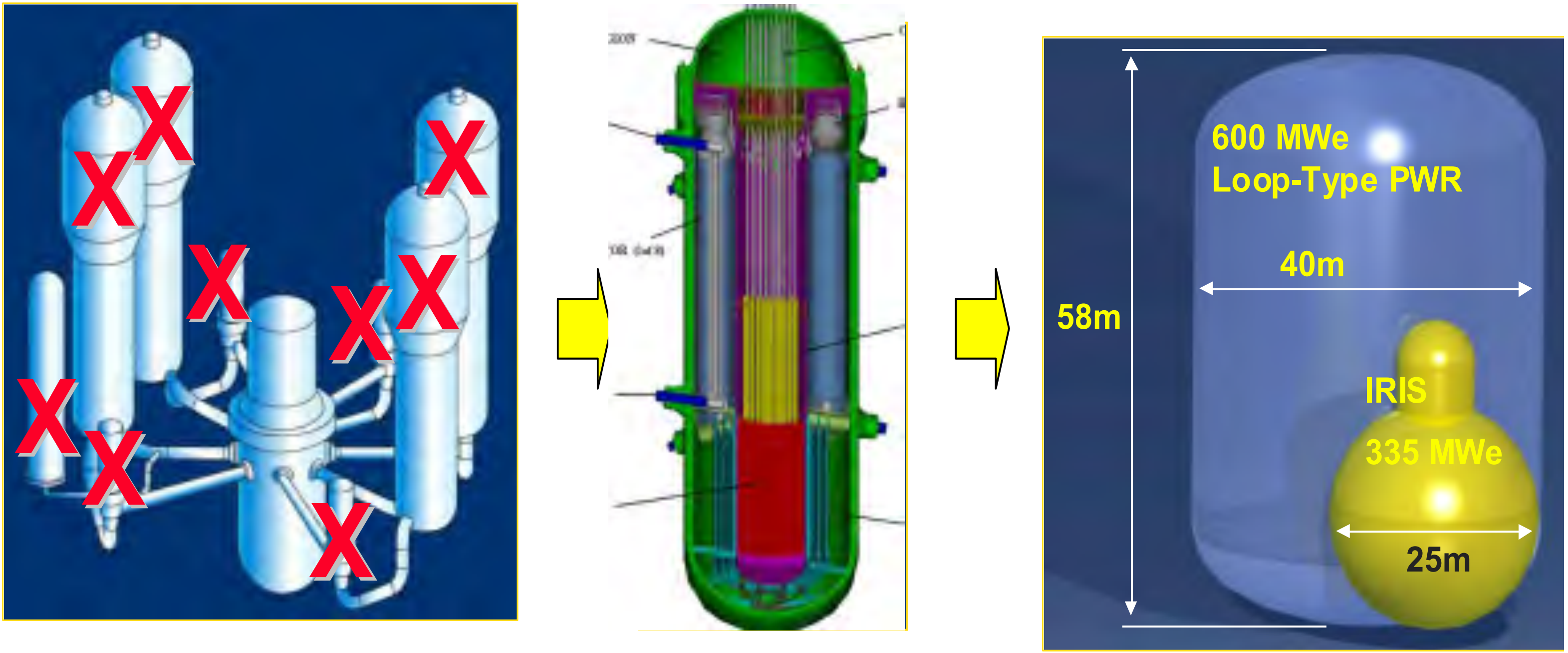

- Integral configuration eliminates loop piping and external components
- Enables compact containment and small plant size
- Enhances safety, security and economics
- Particular interest in UK at the moment

SMR System Features

- Simplified or passive safety
  - Integral systems layout
  - Large coolant masses for high thermal inertia
  - High vertical heights to enhance natural convection
  - Passive designs
  - Need to address multiple units in close proximity after Fukushima
  - Some designs use natural circulation in normal operation
- Underground siting of cores
- Long refuelling cycles
  - Autonomous power sources have very long life cartridge cores (15 to 30 years)

SMR Systems Challenges

- Integral designs will need extensive validation
  - Integrating plant components may increase importance of interactions between components
  - Even for most fully developed designs
- Small size does not necessarily improve safety
- Natural circulation systems with require extensive R&D to validate system behaviour
- Underground siting may improve protection in some scenarios, but not necessarily all scenarios
- Regulatory requirements
  - SMR designs will need to go through the full licensing process

SMR Economic Levers

Lower construction costs from a combination of:

- Simplified design
- Increased modularity/factory build
- Multiple design replications – mass production
- Application of advanced manufacturing techniques
- Shorter construction time

Lower finance costs from:

- Shorter construction time
- Self-financing model where the first module starts to generate the revenue to finance the construction of subsequent modules and limit the borrowing requirement

Lower operating and maintenance costs from a combination of:

- Simplified design with reduced maintenance needs
- Deployment of multiple modules run by a 400 to 500 strong workforce comparable to large plants

Increased supply chain opportunities with host countries potentially able to manufacture a higher proportion of systems

SMR Economic Challenges

All the drivers in favour of SMR economics are currently theoretical and need to be demonstrated to work in practice – this is the biggest challenge they face

- No current SMR has a complete engineering design which is needed before a full engineering cost estimate can be made
  - Economic figures for SMR designs are often just projections with little supporting basis
  - In many cases the projected economics might look attractive at the conceptual stage, but may no longer do so when engineering reality sets in

UK SMR Study: Overview

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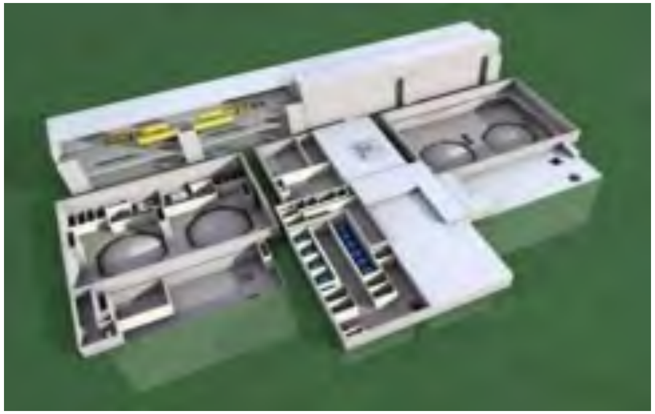
- Government-commissioned industry-led feasibility study into Small Modular Reactors (SMRs)
- Delivered by a consortium of experts from the UK nuclear industry
- NNL leading the study
- Gordon Waddington: Government-appointed independent Project Director
- Interim update on progress submitted; initial discussions with reactor vendors started

UK SMR Study: Scope

"Understand and evaluate the economic and technical claims made by SMR designers and to identify the most appropriate way to utilise UK skills and expertise to maximum effect in the developing SMR market and the means to commercially connect these"



Five Key Ministerial Commission Topics;

1. Global view of the market: feasibility, potential volume, competition
2. Economics: per MW/hr and potential investment costs
3. Technology: best alignment to UK interests
4. The commercial and industrial opportunity for the UK
5. Regulatory Considerations

The SMR Study: Objective

Can Small Modular Reactors (SMRs) provide Nuclear power at an economic price to complement the capabilities of large reactors?

Is there a significant global market for SMRs?

Can UK industry participate at the reactor vendor level in partnership with another country?

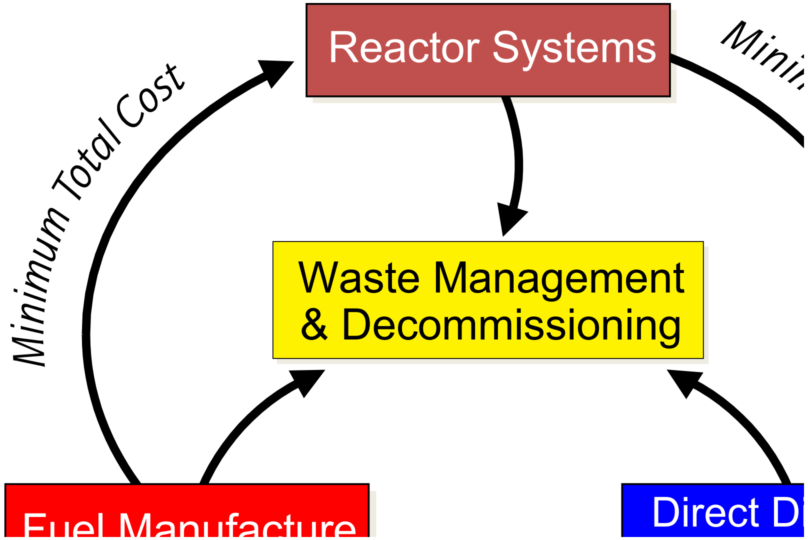
How might a UK-International SMR partnership address global demand?

What is the key intellectual property (IPR) capability that results?

What does the UK government need to do to ensure that UK industry can then pursue this opportunity?

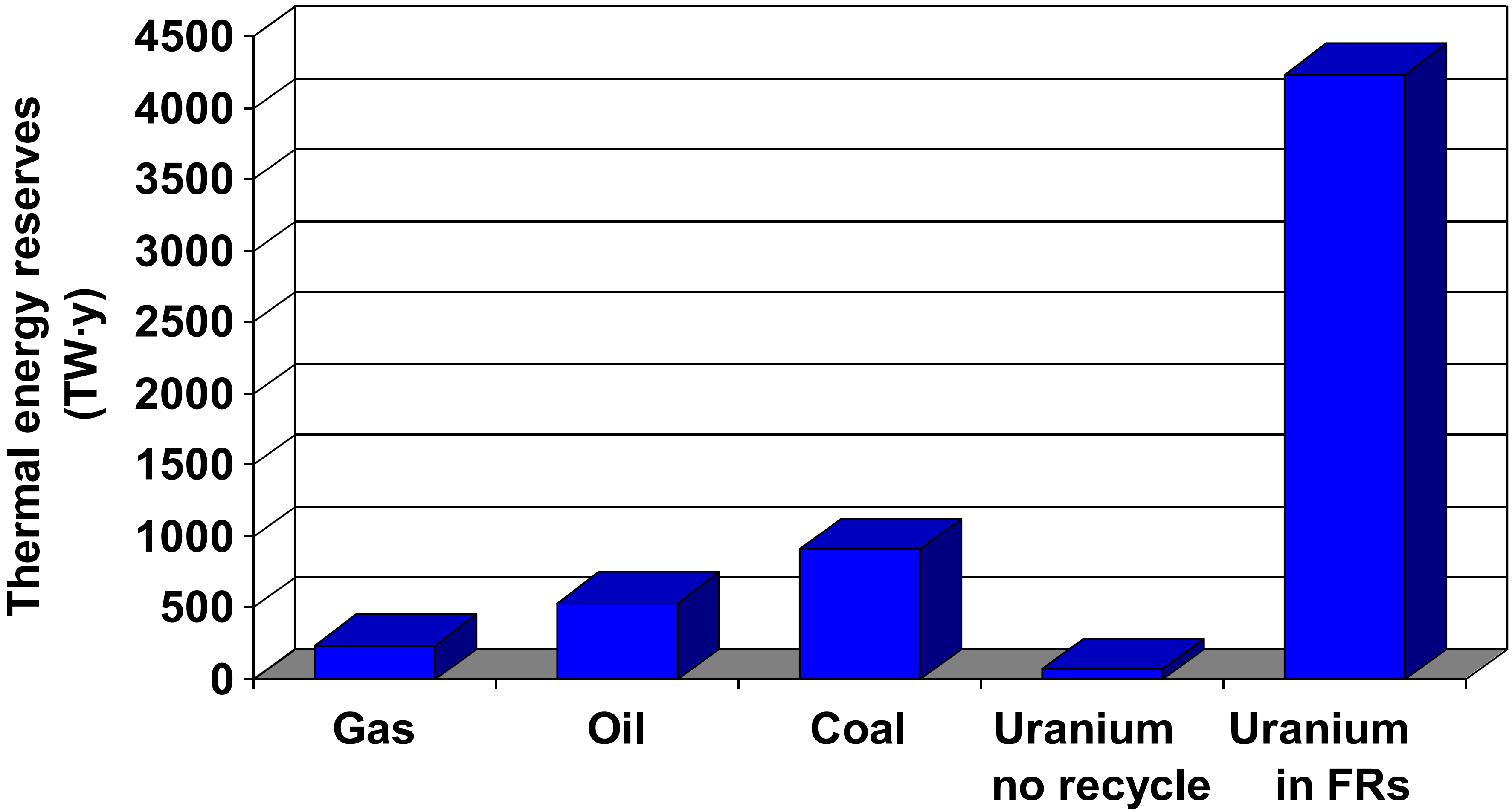
What Influences Fuel Cycle Options?

- Balance of number of parameters including:
  - Economics
  - Proliferation
  - Technology readiness
  - Fuel supply
  - Use of nuclear energy
  - Spent fuel storage
  - Disposal
  - Sustainability



- Worldwide growth of nuclear will impact on UK
- Higher levels of nuclear energy closed cycle more favourable

Sustainable use of resources?



Source: US DOE Energy Information Administration "International Energy Outlook 2004", DOE/EIA-0484(2004)

Note: Gas and Oil include speculative reserves; Coal and Uranium do not

Making our Uranium Last Longer

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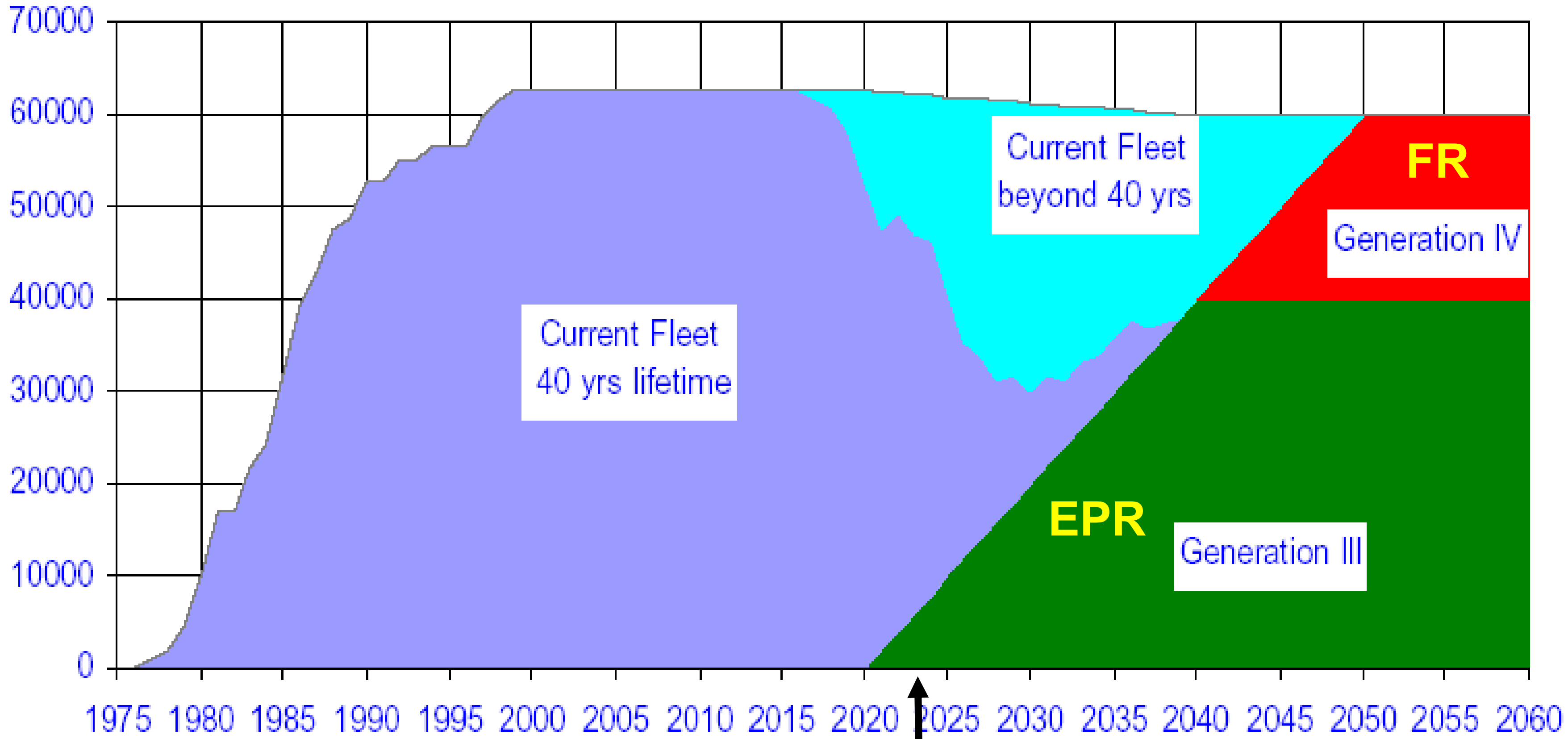
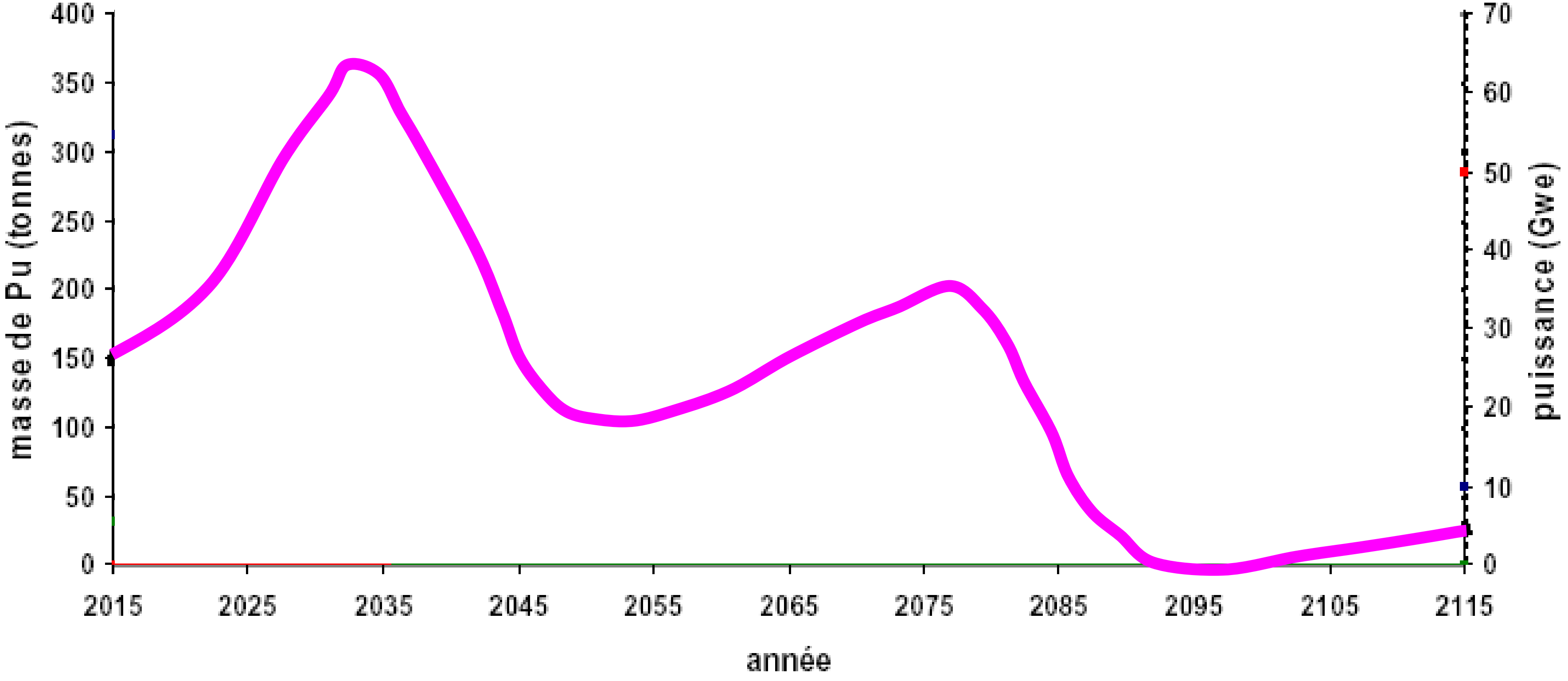
- Mining leaner reserves
- Squeezing out more U-235 from "tails" via further enrichment
- Advanced thermal reactor designs to increase efficiency
- Reprocessing – increases uranium utilisation and enables MOX usage
- Fast breeder reactors – utilise U-238
- Thorium – more abundant than uranium

French Advanced Reactor Deployment

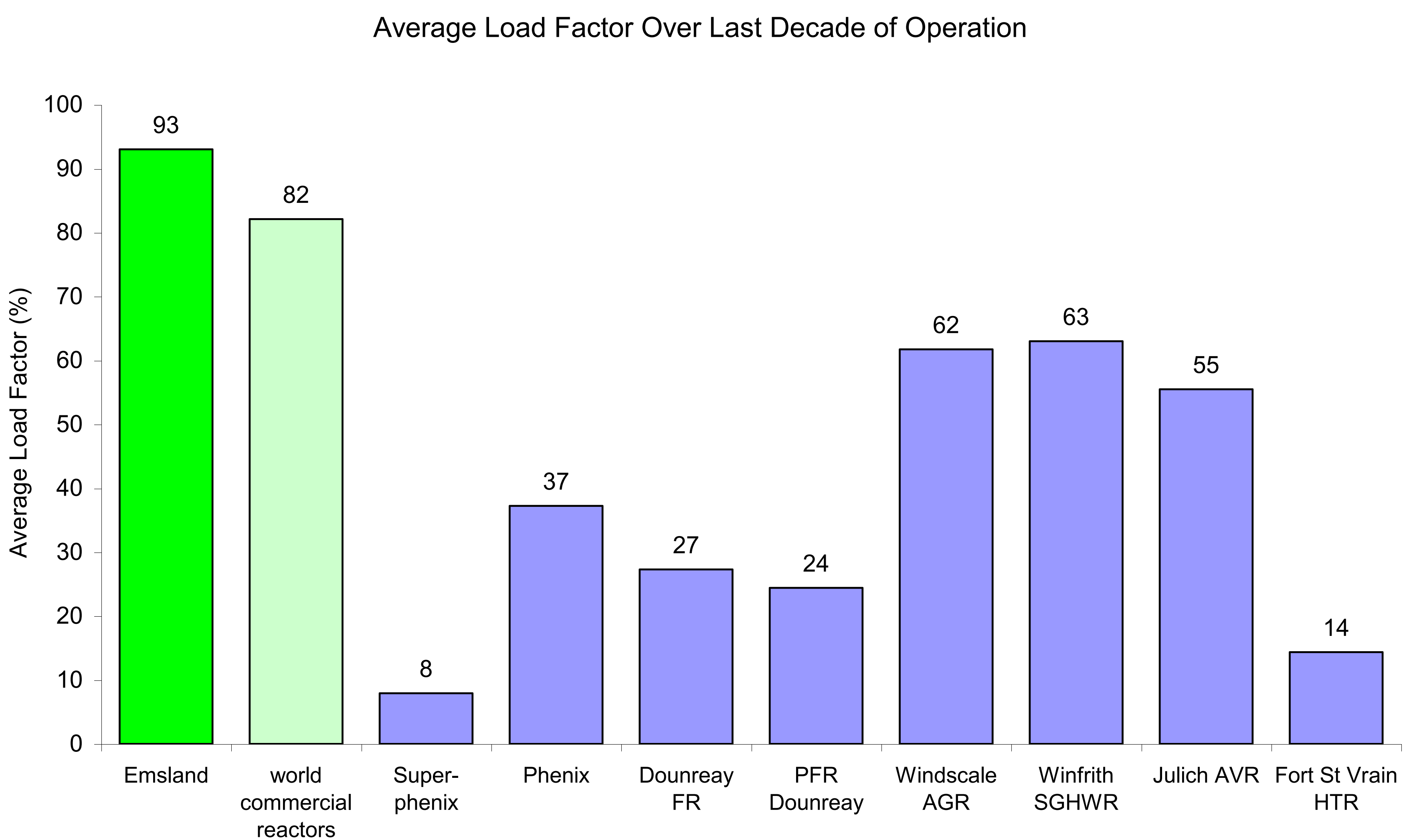


demo Fast Reactor

French Plutonium "Reserves"



Expectations for Load Factor



Wide UK experience with different systems

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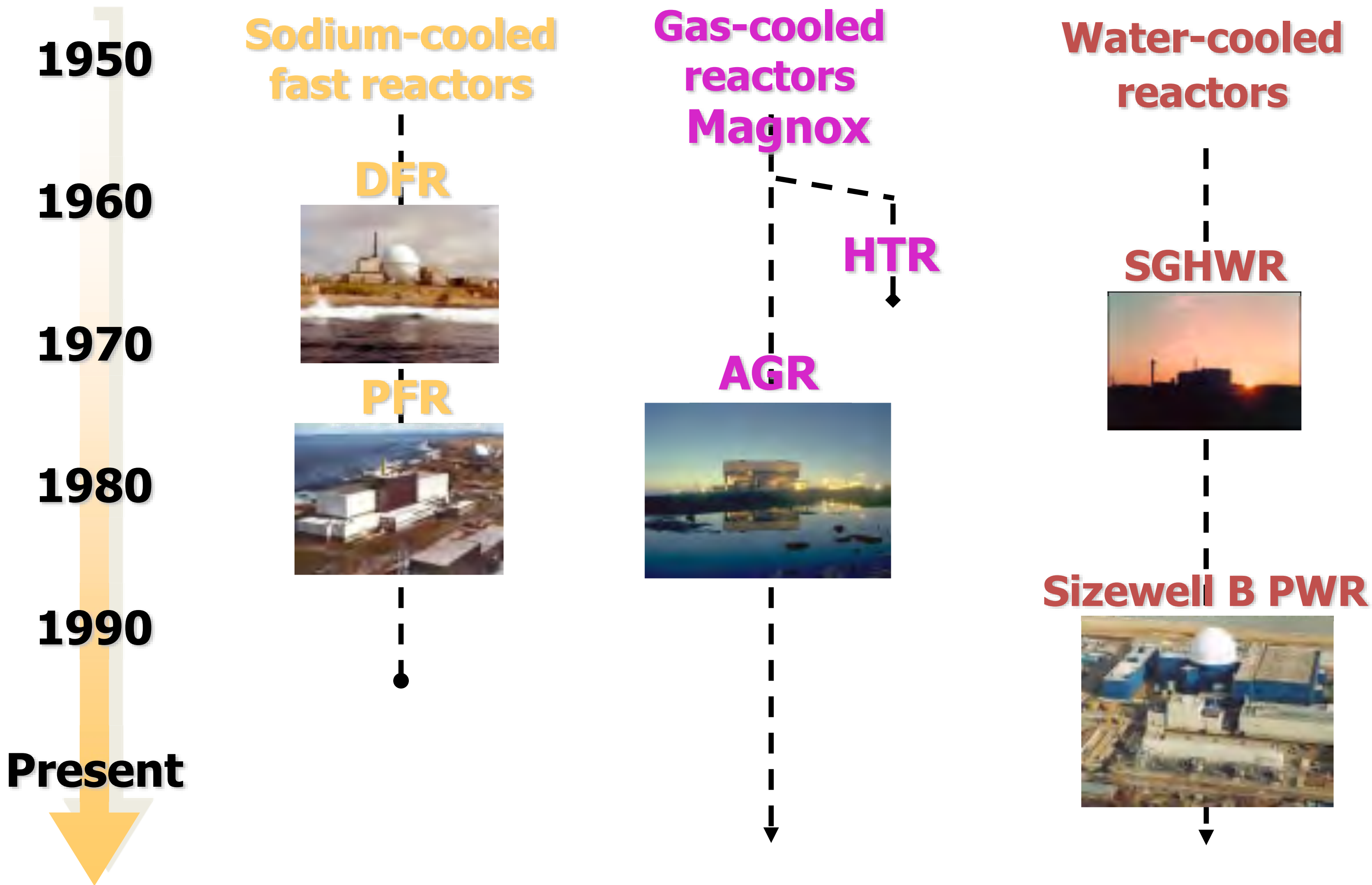

Fuel Cycle: UK Technology and Experience

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- Fuels development experience UO2, MOX, metallic, carbide with full PIE capability

- Advanced fuel cycle options developed

- Significant UK expertise & know-how at industrial scale

Conclusions

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- UK has ambitious targets to meet its energy demand
- Gen III reactor deployment essential but energy scenarios with greater nuclear contribution potentially need advanced reactors (SMRs or other advanced options) and fuel cycles
- Such systems can offer improved resource utilisation, long term environmental benefits but more work required to demonstrate enhanced economics and safety over Gen III.
- UK has significant expertise in such technologies although it is essential investment is made to retain such capability
- International collaboration is essential, although the UK can be well placed to export its technology know-how

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