Overview of UKNNL activities supporting advanced reactor systems and their related fuel cycles

Dr. Michael Edmondson, Dr. Seddon Atkinson, Ms. Nassia Tzelepi

18 March 2026

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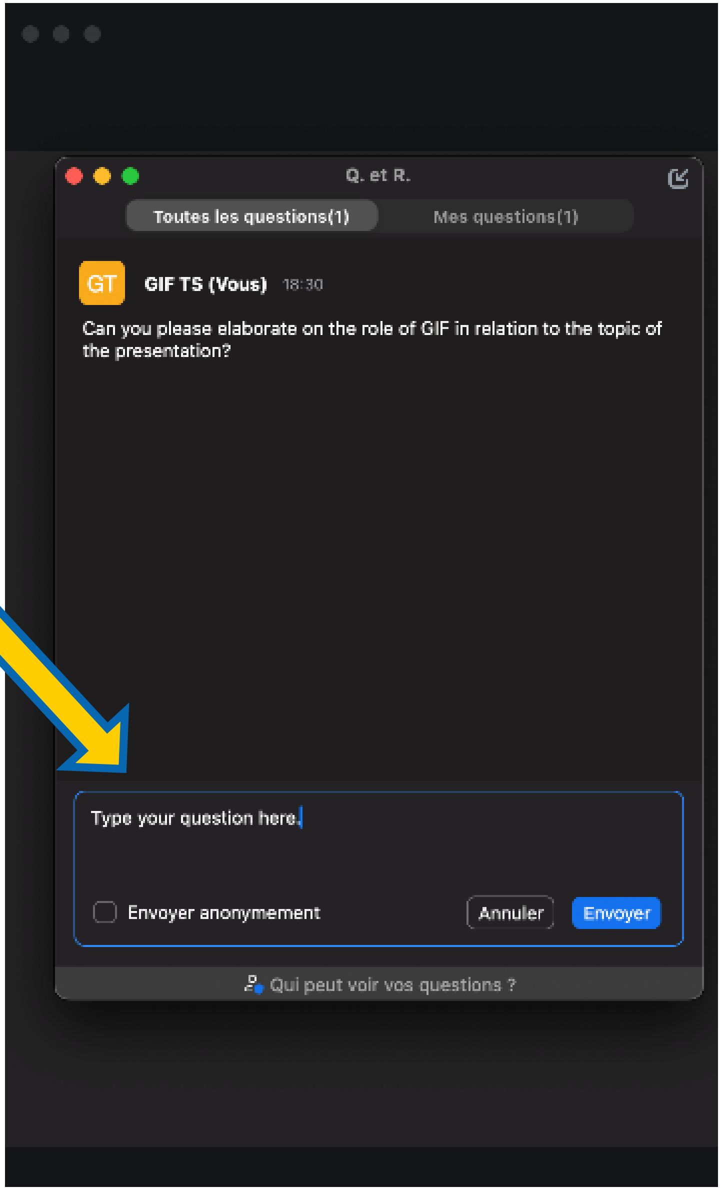

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United Kingdom National Nuclear Laboratory

Meet the Presenters

Dr. Michael Edmondson BSc (Hons) PhD FRSC CSci CChem is a Cross Discipline Technical Lead and Associate Fellow at UKNNL. He is key figure in the waste management and decommissioning directorate and the lead for molten salt technologies. Mike draws on experience of working in a variety of roles supporting operations at Sellafield since 2003; during which time he has led projects associated with reprocessing, historic waste management, clean-up and effluent treatment. As well has his leadership in molten salt technologies, Mike has a keen interest in recycle and decommissioning techniques with a mission to improve safety, reduce costs and timescales through innovation. He chairs the UK Molten Salt Technology Platform, is vice chair of the NEA Expert Group on Fuel Recycle and Waste Treatment and has chaired several international workshops on molten salt technologies.

Dr. Seddon Atkinson BEng (Hons) PhD CEng is a technical lead at UKNNL and a Chartered Engineer. He works across a range of disciplines related to Advanced Nuclear Technology which started during his PhD which was based on the design optimisation of the U-Battery which was a 10 MWth High Temperature Gas-Cooled Reactor (HTGR). Seddon has been working on the UKJ-HTR programme which looked at deploying a HTGR in the UK to supporting industrial applications for the last few years. Seddon is the UK delegate for the OECD-NEA Working Party on Scientific Issues of Reactor Systems (WPRS) and co-leads UKNNL's internal core science programme for Reactor Technology. Alongside new reactor projects, Seddon works in the area of Safeguards and Non-Proliferation supporting the IAEA on their ongoing mission.

Ms. Nassia Tzelepi FInstP FNuc CEng MBA is the Senior Fellow and Technology Leader for Graphite Technology and Post Irradiation Examination. Her responsibilities include (i) providing strategic direction and technical leadership for graphite technology in UKNNL, (ii) consultancy to support lifetime extension, graphite waste management and new reactor technology design and licensing, (iii) maintaining measurements standards by chairing the ASTM committee D02.F, and (iv) representing UK graphite skills and capability at GIF. Nassia is currently the cross-discipline technical lead for the UKJ-HTR programme under the Advanced Modular Reactor (AMR) Phase B.

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National Nuclear
Laboratory

We are the government's lead civil laboratory for nuclear fission

We provide the science, technology and world-leading laboratories to support the country's civil nuclear programmes and ensure they are delivered safely and cost-effectively.

Our mission is to enable and deliver nuclear outcomes for government, and to support growth of the UK nuclear sector

To achieve our mission we will:

- Be a custodian of national capabilities and infrastructure critical for national and energy security
- Deliver practical nuclear research and enable decommissioning programmes
- Become government's lead civil technical and strategic advisor for nuclear fuels and nuclear materials
- Provide expertise and facilities to be a platform for the private sector to accelerate the deployment of technology to market
- Carry out research to continue securing the safe operation of nuclear plants domestically and internationally
- Champion and nurture advanced nuclear skills

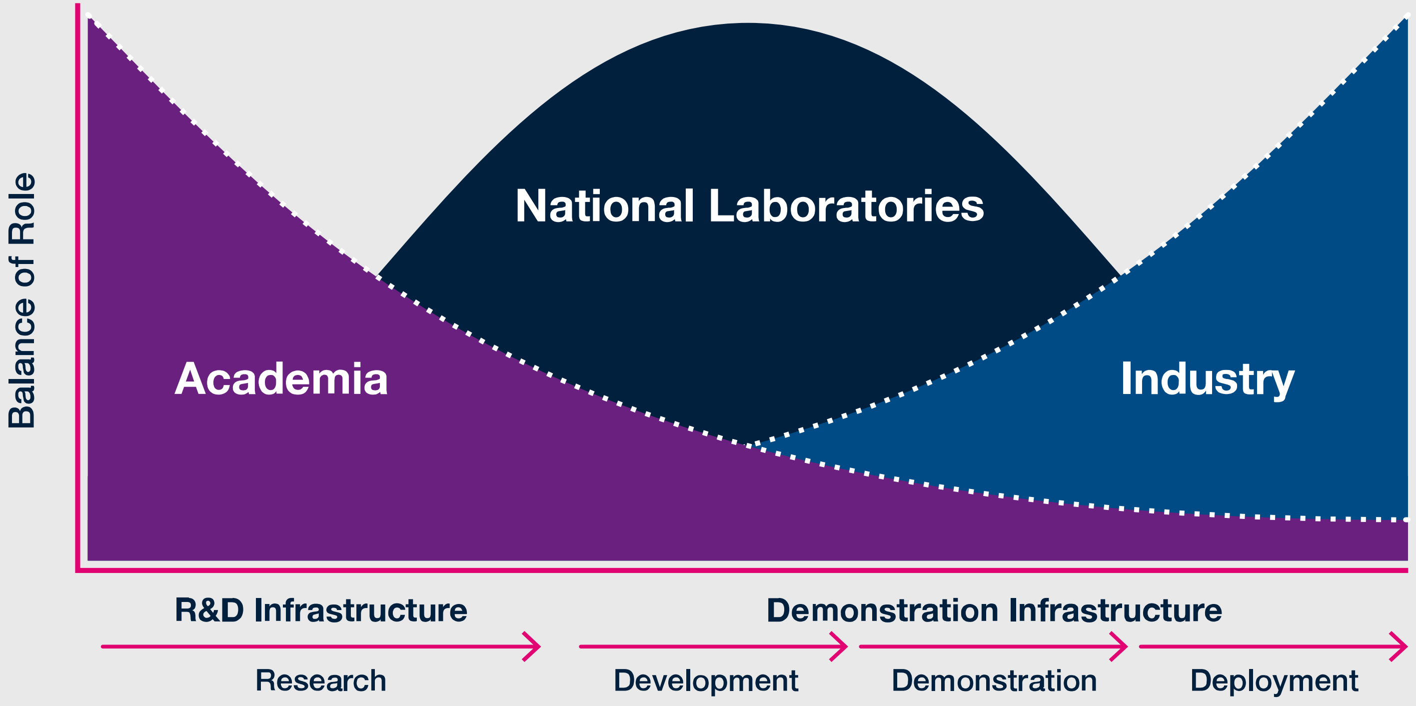
We are a Public Sector Research Establishment - government owned and publicly funded

By reinvesting our earnings into cutting-edge science and research, we maintain a broad base of knowledge and practical capability to keep the UK flexible, adaptive and competitive.

Our unique role in technology development

United Kingdom National Nuclear Laboratory

UKNNL occupies a unique position in the nuclear innovation environment, spanning technology readiness levels from 'proof of concept' to full scale demonstration and beyond; taking science from inactive laboratory-scale demonstration to prototype deployment with active nuclear materials.



UKNNL Laboratories

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Workington Laboratory
A non-active science, engineering and rig-testing facility, that complements our active facilities. A wide range of equipment and flexible areas that can enable the efficient design and implementation of non-active trials as a precursor to active trials in our laboratories.

Central Laboratory
One of the most advanced nuclear laboratories in the world, home to the plutonium science research capabilities, with glove box facilities and a versatile active rig hall. Central Laboratory plays a pivotal role in the UK's ability to handle plutonium and find solutions for its long-term disposal.

Vitrification Test Rig
A full-scale, non-active facility designed to replicate the core processes to develop and optimise methods for immobilising high-level radioactive waste in a stable glass form.

Workington Laboratory

Central Laboratory

Windscale Laboratory

Preston Laboratory

Windscale Laboratory
13 shielded hot cells (caves). Capable of forensic post-irradiation examination of full-size nuclear fuel rods, reactor core components and a range of high-radioactivity items. Capabilities underpinning the safety case of the UK's Continuous At Sea Deterrent, the safe operations Advanced Gas-cooled Reactors and high active material research

Preston Laboratory
Cutting-edge laboratories for uranics research and development. Advanced nuclear fuel development and quality assurance of AGR fuels for Springfields Fuels. A unique and vital facility offering the only available treatment route for many UK residue liabilities. Provides Analytical capability to Effluents and Safeguard programmes and UKAS accredited laboratory. Home to the IAEA Collaborating Centre for advanced fuel and fuel cycles.

£2bn
The value of the nuclear facilities we manage

Supporting our operations

UKNNL's HQ is in Warrington, a hub for nuclear in the North West. Our offices in Stonehouse and Culham deliver a range of modelling and simulation solutions and are home to our professional services and support functions.

Four major change drivers for the UK nuclear sector

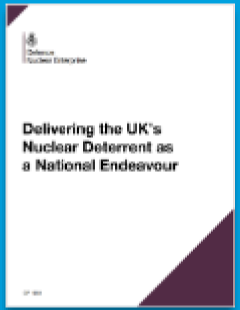
Advanced Gas – cooled Reactors (AGR) coming offline
Decommissioning

(Nuclear Decommissioning Authority restructure, shift from AGR to PWR)

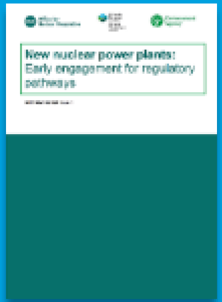
NDA
NRS
Sellafield Ltd
NTS
Nuclear Waste Services

R&D Demand
(People, facilities, programmes)

Recapitalisation of the Deterrent Programme
(Defence Nuclear Enterprise)


Delivering the UK's Nuclear Deterrent as a National Endeavour

New Generating Capacity by 2050
(large, small and advanced reactors and associated fuel cycle)


New nuclear power plants: Early engagement for regulatory pathways

Emergence of 'new' Nuclear Applications
(maritime, defence, industrial heat, isotopes from 'waste', new therapeutics, space power)

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UK Nuclear Context

- UK nuclear reactors have provided 12-20% of UK need for consistent, reliable power for the last 70 years
- We've primarily operated Magnox and AGR reactors and a single PWR
- Those reactors were complimented by a central reprocessing centre at Sellafield which operated two lines; one for Magnox (U metal) and one for Oxide (UO_2)
- All Magnox reactors and reprocessing have ceased operations and are in clean-up and decommissioning
- We currently have 9 operating reactors, across 5 sites (2 AGRs/site + 1PWR)
- The last AGR is due to retire around 2030, and the PWR at Sizewell will close in 2035 (2055?)
- The UK is investing heavily in renewable energies – primarily wind and solar…
  …but we need New Nuclear, and fast

UK Nuclear Energy Policy Evolution

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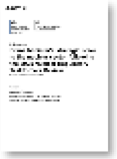
Civil Nuclear Energy: Policy Landscape

Overarching Policies:



PM Strategic Steer
- Highlights importance of nuclear for energy and national security
- Emphasis on regulation as a key enabler

Clean Energy Superpower Mission
- Clean Power by 2030
- Accelerating to Net Zero

Kickstarting Economic Growth
- Modern Industrial Strategy
- Sector Plans

✓ Delivery of life extensions and new gigawatt-scale plants to close the energy gap;

✓ Delivery of an SMR fleet and privately financed advanced nuclear projects

✓ Establishment of sovereign fuel capabilities.

Future nuclear new build programme:

Policy initiatives focus on establishing and delivering a programme **overseen by GBE-N**, with an increasing level of public sector investment and direct Government intervention **in PWR technologies.** Policy supportive of AMRs projects led by the private sector, with new National Policy Statement enabling more siting options.

GW scale reactors	Hinkley Point C: Under construction. Operational from 2030 at earliest Sizewell C: Final Investment Decision Announced in July 2025 HMG will be largest shareholder (44.9%) £14.2bn HMG investment announced in June budget. Further suitable GW sites being explored by GBE-N
Small Modular Reactors	RRSMR: preferred bidder in SMR competition £2.5bn pledged by HMG this spending review 3 units supported initially Other SMRs may be supported via ANT framework (see box below)
Advanced Nuclear Technologies	Policy shifting from HMG supporting technology development to enabling projects to be deployed. • UKNNL AMR RD&D programme ceasing Feb 2026 • Advanced Nuclear Framework (published Feb 2026) outlines a process for private sector developers to progress projects to deployment with HMG enabling support • Potential for projects to access National Wealth Fund

Fuel

Policies and funding aim to reduce reliance on certain nuclear fuel imports and expanding sovereign fuel capabilities

LWR fuels	Westinghouse received £10.5 million in grants to help future-proof UK LWR fuel fabrication
Coated Particle Fuels	• UKNNL AMR RD&D programme ceasing Feb 2026 • DESNZ exploring continuation funding options • International fuel developers interested in UK market
Advanced Fuels	• Policy for UK Pu stockpile not to be made available for advanced fuels

HALEU	• Policy to reduce global reliance on Russian produced HALEU
	• £300m HALEU fund launched in 2024:
	  • £196m to Urenco to build commercial scale HALEU enrichment facility
	  • £70m made available to support the development of a
	  • commercial HALEU deconversion facility in the UK.
	  • £18m for UKNNL to build HALEU deconversion pilot plant
	  • Potential further £20m for accelerated HALEU deconversion programme

10-year outlook – future nuclear market

Civil Energy

Operating fleet

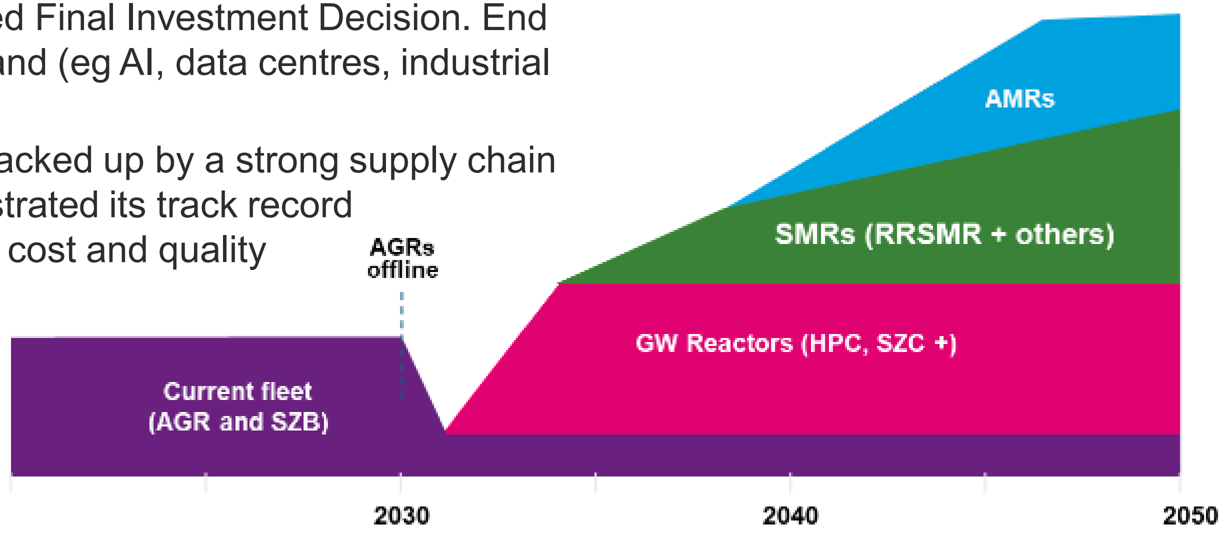
- UK generating fleet consisting of GW, SMR – Light Water Reactor technologies only
- Operational support provided by UK companies

Fuel cycle

- LWR fuel for generating fleet supplied by overseas manufacturers – US and France
- HALEU supply established to domestic and international market
- Coated Particle Fuel capability established
  - UKNNL pilot scale (i.e. UK capability)
  - Westinghouse (US) or Rolls Royce (UK) commercial scale production
- Fuel for other AMRs at R&D stage (UKNNL, academia)

New build programme

- Continued expansion of fleet (GW, SMR)
- AMRs technologies licensing - combination of UK and international technologies – projects achieved Final Investment Decision. End users increasingly driving demand (eg AI, data centres, industrial decarbonisation)
- Major UK design capability is backed up by a strong supply chain which has successfully demonstrated its track record for delivering new build to time, cost and quality



20-year outlook – future nuclear market

Civil Energy

Operating fleet

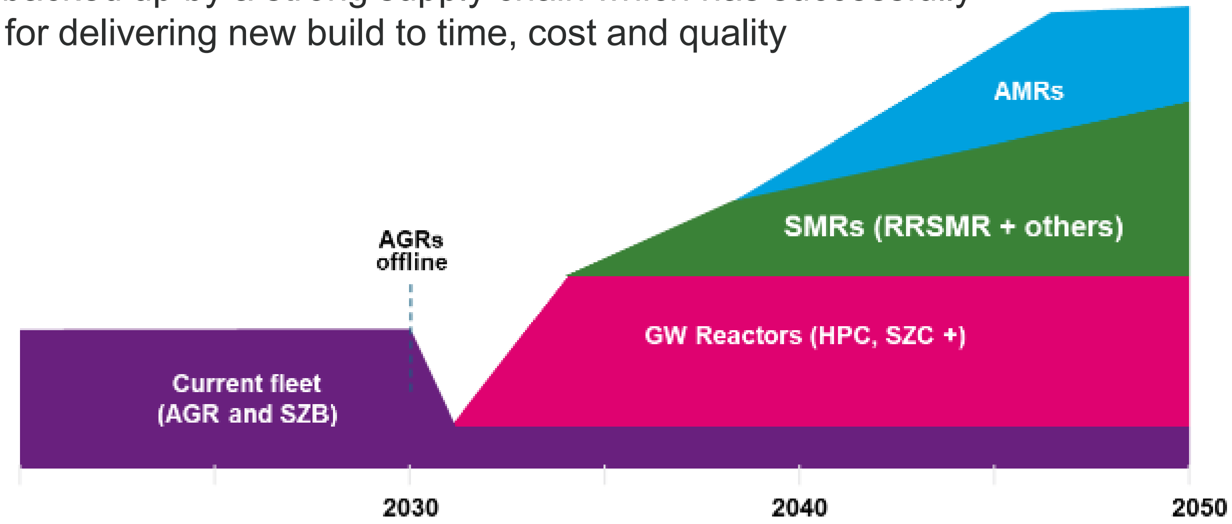
- UK generating fleet consisting of GW, SMR and AMRs (10-20GW) – combination of UK and international technologies
- Operational support provided by UK companies (e.g. fuel validation and PIE)
- Nuclear plant supplying heat to industrial end users

Fuel cycle

- Fuel for generating fleet manufactured in UK facilities – LWR and novel fuel cycles (CPF, molten salts)
- HALEU supply established to domestic and international market

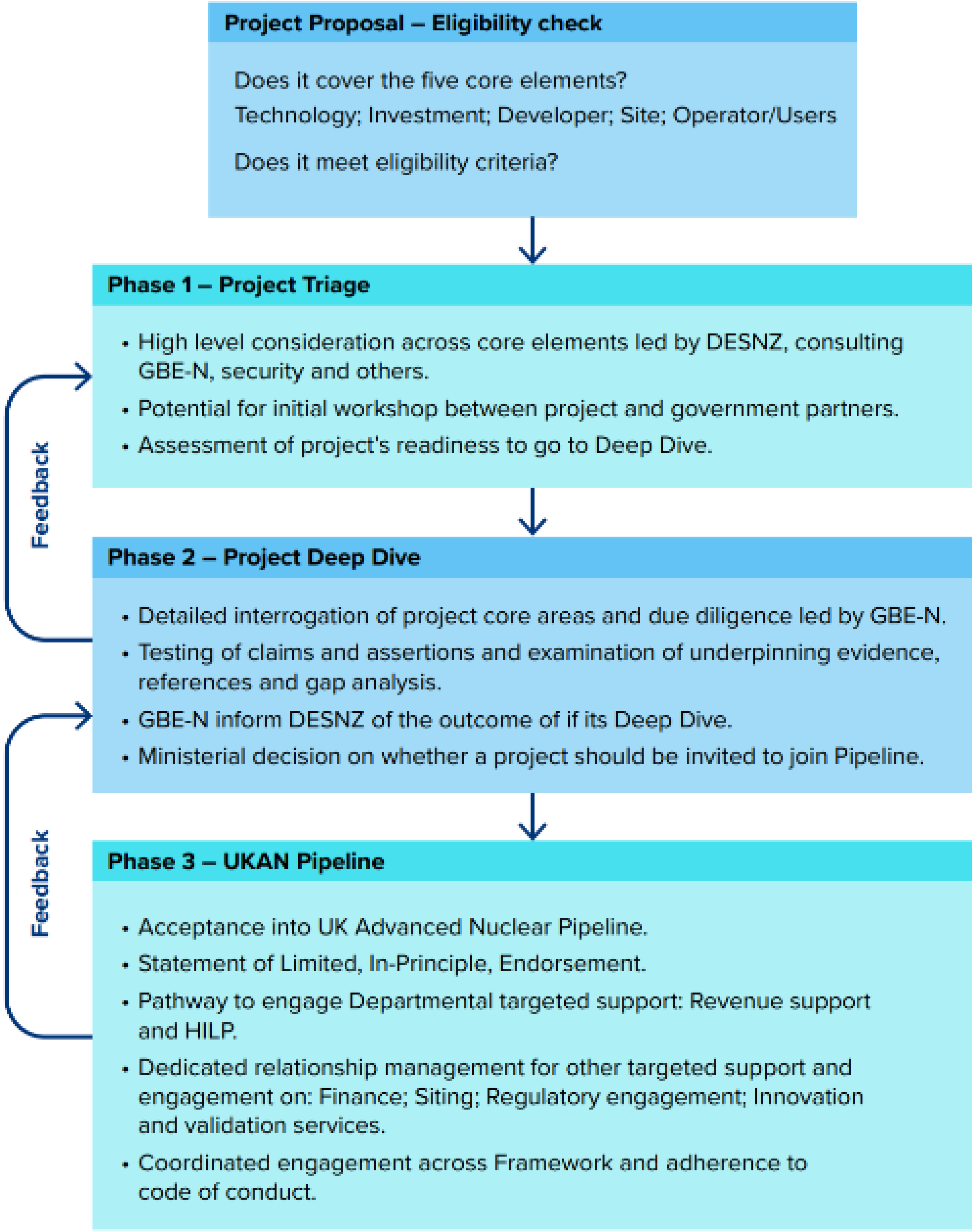
New build programme

- Continued expansion of fleet (GW, SMR, AMR)
- Major UK design capability is backed up by a strong supply chain which has successfully demonstrated its track record for delivering new build to time, cost and quality

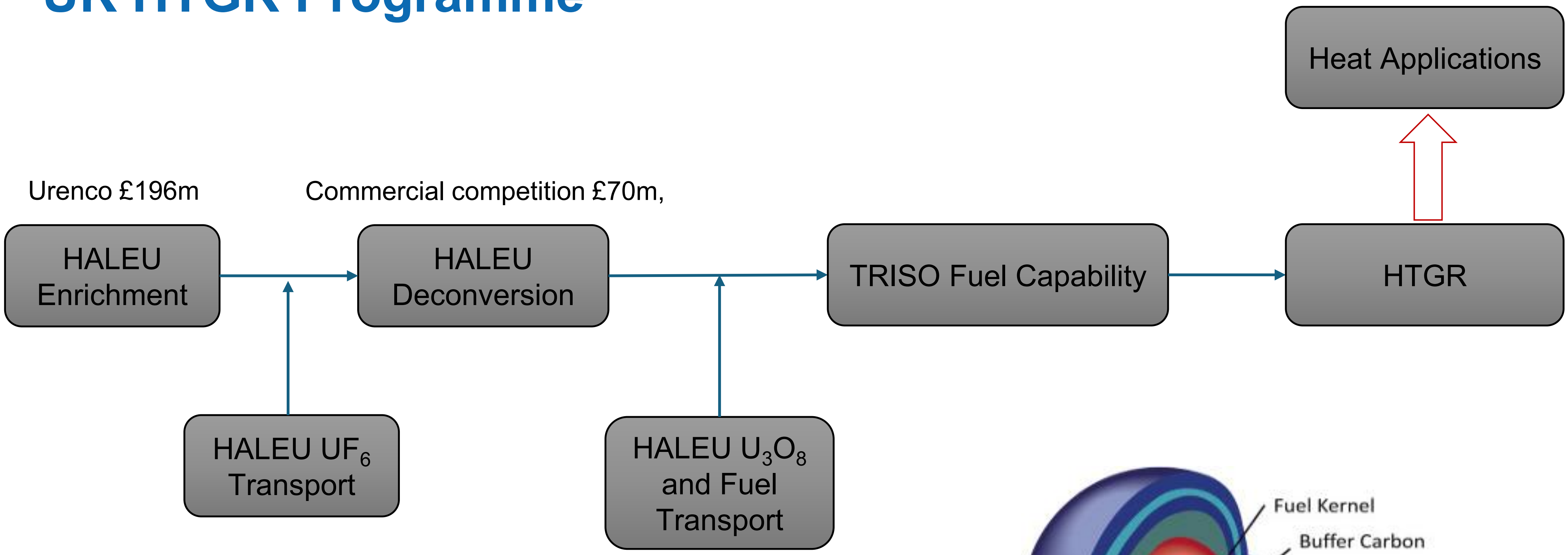


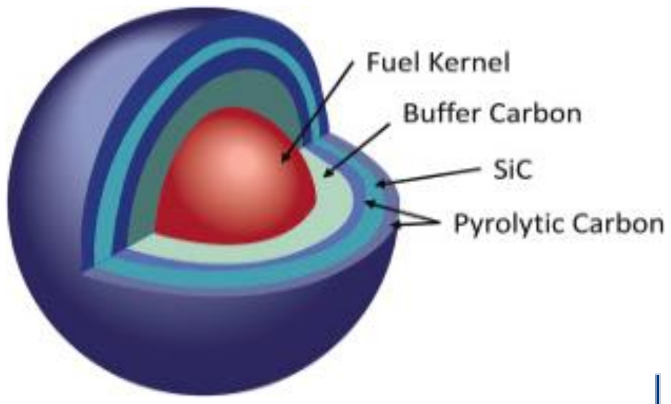
Advanced Nuclear Framework

- The framework is in place for DESNZ and GBE-N to review **privately led** projects and assess their ability to decarbonise the UK
- Review leads to an endorsement which they hope will attract more private funding
- Enables UK Government to use policy to support such as contract for difference or high impact, low probability protections
- Can help vendors engage with the National Wealth Fund but the business case would expect there to be a return on investment
- "*This is a framework to support private projects, not to develop a portfolio of government-funded projects*"



UK HTGR Programme



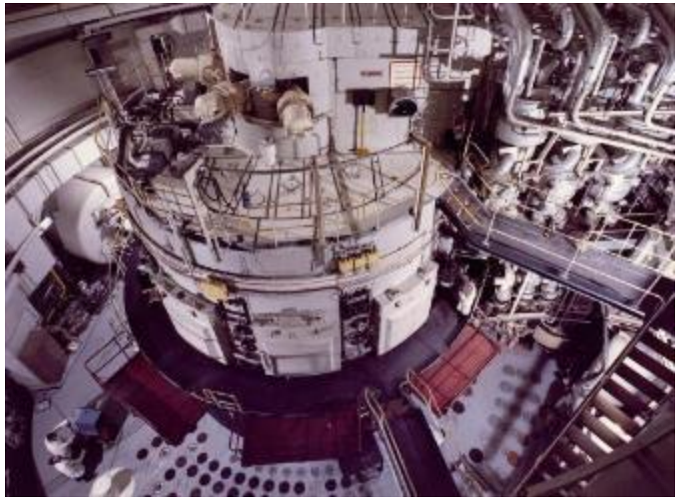


UKJ-HTR Technology History

1965 – 1976 DRAGON

1998 – present day HTTR

UKJ-HTR



- Consortium led by **UKNNL** and **JAEA**
- Extensive experience in both UK and Japan
- Longstanding collaborative relationships

- Government support from both sides
- UK (Amentum and EDF) and Japanese (MHI and NFI) industry supporting

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Deconversion and Fuel Programme

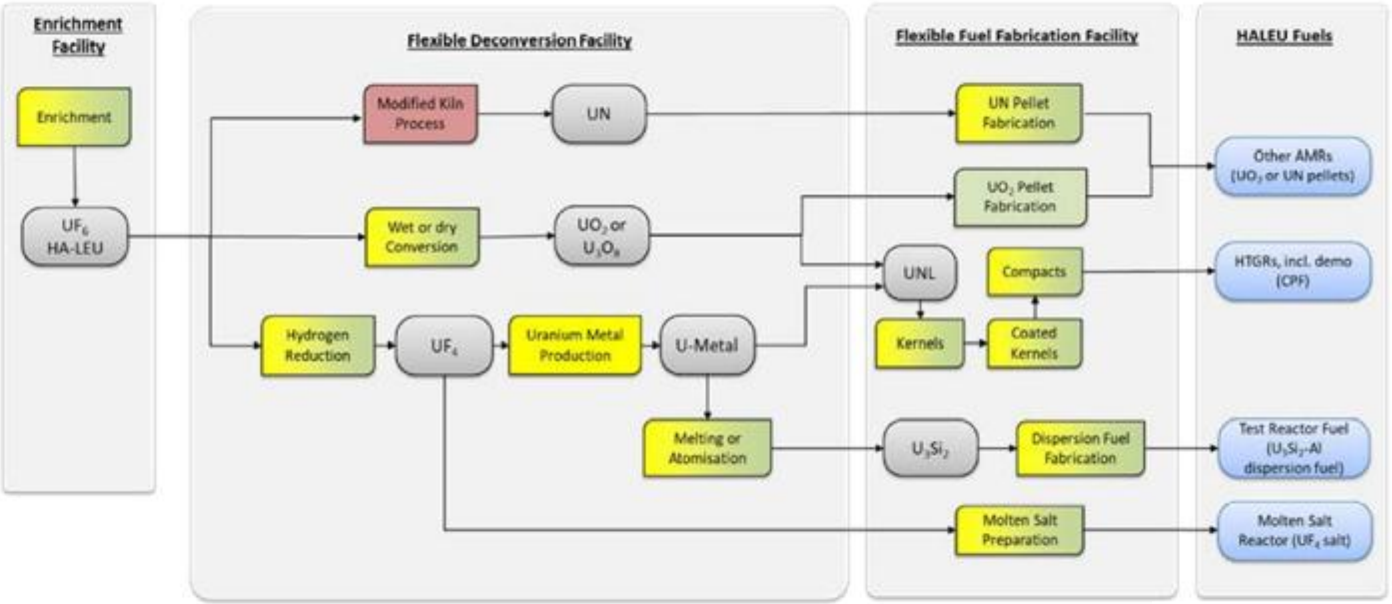
Fuel – Introduction

- Fuel is a major area of interest for UK
- Established capability in UO_2 at Springfields operated by Westinghouse and Framatome are designing a facility in Bristol
- All reactors will need fuel, but some reactors require greater levels of enrichment (HALEU)
- UK is a leader in enrichment technology with Urenco's headquarters based here
- 4 development areas:
  - HALEU Deconversion
  - Coated Particle Fuel / TRISO
  - Molten salts
  - MOx (for disposal)

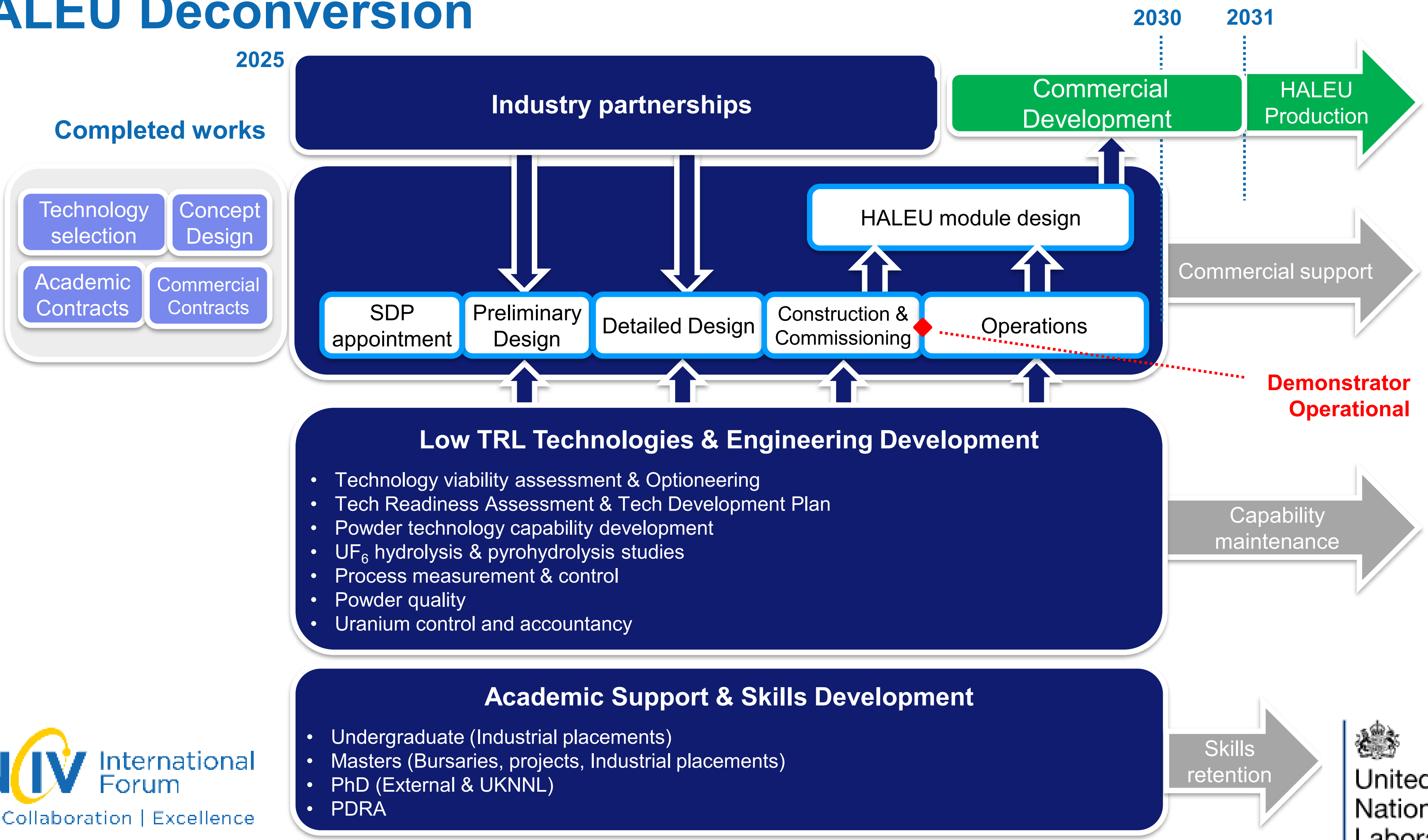
...and opportunity being exploited for Space

HALEU Deconversion

- In late 2024, DESNZ launched the HALEU Deconversion competition
- A facility that can match the output of Urenco's enrichment facility, exploring different options for the final deconverted product. HMG has seen interest in various oxides (U_3O_8, UO_2, UO_3), metallic uranium, and intermediates (UF_4)
- Awarded **£18m** to UKNNL to design and build two research rigs to conduct deconversion experiments
- The rigs will use natural uranium but be designed to be compatible with genuine HALEU



HALEU Deconversion



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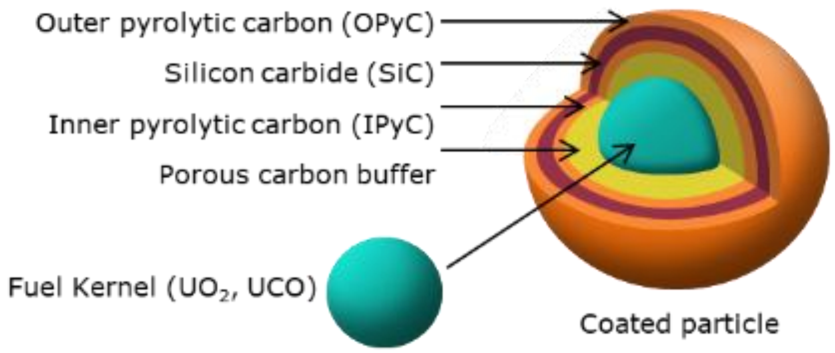
Coated Particle Fuel (CPF) Programme

- Demonstrate technology progression to TRL 4/5 through an end-to-end process demonstration at pilot scale plant in collaboration with Nuclear Fuel Industries (NFI) Japan
- Regulatory engagement
  - Fuel Qualification
  - Safety & Security
  - Environmental
  - Engineering Design Aspects
- Develop evidence base and strategy for fuel qualification
  - Irradiation Testing Schedule
  - UK CPF Qualification Plan and Activities
  - CPF fuel performance codes
  - Fuel Post Irradiation Examination (PIE) requirements
  - Validation of PIE and Spent Fuel 5-Year Plan
- Invest in skills and capabilities needed for the future



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CPF Programme – Graphite Matrix Production Plant

A3:3 Raw Materials
- 64% Natural Graphite
- 16% Synthetic Graphite
- 20% Phenolic Resin

Milling
- Target particle size of 15 µm
- Particle size analysis conducted using SEM and PFIB

Mixing
- Returned to mill without grinding balls and ran at a lower speed.

Compaction
- Die set temperature = 200 °C.

Green Body Compacts
- Photography and Mensuration conducted.

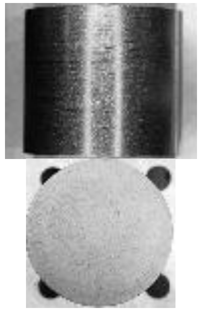
Carbonisation
- 800 °C for 20 hours.
- Argon atmosphere.

Cool to Ambient Temperature
- Compacts inspected and thermocouple removed.

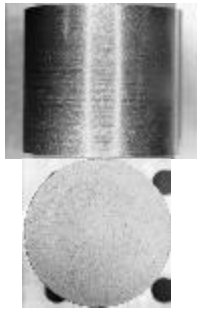
Annealing
- 1950 °C for 4 hours.
- Argon atmosphere.

Final Compacts
- Photography and Mensuration conducted.
- Sent for Machining.

Green body



Post Carbonisation



Post Annealing

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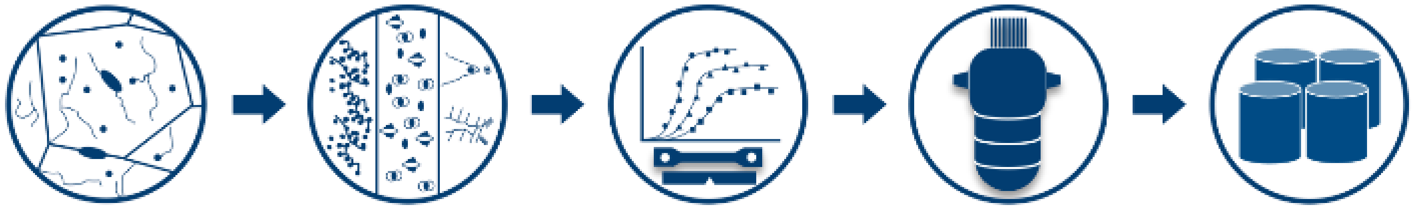
Plant Lifetime and HTGR Programme

Reactor Operation and Plant Lifetime Extension

- Well-established UKNNL capabilities to support licensees, regulators and international collaborations:
  - Civil and Defence Fuel PIE
    - Analysing fuel from the current generating fleet to understand its performance
    - Providing information for safety cases, design improvements and life predictions
    - Supporting current and long-term handling and storage of spent fuel
  - Reactor Chemistry and Corrosion (gas-cooled (AGR) and water-cooled (PWR, BWR) reactor chemistry)
    - Accident (iodine) chemistry (e.g., INSPECT model for EDF Energy Generation Ltd);
    - CRUD chemistry and deposition (e.g., BOA model for EPRI);
    - pH control additives and corrosion inhibition (e.g., REACTORUI for Rolls Royce);
    - Radiation chemistry (e.g., DEMO fusion radiolysis model for UKAEA);
    - Material release, transport, activation and deposition (e.g., UK SMR).
    - Specialised experimental methods relevant to high temperature reactor coolants (e.g. High temperature high pressure helium loop at the University of Bristol)

Reactor Operation and Plant Lifetime Extension

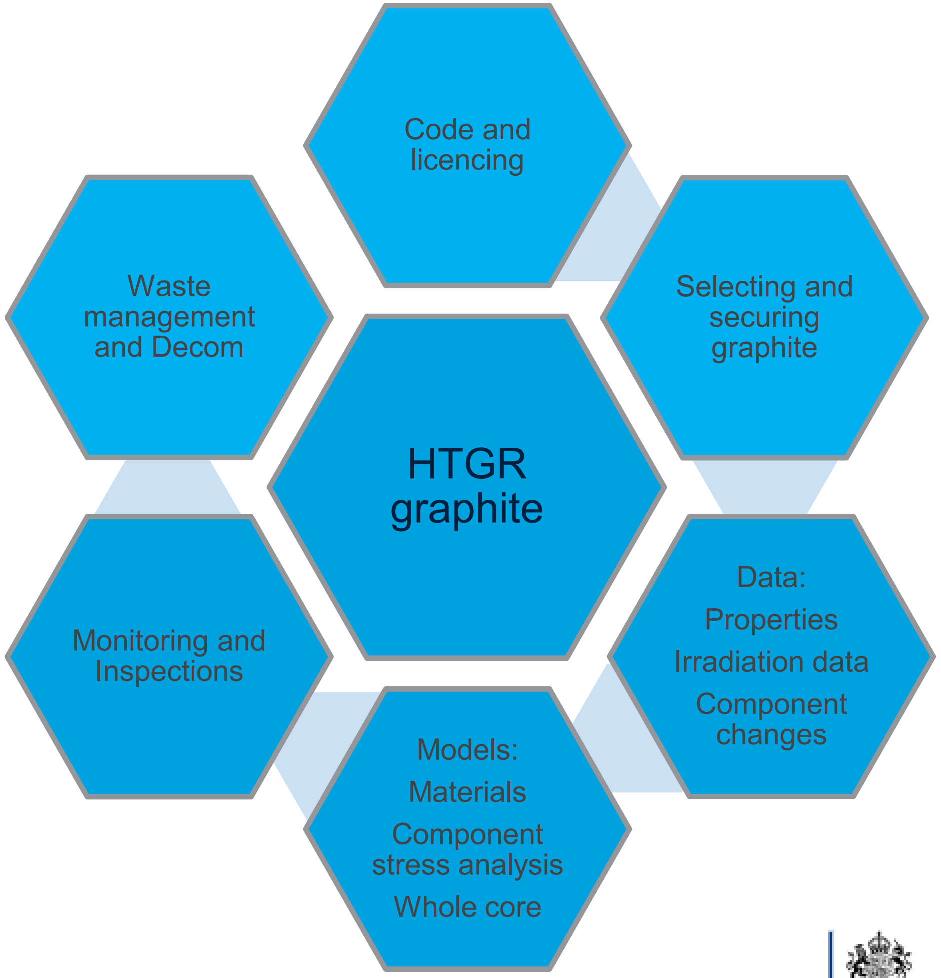
- Well-established UKNNL capabilities to support licensees, regulators and international collaborations:
  - Materials and structural integrity



- Improve mechanistic understanding of in-reactor materials performance
- Support safety cases for plant operation, life extension, and decommissioning strategies
- Develop capabilities in materials performance and component integrity to support current and future reactor operations
- Strong international collaborations
  - IL TROVOTORE – continuation of EU Programme looking at Accident Tolerant Fuel Claddings/Coatings
  - FRACTESUS – Fracture mechanics testing of irradiated RPV steels by means of sub sized specimens
  - ENTENTE – European Database for Multiscale Modelling of Radiation Damage
  - GEMINI 4.0 - HTR design for cogeneration

Reactor Operation and Plant Lifetime Extension

- Well-established UKNNL capabilities to support licensees, regulators and international collaborations:
  - Graphite
    - Scientific support through theoretical studies, modelling, experiment design and characterisation to all aspects of graphite technology, from manufacture to graphite waste management
    - UKNNL's breadth of experience enables us to combine graphite knowledge with other UKNNL expertise to provide a complete solution (Fuels, Radiochemistry, Inspections/instrumentation, Nuclear and Reactor Physics, Environmental Characterisation)



Reactor Operation and Plant Lifetime Extension

- Well-established UKNNL capabilities to support licensees, regulators and international collaborations:
  - Graphite PIE
    - Sole providers of graphite PIE for the UK reactors
    - Safety Case support
    - Waste Management and Decommissioning
    - International Collaborations

Low and High Active PIE: 250,000 measurements, over **20,000** samples

- ASTM Committee D02.F on Manufactured Carbons and Graphites
- NEA Expert Group on Structural Materials (EGSM)
  - Best Practice on Microstructural Characterisation of Pyrocarbon and graphite materials

International Collaborations on Graphite

- ASME Task Group on Section XI – Div.2: Nonmetallic Component Degradation and Failure Monitoring
- ASME Section III – Design of Non-metallic Components for HTRs
- Member of Generation IV Forum (GIF) – VHTR/Materials
- EU Horizon 2020 programme GEMINI4.0
- IAEA collaborative research projects on graphite waste management
- UK/US Irradiation Programme NIFT-E

ASME SETTING THE STANDARD

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GEMINI

IAEA

INL Idaho National Laboratory

United Kingdom National Nuclear Laboratory

AMR Phase B RD&D Programme – UKJ-HTR Aims

Contribution to
Net Zero by 2050

Advanced Modular Reactor Demonstrator – High Temperature Gas Reactor

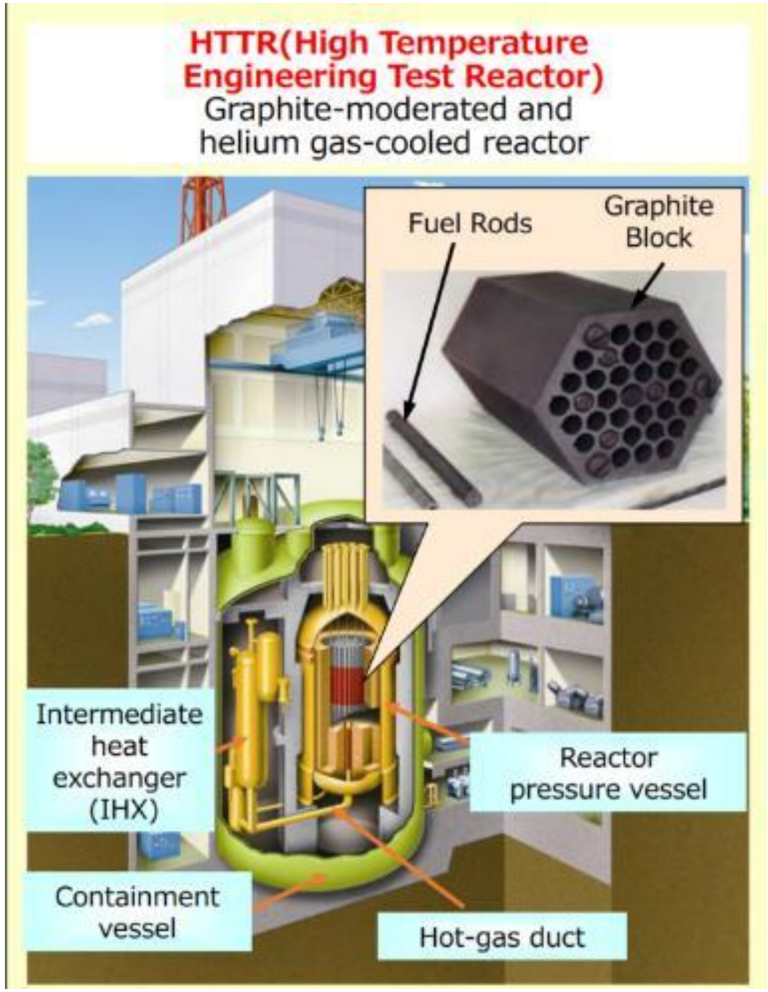
Demonstrate HTGR Technology
Reduce Risk and Maximise UK Benefits

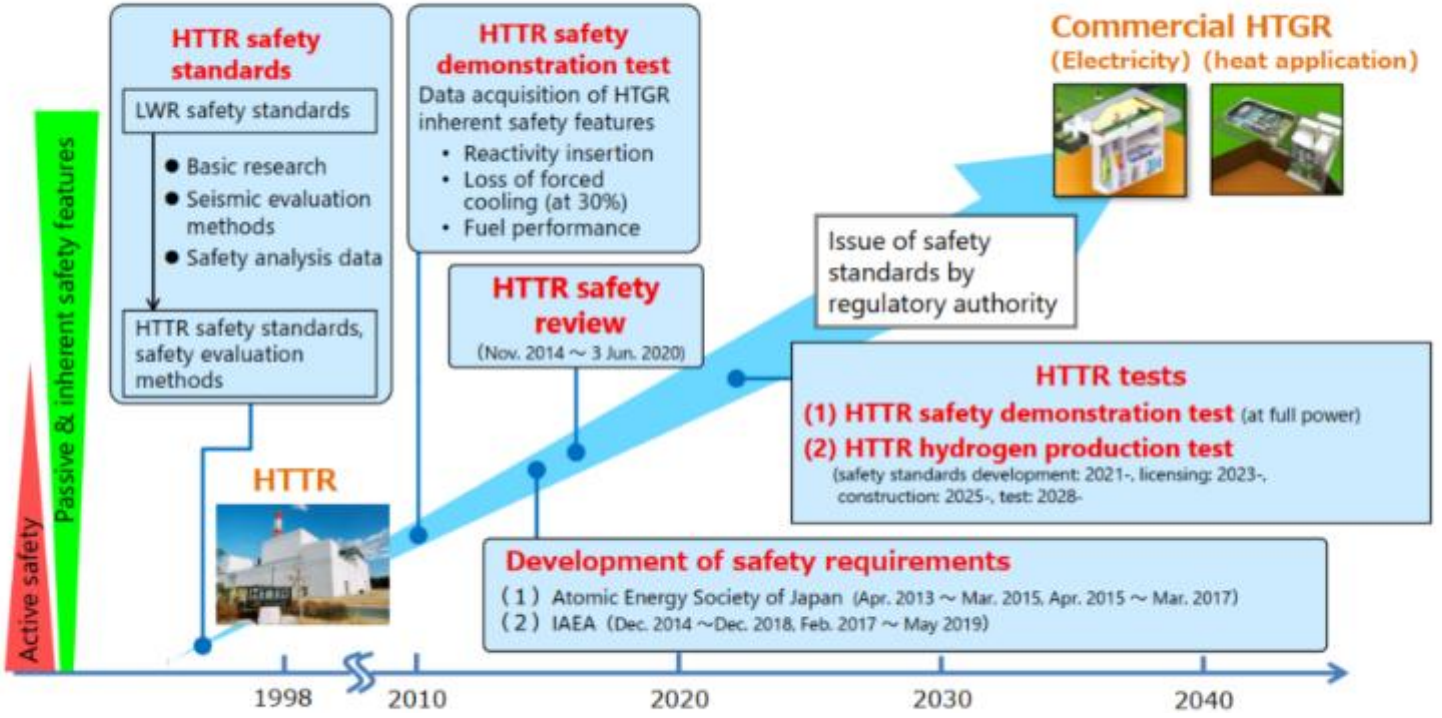
- Identify cost effective way to overcome market failures and incentivise private sector investment in HTGR technology
- Identify innovative technologies that can be developed within budget and timescale and develop technologies to at least TRL7
- Demonstrate that HT heat can be safely extracted from HTGRs and used to decarbonise heat demand from key sectors.
- Develop the UK supply chain, to deliver a HTGR Demonstration and underpin supply chain confidence towards commercialisation.
- Generate IP, skills, and knowledge to position the UK to take advantage of export opportunities associated with HTGR technology

AMR Phase B RD&D Programme – UKJ-HTR Objectives

- OBJECTIVE 1: Design Progression
  - Focus is on Front-End-Engineering-Design (FEED) progression to enable Phase C progression. This includes the following tasks:
    - Design development suitable for providing UK Regulators with confidence around design trajectory.
    - Design development for taking forward and develop into detailed design in Phase-C
    - End-user analysis to gauge suitability of reactor capacity
- OBJECTIVE 2: Research and Development
  - Prioritisation of Key 'no regrets' Technology Development (TD) activities to be carried out in parallel with and as part of the development design and enable Phase C, to support UK IP development and UK Skills and Capabilities
- OBJECTIVE 3: Phase-C Delivery Plans
  - Production of detailed cost estimates for AMR Phase C Programme
- OBJECTIVE 4: Skills and Capability
  - Establish the required skills and capabilities in the UK supply chain, sufficient to form a basis of expansion to deliver a HTGR demonstration and potential fleet

AMR Phase B RD&D Programme – UKJ-HTR Technology





Thermal power	**30 MW**
Fuel	**Coated fuel particle / Prismatic block type**
Core material	**Graphite**
Coolant	**Helium gas**
Inlet temp.	**395°C**
Outlet temp.	**850/950°C**
Pressure	**4 MPa**

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UKJ-HTR

United Kingdom National Nuclear Laboratory

Parameter	HTTR	HTR50S	GTHTR300, 300C	UKJ-HTR [Preliminary]
Thermal power (MWth)	30	50	600	**150-250**
Inlet temperature (^{o}C)	395	325	587 (at core inlet) 594 (at core inlet)	**325**
Outlet temperature (^{o}C)	850 / 950 (two operation modes)	750 (phase I) 900 (phase II & III)	850 (electricity) 950 (cogeneration)	**750 (Start Demo) 850 / 950 (Operation)**
Coolant & pressure (MPa)	Helium / 4	Helium / 4	Helium 6.9 (electricity) 5.1 (cogeneration)	**Helium / 4**
Average power density (MW/m^3)	2.5	3.5	5.4	**2.5**
Core diameter / height (m)	2.3 / 2.9	2.3 / 3.48	4.1 / 8.4 (annular core)	**4.1 / 8.4 (annular core) Maximum**
Fuel block height (m)	0.58	0.58	1.05	**1.05**
Number of fuel column	30	30	90	**90**
Number of layer	5	6	8	**8**
Fuel type	Sleeve	Sleeve (phase I) Monolithic (II & III)	Monolithic	**Sleeve (Phase C1 & C2) Monolithic (when available)**
Enrichment (%)	3.4 - 9.9	3.4 - 9.9 (Phase I) <15 (Phase II & III)	7 – 16.8	**3.4 - 9.9 (near-term) < 19.75 (when available)**
RPV diameter / Height (m)	5.5 / 13.2	5.5 / 15	8 / 23	**8 / 23 (Maximum)**
Material of RPV	2 1/4Cr-1Mo steel	Mn-Mo steel	Mn-Mo steel	**Mn-Mo steel**
Operational Life (Years)	20	40	60	**40**
Refuelling Cycle	21	24	18-24	**18-24**

AMR Phase B RD&D Programme – UKJ-HTR Design Progression

- UK / Japan Requirements Alignment
  - Nuclear Codes and Standards
  - UK legislative and regulatory requirements
  - Cross-cutting requirements
- UKJ-HTR Early Concept Design
- Individual Discipline Reports
  - 3SE Report (Safety, Security, Safeguards and Environment) in the format of the IAEA SSG-61 Safety Analysis Report
  - Final Phase B Report
    - Outcome of the FEED: Readiness and Suitability
- In collaboration with Amentum and independent review by EDF Energy, from an operator's point of view

Mechanical Discipline Report
Handling & Lifting Discipline Report
Control Systems Discipline Report
Electrical Discipline Report
Civil and Structural Discipline Report
Structural Discipline Report
Decommissioning Discipline Report
Security Input
Environmental Input
Safety Input
Human Factors Report
Fuel and Core

JAEA

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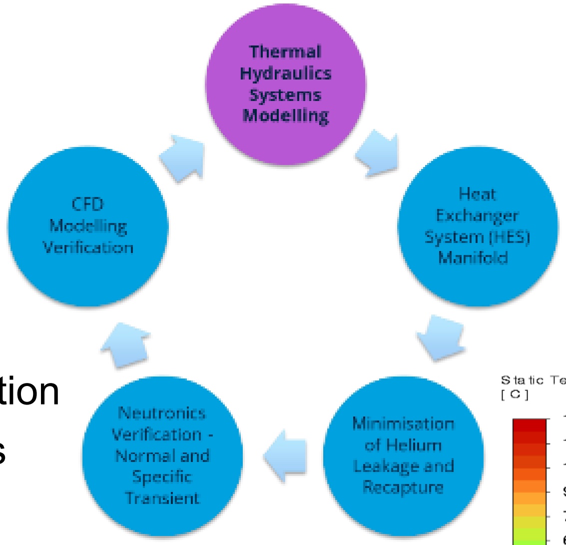
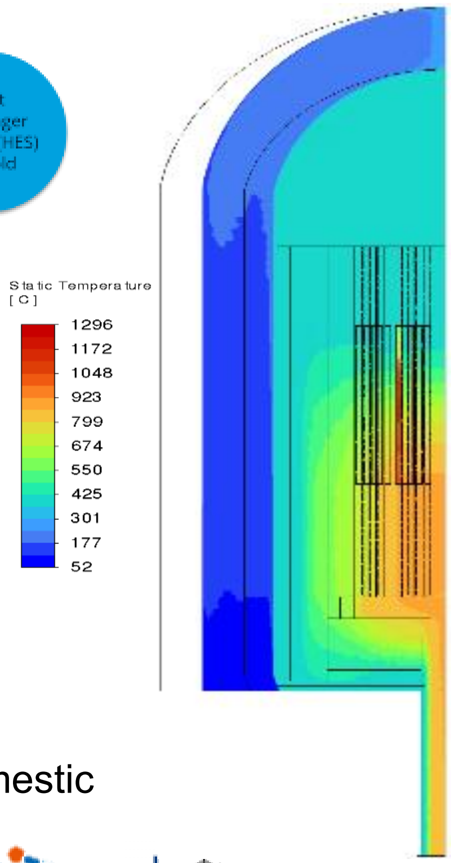
AMR Phase B RD&D Programme – UKJ-HTR Design Progression

- Regulatory Engagement
  - 6 Topic Areas
    - HTGR System and Component Configuration
    - Safety Aspects
    - Fuel and Core and Engineering Design Maturity
    - Siting, Security & Emergency Planning Arrangements (EPA)
    - Operations and Electrical Engineering, Control & Instrumentation (EC&I)
    - Environmental and Radioactive Waste Management & Nuclear Liabilities
  - Over 20 meetings with ONR and EA
- 1-day workshop with JAEA presenting LfE from the HTTR design and operation to UK regulators
- Monthly meetings with DESNZ and NIRO

AMR Phase B RD&D Programme – UKJ-HTR Design Progression

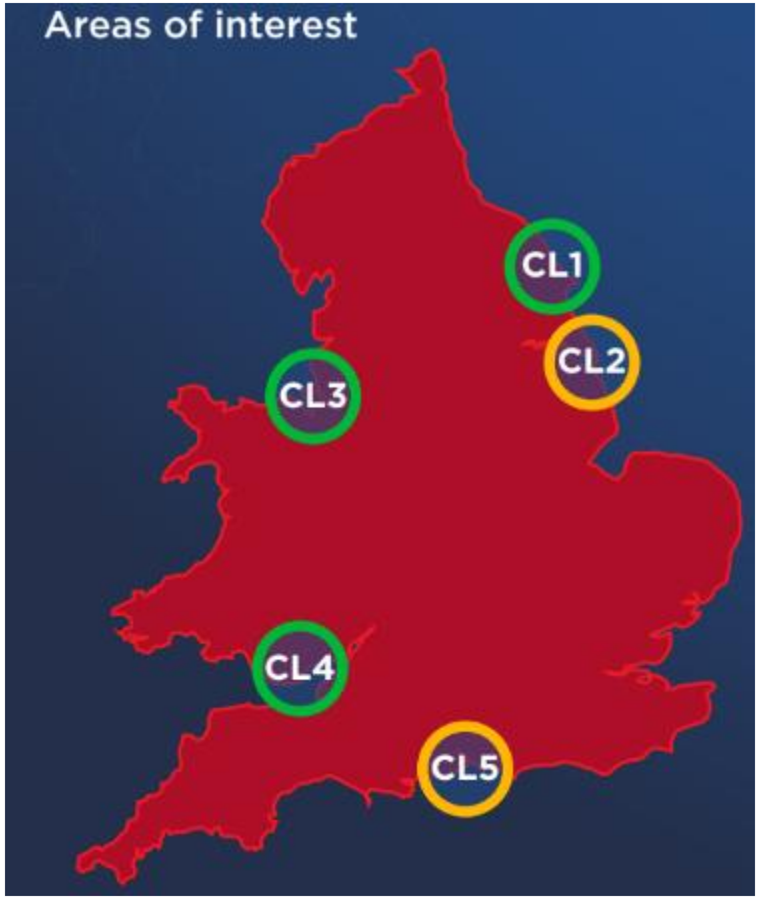
- Technology Development
  - TD01: HES manifold
  - TD02: AI to accelerate material qualification
  - TD03: Neutronics modelling verification
  - TD04: Thermal hydraulics modelling verification
  - TD05: CFD modelling verification
  - TD06: Neutronics thermal hydraulics coupling modelling analysis verification
  - TD07: Digitisation of nuclear power plant EC&I systems via WiFi systems
  - TD08: Helium leakage and prevention
  - TD09: Materials degradation and structural integrity
  - TD10: Graphite disposal and spent fuel management
- The aims of the Technology Development (TD) areas are to:
  - accelerate technology maturity and commercialisation
  - minimise the uncertainties and risk in the implementation phase of a HTGR demonstrator
  - maximise the benefit to the UK by developing UK skills and IP and delivering a design tailored to domestic requirements.





AMR Phase B RD&D Programme – UKJ-HTR Commercialisation

- UK Skills and Supply Chain
  - Understand the likely challenges and shortages with specific relevance to HTGRs
    - UKNNL review of skills and capability for Underpinning Science
    - Amentum review of Engineering and Manufacturing Skills
    - EDF Energy review of Operational Skills
- Transport and Logistics
  - Assessment of the UK's Transport Networks for viability and applicability to transport large indivisible HTGR components such as RPV

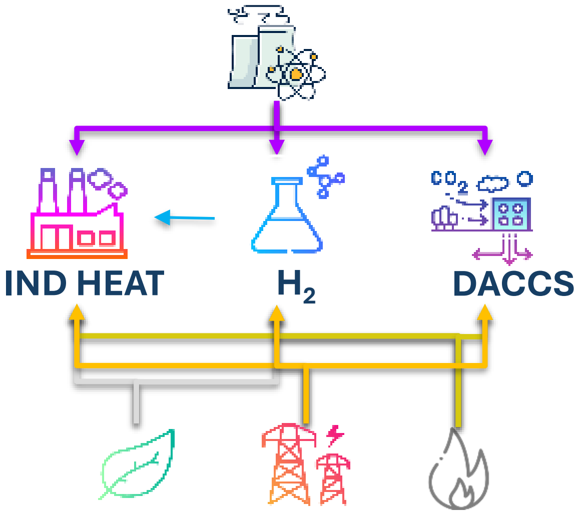


AMR Phase B RD&D Programme – UKJ-HTR Market Need

- End user engagement completed ca. 30 1:1 meetings with end users from a range of sectors
- Held several Energy Users Advisory Board
- Key Barriers:
  - Lack of clarity for specific technical information, such as how the UKJ-HTR will integrate with existing systems and its output/energy vector
  - End-users hesitant to be first adopters due to perceived risks

AMR Phase B RD&D Programme – UKJ-HTR Market Need

- Context
  - The proposed reactor can deliver reliable, zero carbon, high temperature heat
  - This could have applications across industrial heat, hydrogen production, DACCS
  - DESNZ wish to understand the extent of that market potential in the UK
- Why use whole energy system modelling?
  - For each potential application above, there are various low carbon propositions:
    - Industrial heat: electrification, biomass, hydrogen, natural gas + CCS
    - Hydrogen production: electrolysis, natural gas + CCS, biomass + CCS
    - DACCS: electricity, natural gas + CCS



- A technology agnostic, whole systems analysis can identify the conditions where HTGRs are deployed as part of the overall least cost energy mix
- ESC's Energy Systems Modelling Environment
  - ESME finds the least cost UK energy system pathway
    - Satisfying energy service demand projections to 2050
    - Under tightening carbon budgets reaching net zero
    - With a catalogue of ~400 technologies and resources
    - Balancing energy within-year, within-day, for 12 UK regions

ESME
Energy Systems Modelling Environment

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AMR Phase B RD&D Programme – UKJ-HTR Market Need

- Base Case
  - This study uses ESC's Clockwork scenario as a starting point. By 2050:
    - Biomass use more than doubles (reference case)
    - CCS achieves 95% capture rates (reference case)
    - Renewables capacity climbs to 142GWe (with abundant storage)
    - 12GWe of Gen III nuclear for baseload electricity
    - 22GWe of SMRs for cogeneration of electricity and district heating
- In short, a techno-optimistic scenario with a wide range of low carbon solutions available to support industry, hydrogen production and DACCS
- As such, the Base Case might be viewed as a conservative estimate of the value of HTGRs

2050 HTGR Capacity (GW thermal)			
	Capex		
	High	Ref	Low
Base case	2.8	**2.9**	5.6
High BIO	-	**0.5**	-
High CCS	-	**0.6**	-
Low BIO	2.6	**4.7**	7.5
Low CCS	4.7	**5.3**	7.5
High IND	2.9	**4.7**	7.2
All 3	6.9	**7.8**	7.8
All 3 Fast	8.0	**11.0**	12.7

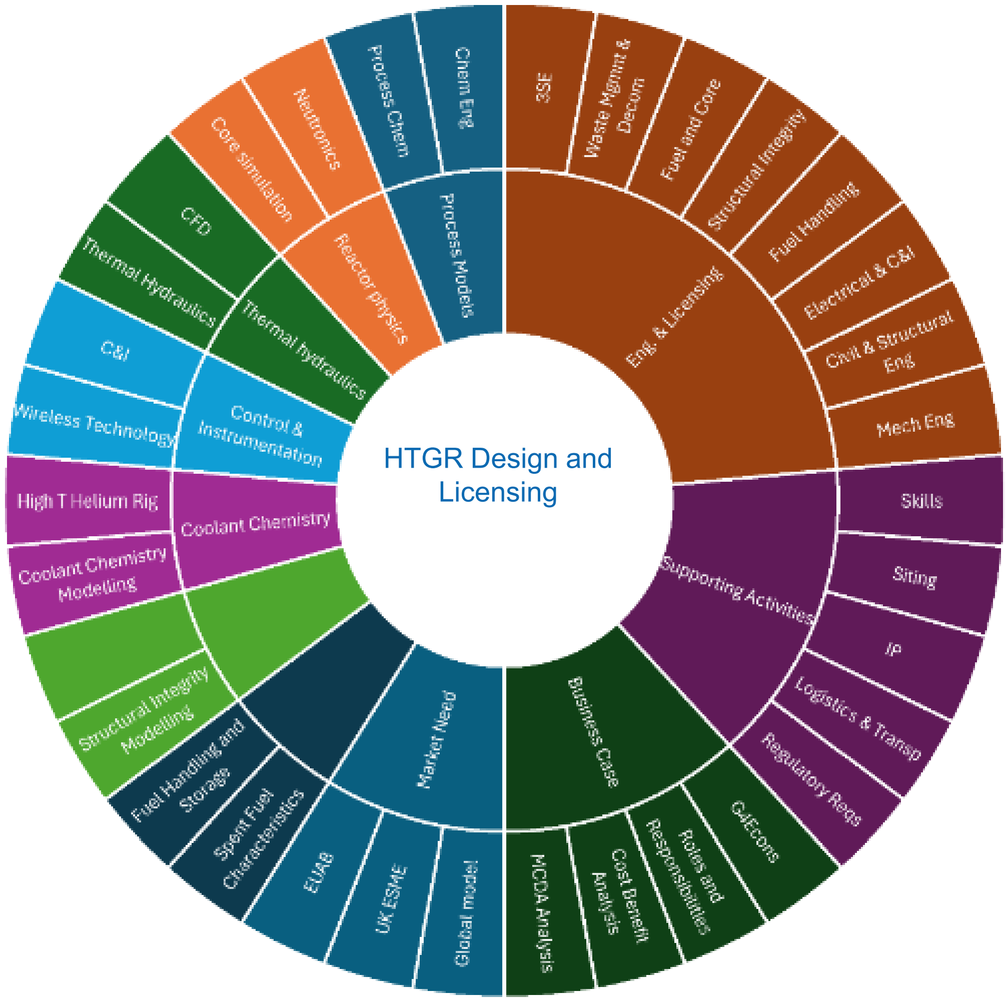
Indicative units (250MW each)
2.9GW, ~12 units

AMR Phase B RD&D Programme – UKJ-HTR Business Case

- Outline Business Case (OBC)
  - Cost and Schedule of Phase C (Final design and licensing, Construction and Commissioning)
  - Based on G4ECons approach and model
  - Included a Multi Criteria Decision Analysis
- Project Initiation Document (PID)
  - Project Definition – outlining the scope of Phase C, its objectives, a Product Breakdown Structure, and Deliverables
  - Phase C business case – looking beyond the demonstrator or FOAK to a commercial fleet
  - Risks – to successful delivery of the next phase
    - how they can be mitigated
  - Roles and responsibilities – a number of options are considered

AMR Programme Summary

- In collaboration with JAEA's world-leading capabilities and in combination with the UK Fuels programme, UKNNL has formed an integrated network successfully delivering design review, FEED information transfer, regulatory engagement and end user engagement for this reactor system.
- Beyond delivering project outputs, the programme significantly upskilled UKNNL and the UK supply chain. The project built depth within specialist teams while simultaneously raising baseline capability across the wider organisation.
- This upskilling will enable more effective collaboration in the future and efficient delivery of design reviews of any AMR programme.



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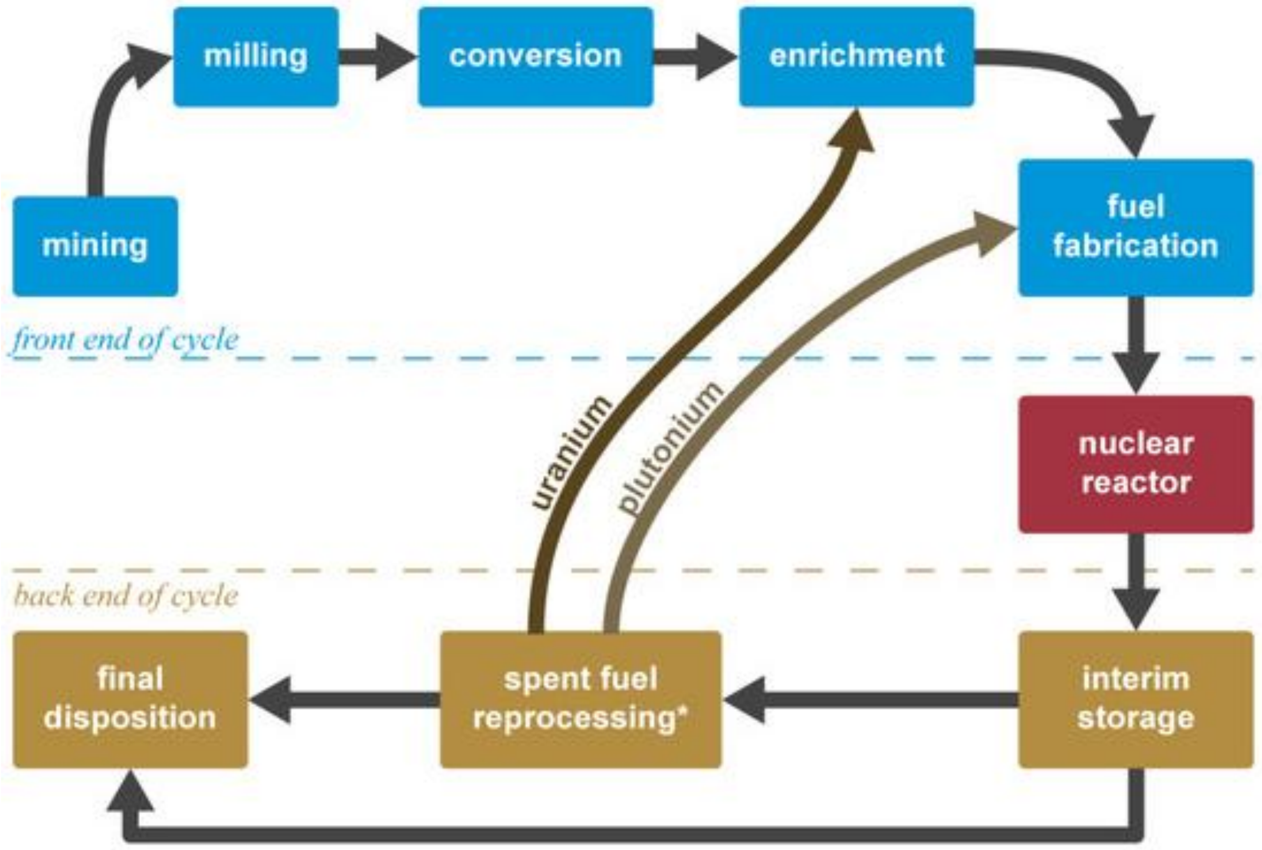
Insights into other work

Fuel Cycle – Separation

- Reprocessing
- Advanced reprocessing
- Pyrochemical processing
- Fission product removal ‘vs’ fuel separation

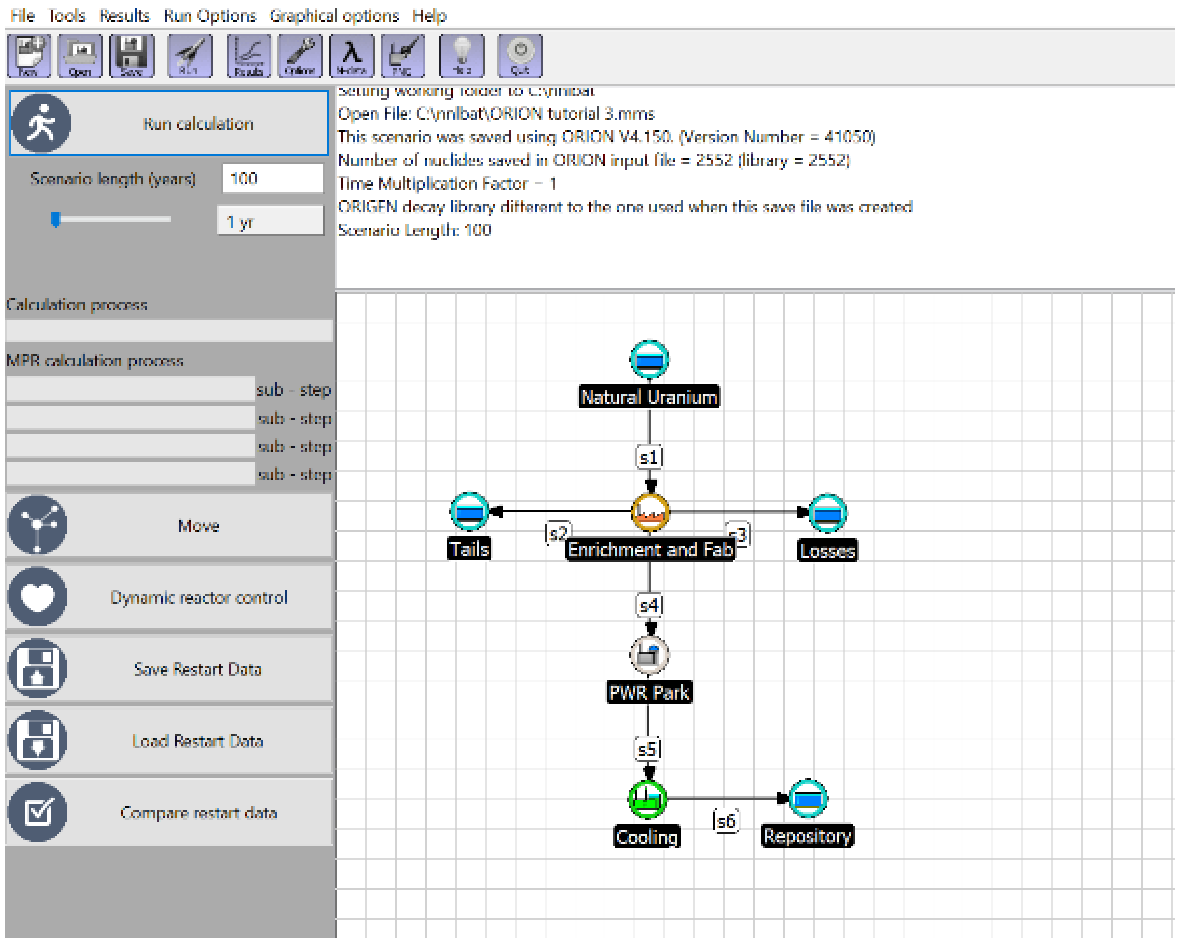


Costa Peluzo, B. M. T., & Kraka, E. (2022). Uranium: The Nuclear Fuel Cycle and Beyond. International Journal of Molecular Sciences, 23(9), 4655. https://doi.org/10.3390/ijms23094655

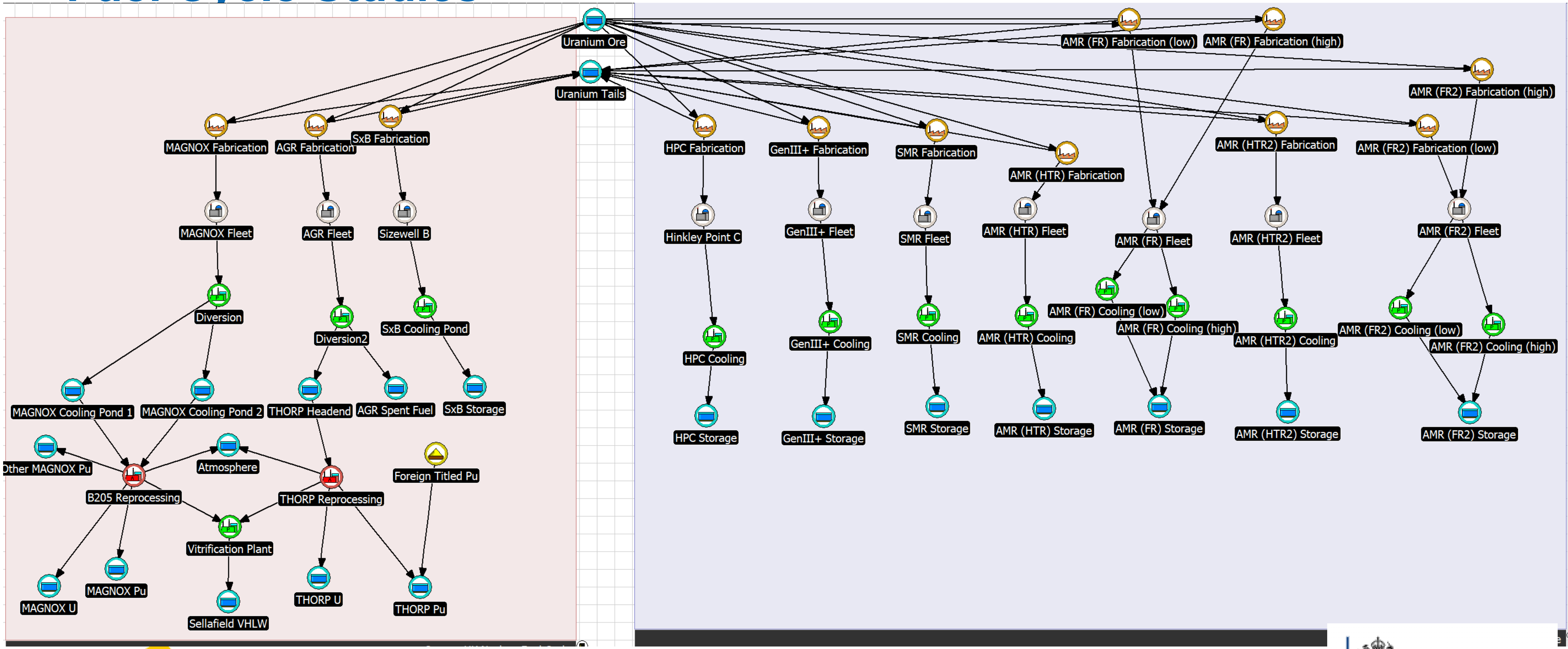
Fuel Cycle Studies

UKNNL develop the ORION code which tracks nuclear material across the fuel cycle

- Tracks material (~2000 radionuclides) throughout fuel cycle
- Allows for optimisation studies to be performed quickly
- Allows for understanding of uranium required, plutonium produced, waste management options



Fuel Cycle Studies



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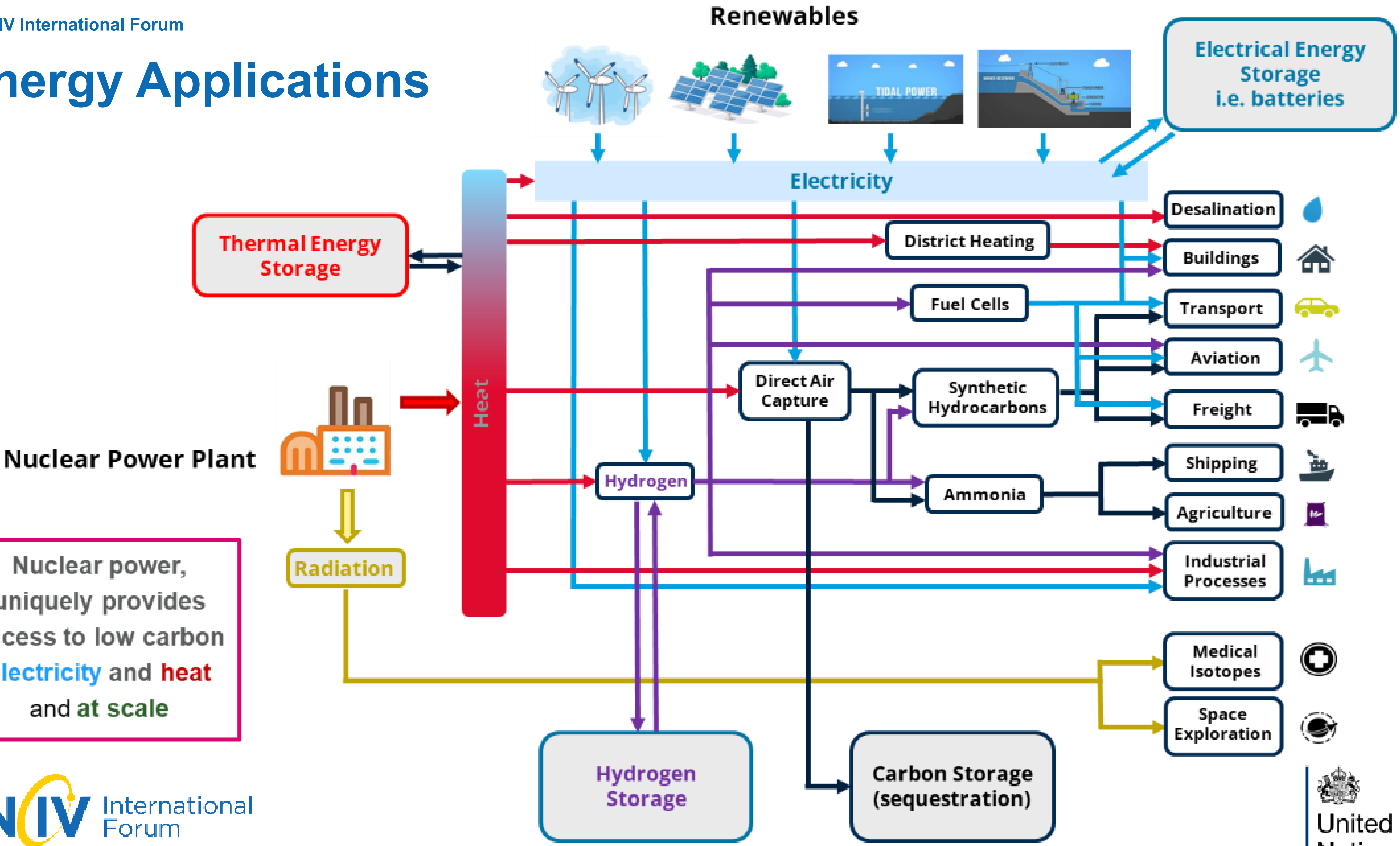
Energy Applications



Nuclear power, uniquely provides access to low carbon **electricity** and **heat** and **at scale**

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Waste Treatment and Processing

- UKNNL have supported reprocessing at Sellafield since its inception, development sites such as Harwell and Dounreay – all of these generate gaseous, liquid and solid wastes in different forms
- UKNNL therefore have a real depth of understanding in wasteforms – particularly glasses and cements; but also ceramics and more novel wastes such as those from HIP, thermal treatments and minerals
- We are currently responding to global challenges in the supply of materials for 'traditional' nuclear cements; developing products for new wastes being generated from decommissioning activities
- This is experience will be invaluable in developing wastes for Gen IV reactors

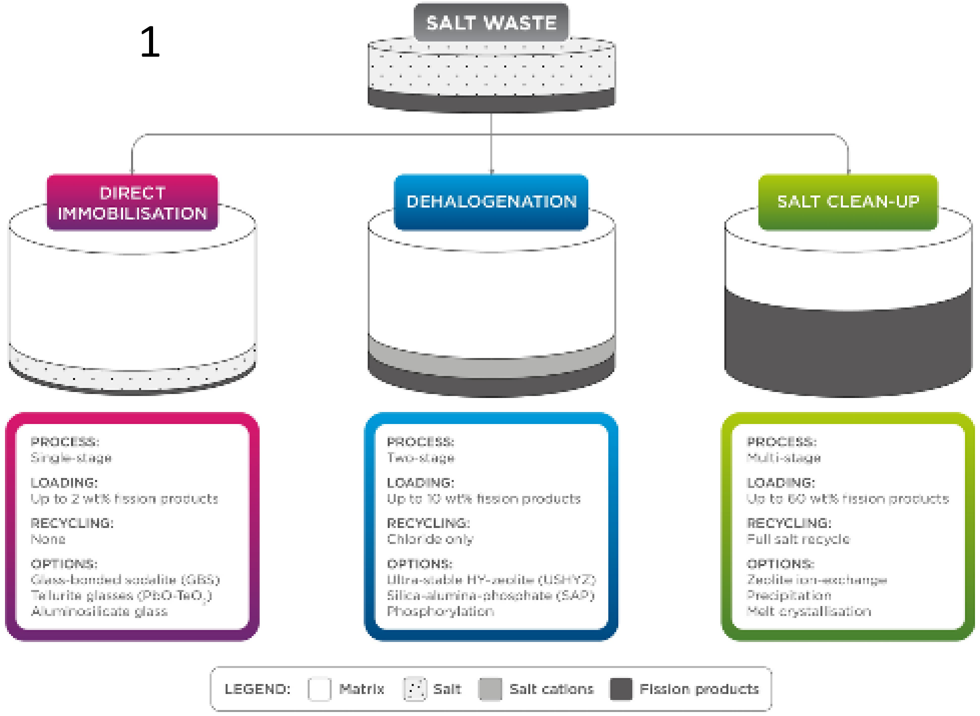



1 Cutaway section of simulated encapsulation of hulls from Sellafield (Sellafield Visitors Centre)
2, Movement of a waste drum in store
3, UKNNL's vitrification test rig
4, UKNNL's Preston Lab Rig Hall, with many treatment operations

Waste Treatment and Processing

- Waste doesn't bring in the investors
- Best Available Technology (BAT) and compliance with waste disposal will be necessary to comply with regulation
- UKNNL have an internal programmes developing solutions such as the AFCP programme on pyrochemical processing wastes

1



1 Routes to salt waste treatment, UKNNL Pyrochemical Processing Wastes project.
2, Robots for handling and processing waste for Sellafield Box Encapsulation Plant, development work carried out by UKNNL
3, Hot Isostatic Press – Royce Institute – part of UKNNL led National Nuclear Users Facilities

2

3

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Safeguards and Security

- Safeguarding of GenIV reactors presents a challenge to conventional approaches
- Working in a bilateral activity with the US we are developing a new approach to how to ensure robust safeguard measures can be applied
- By starting with, arguably the most novel – MSRs, we aim to develop a process applicable to all reactor types

Summary Slide

- The UK must deliver nuclear energy at pace to compensate for retiring reactors and to meet our net zero ambitions
- Significant regulatory and policy change has occurred to make the UK an attractive place to deliver new nuclear
- The UK is open to all Gen IV technologies as demonstrated by the Advanced Nuclear Framework
- UKNNL is providing advice and assurance on scientific, engineering and strategic areas to ensure technologies that will meet the future needs of the UK are delivered
- HTGR technology is a good fit with UK requirements building on our history and strength in enrichment, deconversion and CPF production
- UKNNL is maintaining and building skills in all GenIV technologies and all aspects of the fuel cycle
- UKNNL remains open to collaboration and support to fuel, reactor and waste development
- The UK is an excited to be welcoming in a ‘golden age of nuclear’

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Thank you

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Upcoming Webinars

Date	Title	Presenter
29 April 2026	Overview of the Advances in Monitoring Techniques for Molten Salt Reactor and Fuel Cycle	Dr. Sungyeol Choi, Seoul National University, Republic of Korea
5 May 2026	Joint GIF/IAEA Webinar: AI advances in the nuclear energy sector	Panelists: Prof. Abdel Khalik, Purdue University, USA; Mr Shahab Dabiran-Zohoory OECD - Nuclear Energy Agency; Prof. Pavel Tsvetkov, (Texas A&M University, USA) Moderators: Dr. Alexei Miassodeov IAEA; Dr. Patricia Paviet, PNNL, USA
18 June 2026	Defensive Cyber Security Architecture and Impact on GenIV Reactors	Dr. Rick Bodner, Canadian Nuclear Laboratories, Canada

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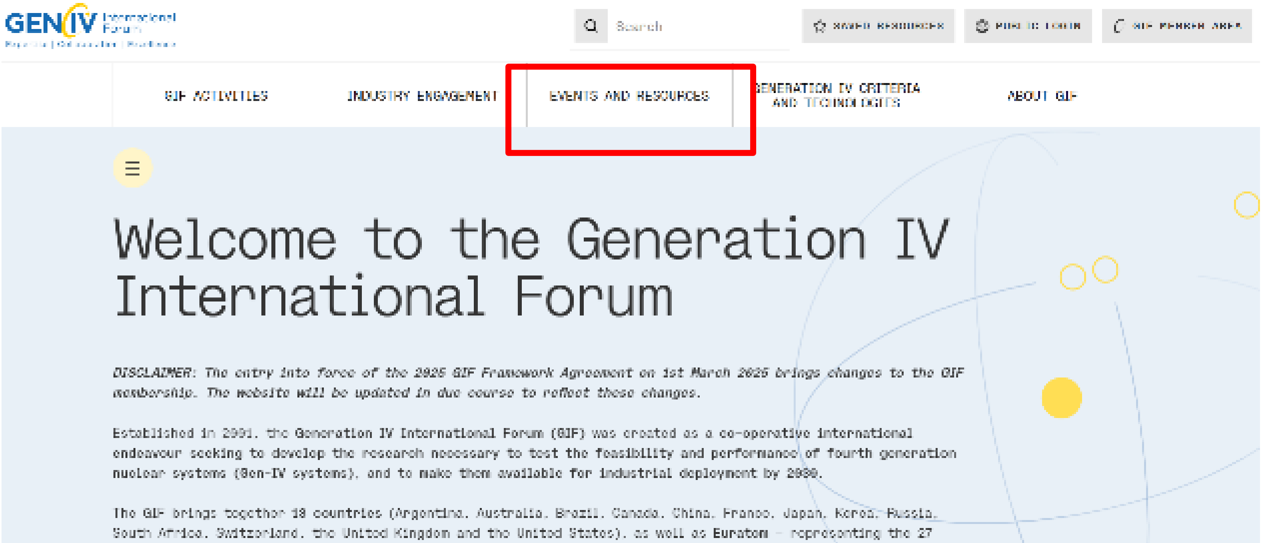
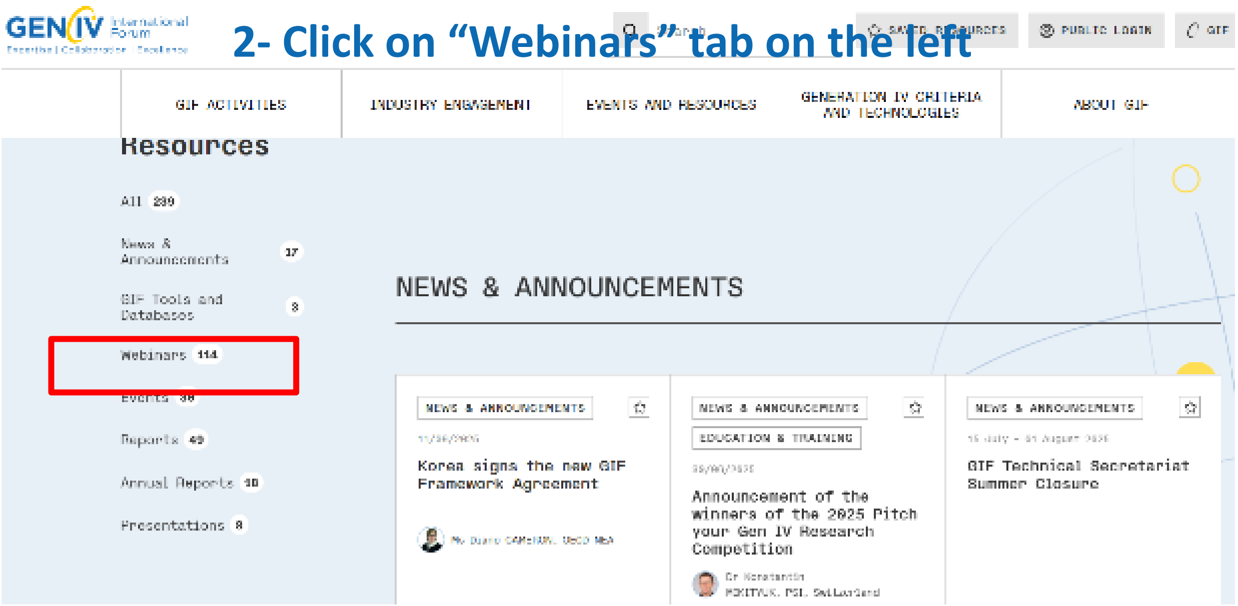
How to find the recorded GIF webinars – www.gen-4.org

1- Click on “Events and Resources Tab



2- Click on “Webinars” tab on the left



3- Click on “HERE” to see all the webinars

Or

4-Use the Year and Resource tag and click on Filter