ADVANCED NUCLEAR FUELS IN THE UK

INNOVATION AND REGULATORY READINESS

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ABSTRACT

- The United Kingdom is entering a period of renewed nuclear development, accompanied by efforts to strengthen domestic fuel-cycle capabilities for both new-build reactors and emerging advanced reactor designs. This policy and technical perspective considers conventional low-enriched uranium (LEU), the UK's emerging LEU+ capability, high-assay low-enriched uranium (HALEU), and coated-particle fuels such as TRISO with a particular focus on the regulatory readiness needed to support their development and deployment. The 2026 LEU+ proof-of-concept at Urenco Capenhurst is used as a practical example through which to examine what "regulation as an accelerator" can mean in a nuclear context.

- The central argument is not that regulatory scrutiny should be reduced but rather that the deployment of advanced nuclear technologies can be supported through regulatory readiness inspections and early regulatory engagement. These mechanisms may reduce late redesign and programme uncertainty without compromising regulatory independence or high standards of nuclear safety.

INTRODUCTION

Recent investment decisions have begun to translate the United Kingdom's renewed nuclear ambitions into a substantial programme of new nuclear development. The 2025 Spending Review committed £14.2 billion to Sizewell C, which reached final investment decision in July 2025, alongside a further £2.5 billion for the UK's Small Modular Reactor (SMR) programme [1,2]. Great British Energy – Nuclear (GBE-N) subsequently selected Rolls-Royce SMR as its technology partner to deliver an initial fleet of three SMRs in the UK [3].

The 2026 Advanced Nuclear Framework, a policy strategy published in February 2026 by the Department for Energy Security and Net Zero, is intended to support the development, commercialisation and deployment of private innovative nuclear projects, and identifies regulation and nuclear fuel among the enabling conditions needed for projects to succeed [4].

The expansion of the UK's nuclear sector creates an important challenge for the nuclear fuel cycle as different reactor technologies may have fuel requirements that differ from those of the existing fleet. Some new reactor designs can use conventional low-enriched uranium (LEU) enriched to approximately 3-5% uranium-235 while others may require higher enrichments or alternative fuel forms [5]. The deployment of advanced reactor technologies may drive the demand for advanced nuclear fuels and fuel forms, including high-assay low-enriched uranium (HALEU) and coated-particle fuels (CPF) such as TRISO. The uranium enrichment categories relevant to existing and advanced reactors are summarised in Table 1.

Fuel cycle capability is consequently becoming increasingly relevant to both the UK's nuclear ambitions and its wider energy security objectives.

This challenge comes at a time when the approach to nuclear regulation in the UK is evolving. In 2025, the Nuclear Regulatory Taskforce completed a wide-ranging review of civil and defence nuclear regulation and recommended a "radical reset" of UK nuclear regulation to make it more streamlined and proportionate [6].

Against this background, the UK's emerging advanced fuel capability provides an opportunity to examine how regulatory readiness can support fuel innovation in practice. The following sections consider the evolution from conventional LEU towards LEU+ and HALEU, alongside advanced fuel forms such as TRISO, before examining how regulation can enable innovation to progress safely.

THE UK'S CURRENT NUCLEAR GENERATING FLEET

As of 2026, the UK's current generating civil nuclear fleet consists of nine reactors at five power stations: eight Advanced Gas-cooled Reactors (AGR) and one Pressurised Water Reactor (PWR) at Sizewell B, which introduced the PWR technology to the UK in 1995 [7,8].

PWRs use light water at high pressure as both a coolant and a moderator and typically use uranium fuel enriched to approximately 3-5% uranium-235. Natural uranium contains approximately 0.7% uranium-235 and is not suitable for a conventional light-water PWR core without enrichment [9].

A more diverse reactor fleet will not create a single uniform demand for advanced fuel. The fuel requirements will depend on specific reactor design and intended operating conditions. Against this background, the important UK question is not simply whether advanced fuels can be manufactured. It is whether fuel development, qualification, transport, safeguards, environmental permitting and waste planning can mature in parallel with reactor programmes.

Fuel Type Category	Acronym	uranium-235 enrichment	Example Application
Natural Uranium	NatU	~0.711%	Enrichment feedstock
Low-enriched Uranium	LEU	>0.711% to ≤ 5.0%	Current PWRs, Rolls-Royce SMR
Low-enriched Uranium Plus	LEU+	>5.0% to ≤10%	Commercial LWRs, advanced reactor fuel development
High-assay Low-enriched Uranium	HALEU	>5.0% to <20%*.	Natrium reactor, Xe-100 and other advanced reactor designs

Table 1: Summary of uranium enrichment categories discussed in this paper.
***Please note that HALEU is formally defined as uranium enriched above 5% and below 20% uranium-235. LEU+ is shown as an intermediate enrichment range.**

FUEL REQUIREMENTS FOR ADVANCED REACTORS

Worldwide interest in advanced reactor technologies continues to grow, with numerous designs currently under development. One of these types, which is particularly relevant to the UK, is Small Modular Reactors (SMRs). SMRs encompass a range of technologies but are generally defined as reactors with a power capacity of up to 300 MW(e) per unit, which is about one third of the capacity of a traditional reactor [10]. SMRs are smaller and modular, so components can be factory assembled and transported as a unit [10]. Rolls-Royce SMR successfully secured a contract with Great British Energy – Nuclear to be the first supplier of SMRs in the UK [11].

When it comes to fuel types needed for SMRs, this can vary, and for some the conventional LEU remains sufficient. For example, the Rolls-Royce SMR design will use uranium that is enriched to no greater than 4.95% uranium-235, which sits in the LEU range [12]. However, many SMR designs require uranium that is enriched to higher percentages. For example, the Natrium reactor developed by TerraPower is a sodium-cooled fast reactor that uses uranium enriched to 12-15% uranium-235 [13].

HALEU

A type of enriched fuel that is being used for more advanced reactor types, including some SMR designs as discussed above, is HALEU fuel which is uranium enriched above 5% and below 20% uranium-235. For reactor designs developed around it, HALEU fuel can support smaller cores and longer operating cycles with potential increased efficiency over existing technologies [14]. Moving above 5% enrichment affects more than the enrichment process. It can have implications across the entire fuel cycle including potential effects on criticality-safety assessment, fuel fabrication, storage and transport [15].

The UK currently does not have an operating commercial HALEU production capability. To address this gap, the UK government awarded £196 million to Urenco, a global uranium enrichment company, to develop an advanced fuel facility to produce HALEU at its Capenhurst enrichment site [16]. The facility is targeting first operations in 2031 and will form part of a wider programme intended to establish a domestic HALEU capability to improve energy security at home and abroad [17].

TRISO and the proposed Xe-100 deployment

Coated-particle fuels (CPF), more commonly known as TRI-structural ISOtropic (TRISO) fuels, are also relevant to the UK's advanced reactor ambitions. TRISO fuels consist of a fuel kernel of fissile material coated in layers consisting of a porous carbon buffer, an inner pyrolytic carbon, a silicon carbide (SiC) layer and an outer pyrolytic carbon layer [18], as seen in Figure 1.

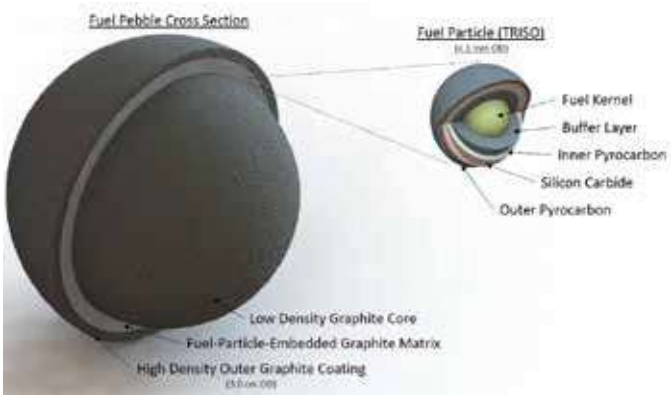


Figure 1: Schematic of TRISO fuel architecture, showing the coated fuel particle and its incorporation within a graphite fuel pebble.

TRISO is relevant to the UK in part because X-energy and its partners have identified Hartlepool as a proposed location for an initial UK Xe-100 deployment [19]. The Xe-100 reactor is an advanced modular reactor, with the core made of graphite and filled with 15.5% enriched fuel pebbles [19]. These pebbles each contain thousands of TRISO fuel particles. The coating layers are designed to retain fission products under normal operating and specified accident conditions [20]. X-energy is developing TRISO-X fuel-fabrication capability in Oak Ridge, Tennessee [21], while future UK fuel-supply arrangements remain to be confirmed.

Reactor siting should also be distinguished from fuel fabrication. A proposed reactor location does not establish where its fuel will be manufactured. For any future UK deployment, reactor assessment, site licensing, environmental permitting and fuel qualification would need to mature on parallel schedules.

LEU+: a regulatory readiness case study

Low-enriched Uranium Plus (LEU+) is an industry term generally used for uranium enrichment levels above the conventional 5% light-water reactor range and up to approximately 10%. In the UK, it also

provides a practical intermediate step between established enrichment capability and the planned HALEU enrichment range [22].

In May 2026, Urenco announced that its Capenhurst site had successfully produced LEU+ during its first trial run after a Regulatory Readiness Review and subsequent permission from the Office for Nuclear Regulation (ONR) [23]. The LEU+ was sampled at 7%, which has now demonstrated Urenco's ability to produce LEU+ [23].

The ONR's April 2026 readiness inspection supported work to release the regulatory hold-point for Phase 1 of the LEU+ project. Urenco UK intended to implement a modification to enrich uranium-235 up to 7.5%, with the Phase 1 trial at 7% and a 0.5% safety margin [24]. The ONR completed a readiness inspection prior to the trial, making judgements against Licence Condition (LC) 10 for training, LC22 for Modification or Experiment on Existing Plant, and LC24 for operating instructions. Inspectors considered changes to relevant safety cases, preparations for commissioning tests and plans for filling the LEU+ demonstration cylinder. After the readiness inspection, ONR concluded that the site was ready to complete the LEU+ proof of concept trial and assigned green ratings across the sampled licence conditions [24].

The LEU+ trial demonstrates how regulatory readiness inspections and timely engagement with the regulator can support fuel innovation in practice. By considering the required safety case changes, operating arrangements and regulatory requirements before the trial began, the higher enrichment activity could proceed in a controlled and phased way. This provides a useful example of how regulatory readiness enabled a controlled Phase 1, although it does not quantify whether the approach reduced the overall project schedule or cost.

Early regulatory engagement as an accelerator

Early regulatory engagement can enable new nuclear technologies to progress by allowing regulatory considerations to be understood while designs and project plans are still developing. As discussed in the LEU+ example, early regulatory engagement can be seen as a mechanism to accelerate innovation in the nuclear industry.

In Great Britain, the ONR, the Environment Agency and Natural Resources Wales have provided an early engagement route in response to the government's ambition for new nuclear which has signalled an increased demand for engagement with regulators. The voluntary and flexible process allows reactor vendors, developers and prospective licence or permit holders to seek regulatory advice before entering more formal processes such as Generic Design Assessment, licensing and environmental permitting [25].

The process benefits both applicants and regulators. Developers can gain a clearer understanding of regulatory expectations, potential routes to deployment and the evidence required to support safety, security and environmental justifications. Regulators can develop an understanding of the proposed technologies for deployment, and the readiness of applicants to progress to more formal regulatory processes [25].

These principles are reflected in the ONR's 2026 Strategy which sets out a vision to become a "modern, agile and productive regulator enabling innovation and growth" whilst continuing to provide strong regulatory decision making [26]. The strategy promotes streamlined coordination between regulators, stronger collaboration with UK counterparts to reduce duplication across the nuclear lifecycle, and closer international cooperation. One of its objectives is to enable accelerated deployment of new reactors through appropriate recognition of regulatory assessments undertaken elsewhere, subject to due diligence and while retaining independent decision making. The ONR states that greater recognition of assessments could reduce the burden on applicants and reduce the time and cost associated with gaining design acceptance for deployment.

Early engagement is already being utilised across a range of nuclear technologies. As of 2026, the ONR lists five reactor developers participating in the process. Its application is also beginning to extend across the wider fuel cycle. For example, Quantum Leap Energy has entered the process for enrichment technology, while Framatome United Advanced Fuels Ltd is participating in relation to fuel fabrication. This demonstrates that early engagement is relevant not only to reactor deployment, but also to the development of new enrichment and fuel-fabrication capabilities [25].

Early engagement should therefore be understood not as a substitute for formal regulatory assessment but as a way of identifying potential regulatory issues earlier in development

Considering the full fuel lifecycle

Advanced fuel development must also consider how irradiated fuel will be stored, transported and eventually managed as many advanced reactor designs use or propose novel fuels, coolants and materials that may improve performance but could also generate new waste streams [27].

This issue was highlighted in the Committee on Radioactive Waste Management 2024 position paper on Development of Small Modular Reactors and Advanced Modular Reactors – Implications for the Management of Higher Activity Wastes and Spent Fuel [27]. The report argues that spent fuel and waste management uncertainties should be addressed when technologies are being selected for investment, development, construction and operation and that developers of new reactors must have a sufficient waste management capability [27].

As such, the UK government has stated that it is taking steps to ensure all reactor proposals demonstrate a viable waste management route through to disposal for all their spent fuels and waste arisings before the deployment of any new technology and that it remains committed to ensuring the responsible treatment, storage and disposal of any associated wastes and nuclear materials [28].

Early engagement with ONR, the Environment Agency and other regulators can help identify storage, transport and disposability requirements while reactor and fuel designs remain capable of change [25,27]. Regulatory readiness should therefore extend across the fuel cycle which must involve addressing the uncertainties about such management at an early stage, to avoid costly mistakes by designing reactors without sufficient consideration of how spent fuel and wastes would be managed.

CONCLUSION

The UK's advanced fuel opportunity is not defined by a single technology. It spans emerging LEU+ capability, planned HALEU production, coated-particle fuels such as TRISO and the arrangements needed to transport, use and manage these fuels across their lifecycle. The Capenhurst LEU+ trial provides a practical example of regulatory readiness, demonstrating how regulatory requirements can be addressed before a new capability is introduced.

Regulation can support fuel innovation when regulatory

requirements are considered alongside technology development. The ONR's wider early engagement approach and 2026 strategy demonstrate how earlier engagement, clearer expectations and greater coordination between regulators could reduce late redesign and programme uncertainty while strengthening confidence that safety and environmental considerations have been built into the technology from the outset.

This does not mean reducing regulatory scrutiny or replacing formal assessment, but considering safety, security, safeguards, transport, environmental and waste challenges from the outset. Regulation should therefore not be viewed as a barrier to innovation, but as a strategic lever through which the UK can unlock long-term growth and capability in its nuclear industry.

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