ENERGY

UK FAST REACTOR

A ROADMAP FOR DEVELOPMENT

Institution of MECHANICAL ENGINEERS

Since the 1950s, 'Fast Neutron Reactors', or Fast Reactors, have been researched due to their potential to utilise uranium much more efficiently than conventional reactors. However, for the past few decades while uranium prices have been relatively low, there has been little incentive in the UK for further work on this technology. In March 2013 the UK Government published its long-awaited 'Nuclear Energy R&D Roadmap'[1], which sets out the research outcomes that will support implementation of future nuclear technology pathways. As part of the plan, Fast Reactor technology is once again being considered as a means of deriving more energy from nuclear fuel. This policy statement considers how a commercial approach to building a UK Fast Reactor could effectively meet the Government's nuclear objectives and benefit UK industry more broadly.

The Institution of Mechanical Engineers recommends that:

1. **The UK Government should consider funding the development of Fast Reactor technology now.** To set the UK on a pathway towards a 'Closed Fuel Cycle', in accordance with the Government's proposed Nuclear Energy R&D Roadmap[1], some initial strategic public funding is needed to demonstrate key elements of the technology and act as a catalyst to stimulate commercial investment to develop a plant.
2. **The UK Government must commit to pay for the disposition of the plutonium stockpile in an operational reactor.** Once initial development has been stimulated to follow a commercial pathway, an operational reactor will emerge earlier than if a long-term Government-funded research & development programme is pursued. This will benefit the UK through disposition of the nation's plutonium stockpile in a shorter timescale than via alternative approaches. However, for the commercial solution to be sufficiently attractive, it will be necessary for the Government to commit to pay for the disposition of the UK's plutonium stockpile once a reactor is operational.
3. **The UK Government needs to recognise the potential opportunity for UK industry in Fast Reactor technology.** The development of Fast Reactor technology in the UK provides the potential for the country to become a world leader in the associated engineering and manufacturing. This would lead to a long-term export opportunity for UK business and enable the UK to regain a position as a leading player in nuclear power, rather than an informed customer for imported technology and engineering.

THE UK PLUTONIUM STOCKPILE

The plutonium stored in the UK is derived largely from nuclear fuel reprocessing activities that have been ongoing at Sellafield since the 1950s, when plutonium separation was carried out in support of military requirements for defence purposes. In the 1960s, it was realised that plutonium might have a future as fuel for Fast Reactors and, therefore, the amount of accumulated plutonium was increased. In parallel, the Government funded a substantial research & development programme to develop initially a prototype Fast Reactor plant at Dounreay in northern Scotland, and then a commercial design. Despite the build-up of plutonium for fuel, in 1994 the UK Government abandoned almost all research into Fast Reactors as, at that time, it was thought that the technology would not be commercially viable for large-scale electricity production. However, plutonium production at Sellafield continued and, as a result, the UK accumulated a large stockpile of the material without a clear plan for using it.

In March 2013, the Institution of Mechanical Engineers published its policy statement on potential options for re-use of the UK's plutonium stockpile[2] and made recommendations for a portfolio approach to its utilisation and storage. It concluded that Fast Reactors could be the most commercially viable way to burn up suitable parts of the stockpile, generating low-carbon electricity and reducing the long-term hazard, recommending that the Nuclear Decommissioning Authority (NDA) should identify fuel from within the stockpile that could be recycled in such facilities.

THE FAST REACTOR OPTION

As well as plutonium, spent fuel from conventional thermal nuclear reactors contains transuranics, such as americium, curium and other isotopes of plutonium. These have a significant fission cross-section in the fast neutron spectrum, but not in the thermal neutron range, hence their presence in this remaining material. A Fast Reactor has the ability to fission these transuranics and will thus 'burn' such materials as fuel, whereas a conventional reactor will not. Therefore a Fast Reactor can produce additional electricity per unit of fuel, effectively recycling spent material from thermal reactors and thereby improving overall resource utilisation.

The Government's Nuclear Energy R&D Roadmap[1] considered two very different approaches for a Fast Reactor. The first is a small, modular, commercial option and the second is a large, international, collaboration option.

Since 1981, GE Hitachi Nuclear Energy has been developing a technology that could help deliver in the case of the first approach, known in the USA as the 'Power Reactor Inherently Safe Module' (PRISM) reactor[3]. If it were adopted in the UK, material from the nation's spent fuel stockpile (including plutonium) could be used to make Fast Reactor metal fuel, in a relatively simple manufacturing facility, and then utilised in this small modular commercial option. When the plutonium and other associated actinides in the recycled fuel are 'burnt up', the used material would be removed from the unit for final reprocessing, or it could be stored in the Government's proposed Geological Disposal Facility. If reprocessed, while some nuclear waste would be produced, it would be much smaller in volume and have a considerably shorter half-life than the plutonium in its current form. Some uranium could even be extracted from the waste to make fuel for conventional reactors. By using a Fast Reactor in this way, combined with conventional reactors, maximum use can be made of the mined uranium, and high-level waste could be minimised. It has been estimated that two PRISM reactors, generating a combined electricity output of over 600MW, could disposition all the UK's plutonium stockpile within a few decades of operation.

PRISM is a commercial option. While it may well require some initial Government funding to support the work to validate the design for the purposes of licensing, construction could be funded on a commercial basis, provided that there is a stable Government policy framework and predictable regulatory environment. With an initial payment for the disposition of the plutonium stockpile, and an electricity generation income stream underpinned by the proposed 'Contract for Difference' mechanism, it is entirely possible that a PRISM facility could generate a net operating profit over a 60-year life[2], thus making it attractive to potential investors.

The second potential route to Fast Reactor technology could be based on the French-led 'Astrid' (Advanced Sodium Technological Reactor for Industrial Demonstration) proposal[4]. In contrast to PRISM, which is a small, modular concept, this technology is a large, loop reactor being developed as a prototype through a project that is open to international participation. While this collaboration could reduce the development costs, it is not characterised by the entrepreneurial approach of the PRISM project and is likely to be delivered on a much longer timeframe with less commercial focus.

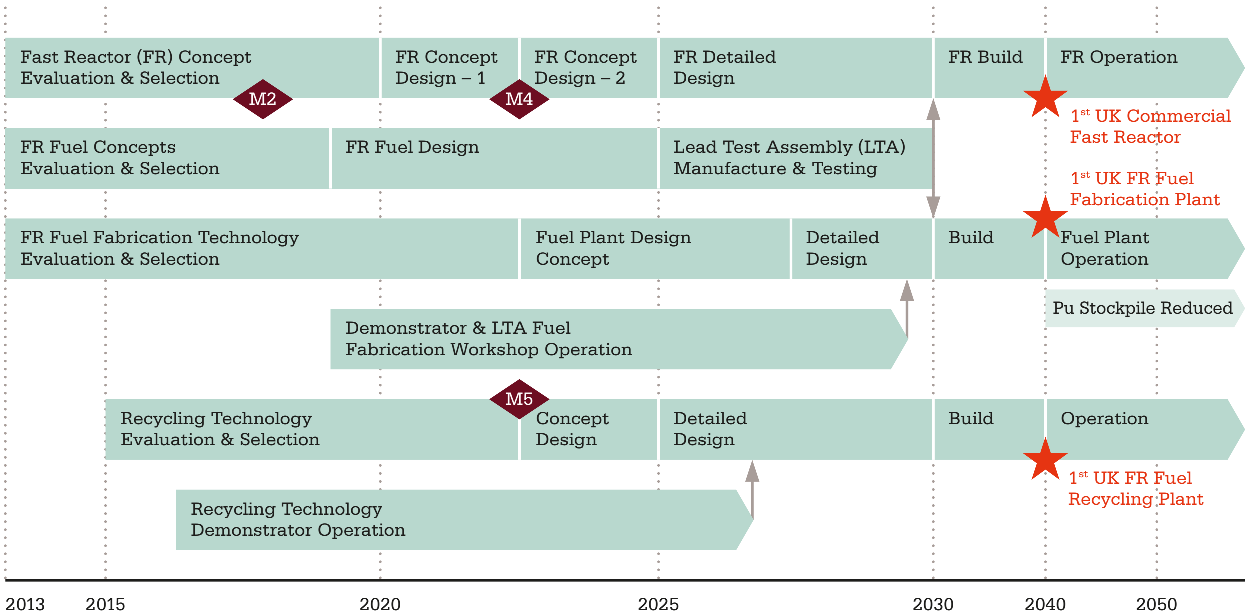
UK NUCLEAR ENERGY R&D ROADMAP

In March 2013, the UK Government published its strategy for future nuclear R&D, defining potential pathways[1] in a roadmap for the nation's activities in this area. One of the pathways considers a transition to a 'Closed Fuel Cycle'. In addition to the current conventional reactors, the latter requires the use of Fast Reactors burning fuel manufactured from conventional spent fuel, with an associated recycling facility to extract uranium from the used Fast Reactor fuel, which can then be used in conventional reactors.

The Government believes that the transition to a Closed Fuel Cycle would not be immediate and would need to be phased, in accordance with the development of advanced technologies including Fast Reactors and advanced reprocessing methods.

Given the limited funds that are likely to be available from the Government for development in these areas, the routes being considered in **Figure 1** could be described as a collection of 'B-roads' rather than 'motorways'. The speed of development is limited by the availability of funding, so international collaboration is being considered by the Government, and funding is likely to be focused on national laboratories rather than commercial organisations. This pathway would not deliver Fast Reactor operation until 2040 and would leave most of the UK's plutonium stockpile in a vulnerable state for at least another 30 years. In addition, such an approach misses out on an opportunity to develop UK engineering and manufacturing capability in Fast Reactor technology, and to pursue a UK industrial strategy that would return the nation to a position of leadership in the global nuclear sector.

Figure 1: UK Government Pathway to Fast Reactor Deployment



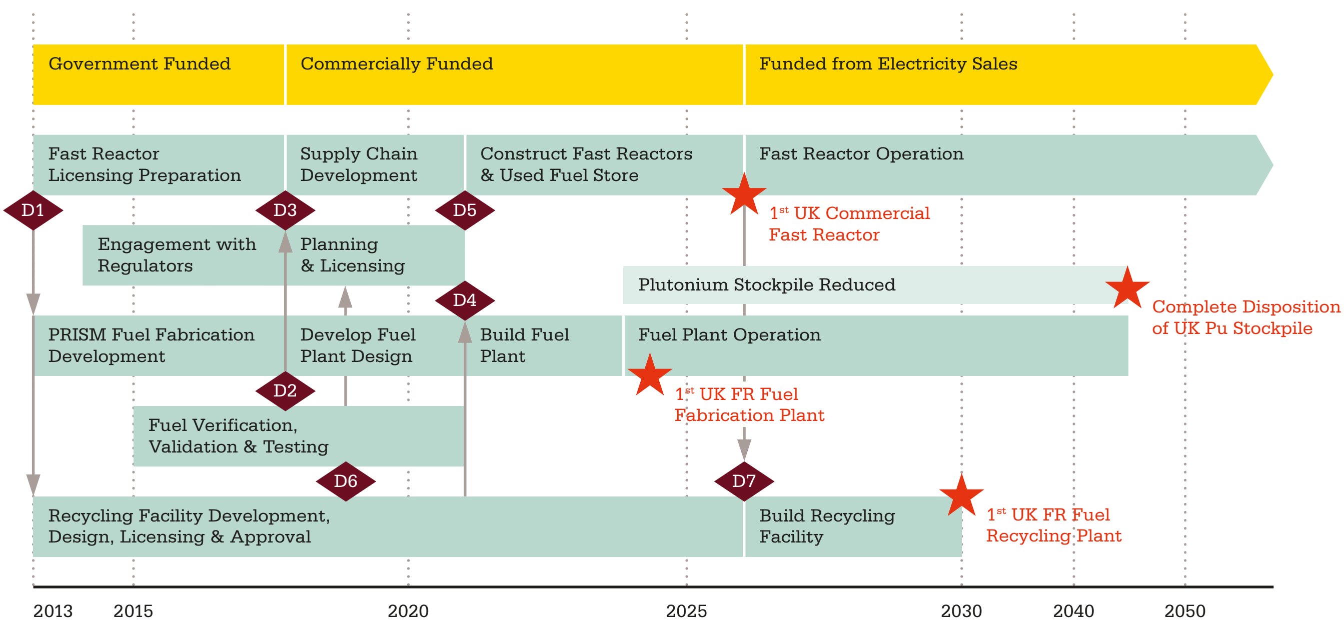
M2 Decision Point – design commercial Fast Reactor through international demonstration project participation.
M4 Decision Point – proceed with design of UK commercial Fast Reactor.
M5 Decision Point – proceed with design of UK recycling plant.

COMMERCIAL DEVELOPMENT FROM GOVERNMENT-FUNDED RESEARCH

As an alternative to the Government's proposed approach, **Figure 2** presents a roadmap developed by the Institution of Mechanical Engineers. This shows how a commercially driven project could deliver the required outputs much earlier. A key feature of this approach is that although initial Government funding would be needed to demonstrate that the required fuel could be manufactured from the more-difficult element of the UK stockpile and to support work to validate the design for the purposes of licensing, with the right incentives in place, commercial organisations would be willing to take over the investment to develop the design and build the plant. It can be seen from **Figure 2** that with a well-funded, commercial approach, Fast Reactor operation could be achieved 14 years earlier and plutonium stockpile reduction begun 17 years earlier. For this approach to work, rather than committing to long-term international collaborative work, the Government would need to make only a modest commitment to pay for the disposition of the plutonium stockpile as it is manufactured into fuel. It would not need to fund long-term development or pay for securely managing the plutonium stockpile for as long a period. Committing to a commercial Fast Reactor which would deal with the stockpile, would also avoid the need to plan for this material going into the Geological Disposal Facility, potentially saving billions of pounds.

A significant benefit of taking this approach is that commercial development of Fast Reactor technology in the UK would lead to the establishment of engineering and manufacturing capability, which could provide a significant export opportunity for the nation in the coming decades, as well as reinvigorate skills within the nuclear sector in regions of the country experiencing industrial decline. It is anticipated that Fast Reactor technology, supporting Closed Fuel Cycle operation, will become more significant as environmental, fuel resource depletion and energy security concerns become increasingly important in national energy strategies[5]. In anticipation of these potential emerging markets, India has established a national Fast Reactor programme, China has initiated activity in this area and Russia is now funding new development. China and Russia have long-term government-managed projects, while India is at a very early stage of exploratory activity. Therefore an opportunity exists for the UK to move rapidly through a commercial approach to development and take 'first mover' advantage. Such a strategy would shift the UK from its current position of informed customer for imported technologies back to that of a world leader in nuclear technology.

Figure 2: Alternative Commercial Pathway to Fast Reactor Development



D1 Decision Point – select the PRISM Fast Reactor design concept and engage with the reactor vendors & their supply chain.
D2 Decision Point – fuel fabrication process proven.
D3 Decision Point – reactor & fuel design concepts proven, agree commercial model & commit to licensing process.
D4 Decision Point – design approved for fuel plant construction, planning permission granted.
D5 Decision Point – design approved for reactor construction, planning permission granted.
D6 Decision Point – recycling facility constraints defined.
D7 Decision Point – recycling facility approved for construction; start of construction determined by commercial issues.

RECOMMENDATIONS

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PUBLISHED DECEMBER 2013.