NIRAB Annual Report 2022

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Foreword

At a time when the energy trilemma – cost, security of supply, and the drive for Net Zero – is more acute than ever, the potential contribution of nuclear energy in the UK's energy mix to address these challenges is increasingly important. In these circumstances, it has been entertaining, and a privilege, to Chair this latest incarnation of the Nuclear Innovation and Research Advisory Board (NIRAB) for the last year. Our sponsors in the Department for Business, Energy and Industrial Strategy (BEIS) have asked us some challenging questions, both looking backwards at previous actions and decisions, and looking forwards to deliver advanced nuclear energy as quickly as possible.

The next year will be critical in setting the direction of the UK's future nuclear programme. To have significant impact, there has to be firm commitment on a scale proportionate to national need, providing confidence in continuity, needed to build momentum, allow development at pace and realise the wider socio-economic benefits of nuclear power.

Professor Francis Livens

Chair

Nuclear Innovation & Research Advisory Board

Glossary

AMR	Advanced Modular Reactors
ANT	Advanced Nuclear Technologies
BEIS	Business Energy and Industrial Strategy
CPF	Coated Particle Fuel
DCO	Development Consent Order
EA	Environment Agency
FOAK	First Of A Kind
GDA	Generic Design Assessment
GIF	Generation IV Forum
GBN	Great British Nuclear
HALEU	High Assay Low Enriched Uranium
HMG	Her/His Majesty's Government
HoC	House of Commons
HoL	House of Lords
HTGR	High Temperature Gas Reactors
JET	Joint European Torus
KPI	Key Performance Indicator
MoD	Ministry of Defence
NIRAB	Nuclear Innovation and Research Advisory Board
NIRO	Nuclear Innovation Research Office
N-DWG	NIRAB Delivery Working Group
N-TWG	NIRAB Technology Working Group
N-UCWG	NIRAB Use Case Working Group
NSAN	National Skills Academy for Nuclear
NSSG	Nuclear Skills Strategy Group
NIP	Nuclear Innovation Programme
ONR	Office of Nuclear Regulation
RAB	Regulated Asset Base
RAG	Red-Amber-Green
R&D	Research and Development
RD&D	Research Development and Demonstration
T&CP	Town and Country Planning
SMR	Small Modular Reactor

Contents

Executive Summary

The third iteration of the Nuclear Innovation and Research Advisory Board (NIRAB) was convened in autumn 2021 comprising of experts from industry, academia, and independent consultants with diverse backgrounds. Since then NIRAB has been developing and evolving and delivering a programme of work. This report provides an overview of the work of NIRAB over the year to October 2022.

Development of the work programme identified three key areas of work: Technology, Delivery, and Use Case. The focus of the NIRAB **Technology** Working Group (NTWG) is to advise on research and development needs for new nuclear, with a focus on (Advanced Modular Reactors) AMRs. The **Delivery** Working Group (NDWG) has a focus on innovations in delivery methodology needed to bring forward AMRs, and in particular High Temperature Gas Reactors (HTGRs) to build a demonstrator by early 2030's. The **Use Case** Working Group (NUCWG) has a focus on the potential end user requirements and market for AMRs and their role in decarbonising hard to reach sectors such as, transport and industry to supply to a heat and hydrogen economy, and thus supporting the achievement of Net Zero by 2050.

Over the past 12 months NIRAB has developed and provided several written outputs:

- NIRAB Early Advice to BEIS to support the Advanced Modular Reactor Research, Development and Demonstration Programme (AMR RD&D), March 2022.
- NIRAB Advice to Regulators on Scope of AMR RD&D programme, July 2022.
- NIRAB paper on Review of Nuclear New Build Approval Processes, September 2022.
- Response to House of Lords Inquiry on People and Skills, September 2022.
- NIRAB response to House of Commons Science and Technology Committee Inquiry on Nuclear Power, September 2022.
- NIRAB Overview of Impact of Nuclear Innovation Programme (2016-2022), October 2022.

NIRAB has also engaged with senior officials in BEIS on their advice, with regular attendance at NIRAB plenary meetings from officials and Chief Scientific Advisor Professor Paul Monks. NIRAB continues to develop its work programme to support the AMR RD&D programme as part of a roadmap to support delivery of a HTGR demonstrator.

Key messages

There are several key messages that have emerged from NIRAB's work to date that are highlighted:

Nuclear Energy Ambition

There needs to be greater certainty on the number and types of nuclear reactors required in the UK to provide confidence, enable the nuclear supply chain and stimulate private investment. While NIRAB welcomes the target of 24GW electrical equivalent by nuclear announced in the energy security strategy, this will take the UK only a fraction of the way to decarbonisation. For HTGRs, the market for heat and their other products needs to be defined.

NIRAB welcomes the proposal for Great British Nuclear (GBN) and the Future Nuclear Enabling Fund (FNEF) to bring forward new nuclear projects. While the GBN model is still unclear, action to support accelerated delivery of new nuclear projects, including large GW scale, SMR and AMR is positive. Establishing a clear "UK Offer" to new nuclear projects is essential, as the market has failed at Wylfa and Moorside in the recent past.

Nuclear energy has huge potential to support independent UK energy supplies. It is imperative that the UK has a clear strategy for all reactor types, addressing all aspects of the fuel cycle, including enrichment, fuel design, manufacture and qualification, and irradiated fuel handling, reactor operation, and decommissioning, underpinned by the UK supply chain which is well positioned to support.

The UK is an international front-runner in several areas and NIRAB suggests that sufficient investment is made to realise export and collaboration opportunities, in particular in fuels, graphite, and structural integrity codes and standards. Immediate funding is required to capitalise on these opportunities. The UK should have a high ambition approach to nuclear fission R&D to accelerate programmes and bring in inward investment. The approach to fusion R&D is an exemplar of what can be achieved: fusion research drives major beneficial change and stimulates innovation, in a similar manner to a space programme, as witnessed with the success of the JET Demonstration reactor hosted in the UK, which benefitted from long term HMG commitment and identification of a single lead organisation. This international centre of excellence became a major asset for the UK, leveraging external investment and attracting allied developments.

Regulatory processes and timescales for delivery

NIRAB has undertaken a review of the statutory approval processes for new nuclear in the UK, and their applicability to Advanced Nuclear Technologies (ANTs)[1]. Cross-cutting areas including design maturity, organisational capability, financing, supporting infrastructure and cross-regulatory boundary issues were also considered. This work concluded that, although there was the need to optimise some approval processes for ANTs, this would not in general save significant time to deployment of nuclear. The exception was Planning where it was concluded that the policy and processes currently in place could cause significant delay to deployment of ANT if updates / changes were not made. HMG should update nuclear specific siting policy urgently and ensure that it is applicable to ANT including multiple energy vectors and co-generation. In addition, it was determined that the cross-cutting and non-regulatory factors ultimately determine the pace of delivery.

Research and Development

NIRAB has assessed the impact of the BEIS funded Nuclear Innovation Programme (NIP) (2016 – 2022). Our conclusion is that the programme has undoubtedly had a significant positive impact. The sustained loss of critically at risk-skills has been interrupted by the multi-pronged approach of the NIP and has enabled the UK to re-engage with international research bodies, restoring the status of the reputation of the UK as a valuable research partner. Continuous multi-year research and innovation funding will be required if the benefits to date are to be sustained, and a more ambitious programme will be required to build on progress.

The NIP has supported research relevant to HTGRs and NIRAB advises that a follow-on research programme be commissioned as soon as possible covering the same or similar programme areas. Such a programme should be designed, as far as possible, to minimise any

[1] Advanced Nuclear Technologies refers to Small Modular Reactors (SMRs) which utilse Gen III reactor technology and Advanced Modular Reactors (AMRs) which are Gen IV reactors, including High Temperature Gas Reactors (HTGRs)

stop-start approach to funding and to provide the certainty and continuity of research that will maximise benefit. The programme should have dual objectives: the first is to develop engineered solutions towards licensable HTGR technology and associated infrastructure, opening the potential to deliver an HTGR fleet; the second is to maintain and extend broad strategic knowledge and technical capability and capacity (beyond HTGRs) to underpin future energy policy and support the future UK nuclear industry (fission and fusion), without prematurely foreclosing options.

High Temperature Gas Reactor (HTGR) Demonstration

In NIRAB's view the primary purpose of HTGRs should be heat rather than electricity, and products from that heat, for example hydrogen, ammonia or synthetic fuels, industrial and process heating. The AMR RD&D programme should demonstrate that HTGRs can competitively deliver across these future energy vectors, coupling the reactor with pilot scale utilisation of the heat off-take. Such an integrated demonstration is fundamental to both the economic and safety cases. Ultimately a more detailed understanding of economic costs, siting requirements, heat offtake mechanisms and compatibility with end user requirements will dictate reactor design. The demonstration should not focus exclusively on technical aspects since it will also have to establish a social license to operate.

NIRAB advises that the demonstrator needs to be as close as possible to a first of a kind (FOAK) or prototype to support timely roll-out of a fleet (provided the demonstrator meets programme objectives of early 2030s' and the case is made for fleet build), for HTGRs to make a significant contribution to net zero by 2050. These deployment timescales are challenging and need innovative solutions and high 'ambition'. The nuclear sector should collaborate and benefit from advances and challenges in other sectors, for example delivery of major infrastructure projects such as HS2.

End User Requirements

NIRAB have identified engagement with end users and user groups as a key stage in the development of a deployment strategy for AMRs. It is essential that the intended end-use of AMRs is properly understood since the technical challenges are potentially different depending on the use of the plants, as they may operate in different temperature regimes and transfer heat by different energy transfer mechanisms. It is also essential to understand the energy form that end users require - a stream of hot gas may offer efficiency benefits, but most users are currently adapted to consume a combustible product. There is much uncertainty around the parameters of an AMR that could have the greatest impact in the UK on Net Zero 2050 (such as power output and temperature). An understanding of the potential overall UK market drivers and size will be crucial, and engagement with potential end users of an AMR is essential to understand and potentially shape the market need, and to make end-users aware of the potential benefits of energy from nuclear as a low carbon source.

International Collaboration

If the UK is to invest successfully in new nuclear, in particular AMRs, it will be essential to work collaboratively with international partners to share costs and risk and capitalise on experience. These collaborative programmes work when members can share information on AMR designs with other country programmes, to build overall progress at the pace required and to share cost; develop future international markets for export; help standardise technologies and work with partners to address regulatory challenges. Maintaining membership of Generation IV

Forum (GIF) and continuing with international action plans (e.g. with Canada and US) are essential routes to, for example, data sharing, access to facilities, economic modelling, and regulatory good practice. The UK regulators could play a greater role in advising regulators in emergent countries, leading to export opportunities.

1. Introduction

The Nuclear Innovation and Research Advisory Board (NIRAB) is a group of independent experts which work in partnership with the Nuclear Innovation and Research Office (NIRO) to advise ministers, government departments and agencies on issues related to nuclear research and innovation in the UK. NIRAB also invites observers from the Office for Nuclear Regulation (ONR), Environment Agency (EA), Ministry of Defence (MOD), and The Engineering and Physical Sciences Research Council (EPSRC) and BEIS Chief Scientific Adviser, to attend plenary meetings. Details of NIRAB membership can be found in Appendix 1, and Terms of Reference can be found at www.nirab.org.uk.

The third iteration of NIRAB was convened in autumn 2021 with experts from industry, academia, and independent consultants with a broad range of expertise. Since then NIRAB has been developing and evolving a programme of work. This report provides an overview of the work of NIRAB over the year to September 2022.

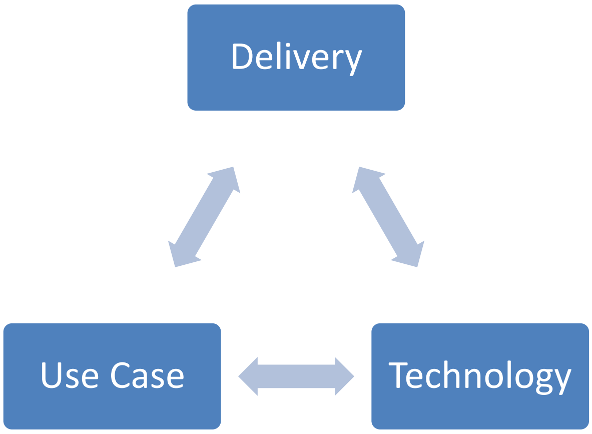
NIRAB's work programme has been developed following a steer from the Department for Business Energy and Industrial Strategy (BEIS) on the key areas of focus relevant to the Advanced Modular Reactor Research, Development and Demonstration Programme (AMR RD&D), to advise:

- Has the FY16-21 BEIS Nuclear Innovation Programme made a positive impact on nuclear innovation in the UK? What else needs to be prioritised? Also what R&D within the UK we can stop resourcing as it is out of date or nugatory?
- What do we need in terms of R&D in order to build an AMR demonstrator to the timescale necessary for a meaningful contribution to net zero carbon emissions by 2050?
- How does the UK deliver an AMR demonstrator to the timescale required? – Can the membership of NIRAB offer their expert opinions on how this can be achieved using innovative methods from their experience and knowledge maximising UK content?
- How can we further exploit the technology to benefit our zero carbon ambitions? Heat/Power/hydrogen/synthetic fuels all are technically feasible however, what could be the best approach via a demonstrator to show the diversity of applications a fleet could have at competitive costs?

NIRAB will also consider other areas for advice it thinks necessary on R&D to support civil nuclear energy.

2. Workstreams

Following extensive discussion of the key themes and tasks that are relevant to address the questions posed, three workstreams on Technology, Delivery, and Use Case emerged and were convened in February 2022. Appendix 2 outlines the broad areas / topics for consideration in the NIRAB work programme. These topics were prioritised and evolved into task and deliverables as outlined below.



The focus of the NIRAB **Technology** Working Group (NTWG) is to advise on research and development needs for new nuclear, with a focus on AMRs. The **Delivery** Working Group (NDWG) has a focus on innovations needed to bring forward AMRs, and in particular High Temperature Gas Reactors (HTGRs) to build a demonstrator by the early 2030's, a HMG ambition set out in the Prime Minister's Ten Point Plan[2] and Energy White Paper[3] , published in 2020, outlining the role that is envisaged for nuclear energy in meeting Net Zero targets. The **Use Case** Working Group (NUCWG) has a focus on understanding the requirements of the potential end users and market for AMRs and their role in decarbonising hard to reach sectors such as, transport and industry to supply to a heat and hydrogen economy, and thus provide a lower risk path to achieving Net Zero by 2050.

2.1 Technology

The key tasks identified for the NTWG are outlined below, and progress on these is outlined:

1. Overview of the impact of the BEIS funded Nuclear Innovation Programme, 2016-2021.

This work has been recently completed and more detail on outcomes can be found in Section 3.6. The review is a high-level overview of NIRAB's view on whether the NIP has supported the aspirations of the 2013 Nuclear Industrial Strategy and fulfilled its high-level objectives. NIRAB is aware that HMG is in the process of commissioning a comprehensive evaluation of the NIP via a commercial process which is likely to report in late 2023, and will provide additional advice via input to this. NIRAB does not have access to detailed information such as project deliverables or KPI data, and therefore NIRAB advice to BEIS has been developed based upon open literature, principally from information provided within the NIP summary brochure[4] which summarises the scope and the key achievements of each of the contracts

[2] The Ten Point Plan for a Green Industrial Revolution, HMG, 2020

[3] Energy White Paper – Powering our Net Zero Future, HMG, December 2020

[4] Nuclear_Innovation_Programme_Brochure.pdf (nirab.org.uk)

making up the NIP, alongside NIRAB members own expertise and involvement in the various programmes.

In summary NIRAB has found that the NIP has undoubtedly had a significant positive impact, addressing some of the problems faced by the sector at the outset of the programme and contributing to meeting some of the broad objectives agreed by HMG and Industry. Some level of ongoing research and innovation funding will be required if the benefits to date are to be sustained or built on. For example, advanced fuel cycle capability is no longer at immediate risk, but some level of work will be required to prevent the recurrence of that risk.

2. Identify prioritisation criteria to be applied when offering advice to HMG on a future innovation and research programme.

In order to develop prioritisation criteria it was necessary to clarify the objectives of any future programme. Discussion led to the development of the following objective for future R&D programme, which will be used in the development of prioritisation criteria:

A future programme (following on from NIP) should comprise parallel portfolios - for foundational research and applied research (innovation) respectively. In the first, UK will aim to maintain and extend a broad strategic knowledge and technical capability to support the future UK nuclear industry (fission and fusion). Focus will be on delivering sovereign security, IP leadership and export benefits. In the second, UK will focus on developing engineered solutions towards licensable HGTR technology and associated infrastructure, opening the potential to deliver an HTGR fleet. Together, these dual streams should aim to raise UK position on the international stage while growing the UK intelligent customer capability around fission and fusion energy of all types.

3. Recommendations for future nuclear R&D funding beyond NIP

This task will be informed where possible by the outcomes of Phase A of the AMR RD&D programme. For an initial view, NTWG considers that a future programme (following as quickly as possible on from NIP) should comprise parallel portfolios - for foundational research and applied research (innovation) supporting HTGR demonstration respectively (as described above). NIRAB remains concerned that there are a broad range of skills and innovations that will not be retained through current commercial routes and need funding support including access to facilities. At a high level NTWG suggests a similar programme to NIP scope with the same or similar themes, with more (but not exclusive) focus on HTGRs.

Some specific areas for recommendations for the R&D programme include:

a. Identify what is needed for UK fuel cycle, including coated particle fuel (CPF), and High Assay Low Enriched Uranium (HALEU) enrichment, fuel production and disposal.

   Identification of the scope of fuel cycle services that will need to be in place to support operation of a HTGR and a review of overall UK capability and potential challenges to meet these specific requirements is underway. This task is in progress and expected to be complete in the autumn of 2022.

The following NTWG tasks have not yet been actioned but are being considered in the work programme for 2022/23:

b. How does the UK build appropriate capability / collaboration for AMRs, for example in areas such as neutronics, thermal hydraulics, digital design, computer modelling.
c. Understand key technical challenges potentially associated with accelerated deployment with:
   - Advanced manufacturing and materials (including behaviour of graphite for use in a helium environment)
   - Modular build
   - Life cycle performance
   - Sustainability
   - Integrated hydrogen, synthetic fuel, co-generation and its implication for safety system design etc.
d. Consider materials irradiation capability and facilities, including international collaborations.

2.2 Delivery

The key tasks identified for the NDWG are outlined below, with an update on progress:

1. Regulation and licensing of innovative technologies

This work has seen significant progress. Representatives from the regulators (ONR and the Environment Agency) have observer status at NIRAB and now attend meetings. The regulators have also provided presentations on their work to prepare for advanced nuclear technologies (ANT) and approach to regulating innovative nuclear technologies. The NDWG has undertaken a review of the regulatory approval processes and provided advice in the form of a report to BEIS. This work concluded that, although there was the need to optimise some approval processes, this would not in general save significant time to deployment of nuclear. The exception was Planning (i.e. the approval to build achieved either by Development Consent Order (DCO) or Town and Country Planning (T&CP) depending on the electricity generation capacity of the facility) where it was concluded that the policy and processes currently in place could cause significant delay to deployment of ANT if changes were not made. In addition it was determined that it was cross-cutting and non-regulatory factors which ultimate determined the pace of delivery; design maturity, operator capability, financing, supporting infrastructure and cross-regulatory boundary issues. Suggested improvements have been made to de-risk across these areas to enable future nuclear deployment.

2. Economics and investability of nuclear projects

This work will consider the potential financing challenges for an AMR demonstration plant. This will include considering the applicability of existing financing models, such as Regulated Asset Base (RAB), and whether new models are needed to support. Factors such as the lifetime of the AMR demonstrator will be considered, for example a short operational lifetime with limited opportunity to generate income may put at risk the economic viability of the project for vendors and long-term obligations such as decommissioning unless innovative financing is considered which may be demonstrator specific. This work will need to be informed by outputs from other NIRAB working groups such as the use-case to consider the costs and likely operational life of the AMR demonstrator.

3. Operator capability and design maturity

The work undertaken in task 1 identified both design maturity and operator capability are critical elements in delivery of an AMR demonstration plant. Currently AMR technology is relatively novel and lacks large scale operational experience at the power outputs being proposed which could delay entering regulatory process and ultimately gaining approval for construction. Therefore accelerating design maturity and ensuring that both vendors and regulatory bodies are prepared to engage is a key enabling activity. The UK lacks a diverse operator capability with EDF the only civil nuclear power operator. Operator capability is a key requirement for entering licensing and permitting processes and development of operator capability is a key area which needs to be enabled to deliver new nuclear build. NDWG will consider what is needed to progress design maturity and operator capability and provide a report to BEIS highlighting recommendations and advice.

4. Siting and planning policy: how to accelerate

The work to review and provide recommendations on siting and planning (in addition to those already made in Task 1) has begun. The NDWG is currently considering what areas it should focus on. A review of all factors which may influence siting is being undertaken, this includes the energy vector being generated, end-user requirements, influencing factors such as socioeconomic considerations, regulatory and planning and HMG policy. Engagement with relevant bodies and BEIS leads will be undertaken to inform priority areas for NDWG to provide advice.

5. Skills and capability

A skills focussed meeting was held to gather insight into ongoing initiatives. Presentations on the Nuclear Skills Strategy Group (NSSG) and National Skills Academy for Nuclear (NSAN) were given to the group. It was agreed that full NIRAB had to be consulted to determine AMR Skills and Workforce requirements at a later date when more information from AMR RD&D is available, and the scope of a demonstrator is better defined.

6. Facilities

The output from task 1 determined that supporting infrastructure was a key enabling requirement for advanced nuclear deployment. This includes fuel route, waste management and R&D facilities. Failure to proactively invest and develop the advanced nuclear supply chain will cause delays in the delivery of a future nuclear project including the AMR demonstrator. The group proposes to work with the NTWG to better understand what supporting infrastructure will be needed and provide advice to BEIS on how this could be delivered.

2.3 Use Case

Since its first meeting in February 2022, the NIRAB Use Case Working Group (NUCWG) has met regularly with the aim to define and deliver a work programme that will identify the best approach to a demonstrator programme that will show the diversity of applications a fleet could have at competitive costs.

This is a highly challenging area as the timescales for fleet deployment of HTGRs will likely not be until the late 2030s, at which time the transition to Net Zero may have significantly impacted the way in which heat and energy are used in industry. The NUCWG has also identified unknowns surrounding HTGR technology itself, which could limit the use cases for which HTGR can be deployed such as:

- The form that end users of heat from a HTGR want to use energy. A stream of hot gas may offer efficiency benefits, but most users are currently adapted to consume a combustible product.
- The constraints around siting a HTGR. The technology is claimed to offer significant safety benefits over current commercial nuclear technologies that could in principle allow HTGRs to be situated in new inland locations to support industry. However, gaining the approval of regulators and public opinion is uncertain. Similarly, the ability to site nuclear heat usage plants adjacent to the reactors may vary with technology and will require study.
- Technology challenges, such as the performance of high temperature components, could require further R&D to substantiate. Furthermore, process industries are developing technologies that are less energy intensive and could function at lower temperatures. This creates uncertainty around the outlet temperature that a HTGR should target.
- It is likely that modular construction techniques will reduce the cost and time to deployment for HTGRs. However, this approach may impose design constraints on a HTGR, such as the size of large forgings limiting reactor power.

BEIS is running the AMR RD&D competition[5] in parallel to the discussions of the NUCWG. The AMR RD&D programme will gather some information for BEIS on the demands of some end users and will provide the views of some reactor vendors on technology and siting challenges for HTGRs. The NUCWG is cautious of providing advice that could constrain the scope of this programme, and that has limited the scope of some discussions within the NUCWG. It is the view of the NUCWG that any demonstrator programme that leads to a fleet deployment that impacts Net Zero should be considered a success, and there are many feasible combinations of HTGR technology and end use that could achieve this.

The NUCWG has considered the pros and cons of different use cases, the understanding of the UK energy market in the 2040s, and the relative efficiencies of different hydrogen production technologies (noting the potential for increased efficiencies with HTGR technology). We have also used publicly available data to estimate the requirements for energy generation within the UK in order to achieve Net Zero, estimating an equivalent of ~150 – 200GWe from nuclear power stations (although much is likely to come from renewable sources). This highlights the scale of the challenge and the need for multiple energy sources.

The NUCWG plans to continue to examine the issues noted above, targeting advice to BEIS to support the AMR RD&D programme as noted above. The specific topics identified are:

- Establishing a route map to transition from a demonstration reactor to a fleet reactor is essential to understand the potential impact on Net Zero. The NUCWG will identify key questions that must be addressed to understand the impact of a proposed HTGR development plan on Net Zero.
- Definition of some fundamental attributes of a demonstration HTGR that are likely to lead to a significant contribution to Net Zero in the UK market. This will be independent of the views of vendors in the AMR RD&D competition and help BEIS to assess the applications.

[5] https://www.gov.uk/government/publications/advanced-modular-reactor-amr-research-development-and-demonstration-programme

- Noting that the attributes of a successful reactor programme will be different for different use cases, the outputs from the NUCWG will look into using the output from the two items above to generate a decision-tree that could be used to match reactor attributes to use cases. This could help BEIS understand where technology choices may limit the application of a HTGR to certain use cases.

3. NIRAB Advice

Over the past 12 months NIRAB has developed and provided several written outputs. These will be made available on the NIRAB website at the earliest opportunity:

3.1 NIRAB Early Advice to BEIS to support the Advanced Modular Reactor Research, Development and Demonstration Programme (AMR RD&D), March 2022.

NIRAB broadly welcomes the proposal for a three-phase approach to delivery of the AMR RD&D programme[6]. However, there are several points that NIRAB advises BEIS should urgently consider within the programme, in summary:

- NIRAB advises that continuous multi-year funding support should be maintained to ensure that the capacity developed via NIP is retained and built upon in order to ensure that the sector is in a position to deliver phases B and C of the AMR RD&D programme – the design and construction of a demonstrator. Any hiatus in funding will inhibit delivery to the required timescales, and likely add cost.
- We advise that BEIS consider fuel cycle strategy as a priority, and do so in parallel to the development of a reactor design of choice. This should include fuel supply, fuel performance, and spent fuel management as well as a source of appropriate fissile material (uranium of an appropriate enrichment level or plutonium).
- It is essential that the use case for AMRs is understood in the context of the UK's requirements, which will differ from those of other nations with varying infrastructure and demographics. This in turn will assist in identifying the specifications for a reactor that will best support the UK markets. NIRAB advises that the primary purpose of HTGRs should be the heat outputs (rather than electricity) and the vectors that this could potentially support, including for example the hydrogen economy, district and industrial heating, synthetic fuels and ammonia production.
- From initial analysis that NIRAB has done to date on use case, the need to make a significant contribution to net zero by 2050 and other parameters, we advise that the demonstrator needs to be as close as possible to a first of a kind (FOAK) to support timely roll-out of a fleet, provided the demonstrator meets programme objectives and the case is made for fleet build. Ultimately a more detailed understanding of economic costs, siting requirements, heat offtake mechanisms and compatibility with end user requirements will impact on the choice of reactor. Since the demonstrator needs to be a 'near-FOAK' design,

[6] Advanced Modular Reactor Research, Development & Demonstration Programme: Indicative Programme Outline (nirab.org.uk)

this work on use case and reactor size is needed urgently, and NIRAB is ready to play its part.

- With regards to the temperature of the heat outputs, we suggest that this should be within existing limits that materials degradation can confidently withstand, noting that the majority (70%) of current UK heat demand is for temperatures < 500°C.
- Two key factors will set the pace of delivery timescales: Design maturity will impact on progress through Generic Design Assessment (GDA); and operator capability will impact on progress through licensing and permitting. A priority for the AMR RD&D programme is to establish a competent authority who can own, develop and operate the demonstrator via a programmatic approach, with potential to expand to support a fleet of reactors. International collaboration could facilitate AMR development and, in some areas, may be essential.
- Siting will also be pivotal for delivery and BEIS plays a key role in specifying site requirements. BEIS should explore the possibility of site specific but plant independent (within limits) assessments that could be carried out now to support planning consents for prospective sites in advance to accelerate the timeline for delivery. The process needed to nominate and assess additional sites that are suitable for large, SMR and/or AMR needs to be defined.
- In summary, for energy security, it is imperative that the UK has a clear strategy on enrichment, fuel manufacture and qualification, reactor operation, and fuel cycle, underpinned by the UK supply chain which is well positioned to support. There is no time for delay and the UK should seek to accelerate activities that can support delivery of new nuclear, including on siting, licensing, financing, and establishing a competent authority, whilst maintaining rigour in the process with respect to safety and security. Continuous investment in R&D and capacity building is necessary to support delivery and added value for UK.

3.2 NIRAB Advice to Regulators on Scope of AMR RD&D programme, July 2022.

The Office for Nuclear Regulation (ONR) and the Environment Agency (EA), who are observers of NIRAB, requested advice on the scope of the regulatory aspects of the AMR RD&D programme. This advice supported the development of ONR/EA guidance for successful contactors to Phase A of the AMR RD&D programme. In NIRAB's view, the guidance and request for information should focus on those regulatory aspects that are novel for high temperature gas reactors (HTGRs), and different to current generating systems. Within the context of the pressing dual challenges of energy security, and net zero by 2050, in NIRAB's view, additional important areas for consideration include:

- We note there is a large amount of international experience with HTGR systems, and this has broadly identified a number of challenges specific to HTGR systems, in particular: verification and validation of the fuel route; in-core inspection and instrumentation; graphite dust (which will have some similarities with the UK's Magnox and AGR fleet); disposability of fuel/graphite and other waste streams specific to HTGRs.

- Other regulators internationally have considered HTGRs, and it would be worthwhile engaging with them on their experiences and ensuring any learning is implemented into the UK programme.
- Understanding novel features, including any elements of autonomous and remote operation, control and protection systems, security (including cyber security), containment and passive safety philosophies (noting not just containment of fission products but also protection against external hazards). How will the designers and operators deal with limited availability of relevant good practice for the demonstrator? International best practice will be invaluable to address several of these issues.
- An early understanding of the Instrumentation and Control Philosophy proposed, the approach to human-machine interface, passive safety focus, operator intervention times, and cyber security of the plant and the remote operation.
- Identify potential weaknesses in the existing designs, safety cases and engineering substantiation (including elements of transportation and management of high assay low enriched uranium fuel) that may require research and development.
- An understanding of the rigour and security of the proposed design process, the use of digital twins and information planned to be gathered to support proving the design during demonstration.
- How the demonstration facility might be operated to provide confidence in the design, and how features connected with potential use cases, including multi-unit sites, might be addressed, at demonstration or in the future.
- Constraints on design codes and substantiation of materials at higher temperature.
- Addressing features and hazards connected to the ambition for a broader fleet approach for AMR to target harder to decarbonise industries through heat, hydrogen, synthetic fuels as well as electricity.
- Comment on the range of existing operating experience and other relevant good practice, and the role of the demonstrator to build on this.
- Whilst continuing to secure information that facilitates framing the next potential phases of regulatory assessment, including skills and capability plans that might be required, and how UK regulators may play an instrumental role in shaping regulatory assessment of HTGRs in the current context.

3.3 NIRAB paper on Review of Nuclear New Build Approval Processes, September 2022.

The Nuclear Innovation and Research Advisory Board (NIRAB) has undertaken a review of the statutory approval processes for new nuclear in the UK, and their applicability to Advanced Nuclear Technologies (ANTs). Each approval process has been examined and given a Red-Amber-Green (RAG) rating based on the readiness to enable deployment of ANTs in the UK and suggestions made on how these could be optimised, which is summarised below in Table 1:

Table 1: Suggestions for improvements to approval processes for applicability to SMR/AMRs

Approval process	Current status	Improvements for applicability to SMR/AMR
Regulatory Justification	AMBER	The current system for regulatory justification is project specific and HMG should be prepared to undertake the assessment of potentially multiple submissions in parallel, to prevent delays to the acceleration of new nuclear projects. HMG should undertake a review to consider Regulatory Justification of technology groups (e.g. PWR, HTGR) rather than individual designs and ensure the process is streamlined and avoids duplication with other approvals.
Planning	RED	HMG should update nuclear specific siting policy urgently and ensure that it is applicable to ANT including multiple energy vectors and co-generation. HMG should review the current threshold approach and the feasibility of non-DCO planning routes for nuclear facilities.
Generic Design Assessment (GDA)	AMBER	Regulators should review the GDA process to ensure it enables entry and assessment of innovative and novel designs including both the reactor and heat take off mechanisms. Regulators should produce guidance on re-use of submission from other countries in the GDA process and explore harmonisation between design assessment processes.
Early regulatory engagement	AMBER	Regulators should embed and offer early pre-GDA engagement to industry to de-risk entry into GDA, licensing and permitting.
Nuclear licensing	AMBER	ONR should produce guidance on non-traditional nuclear deployment models, including for alternative protection and control strategies, multi-unit sites, co-generation and cross-boundary regulatory approaches.
Environmental permitting	AMBER	The Environment Agency (working with other UK environmental agencies where appropriate) should ensure an integrated approach between radioactive and non-radioactive assessment and permitting processes and avoid any duplication between processes (including planning and Habitats Regulation). The Environment Agency should also consider implications on non-traditional deployment models (e.g., multi-unit sites and shared services).

Cross-cutting areas including design maturity, organisational capability, financing, supporting infrastructure and cross-regulatory boundary issues are also discussed and suggestions to overcome any potential delays identified. Specifically:

- Design maturity is a key factor which determines the readiness for entry and progress through approval routes. HMG should clarify and provide certainty on nuclear policy to encourage vendors to invest and undertake the necessary R&D to progress designs.
- The capability of the future operator is a key assessment area for licensing and environmental permitting. At this time, the UK does not have an Operator ready to deploy ANTs. HMG should support the development of UK ANT operator capability by through supporting financing and policy activities.
- Given the importance of financing to progress any nuclear project HMG should review the applicability of existing models and explore future models suited to novel designs.
- ANT will require new infrastructure to support deployment (i.e. fuel and waste routes) which must be developed in advance of reactor deployment. HMG should encourage integrated working between reactor vendors, developers, fuel fabrication and waste infrastructure industries to ensure that a suitable supply chain is developed to enable deployment of ANT.
- Non-electricity applications (e.g. direct heat, co-generation etc.) will require collaboration between regulatory bodies in order to avoid duplication and provide clarity to prospective designers and operators. HMG should facilitate the discussion of cross-boundary regulatory issues and work with responsible bodies and organisations to clarify expectations to ANT developers.

NIRAB has concluded that although there are opportunities to optimise statutory approval processes to support delivery of ANT these in isolation would not reduce the time for deployment significantly as it is the cross-cutting areas that drive the pace of progress and HMG should ensure that government support, including financing and policy, is in place to reduce the barriers for vendors and developers.

3.4 NIRAB response to House of Lords Inquiry on People and Skills, September 2022.

While this Parliamentary Inquiry on People and Skills in UK Science, Technology, Engineering and Mathematics was not necessarily focussed on nuclear energy, NIRAB provided a view on the nuclear skills landscape and made suggestions for initiatives to support the development of nuclear skills, some applicable to other sectors.

3.5 NIRAB response to House of Commons Inquiry on Nuclear Power, September 2022.

The Commons Science and Technology Committee launched an inquiry into the Government's approach to developing new nuclear power. NIRAB's response focussed on technical challenges for AMRs, and delivery challenges for new nuclear across the piece, in line with their remit and advice to BEIS.

3.6 NIRAB Overview of Impact of Nuclear Innovation Programme (2016-2022)

NIRAB has assessed the impact of the Nuclear Innovation Programme (NIP) funded by BEIS between 2017 and 2022. The assessment has considered whether the NIP has changed the research landscape and the extent to which it has achieved the programme's high-level objectives. Our conclusion is that the programme has undoubtedly had a significant positive impact. The sustained loss of critically at-risk skills has been interrupted by the multi-pronged approach of the NIP and has enabled the UK to re-engage with international research bodies, restoring the status of the reputation of the UK as a valuable research partner. Some level of ongoing research and innovation funding will be required if the benefits to date are to be sustained, and a more ambitious programme for acceleration will be required to build on to progress. For example, advanced fuel cycle skills are no longer at immediate risk, but some level of work will be required to prevent the recurrence of that risk.

The programme has supported research relevant to High Temperature Gas Reactors (HTGR), which have recently been identified by BEIS as the preferred Advanced Modular Reactor (AMR) design. NIRAB advises that a follow-on research programme be commissioned as soon as possible covering the same or similar programme areas. Such a programme should be designed, as far as possible, to minimise any stop-start approach to funding and to provide the certainty and continuity of research that will maximise benefit. The programme should have dual objectives. The first is to develop engineered solutions towards licensable HTGR technology and associated infrastructure, opening the potential to deliver an HTGR fleet. The second is to maintain and extend broad strategic knowledge and technical capability to underpin future energy policy and support the future UK nuclear industry (fission and fusion), without prematurely foreclosing options.

4. Forward Look

NIRAB continues to develop their work programme and independent advice, with a long-term aim of informing the UK's roadmap for delivery of a HTGR demonstrator to support the AMR RD&D programme. The priority tasks for the working groups are:

- Recommendations for future nuclear R&D beyond NIP, including prioritisation criteria.
- Planning and siting: review of siting policy and consideration of future criteria for HTGR demo and fleet.
- Continue to develop the use cases for AMRs with an understanding of end user requirements through scenario setting.

Appendix 1: NIRAB Membership

The Chair

Professor Francis Livens, Director of the Dalton Nuclear Institute

Professor Francis Livens is Director of the Dalton Nuclear Institute, responsible for coordination of nuclear research and education across The University of Manchester. He is particularly focused on the linkages between Science & Engineering and Humanities, addressing the societal, cultural and organisational aspects of implementing nuclear technologies in modern societies. He was Nuclear Theme Champion at the Henry Royce Institute from 2017 to 2021. Francis has worked for over 30 years in environmental radioactivity and actinide chemistry, starting his career with the Natural Environment Research Council, where he was involved in the response to the Chernobyl accident. He has worked in many aspects of nuclear fuel cycle research, including effluent treatment, waste immobilisation and actinide chemistry. He has been a member of NIRAB since 2018, is a member of the Office of Nuclear Regulation Independent Advisory Panel, and has recently been appointed as Non-Executive Director of NDA. He has also performed numerous other important advisory roles in the UK and internationally, as a recognised expert in radiochemistry in particular plutonium and nuclear materials.

Members

Kirsty Armer, Director of Westinghouse Government Services UK

Kirsty Armer is the Director of Westinghouse Government Services UK and brings over 25 years' nuclear experience in a wide variety of leadership roles encompassing commercial sales, nuclear fuel manufacturing operations, decommissioning and waste management, quality and continuous improvement, and health physics and safety – in the UK and globally within Westinghouse. She has been a board director of Springfields Fuels Limited for over 10 years and has extensive experience in nuclear site operations. Kirsty holds a BSc degree in Physics from Manchester University, an MBA from Lancaster University and is a certified Lean Six Sigma Black Belt.

Alyson Armett, Strategy and Planning Director for Sellafield Ltd

Alyson Armett is the Strategy and Planning Director for Sellafield Ltd, the company responsible for the operation and clean-up of the UK's largest nuclear site. She is responsible for setting the strategic direction for the business and developing its strategic and delivery plans in line with Government policy and Nuclear Decommissioning Authority strategy. Prior to joining Sellafield Ltd, Alyson worked for the Nuclear Decommissioning Authority and has a thorough knowledge of the challenges associated with decommissioning the UK's civil nuclear sites.

Alyson is a highly experienced portfolio and programme manager with experience of delivering and assuring complex portfolios and programmes of work in highly regulated environments in the public and private sectors. She is a chartered engineer and registered project professional; has a degree in physics from the University of Edinburgh and a MBA from Warwick University; and is a high-risk review team leader for the Cabinet Office's Infrastructure and Projects Authority. Prior to joining the nuclear industry, Alyson worked in engineering, operational and technical consultancy roles in the rail and steel industries.

Maggie Brown, Supplier Relationship Management, EDF Energy

Maggie Brown is currently working for EDF Energy on the Hinkley Point C (HPC) project where she is responsible for developing and delivering the Supplier Relationship Management strategy, which focuses on identifying joint value opportunities with industry impact. Prior to HPC, Maggie was an Innovation Manager for Crossrail's award-winning innovation programme where she was responsible for delivering innovation projects as well as driving the development of the i3P (Infrastructure Industry Innovation Platform), the infrastructure industry's first collaborative innovation delivery programme. Her experience is backed by an MSc in Political Sociology from the LSE where she learned about public policy and organisational politics. Her project management roles span across multiple sectors in the public, non-profit, and private spheres. Maggie is also the proud mother of an exuberant toddler who keeps her on her toes.

Gordon Bryan, Independent Expert

Gordon Bryan is recently retired after a 40 year career in the nuclear industry. The first 25 years were spent with British Nuclear Fuels, which operated across the whole nuclear fuel cycle, from fuel fabrication through reactor operation, spent fuel management and waste management and disposal. During this time he carried out a variety of roles which involved both the execution and the commissioning of research programmes. In subsequent roles he worked on the development of corporate strategies for decommissioning, waste management and wider liabilities management. This provided a good understanding of not only the technical challenges and opportunities facing the industry, but also how decisions made in one part of the fuel cycle have implications in others. From 2005 to 2020 Gordon worked for the National Nuclear Laboratory. Between 2014 and 2020 his role involved the facilitation of the work of NIRAB and the provision of technical support to BEIS.

Professor Gregg Butler, Head of Strategic Assessment, Dalton Nuclear Institute

Professor Gregg Butler read Metallurgy and completed a PhD on uranium alloys at University College Swansea. He worked for British Nuclear Fuels plc in R&D, planning, commercial, plant and general management posts in fuel manufacture, centrifuge enrichment, reprocessing, waste treatment and disposal. Gregg was Deputy Chief Executive from 1993-1996, a Director of UK Nirex (1990-1994), and MD of Pangea Resources Australia Pty Ltd (1998/99). He was a member of the Radioactive Waste Management Advisory Committee (1994-2004), and of the Committee on Radioactive Waste Management (2012-2019).

Gregg is now Head of Strategic Assessment at the Dalton Nuclear Institute and directs Integrated Decision Management Ltd. He has published extensively on a broad range of nuclear topics, recently centred round the role of '*nuclear energy in general and AMRs in particular*' in '*Carbon Net Zero by 2050'*, and the need for a '*Level Playing Field'* in assessing the UK's various possible decarbonisation paths.

Alun Ellis, Independent Expert

Alun Ellis is an independent member of the EdF Generation Nuclear Safety Committee and an independent assessor for the University of Cumbria nuclear engineer and nuclear scientist apprenticeship scheme. He worked for 40 years as an engineer, manager and director in the civil nuclear industry. As well as operational positions at Wylfa and Trawsfynydd he managed technical projects to support operation of the Magnox power stations and directed research, development, and community engagement activities to progress the establishment of a geological disposal facility for UK higher activity nuclear wastes. Alun is a Chartered Engineer and a Fellow of the Institution of Mechanical Engineers.

Kirsty Gogan, Managing Partner of LucidCatalyst / co-founder of TerraPraxis

Kirsty Gogan is managing partner of LucidCatalyst, a highly specialised international consultancy offering thought leadership, strategy development and techno-economic expertise focused on multiplying and accelerating zero carbon technology options available for rapid, large-scale and competitive decarbonisation of the global economy. Kirsty is also co-founder, with Eric Ingersoll, of TerraPraxis, a non-profit organisation working with an extensive global network to define, incubate and initiate scalable strategies to deliver prosperity and decarbonisation. TerraPraxis published the widely cited report: *Missing Link to a Livable Climate: How Hydrogen-Enabled Synthetic Fuels Can Help Deliver the Paris Goals* (2020). The US National Academies of Sciences, Engineering, and Medicine recently appointed Kirsty to serve on a committee to identify opportunities and barriers to the commercialisation of advanced nuclear technologies over the next 30 years. Kirsty sits on the Board of the US NGO, Nuclear Innovation Alliance, and is a co-founder of the global Clean Energy Ministerial Flexible Nuclear Campaign.

Martin Goodfellow Technical & Assurance Director, Nuvia UK

Martin Goodfellow is Technical & Assurance Director, and also leads the Products & Innovation business, at Nuvia UK. Martin has significant experience of engineering, science, and research & development (R&D) across the nuclear, defence, and energy sectors. He has spent much of his career engaged in a combination of complex system design, collaborative R&D, and technical customer facing roles. Latterly, Martin held various responsibilities relating to Small Modular Reactor (SMR) development; combining his technical and commercial experience to successfully drive forwards the design and funding for a UK SMR R&D programme. Martin has a doctorate in nuclear engineering from the University of Manchester, is a Chartered Engineer, Chartered Physicist and a Member of both the Institution of Engineering and Technology and the Institute of Physics. Through his work he has generated multiple patents and has published both academically and industrially on topics including Nuclear New Build, SMRs, systems design and manufacturing technology.

Professor Malcolm Joyce, Nuclear Engineering and Associate Dean for Research, Lancaster University

Malcolm Joyce is Professor of Nuclear Engineering at Lancaster University and Associate Dean for Research (Cross-faculty). His industrial experience includes Smith System Engineering Ltd., BNFL plc. and Hybrid Instruments Ltd. He specialises in nuclear instrumentation, particularly radiation imaging with robots and neutron detection. He is a Chartered Engineer, a Fellow of the Nuclear Institute, Editor on the journal 'Progress in Nuclear Energy' and Associate Editor for IEEE Transactions on Nuclear Science. He led the Nuclear Lessons Learned study, on behalf of the Royal Academy of Engineering and Engineering the Future, and is co-investigator of the management group of the National Nuclear User Facility (NNUF). He received a higher Doctorate (DEng) in 2012, was awarded the James Watt medal by the Institution of Civil Engineers (ICE) in 2014 and a Royal Society Wolfson Research Merit Award in 2016. In 2017 he completed the text: 'Nuclear Engineering: A Conceptual Guide to Nuclear Power'.

Mike Lewis, Director of Lewis Risk Consulting Limited

Mike Lewis is a chartered nuclear engineer with over 40 years experience in the nuclear sector in the UK and internationally (Europe, Canada, Middle East). He brings knowledge and insight from positions in nuclear design, engineering, operations, and expert services, for established and new build nuclear facilities. Mike's principal technical expertise lies in the technology, safety and risk assessment, and licensing of nuclear power stations. In addition to leading a number of key projects in these areas during his career, he now provides expert advice to a UK nuclear safety committee and to organisations on the potential applications of nuclear technology.

Mike was previously Head of Nuclear Technology at Horizon Nuclear Power, Head of a team delivering international nuclear services, consultant to the IAEA, and is now the Director of Lewis Risk Consulting Limited.

Professor Edoardo Patelli, University of Strathclyde

Edoardo Patelli is a Professor in Risk and Uncertainty and the head of the Centre for Intelligent Infrastructure at the University of Strathclyde. He is also the Chair of the Technical Committee on Simulation for Safety and Reliability Analysis for the European Safety and Reliability Association (ESRA) and a member of the Committee on Probability and Statistics in the Physical Sciences (part of the Bernoulli Society). Before this, Prof Patelli was the deputy director of the Institute for Risk and Uncertainty and co-director of the Centre for Doctoral Training in “Risk and Uncertainty” at the University of Liverpool.

Prof. Patelli is an international expert in numerical simulation and computational methods. He has more than 20 years of experience in developing tools for decision making under severe uncertainty, creating and applying efficient and reliable digital approaches supported by AI technologies for uncertainty management, validation and verification of digital environment, aka digital twins. Current research focuses on understanding human performance and reliability and the interaction with intelligent and autonomous systems.

Amanda Quadling, Director of Materials, UKAEA

In a first career as geologist, Amanda Quadling created and ran diamond exploration laboratories for De Beers and BHP Billiton, managed the Mineralogy Division at the South African Science Council (Mintek) and worked with the South African diplomatic service to advance the aims of the global Kimberley Process to prevent use of conflict diamonds. She negotiated a grant with the SA Diamond Regulator and created Africa’s first diamond provenance facility. Moving to the UK eleven years ago, and following a PhD in Materials Science and Engineering (Imperial College), Amanda was appointed Director of the Ceramic Fibre Centre of Excellence for global corporate Morgan Advanced Materials. As a member of their Technology Advisory Board, she helped shape the international research agenda across their £1bn materials businesses for iron and steel, oil and gas and automotive. Most recently, as Technical Director for M&I Materials she developed R&D roadmaps for their nuclear shielding, and dielectrics and electroceramics businesses in traditional and renewable grid energy, and created new product incubators in collaboration with the University of Manchester’s Graphene Engineering Innovation Centre and Organic Materials Innovation Centre. In 2019, Amanda was named 10th most influential women in UK engineering 2019 (Financial Times). She is now UKAEA’s Director of Materials, a member of the Advisory Board for the Nuclear Futures Institute at University of Bangor, and a member of the Governing Board for the Royce Institute.

Fiona Rayment, Chief Science and Technology Office, NNL

Fiona Rayment has dedicated more than 25 years to NNL and predecessor organisations, BNFL and Nexia Solutions. With extensive strategic and operational experience across a number of different nuclear sites in the UK and internationally, Fiona drives NNL’s science and technology agenda.

A chartered chemist and engineer with a PhD in chemistry from University of Strathclyde, Glasgow, Fiona is a fellow of the Royal Academy of Engineering, the Royal Society of Chemistry and of the UK Nuclear Institute. She has an MBA from Manchester Business School.

Fiona has recently served as a member of Euratom’s Science and Technology Committee, the Idaho National Laboratory's Nuclear Science and Technology Advisory Committee, the American Nuclear Society Board and is immediate past chair of the UK’s Nuclear Skills Strategy Group. Her other roles across the sector include being on the board of the UK Nuclear Institute, a member of the Nuclear Industry Council and a member of the Office of Nuclear Regulation Chief Nuclear Inspector’s Independent Advisory Panel. Fiona is chair of the Scientific Advisory Committee of the Energy Division at CEA - the French Alternative Energies and Atomic Energy Commission and is a Non-Executive Member of the UK Space Agency Steering Board.

In addition to representing the UK at a variety of international meetings, Fiona is a vice chair of the Nuclear Energy Agency’s Steering Committee Bureau, which exists as part of the OECD to facilitate co-operation among countries with nuclear energy infrastructure.

Fiona has long advocated widening participation in science and engineering and champions NNL’s sector-leading approach to diversity and inclusion.

She was awarded an OBE in 2017 and the French Légion d’Honneur in 2020.

John Stairmand, Technical Director of Technology & Cyber Solutions, Jacobs

John Stairmand is the Technical Director of the Technology & Cyber Solutions business of Jacobs. He is a fellow of the IChemE and has worked on nuclear fuel cycle R&D, and subsequently in the pharmaceutical and petrochemical industries. He was Director for the Jacobs Materials Science and Structural Integrity business, developing several reactor-facing internationally leading technologies, and managing the establishment of the “High Temperature Facility”. In his current role he has technical oversight of Jacobs laboratories and associated engineering services with a focus on SMR, AMR, fusion, current class reactors and decommissioning.

John has been an active member of the EPSRC peer review college for about 25 years, and is a member of their Strategic Advisory Network. He is a visiting Professor at the Dalton Nuclear Institute of Manchester University and the Nuclear Futures Institute of Bangor University.

Appendix 2: NIRAB Working Groups Key Areas for Consideration

Technology workgroup

Programme:

- Review of Nuclear Innovation Programme (NIP)
- R&D to be taken forward to demonstration
- Other priority areas

Early Advice:

e.g., no regrets / critical R&D in the following areas:

- Coated particle fuel
- HALEU
- Graphite
- Neutronics
- Lifecycle and sustainability
- Thermal hydraulics and availability of He
- Digital control & instrumentation
- Digital design
- Computer modelling
- Cyber
- Materials & materials performance
- Advanced manufacturing and fabrication
- Advanced construction and modular build
- Codes and standards (including structural integrity)
- Robotics

BEIS questions:

- Has the FY16-21 BEIS Nuclear Innovation Programme made a positive impact on nuclear innovation in the UK?
- What else needs to be prioritised?
- Also what R&D within the UK we can stop resourcing as it is out of date or nugatory?
- What do we need in terms of R&D in order to build an AMR demonstrator to the timescale necessary for a meaningful contribution to net zero carbon emissions by 2050?

Delivery workgroup

Programme:

- Regulation & Licensing
- Licensable entity / delivery consortia
- Economics and investability of nuclear projects
- Public acceptability
- Nuclear facilities
- Uptake of innovation in nuclear
- Coordination with other programmes e.g., STEP and Low Cost Nuclear
- Skills and supply chain development
- UK content
- Siting
- Financing
- International
- Leadership, organisation and responsibility

Early Advice:

- Timeline for delivery
- Identify innovation to optimise and disruptive innovation to accelerate

BEIS questions:

- What do we need in terms of R&D in order to build an AMR demonstrator to the timescale necessary for a meaningful contribution to net zero carbon emissions by 2050?
- How does the UK deliver an AMR demonstrator to the timescale required? – Can the membership of NIRAB offer their expert opinions on how this can be achieved using innovative methods from their experience and knowledge maximising UK content?

Use Case workgroup

Programme:

- Flexible generation
- Energy off-take mechanisms
- Power conversion systems
- Co-generation
- Marine
- What should demonstrator demonstrate?

Early Advice:

- Use case scenarios

E.g. Reactor specifications, based on understanding of use case

BEIS Questions:

- How can we further exploit the technology to benefit our zero carbon ambitions? Heat / power / hydrogen / synthetic fuels all are technically feasible however, what could be the best approach via a demonstrator to show the diversity of applications a fleet could have at competitive costs?