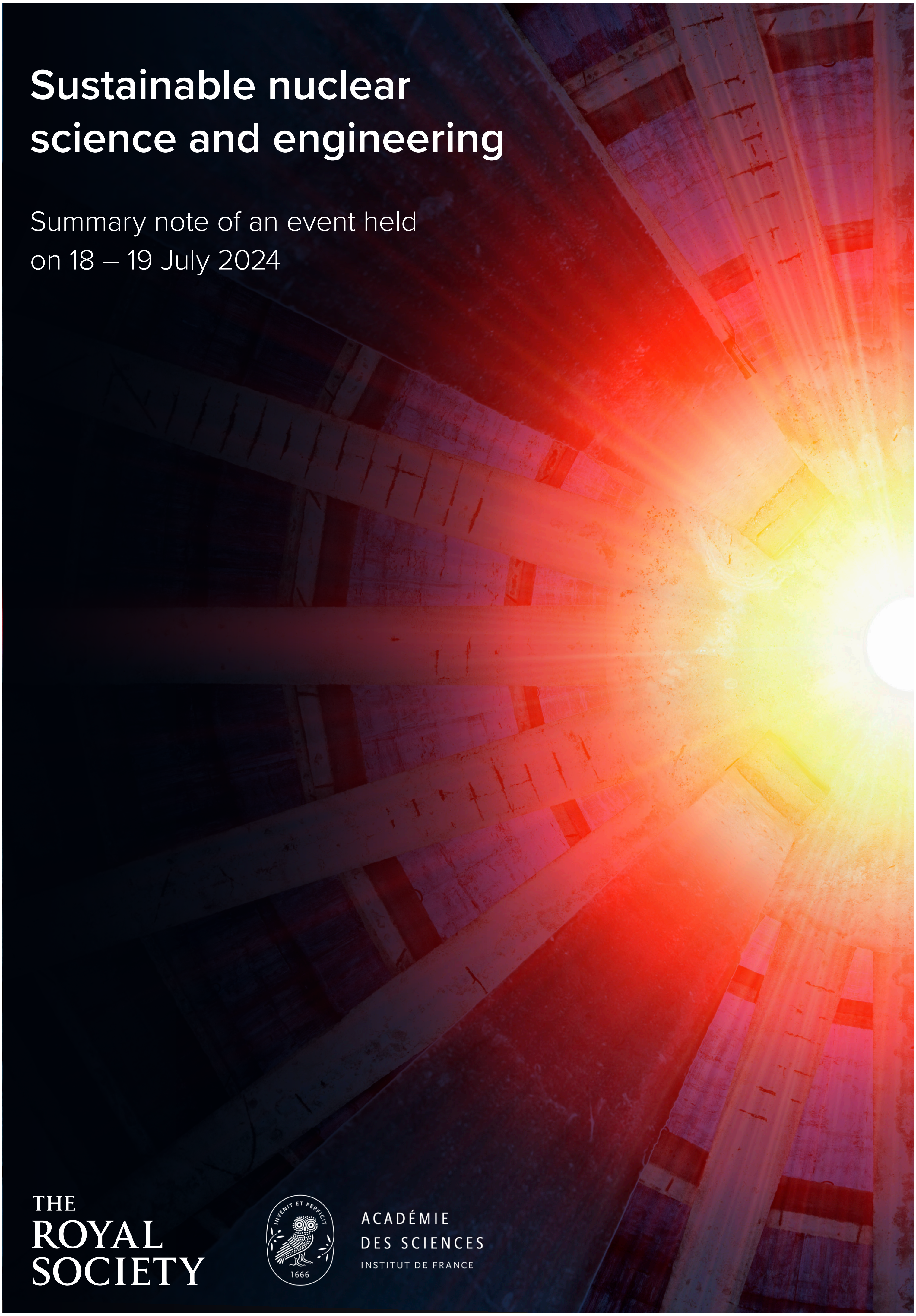

# Sustainable nuclear science and engineering

Summary note of an event held on 18 – 19 July 2024

THE ROYAL SOCIETY

ACADÉMIE DES SCIENCES
INSTITUT DE FRANCE

# Contents

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## Summary note of an event held on 18 – 19 July 2024

### Event summary

The Royal Society and the Académie des sciences co-hosted a bilateral scientific meeting on Nuclear Science and Engineering on 18 – 19 July 2024, bringing together delegates from the UK and France to discuss recent breakthroughs, share best practices, explore areas of mutual interest, and identify opportunities for further collaboration.

This paper has been compiled by the Co-chairs of the event and is based on discussions at the meeting.

### What has prompted the need for this intervention?

Our world is changing. In the last decade, largely theoretical predictions of a changing climate have become real-world threats to economies, societies and livelihoods. Over the same period, the geopolitical stability and globalised markets experienced since the end of the cold war have been eroded by increasing economic and political nationalism. Global threats with significant impact on energy security, thought to have been consigned to the past, have re-emerged.

In this context, the duty of the state to protect its citizens has been emphasised and issues such as food security, health security, energy security, environmental security and border security are in the foreground of political debate. Government policy in the UK and France seeks to provide energy security for their citizens and economies whilst also protecting them from the worst impacts of global climate change.

For this reason, nuclear fission, as a zero-carbon, "always on" power source is experiencing a much-welcome renaissance in both countries, combined with a positive trend in the public acceptance of nuclear energy.

However, the nuclear sector in both countries faces challenges. A decades-long lull in new nuclear build has led to a decline in the research base, the industrial base and the skills base. Current construction projects demonstrate the lag time in reawakening these sectors. Geopolitical instability raises questions about the long-term security of uranium fuel supply. National political vacillation can hinder long-term planning for the future of nuclear power.

The Co-chairs conclusions and recommendations from the meeting are summarised in the following nine key points.

KEY POINT 1

## Delivery of new nuclear must be optimised

Policy certainty and commitment to multiples of projects or a 'fleet' approach is required to maximise value and learning from projects as is recognition of constructability as a key driver.

Optimising delivery is essential. Both the UK and France can learn from current projects like Hinkley Point C and Flamanville in order to improve the construction of large gigawatt (GW)[1] systems, with a focus on reducing complexity, increasing constructability and reducing cost. Forward policy commitments to 'fleets' provides certainty, enables learning and facilitates the deployment of this learning.

For large, small and advanced nuclear systems, design with cutting edge technology and maximising modularity to reduce construction complexity should drive better schedule adherence and delivery as the UK and France new nuclear build programmes expand. Greater systems thinking, increased modularity and the radical changes in human-machine interaction envisaged in the fifth industrial revolution will drive better delivery at lower cost.

KEY POINT 2

## Nuclear can offer more than electricity.

The UK and France should work together to accelerate the demonstration of non-electric applications of nuclear in support of the decarbonisation of sectors hard to electrify.

In addition to delivering low-carbon electricity, nuclear power should also play a role in decarbonising non-electric uses of energy. It should be remembered that a very large proportion of the energy consumed in the UK and France is used to produce heat, notably in the home (heating) and in industry (production of steel, hydrogen, fuels, chemical feedstocks, etc.). Nuclear power, via large light-water reactors, small light-water reactors and also advanced systems capable of generating higher temperatures, has the advantage of being able to meet a significant proportion of energy demand in the form of heat, and this advantage is currently insufficiently exploited. This dual use of electricity and heat supplied by nuclear reactors is known as "cogeneration". The Royal Society's publication on nuclear cogeneration has already described what this role could look like [2].

There is an urgent need to move on to real demonstration projects for these non-electric applications of nuclear power, such as the supply of heat in district heating networks, for seawater desalination and for industrial processes that will not be electrified. There are many technical and economic issues to be addressed, such as the storage and transport of heat, or the conditions under which industries can use small modular reactors (SMRs)[3], or adapting the use of nuclear heat (district heating, steel, hydrogen and fuel/chemicals production) to the temperature level permitted by each reactor family (300°C for water-cooled reactors and 1000°C for very-high-temperature reactors). Research will be needed to meet these challenges, and the two countries should join forces to demonstrate this potential.

1. A watt is a measure of power and there are 1 billion watts in 1 GW, 1 million watts = 1 megawatt (MW) and 1,000 watts = 1 kilowatt (kW).
2. Nuclear Cogeneration: civil nuclear in a low-carbon future. The Royal Society (2020). https://royalsociety.org/news-resources/projects/low-carbon-energy-programme/nuclear-cogeneration/ (accessed 6 August 2024)
3. The International Atomic Energy Agency definition of Small modular reactors (SMRs) is: advanced nuclear reactors that have a power capacity of up to 300 MW(e) per unit, which is about one-third of the generating capacity of traditional nuclear power reactors. However, the UK Government uses the terminology Advanced Nuclear Technologies (ANTs) which encompass a wide range of nuclear reactor technologies under development. The technologies share common attributes; advanced nuclear technologies fall into one of 2 groups: Generation III water-cooled SMRs, similar to existing nuclear power station reactors but on a smaller scale, or Generation IV and beyond Advanced Modular Reactors (AMRs), which use novel cooling systems or fuels to offer new functionality (such as industrial process heat) and potentially a step change reduction in costs.

**KEY POINT 3**

## UK and France can lead on demonstrating advanced systems

The UK should lead on demonstration of the High Temperature Gas Reactor (HTGR) with French support and France on demonstration of Fast Reactor technology with UK support, this optimises the pathway to demonstration and ensures both UK and France get the benefits from HTGR and Fast Reactor technology.

Long term sustainable fuel cycles and the optimal use of resources need to become areas of focus for the UK and France. Rightly, climate and energy security are priorities now. However, for the long-term strategic security of both UK and French national nuclear ambitions, there should be a 'nuclear beyond 2050' plan with a focus on securing a sustainable national supply of fuel that matches the long term energy needs of the UK and France out to and beyond 2100. The geopolitical situation as far as uranium resources are concerned is unlikely to improve in the coming years, therefore the question of sovereignty of nuclear fuel resources must be addressed now, at the research and the prototype level, to be ready to deploy the relevant fleet when needed.

Fast Reactors (FR) will be needed long term and these are very much in the French forward plans with a focus on Sodium Fast Reactor (SFR) technology (after pausing the ASTRID (Advanced Technological Reactor for Industrial Demonstration) programme[4]) and exploring Molten Salt Reactor (MSR) technology. The SFR technology is at a much higher TRL than MSR. Given the long timeframes, the market will not deliver this technology immediately, and MSR will most probably come even after SFR, requiring a substantial additional research effort.

There is a need for a demonstration programme for fast reactor and advanced fuel cycle technology, alongside the UK HTGR demonstration and the France 2030 programme. There is a real opportunity for UK to lead HTGR demonstration with French support and France to lead SFR demonstration with UK support. Such an arrangement would make best use of UK and French public money, reducing costs for both sets of taxpayers.

**KEY POINT 4**

## Long term fuel supply can be secured

The UK and France should 'double down' on their commitments as part of the 'Sapporo 5', including investing in front end fuel cycle R&D and building collaborative links

There is a need to secure the front end of the fuel cycle, removing any reliance on Russia. The UK and France have a rich heritage in the fuel cycle (including enrichment, conversion, deconversion and fabrication) and must return – at speed – to having full capability and capacity. This will require a parallel commitment to underpinning research and development to ensure optimisation while building the necessary supply chain and skills pipeline. Current generation and advanced technology fuels for light water reactors should be an area where UK and France can increase collaborative research and development (R&D). Collaboration on existing generation fuels and driving towards advanced technology fuels together will ensure UK and France are playing a leading role in optimising the current and future fleet of reactors thus improving the economic competitiveness of nuclear, reducing energy bills and providing energy security. In the long term the UK and France should re-engage to work on fast reactor technologies and their associated fuel cycles to give freedom from reliance on uranium imports.

4. ASTRID reactor design, CEA (2010). https://www.cea.fr/energies/iresne/en/Pages/Our%20achievements/Design%20and%20innovation/ASTRID%20reactor%20design.aspx (accessed 31 July 2024)

**KEY POINT 5**

## Advanced fuels can fuel the future

The UK and France should accelerate the scale up of advanced fuels for advanced reactors, optimising the pathway to commercial scale production in the UK and France working collaboratively with the UK leading on High Temperature Gas Reactor (HTGR) fuels and France on Fast Reactor Fuels.

Meeting demand for advanced modular reactor fuels will be a key enabler of the deployment of advanced reactor systems in the UK and France. For example, the demand for TRISO (TRi-structural ISOtropic particle fuel) or coated particle fuel (CPF) in the UK to support the demonstration of a high temperature gas reactor (HTGR) by the early 2030s or providing fuel for the France 2030[5] programme. There are challenges still to be addressed to produce these fuels at pilot and commercial scale for both France and UK. Similarly, the industrial reprocessing of the fuel for multirecycling in SFR will require some technological development. The UK and French government should enable, support and accelerate programmes to deliver these fuels.

**KEY POINT 6**

## Nuclear is sustainable

We should remember the three Rs for nuclear fuels – reduce, reuse, recycle. France has committed to working on future advanced fuel cycles and the UK should maintain capability in fuel recycling following the end of industrial scale reprocessing in the UK. A collaborative programme should be established focused on advanced recycle demonstration supporting both UK capability maintenance and French planning for new facilities.

Advanced fuel cycles and recycling will be necessary as part of the long term sustainable nuclear pathway, including a fast reactor programme as outlined. The UK and France can do much together in order to deliver a sustainable recycling system. The UK is coming out of reprocessing and without a programme of investment to maintain capability at an R&D level it will lose it. France has committed to building a new reprocessing facility planned in France for post 2040/45[6]. The UK and France should explore working together to deploy advanced recycle capabilities in this new facility, building on the work the UK completed as part of the investment in the UK Advanced Fuel Cycle Programme (AFCP)[7].

5. Presentation of the France 2030 plan, Elysee (2021). See: https://www.elysee.fr/emmanuel-macron/2021/10/12/presentation-du-plan-france-2030 (accessed 31 July 2024).
6. France sets out long-term nuclear recycling plans, World Nuclear News (2024). See: https://world-nuclear-news.org/Articles/France-confirms-long-term-recycling-plans (accessed 5 August 2024).
7. Fuelling Net Zero, the UK Advanced Fuel Cycle Programme (2024). See: https://afcp.nnl.co.uk/ (accessed 10 August 2024).

### KEY POINT 7

## The nuclear sector can deliver the skills it needs.

The UK and France should develop and share best practice for skills and capability development. Maximising value through exchange of personnel and establishing a joint skills programme.

The decades-long lull in new nuclear in both countries has led to a wholly sensible focus of nuclear sector workers on either the operation of existing reactors or the decommissioning of those shut down. The nuclear renaissance will require a significant expansion of the workforce, especially in areas where resources have dwindled such as new build and the fuel cycle. The nuclear industry needs to be attractive to those with transferable skills by, for example, providing strong and consistent demand signals. Nuclear science and research need to be attractive to future subject matter experts.

There are significant opportunities for the UK and France to work together to accelerate time to competence. Joint engineering and doctoral training programmes between universities and exchange programmes at the level of technicians should be explored. Joint R&D programmes in materials science, in neutronics and in thermal hydraulics could benefit both sides. Sharing experimental facilities (eg at NNL in the UK and at CEA in France) and the computing power that supports these facilities would enhance the countries' capabilities.

### KEY POINT 8

## The UK and France can deliver new nuclear R&D infrastructure

The UK and France should share strategic plans for future nuclear infrastructure for research and development. At least one joint initiative should be identified and taken forward, this could build on an existing relationship (eg the Jules Horowitz Reactor) or scope for new capability such as a Zero Power (training) Reactor.

Infrastructure for the future is a key consideration for both the UK and France. Both countries rely on ageing infrastructure for nuclear science and engineering. A much-needed programme of investment is taking place in both UK and France. However, nuclear infrastructure is expensive and there should be opportunity for the UK and France to work together to relieve some of this burden, delivering world leading nuclear R&D infrastructure the enable and accelerate the UK and France forward nuclear programmes.

KEY POINT 9

## The UK and France can enhance their bilateral cooperation

In the 2023 Statement of Cooperation on Civil Nuclear Energy[8] the UK and French governments expressed their desire to "enhance their bilateral cooperation in the realm of civil nuclear". Our meeting between the Royal Society and the Académie des Sciences has provided a forum in which numerous excellent ideas have been proposed to fulfil that desire. The Royal Society and the Académie des Sciences should jointly establish the "senior UK-France contact group".

Now is the time to cement and operationalise a programme of collaboration between the UK and France. Such a programme will require political support, funding and a governance mechanism.

As a next step, we recommend that the Royal Society and the Académie des Sciences jointly establish the "senior UK-France contact group" envisaged in the Statement of Cooperation and that this contact group works to define the detailed shape of our future collaborative effort.

8. GOV.UK (2023). Statement of Cooperation on Civil Nuclear Energy between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the French Republic. See: https://assets.publishing.service.gov.uk/media/647f6f7a103ca6000c039a64/uk-france-nuclear-cooperation-statement-final.pdf (accessed 10 August 2024).

# Introduction and background

Founded in 1660 and 1666 respectively, the Royal Society and The French Academy of Sciences are independent scientific academies of the UK and France dedicated to promoting excellence in science for the benefit of humanity. At a pivotal time for climate and energy security, the academies brought together experts to provide a view on the role of nuclear energy.

The two founding nations in harnessing nuclear energy are now looking again to the atom as they face into the two fundamental challenges of our time, climate and energy security.

The Royal Society and the Académie des Sciences convened internationally respected experts representing a cross section of government, industry, national laboratory and academia from the UK and France to consider how the nuclear renaissance can be nurtured in both countries, how the challenges facing the sector might be overcome and how the UK and France should work together.

Experts dissected, diagnosed and discussed the role of nuclear science and engineering including: How did we get here? Where are we going? How do we get there?

Through analysis and discussion, a clear view on the challenges and opportunities was achieved, with a focus on how the UK and France could collaborate moving forwards.

This paper provides a summary of the expert meeting. It is not intended to be a transcript but to capture the key outputs and points from the two days. The meeting covered existing generation nuclear (so called Generation III and III+) as well as small and advanced modular reactors and some aspects of Generation IV. There was also a focus on fuel and fuel cycle. Finally, skills and training were discussed. The meeting did not look at market analysis, commercial or financing in detail; wider nuclear applications such as medical were also not the main focus of the discussion. The focus was on the science and the underpinning for power (and heat) generation and the role of nuclear in climate and energy security. Ensuring the challenges we face today are not avoided tomorrow and that future deployment benefits from the best understanding of nuclear science and engineering.

There are similarities and differences in the UK and French landscape and approach. However, there are significant opportunities for the UK and France to work together in achieving their future ambitions.

A brief history of the UK and France civil nuclear sector is followed by sections focussed on different areas of the nuclear landscape. Finally, there are some concluding comments from the Co-chairs of this timely meeting.

# The civil nuclear landscape in the UK and France – a brief history

The UK and France were pioneers in the science of nuclear physics and the engineering of nuclear reactors. Although, the UK and French nuclear programmes were separate they have followed a similar course over the last eighty years in many respects.

Both countries built their first reactors in the 1940s and commissioned their first nuclear power stations in the 1950s. In this post-war period, both countries had dual military and civil objectives for their respective nuclear programmes with reactors producing both electricity and plutonium.

Both the UK and France chose gas cooled, graphite moderated reactors for their first generation of commercial nuclear reactors in the 1950s and 1960s, the UK commissioning 26 Magnox[9] reactors and France commissioning 9 UNGG (Natural Uranium Gas Graphite) reactors.

In the 1970s, 1980s and 1990s, the countries' paths diverged somewhat with the UK building 14 advanced gas cooled reactors (AGR)[10] and one pressurised water reactor whilst France expanded its programme massively, building 58 pressurised water reactors (PWR)[11]. In parallel, both countries funded experimental fast breeder programmes and both countries had extensive nuclear fuel programmes.

The 2000s and 2010s saw a lull in the nuclear programmes of both countries with no new reactors being commissioned and the winding down of experimental programmes. However, the UK and France are now both building European Pressurised Reactors (EPRs)[12]. France is expecting to build between six and fourteen EPRs whilst the UK (under the plans of the previous government) has the ambition to build up to 24GW capacity by 2050.

### Current deployment

France has 18 commercial nuclear power plants with a total of 56 PWR reactors, providing about 70% of electricity. The UK has 5 power plants with a total of 8 AGRs and 1 PWR, providing about 15% of electricity.

### Current policy priorities

Although the second half of 2024 represents a period of political change for both countries, it is expected that the favourable view of new nuclear will remain in both countries, recognising the climate commitments of both nations and their energy security concerns.

9. Magnox is a type of nuclear power/production reactor that was designed to run on natural uranium (natural uranium is uranium with the same isotopic ratio as found in nature) with graphite as the moderator and carbon dioxide gas as the heat exchange coolant. The name comes from the magnesium-aluminium alloy (called Magnesium non-oxidising), used to clad the fuel rods inside the reactor.
10. The AGR design retained the Magnox's graphite moderator and carbon dioxide coolant but increased the cooling gas operating temperature to improve steam conditions.
11. A common nuclear power reactor design in which very pure water is heated to a very high temperature by fission, kept under high pressure (to prevent it from boiling), and converted to steam by a steam generator (rather than by boiling, as in a boiling-water reactor). The resulting steam is used to drive turbines, which via generators produce electrical power.
12. The EPR is a Generation III+ pressurised water reactor design. It has been designed and developed mainly by Framatome (part of Areva between 2001 and 2017) and Électricité de France (EDF) in France, and by Siemens in Germany. In Europe this reactor design was called European Pressurised Reactor, and the internationalised name was Evolutionary Power Reactor, but is now simply named EPR.

# A UK and France expert view on challenges and opportunities

**Existing Generation Nuclear – 'Generation 3 and 3+ systems'[13]**

Operating reactors

Neither the UK nor France have commissioned a new nuclear power reactor since the 1990s. This means both have an ageing fleet but both also have ongoing and future demand for nuclear power. In this context, extending the lifespan of existing reactors is a high priority for both countries.

The challenges of extending the UK's AGR fleet are substantial but necessary if the UK is to achieve its new mission of completely decarbonising the grid by 2030. The close working between operator and regulator to achieve extensions reliably and safely is key. Maintaining the unique skills base for AGRs in the UK (eg on graphite) will be essential in the short term, but also will be important for Generation 4 high temperature gas cooled reactors (HTGR).

Although the technical challenges of extending France's PWR fleet are less than for AGRs, the scale of the challenge (56 reactors) and the length of extensions required (decades) are significant. France will need to maintain a large PWR skills base in addition to the nuclear infrastructure and components. An interventionist approach is taken to the supply chain to ensure continued provision of technologies (eg even spare parts).

There are opportunities for the shared UK/France operator and the different regulators in each country to work much closer together on approaches to PWR life extension.

New build

The significant delays and cost overruns experienced in the construction of EPRs in France (Flamanville) and the UK (Hinkley Point) have adversely impacted the image of new nuclear, denting the confidence of governments, investors and consumers.

Although many of the reasons for these troubled projects are understood (eg re-starting construction after decades on inactivity) it is imperative that the UK and France learn lessons from what has happened and find solutions that will lead to future projects (eg EPR2[14]) being delivered on time and on budget.

"In France it's essential to keep the fleet going. There is much to do in maintaining knowledge and ability to make stuff. There is a need for supply chain sovereignty which means re-learning and developing manufacturing routes."

**Commentary from the event Co-chairs.**

"60 and possibly 80-year lifespans for existing French fleet are essential to allow for EPR2 design to be realised and any SMR to be properly designed."

**Commentary from the event Co-chairs.**

13. Several generations of reactors are commonly distinguished. Generation I reactors were developed in the 1950-60s and the last one (Wylfa 1 in the UK) shut down at the end of 2015. They mostly used natural uranium fuel and used graphite as moderator. Generation II reactors are typified by the present US and French fleet and most in operation elsewhere. They typically use enriched uranium fuel and are mostly cooled and moderated by water. Generation III are the advanced reactors evolved from these, the first few of which are in operation in Japan, China, Russia and the UAE. Others are under construction and ready to be ordered. They are developments of the second generation with enhanced safety. There is no clear distinction between Generation II and Generation III. Generation IV designs are still on the drawing board. Of seven designs under development with international collaboration, four or five will be fast neutron reactors. Four will use fluoride or liquid metal coolants, hence operate at low pressure. Two will be gas-cooled. Most will run at much higher temperatures than today's water-cooled reactors.

14. EDF, Framatome and the other sector manufacturers are currently working together on an optimised EPR design, in the context of the EPR2 project. This collaboration is aiming to put forward an enhanced industrial solution in anticipation of a renewal of the French fleet. The first plants are expected to be commissioned by 2035. The optimised EPR will replicate the best features of the EPR design but will also incorporate improvements drawn from the operating experience of current EPR projects (Flamanville 3, Taishan and Hinkley Point C).

A balance will need to be struck between innovation that might lead to improved delivery and a strong desire for replication of design to drive down costs. For this reason, it may be that innovation in construction methodology and management is prioritised in the short and medium term over any change in reactor design.

"A step back is needed for EPR2 to properly incorporate 21st Century project management and accommodate and improve the constructability of a very complex design."

**Commentary from the event Co-chairs.**

The fifth industrial revolution ("Industry 5.0") will have much to offer in terms of manufacturing and construction innovation, including the role of AI and radical changes in human-machine interaction.

Despite the set-backs, governments and investors should recognise that as new build proceeds, delivery will accelerate and costs will reduce. France itself shows that delivering multiple nuclear power plants at speed is possible. The UK's current nuclear submarine build programme shows that a fleet approach does lead to a reduction in costs after the first of a kind is built. Critical to future delivery is long-term strategic thinking, political commitment, unchanging demand signals and a fleet approach.

The future construction of EPRs in the UK and France is essentially an international project. There are many opportunities to maximise the benefits of this through shared learning, shared data, shared workforce development and shared R&D programmes.

"There is no global supply chain any more even for items as basic as end fitting screws! It is essential that Europe can make what is needed otherwise it is impossible to improve components."

**Commentary from the event Co-chairs.**

### Small modular reactors

The UK and France are both investing in the development of small modular reactors which have the potential to be factory-built, faster to deploy, at less cost and with more flexibility of operation. However, as with larger reactors, the full benefit of SMR technology will only be realised if there is policy certainty and the investment to construct fleets of SMRs. As grids are decarbonised globally in the 2030s, SMRs have the potential especially to replace coal-fired power stations, but the technology must be ready to embrace this opportunity. A difficult balance must therefore be struck between the innovation in fabrication that will optimise the benefits of SMRs and the need for speed to market.

"As a priority in any design there should be an in depth analysis of how the design and construction interact."

**Commentary from the event Co-chairs.**

### New opportunities for Generation 3

Innovation in other sectors may offer opportunities in the way in which Generation 3 reactors are used beyond providing baseload electricity to the grid. Co-location of industries with power plants might realise some of these opportunities. For example, the power required to run data centres and AI or the heat and electricity required to run massive horticultural or vertical farming installations. Although not producing the very high temperature of Generation 4 reactors (see next section), Generation 3 reactors can provide heat for industrial processes (on a local scale in the case of SMRs).

**KEY POINT 1**

## Delivery of new nuclear must be optimised

Policy certainty and commitment to multiples of projects or a 'fleet' approach is required to maximise value and learning from projects as is recognition of constructability as a key driver.

# Future Systems – ‘Generation 4’

**Beyond electricity**

Generation 4 (and Generation III) systems can provide much more than baseload electricity to the grid and have the potential to assist in the decarbonisation of difficult to reach areas of the economy. Examples include the generation of hydrogen as a carbon-free alternative fuel, provision of district heat for housing, the production synthetic fuels for aviation, high temperature process heat for industrial purposes (eg steel manufacture) and the provision of desalinated drinking water.

For these reasons, it is important that the UK and France integrate nuclear energy more widely into future industrial policy and strategy.

“We have to decarbonise energy, not just electricity and HTGR and FR could play a role in this, supplying heat as well as electricity to industry.”

**Commentary from the event Co-Chairs.**

“To make progress in advanced systems we need to build something. You don’t get close to commercial realisation with paper studies.”

**Commentary from the event Co-chairs.**

**KEY POINT 2**

## Nuclear can offer more than electricity.

The UK and France should work together to accelerate the demonstration of non-electric applications of nuclear in support of the decarbonisation of hard to abate industry sectors

**Energy security**

A secure, reliable supply of uranium is essential for the continued operation of Generation 3 reactors. There is currently confidence in that supply globally. However, in a situation where a limited number of countries have uranium deposits, the long-term geopolitical risks to supply are significant. The energy crises of the 20th century (oil) and 21st century (gas) give grounds for both pessimism and caution.

“It takes 70 – 80 years to achieve a 100% FR fleet. We need 60 years of fuel available to give investors confidence so we need to start with the FR journey now.”

**Commentary from the event Co-chairs.**

Neither the UK nor France has domestic deposits of uranium. For this reason, Generation 4 fast reactors which can “breed” new fissile material and can be fuelled with existing depleted uranium or plutonium stocks are an attractive means of securing energy security in the second half on this century, without requiring mining activities.

“Massive waste reduction and true sustainability can only be achieved with Fast Neutron Reactors.”

**Commentary from the event Co-chairs.**

Both the UK and France are investing in Generation 4 development with the aim of demonstrating systems in the 2030s and deploying systems from the middle of this century. However, the focus of this investment and the scale of the investment are not at the level required. Given the opportunity for the UK and France to ensure energy security over the next century, these programmes should be accelerated.

"In Gen IV it is essential that the fuel cycles have the same prominence in R&D as the reactors. In most cases the reactor has been the focus: this needs to switch to the fuel cycle."

**Commentary from the event Co-chairs.**

### The need for a bilateral programme

The development of nuclear reactors, like any large-scale energy infrastructure development, is expensive. Since the 1950s, the UK and France have together spent more than €1bn on world leading fast reactor programmes – with operating reactors in the UK and France. Working together now would reduce future costs for each country and take full advantage of the decades of experience of both countries' nuclear sector.

Although the UK and France are both members of the Generation IV International forum[15], there is scope for much closer integration of the UK and French programmes. The technology choices for advanced reactors are different between the countries and this divergence represents an opportunity for synergy rather than a risk of separation. A bilateral agreement could be reached for the UK to support France in its focus on the Sodium Cooled Fast Reactor (SFR) and for France to support the UK in its focus on the High Temperature Gas Cooled Reactor (HTGR). In this way, both technologies would be brought to fruition without duplication of effort.

"Confidence is required in the sector so step by step improvement has been the way which takes decades as everything is targeted so we need to start on next generation now."

**Commentary from the event Co-chairs.**

"There is a limit to what a market will do."

**Commentary from the event Co-chairs.**

**KEY POINT 3**

## UK and France can lead on demonstrating advanced systems

The UK should lead on demonstration of HTGR with French support and France on demonstration of Fast Reactor technology with UK support, this optimises the pathway to demonstration and ensures both UK and France get the benefits from HTGR and Fast Reactor technology.

15. Generation IV International Forum (2024). See: https://www.gen-4.org/ (accessed 15 August 2024).

# Fuels and the fuel cycle

### Fuel for the current fleet

The UK and France have a rich heritage in the fuel cycle (including enrichment, conversion, deconversion and fabrication). There is a need to secure the front end of the fuel cycle removing reliance on Russian influence. The UK and France must return – at speed – to having full capability and capacity. There should be a move to a parallel commitment to underpinning research and development to ensure optimisation while building the necessary supply chain and skills pipeline.

> "Advanced Technology Fuels (ATF) still have development pathways to explore."
>
> **Commentary from the event Co-chairs.**

In both the UK and France (and elsewhere) current fleets of light water reactors (PWRs in the case of UK and France) will need to run decades longer than was originally intended. Innovation in fuel type and fuel manufacture is part of the life extension story and an area where the two countries can work together.

> "Fuel designs for EPR2 should be able to accommodate degraded Pu in MOX."
>
> **Commentary from the event Co-chairs.**

Collaboration on existing generation fuels and driving towards advanced technology fuels together will ensure UK and France are playing a leading role in optimising the current and future fleet of reactors thus improving the economic competitiveness of nuclear, reducing energy bills and providing energy security. Current generation and advanced technology fuels for light water reactors should be an area where UK and France can increase collaborative research and development (R&D).

**KEY POINT 4**

## Long term fuel supply can be secured.

The UK and France should 'double down' on their commitments as part of the 'Sapporo 5', including investing in front end fuel cycle R&D and building collaborative links

### Fuel for small modular and advanced modular reactors (AMRs)

Many small and advanced modular reactor concepts will require a new generation of fuels. Many demand higher enrichment of uranium. As fuel types take many years to develop it is imperative that this happens in parallel to reactor development. However, with many reactors and very varied stages of development, that does lead to a very wide variety of fuel types.

Both the UK and France are developing advanced fuels for new small and advanced reactor types. This is especially the case in the UK for the fuel needed for the HTGR demonstration and in France for fuel for the France 2030 programme.

> "A technology platform is required to prepare fuel for GenIV. This includes HALEU, UF6 up to 20%, metal fuel, oxide fuel and TRISO all of which require R&D."
>
> **Commentary from the event Co-chairs.**

**KEY POINT 5**

## Advanced fuels can fuel the future

The UK and France should accelerate the scale up of advanced fuels for advanced reactors, optimising the pathway to commercial scale production in the UK and France working collaboratively with the UK leading on HTGR fuels and France on Fast Reactor Fuels.

"You haven't got a reactor if you haven't got the fuel cycle that goes with it sorted."

**Commentary from the event Co-chairs.**

"Pu is tomorrow's fuel. It is essential to preserve it for use and wait: not waste it."

**Commentary from the event Co-chairs.**

### Open and closed fuel cycles

In France the entire fuel cycle is integrated, including enrichment, fuel production, fuel use, fuel storage and fuel reprocessing. France aims for a closed fuel cycle[16] to reduce the need for uranium and to lower the amount/radioactivity of nuclear waste. After reprocessing, France produces both mixed oxide (MOX) and reprocessed uranium (RepU)[17] fuel both of which reduce the uranium demand by 10%. In the UK, industrial scale reprocessing ceased in 2022 and the UK therefore currently operates an mopen or 'once through' fuel cycle.

Advanced fuel cycles and recycling will be necessary as part of the long term sustainable nuclear pathway, including a fast reactor programme as outlined. So what can the UK and France do together to deliver a sustainable recycling system? The UK is coming out of reprocessing and without a programme of investment to maintain capability at an R&D level it will lose it. France has committed to building a new reprocessing facility planned in France for post 2040/45. The UK and France should explore working together to deploy advanced recycle capabilities in this new facility, building on the work the UK completed as part of the investment in the UK Advanced Fuel Cycle Programme (AFCP).

16. In the open fuel cycle, uranium (in nuclear fuel) is used once in a nuclear reactor and then stored for final disposal, while in the closed fuel cycle the spent (used) fuel is recycled to reuse the still deployable materials and to reduce the waste lifetime.

17. Reprocessed uranium (RepU) is the uranium recovered from nuclear fuel reprocessing.

KEY POINT 6

## Nuclear is sustainable

We should remember the three R's for nuclear fuels – reduce, reuse, recycle. France has committed to working on future advanced fuel cycles and the UK should maintain capability in fuel recycling following the end of industrial scale reprocessing in the UK. A collaborative programme should be established focused on advanced recycle demonstration supporting both UK capability maintenance and French planning for new facilities.

### Knowledge retention

Both UK and France have a rich legacy of knowledge and experience in the fuel cycle that will most likely be needed in future years and for future technologies. It will be important to carefully collate and curate this knowledge and experience, especially while key staff members are still part of the workforce.

"There is a complex ecosystem for each reactor type. Collaboration is essential especially with a closed fuel cycle."

**Commentary from the event Co-chairs.**

"There is scope to look at 'safeguarded by design', use of online sensors, avoid Pu transportation and co-locate fuel fabrication with recycle."

**Commentary from the event Co-chairs.**

"On innovative fuels there is much still to be done. Alternative processes for recycle need to be properly examined. On Molten Salts despite the hype the technology is in its infancy."

**Commentary from the event Co-chairs.**

"UK has expertise in designing and operating and closing reprocessing plants. Before all the expertise is lost there should be a programme for sharing with France and possibly building together a pilot of France focused on the future."

**Commentary from the event Co-chairs.**

# Skills and infrastructure

### The nuclear workforce today

France and the UK have the largest nuclear workforces in Western Europe. France has approximately 220,000 people and the UK 80,000. Much of this workforce are not nuclear 'specialists' and are applying generic skills or transferable skills (eg engineering, metallurgy and metal forming, construction, project management) to nuclear projects. A minority of the workers needed in the sector have nuclear know-how essential to their roles and an even smaller number of nuclear subject matter experts are needed.

### Future demand

A nuclear 'renaissance' in both UK and France will demand expansion of the nuclear workforce in both countries. Much of this expansion will be in areas that have declined in recent decades (eg new build construction or fuel reprocessing). For example, it is projected that the UK workforce will need to grow by 50% (40,000 people by 2030). Meeting this demand is complicated by the fact that many of those with the skills most needed will retire over this same period.

### Transferable skills

For those workers with generic skills applicable across sectors, three challenges face both France and the UK. The first is that the size of the increase in demand is significant in some areas, especially related to construction. The second is that other sectors can and will compete for this workforce (eg aerospace projects for engineers or other major infrastructure projects for construction workers). The third is that, as new build gathers pace, multiple projects will be underway simultaneously so moving workers from A to B will not be possible.

Both the UK and France are encouraging new entrants into the nuclear sector through strong demand signals (for example, the 'Destination Nuclear'[18] campaign in the UK).

### Nuclear expertise

Those with nuclear expertise include nuclear operators, nuclear safety experts, nuclear scientists and nuclear engineers. Building this area of the workforce requires foresight and a long-term approach including dedicated MSc, PhD and postdoctoral programmes. Unfortunately, evidence from the UK is that the academic staff in universities qualified to offer these programmes is in decline. Funding for this important work needs to be longer-term – decades rather years.

> "If you don't maintain capability it will wain away within a decade. There needs to be a multi-year commitment to skills by bringing back the ability to make and construct stuff. Technician and student programmes should be an essential part of a bilateral people plan."
>
> **Commentary from the event Co-chairs.**

### Planning together, training together, learning together

The UK and France will experience similar nuclear skills demands and face similar challenges in meeting that demand. There is much they can do together to plan for the size and composition of the workforce and to jointly address some of the challenges. For example, a common MSc course run by a consortium of UK and French universities and a joint doctoral training programme including student exchange and common taught elements. Ultimately, the vibrancy of the R&D sector in each country in some of the areas mentioned in previous chapters will serve to make nuclear science and engineering an attractive destination.

18. Destination Nuclear (2024). See: https://www.destinationnuclear.com/ (accessed 15 August 2024).

**KEY POINT 7**

## The nuclear sector can deliver the skills it needs.

The UK and France should develop and share best practice for skills and capability development. Maximising value through exchange of personnel and establishing a joint skills programme.

Infrastructure for the future is a key consideration for both the UK and France. Both rely on ageing infrastructure for nuclear science and engineering. A programme of investment is needed and is taking place in several areas in both UK and France. However, nuclear infrastructure is expensive and there should be opportunity for the UK and France to work together to relieve some of this burden, delivering world leading nuclear R&D infrastructure that enables and accelerates the UK and France forward nuclear programmes.

**KEY POINT 8**

## The UK and France can deliver new nuclear R&D infrastructure

The UK and France should share strategic plans for future nuclear infrastructure for research and development. At least one joint initiative should be identified and taken forward, this could build on an existing relationship (eg the Jules Horowitz Reactor) or scope for new capability such as a Zero Power (training) Reactor.

# Concluding thoughts from the Co-chairs

From Becquerel to Rutherford, from Chadwick to Curie, splitting the atom was essentially a British and French endeavour. Since then, our countries have a shared history of success in nuclear science and engineering. This success has provided a source of green power to our citizens and our economies for seventy years.

As we look towards the next seventy years, our governments share the same policy priorities of decarbonisation and energy security, we share the same nuclear power operator, we are building the same new nuclear reactors and we have an increasingly interconnected electricity grid. Working together is therefore both natural and essential.

In the context of the climate emergency and a deteriorating geopolitical situation, now is the time to work together if our countries wish to meet their net zero commitments and secure their energy supply for the rest of this century.

**KEY POINT 9**

### The UK and France can enhance their bilateral cooperation

In the 2023 Statement of Cooperation on Civil Nuclear Energy the UK and French governments expressed their desire to "enhance their bilateral cooperation in the realm of civil nuclear". Our meeting between the Royal Society and the Académie des Sciences has provided a forum in which numerous excellent ideas have been proposed to fulfil that desire. The Royal Society and the Académie des Sciences should jointly establish the "senior UK-France contact group".

Now is the time to cement and operationalise a programme of collaboration in the areas mentioned in previous chapters and consistent with those outlined in the Statement of Cooperation. Such a programme will require political support, funding and a governance mechanism.

As a next step, we suggest that the Royal Society and the Académie des Sciences jointly establish the "senior UK-France contact group" envisaged in the Statement of Cooperation and that this contact group works to define the detailed shape of our future collaborative effort.

**Dame Sue Ion FREng FRS**
Chair of the Royal Society Science, Industry and Translation Committee

**Professor Yves Bréchet**
Académie de sciences

**Dr Paul Nevitt**
National Nuclear Laboratory

**Professor Marc Fontecave**
Académie de sciences and Collège de France

# Summary of key points

**KEY POINT 1**

Delivery of new nuclear must be optimised

Policy certainty and commitment to multiples of projects or a 'fleet' approach is required to maximise value and learning from projects as is recognition of constructability as a key driver.

**KEY POINT 2**

Nuclear can offer more than electricity.

The UK and France should work together to accelerate the demonstration of non-electric applications of nuclear in support of the decarbonisation of hard to abate industry sectors.

**KEY POINT 3**

UK and France can lead on demonstrating advanced systems

The UK should lead on demonstration of HTGR with French support and France on demonstration of Fast Reactor technology with UK support, this optimises the pathway to demonstration and ensures both UK and France get the benefits from HTGR and Fast Reactor technology.

**KEY POINT 4**

Long term fuel supply can be secured.

The UK and France should 'double down' on their commitments as part of the 'Sapporo 5', including investing in front end fuel cycle R&D and building collaborative links.

**KEY POINT 5**

Advanced fuels can fuel the future

The UK and France should accelerate the scale up of advanced fuels for advanced reactors, optimising the pathway to commercial scale production in the UK and France working collaboratively with the UK leading on High Temperature Gas Reactor (HTGR) fuels and France on Fast Reactor Fuels.

**KEY POINT 6**

Nuclear is sustainable

We should remember the three R's for nuclear fuels – reduce, reuse, recycle. France has committed to working on future advanced fuel cycles and the UK should maintain capability in fuel recycling following the end of industrial scale reprocessing in the UK. A collaborative programme should be established focused on advanced recycle demonstration supporting both UK capability maintenance and French planning for new facilities.

**KEY POINT 7**

The nuclear sector can deliver the skills it needs.

The UK and France should develop and share best practice for skills and capability development. Maximising value through exchange of personnel and establishing a joint skills programme.

**KEY POINT 8**

The UK and France can deliver new nuclear R&D infrastructure

The UK and France should share strategic plans for future nuclear infrastructure for research and development. At least one joint initiative should be identified and taken forward, this could build on an existing relationship (eg the Jules Horowitz Reactor) or scope for new capability such as a Zero Power (training) Reactor.

**KEY POINT 9**

The UK and France can enhance their bilateral cooperation

In the 2023 Statement of Cooperation on Civil Nuclear Energy the UK and French governments expressed their desire to "enhance their bilateral cooperation in the realm of civil nuclear". Our meeting between the Royal Society and the Académie des Sciences has provided a forum in which numerous excellent ideas have been proposed to fulfil that desire. The Royal Society and the Académie des Sciences should jointly establish the "senior UK-France contact group".

# Appendix 1: Challenges, opportunities and areas for collaboration

## Existing generation nuclear – 'Generation 3 and 3+ systems'

| Challenges / opportunities | Collaboration |
|---|---|
| **AGRs** – there is a need for specialist skills related to AGRs for the existing fleet and for future HTGR development, skills might be lost in between these two technologies. | UK and France could work together on developing demonstration projects and actively manage the transition of skills and workforce between existing and future gas-cooled reactors. |
| **EPR construction** – evolution in construction working practices is needed (for example 1200 steel fixers are needed on site each day for every build). | UK and France should share learning on EPR/EPR2 construction and share best practices. |
| **SMR optimisation and timing** – need to balance necessary innovation in manufacturing and construction (eg isostatic pressing and electro beam welding) with emphasis on speed to market. | There are some pre-competitive elements of the modular manufacturing process that could form the basis on a joint R&D programme between the UK and France. |
| **SMR design** – should the UK and France compete or collaborate on SMR design? | There is a possibility that UK and France could agree at both political and industrial level that only one design is necessary for both PWR and SMR. |
| **Modularity and transport** – modularity is a significant opportunity but final assembly and transport to site could be a challenge. | UK and France could together explore the solutions to optimal deployment of modular construction technology, for example coastal sites enabling sea transport. |
| **pH raisers** – water in PWRs needs to be slightly alkaline. The chemical used (Lithium-7 – isotopically enriched lithium hydroxide) is only produced in Russia and China generating supply concerns. | UK and France should explore further joint research into the use of effective and compatible alternative alkalis such as potassium hydroxide. |
| **Materials** – data on materials aging and degradation is important to addressing these issues in an ageing fleet. | UK and France should establish arrangements to share data in a smart way. |
| **Beyond electrons** – a real opportunity exists but transporting heat is a challenge and transporting Hydrogen is inefficient. Could transport steam. | UK and France could together explore the optimal deployment of non-electric nuclear energy, addressing transport and public engagement challenges |
| **Load following** – French reactors are used more for load following than UK reactors but that might change as the amount of renewables on the grid increases. Load following has impacts on power plant cost and performance including impacting efficiency, lifespan and maintenance. | UK to learn from the French experience of load following and for both to explore optimal response to increased renewables. |
| **Co-location** – there is an opportunity to couple nuclear energy with power-hungry data centres and AI operations. | UK and France to explore the opportunities presented by new power-hungry technologies. |

**Existing generation nuclear – 'Generation 3 and 3+ systems'** (continued)

| Challenges / opportunities | Collaboration |
| --- | --- |
| **Provider** – UK and France have a shared provider in EDF. The opportunities that this brings for collaboration may not yet be fully realised. | EDF to consider ways in which it can foster collaboration (eg R&D, industry, supply chains). |
| **Regulator** – UK and France regulators have different approaches and perspectives. | UK and French regulators should share best practices, especially in the role of the regulator as an enabler. |
| **Supply chains** – challenges in consolidating the relationships between the UK/FR supply chains which will be important for EPR/EPR2 but also for export markets. | Strengthen the links between Groupement des Industriels Français de l'Energie Nucléaire and the Nuclear Industry Association (eg cross-invitation of representatives to events organised by the two associations). Joint exploration of how to improve the efficiency of the export licensing process.<br><br>Support for connecting French and British companies and industry players. |
| **Financing** – financing GW projects remains a challenge, as does investor understanding of the life cycle and time scales associated with these projects. | UK and France to exchange best practice on financing models. |
| **Public Engagement** – public view of nuclear is changing but there needs to be constant engagement eg on siting of new reactors. | UK and France should work together on public engagement, recognising similarity of new build but also differences in public perceptions. |

### Future systems – 'Generation 4'

| Challenges / opportunities | Collaboration |
|---|---|
| **Safety** – although Gen4 systems are in theory safer, much R&D is needed to both ensure and assess safety. | UK and France to work together on key safety-related technologies such as the development of high-temperature materials, the testing of reactor materials, insulation of reactors at above 600 degrees Celsius and the ability to physically look into reactors. |
| **Proliferation** – there is a theoretical risk of diversion of Gen4 fuel eg plutonium. | UK and France to consider proliferation risk assessment and risk management as well as communicating with stakeholders and publics. |
| **Fuels** – both UK and France have stored resources such as plutonium which could be used to fuel Gen 4 reactors in future. There is a risk that these resources are consigned to non-retrievable storage (eg geological disposal). | UK and France to work together on fuels for a range of Gen 4 reactors and ensure that potentially important resources such as plutonium are not lost (buried) before optimal decisions can be made. |
| **Decarbonising other sectors** – Gen 4 reactors have the potential to decarbonise hard to abate industries. | UK and France to explore the diverse use of future reactor technologies, for example steel production, mining, shipping, horticulture. |
| **Location** – if Gen 4 demonstrators are to be built, is there a possibility to build them in a location where one of the opportunities above can be tested? | In addition to collaborating on HTGR and SFR demonstrators as mentioned in the main report, UK and France to consider the location of demonstrators. |
| **Fragmentation of R&D** – more needs to be done to bring together UK and French R&D communities, especially the two national laboratories. | In the context of advanced reactors, NNL and CEA should organise study visits between the two laboratories and their facilities (in a context of the evolution of NNL towards a true national laboratory). The two countries should continue to play leading roles in the Generation IV Forum. For example, in the autumn of 2024, the UK will organise the meeting of the Policy Board and the Expert Group (the two governance bodies of this international forum). |
| **Parliamentary liaison** – parliaments will be involved in decision making on the future of Gen4. Parliamentarians will need access to the very best advice to inform those decisions. | The Royal Society and Académie des Sciences should continue working closely with those parliamentary bodies tasked with linking science with policy (OPECST and POST). |

## Fuels and the fuel cycle

| Challenges / opportunities | Collaboration |
| --- | --- |
| **MOX** – MOX is used more widely in other parts of the world than either the UK or France. It can be reused and can incorporate plutonium recovered from spent nuclear fuel, thus closing the fuel cycle. | Although there is some collaboration between the UK and France on MOX, this should be expanded as the potential for MOX fuel is realised. |
| **HALEU** – HALEU has great potential but is expensive and produces a lot of nuclear waste. | UK and France to collaborate on developing regulation for HALEU, evaluating potential fuels, reducing cost and reducing waste. |
| **TRISO** – TRISO particles are resistant to melt down and therefore future reactors can be safer and can be sited in areas of high population. | UK and France to collaborate on the development of advanced fuels, including TRISO, for a range of reactor types. |
| **Plutonium** – both UK and France have stored plutonium which could be used to fuel reactors in future. There is a risk that these resources are consigned to non-retrievable storage (eg geological disposal). | UK and France to ensure that potentially important resources such as plutonium are not lost before optimal decisions can be made. |
| **Accident tolerance** – the addition of a chromium coating to fuel can improve thermal reactivity and accident tolerance. | UK and France to further evaluate the potential of chromium coated fuel rods. |
| **Space** – reactors in space will need to be immensely accident tolerant and light. | UK and France to set up a future-oriented group to consider how reactors can be safe enough and light enough to be propelled into space. |
| **Waste** – there is a need to have foresight on handling waste from advanced fuels. | In addition to joint programmes on the development of advanced fuels, a workstream on the management of resulting wastes should be set up. |
| **Simulated fuels** – are of great use as a research tool but can be costly. | UK and France to collaborate more on simulated fuels and thus reduce the cost to each nation. |
| **Regulation** – UK and French regulators take a different approach to the regulation of fuels and the fuel cycle. | UK and French regulators to consider the possibility of matching regulation, especially of advanced fuels currently being developed. |
| **R&D infrastructure** – infrastructure and facilities for nuclear fuel R&D are ageing in both UK and France. Investment is required. | UK and France to consider investment decisions together so that the work can be split and the costs can be shared. |
| **R&D funding** – collaboration can be difficult due to the "double jeopardy" problem. | UK and French funders of nuclear R&D to consider closer alignment and more joint programming. |
| **R&D mobility** – of researchers between UK and France may not be optimal and may have reduced in recent years. | UK and French funders of nuclear R&D to consider investing in and encouraging greater mobility between the countries. |

### Skills and infrastructure

| Challenges / opportunities | Collaboration |
|---|---|
| **Training needs** – UK and France nuclear sectors need to train approximately 100,000 people within 10 years. | UK and France should work together to address training and workforce need, for this reason the bilateral working group between DESNZ and DGEC on skills is welcomed. |
| **Mobility** – Brexit, immigration costs and COVID have had negative impacts on the movement of the nuclear workforce and trainees between the UK and France. | UK and France should facilitate the mobility of nuclear personnel, nuclear academics and nuclear trainees/students between the two countries. This will require funding. |
| **Connectivity** – connection between UK and French workers/trainees promotes open minds, encourages innovative thinking and builds important networks for the future. | UK and French funding bodies should consider a joint MSc course run by a consortium of UK and French universities. Similarly, a joint doctoral training programme which includes student exchange between the countries and common taught elements. The Laureate programme between the UK and France should be continued, as should the Ladies in Nuclear programme. |
| **EPR** – UK and France are building the same reactor and require similar skills for construction. | UK and France should plan together for the workforce need and facilitate movement between sites |
| **National laboratories** – NNL and CEA have crucial roles to play in skills development and workforce provision. | NNL and CEA should establish a Framework through which an increased number of technical exchanges can be arranged. |

# Appendix 2: List of acronyms

**AGRs**
Advanced Gas-cooled Reactor

**AMRs**
Advanced Modular Reactors

**ANTs**
Advanced Nuclear Technologies

**CEA**
Commissariat à l'énergie atomique et aux énergies alternatives

**DESNEZ**
Department for Energy Security & Net Zero

**DGEC**
Direction générale de l'énergie et du climat

**EPRs**
European Pressurised Reactors

**FR**
Fast Reactors

**HALEU**
High-Assay Low-Enriched Uranium

**HTGR**
High Temperature Gas Reactor

**MOX**
Mixed oxide

**MSR**
Molten Salt Reactor

**NNL**
National Nuclear Laboratory

**PWRs**
Pressurised Water Reactors

**RepU**
Reprocessed uranium

**SFR**
Sodium Fast Reactor

**SMRs**
Small Modular Reactors

**TRISO**
TRi-structural ISOtropic particle fuel

**UF6**
Uranium hexafluoride

# Appendix 3: Attendees

The Royal Society and the Académie des sciences would like to thank the following people for supporting this event.

| Co-chairs |
|---|
| Dame Sue Ion FREng FRS, Chair of the Royal Society Science, Industry and Translation Committee and Office for Nuclear Regulation Independent Advisory Panel and UK National Skills Academy for Nuclear. |
| Professor Yves Bréchet, Académie de sciences |
| Dr Paul Nevitt, National Nuclear Laboratory |
| Professor Marc Fontecave, Académie de sciences and Collège de France |

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| James Musisi, Policy Adviser, Europe, International Affairs |
| Laura Wilton, Head of Europe and Asia, International Affairs |
| Ian Wiggins, Director of International Affairs, International Affairs |
| Paul Davies, Senior Policy Adviser, Science Policy |

| Académie des sciences staff |
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| Sophie Grelat, Chargée de Relations Internationales, Académie des sciences |
| César Manrique Milla, Adjoint au directeur, responsable des dossiers internationaux, Académie des sciences |

| Event participants |
|---|
| Professor Tim Abram FREng, University of Manchester |
| Pierre-René Bauquis, IFP School |
| Vincent Berger, High Commissioner for Atomic Energy |
| Alban Bertrand, Ecole Normale Supérieure |
| Dr Will Bodel, University of Manchester |
| Bernard Boullis, Formerly French Alternative Energies and Atomic Energy Commission (CEA) |
| Simon Bowen, Great British Nuclear |
| Professor Colin Boxall, Lancaster University |
| Dr Kate Canning, Nuclear Decommissioning Authority |
| Fanny Courtin, IMT Atlantique – Subatech Lab |
| Christopher Darby, Norwich Institute for Sustainable Development |
| Nicolas Devictor, French Embassy in the United Kingdom |
| David Eaves, Westinghouse Springfields |
| Alexis Findykian, DIAMMS – Délégation interministérielle aux approvisionnements en minerais et métaux stratégiques |
| Bernard Fontana, Framatome |
| Mark Foy, Office for Nuclear Regulation |
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| Francois Gauché, Framatome |
| Dave Goddard, National Nuclear Laboratory |
| Dr Dominique Grenêche, French Nuclear Society and American Nuclear Society |

| **Event participants** (continued) |
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| Deborah Hill, National Nuclear Laboratory |
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| Professor Paul Howarth, National Nuclear Laboratory |
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| Dr Laetitia Jubin, Saint-Gobain |
| Dilek Kale, University of Manchester |
| Chetan Kotur, Laing O'Rourke |
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| Robin Taylor, National Nuclear Laboratory |
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