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UK HTGR Programme

Opportunities for UK-Japan Collaboration

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1. History of Gas Reactors in the UK
2. UK Strategy for Net Zero and Role of HTGRs
3. UK AMR Research, Development & Demonstration Programme
4. UK-Japan Collaboration

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1. History of Gas Reactors in the UK

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Commercial Gas Reactors

- UK's historical and existing commercial reactor fleet almost entirely gas-cooled
  - 26 Magnox
  - 14 AGR
  - Just 1 PWR
- All Magnox reactors now in decommissioning. 6 AGR reactors in defueling. Remaining AGRs currently due to shut down by 2030
- Future GW-scale commercial fleet centres on LWRs. But significant expertise remains in commercial gas-cooled reactor operation, including at relatively high temperatures (AGR outlet temperature is 650ºC), aligning well with future HTGR use

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Dragon

- World's first HTGR reactor was built in the UK, at the Winfrith site, as an OECD project
- Construction started in 1959 and reactor operated from 1965 to 1976
- Helium cooled, graphite moderated with TRISO fuel
- Initially fuelled with HEU, later converted to LEU fuel
- Reactor now being decommissioned; most plant other than the core has already been removed

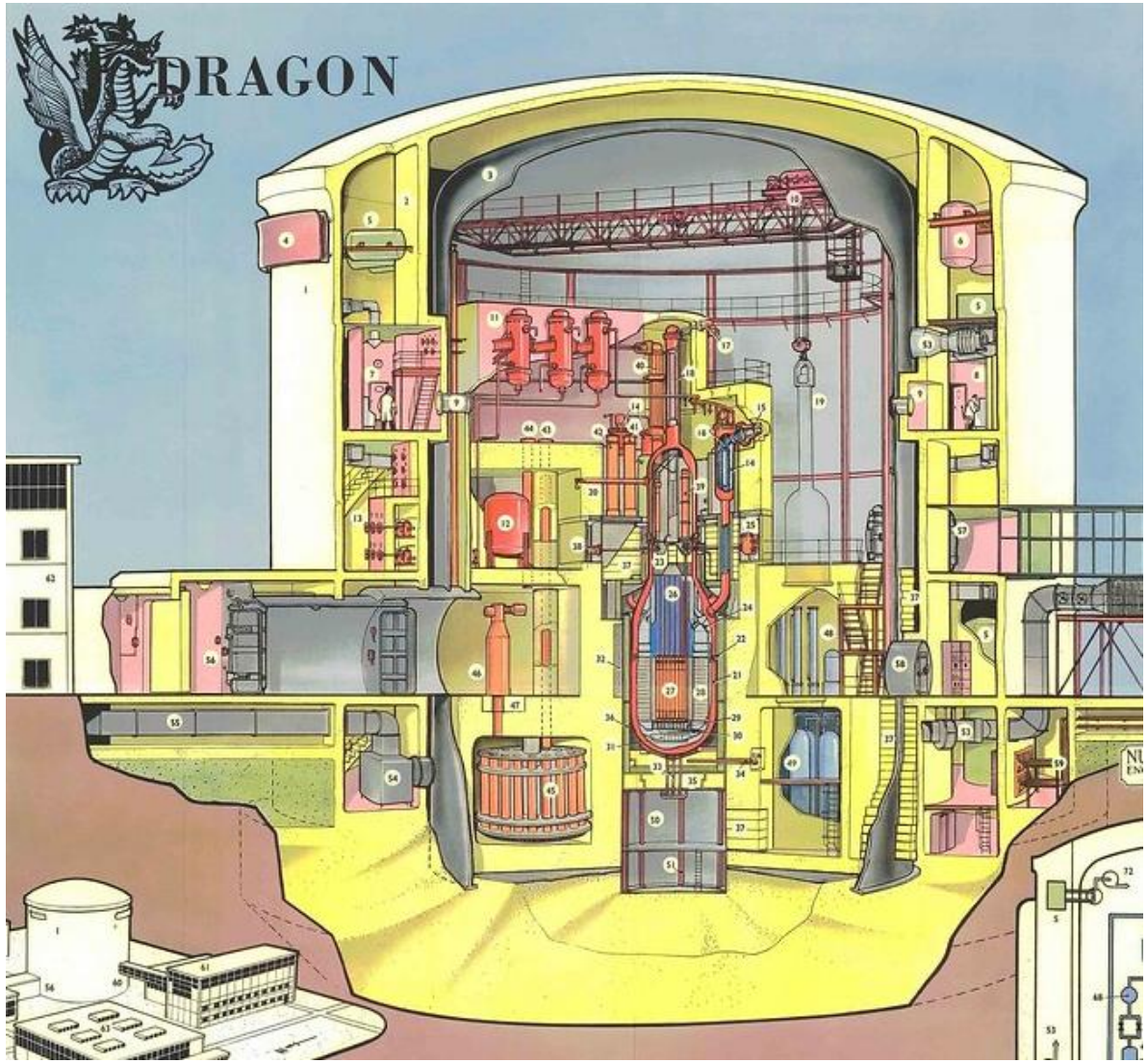

Image from NEI Magazine

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2. UK Strategy for Net Zero and Role of HTGRs

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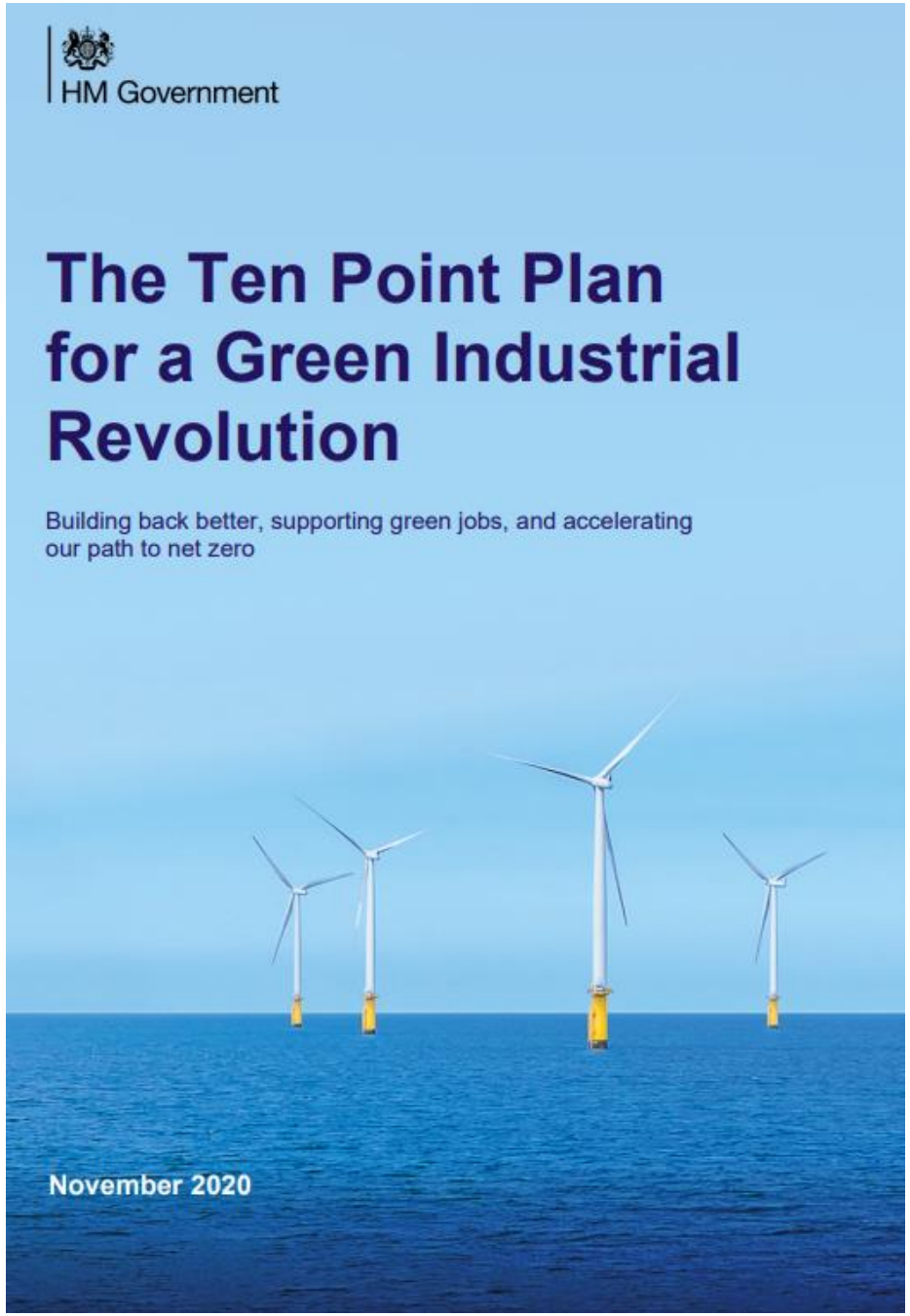
Net Zero and the Ten Point Plan

- UK has committed to achieving net zero by 2050. Ten Point Plan released in November 2020 laying out strategy to achieve this
- Point 3 is "*Delivering New and Advanced Nuclear Power*"
- Included announcement of government investment of up to £215M (¥34Bn) in SMRs and up to £170M (¥27Bn) in Advanced Modular Reactors (AMRs), as well as £40M (¥6.5Bn) to develop regulatory frameworks and support UK supply chain development
- Included aim to build an AMR demonstrator by the early 2030s at the latest



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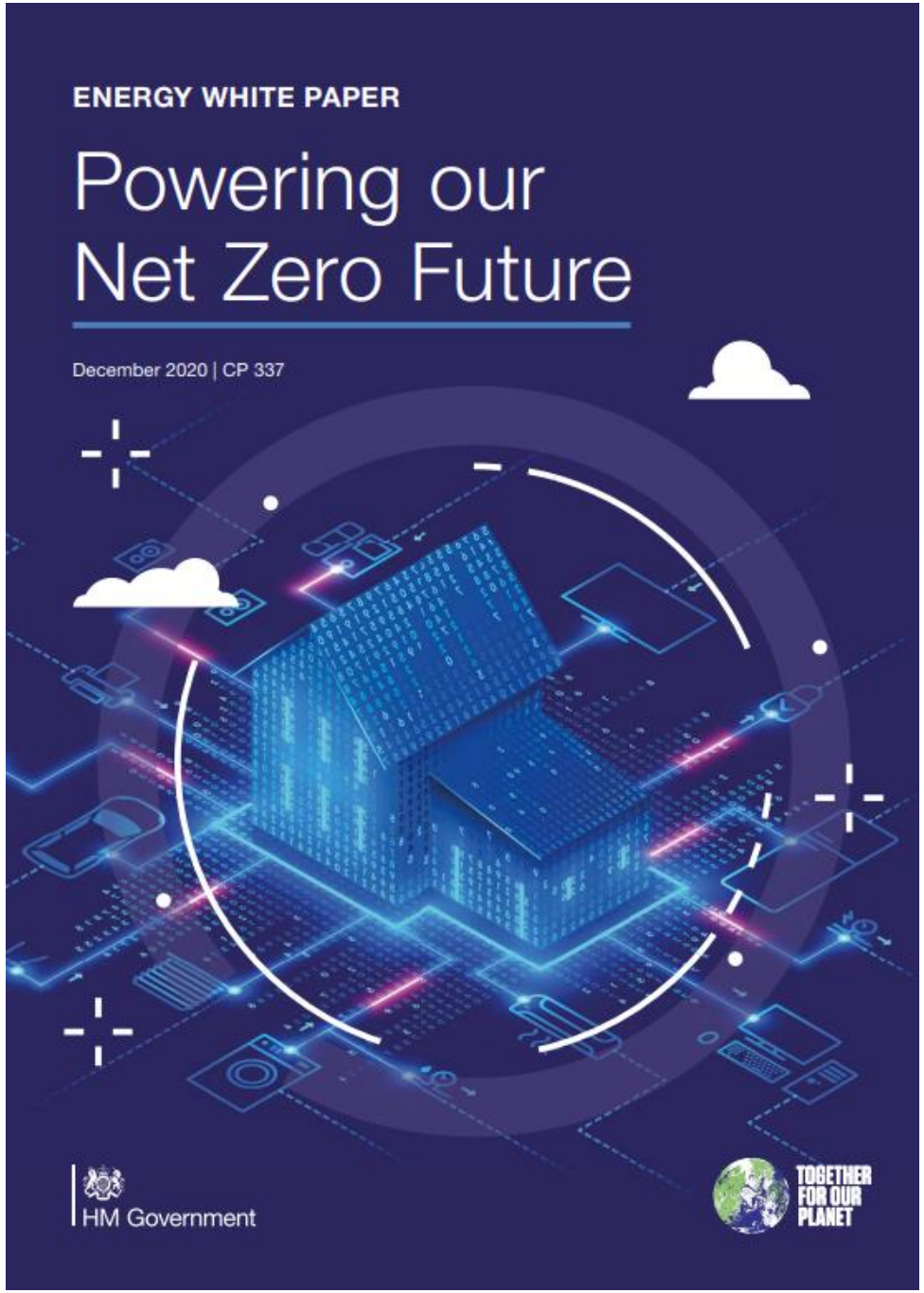
Energy White Paper and Energy Security Strategy

- Followed by Energy White Paper in December 2020, reaffirming the strategy in the Ten Point Plan and providing further detail
- British Energy Security Strategy, released in April 2022, doubled down on the importance of nuclear energy to the UK for energy security as well as decarbonisation
- Main focus on accelerating new build, especially GW-scale, including creation of Great British Nuclear vehicle. Included a statement that "***we will also collaborate with other countries to accelerate work on advanced nuclear technologies, including both Small Modular Reactors and Advanced Modular Reactors***"



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From AMR to HTGR

- Key aim for UK AMR Programme is "*to demonstrate that AMRs can produce high-temperature heat which could be used for low-carbon hydrogen production, heat for industrial processes and domestic use and cost-competitive electricity generation, in time for any potential commercial AMRs to support net zero by 2050*". Initially this was technology agnostic
- NIRO advice, released in July 2021, was that HTGRs should be the preferred technology
- Following a public consultation on this decision, this advice was adopted and the UK AMR Programme is now focused on HTGRs
- In parallel, government continues to support development of all AMRs as part of wider policy on advanced nuclear activities

niro NUCLEAR INNOVATION AND RESEARCH OFFICE

Advanced Modular Reactors
Technical Assessment

July 2021

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What will the UK HTGR look like?

- Technical criteria (thermal power, temperature, specific end uses etc.) have not been set by government at this stage
- Instead, the programme has set broad objectives and is looking to industry to propose the best solutions to achieve the goals of the programme
- This means that key decisions such as reactor size, type, outlet temperature, optimised end use etc. have not yet been made. These are some of the questions being assessed by successful bidders into Phase A of the demonstration programme

Objective	Description
1	Identify the most cost effective and expedient way to overcome market failures and incentivise private sector investment in HTGR technology as an option for supporting the Net Zero 2050 target.
2	Develop supporting innovative technology and fuels.
2.1	Identify innovative technologies that can be developed within budget and timescale constraints and in-line with Value for Money (VfM) principles, that could reduce the lifetime cost of HTGR systems.
2.2	Develop any such technologies to at least TRL 7.
3	Demonstrate that high temperature heat can be safely and efficiently extracted from HTGRs at various discrete temperatures (in accordance with likely use cases) and used to decarbonise heat demand from key sectors.
4	Develop the UK supply chain, including fuel supply, to deliver a HTGR demonstration and underpin supply chain confidence towards commercialisation.
5	Generate IP and skills to position the UK to take advantage of export opportunities associated with HTGR technology and fuels.

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3. UK AMR Research, Development & Demonstration Programme

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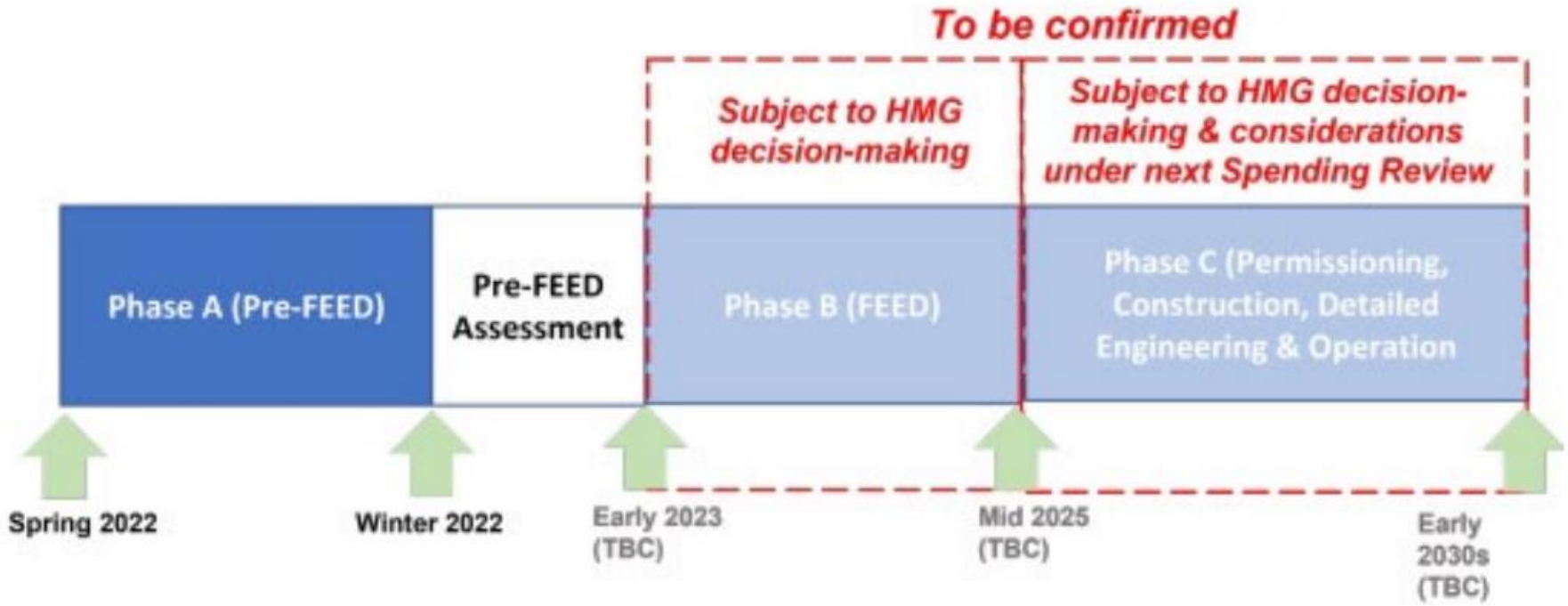

Overall UK AMR RD&D Programme

- Phase A is currently ongoing and comprises a pre-FEED (Front-End Engineering Design) study. This phase funds four reactor demonstration projects of up to £500k (¥80M) each and two fuel demonstration projects of up to £250k (¥40M) each
- Phase B covers a full FEED study. It is currently open for applications and will close on 5th March 2023, with an intention to start Phase B as soon as possible in FY23. It will fund two reactor demonstration projects with up to £27.5M (¥4.5Bn), with matched funding required. Fuel will be covered separately – announcements to follow soon
- Phase C is outside of the current Spending Review and so is subject to government decision making and budget considerations. Phase C is expected to be a down-selection from Phase B

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Phase A Successful Organisations

Reactor Demonstration

EDF Energy Nuclear Generation Limited: will focus on end-user requirements to determine the reactor design characteristics most suitable for a HTGR demonstration in the 2030s. EDF proposes the Hartlepool Heat Hub as a host site for the UK's first HTGR demonstration

***National Nuclear Laboratory:* will coordinate a UK-Japan team (NNL, Japan Atomic Energy Agency (JAEA) and Jacobs) to leverage a proven HTGR baseline from Japan and adopt an innovative approach in its design, build, construction and operation. The project aims to deliver an end-to-end solution that is energy user led while bringing together national and international supply chains**

U-Battery Developments Ltd: will determine the optimum size, type, cost, and delivery method for a U-Battery advanced modular reactor demonstration. The U-Battery AMR aims to provide a source of low carbon, locally embedded process heat and power that can displace the use of fossil fuels

Ultra Safe Nuclear Corporation UK: will build on USNC's existing micro modular reactor (MMR) design as a foundation to develop and demonstrate a modified MMR+ design best suited to UK industry's current and projected future process heat demands. This includes a demonstration of hydrogen and sustainable aviation fuel (SAF) production

Fuel Demonstration

***National Nuclear Laboratory*: aims to deliver a domestic commercial fuel supply starting with the first fuel load for the HTGR demonstration. NNL, Urenco Limited and JAEA will collectively collaborate to develop coated particle fuel (CPF) to full scale commercialisation, to support HTGR technologies which will bolster UK security of energy supply and enable UK fuel to be delivered to a worldwide export market**

Springfields Fuels Limited: aims to determine the most effective route for the secure and reliable supply of coated particle fuel, in collaboration with Urenco Limited, to support the range of potential HTGR technologies which may come forward in the UK. This study will focus on UCO-kernel TRISO as the standard CPF fuel type for contemporary HTGR designs but will design the facility for maximum flexibility to manufacture a wide range of variations on this fuel.

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Phase B Structure

- Overall aim is to develop two projects at least to the point where they can enter the regulatory review process. Phase B is not a down-selection from Phase A
- Phase B will comprise a full FEED study with additional support activities (FEED+). Objectives for Phase B are shown, and flow down from the overall programme objectives
- Phase B will run until the end of February 2025
- Applications for Phase B will close on 5th March 2023

OBJECTIVE 1: Design Progression

By February 2025, develop two innovative HTGR Front-End-Engineering-Designs (FEEDs) to the point that they are ready for regulatory review (this can be measured against the requirements to enter GDA and progress through Step 2, or alternatively, the direct nuclear site licence and Environmental Permitting application processes).[3]

OBJECTIVE 2: Research and Development

Identify what essential, 'no regrets' Technology Development (TD) activities need to be carried out in parallel with and as part of the development of the selected HTGR design(s) to maintain the option of a Phase C schedule ending in the early 2030s. Then, develop this technology to the TRL needed to maintain the proposed Phase C schedule by February 2025.

OBJECTIVE 3: Phase C Delivery Plans

For each design, produce detailed cost estimates for Phase C of the AMR RD&D Programme as follows:

a. OBC accuracy level[4] by April 2024
b. FBC accuracy level by February 2025
c. By August 2024, develop project delivery plans that can meet the phase C down-selection minimum threshold.

OBJECTIVE 4: Skills and Capability

Establish the required skills and capabilities the UK supply chain sufficient to form a basis of expansion to deliver a HTGR demonstration and potential fleet.

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4. UK-Japan Collaboration

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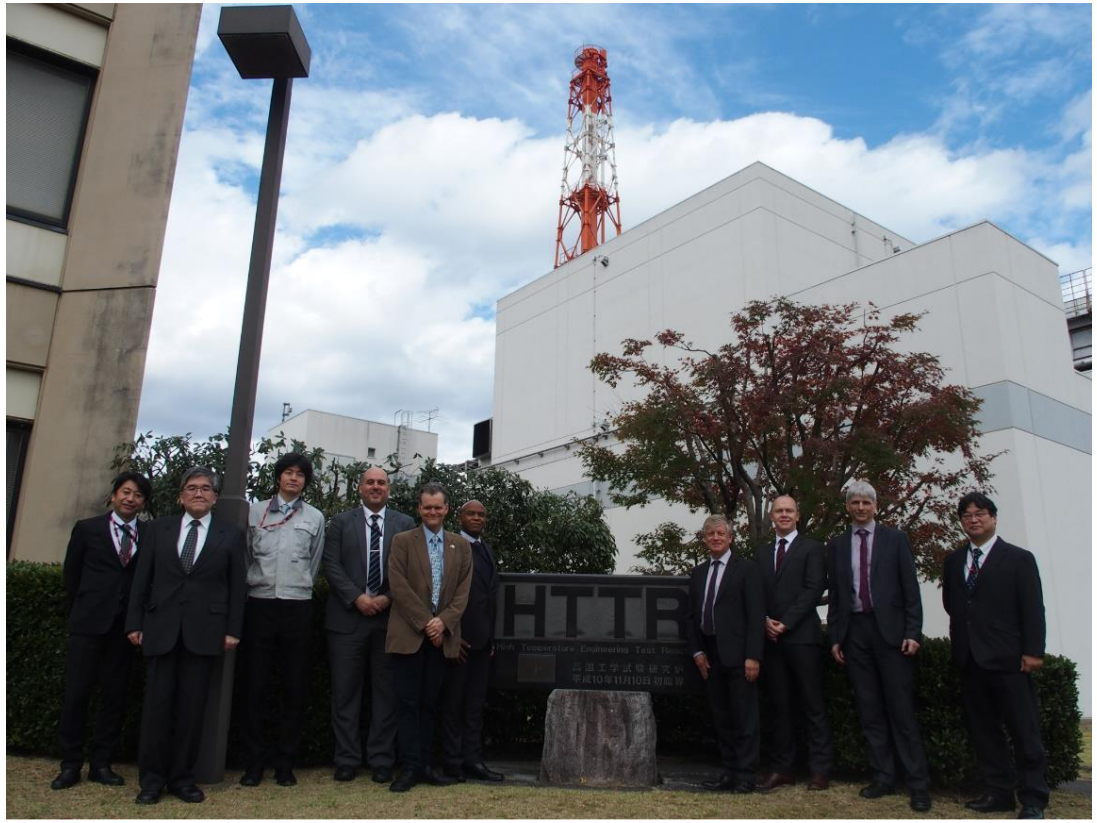
Collaboration in Phase A and Phase B

- Delighted to see consortia including Japanese partners involved in both reactor and fuel sections of Phase A
- Consortia led by NNL, with Jacobs, from the UK side, and by JAEA from Japan. Team are working well together to deliver Phase A requirements
- Teams for Phase B are currently being developed. Anticipate strong UK-Japan bid to be submitted. Led by JAEA from the Japanese side
- Phase B is much greater in scope than Phase A (depending on amount of matched funding, likely ¥6Bn to ¥9Bn)
- UK recognises excellent Japanese capability in HTGR technology – look forward to benefitting from the skills and knowledge in this room today



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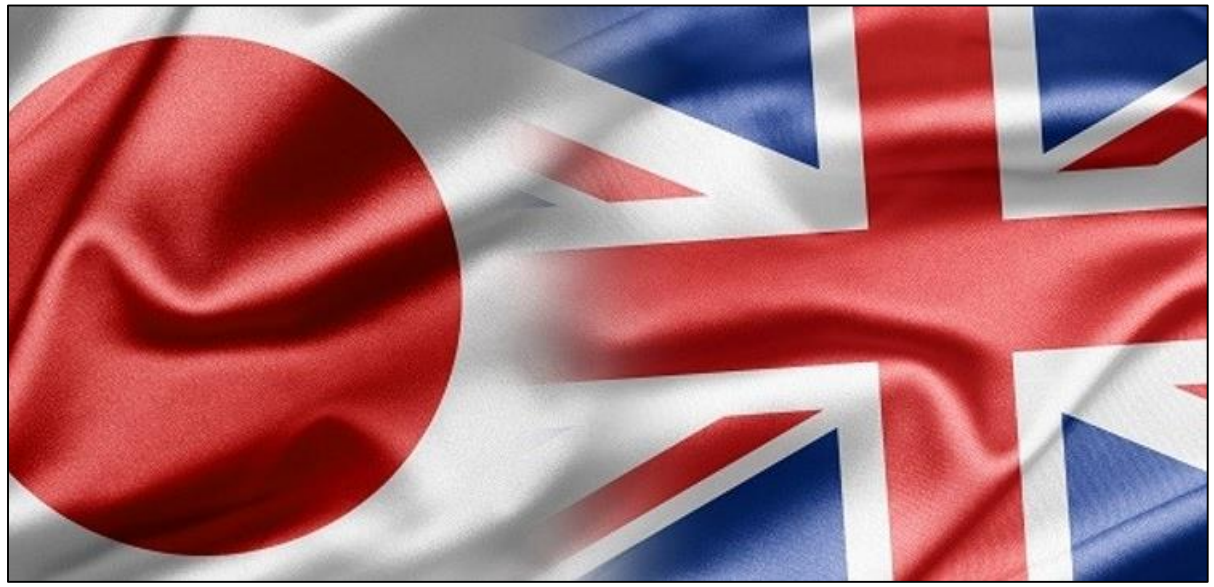
Benefits of UK-Japan Collaboration

- UK and Japan make ideal partners. We are close, like-minded allies with similar goals for energy security and decarbonisation
- Technically, the skills and gaps on both sides match well, meaning we can complement each other to create a better outcome for both sides
- Strategically, our goals for HTGRs align, such that UK-Japan collaboration on the UK demonstrator can drive forward not only the British, but also the Japanese HTGR programme
- While our business cultures differ, UK and Japanese companies work together well and have a long history of collaboration in nuclear
- I look forward to success!