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BRIEFING PAPER

Number CBP 8176, 26 February 2021

New Nuclear Power

By Suzanna Hinson

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Contributing authors: Paul Bolton (statistics)

Summary

This paper summarises current developments in nuclear power, including conventional reactors, advanced designs, nuclear research and waste disposal. This paper does not seek to provide a detailed analysis of the possible merits and limitations of nuclear as a power source. It also does not discuss other uses of nuclear materials such as nuclear weapons or medical uses of radioisotopes.

Nuclear power plants in the UK

The UK has 15 existing reactors, generating about a fifth its electricity, and 13 others are at various stages of the construction or planning process.

In September 2016, the May Government gave the final go-ahead to Hinkley Point C, the first nuclear power station for a generation. The May Government also announced a Nuclear Sector Deal as part of the Government's Industrial Strategy, with £200 million to support the industry.

However in November 2018, the collapse of private sector support for a new plant at Moorside, and in January 2019 the suspension of the Hitachi project at Wylfa, cast doubt on the future of nuclear plants in the UK.

To address this, the Johnson Government has consulted on alternative financing models for new reactors and entered negotiations with developer EDF about a new nuclear plant at Sizewell.

Research and development

Successive Governments have been supportive of nuclear power, including funding for research and innovation into nuclear technologies. The Cameron Government announced initiatives and funding for advanced reactors, including £250 million for development. The May Government announced support for nuclear power in the Industrial Strategy as well as specific funding in areas such as small modular reactors. The Johnson Government has also announced support for advanced nuclear - including fusion technology - in the Ten Point Plan for a Green Industrial Revolution, and Energy White Paper.[1]

Waste management

Nuclear waste comprises many different products and can be split into categories from low to high level waste. The UK's policy for long-term high-level waste disposal is a deep geological disposal (GDF) facility. Despite a 2008 siting process for a facility ending in 2013 with no community willing to host the facility, successive Governments have remained committed to a GDF and the May Government published a new National Policy Statement on disposal. Until a suitable site is identified and the facility constructed, waste will continue to be stored at existing sites such as Sellafield.

[1] Put simply, fusion is a reaction where atomic nuclei are fused, rather than split as in fission. This type of reaction remains in research development rather than being commercially deployed as fission is.

1. Background

Following a focus on nuclear technology for defence after the Second World War, the UK announced support for a civil nuclear power programme in 1953. In 1956, the UK opened Calder Hall, a dual purpose nuclear power plant which supplied the first nuclear power for the National Grid (in addition to producing plutonium for military purposes).[2,3]

The UK then had a period of intense civil nuclear construction through the 1970s and 1980s with the last reactor at Sizewell completed in the UK in 1995.

Today the UK has fifteen reactors at eight plants,[4] able to supply about 21% of UK electricity demand.[5] The vast majority of these reactors are due to reach the end of their operating lives and be shut down before 2030 (following some life extensions) as the table below shows.[6]

Existing reactors in the UK

Location	Reactor type	Capacity (MWe)[7]	First power	Expected shutdown
Dungeness (B)	Advanced gas-cooled Reactor (AGR)	2 x 520	1983 &1985	2028
Hartlepool	Advanced gas-cooled Reactor (AGR)	595 & 585	1983 & 1984	2024
Heysham	Advanced gas-cooled Reactor (AGR)	580 & 575	1983 & 1984	2024
Heysham II	Advanced gas-cooled Reactor (AGR)	2 x 610	1988	2030
Hinkley Point (B)	Advanced gas-cooled Reactor (AGR)	475 & 470	1976	2023
Hunterston (B)	Advanced gas-cooled Reactor (AGR)	475 & 485	1976 &1977	2023
Torness	Advanced gas-cooled Reactor (AGR)	590 & 595	1988 & 1999	2030
Sizewell (B)	Pressurised Water Reactor (PWR)	1198	1995	2035

There are thirteen proposed new reactors at six different sites at various stages of the development process.[8] These six sites for new nuclear power are discussed in sections 3.1-6. Hinkley Point C was granted final approval in 2016 for two reactors, making it the first nuclear power plant under construction in the UK for 25 years.

Numerous factors have contributed to a decline in nuclear construction. The upfront cost of nuclear power can exceed that of other sources[9], leading to the need for subsidies or long contract settlements. The meltdown of Fukushima in 2011 contributed to weakening

2 World Nuclear Association, *Nuclear Development in the United Kingdom*, [accessed July 2020]
3 Kenneth Jay, Calder Hall, The Story of Britain's First Atomic Power Station, UKAEA, 1956
4 Not all reactors are operating at all times due to planned shutdowns.
5 When all reactors are operating. World Nuclear Association, *Nuclear Power in the United Kingdom*, February 2020
6 All information in the table is from World Nuclear Association, *Nuclear Power in the United Kingdom*, July 2020
7 Unit of power – megawatt equivalent.
8 Gov.uk, *Realising the vision for a new fleet of nuclear power stations*, 20 April 2016
9 National Audit Office, *Hinkley Point C*, 23 June 2017

global public support for nuclear power,[10] and a new series of safety measures[11] that added to costs and timescales. Also the accumulation of nuclear waste continues to draw criticism due to a lack of disposal solutions,[12] as some point to renewables such as wind and solar as a cleaner alternative.[13]

Nuclear power is also a politically controversial energy source. The Scottish National Party and Green Party do not support nuclear power, while the Conservatives and Labour do.[14] Some commentators have questioned the value for money of nuclear power, particularly the Hinkley C deal[15], following a fall in the cost of renewables such as offshore wind.[16] Data from the Government's Energy and Climate Change Public Attitudes Tracker (collected in the UK in March 2020) found that when asked whether or not they supported nuclear energy, 41% of respondents answered neutrally, 32% said they supported the prospect, and 23% opposed it.[17]

Supporters of nuclear power say it can provide reliable, baseload power,[18,19] bolster energy security,[20] provide industrial or domestic heat[21] and potentially reduce the legacy of nuclear waste produced by reactors and weapons through re-use as fuel (see Box 9).[22] Nuclear power is also a low-carbon power source, as the fission process produces no greenhouse gas emissions and the Intergovernmental Panel on Climate Change (IPCC) estimated (by combining reviews) that the average full lifecycle emissions of nuclear are below those of all fossil fuels and some renewables.[23,24]

Successive Governments[25,26,27,28] have supported nuclear power. Reactor designs have changed over time; from advanced gas cooled reactors, to pressurised water reactors, to European pressurised reactors (e.g Hinkley C) and other new advanced designs known as Generation III (see Box 1). The current and previous Conservative Governments have also been supportive of innovation, such as small modular reactors, fast reactors, molten salt reactors and other Generation IV designs.[29]

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10 Ed Crooks, *Public scepticism could turn off the nuclear reactors, Financial Times,* 23 November 2014
11 *Reuters*, *IAEA States back post-Fukushima nuclear safety plan*, 22 September 2011
12 Rob Broomby, *UK's plutonium stockpile dilemma*, *BBC,* 24 February 2013
13 Greenpeace, *Nuclear power is part of the problem,* 1 July 2016
14 Simon Evans, *Election 2019: What the manifestos say on energy and climate change*, *Carbon Brief,* 22 November 2019
15 Roger Harrabin, *Offshore wind power cheaper than new nuclear*, *BBC*, 11 September 2017
16 Gov.uk, *Contracts for Difference (CFD) Third Allocation Round Results*, 20 September 2019
17 4% answered "Don't know/no opinion". Gov.uk, *Energy and Climate Change Public Attitudes Tracker: Wave 33*, 7 May 2020
18 Baseload is the permanent minimum load that a power system is required to deliver. Historically baseload has been supplied by fossil fuels and nuclear which are sometimes described as "continuous power" (though all generators are prone to outages). For more information see the Library briefing paper on Electricity Grids (January 2019).
19 Nuclear Energy Institute, *Nuclear Energy's Unmatched Reliability*, 22 June 2014
20 Nuclear Energy Agency, *The security of energy supply and the contribution of nuclear energy*, 2010
21 International Atomic Energy Agency, *Industrial Applications and Nuclear Cogeneration* [accessed July 2020]
22 World Nuclear Association, *Military Warheads as a source of nuclear fuel*, February 2017
23 IPCC, *Working Group III Contribution to the IPCC Fifth Assessment Report, Annex III- Technology Specific Cost and Performance Parameters,* 2014, Table A.11.2 (p. 1335)
24 IPCC, *Renewable Energy Sources and Climate Change Mitigation. Summary for policy makers and technical summary*, 2012, Figure SPM.8 (p.19) and Table A.II.4 (p.190)
25 Deborah Summers and Andrew Sparrow, *Gordon Brown unveils economic measures to prepare UK for downturn*, *The Guardian,* 19 December 2008
26 Gov.uk, *Long-term Nuclear Energy Strategy*, 26 March 2013
27 Gov.uk, *Realising the vision of a new fleet of nuclear power stations*, 20 April 2016
28 Our Plan, *Conservative Manifesto* 2019
29 Gov.uk, *Funding for nuclear innovation* (updated 8 January 2020)

Box 1: Nuclear Generations

Generation is a term used to group types of nuclear reactor based on how advanced they are. Generation I includes Magnox reactors, Generation II describes the reactors in the UK's current fleet, and Generation III including the European Pressurised Reactor (Hinkley Point C), the AP100 and ABWR (more advanced versions of these reactors are known as Generation III+). Generation IV reactors are currently mostly in a research phase and can have advanced safety, efficiency, fuel and waste features.

The energy mix in the UK is changing. The Government has committed to phasing out unabated coal[30] by 2025 at the latest[31,32] meaning new energy generation is required. The Government also has a series of decarbonisation targets; in June 2019, the May Government amended the *Climate Change Act 2008* to include a new net zero greenhouse gas emissions target by 2050 (relative to 1990 levels).[33] As energy supply is decarbonised, there is a need to secure sufficient supply on an electricity grid which will include more intermittent renewables. Though batteries, demand side response and smart grids will help balance the new energy system[34], some policy makers argue that nuclear power should also be part of a diverse future mix of power sources.[35]

30 Meaning coal burnt for power generation without carbon capture usage and storage technology.
31 Gov.uk, *Coal generation in Great Britain: The pathway to a low-carbon future,* 13 November 2016
32 The Johnson Government is consulting on bringing the deadline forward one year to 2024. See Gov.uk, *End of coal power to be brought forward in drive towards net zero*, 4 February 2020
33 Commons Library, *Legislating for net zero*, 27 June 2019
34 For more information and commentary, see the Library briefing paper on Electricity Grids (January 2019)
35 HL Deb 26 January 2017 vol 778 c779

2. Nuclear Power Policy

2.1 History of support

After a period without construction following the completion of Sizewell B in 1995, the then Prime Minister Tony Blair said in a speech to the Confederation of British Industry (CBI) in 2006 that the Government would again pursue new nuclear power:

> The facts are stark. By 2025, if current policy is unchanged there will be a dramatic gap on our targets to reduce CO_2 emissions, we will become heavily dependent on gas and at the same time move from being 80% to 90% self-reliant in gas to 80% to 90% dependent on foreign imports, mostly from the Middle East, and Africa and Russia.
>
> These facts put the replacement of nuclear power stations, a big push on renewables and a step change on energy efficiency, engaging both business and consumers, back on the agenda with a vengeance. If we don't take these long-term decisions now we will be committing a serious dereliction of our duty to the future of this country.[36]

In July 2006, the Labour Government published 'The Energy Challenge Review', saying there was no single energy solution and calling for new nuclear to be included with a wider push for renewables and energy efficiency to achieve a low-carbon, secure, and affordable supply of energy, together known as the energy trilemma.[37]

Following a consultation, the Labour Government under Prime Minister Gordon Brown, released a White Paper on Nuclear Power saying the Government would take active steps to open up the way to the construction of new nuclear power stations.[38]

In 2009, the Brown Government published a list of possible nuclear sites.[39] The 2011 National Policy Statement (which sets out the policy framework that planning decisions on infrastructure should follow),[40] published by the Coalition Government, built on this and identified eight sites suitable for new nuclear reactors. Of these, six are in some stage of planning or development for a new nuclear power station.[41] A range of possible reactors are being considered as shown in the table in Section 3.[42] All of these proposed reactors are classed as Generation III or Generation III+ reactors (see Box 1).

Conservative Governments from 2015 have continued to support new nuclear. The final go ahead for Hinkley Point C was given by the May Government in 2016. In December 2020, the current Johnson Government set out in the Energy White Paper an aim to "bring at least one large scale nuclear project to the point of Final Investment Decision by the end of this Parliament, subject to clear value for money and all relevant approvals."[43] Successive Governments have also supported nuclear research, as set out in section 4.

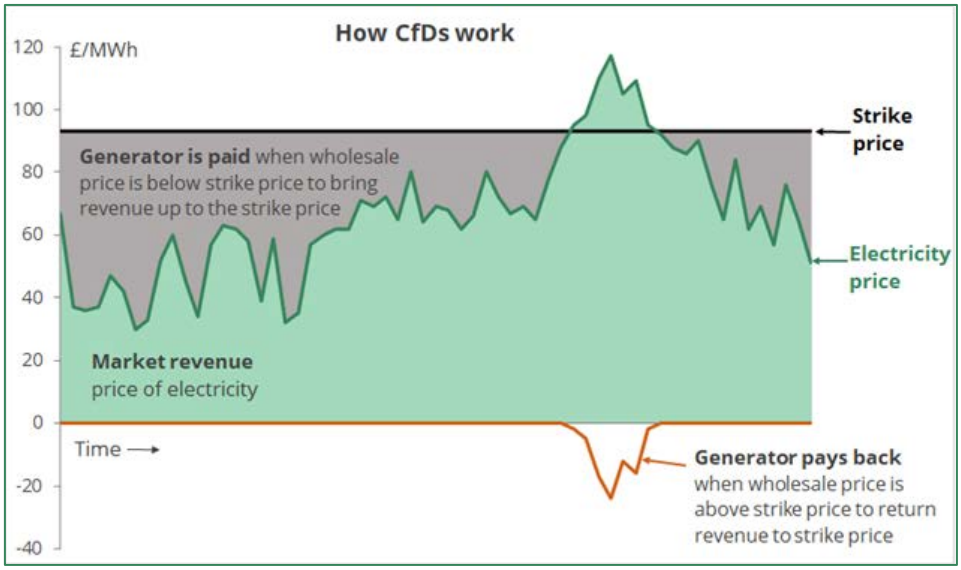
2.2 Funding new nuclear power

Hinkley C funding model: strike prices

At present, UK nuclear power stations are privately built and owned. Developers, such as EDF in the case of Hinkley, build the power plants and operate them. To ensure a return

36 The National Archives, *Speech at the CBI annual dinner*, 16 May 2006
37 HM Government, *The Energy Challenge*, Energy Review, July 2006
38 HM Government, *A White Paper on Nuclear Power*, January 2008
39 Department of Energy and Climate Change, *Towards a nuclear national Policy Statement*, January 2009
40 Department for Energy and Climate Change, *New Nuclear Sites/National Policy Statement*, 19 July 2011
41 World Nuclear Association, *Nuclear Power in the United Kingdom*, February 2020
42 All information in the table is from World Nuclear Association, *Nuclear Power in the United Kingdom*, February 2020
43 HM Government, *Energy White Paper: powering our net zero future*, December 2020

on the investment, the Government negotiates with the developer a contract for difference (or CfD) which includes a "strike price". This is a set price for electricity produced by the finished power station, confirmed for a certain number of years. The developer is guaranteed this price, so if the market rate[44] for power is below the strike price, the developer is paid an effective top-up. These top-up payments are ultimately passed on to consumer electricity bills. However, if the market price exceeds the strike price the developer must pay back the difference meaning customers are protected from overpayment. This system of payment and repayment relative to the market rate to ensure a fixed return is shown in the figure below.



More information on CfDs is available in the Library briefing paper on Support for low carbon power (April 2020).

Hinkley Point C was given final approval by the May Government on 15 September 2016 with a strike price of £92.50/MWh (see section 3.1 for details).[45] A number of reports from the National Audit Office[46] and Public Accounts Committee have said that there is a strategic case for nuclear but the Hinkley deal is poor value for money for consumers as the price, fixed for 35 years, is seen as "locking" customers into paying a higher price than that offered by other technologies.[47]

Proposed funding model: RAB model

In October 2017, it was reported that Richard Harrington, the then Parliamentary Under Secretary of State for the Department of Business Energy and Industrial Strategy (BEIS), said that nuclear was necessary but that a finance model like Hinkley was "unlikely" to be used again and that a "third model" existed between private and public funding.[48]

On 4 June 2018, the then Secretary of State for BEIS Greg Clark said in a statement about Wylfa that the then May Government was "reviewing the viability of a regulated asset base (RAB) model" that could "deliver the Government's objectives of value for money,

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44 Strike prices are only available for certain low carbon developments such as nuclear; all other energy generators are paid the market rate

45 Gov.uk, *Government confirms Hinkley Point C project following new agreement in principle with EDF*, 15 September 2016

46 National Audit Office, *Hinkley Point C*, 23 June 2017

47 House of Commons, Public Accounts Committee, Third report of session 2017-19, *Hinkley Point C*, 22 November 2017

48 Jilian Ambrose, *Government to rethink Hinkley Point Funding model for future projects*, *Telegraph*, 3 October 2017

fiscal responsibility and decarbonisation".[49] On 22 July 2019, the May Government published a consultation on a RAB model of funding for new nuclear power projects (see Box 2) which stated:

> Our assessment has concluded that, by providing regulated returns to investors, a RAB model has the potential to reduce the cost of raising private finance for new nuclear projects, thereby reducing consumer bills and maximizing value for money for consumers and taxpayers.[50]

The consultation sought views on how a RAB model could be implemented for new nuclear; it closed on 14 October 2019.

In December 2020, the Johnson Government published the response to the consultation. This reiterated the Government's support for new nuclear, and set out how the Government will continue to explore RAB and other financing options to deliver new nuclear:

> 100. Having assessed the consultation responses, including the broad agreement from industry and those members of the public who were not in-principle opposed to nuclear to our proposals, we believe that a RAB in line with the high-level design principles set out in the consultation remains a credible basis for financing large-scale nuclear projects.
>
> 101. In particular, it is clear that if any model is to attract private financing it will likely require:
>
> - A variable £/MWh price allowing for the revenue stream to be adjusted by the Regulator as circumstances change.
> - An Allowed Revenue during construction to reduce the scale and cost of financing, increasing deliverability and reducing total cost to suppliers and consumers.
> - Some level of risk sharing between investors and consumers / taxpayers.
>
> 102. Following the consultation, Government will continue to explore a range of financing options with developers, including RAB. As noted in the consultation, raising the capital required for a new nuclear project is likely to be challenging given the significant investment commitment needed for a new nuclear project developer to reach a FID. Alongside considering the RAB model we will also continue to consider the potential role of government finance during construction, aligning with suggestions from some of the consultation responses, provided that there is clear value for money for consumers and taxpayers and subject to all relevant approvals.[51]

Box 2: What is a Regulated Asset Base (RAB) model?

A Regulated Asset Based (RAB) model is a way of financing new infrastructure. It is already used in some UK industries (generally for monopolies) for example the gas and electricity networks owners and operators, under a model known as RIIO (Revenue = Incentives + Innovation + Outputs). Under RIIO, the energy regulator (Ofgem) sets a price the network companies can charge for the use of their grid infrastructure over a set time period. Ofgem can increase or decrease this price, to reflect issues like the need for extra investment in the infrastructure. The price that networks can charge for their infrastructure is ultimately passed on by suppliers to energy consumer bills[52] (more information on RIIO is available in the Library briefing paper on Electricity grids section 1.2).

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49 HC Deb, 4 June 2018, Vol 642, c76-77
50 Gov.uk, *Regulated Asset Base (RAB) model for nuclear*, 14 December 2020
51 Gov.uk, *Regulated Asset Base (RAB) model for nuclear*, 14 December 2020
52 Under the competitive energy market, suppliers can set their own tariffs, and customers can switch supplier to get better deals. More information on what makes up an energy bill is available in the Library briefing paper on Energy bills and tariff caps (August 2019)

The RAB model for nuclear could operate in a similar way but differ in that energy consumers would be charged for the use of the infrastructure while it was being built, i.e. before they can use and benefit from it. RAB models are already in use in the UK for single construction projects, such as the Thames Tideway Tunnel Sewerage project.

For nuclear, the proposed model would involve an independent regulator setting a price which a developer can then charge to users for the provision of the company's infrastructure, such as a new nuclear power plant. Energy suppliers would be the infrastructure users who would be charged for the nuclear plant, and the suppliers could pass the charge on to their customers through their electricity bills (as with RIIO and strike prices). The charge would be applied to energy customer bills during construction of a plant and during its operational life. The exact level of the charge, and duration that it is charged, may vary over the plant's lifetime, and between projects. The Government's consultation on a RAB model for nuclear set out these key features of the model:

a) Government protection for investors and consumers against specific remote, low probability but high impact risk events, through a Government Support Package (GSP);
b) A fair sharing of costs and risks between consumers and investors, set out in an Economic Regulatory Regime (ERR);
c) An economic regulator (the 'Regulator') to operate the ERR; and
d) A route for funding to be raised from energy suppliers to support new nuclear projects, with the amount set through the ERR, during both the construction and operational phases (the 'Revenue Stream').

Because under a RAB model consumers are required to pay for the infrastructure while it is being built, consumers are at risk from cost-overruns and delays to construction, which have been common in recent examples of nuclear construction in Europe and the USA. Strike prices do not include this risk, as customers do not start paying for the plant until it is generating so the risks of increasing costs and delays during construction fall on the developer. Instead, the RAB model gives developers a guaranteed return from the start of the project. The aim of this is to lower their risk and the cost of borrowing money, making investment more attractive.

In response to the consultation, some raised concerns about the risk of higher costs to consumers: Doug Parr of the environmental charity Greenpeace reportedly said the model "simply shifts the liability for something going wrong from nuclear firms to consumers".[53] Nick Butler in the Financial Times said while the system works well for industries such as water with proven technologies and low risks, for new nuclear it is "far from convincing" due to the high construction risks.[54] However the industry trade body, the Nuclear Industry Association (NIA), said in a statement that as the RAB model promises to reduce the total cost of building new nuclear power, the cost passed on to consumers could also be reduced.[55]

The International Atomic Energy Agency 2008 report on 'Financing of New Nuclear Power Plants'[56] argues there are a number of ways to finance nuclear power and a World Nuclear News article entitled 'Innovative ways of funding nuclear power projects'[57], describes various types of funding used around the world, all of which have an element of state support.

53 Madeleine Cuff, *'Action across all areas': Government releases flurry of new plans for nuclear, smart grids and CCS*, *Business Green*, 23 July 2019
54 Nick Butler, *How can we pay for new nuclear power stations?*, *Financial Times,* 9 September 2019
55 NIA, *NIA responds to the publication of the consultation on the RAB model for nuclear*, 22 July 2019
56 International Atomic Energy Agency, *Financing of New Nuclear Power Plants*, September 2008
57 Fiona Reilly, *Innovative ways of funding nuclear power projects*, *World Nuclear News,* 18 February 2016

3. Potential new plants

The Coalition Government's 2011 National Policy statement (NPS)[58] identified eight sites suitable for new nuclear reactors by the end of 2025, of which six are in some stage of planning or development. A new NPS is expected; the Government has stated its intention is to carry forward existing sites into the new NPS subject to them meeting updated criteria and environmental assessments.[59]

Planned reactors in the UK (Generation III and III+)[60]

Location	Reactor type	Capacity (MWe)	Developer	Planned completion date	Progress	Estimated cost
Hinkley Point	European Pressurised Reactor	2 x 1630[61]	EDF and China General Nuclear (CGN)	2025 (risk of 9-15 months delayed delivery)	Under construction	£21.5 – 22.5 bn (Original estimate £18bn)[62]
Sizewell	European Pressurised Reactor	2 x 1630	EDF and CGN	2031 (reported suggestion)[63]	Financing negotiations ongoing	Estimated at £20 bn[64]
Moorside	AP1000 or APR14000	3 x 1200	NuGen (Toshiba and Kepco)	Unknown	No developer - Toshiba pulled out in 2018.	Unknown
Wylfa Newydd	Advanced Boiling Water Reactor	2 x 1380	Horizon nuclear power	Unknown	On hold since January 2019. New 'Clean Energy Hub' planned.	Reported to be £15 billion[65]
Oldbury	Advanced Boiling Water Reactor	2 x 1380	Horizon nuclear power	Unknown	On hold since January 2019. Intended to follow Wylfa.	Unknown
Bradwell	Hualong One	2 x 1150	CGN and EDF	Early 2030s (reported suggestion)[66]	Generic Design Assessment in progress	Unknown

58 Department for Energy and Climate Change, *New Nuclear Sites/National Policy Statement*, 19 July 2011
59 Gov.uk, *Government to support development of next-generation nuclear technology*, 7 December 2017
60 Table source: World Nuclear Association, *Nuclear Power in the United Kingdom*, February 2020
61 The Government say Hinkley will power 6 million homes: Gov.uk, *Hinkley Point C to power six million UK homes*, 21 October 2015
62 EDF, *Update on Hinkley Point C project*, 25 September 2019 (2015 prices)
63 Oleg Vukmanovic, *EDF sees UK Hinkley C nuclear plant online by end of 2025,* *Reuters,* 17 January 2018
64 The Sizewell C Project, Funding Statement, May 2020
65 Emily Gosden, *Wylfa nuclear plant would be funded by taxpayers, admits minister*, *The Times*, 5 June 2018
66 Susanna Twidale, *China to help plug UK nuclear power gap as Japanese plans falter*, *Reuters,* 17 January 2019

Box 3: The Office for Nuclear Regulation

The Office for Nuclear Regulation (ONR) is a statutory independent organisation responsible for regulation of nuclear safety and security across the UK. One of the key roles of the ONR is to approve new reactor designs for construction in the UK. This process is known as a Generic Design Assessment (GDA) and is undertaken in collaboration with the Environment Agency. A GDA involves a technical assessment of the design and usually takes four years to complete. GDAs are paid for by the developer. There are other permissions, such as site licensing, environmental permits and planning consent that are required before a nuclear power plant can begin construction. Further information on the regulatory process is available in the Environment Agency's and ONR's 2013 document 'A guide to the Regulatory Process'. As nationally significant infrastructure projects, nuclear power plant's planning permission is granted by the Secretary of State following guidance from the Planning Inspectorate.

3.1 Hinkley Point C

Box 4: The European Pressurised Reactor (EPR)

The EPR is a Generation III pressurised water reactor designed by Areva NP and EDF energy.[67] In addition to the UK, there are EPR units under construction in Finland and France, and recently completed units in China, though all have been experienced delays or delivery behind schedule. The EPR completed the Office for Nuclear Regulation's Generic Design Assessment (GDA) in December 2012, allowing it to be built in the UK.[68]

Hinkley Point in Somerset is already the site of a decommissioned Magnox reactor (Hinkley Point A) and an operating advanced gas cooled reactor (Hinkley Point B). The site was included as one of eight identified for new development by the Government's NPS in 2011. It was granted a license in 2012 from the ONR[69] and the intention of developers EDF and China General Nuclear (CGN) is to build two EPR units (see Box 4) with a total output of 3.2GW.[70] Although it is now under construction, there have been a number of setbacks for the Hinkley Point C project.

In December 2013, the European Commission opened an investigation to assess whether the project broke state aid rules. The Commission subsequently approved the project in 2014, but in June 2015, the Austrian government filed a legal complaint with the European Commission on state subsidies.[71] In July 2018, the General Court of the European Union dismissed the action brought by Austria.[72]

The United Nations Economic and Social Council, under the Convention on Environmental Impact Assessment in a Transboundary Context also expressed concern that the UK had failed to fully consult neighboring countries on the project.[73] The UK indicated that it

67 Areva & EDF, *UK EPR Generic Design Assessment* [accessed July 2020]
68 ONR, *UK regulators confirm acceptance of new nuclear reactor design*, 13 December 2012
69 ONR, *ONR grants nuclear site license for new UK power station*, 26 November 2012
70 PQ HL2607 [Hinkley Point C power Station] 2 November 2017
71 Agence France-Presse, *Austria files legal complaint against UK's Hinkley Point C nuclear plant*, *The Guardian*, 6 July 2015
72 General Court of the European Union, Press release no104/18, The General Court confirms the decision by which the Commission approved the aid provided by the UK in favour of the Hinkley Point C nuclear power station, 12 July 2018
73 United Nations Economic and Social Council, *Meeting of the Parties to the Convention on Environmental Impact Assessment in a Transboundary Context*, 26 November 2018

would in future notify the relevant Parties for all future nuclear power plant development applications.[74]

Original construction was planned to be completed by 2023. However in 2015, EDF announced that this target would not be met and delayed a final investment decision.[75] This decision was delayed again in early 2016.[76]

On the 28 July 2016, the EDF board approved the project but on the same day the Secretary of State for Business, Energy and Industrial Strategy announced that the Government, under the then new Prime Minister Theresa May, was delaying its final decision.[77] On 15 September 2016, the May government gave final approval to the project.[78]

The plant, with an original projected completion date of 2025 and lifetime of sixty years, had an original estimated construction cost of £18 billion and a strike price for the power it produces of £92.50/MWh for 35 years.[79] The construction is two thirds funded by EDF and a third by Chinese state-owned company CGN. The agreement between EDF and CGN covers cooperation on the Hinkley, Sizewell and Bradwell projects. In September 2015, the then Chancellor George Osbourne announced a £2 billion government loan guarantee for the Hinkley project financing.[80][81]

The deal has been criticised by the National Audit Office amongst others for locking the UK into high energy costs.[82] The Public Accounts Committee published a report on Hinkley Point C on 22 November 2017. They argued that the financial case for Hinkley had weakened over time, the deal locked consumers into long term costs, and that the Government needed to clearly set out the long-term plans for achieving wider benefits.[83]

Project updates

In July 2017, EDF said that "project completion costs are now estimated at £19.6 billion (in 2015 sterling) an increase of £1.5 billion". The reasons for the cost increase were listed as "better understanding of the design adapted to the requirements of the British regulators, the volume and sequencing of work on site and the gradual implementation of supplier contracts". EDF also said that the risk of deferral of delivery was estimated at around 15 months for Unit 1 and 9 months for Unit 2; such a delay could add a further £0.7 billion (in 2015 prices) to the final cost.[84]

In September 2019, EDF announced another increase in the total project completion cost to between £21.5bn and £22.5 billion; an increase of £1.9 to £2.9 billion (in 2015 sterling). The reasons listed for this increase were "challenging ground conditions which

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74 United Nations, Economic and Social Council, *Report of the Implementation Committee on its thirty-eighth session*, 18 May 2017
75 Michael Stothard and Christopher Adams, *EDF delays investment decision on UK nuclear reactor plans*, *Financial Times*, 12 February 2015
76 Emily Gosden, *Hinkley Point go-ahead delayed amid EDF funding doubts*, *The Telegraph,* 26 January 2016
77 Graham Ruddick and Jamie Grieson, *Hinkley Point C in doubt after British government delays approval*, *The Guardian,* 29 July 2016
78 Gov.uk. *Government confirms Hinkley Point C project following new agreement in principle with EDF*, 15 September 2016
79 Gov.uk, *Government confirms Hinkley Point C project following new agreement in principle with EDF*, 15 September 2016
80 The Government are not providing a loan, rather they have guaranteed that the tax-payer will pay back up to £2billion of loans from commercial advisors, should the developers become bankrupt.
81 Gov.uk, *£2 billion support for Hinkley Point*, 21 September 2015
82 National Audit Office, *Hinkley Point C*, 23 June 2017
83 House of Commons, Public Accounts Committee, Third report of session 2017-19, *Hinkley Point C*, 22 November 2017
84 EDF, *Clarifications on Hinkley Point C project*, 3 July 2017

made earthworks more expensive than anticipated, revised action plan targets and extra costs needed to implement the completed functional design, which has been adapted for a first-of-a-kind application in the UK context." EDF also said the risk of a delay to delivery (by 15 months for Unit 1 and 9 months for Unit 2) had increased.[85]

In January 2021, EDF published a further project update including the impact of Covid-19 on delivery. EDF stated the project had made good progress, but that a review of the impact of the pandemic on the schedule and cost had concluded[86]:

- The start of electricity generation from Unit 1 is now expected in June 2026, compared to end-2025 as initially announced in 2016.
- The project completion costs had increased and are now estimated in the range of £22 to 23bn (in 2015 prices – compared to an original projected cost of £18bn).
- The risk of delay of Units 1 and 2 is unchanged at respectively 15 and 9 months.

3.2 Sizewell C

The Sizewell nuclear site in Suffolk already has one pressurised water reactor (Sizewell B - due to close in 2035)[87] and two Magnox reactors currently being decommissioned (Sizewell A). EDF is developing the project and plan to build a further two EPR units (see Box 4) with a total capacity of 3.2 GW[88] in a new power station: Sizewell C.

EDF began their first stage of consultation in 2013, and completed four stages.[89] On 27 May 2020, an application for a Development Consent Order for the project was submitted to the Planning Inspectorate.[90] EDF said in a press release that the application had been deferred by 2 months due to the Coronavirus pandemic. The release also sets out some advantages of the project, such as jobs created and value for UK companies. The Planning Inspectorate accepted the application for examination on 24 June 2020.[91] Further information, including documents and updates, are published on the Planning Inspectorate's website. These include a funding statement, putting the price of the project at £20 billion.[92] The Government will make the final decision on the project once the Planning Inspectorate has completed the process. On 30 June 2020, EDF also applied to ONR for a site licence. ONR said it does not expect to reach a decision until at least the end of 2021.[93]

In December 2020, the Government announced that it would enter negotiations with EDF in relation to Sizewell C.[94] The announcement came alongside the publication of the Government's Energy White Paper which included an aim to "bring at least one large scale nuclear project to the point of Final Investment Decision by the end of this Parliament, subject to clear value for money and all relevant approvals."[95] In response to the announcement, EDF said in a statement that "The time for action is now and we look forward to working with the Government to implement its energy and climate policies, including the financing of new nuclear."[96]

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85 EDF, *Update on Hinkley Point C project*, 25 September 2019
86 EDF, *Hinkley Point C project update*, 27 January 2021
87 EDF energy, *Sizewell B power station* [accessed July 2020]
88 PQ 12499 [Nuclear power stations: construction] 19 October 2015
89 EDF energy, Sizewell C proposals [accessed July 2020]
90 EDF, *Sizewell C submits planning application*, 27 May 2020
91 National Infrastructure Planning, *The Sizewell C Project* [accessed July 2020]
92 The Sizewell C Project, Funding Statement, May 2020
93 ONR, *New nuclear site licence application for Sizewell C*, 30 June 2020
94 HCWS642, *Business Update*, 14 December 2020
95 HM Government, *Energy White Paper: powering our net zero future*, December 2020
96 EDF, EDF's response to Government plans to enter into negotiations on Sizewell C, 14 December 2020

Under the strike price funding model, it has been reported that the Hinkley Point C strike price could fall to £89.50/MWh (from £92.50) if a new plant at Sizewell C is also approved.[97] This is due to intended increased efficiencies in development and testing across the two reactors.

3.3 Moorside

Box 5: The AP1000 reactor

The AP1000 is a Pressurised Water Reactor, a type of light water reactor. The reactor is supplied by Westinghouse Electrical Company, an American company majority owned by Toshiba. Four units have been completed in China and were operating by January 2019.[98] A further two units are under construction in the USA, though two have been cancelled due to cost concerns[99], whilst six are reportedly planned in India[100]. The AP1000's GDA was completed in the UK in March 2017.

NuGen, the company which had intended to develop Moorside, was previously formed of a joint venture between Toshiba and ENGIE (formerly GDF SUEZ). The consortium planned to build three AP100 units (see Box 5) at Moorside near Sellafield in Cumbria with a total output of 3.6 GW.[101] The future of this and all other AP1000 projects was called into question in 2017 due to the financial issues of Toshiba. Westinghouse Electric, who designed the AP1000 and are owned by Toshiba, filed for bankruptcy in March 2017. As a result ENGIE sold its 40% share in NuGen to Toshiba. As the now sole owner of NuGen, Toshiba announced its intention to sell stakes in the Moorside project or pull out all together.[102]

Two potential bidders for stakes in Moorside came forward: the majority state owned Korean Electric Power Corporation (Kepco) and CGN of China which is already involved in Hinkley C, Bradwell and Sizewell C[103]. Kepco was reported to be the preferred bidder due to its track record of building reactors in the United Arab Emirates on time and on budget.[104] In December 2017, the media reported that a provisional deal had been reached between Toshiba and Kepco. However, Kepco stated that it would want to build its own reactor, an APR1400, which would require a new Generic Design Assessment (GDA – see Box 3) meaning the project would be delayed.[105]

In a speech to the 2017 Nuclear Industry Association Conference, the then Parliamentary under Secretary of State for BEIS Richard Harrington welcomed the potential agreement:

> We want to build on the momentum created by Hinkley and we continue to work closely with EDF, CGN, Horizon and Nugen on their proposals for future plants. I also

97 National Audit Office, *Hinkley Point C*, 23 June 2017
98 World Nuclear News, *Fourth Chinese AP100 enters commercial operation*, 9 January 2019
99 Brad Plumer, U.S. *Nuclear comeback stalls as two reactors are abandoned*, *New York Times*, 31 July 2017
100 *Reuters, U.S and India commit to building six nuclear power plants*, 13 March 2019
101 PQ 12499 [Nuclear power stations: construction] 19 October 2015
102 Bradley Gerrard, *Toshiba considers sale of Moorside nuclear project in Cumbria as own survival in doubt in wake of £7bn losses*, *The Telegraph*, 11 April 2017
103 Andrew Ward and Jim Pickard, *UK Government to bolster support for nuclear power*, *Financial Times,* 3 December 2017
104 Adam Vaughan, *Korean energy firm rescues UK's Moorside nuclear power project*, *The Guardian,* 6 December 2017
105 Jillian Ambrose, *Kepco confirms talks with Toshiba over UK nuclear — but only with its own reactors*, *The Telegraph*, 28 June 2017

> welcome the news that Toshiba has selected a preferred bidder for the Nugen project, and we now look forward to continuing to work with KEPCO to discuss their plans.[106]

On 8 November 2018, Toshiba announced that it would "take steps to wind up NuGen" and "withdraw from nuclear power plant construction project in the UK". The press release stated the reason for the closure was that Toshiba did not anticipate being able to complete the sale of NuGen and was concerned about the costs of continuing to operate NuGen.[107]

A spokesperson for the Government is reported to have said:

> We understand that Toshiba have faced a difficult decision in ending their involvement in new nuclear projects outside of Japan in light of their well-known financial challenges.
>
> All proposed new nuclear projects in the UK are led by private sector developers and while the government has engaged regularly with the companies involved, this is entirely a commercial decision for Toshiba.[108]

The Nuclear Industry Association (the industry trade body) said the development was "sad news for all those involved in the project and for the nuclear sector" and said it was vital that the Government facilitated new nuclear on the site "for the sake of the energy security of the UK and the local economy in Cumbria".[109] However some other energy industry commentators have suggested the development could be seen as an "opportunity" to pursue other technologies such as renewables.[110]

In July 2020, it was reported that a consortium of businesses is developing plans for a Clean Energy Hub at the Moorside site in Cumbria. The reports state that the plans include a new EPR reactor (the same as at the Hinkley and Sizewell projects) and advanced module reactors.[111] More information on the proposals is available in a brochure from the Moorside Clean Energy Hub.

3.4 Wylfa Newydd

Box 6: The Advanced Boiling Water Reactor (ABWR)

The ABWR is a Generation III boiling reactor, also a type of light water reactor. There are four operating units in Japan which were completed on time and under budget.[112] More were under construction in Japan and Taiwan but progress has been suspended. Two reactors have been proposed in the USA. The ABWR reactor completed the UK GDA process in December 2017.[113]

106 Gov.uk, *Nuclear Industry Association (NIA) annual conference 2017*, 7 December 2017
107 Toshiba Cooperation, *Toshiba to take steps to wind up Nu-Generation, withdraw from Nuclear Power Plant construction project in UK, and to record of loss on valuation of stock subsidiaries and affiliated (non-consolidated)*, 8 November 2018
108 Adam Vaughan, *UK nuclear power station plans scrapped as Toshiba pulls out*, *The Guardian,* 8 November 2018
109 Nuclear Industry Association, *NIA respond to Toshiba's decision to wind-up NuGen*, 8 November 2018
110 Priyanka Shrestha, *Toshiba pulls out of UK nuclear power venture*, *Energy Live News,* 8 November 2018
111 BBC news, *Moorside: Nuclear power schemes proposed for Cumbria site*, 1 July 2020
112 Hitachi News Release, *Hitachi-GE's UK ABWR takes a further step forward in GDA*, 30 October 2015
113 ONR, *Regulators approve new nuclear power station design*, 14 December 2017

Horizon Nuclear Power planned to build two ABWRs (see Box 6) with a total capacity of 2.7GW[114] next to the existing site at Wylfa on Anglesey in Wales, which has two closed Magnox reactors.

Horizon is a British Company and was originally an E.ON and RWE joint venture but was bought by the Japanese company Hitachi in 2012. Horizon previously stated that its aim was to have all permissions for Wylfa in place by 2018 so that construction could begin in 2019, though the project has since been suspended (see below).[115] There was also the possibility of Korean involvement in Wylfa as well as Moorside. State owned company Korea Hydro and Nuclear Power (KHNP) had been reported as potential investors in the plant.[116]

In July 2016, the House of Commons Welsh Affairs Committee published a report which examined 'The future of nuclear power in Wales'. The report recommended, amongst other things, that nuclear should be supported but not at any cost and therefore the Government should negotiate a strike price for Wylfa below that of Hinkley Point C and competitive with renewables sources.[117]

The then Government's response, published in October 2016, expressed support for nuclear and said it was too early to say what the cost of Wylfa would be as the proposal was still in the planning stages.[118]

In December 2017, a *Times* article reported that Horizon could stop funding the Wylfa plant by the middle of 2018 if they did not agree a viable financial support package from the Government. According to the article, Japanese owned Horizon had already spent £2 billion on the project and were in talks with the UK and Japanese Governments about direct state funding but would not continue "throwing a bottomless pit of cash at a project without some certainty it can get to a successful conclusion".[119]

On 4 June 2018, the then Secretary of State Greg Clark said in a statement that the Government was considering direct investment in the project:

> Both the National Audit Office and the Public Accounts Committee have recommended that the Government consider variations from the Hinkley Point C financing model [contracts for difference] in order to reduce costs to consumers. In line with the NAO and PAC's clear findings and recommendations, for this project the Government will be considering direct investment alongside Hitachi, Japanese Government agencies and other parties.[120]

However, Mr Clark said it was the Government's objective 'in the longer term' for nuclear projects to be financed by the private sector:

> It remains the Government's objective in the longer term that new nuclear projects, like other energy infrastructure, should be financed by the private sector. Alongside our discussions with developers, we will be reviewing the viability of a regulated asset base model as a sustainable funding model, based on private finance for future projects beyond Wylfa, that could deliver the Government's objectives of value for money, fiscal responsibility and decarbonisation.[121]

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114 PQ 12499 [Nuclear power stations: construction] 19 October 2015
115 World Nuclear News, *Attracting investors to new nuclear projects in the UK*, 4 May 2016
116 John Collingridge, *Koreans target £10bn Welsh nuclear plant*, *The Times*, 23 July 2017
117 House of Commons Welsh Affairs Committee, *The future of nuclear power in Wales*, Second report of session 2016-17, 19 July 2016
118 House of Commons Welsh Affairs Committee, *The Future of nuclear power in Wales: Government response to the Committee's Second Report of Session 2016-17*, 17 October 2016
119 Emily Gosden, *Hitachi will stop Anglesey nuclear plant funds without deal.* *The Times*, 8 December 2017
120 HC Deb, 4 June 2018, Vol 642, c76-77
121 HC Deb, 4 June 2018, Vol 642, c76-77

Although the statement did not mention a strike price, press reports at the time suggested it could be £15 below the £92.50 per megawatt hour that was negotiated for Hinkley Point C.[122] The lower price would be due to the Government investment in the project.

However, on 17 January 2019, Hitachi announced they would suspend their UK nuclear power station projects:

> Hitachi has held detailed discussions with the UK Government over various options about how the UK Government might support the project including potential for equity and debt investments. The parties, with the cooperation of the Japanese Government, have held discussions in good faith in regard to the financial structure for the project and various conditions for the building and operation of the nuclear power station.
>
> Since the acquisition of HNP, Hitachi has set the following three points as the main criteria for business continuation and reviewed the Horizon Project from the viewpoint of its economic rationality: (1) securing reasonable returns as a private enterprise, (2) realizing a financial structure on the premise of making Horizon Project off balance sheet, (3) limiting an investment amount to an acceptable range as a private enterprise.
>
> Unfortunately, despite the best efforts of everyone involved the parties have not been able to reach an agreement to the satisfaction of all concerned. As a result, Hitachi has decided to suspend the project at this time from the viewpoint of its economic rationality as a private enterprise, as it is now clear that further time is needed to develop a financial structure for the Horizon Project and the conditions for building and operating the nuclear power stations.[123]

Following the announcement, Mr Clark made a statement in response to the announcement, setting out details of the negotiations:

> Following Hitachi's announcement I can set out in more candid terms the support that the Government was willing to offer in support of the project. Firstly, the Government was willing to consider taking a one third equity stake in the project, alongside investment from Hitachi and Government of Japan agencies and other strategic partners. Secondly, the Government was willing to consider providing all of the required debt financing to complete construction. Thirdly, the Government agreed to consider providing a Contract for Difference to the project with a strike price expected to be no more £75 per megawatt hour.
>
> I hope the House would agree that this is a significant and generous package of potential support that goes beyond what any Government has been willing to consider in the past. Despite this potential investment, and strong support from the Government of Japan, Hitachi have reached the view that the project still posed too great a commercial challenge, particularly given their desire to deconsolidate the project from their balance sheet and the likely level of return on their investment.
>
> Mr, Speaker, the Government continues to believe that nuclear has an important role to play, but critically it must represent good value for the taxpayer and the consumer. I believe the package of support that we were prepared to consider was the limit of what could be justified in this instance.[124]

The then Secretary of State also said that the Government would continue discussions with Hitachi.

In response to the statement, MPs expressed concern for the future of the UK nuclear industry, and future UK energy capacity.[125] In May 2019, the House of Commons Welsh

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122 *Strike price for Wylfa nuclear plant far lower than Hinkley*, *Financial Times*, 31 May 2018

123 Hitachi, *Hitachi Announces Suspension of UK Nuclear Power Stations Construction Project*, 17 January 2019

124 Department for Business, Energy and Industrial Strategy, *Statement on suspension of work on the Wylfa Newydd nuclear project*, 17 January 2019

125 HC Deb, Nuclear Update, 17 January 2019

Affairs Committee published a report recommending that the Government complete its assessment of the alternative financing model (RAB see section 2.2) as soon as possible. The Committee also said that if Hitachi did not want to resume development, the Government should encourage Hitachi to sell the site and seek other developers.[126]

Horizon has reportedly said there are "several parties" interested in the scheme but funding remained the key issue.[127]

3.5 Oldbury

Horizon also planned to build two new ABWRs (see Box 6), also with a total capacity of 2.7 GW, at Oldbury in Gloucestershire on the site of two closed Magnox reactors.[128] The main construction works were projected to begin after Wylfa had begun operation. Horizon say that since experience with the Wylfa power station was expected to inform development at Oldbury, much less is known of likely timescales.[129]

In 2015, in response to parliamentary questions relating to Oldbury, the Government said that proposals had been put forward but are at too early a stage to estimate costs or timescales for operation.[130, 131]

In a speech in April 2016, the then Energy Secretary Andrea Leadsom referred to Oldbury in a list of power plants (including the others discussed in this section) proposed by industry that could deliver up to 18 GW of nuclear power, whilst outlining the Government's support for nuclear power:

> Hinkley C is only the first in a series of proposed new nuclear projects in the pipeline. It will blaze a trail for further nuclear development. Industry has set out proposals to develop 18 gigawatts of new nuclear power in the UK at six sites – Hinkley Point, Sizewell, Bradwell, Moorside, Wylfa and Oldbury. This pipeline could deliver around a third of the electricity we will need in the 2030s; reduce our carbon emissions by more than 40 million tonnes; bring an estimated £80 billion of investment into the UK and employ up to 30,000 people across the new nuclear supply chain at the peak of construction.[132]

In January 2019, Hitachi announced they were suspending their UK nuclear power station projects,[133] which impacts both the Wylfa and Oldbury projects. More information is available in section 3.4 above.

3.6 Bradwell

Box 7: Hualong One Reactor

Hualong One (also known as HPR1000) is a Generation III, pressurised water reactor. There are no Hualong One's currently operating globally. A number of reactors are under construction currently to schedule in China, with grid connection of the first units planned for 2020. More reactors are under construction in Pakistan with plans for further reactors in countries around the world.[134]

126 House of Commons Welsh Affairs Committee, *The suspension of work on Wylfa Newydd nuclear power station*, Third Report of Session 2017-19, 3 May 2019
127 Business Live, *Wylfa Newydd developer wants "progress" on nuclear funding*, 15 December 2020
128 World Nuclear Association, *Nuclear Power in the United Kingdom*, October 2019
129 Hitachi, *Oldbury – About Our Site* [accessed July 2020]
130 PQ12499 [Nuclear Power Stations: Construction] 19 October 2015
131 PQ11023 [Nuclear Power Stations: Construction] 9 October 2015
132 Gov.uk, *Realising the vision for a new fleet of nuclear power stations*, 20 April 2016
133 Hitachi, *Hitachi Announces Suspension of UK Nuclear Power Stations Construction Project*, 17 January 2019
134 World Nuclear News, *China starts building first Hauilong One Unit*, 7 May 2015

As part of the agreement that saw state-owned China General Nuclear (CGN) take a 33.5% stake in EDF Energy's Hinkley Point C, CGN also agreed to form a joint venture company with EDF Energy to seek regulatory approval for a UK version of the Hualong One design (HPR1000) – see Box 7. The joint venture company is called General Nuclear System and CGN have a 66.5% stake.[135] The new reactor is planned for Bradwell, Essex where there is already a partially decommissioned Magnox reactor. More information on the role of China in the UK's nuclear industry is given in Box 8.

The Department of Business, Energy and Industrial Strategy (BEIS) asked the ONR to begin the Generic Design Assessment (GDA) of Hualong One in January 2017.[136] As with all GDAs this is paid for by the developer. The ONR announced that Step 3 of the GDA was completed in February 2020.[137] The GDA is expected to be completed in 2021 according to the ONR, after which other permissions will need to be granted.[138]

Box 8: The role of China in UK nuclear

There has been debate about the role of China in the UK's nuclear industry. As set out above, state-owned China General Nuclear (CGN) owns a 33.5% stake in Hinkley C, has the option to take a 20% stake in Sizewell C, and has a majority stake to build its own reactor design (Haulong One) at Bradwell.

Restrictions on equipment used by Chinese telecommunications company Huawei in UK

In July 2020, the UK Government announced a series of measures to remove equipment from Chinese communications company Huawei from UK telecommunications - specifically 5G - networks (which are privately owned). This includes banning the purchase of new Huawei 5G equipment after the end of 2020 and removing all existing equipment by the end of 2027. There had been widespread debate about the issue and the Government had already placed restrictions on the use of Huawei equipment and other "high-risk vendors". In a statement, the Government said while the decision would further delay the roll out of 5G, it was necessary to reflect a new security assessment from the National Cyber Security Centre following further US sanctions on Huawei. On the UK's relationship with China, the Minister Oliver Dowden said:

> Let me assure Members that this Government are clear-eyed about China. We have been robust in our response to the imposition of new security laws in Hong Kong, including through our generous offer to British national overseas passport holders. We want a modern and mature relationship with China based on mutual respect where we can speak frankly when we disagree, but also work side-by-side on the issues where our interests converge.[139]

Scrutiny of Chinese involvement in the nuclear industry

It was reported that China's ambassador to the UK had privately said that the Huawei decision could undermine plans for other Chinese companies who are involved in UK infrastructure, such as HS2 and nuclear power.

Following the Huawei decision, press reports[140] have suggested that China's role in UK nuclear power is now also coming under scrutiny. Various politicians, academics, and business leaders are reported to be wary of Chinese involvement in the UK nuclear industry. The concerns cited include similar issues

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135 EDF energy press release, *Agreements in place for construction of Hinkley Point C nuclear power station*, 21 October 2015

136 WMS, 10 January 2017, HCWS398

137 ONR, *Generic Design Assessment (GDA) of new nuclear power stations*, 13 February 2020

138 ONR, Natural Resources Wales and Environment Agency, *Assessing new nuclear reactor designs, Generic Design Assessment Periodic Report*, November 2016 – January 2017

139 HC Deb, *UK Telecommunications*, 14 July 2020, Vol 678, C1375

140 See for example *Iain Duncan Smith: UK needs to urgently review nuclear contracts with China*, *Sky news*, 13 July 2020; *China threatens to pull plug on new British nuclear plants.* *The Times*, 7 June 2020; *No business need at all now for a Chinese nuclear plant in the UK*, *The Guardian,* 7 July 2020; *China's role in UK nuclear power comes under scrutiny*, *The Telegraph* (paywall) 9 July 2020

surrounding the security of national infrastructure as those raised regarding Huawei, as well as wider issues that have impacted the UK's relationship with China, such as the COVID-19 crisis and action in Hong Kong. Chinese involvement in the nuclear industry has been described in some reports as the "next" or "new Huawei".

The potential impact on the nuclear industry is considered by the *Financial Times*, which reported that cutting ties with CGN could leave the UK's nuclear programme "in limbo" given a lack of other foreign companies keen to invest. The article quotes former Treasury Minister Jim O'Neill saying it would be "cavalier" to reject CGN without an alternative, and other stakeholders expressing concern that any move against CGN could worsen UK relations with China. The article suggests the possibility of "retaliations" from China, such as limiting investment in the City of London or limiting Chinese students to the UK. [141]

[141] *Tory hawks press button on nuclear power battle with China*, *Financial Times* (paywall), 20 July 2020

4. Nuclear Research

Successive Governments have supported research and development in nuclear power. Current support schemes are outlined in the following sections. In summary, the current support focuses on advanced nuclear reactors (see Box 8), such as small modular reactors, increasing the competitiveness of the nuclear industry through the Industrial Strategy's Nuclear Sector Deal, funding nuclear innovation including new fuels, reactor designs, and fuel recycling processes, and supporting nuclear fusion.

Box 8: What are advanced reactors?

Advanced nuclear reactors, when referring to fission technology, tends to refer to Generation IV nuclear designs that are mostly in the research or prototype stage. This next generation of designs have the potential for various possible benefits and as such are being developed by countries around the world, including the UK. Certain types of advanced reactors can be small and modular, run on alternative fuels such as thorium, or operate with fusion instead of fission.

In 2001, the Generation IV International Forum (GIF) was founded by Canada, France, Japan, South Africa, South Korea, the United States, Argentina, Brazil and the UK. This group identified six key technologies which have the potential to be commercialised and offer advantages over the Generation III reactors that are currently in use.[142] These six reactors are:[143]

- Fast Reactors:
  - Gas cooled fast reactor
  - Lead cooled fast reactor
  - Sodium cooled fast reactor
- Epithermal reactors:
  - Molten salt reactor
- Thermal reactors:
  - Supercritical water cooled reactor
  - Very high temperature reactor

These reactors have the potential for reduced waste (as well as the option to use existing waste as fuel)[144], greater efficiency, passive safety[145] and lower costs.[146] Multiple designs for these new reactors are actively being developed. Some of the reactor designs have also been modified to be small and modular[147] and entered into a Government competition (see below).

However, the lack of demonstration of Generation IV reactors means their benefits are yet to be tested. Although many countries are developing these reactors, few working examples are currently in operation.[148]

Small Modular Reactors (SMRs)

Small modular reactors are mini versions of nuclear reactors.[149] They are intended to consist of standard, components so they can be mass produced and quickly assembled with multiple 'modules' rather than being large, one-of-a-kind construction projects. To be classed as an SMR, reactors have to produce an electrical output of 300 MW (megawatts) or less. Globally there are some 45 designs at various stages of development.[150]

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142 Generation IV International Forum (GIF), *Generation IV Systems*, [accessed July 2020]

143 Fast, epithermal and thermal refers to the speed of the neutrons in the reactor that cause nuclear fission. The majority of reactors currently in use are thermal reactors, which is where the neutrons are slowed so they are more likely to cause fission.

144 Office of Nuclear Energy (America), *Benefits of Small Modular Reactors (SMRs)* [accessed July 2020]

145 Passive safety involves a design approach to safety using natural forces or phenomena such as gravity, pressure differences or natural heat convection, meaning that no active intervention is required. IAEA.org, *Small modular reactors* [accessed July 2020]

146 The Engineer, *The case for small modular nuclear reactors in the UK*, 30 May 2014

147 World Nuclear Association, *Small Nuclear Power Reactors*, November 2017

148 World Nuclear Association, *Generation IV Nuclear Reactors*, May 2017

149 For background information, see the Parliamentary Office of Science and Technology's note on *Small Modular Reactors* (July 2018)

150 IAEA.org, *Small modular reactors* [accessed July 2020]

Nuclear Future (the journal of the Nuclear Institute) have identified a number of potential advantages to SMRs:

- Their smaller size and cooling requirements allow additional sites to be considered which would be unsuitable for large power stations.
- Their lower power is more compatible with distributed generation and electricity grids, complementing intermittent renewable energy technologies.
- They provide an opportunity to implement newer, safer designs.
- They offer financial and deployment-time advantages compared to large-scale nuclear – owing to modular design and the ability to manufacture them in a factory. [151]

The Nuclear Industry Association (a trade body) has estimated the international market for SMRs at £250-400 billion [152] based on approximately 65-85 GW (gigawatts) of new capacity by 2035. [153] A range of issues, barriers and questions will need to be addressed before SMRs have the potential to be developed commercially in the UK. These are in addition to finding the finance to develop and build SMRs. The House of Commons Energy and Climate Change Committee summarised these issues in a 2014 report on Small Nuclear Power as:

- Cost and investment risk
- Regulatory assessment
- Siting considerations
- Safety and security
- Public engagement [154]

The Committee ultimately concluded that SMRs are a viable proposition that the Government should support:

> Small modular reactors (SMRs), particularly those based on known nuclear technologies, are a viable proposition for future deployment in the UK in the next decade. They could potentially have a key role to play in delivering low carbon energy at lower upfront capital cost compared to large conventional nuclear reactors.
>
> We recommend the Government takes a proactive role in driving forward the development and deployment of these reactors in the UK. [155]

The Cameron Government commissioned a Techno-Economic Assessment by the consultancy firm Atkins on SMRs. The report was finished in July 2016 but was not published by the Government until 7 December 2017. The report found that initially, SMRs would be more expensive than conventional reactors, but the technology should be able to cut costs more quickly than large reactors. [156]

4.1 The Ten Point Plan and Energy White Paper

Towards the end of 2020, the Johnson Government announced a Ten Point Plan for a Green Industrial Revolution and published an Energy White Paper. Both included announcements on support and funding for nuclear innovation through an Advanced Nuclear Fund. The Energy White Paper set out the support:

> Subject to future HMT Spending Reviews, we have provided a £385 million in an Advanced Nuclear Fund with up to £215 million investment to develop a domestic

151 *'Small modular reactors in the UK'*, Nuclear Future, September/October 2015 pp32-37
152 Nuclear Industry Association, *Small Modular Reactors* [accessed July 2020]
153 Excluding sea-water desalination applications.
154 House of Commons Energy and Climate Change Committee, *Small Nuclear Power*, 9 December 2014
155 House of Commons Energy and Climate Change Committee, *Small Nuclear Power*, 9 December 2014
156 Atkins, *SMR Techno-Economic Assessment*, 21 July 2016

> SMR design that could potentially be built in factories and then assembled on site. It is expected to unlock up to £300 million private sector match-funding.
>
> To help bring advanced nuclear technologies to the market, we will also invest an additional £40 million in developing the regulatory frameworks and supporting UK's supply chain. As the first major commitment of the programme, in 2021 we will open the Generic Design Assessment to SMR technologies, the regulatory process through which developers can obtain approval for their proposed design approach.
>
> Supporting the development of our supply chain now will increase our chances of having indigenous expertise capable of leading the world in developing the nuclear technologies of the future - SMRs and AMRs - a global market estimated by some to be worth approximately £250 billion to £400 billion by 2035.
>
> We are also committing up to £170 million of the Advanced Nuclear Fund to a R&D programme on AMRs – the next generation of nuclear technologies. Our aim is to build a demonstrator by the early 2030s at the latest to prove the potential of this technology and put the UK at the cutting edge against international competitors.[157]

The Government has said that up to £30 million of existing contracts and commitments from nuclear sector deals and nuclear innovation programmes (see sections below) are included in the announced Advanced Nuclear Fund.[158] Information on previous funding, some of which continues to be supported through the Advanced Nuclear Fund, is set out below.

4.2 SMR Competition

In the 2015 Spending Review and Autumn Statement, the then Chancellor George Osbourne announced £250 million over 5 years for nuclear innovation. The Government described this as:

> An ambitious nuclear research and development programme that will revive the UK's nuclear expertise and position the UK as a global leader in innovative nuclear technologies.[159]

In March 2016, the Cameron Government launched the first phase of an SMR competition to identify the best value small modular reactor design for the UK with an aim to be building one of the world's first SMRs in the 2020s.

The objective of Phase One was to gauge market interest among technology developers, utilities, potential investors and funders in developing, commercialising and financing SMRs in the UK.[160]

The then Government originally envisaged that this first phase of the competition would last until autumn 2016, with the next steps informed by the output of Phase One.[161]

In May 2017, the House of Lords Science and Technology Committee criticised the delays to the SMR competition. Their report on 'Nuclear research and technology: Breaking the cycle of indecision' concluded:

> We are disappointed that the Government launched a competition for SMRs and has not kept to its stated timetable. This has had a negative effect on the nuclear sector in the UK and if the Government does not act soon the necessary high level of industrial interest will not be maintained. It is particularly alarming that the results of Phase One of the competition, which does not involve the selection of an SMR design, have yet to be announced by the Government. (Paragraph 98)

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157 HM Government, *Energy White Paper*, page 50-51
158 PQ124252, *Nuclear Reactors: Finance*, 2 December 2020
159 Gov.uk, *Spending Review and Autumn Statement 2015*, 27 November 2015
160 Gov.uk, *Small Modular Reactors competition: phase one*, 17 March 2016
161 World Nuclear News, *UK Government launches SMR competition*, 18 March 2016

> We did not detect any urgency from the Government to make a decision on the SMR competition. Whilst acknowledging the need for due care, the Government must publish its strategy for SMRs without delay if industrial interest is to be maintained and if commercial opportunities are not to be missed. We have reached a critical moment for the future of the United Kingdom as a serious nuclear power strategically positioned to capture coming opportunities. (Paragraph 99)[162]

The May Government responded to this report in September 2017. The response referred to the Industrial Strategy and soon to be made announcements (see below) as indicators that the Government is committed to nuclear power but said on the deployment of SMRs that there are 'a number of technical, commercial, regulatory and public acceptability questions that need to be addressed'.[163]

4.3 Government Advanced Modular Reactor Project

In December 2017, the small modular reactor competition was closed. The May Government said there had been "successful engagement with industry"[164] and announced a new package of support for nuclear power. Amongst the announcements were commitments for developing SMRs, though the then Minister Richard Harrington's written statement said this term was too narrow and so the Government would instead use the term "advanced nuclear" for "technologies coming forward after the current generation of nuclear power stations".[165] The Government's Policy Paper on 'Advanced Nuclear Technologies' specifies that SMRs were split into two broad categories based on technology level: Generation III and Generation IV.[166]

According to a speech to the Nuclear Industry Association Conference by the then Parliamentary under Secretary of State for BEIS Richard Harrington, the support was based on three key requests from industry that emerged as part of the SMR competition:

- Better and earlier access to regulators
- Help to turn new developer's ideas into detailed designs
- Create the right market conditions to enable developers to bring new reactors to market.[167]

The Minister's written statement said the total funding available to develop and regulate designs (the first two requests from industry) was £56 million and would be spent on a two-phase advanced modular reactor project over three years (the Policy Paper on 'Advanced Nuclear Technologies' clarifies that only Generation IV reactors are eligible for this support):

- Phase 1 comprises up to £4 million for around eight reactor vendors to carry out detailed technical and commercial feasibility studies and up to £7 million to further develop the capability of nuclear regulators[168] who support and assess advanced nuclear technologies.
- Subject to Phase 1 demonstrating clear value for money through a formal re-approval process with the Treasury, up to £40 million will be available for three to

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162 House of Lords Science and Technology Committee, *Nuclear research and technology: Breaking the cycle of indecision*, 2 May 2017
163 *Government response to the House of Lords Science and Technology Select Committee report: 'Nuclear research and technology: Breaking the cycle of indecision'*, 15 September 2017
164 Gov.uk, *Small Modular Reactors Competition*, 7 December 2017
165 HC WS [Energy policy] 7 December 2017, V632, C57WS
166 Gov.uk, *Advanced Nuclear Technologies*, 7 December 2017
167 Gov.uk, *Nuclear Industry Association (NIA) annual conference 2017*, 7 December 2017
168 Nuclear regulators, in the case of GDAs for new reactor designs, will be the Office for Nuclear Regulation (ONR)

> four vendors of advanced modular reactor R&D projects to accelerate the development of their designs and up to a further £5 million for regulators.[169]

In September 2018, when announcing the Nuclear Sector Deal (see below), the Government said eight organisations have been awarded contracts to produce feasibility studies under Phase 1.[170] In July 2020, the Government announced the successful projects for phase 2,[171] as well as confirming the £40 million funding.[172]

To address the third request from industry, "to create the right market conditions to enable developers to bring new reactors to market", the then Minister stated that an expert finance group will be set up to "advise how small and advanced reactor projects could raise investment in the UK […] and demonstrate the commercial proposition of small reactors in the emerging nuclear market."[173] The Expert Finance Working Group on Small Reactors was established and reported in August 2018. Their recommendations included:

- setting out a clear policy and market framework
- integrating energy, nuclear and finance sector stakeholders
- focusing on bringing first-of-a-kind (FOAK) projects to market
- establishing an advanced manufacturing supply chain initiative
- optimising the Generic Design Assessment (GDA) process
- making sites available to FOAK small nuclear projects
- setting out a new infrastructure fund[174]

The speech also included announcements on funding for the nuclear innovation programme[175], fusion research, deep geological disposal, national policy statements and on the industrial strategy sector deal.[176]

4.4 The Low-Cost Nuclear Challenge

The 2017 speech did not include any specific announcement for small modular Generation III reactors. This includes the reactor by Rolls Royce who were widely reported to be in discussion with the Government.[177] The reactor could breach the technical definition of an SMR of being less than 300 MW as the Rolls Royce design is 220 - 440MW.[178]

However, in July 2019 the then Secretary of State for BEIS (Greg Clark) announced that the May Government was proposing up to £18 million of funding for a consortium led by Rolls-Royce to develop a first-of-a-kind SMR:

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169 Gov.uk, *Government to support development of next-generation nuclear technology*, 7 December 2017
170 Gov.uk, *Advanced Modular Reactor (AMR) Feasibility and Development Project*, September 2018. Note this webpage refers to £44 million funding because it does not include the £12 million (£7 million in phase 1 and a further £5 million in phase 2 as above) allocated to regulators.
171 Gov.uk, *Advanced Modular Reactor (AMR) Feasibility and Development Project*, 10 July 2020
172 Gov.uk, *£40 million to kick start next-gen nuclear technology*, 10 July 2020
173 HC WS [Energy policy] 7 December 2017, V632, C57WS
174 Gov.uk, *Market framework for financing small nuclear*, 7 August 2018
175 The nuclear innovation programme was launched in November 2016 with £20 million for Advanced Fuels, Materials and Manufacture, Advanced Reactor Design; Recycling and Reprocessing, and Strategic Tools and Nuclear Facilities.
176 These announcements are discussed in relevant parts of this paper.
177 Financial Times, *Development of small nuclear power plants gathers pace*, 7 November 2017
178 Rolls-Royce, *Small Modular Reactors – once in a lifetime opportunity for the UK*, 2016

> We are proposing to invest up to £18 million of government money in the creation of innovative mini nuclear power stations which are smaller and less expensive to build than traditional nuclear plants. A consortium led by Rolls-Royce has proposed a significant joint investment of more than £500 million focused on designing a first-of-a-kind small modular reactor (SMR). The consortium expects to more than match any government funding both by direct investment and by raising funds from third party organisations.
>
> A working model is expected to be up and running in the early 2030s, creating 40,000 jobs at its peak, with each power station producing enough clean energy to power 750,000 homes.[179]

The Johnson Government later confirmed in November 2019 that the public investment of £18 million comes from the Industrial Strategy Challenge Fund (see section 4.2 below) and will contribute to an initial £36 million joint public and private investment in the consortium.[180] This funding was in addition to the AMR competition, and further funding for regulators to build readiness for SMRs, described above.[181]

4.5 Industrial Strategy: A Nuclear Sector Deal

The May Government's Industrial Strategy Green Paper, published in January 2017, included a proposition for a Sector Deal for nuclear power.[182] Sector Deals involve the Government working with the private sector to promote productivity. The White Paper, published in November 2017 reiterated this support for a Nuclear Sector Deal stating:

> The nuclear sector […] is in advanced discussions with the government on a range of ambitious proposals to increase competitiveness and achieve greater value at both national and regional levels.[183]

On 7 December 2017, in addition to the series of measures to support nuclear power announced by the May Government[184] the Nuclear Industry Council (co-chaired by the then Minister Richard Harrington and re-established in February 2017 as a forum for engagement between Government and industry) also published a report outlining their proposals to the Government for a Sector Deal.[185] The proposals included ensuring that projects are delivered on time and within budget and requesting the Government explores alternative financing options.

On 27 June 2018, the May Government released the details of the Nuclear Sector Deal. The then Secretary of State Greg Clark announced the strategy in Trawsfynydd in Wales, the site of a closed Magnox reactor, and also laid a Written Statement on 28 June 2018 which summarised key parts of the Deal:

> The Government has worked closely with the sector champion Lord Hutton and industry leads from the Nuclear Industry Council to develop a number of proposals by 2030, which include:
>
> - 30 per cent cost reduction in the cost of new build projects
> - Savings of 20 per cent in the cost of decommissioning compared with current estimates

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179 HM Government, *Innovative funding models and technologies to drive investment in new wave of low carbon energy*, 23 July 2019.
180 Gov.uk, *Advanced Nuclear Technologies*, 5 November 2019
181 HM Government, *Innovative funding models and technologies to drive investment in new wave of low carbon energy*, 23 July 2019.
182 HM Government, *Building our Industrial Strategy. Green Paper*, January 2017
183 HM Government, *Industrial Strategy. Building a Britain fit for the future*, 27 November 2017
184 Gov.uk, *Government to support development of next-generation nuclear technology*, 7 December 2017
185 Nuclear Industry Council, *The Nuclear Sector Deal. Nuclear Industry Council proposals to Government for a Sector Deal*, 7 December 2017

- Women to make up 40 per cent of the nuclear sector by 2030
- Win up to £2bn domestic and international contracts

> The Deal contains mutual commitments to drive greater productivity, innovation and exports by: adopting innovative advanced manufacturing and construction techniques in new nuclear projects; supporting advanced nuclear technologies including small modular reactors (SMRs) and a range of research and development activities; a joint review of the decommissioning pipeline to achieve greater value for the taxpayer and to boost exports; a supply chain competitiveness programme to support UK business to build capabilities to win work domestically and internationally; and a range of proposals to support a future workforce including a new apprenticeship standard and a commitment to a more diverse workforce, including a target of women making up 40% of the nuclear sector by 2030.
>
> The UK has consistently been a world leader in nuclear technology and has been at the forefront of many new developments in the industry. This Deal will continue that tradition through the establishment of a new framework to support the development and deployment of SMRs and the innovative technologies that support them. This support is designed to challenge the industry to bring forward technically and commercially viable propositions that would lead to the deployment of new reactors that would be investable and cost competitive in the energy system.[186]

An urgent question on the deal was asked by John Woodcock MP on 28 June 2018. Sam Gyimah, then a Minister of State for BEIS, responded to questions from MPs.[187] MPs were supportive of the proposals, but critical that the Secretary of State was not available to answer questions and provide further detail. Other MPs questioned the Government's support for renewables with the announcement coming in the same week that the Government announced they would not support the Swansea Bay Tidal Lagoon.[188]

The Nuclear Industry Association (NIA) welcomed the deal, with the CEO Tom Greatrex saying:

> The NIA is delighted that the Nuclear Sector Deal has now been published.
>
> This ambitious deal between industry and Government will ensure nuclear plays a key role in providing the UK's low-carbon energy supply for the future, maximising opportunities in overseas markets, leveraging technology and innovation and increasing competitiveness.
>
> By ensuring new nuclear and decommissioning projects are delivered in a more cost-effect manner, it will also provide a major benefit to the consumer.
>
> Industry and Government will now work together through the NIC to develop an implementation plan to ensure these objectives are delivered successfully.[189]

A debate on the nuclear sector deal was held on 11 July 2018, led by Trudy Harrison MP. Members broadly supported the deal and raised issues such as the need for cost reductions for new nuclear, and the need for a diverse energy mix including nuclear and renewables.[190]

4.6 Nuclear Innovation Programme

In 2015, as part of the Spending Review, the Government announced a nuclear fission research and development programme, known as the Nuclear Innovation Programme.[191]

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186 HC WS [Industrial Strategy] 28 June 2018, HCWS804
187 HC Deb, Nuclear Sector Deal, 28 June 2018
188 HC Deb, Energy policy, 25 June 2018, vol 643
189 Nuclear Industry Association, *The Nuclear Sector Deal Launch*, 28 June 2018
190 HC Deb, Nuclear Sector Deal, 11 July 2018, vol644
191 Gov.uk, *Funding for nuclear innovation*, updated 8 January 2020

The Government said that between 2016 and 2021, it expected to invest around £180 million in nuclear innovation.

The funding includes support for developing advanced fuels, safe and efficient reactor designs, fuel recycling processes, and data to inform future decision making in the nuclear sector.

The funding has been split between a number of phases and types of support, summarised below (more information, including a breakdown of the funding at each stage is available from the Government webpage on Funding for nuclear innovation):

- **Phase 1:** In November 2016, as part of the first phase of the programme, over £20 million of funding was available to split between five nuclear projects. The Government has said that contracts worth £12.5 million have been awarded and work has commenced.
- **Phase 2:** In December 2017, as part of the announcements above, the second phase of the project was launched, which included £8 million for work on safety and security, and advanced fuels.
- **Phase 3:** The Government published invitations for tender in December 2018 which included thermal hydraulic model development, and advanced reactor design.
- **Advanced manufacturing and materials:** As part of the first phase of the Nuclear Innovation Programme, the Government has also awarded £5 million of contracts for work on nuclear advanced materials and manufacturing. This funding was Phase 1 of the advanced manufacturing and materials funding stream.[192] The Government subsequently announced Phase 2; a £20 million investment programme focusing on increasing the manufacturing or technology readiness levels of technologies, including those established in Phase 1, towards demonstration and commercialisation. In July 2020, the Government announced the successful projects.

4.7 Nuclear Fusion

All nuclear reactors discussed above, rely on nuclear fission for the production of heat (which is ultimately converted into electricity). Nuclear fusion has been a research topic for many decades but is not yet ready for commercialisation. Fusion powers the Sun and stars as hydrogen atoms fuse together to form helium, and matter is converted into energy at very high temperatures.[193]

Information on the impact of the UK's departure from the EU on fusion projects is outlined in the Library briefing paper on Brexit: energy and climate change (June 2020).

The Joint European Torus (JET)

The Joint European Torus (JET) is a fusion power project at the Culham Centre for Fusion Energy in Oxfordshire. Euratom[194] provides 87.5% of the funding for the Joint European Torus (JET) programme and the UK Government funds the remaining 12.5% itself. As the UK's exit from the EU also involved leaving Euratom, the future of the project will be determined as part of the negotiations.[195] The Government has said it will guarantee funding for UK participation in JET until the end of 2020.[196]

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[192] This is separate to Phase 1 of the Nuclear Innovation Programme.
[193] World Nuclear Association, *Nuclear Fusion Power*, updated December 2019
[194] Further information can be found in the Library briefing paper on Euratom.
[195] *EUROfusion statement on Brexatom*, 27 January 2017
[196] Gov.uk, *Nuclear research after Brexit*, 13 August 2019

The International Thermonuclear Experimental Reactor (ITER)

International Thermonuclear Experimental Reactor (ITER) is a project to build the world's largest 'tokamak', a magnetic fusion device designed to prove the feasibility of fusion. The ITER agreement was signed in 2006 by China, the EU, India, Japan, South Korea, Russia and the US, and building of the tokamak has been underway in France since 2010. The official start of ITER operation is scheduled for December 2025.[197] The UK is a key participant in ITER and sends information, results and design studies from its JET programme to the French site.

The National Fusion Technology Platform

On 7 December 2017, amongst other announcements to support the nuclear industry, the Government committed £86 million of funding for a National Fusion Technology Platform. The Platform is expected to be constructed at Culham in Oxfordshire and will open in 2020.[198] The Platform will comprise of two centres:

- Hydrogen-3 Advanced Technology (H3AT) will research how to process and store tritium, one of the fuels that will power commercial fusion reactors;
- Fusion Technology Facilities (FTF) will carry out thermal, mechanical, hydraulic and electromagnetic tests on prototype components under the conditions experienced inside fusion reactors.

The Government press release stated:

> The new facilities will support British industry and help to secure around £1 billion in contracts from the key international fusion research experiment ITER, now being built in France, and other global fusion projects. Looking further ahead, they will enable UKAEA to develop technology for the first nuclear fusion power plants and put UK industry in a strong position to exploit the commercialisation of this highly promising low-carbon energy source.[199]

STEP

In October 2019, the then Secretary of State for BEIS under the Johnson Government (Andrea Leadsom) announced £220 million of funding for the conceptual design of a fusion power station – the Spherical Tokamak for Energy Production (STEP). The Government press release stated that a design would be completed by 2024, and there was a "realistic prospect of constructing a powerplant by 2040".[200]

The Government also announced an £184 million investment to upgrade the Culham Science where UK fusion development is currently based.[201]

The Johnson Government's 2020 Ten Point Plan and Energy White Paper reiterated support for fusion. The Ten Point Plan stated:

> We are doubling down on our ambition to be the first country in the world to commercialise fusion energy technology, enabling low carbon and continuous power generation. We are already providing £222 million for the visionary STEP programme (Spherical Tokamak for Energy Production), which aims to build the world's first commercially viable fusion power plant in the UK by 2040, and £184 million for new fusion facilities, infrastructure and apprenticeships to lay the foundations of a global hub for fusion innovation in the UK.[202]

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197 ITER, *When Will ITER Be Operational?*, [accessed July 2020]
198 Gov.uk, *£86 million boost for UK nuclear fusion programme*, 7 December 2017
199 Gov.uk, *£86 million boost for UK nuclear fusion programme*, 7 December 2017
200 Gov.uk, *UK to take a big 'STEP' to fusion electricity*, 3 October 2019
201 Culham Science Centre, *Culham to be global fusion hub in £184M transformation*
202 Gov.uk, *The Ten Point Plan for a Green Industrial Revolution*, 18 November 2020

The Government has also called on local communities to host the STEP prototype fusion plant, saying the development could bring local jobs. Communities can apply until the end of March 2021.[203]

4.8 Thorium

Thorium is not a nuclear fuel as such, but can "breed" fuel as a result of nuclear reactions taking place within a variety of reactors. Thorium is "fertile" rather than "fissile" – it is not directly useable as a nuclear fuel however, it can be used in a nuclear reactor to produce uranium-233 which is fissile.[204]

The UK has some experience of using thorium in this way – in a past demonstration project. However, a report by the National Nuclear Laboratory, published in 2010 did not view thorium as being a promising area of work for the UK.[205] The UK has no significant geological deposits of either thorium or uranium – though it has stocks of both uranium and plutonium that can be used in existing commercial reactor designs.

The Energy and Climate Change Committee's 2014 inquiry into small nuclear power also considered the use of thorium in nuclear reactors. The Committee found:

> There are a number of advantages to switching to a thorium fuel cycle; however, the evidence we have heard suggests that this will not be a viable option unless the price of uranium changes drastically. The UK must for now remain an active participant in thorium research and development. We recommend that the Government commission a study to confirm the potential benefits of thorium in the longer-term and how any potential barriers to its use might be overcome.[206]

The Government's response, published on 5 March 2015 reciprocated the Committee's interest in thorium, pointed to existing research, and said further analysis would be necessary, though did not commission a review as recommended.[207]

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203 Gov.uk, *Home sought for UK's ground breaking prototype fusion power plant*, 2 December 2020
204 World Nuclear Association, *Thorium*, February 2017
205 House of Commons Library, *Thorium energy*, 24 June 2013
206 House of Commons, Energy and Climate Change Committee, *Small nuclear power*, Fourth report of session 2014-15, 9 December 2014
207 House of Commons, Energy and Climate Change Committee, *Sixth Special Report, Small Nuclear Power, Government response*, 5 March 2015

5. Legacy management

Nuclear waste comprises many different products (spent fuel, plutonium, actinides etc.) and is split into categories of low level waste and high level waste based on its radioactivity. The Nuclear Decommissioning Authority (NDA) is the executive non-departmental public body that manages waste disposal in the UK.

The Government's policy on managing nuclear waste is set out on the Gov.uk website. A summary of the policy for different levels of waste was set out in May 2016 in response to a parliamentary question:

> The UK Government has clear policies for the safe and secure short and long–term management of radioactive waste.
>
> The UK Government published a Policy Statement for the management of Low Level Waste (LLW) in 2007. In accordance with it an updated UK Nuclear Industry LLW Strategy was published by DECC in February 2016. It requires the application of the waste management hierarchy. It means disposal of LLW should be a last resort and waste avoidance, recycling and reuse of waste should be considered first. This will preserve capacity in the UK's national LLW repository in West Cumbria so it can continue to dispose of the highest priority LLW only.
>
> The policy for higher activity waste is contained in the Implementing Geological Disposal White Paper published by DECC in 2014. The policy is that higher activity waste from nuclear facilities will be held in safe and secure interim storage facilities on nuclear licensed sites until a Geological Disposal Facility (GDF) is available for final disposal.[208]

5.1 Deep Geological Disposal

Since 2006 the Government's strategy for radioactive waste management has centred on a deep geological facility (GDF).[209] A GDF involves isolating radioactive waste within multiple protective barriers, deep underground, to ensure that no harmful quantities of radioactivity ever reach the surface environment.[210] Such schemes are also favoured by other countries around the world; Sweden, Finland and France are constructing facilities and the USA already has a facility for disposal in operation.[211]

The long-term disposal policy for higher level radioactive wastes derives from the publication of the recommendation by the Committee on Radioactive Waste Management (CoRWM) in July 2006:

> For over three decades, efforts to find solutions to the problem of long-term radioactive waste management in the UK have failed. Government initiated a fundamental review of policy and appointed the Committee on Radioactive Waste Management (CoRWM) to take this forward. CoRWM has adopted an innovative approach, based on engagement with the public and stakeholders, expert knowledge and reflection on ethical issues. Consideration of these inputs has led to a set of interdependent proposals which recommend: (1) geological disposal as the end state; (2) the vital role of interim storage; and (3) a new approach to implementation, based on the willingness of local communities to participate, partnership and enhanced well-being. The proposals form a basis for Government to act upon without delay.[212]

In October 2006, the Labour Government accepted CoRWM's recommendations and in June 2008, published 'Managing Radioactive Waste Safely – A Framework for

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208 PQ HL128, 31 May 2016
209 Office of Nuclear Regulation, *Geological disposal* [accessed July 2020]
210 Gov.uk, *Geological disposal of radioactive waste: a guide for communities*, 24 July 2014
211 World Nuclear Association, *Storage and Disposal of Radioactive Waste*, updated March 2020
212 Committee on Radioactive Waste Management, *Managing our Radioactive Waste Safely*, July 2006

Implementing Geological Disposal White Paper'.[213] This advocated a voluntarism or partnership approach to finding a site for the repository under which communities would be invited to open up without commitment discussions with Government on the possibility of hosting the geological disposal facility in the future.

The siting process set out in the 2008 White Paper operated for five years and although a number of communities engaged with the early stages of the process, by February 2013, there were no longer any communities actively involved in this siting process.

The May Government remained committed to geological disposal. The 'Implementing Geological Disposal Annual Report' from 2016 said:

> The UK Government remains committed to the policy of geological disposal, for the reasons set out in CoRWM's original 2006 report and subsequent UK Government policy documents on radioactive waste management. All major nuclear nations are actively pursuing geological disposal. It is internationally recognised that geological disposal represents the safest and most sustainable option as the end point of the management of high level waste and spent fuel considered as waste. The UK Government continues to favour an approach to siting a Geological Disposal Facility (GDF) that is based on the willingness of local communities to participate in the siting process.[214]

On 25 January 2018, the May Government launched two consultations: one on a draft National Policy Statement for geological disposal infrastructure[215] that was published alongside the consultation,[216] and a second on how the Government should work with communities through the siting process.[217]

A new 'National Policy Statement for Geological Disposal Infrastructure' was designated on 17 October 2019. In a statement, the Parliamentary under-secretary for BEIS Nadhim Zahawi summarised the importance of the new framework:

> It is important that we who have benefitted from nuclear technology take appropriate steps now to manage the waste created from using that technology. Nuclear technology has provided clean energy to our homes and businesses and will continue to play an important role as we transition to a carbon neutral economy. For a long time, we have also used radioactive materials to treat and diagnose serious illnesses, to deliver research and development and to help deliver industrial processes. Radioactive waste is created from a variety of sources including electricity generation, defence and healthcare, and geological disposal is internationally recognised as the safest and most secure means of permanently managing a proportion of this waste not suitable for other management regimes.
>
> The National Policy Statement for Geological Disposal Infrastructure sets out the need for such disposal infrastructure to safely and securely manage the UK's higher activity radioactive wastes. The National Policy Statement provides an appropriate and effective framework for the Planning Inspectorate and the Secretary of State for the Department for Business, Energy and Industrial Strategy to examine and make decisions on development consent applications for geological disposal infrastructure in England.[218]

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213 Gov.uk, *Managing radioactive waste safely: a framework for implementing geological disposal,* 1 June 2008

214 Department for Business, Energy and Industrial Strategy, *Implementing Geological Disposal Annual Report,* November 2016

215 Department for Business, Energy and Industrial Strategy, *Draft National Policy statement for geological disposal infrastructure,* January 2018

216 Gov.uk, *National Policy Statement for geological disposal infrastructure*, 25 January 2018

217 Gov.uk, *BEIS and Welsh Government open geological disposal consultations*, 25 January 2018

218 HCWS18, Infrastructure update, 17 October 2019

In response to the second consultation, the May Government published in December 2018 a policy paper on 'Implementing geological disposal: working with communities'.[219] This sets out the UK Government's policy on managing higher activity radioactive waste through implementing geological disposal.

Until a suitable site is identified and the facility constructed, waste will continue to be stored at sites such as Sellafield.

A Geological Disposal Facility is expected to be expensive due to the scale of the project and relative novel nature of the construction.[220] To address this, new nuclear power developers must cover the cost of nuclear disposal. In a statement on Hinkley C in 2013, the then Secretary of State for Energy and Climate Change, Ed Davey, said:

> Separately, and for the first time ever, to deal with clean-up costs of new nuclear, developers will be required to put money aside in a protected clean-up fund to pay for eventual decommissioning and share the waste management costs. This is anticipated to account for around £2 of the [£92.50/MWh] strike price.[221]

5.2 Reuse in reactors

The UK has the largest plutonium stockpile in the world which has ongoing costs and security risks.[222] The Nuclear Decommissioning Authority (NDA) published a position paper in 2014 on the Government's strategy for plutonium management. It concluded:

> Reuse remains the preferred option and, based on the information provided and against our definitions, there are three credible reuse options:
>
> - reuse as MOX in light water reactors;
> - reuse in CANDU EC6 reactors;
> - reuse in PRISM fast reactors.
>
> We note all the technologies being considered have pros and cons and that no "perfect" solution exists. It may be that a multi-track approach offers best value for money.[223]

Box 9 includes details of the reactors mentioned. It is important to note this approach is not current Government policy but rather a speculative, future option. As the NDA paper concludes:

> Currently, we believe there is insufficient understanding of the options to confidently move into implementation.[224]

Since this paper was published no further announcements have been made in terms of pursing one or all of these reactors. The current Government strategy remains focused on storage followed by deep geological disposal once a suitable facility has been constructed. A detailed summary of the options for legacy management available to the UK are available in POSTnote531.[225]

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219 Gov.uk, *Implementing geological disposal – working with communities: long term management of higher activity radioactive waste*, 19 December 2018
220 Nuclear Engineering International, *Estimating the disposal costs of spent fuel,* October 2011
221 Gov.uk, *Agreement reached on new nuclear power station at Hinkley*, 21 October 2013
222 Rob Broomby, *UK's Plutonium Stockpile Dilemma*, *BBC,* 24 February 2014
223 Nuclear Decommissioning Authority, *Progress on approaches to the management of separated plutonium*, January 2014
224 Nuclear Decommissioning Authority, *Progress on approaches to the management of separated plutonium*, January 2014
225 POSTnote 531, *Managing the UK Plutonium Stockpile*, September 2016

In June 2015, the then Minister Andrea Leadsom set out the Government's view in response to a parliamentary question:

> The UK Government remains open to any credible option that offers the best value for money to the taxpayer. The Nuclear Decommissioning Authority (NDA) are undertaking work for us to:
>
> 1) gain further understanding of reuse options (reuse as MOX and assessment of the credible alternatives PRISM and Candu);
>
> 2) continue to develop the immobilisation[226] option; and
>
> 3) establish potential approaches to acquisition and procurement.
>
> […]
>
> To be clear, only when the Government is confident that its preferred option could be implemented safely and securely, that it is affordable, deliverable, and offers value for money, will it be in a position to proceed.[227]

No location has been specified for these potential reactors, but as the current UK plutonium stockpile is stored at Sellafield, it is possible the reactors will be constructed there. A previous MOX plant was built at Sellafield and the PRISM proposal suggests Sellafield as a location.[228]

Box 9: Reuse reactors

Mixed Oxide (MOX)

MOX is a fuel formed by mixing the plutonium (oxide) with uranium (oxide). To produce MOX, the UK would need to build a new MOX plant, since the UK's previous MOX plant at Sellafield closed in 2011.[229]

The company AREVA has proposed building and operating a new MOX plant based on their MELOX plant in France.[230] The MOX fuel could then be used either in new reactors (EPR, AP1000 and/or ABWR) or the existing Sizewell B power plant or both.

MOX has been used in this way in around 40 Light Water Reactors in Europe,[231] but in the UK it would be a change to current operations which are based on using only conventional uranium fuel. This change would need to go through the regulatory decision processes which could take a number of years.

According to the NDA, it would take 40 years to use all of the reusable plutonium if there were five LWRs using 30% MOX fuel; the timeframe would change with a different number of reactors or different MOX proportion.[232]

CANDU

CANDU is a Canadian pressurised heavy water reactor. There are approximately 30 operating CANDU reactors around the world and more based on the CANDU design.[233]

The company CANDU Energy has proposed building four of their Enhanced CANDU reactors (EC6) in the UK, specifically for the purpose of reusing plutonium. This would require converting plutonium to 'CANMOX' (MOX specifically made for use in CANDU reactors) using a specially built CANMOX fuel plant. The reactors could use the UK's reusable plutonium in 30 years and CANDU estimates that it would take 15 years to have a plant operating.[234] Despite the fact many previous designs have been

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226 This refers to conditioning waste into a stable, solid form. Vitrification is a common form of immobilisation which involves converting waste into glass.
227 PQ 4150 [Plutonium] 24 June 2015
228 The Engineer, *Prism project: A proposal for the UK's problem plutonium*, 13 May 2013
229 Steve Connor, *Day after Sellafield plant is shut, Government ordered to build another*, *The Independent*, 4 August 2011
230 NuclearEnergyInsider, *UK to steer plutonium processing projects by year end*, 8 October 2015
231 World Nuclear Association, *Mixed Oxide (MOX) Fuel*, June 2017
232 POSTnote 531, *Managing the UK Plutonium Stockpile*, September 2016
233 National Energy Board Canada, *Canadian Innovations continue to shape the future of energy*, 29 June 2017
234 POSTnote 531, *Managing the UK Plutonium Stockpile*, September 2016

constructed and are operating around the world, the EC6 reactors have never yet been built and would need to be assessed by a GDA.[235]

PRISM

PRISM is a sodium cooled fast reactor design by GE Hitachi. The reactor process involves converting the plutonium powder to its metal form and combining it with uranium and zirconium to form a solid, metal fuel rod to use in a reactor.

As PRISM reactors have a modular design, they have the potential for shorter construction times and cost, though this is as yet unproven. PRISM is based on the Experimental Breeder Reactor II reactor that operated for over 30 years in the US but was shut in 1994. GE Hitachi thus claim there is no need for a prototype reactor but NDA say that the facilities "have not been industrially demonstrated, especially when considering changes in the regulatory context since the time when much of the technology basis was established. Consequently the proposal overall would require development work".[236]

However, the same paper quotes an external assessment that states there is "no fundamental impediment to UK licencability" of Prism and GE Hitachi estimate licensing these first of a kind facilities could be achieved in 6 years.

The proposed legacy management solution would consist of two reactors, capable of processing all of the reusable UK plutonium over their 60 year life.[237]

[235] POSTnote 531, *Managing the UK Plutonium Stockpile*, September 2016
[236] Nuclear Decommissioning Authority, *Progress on approaches on the management of separated plutonium*, January 2014
[237] POSTnote 531, *Managing the UK Plutonium Stockpile*, September 2016

BRIEFING PAPER
Number CBP 8176
26 February 2021

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