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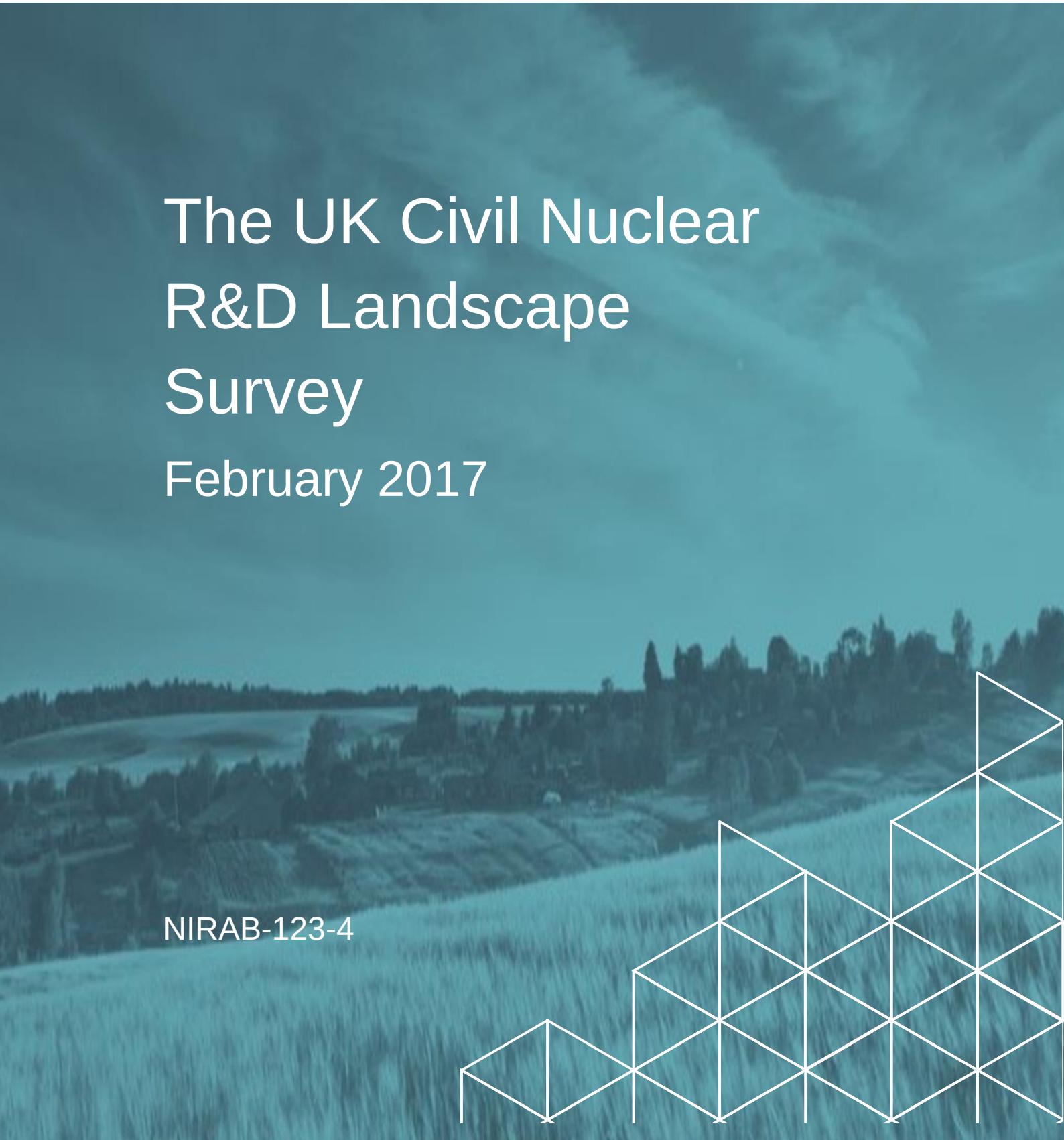

The UK Civil Nuclear R&D Landscape Survey

February 2017

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Executive Summary

This document presents the results of a survey of the UK civil nuclear research and development (R&D) landscape in the 2015/16 financial year (April to March). It provides information on the Government policy landscape, funding sources, magnitude, location and focus of R&D being undertaken in the UK and the level of experience of the R&D community currently engaged in civil nuclear research. It is an update to the landscape review published by Government in 2013.

This survey presents data comparable with the 2013 review so that Government can identify trends and assess the impact of interventions. The survey also seeks to present a useful overview for the UK's community of researchers of the funding sources for nuclear R&D, detailing where research is being undertaken and the focus of that research.

The Civil Nuclear Landscape - Funding

Total funding for civil nuclear R&D in the UK has been collected as part of this survey; it includes public sector contributions and an estimate of private and overseas funding for nuclear fission and fusion research. The figure for total funding for 2015/16 was around £217 million. The 2013 review only presented public sector funding and therefore it is not possible to make a direct comparison or comment on any potential changes.

The rate of public spending in the period since the 2013 review has varied, but overall public sector funding for civil nuclear R&D in 2015/16 was lower than in 2010/11. The Nuclear Decommissioning Authority (NDA) and its Site License Companies (SLCs) dominated public sector funding in both 2011/12 and 2015/16. Research funded by the NDA is needs driven and focussed on waste management and decommissioning. The overall reduction in public sector funding in 2015/16 relative to 2010/11 is primarily a result of a decrease in spending by NDA SLCs.

In the fusion sector, the majority of funding is from the European Union (EU), with the remainder from the UK Research Councils. Public sector funding for fusion has remained stable at around £25 million per annum.

Industry funding data is collected for the first time in this survey, and shows that the focus of research is mainly related to current reactor operations.

Funding for research into advanced nuclear fission technologies is low; this was also a key conclusion in the 2013 review.

The UK's annual public expenditure on nuclear R&D continues to be significantly lower than other major nuclear nations in the Organisation for Economic Co-operation and Development (OECD).

The Civil Nuclear Landscape - Capability

Overall there has been an approximate 19% increase in the number of researchers engaged in civil nuclear research in the UK compared to the 2013 review data. There has been a 5% increase in the number of researchers in our national laboratories. In both

fusion and fission laboratories there has been a significant loss of more experienced staff (individuals with greater than 15 years' experience).

The number of researchers based in industry organisations has increased, and there has been a significant increase in academic activity in civil nuclear R&D. Activity is dominated by a small number of universities with large research groups.

The number of people (in industry, national laboratories and universities) working on research into advanced reactor systems and fuel fabrication remains very low; though there has been a modest increase in activity related to advanced reactors, this is mainly seen in university research.

Objectives for nuclear R&D

This survey highlights that there are number of Government departments with policies relating to civil nuclear energy, and each has its own objectives which are underpinned by R&D. The resulting institutional landscape is complex, with each department enacting its research objectives through a number of different non-departmental public bodies or agencies. A major change in Government, since the previous landscape review, has been the merger of the former Department of Energy and Climate Change (DECC) and Department for Business, Innovation and Skills (BIS) into the new Department for Business, Energy and Industrial Strategy (BEIS). The majority of civil nuclear energy policy resides within BEIS.

Coordination of R&D

Mechanisms have been put in place since 2013 to coordinate public funding of research. In November 2016 the Government announced the formation of the Energy Innovation Board to provide strategic oversight of all energy innovation programmes and coordination of energy innovation activity.

The creation of the Nuclear Innovation and Research Advisory Board (NIRAB) in 2014 provided a forum to aid coordination across public and private sector research. NIRAB ended its three year tenure in December 2016 and there is no confirmed successor that can provide an equivalent forum.

These new mechanisms are in addition to those already in place by individual funders, e.g. the NDA Research Board.

Research facilities

Government has invested around £60 million in new UK nuclear research facilities since the last landscape review, and has announced significant funds for future enhancement of the facility base. In doing so Government has made significant progress in addressing a conclusion from the last review of a paucity of facilities for handling radioactive materials.

International collaboration

The UK is engaged in international collaborative research programmes and has a number of agreements with leading nuclear nations, but there is no overarching strategy or coordination mechanism in place to direct future collaboration activity.

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1 Introduction

1.1 Background

The Nuclear Innovation and Research Advisory Board (NIRAB) was tasked by Government to undertake a survey of the civil nuclear research and development (R&D) landscape. This comprises an update to the review published by Government and overseen by the Government's Chief Scientific Advisor in 2013[1]. The previous review provided Government with, for the first time, a comprehensive view of the landscape of public sector organisations that fund and conduct civil nuclear research. It provided a useful picture of the policy landscape, funding sources, magnitude, location and focus of R&D being undertaken in the UK and the level of experience of the R&D community.

1.2 Purpose

This survey presents data which is, as far as possible, comparable with the 2013 review[2] so that Government can identify trends and assess the impact of interventions. As well as providing data for Government, the survey seeks to present a useful overview for the UK's community of researchers of the funding sources for nuclear R&D, detailing where research is being undertaken and the focus of that research.

1.3 Scope

This survey is limited in scope to the civil nuclear energy sector in the UK. Whilst many of the organisations involved in civil nuclear R&D in the UK also perform research in the nuclear defence sector, defence R&D is excluded from the data presented here. The survey includes both civil nuclear fission and fusion research.

Source information has been gathered using both a 'top down' approach, where Government departments and agencies have provided data on their R&D expenditure, as well as a 'bottom up' approach with UK companies, universities and national laboratories providing information through a questionnaire. The questions sought to elicit the number and experience levels of researchers, the focus of the research and the value and sources of funding in the 2015/16 financial year (April to March). This survey includes responses from: 25 industrial organisations (compared to 21 in the previous review), 4 national laboratories (2 fewer organisations than previously) and 32 universities responded to the survey (compared to 32 in the previous review – although not all the same 32 institutions). The data has been compiled by the Nuclear Innovation and Research Office (NIRO) on behalf of NIRAB.

When presenting funding data the emphasis is on taking a one year snapshot for 2015/16 as a basis for comparison with the previous snapshot. Data has also been gathered on the level of public funding for each of the intervening years since the previous review.

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/168039/13-631-a-review-of-the-civil-nuclear-r-and-d-landscape-review.pdf

[2] The previous landscape survey *A Review of the Civil Nuclear R&D Landscape in the UK (BIS/13/631)* was published in 2013; the UK Government expenditure data presented in the 2013 report was for the 2010/11 financial year. The number of FTEs undertaking research reported in the 2013 report was for 2011/12. Hence, throughout this updated survey the reader should note that all previous landscape review data is from the 2013 published report even when 2010/11 funding or 2011/12 FTE data is discussed.

The data is presented and commentary made where there are significant changes from the 2013 review. This report, however, does not attempt to analyse any underlying causes for changes, or attempt to assess the impact of Government interventions or policy decisions.

1.4 Structure of document

This survey is structured in six sections (Chapter 2 to Chapter 7), with the first of these sections focussing on presenting the data collated from this survey. This data is compared to that presented in the previous 2013 landscape review, where appropriate, and comment made on changes and trends observed in the data. The six sections are:

The UK's Civil Nuclear R&D Landscape

Chapter 2 presents data on funding for civil nuclear R&D in the UK. Annual expenditure by Government departments and agencies is summarised for each year from 2012/13 to 2015/16. The extent of industry and overseas funding is also presented to indicate the balance of source funding. A comparison to other countries is also made using data from the Organisation for Economic Co-operation and Development (OECD).

Chapter 2 then presents data on civil nuclear R&D capability for 2015/16. Number of full time equivalent (FTE) researchers per research theme, level of experience and geographical location in the UK is quantified.

Objectives for civil nuclear R&D in the UK

Chapter 3 outlines Government and private sector objectives for nuclear energy, with a particular focus on where R&D is required to meet those objectives.

Institutional landscape of nuclear R&D in the UK

Chapter 4 describes the structure of the civil nuclear sector in the UK and the institutional landscape for R&D, including Government departments and agencies responsible for nuclear energy, waste management and decommissioning.

Coordination of nuclear R&D in the UK

Chapter 5 describes the mechanisms currently in place in the UK to coordinate research activity.

International collaboration in nuclear R&D

Chapter 6 summarises developments in UK involvement in international collaborations.

Facilities for civil nuclear R&D in the UK

Chapter 7 gives an overview of the additions to the research facility base in the UK, focussing on where there has been Government investment over the past three years. This is not intended to be a comprehensive record of the UK's civil nuclear research infrastructure, but to highlight those new additions to the research base to assist in assessing the impact of Government interventions.

The UK's Civil Nuclear R&D Landscape

This survey presents data so that Government can identify trends and assess the impact of interventions.

2 The UK's Civil Nuclear R&D Landscape

This section of the document presents the data collected on the level of funding for and the capability deployed on civil nuclear research during 2015/16. The data is presented graphically with commentary to highlight key points. There is a significant amount of data presented but there are a few key messages that arise from assessment of the data. For clarity, a summary of the key messages is presented up-front:

Funding:

- The figure for total funding (public, private and overseas) for civil nuclear R&D in the UK in 2015/16 was around £217 million.
- Overall public sector funding for civil nuclear R&D varied throughout the intervening period, but was lower in 2015/16 than the 2010/11 funding data presented in the 2013 review.
- Public funding for nuclear fission and fusion R&D programmes, provided by the NDA (direct), Innovate UK and the Research Councils, has remained relatively stable on an annual basis since the last landscape review in 2013. However there have been fluctuations in total annual expenditure where Departments (formerly BIS and DECC) provided one-off funding for research infrastructure.
- In the fission sector, research funding was dominated by the NDA and its Site License Companies (SLCs) and focussed on waste management and decommissioning. There has been a decrease in expenditure through NDA SLCs when compared to 2010/11 as reported in the previous landscape survey.
- In the fusion sector, the majority of funding is from the EU, with the remainder from the UK Research Councils.
- The UK's annual public expenditure on nuclear R&D is significantly lower than major OECD nuclear nations.

Capability – FTEs and experience:

- Overall there has been an increase of approximately 19% in the number of FTEs engaged in civil nuclear research in the UK to 3170 FTEs since the last landscape review in 2013, with the greatest increase in those conducting research related to decommissioning.
- The total FTEs working on R&D related to advanced reactor systems (117) and fuel fabrication (92) remain very low. The low level of research activity in these areas was highlighted as a concern in the 2013 landscape review.
- There has been a 5% increase in the number of researchers in our national laboratories. In both fusion and fission laboratories there has been a significant loss of more experienced staff.
- Universities have seen the greatest increase in FTEs. Research activity is dominated by a small number of universities with large research groups; the seven universities

with the most FTE staff engaged in civil nuclear R&D have almost all at least doubled their numbers since the 2013 review.

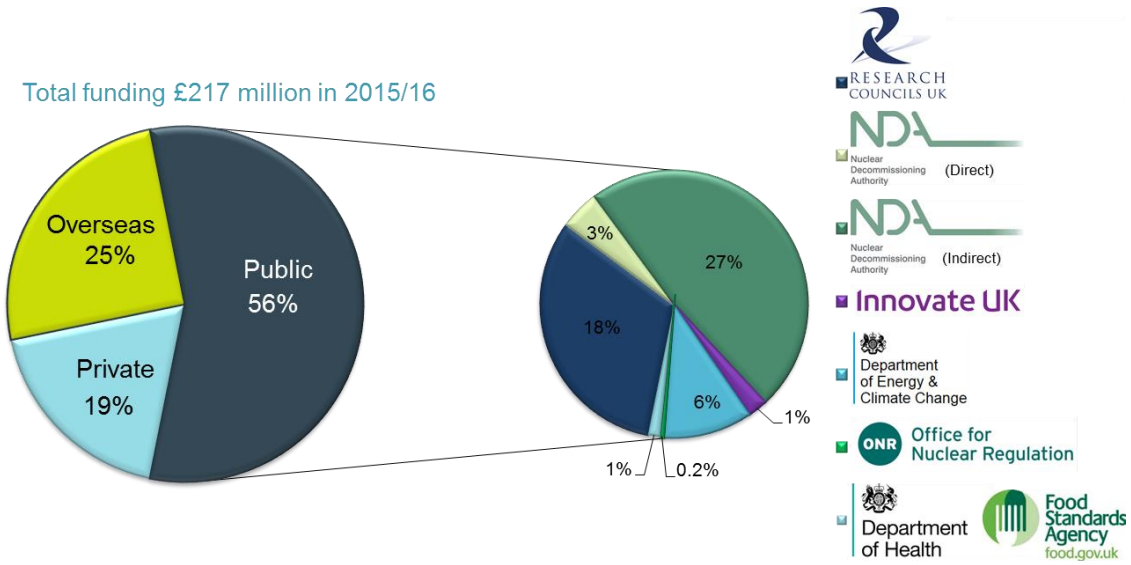
The following pages present a summary of the funding and capability data collated as part of this survey and provided by industry, national laboratories and universities. A comparison is made, where appropriate, to the data presented in the previous landscape review published in 2013. Figure 1 to Figure 5 present the funding data with accompanying commentary, the data included in each of the figures is as follows:

Figure 6 to Figure 17 present the capability data with accompanying commentary, the data included in each of the figures is as follows:

The UK's Civil Nuclear R&D Landscape: Funding

Total funding for civil nuclear R&D in the UK for 2015/16 was around £217 million.

Figure 1. Sources of funding for the total UK civil nuclear R&D portfolio



- The data collected as part of this landscape survey suggests the total funding for nuclear R&D in the UK for 2015/16 was around £217m. Equivalent data, for private and overseas funding, was not presented in the previous 2013 landscape review. Private and overseas funding data has been collated from responses to this survey. Public funding data has been provided by the relevant Government department.
- 25% (around £54m) of funding for civil nuclear R&D in the UK is from overseas sources.
- 56% (around £122m) of funding for UK civil nuclear R&D is public funding. The majority of public funding is from the NDA SLCs[3] (NDA indirect) with the Research Councils UK (RCUK) also providing a significant contribution.
- 19% (around £41m) of funding for civil nuclear R&D in the UK is from private sources. Private funding includes industry and also self-funding from universities and national laboratories.

[3] NDA SLCs includes Radioactive Waste Management Ltd (RWM), Sellafield Ltd, Low Level Waste Repository Ltd (LLWR), Magnox Ltd and Dounreay Site Restoration Ltd (DSRL).

Figure 2. UK Government expenditure on civil nuclear R&D in 2015/16 and comparison to 2010/11 funding

UK Government expenditure on nuclear R&D in financial year 2015/16

Total fission (£95.7m)[a]	Total BIS (£17.4m)[b]	EPSRC (£12m)
		STFC (£0.1m)
		NERC (£2.4m)
		Innovate UK (£2.9m)
	Total DECC (£77.8m)	NDA Direct (£5.8m)
		DECC Direct (£13.1m)
		NDA Indirect (£58.9m)
	Total DWP (£0.5m)	ONR (£0.5m)
Total fusion (£24.6m)	Total BIS (£24.6m)	EPSRC (£24.6m)
Total other (£1.9m)	Total DoH (£0.3m)	PHE (£0.3m)
	Total FSA (£1.6m)	FSA (£1.6m)
	Total Defra (no response)	EA (no response)

UK Government Expenditure on Nuclear R&D in 2010/11 and 2015/16

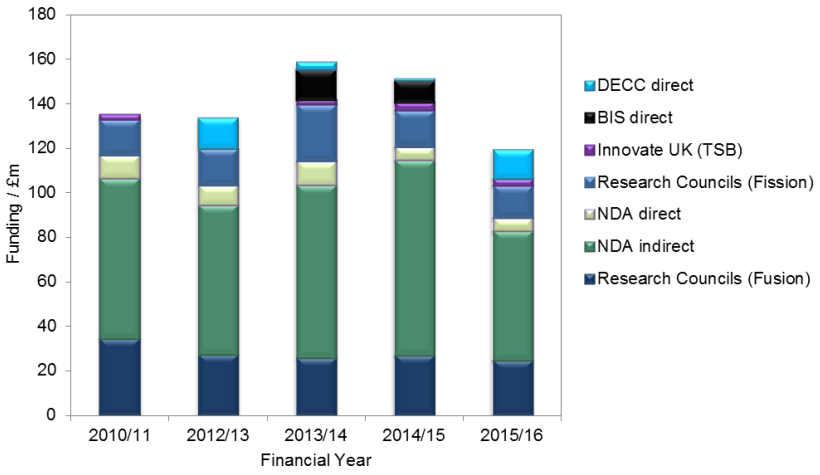
	2010/11	2015/16
Fission NDA Estate	£82.5m[c]	£64.7m
Fission Other	£18.1m	£31m
Fusion	£33m	£24.6m
Other	£4m	£1.9m
Annual Total	£140.6m	£122.2m

[a] The Government also funds nuclear R&D in the UK indirectly through its contribution to the EU budget and therefore to the Euratom programme and other nuclear-related elements of Horizon 2020 Programme (these indirect contributions are excluded from the table).
[b] BIS also provided research funding to universities through their Higher Education Funding Council for England (HEFCE) research allocation. The total amount (for all areas of research and all universities) was £1,558m in 2015/2016. It is not possible to disaggregate this figure to provide data on nuclear R&D. The same situation applies to the funding councils of devolved administrations.
[c] The 2013 civil nuclear R&D landscape review incorrectly reported an R&D spend for NDA SLCs of £121.3m. This value was actually for the total NDA Estate (direct and indirect) 09/10 spend as reported in the House of Lords Select Committee on Science and Technology Report on Nuclear Research and Development Capabilities published in 2011. In addition, the 09/10 value was based upon the best available information at the time and utilised spend that could qualify for R&D Tax Credits. Subsequently an improved methodology for identifying R&D spend (which more accurately reflects the level of research taking place) has been implemented by the NDA and updated values using this new methodology are now reported for 10/11 in line with the methodology used for the 15/16 values. NDA direct R&D was £10.9m in 2010/11, collated estimates for indirect R&D spend in 2010/11 was £71.6m. Estimated indirect R&D spend (spend across the NDA estate, excluding spend by NDA headquarters) in 2015/16 was £58.9m and direct spend (spend by NDA headquarters) was £5.8m.

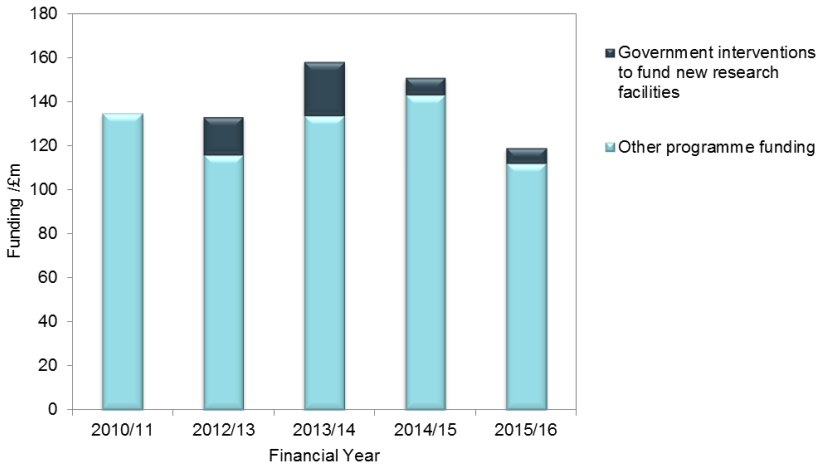
- The annual level of publicly funded nuclear R&D in 2015/16 (£122.2m) is less than Government funding on civil nuclear in 2010/11 (£140.6m). This is mainly due to a reduction in the overall spending for the NDA SLCs as a consequence of progress in establishing their technical baseline for decommissioning. Excluding the NDA SLCs, public funding for nuclear R&D programmes has remained stable between 2010/11 and 2015/16.
- Public funding for fission research, excluding NDA Estate, was £12.4m greater in 2015/16 than 2010/11. This increase is largely dominated by one off capital (£7m) and strategic investments by DECC.
- Fusion research funding appears to have reduced by around £8m between 2010/11 and 2015/16. However, this is an anomaly in the 2010/11 data due to a grant payment being held over from 2009/10 being paid in 2010/11. RCUK indicate that public funding for fusion has actually been stable at around £25m per annum for the past ten years.

Figure 3. Annual UK Government expenditure on civil nuclear R&D between 2010/11 and 2015/16

UK Government expenditure on civil nuclear R&D between 2010/11 and 2015/16 by funding body



UK Government expenditure on civil nuclear R&D between 2010/11 and 2015/16 showing proportion of programme funding and interventions to fund new facilities

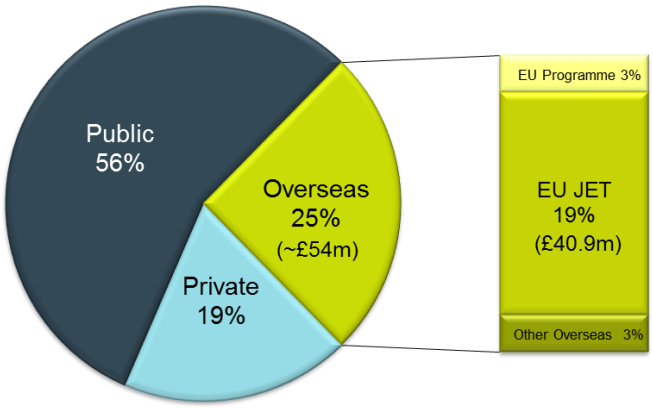


Note: data in the charts excludes Department of Health, Department of Work and Pensions, Food Standards Agency and Defra funding

- NDA funding consistently makes up over 50% of the total UK Government funding for civil nuclear R&D between 2010/11 and 2015/16. It has fluctuated between £64m and £94m over this period.
- Programme funding from RCUK, Innovate UK and NDA direct has remained relatively consistent between 2010/11 and 2015/16. NDA direct funding decreased slightly from 2014 onwards, this is due to RWM being reclassified as a subsidiary of the NDA in 2014; hence the RWM spend (~£6m per annum) from 2014/15 onwards is no longer classified as NDA direct funding but now classified as NDA indirect funding.
- Between 2012/13 and 2015/16 Government made interventions (through BIS, DECC and RCUK) and invested approximately £60m in total in new nuclear research facilities (see Chapter 7).

Figure 4. Overseas funding for civil nuclear R&D in the UK

Origin of overseas funding for nuclear R&D in the UK



UK Participation in Euratom Research Projects

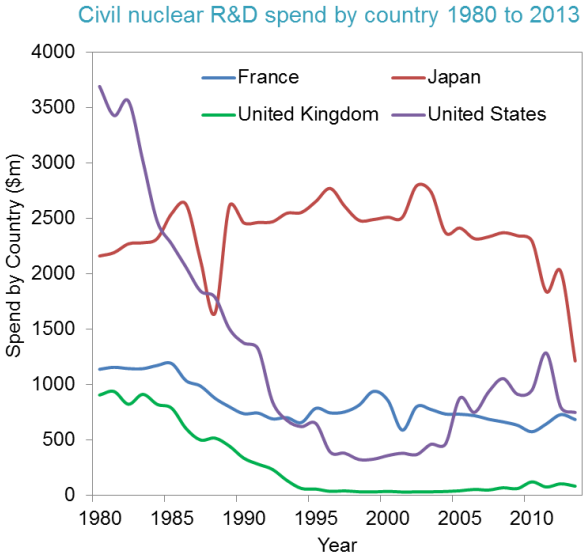
Number of Projects with UK Participants[a]	Approx. Combined Value of Projects per Annum[b]	Approx. Total EU Contribution to Projects per Annum[b]	Approx. Total EU Contribution to UK for Projects per Annum[b]
43	€235m	€124m	€9m

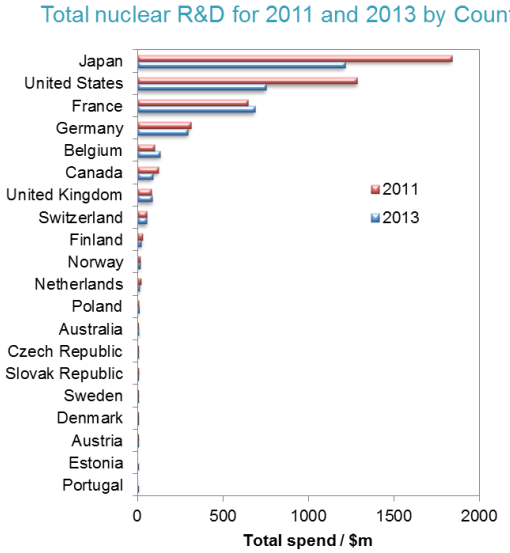
[a] FP7-Euratom and H2020-Euratom projects live between 1st April 2015 and 31st March 2016.
[b] Live projects have start dates from 2011 to 2016 and a range of project durations. The longest project duration is six years with an average project length of around 3.5 – 4 years. The annual value is calculated taking the total value for the duration of the project and assuming a linear spend profile. The total value presented in the table is the sum of the annual value per project for all live projects.

- Overseas funding totals around £54m. The majority of this funding originates from the EU and is dominated by the €56m (£40.9m[4]) per year paid to the United Kingdom Atomic Energy Authority (UKAEA) in relation to the Joint European Torus (JET) project.
- EU funded nuclear research in the UK, in addition to JET, is primarily through involvement in Euratom programmes. Data presented was obtained from the European Commission (EC) Community Research and Development Information Service (CORDIS) database for projects that were live between 1st April 2015 and 31st March 2016 and which had at least one UK participant.
- A total of 43 projects with UK involvement were identified. The available data show that the UK participates in projects with an approximate total annual value of €235m, around €124m of this coming from the EU (€111m from participants) and of the €124m EU contribution approximately €9m in total per year is paid to UK participants.
- The annual EU project funding received by the UK is dominated by the EUROfusion project (EUROfusion started in 2014 and will complete at the end of 2018 with a total project value of €857m); the project has an approximate total annual value of €170m, around €85m of this annual value comes from the EU and of the €85m EU contribution approximately €5.5m in total per year is paid to UK participants (UKAEA) – this is in addition to the €56m per year paid to the UK for the JET contract.

[4] An average rate of exchange of 1.37 euros per £1 has been used for the 2015/16 financial year taken from: *HMRC foreign exchange rates:yearly averages and spot rates* (https://www.gov.uk/government/publications/exchange-rates-for-customs-and-vat-yearly)

Figure 5. A comparison of UK public funding for civil nuclear R&D with other OECD countries





Data extracted December 2016 from OECD iLibrary: http://www.oecd-ilibrary.org/energy/data/iea-energy-technology-r-d-statistics/rd-d-budget_data-00488-en.
IEA (2016), "RD&D Budget", IEA Energy Technology RD&D Statistics (database). DOI: http://dx.doi.org/10.1787/data-00488-en

- Assessment of (Government) funding data, submitted to the OECD International Energy Agency (IEA) database, from 1980 onwards shows a continuous decline in UK nuclear R&D funding from 1980 to around 2000. Since 2000 there has been a gradual but modest increase in funding. However, in 2013 (latest data available from the IEA) funding remained at only 9% of the level spent in 1980.
- This decline is also seen in the historic spend profile of other leading nuclear nations e.g. France and the United States of America (USA), but whose current funding levels remain high (i.e. above $500m per year).
- The UK expenditure on nuclear R&D is low relative to other OECD nuclear nations involved in developing future nuclear reactor technologies. In 2013, the UK had the 7th largest total nuclear R&D budget of the OECD countries (note the data above does not include South Korea, or non-OECD nations Russia, China and India, all of which have significant nuclear research budgets.)

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The UK's Civil Nuclear R&D Landscape:

Capability – FTEs, Research Focus, Experience and Geographical Spread

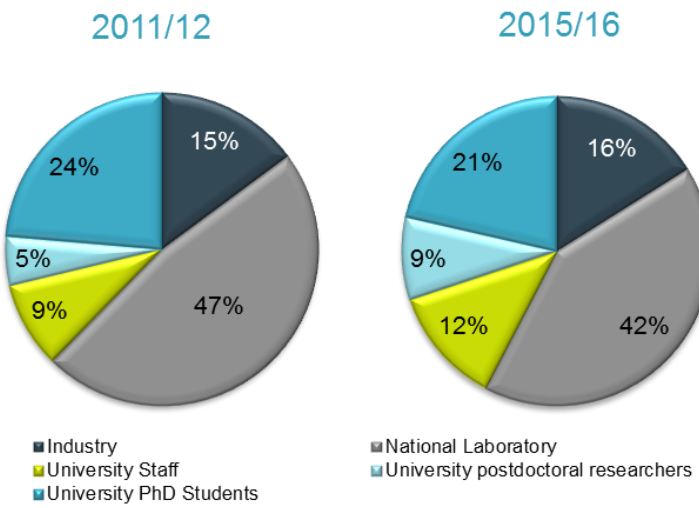
Overall there has been an increase in the number of researchers engaged in civil nuclear research in the UK since the last landscape review in 2013.

Total

Figure 6. A comparison of the total number of FTEs involved in civil nuclear R&D in the UK in 2011/12 and 2015/16

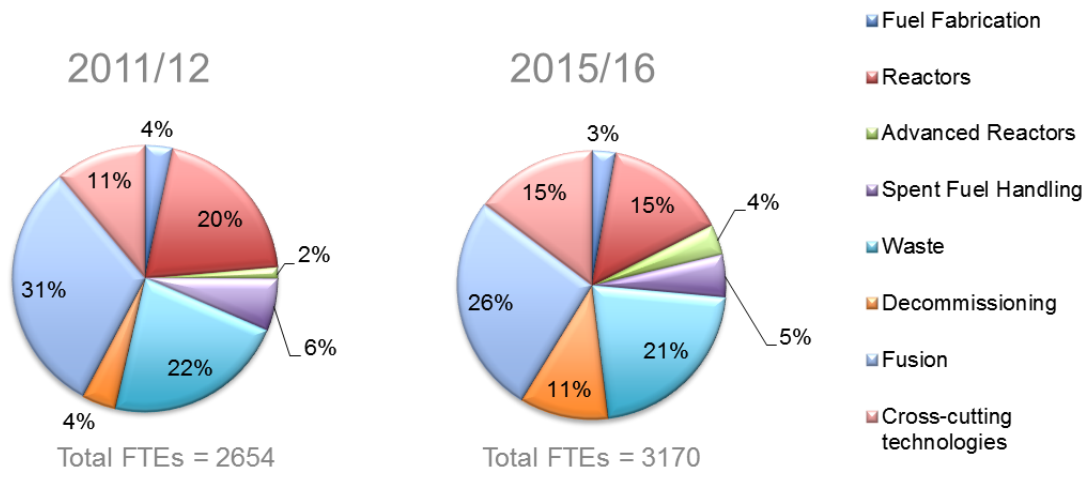
FTE nuclear R&D personnel in the UK in 2011/12 and 2015/16

		2011/12 FTEs	2015/16 FTEs	Difference
	Industry	394	509	+115
	National Laboratory	1260	1317	+57
	University	1000	1344	+344
UK University breakdown	Staff	238	391	+153
	Postdoctoral Researchers	134	274	+140
	PhD Students	628	679	+51
	Total	2654	3170	+516



- Overall there has been a 19% increase in the number of FTEs engaged in civil nuclear research in the UK relative to 2011/12 data.
- The data collected shows industry FTEs have increased by 29% between 2011/12 and 2015/16. Much of the increase is associated with industry organisations responding to this survey that were not included in the previous survey, though a number were actively engaged in R&D in 2011/12. The true increase in industry FTEs is likely to be lower than 29%.
- The number of FTEs carrying out civil nuclear research in academia has increased by 34%, including university staff (up 64%), postdoctoral researchers (up 105%) and PhD students (up 8%).
- There has been a 5% increase in the FTEs in national laboratories working on civil nuclear R&D.

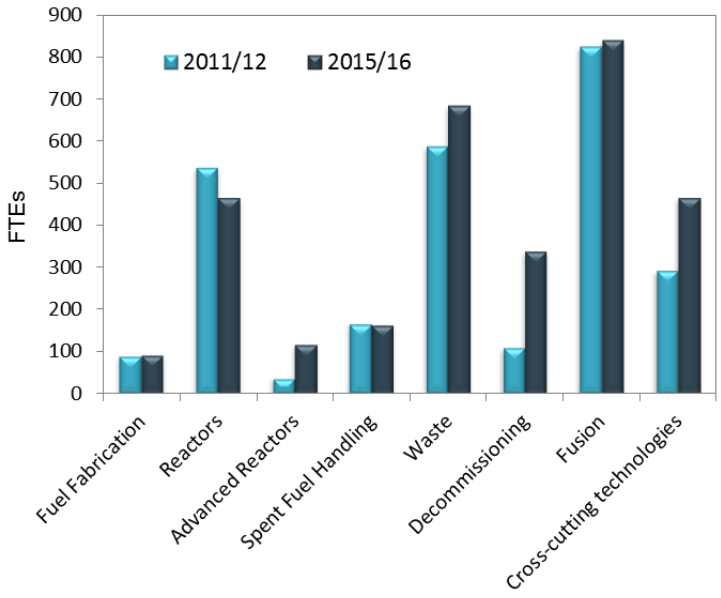
Total	Figure 7. A comparison of the research focus of FTEs involved in civil nuclear R&D in the UK in 2011/12 and 2015/16



Total FTEs = 2654

Total FTEs = 3170

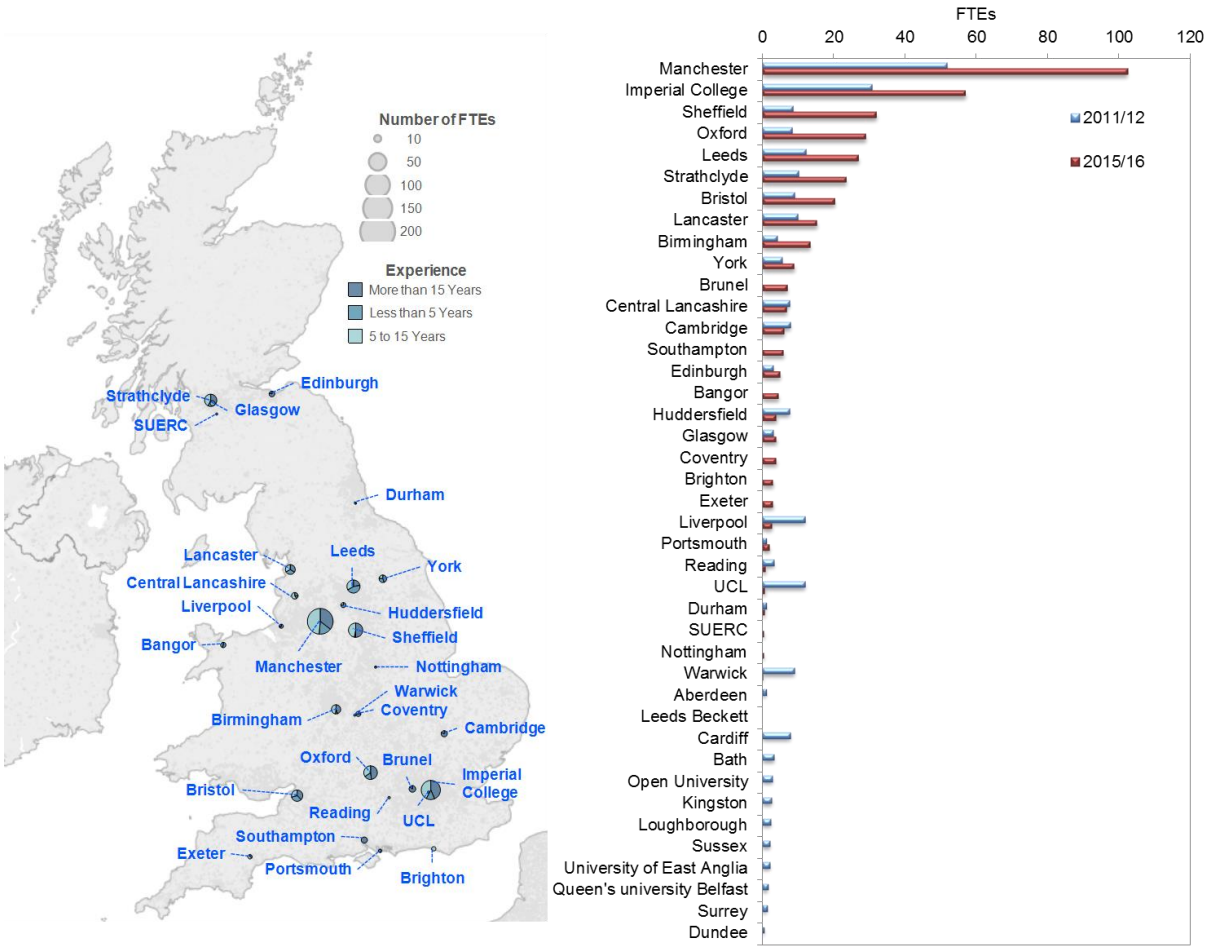
Note: Total FTEs include Phd and postdoctoral researchers



- The number of FTEs working on advanced reactor systems and fuel fabrication has remained very low, areas which were highlighted as concerns in the previous landscape review in 2013.
- The greatest increase in FTE research focus is related to decommissioning, which has seen a near threefold increase when compared to 2011/12.
- Research FTEs focussed on current reactors have decreased by 73 FTEs (13%).
- There has been a noticeable increase in FTEs engaged in cross-cutting technology research, these activities include robotics, modelling and simulation and energy system modelling. These are not unique to the nuclear sector.

University

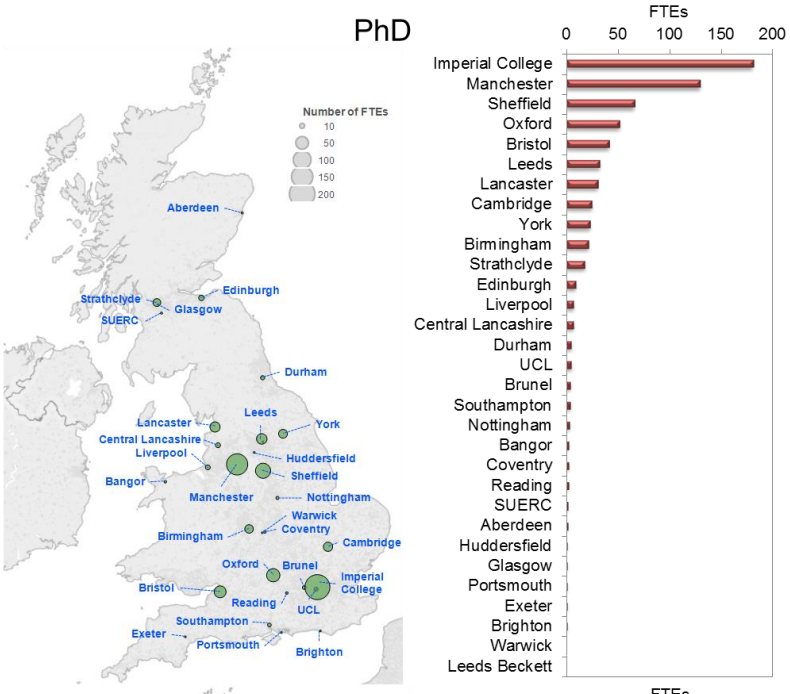
Figure 8. FTEs and geographical spread of UK university staff involved in civil nuclear R&D

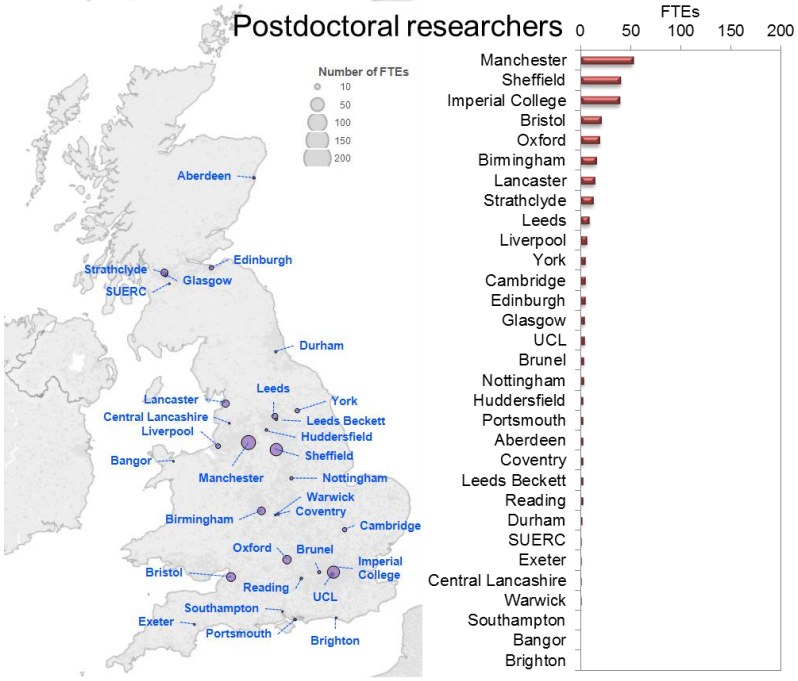


Note: Universities with multiple sites are shown at their primary location only

- There has been a significant increase in academic staff (238 to 390 FTEs) engaged in civil nuclear R&D between 2011/12 and 2015/16.
- Growth is observed across the majority of university respondents. Staff numbers in those universities already the most active in 2011/12 have increased significantly; of the seven universities with most FTEs nearly all have at least doubled their FTE numbers since the previous review.
- Eight new universities have reported as being actively engaged in nuclear research since the previous 2013 review, accounting for 7% of the total university staff FTEs.
- Whilst there are many universities engaged in nuclear research (32 respondents), almost 90% of the academic staff (FTEs) are in 10 universities.
- Ten universities that did report activity in 2013 have either not responded to the 2016 survey or have responded to confirm they no longer engage in nuclear research. Previously these universities accounted for 11% of the total university staff FTEs.

University	Figure 9. FTEs and geographical spread of PhDs and postdoctoral researchers involved in civil nuclear R&D in the UK

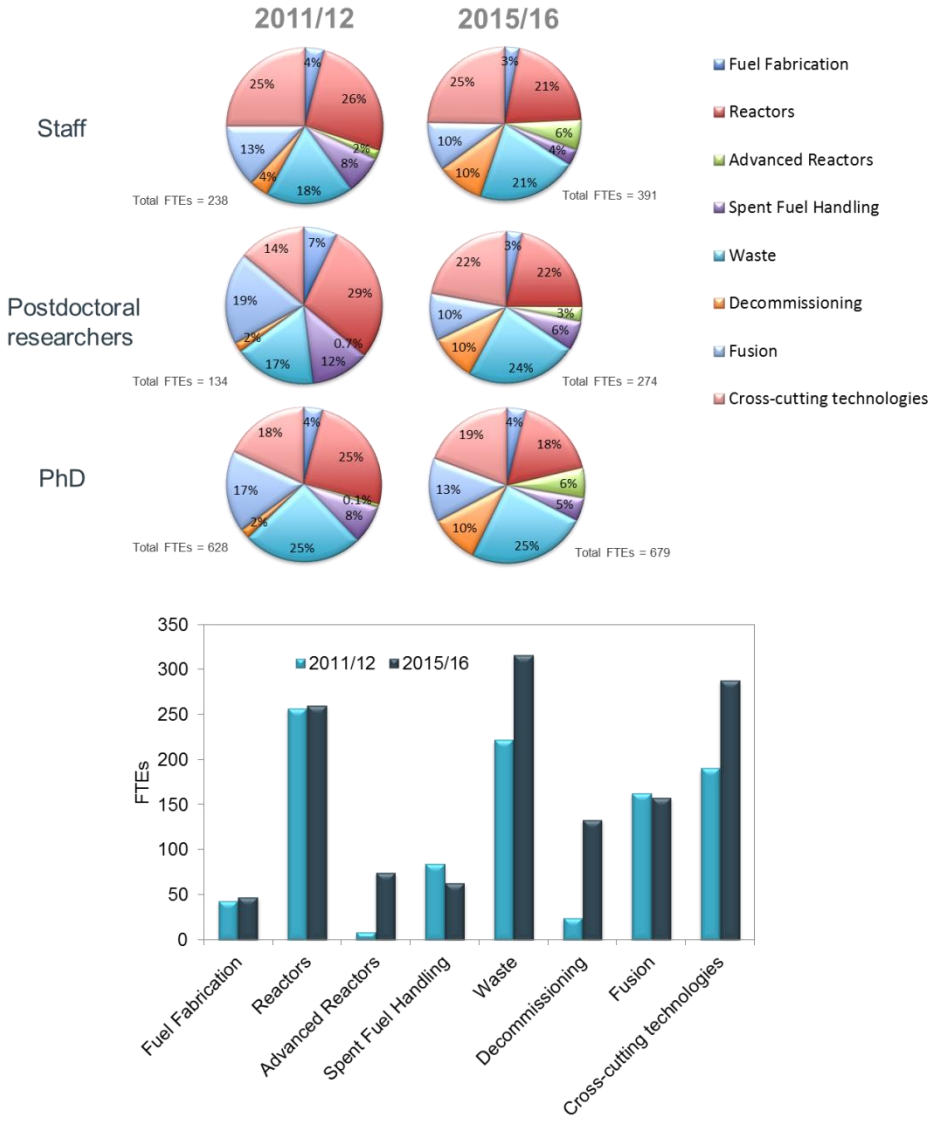




- There has been a significant increase in the number of PhD and postdoctoral researchers engaged in civil nuclear R&D between 2011/12 and 2015/16. In fact, the number of postdoctoral researchers has more than doubled since 2011/12.
- Similar to the data for academic staff, around 90% of the total numbers of PhDs are in 10 universities.
- In addition, around 85% of postdoctoral researchers are in 10 universities.

University

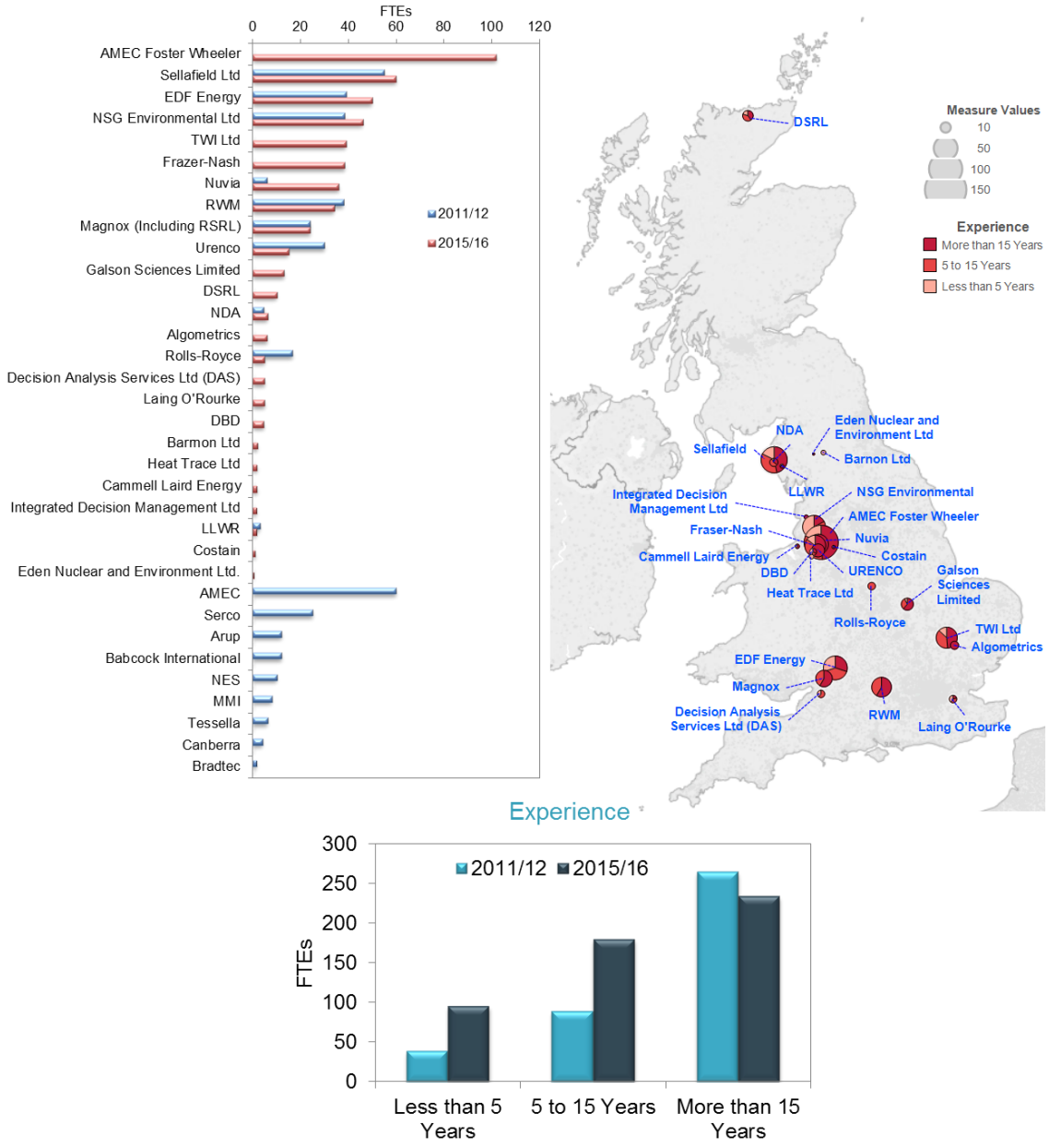
Figure 10. A comparison of UK university civil nuclear R&D research focus (FTEs) in 2011/12 and 2015/16



- Whilst the total FTEs in universities has increased, the distribution of research activity by theme remains broadly similar to 2011/12.
- Most research areas have seen an increase in university FTEs apart from spent fuel handling (down by 22 FTEs) and fusion (down by 5 FTEs). Waste, decommissioning and cross-cutting technologies have seen noticeable increases in the number of FTEs engaged in these areas.
- The distribution of research areas in postdoctoral and PhD research broadly aligns with that of university staff FTEs, as would be expected.
- The total number of Staff, PhDs and postdoctoral researchers working on fuel fabrication and advanced reactors remains low. Though there has been a modest increase in academic staff working on advanced reactors - 2% to 6% of the total R&D FTEs (this equates to an increase from 9 to 25 FTEs). There has also been an increase in PhDs focussed on advanced reactor technology from 0.1% (4 FTEs) to 6% (42 FTEs) between 2011/12 and 2015/16.

Industry

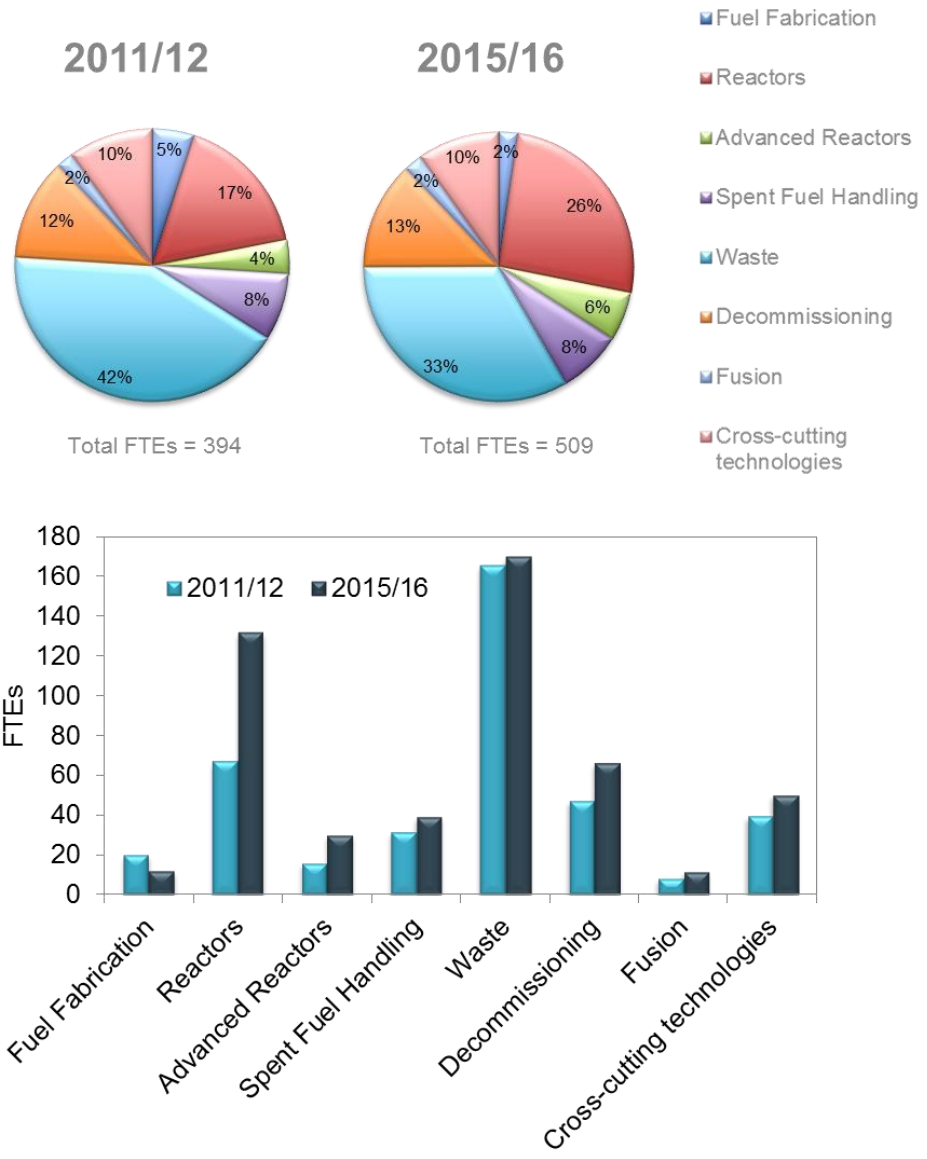
Figure 11. Total FTEs, geographical spread and experience of UK industry involved in civil nuclear R&D



- Assessment of the data show that 87% of industry researchers come from the 10 organisations with the most FTEs.
- The distribution of experience shows a significant increase in the less than five years category and the five to 15 years category. The number of FTEs in the most experienced category (greater than 15 years) has decreased slightly.
- Seven companies that did report activity in 2011/12 have either not responded to this survey or have responded to confirm they no longer engage in nuclear research. Previously these organisations accounted for 14% of the total industry FTE.

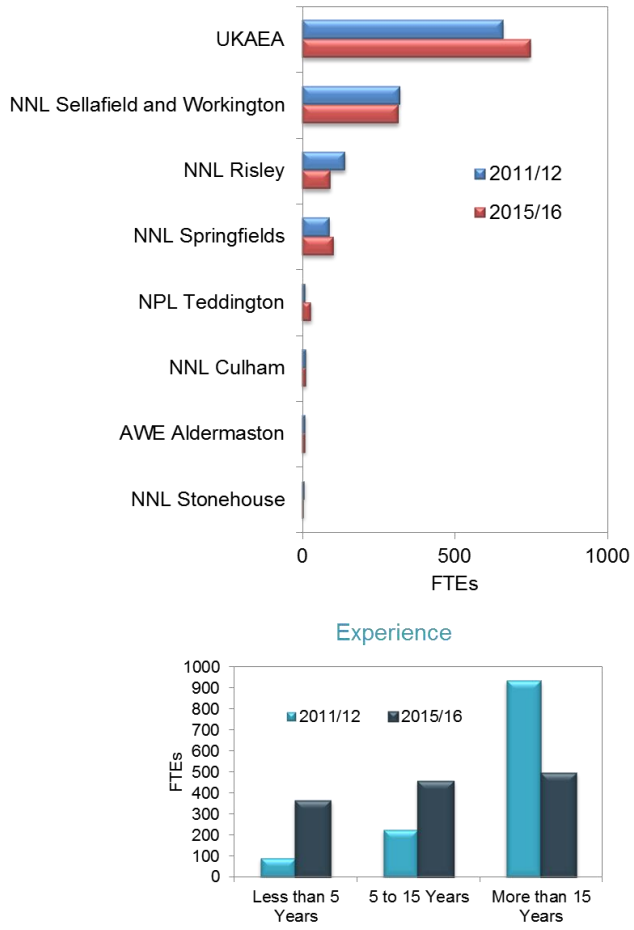
Industry

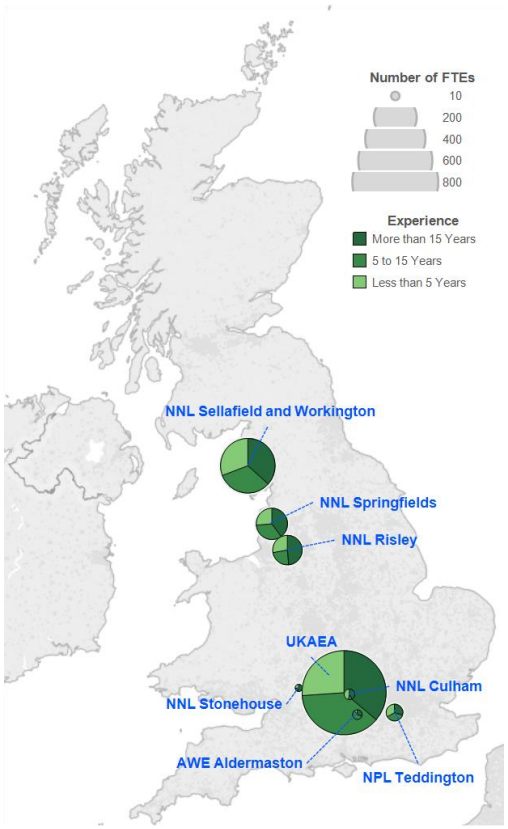
Figure 12. A comparison of UK industry civil nuclear R&D research focus (FTEs) in 2011/12 and 2015/16



- All research areas have seen an increase in industry FTEs other than fuel fabrication research, which has reduced from an already low number in 2011/12 of 20 FTEs to 12 FTEs.
- Industry FTE researchers involved in current reactor research have almost doubled from 67 to 132 since 2011/12.
- Industry FTEs researching advanced reactors remains a small proportion of overall activity (6%, 30 FTEs).

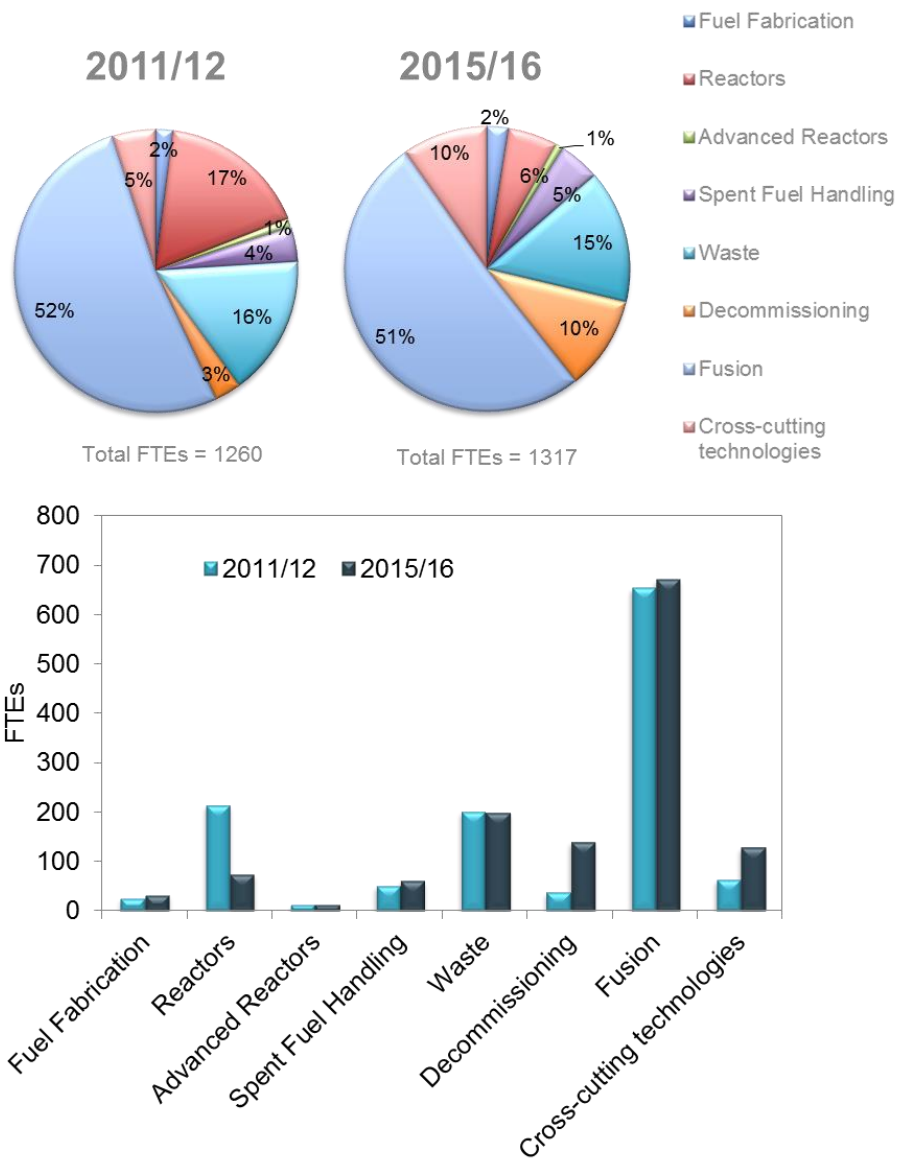
National Labs	Figure 13. Total FTEs, geographical spread and experience in UK national laboratories involved in civil nuclear R&D





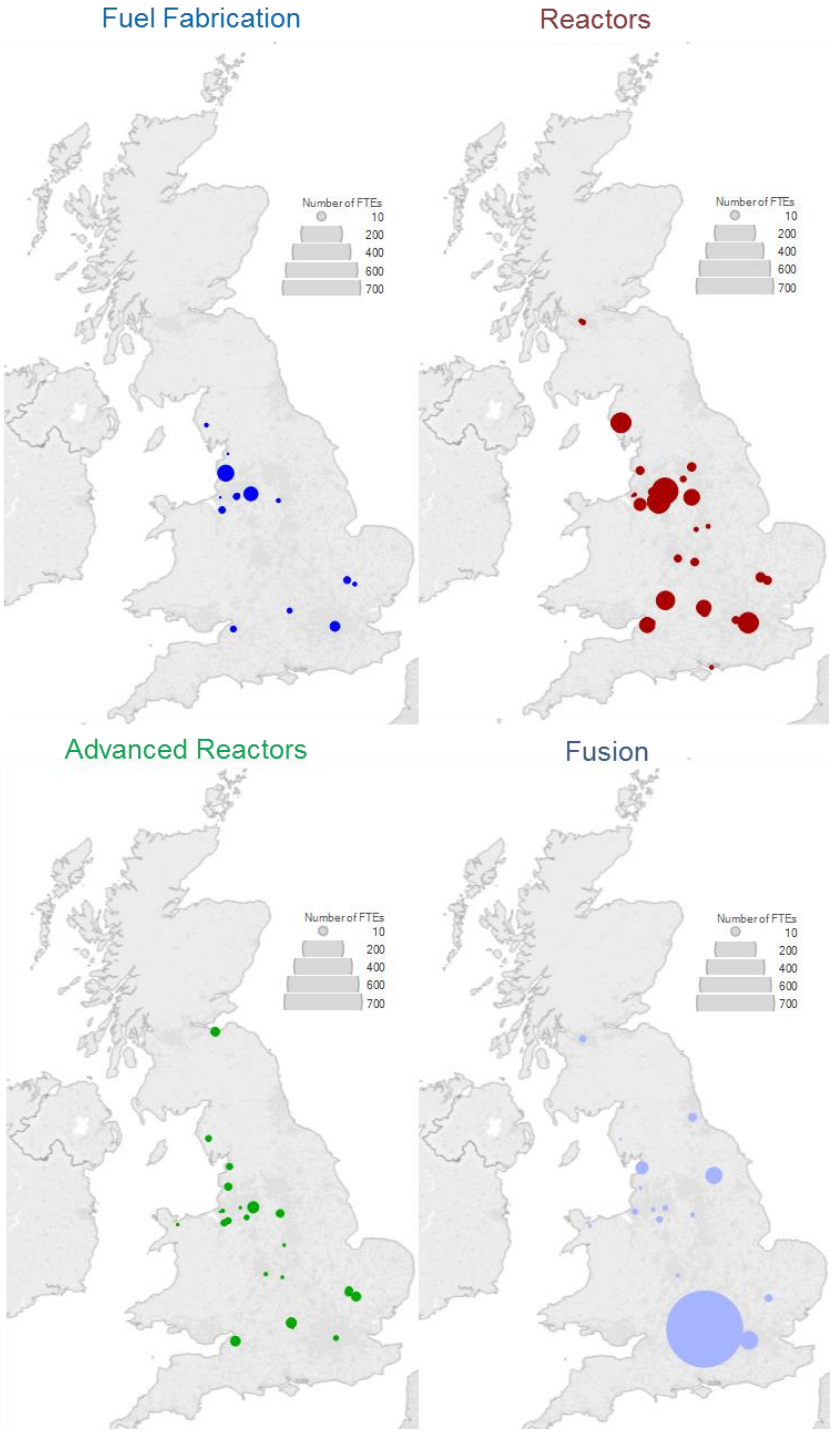
- National laboratory FTEs are mainly within the National Nuclear Laboratory (NNL) for fission related research, and UKAEA for fusion research. The majority of NNL researchers are based across 3 sites in the North West of England, and the entirety of UKAEA researchers based at the Culham site in the south of England.
- The data suggest a 7% decrease in fission (NNL) national laboratories FTEs. This decrease may be explained by NNL having taken a more rigorous approach to defining civil nuclear R&D activity in 2015/16 and also data in the 2013 review included FTEs engaged in defence research which are not included here.
- Although a small proportion of the total national laboratory FTEs, National Physical Laboratory (NPL) report an approximate threefold increase in researchers from 11 to 30 working on civil nuclear R&D. There has also been a 14% increase in the number of researchers working on fusion research at UKAEA.
- In both fission and fusion national laboratories there has been a significant loss of more experienced staff, which is known to predominantly have occurred through retirement. This is countered by an increase in FTEs with less than 5 years' experience in both fission and fusion national laboratories, and a significant increase in those with 5 to 15 years' experience in the fusion national laboratory. The effect of these changes is a more balanced distribution of experience.

National Labs	Figure 14. A comparison of UK national laboratory civil nuclear R&D research focus (FTEs) in 2011/12 and 2015/16



- Activity in fusion research remains broadly similar to 2011/12 levels, and accounts for just over half of national laboratory research. There has been a noticeable increase in FTEs engaged with decommissioning research. Activity related to fuel fabrication (32 FTEs) and advanced reactors (12 FTEs) remains low.
- In the fission sector, the data suggests a large reduction in current reactor research.

Figure 15. Geographical distribution of the total UK civil nuclear workforce in 2015/16 by research theme



- The geographical distribution by research theme has been collected for the first time and is presented for the eight research themes in Figure 15 and Figure 16. There is a significant geographical spread for all research themes except fusion where activity is concentrated at Culham in the south of the UK.

Figure 16. Geographical distribution of the total UK civil nuclear workforce in 2015/16 by research theme

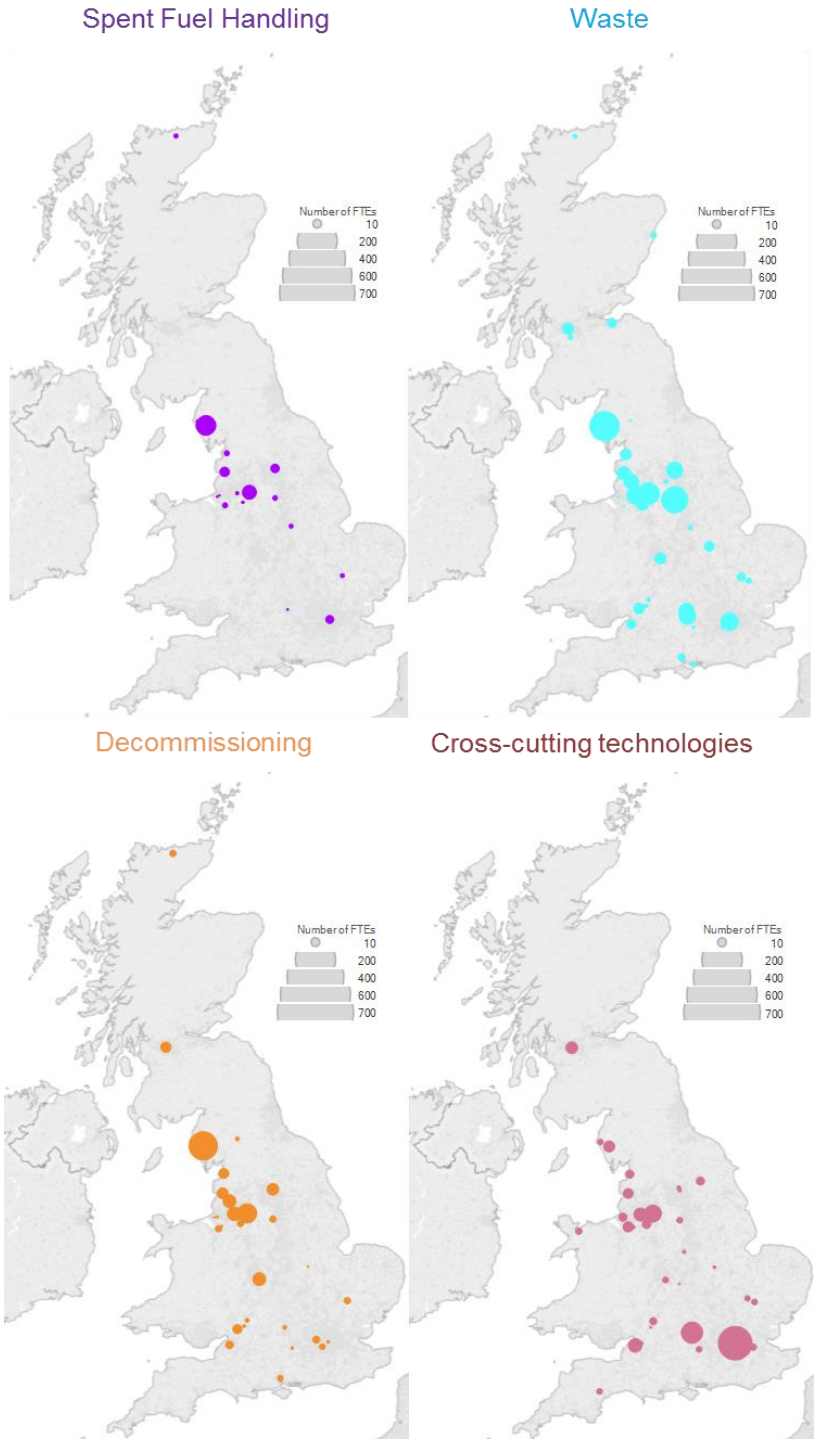
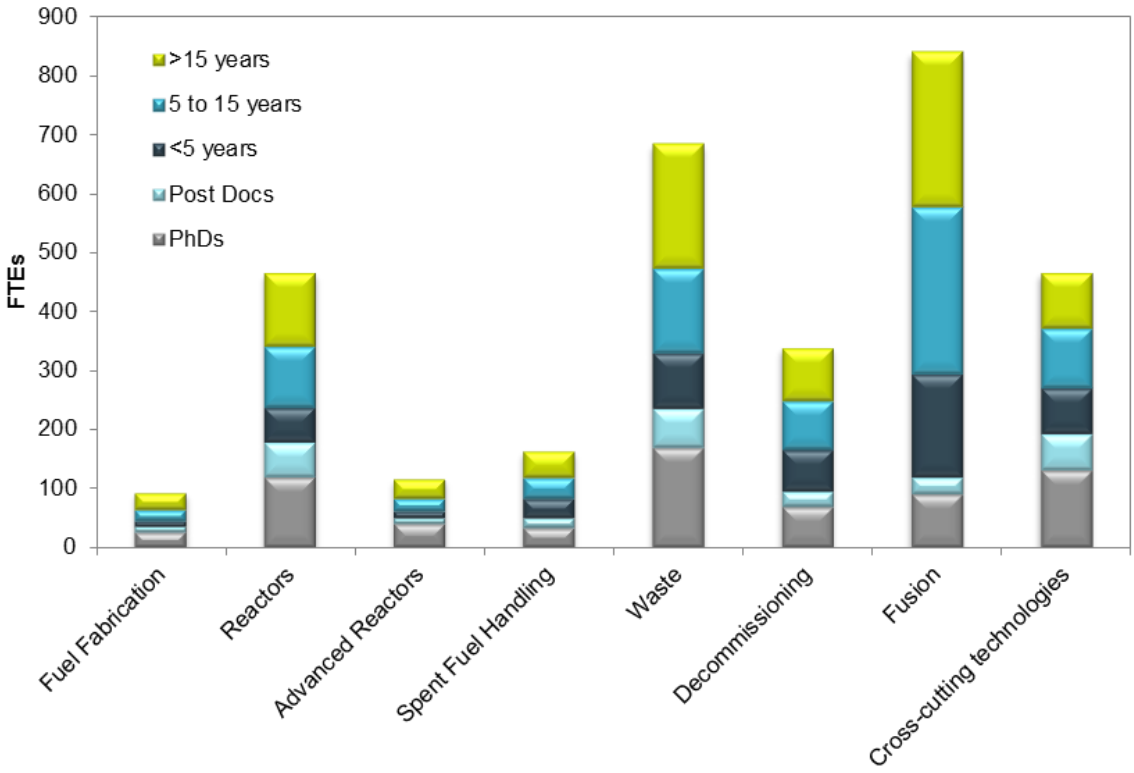
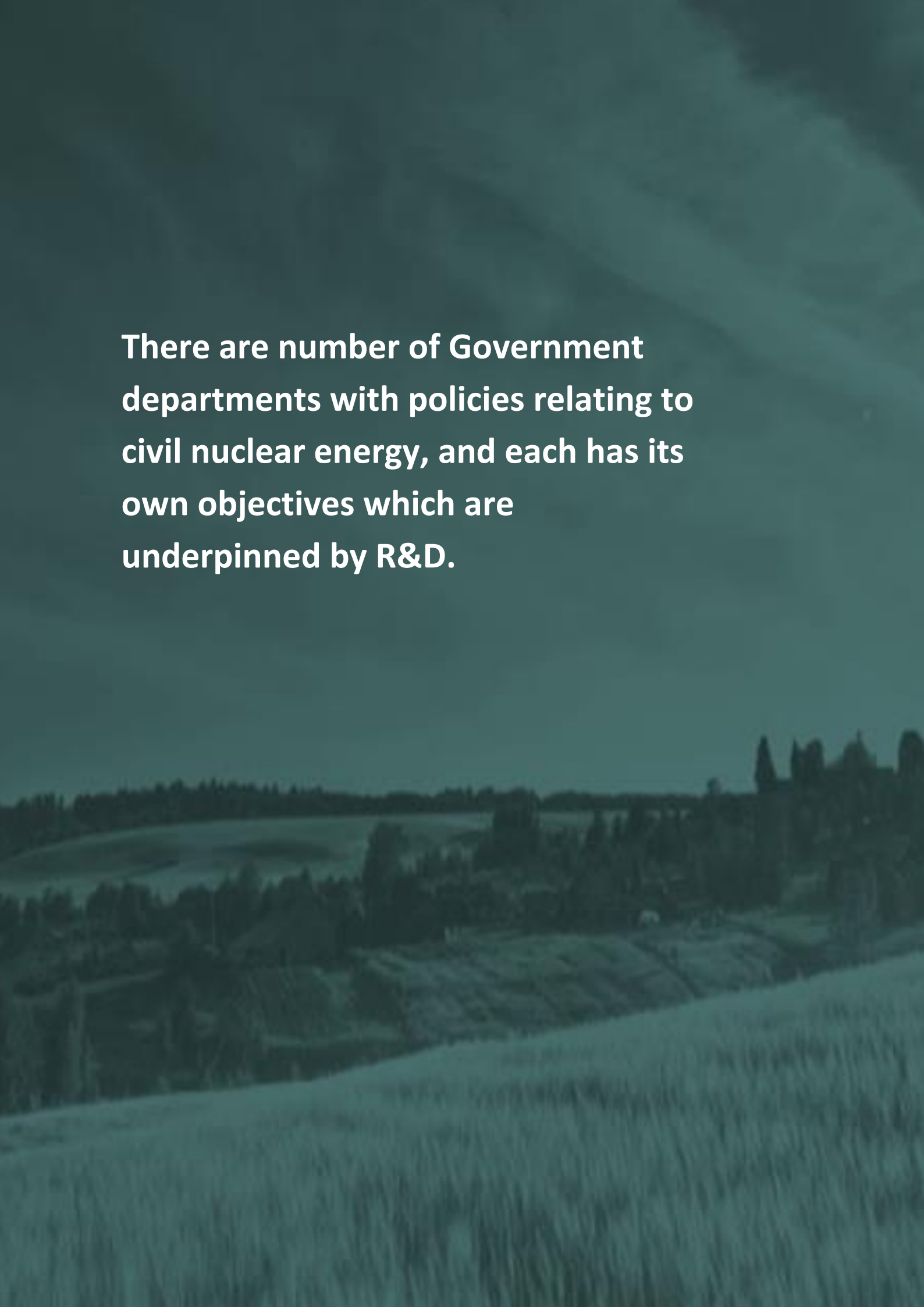


Figure 17. A breakdown of the experience of the total UK civil nuclear R&D workforce in 2015/16 by research theme



- The experience breakdown for the total UK civil nuclear R&D workforce is presented for the first time. It is difficult to draw conclusions from this single dataset but it will provide a baseline from which to compare data collected as part of future landscape surveys.
- As a general point, all the research themes have FTEs in each of the five experience categories.

Objectives for Civil Nuclear R&D in the UK



There are number of Government departments with policies relating to civil nuclear energy, and each has its own objectives which are underpinned by R&D.

3 Objectives for Civil Nuclear R&D in the UK

3.1 Public sector objectives for nuclear R&D

A number of Government departments have policies that relate to civil nuclear energy, and each has its own objectives which are underpinned by R&D.

The majority of policies relating to civil nuclear power belong to the Department for Business, Energy and Industrial Strategy (BEIS), formed in July 2016 following a restructure of the former Department of Energy and Climate Change (DECC) and Department for Business, Innovation and Skills (BIS). The Government's most recent statement of vision for nuclear energy[5] is to have a nuclear sector that:

- has safety and security as its highest priorities, with the UK leading the world in safe and secure operations across the whole fuel cycle.
- continues to contribute to a low carbon and secure energy future, with nuclear energy being deployed efficiently and effectively, competing successfully with other low carbon technologies.
- leads the way in successfully decommissioning redundant nuclear facilities, including the environmentally safe disposal of nuclear waste.
- contributes to employment and prosperity in the UK including by exporting to overseas markets, respecting the imperative of not proliferating nuclear weapons.
- continues to command public confidence, by operating safely, securely, sustainably and transparently.

The most recent statement of government nuclear research and development objectives[6] are:

- To have the right level of nuclear research and innovation to ensure near-term as well as long-term commercial success in domestic and global markets
- For the research base to be underpinned by world-leading facilities which are fully utilised by both national and international customers and which conduct a programme of fission-related research whose scale is consistent with the UK's nuclear aspirations
- To be a respected partner contributing significantly to appropriate international research programmes undertaken with selected international collaborators
- To have a joined up approach to nuclear research and innovation across government, industry and academia, which serves to benefit the UK economy and ensure security of supply.

Other Government departments with policies relating to civil nuclear energy are:

[5] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/168047/bis-13-630-long-term-nuclear-energy-strategy.pdf

[6] https://www.gov.uk/government/publications/nuclear-industrial-strategy-the-uks-nuclear-future

Foreign and Commonwealth Office (FCO) – objectives to enhance prosperity through promoting UK economic interests overseas. FCO also has responsibility for safeguarding the UK's national security by countering terrorism and weapons proliferation.

Department of Health (DoH) – objectives to understand the risk to health of the effects of radiation, supported by its agency Public Health England (PHE).

The Food Standards Agency (FSA) – objectives to understand the impact of radiological discharges in the UK on foodstuffs, and the safety and detection of irradiated food**.**

Department for Environment, Food & Rural Affairs (Defra) – objectives related to the regulation and management of radioactive and nuclear substances and waste. This is actioned through the Environment Agency (EA).

Department for Work and Pensions (DWP) – objectives related to health and safety, enacted through the Office for Nuclear Regulation (ONR).

3.2 Private sector objectives for nuclear R&D

The private sector shares Government's long-term vision for nuclear energy to play a significant role in the UK's energy mix by the middle of the century and beyond. From a commercial perspective the nuclear sector offers significant potential reward, and so R&D objectives in the private sector underpin business objectives.

Institutional Landscape of Nuclear R&D in the UK

The civil nuclear sector in the UK is complex, with a combination of public and private ownership and responsibilities for different aspects across the nuclear fuel cycle.

4 Institutional Landscape of Nuclear R&D in the UK

The civil nuclear sector in the UK is complex, with a combination of public and private ownership and responsibilities for different aspects across the nuclear fuel cycle.

4.1 Sectors of the civil nuclear industry

Waste Management and Decommissioning

Waste management and decommissioning responsibility for the UK's nuclear legacy which includes retired first generation power stations, fuel reprocessing facilities and some aspects of the UK's early defence programme is held by the Nuclear Decommissioning Authority (NDA), an executive non-departmental public body (NDPB) sponsored by BEIS.

Research is commissioned directly by the NDA in order to deliver potential improvements across the estate, and through its Site Licence Companies (SLCs) to support projects at individual sites.

Current Generation

Following the shutdown of the final first generation Magnox reactor at Wylfa in 2015, there are currently eight operational nuclear power stations in the UK (seven stations operating Advanced Gas Cooled Reactors and one station operating a Pressurised Water Reactor). EDF Energy operates all the UK's nuclear power stations and is part owned by the French Government. The operator is responsible for ensuring there is sufficient R&D to underpin safe performance and, where possible, extend the lifetime of its power stations.

Uranium Enrichment and Fuel Manufacturing

Enrichment activities in the UK are undertaken by URENCO, a company which is one third owned by UK Government and the remainder equally by the Dutch Government and two German utilities. Fuel manufacturing is undertaken by Westinghouse, a US company which is majority owned by Toshiba, a Japanese company. Research activity related to enrichment and fuel manufacture is predominantly done overseas within these organisations.

New Nuclear Build

The sector is on the verge of deploying a fleet of new reactors for the first time in two decades. This is a market led approach, with Government undertaking a number of facilitative actions to promote private investment, including delivery of national policy statements, regulatory justification, establishment of the Generic Design Assessment (GDA) process and waste and decommissioning financing arrangements.

Responsibility for the R&D to support the new third generation nuclear power stations to be built in the UK is held by the private sector organisations that are developing the sites. These organisations are consortia of non-UK companies that have access to significant experience in their native countries, specifically France, China and Japan. Their responsibilities cover all stages of the project from construction, commissioning, operations and decommissioning.

Future Nuclear Energy Technologies

The UK Government and industry have stated their vision for nuclear to continue to play a significant and increased role in the UK's energy mix by the middle of the century, which may require the development and deployment of advanced reactor systems different to those currently being built around the world. The UK Government policy for any future technologies is for the market to provide the technologies that can competitively be deployed, with Government providing facilitative actions as appropriate. However, given the long development time and high upfront investment required to commercialise new reactor systems and related fuel cycle infrastructure, Government has recognised it can play a role in supporting early stages of research.

The Government announced in 2015 its intention to commit at least £250 million to fund "*an ambitious nuclear research and development programme intended to revive the UK's nuclear expertise and position the UK as a global leader in innovative nuclear technologies. This includes a competition to identify the best value Small Modular Reactor design for the UK*". The budget for energy innovation transferred to BEIS upon the merger of BIS and DECC and at the time of writing BEIS is in the process of commissioning the first £20 million 2 year phase of research into future nuclear energy technologies. Phase 1 of an SMR competition was also launched in 2016 in which Government sought to engage with interested parties.

4.2 Government agencies and public bodies commissioning civil nuclear R&D

Several Government departments have policy objectives related to nuclear energy and are therefore involved in commissioning or are interested in the output of associated research activity, as outlined in Chapter 2. Departments enact their research needs directly or through a number of different agencies and public bodies, as shown in Figure 18. This section briefly describes the various Government bodies commissioning research; details of funding levels are given in Chapter 2.

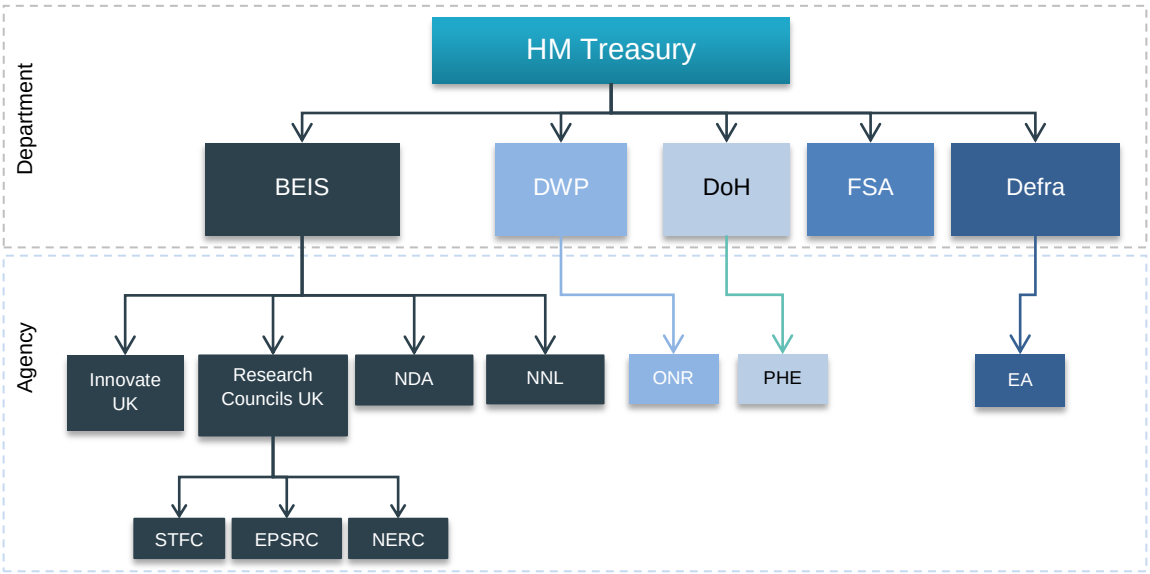


Figure 18. Government agencies and public bodies commissioning civil nuclear R&D

Department for Business, Energy and Industrial Strategy (BEIS)

BEIS is the Government department responsible for much of the UK's public spend on research and innovation. This is primarily done through agencies, but BEIS also commissions nuclear research directly through its Science and Innovation directorate's Energy and Innovation budget.

Innovate UK

Innovate UK is an executive NDPB, sponsored by BEIS. It was formerly known as the Technology Strategy Board until the trading name Innovate UK was adopted in 2014.

Innovate UK's remit is to 'fund and connect' by working with people, companies and partner organisations to find and drive the science and technology innovations that will grow the UK economy. Support is given in various forms including grant funding, public procurement contracts, networking and business advice. The strategic direction of Innovate UK is published as a five year strategy and a delivery plan is published annually. Competitions are launched against specific topics to allow organisations to apply for financial support.

Innovate UK has supported projects with a total value of around £30m over the last three years. It has helped to develop the UK supply chain and primarily supported Small and Medium Enterprises in relation to the NDA estate, life extension of existing plants and nuclear new build.

In 2016, the agency transitioned from a themed to a sector grouping approach to their programmes which are:

- Emerging and Enabling Technologies
- Health and Life Sciences
- Infrastructure Systems
- Manufacturing and Materials

Civil nuclear R&D has been prioritised as part of Innovate UK's strategy for the next four years delivered as part of its Infrastructure Systems programme which will continue to support the development of the nuclear supply chain. However, organisations undertaking civil nuclear R&D also have the opportunity to apply under the other themes where appropriate opportunities arise.

Research Councils

There are seven Research Councils classified as NDPBs who receive funding as part of the Science Budget administered through BEIS. They have a strategic partnership which aligns them under one non-department government body Research Councils UK (RCUK) which seeks to enhance the collective impact of a number of benefits including research.

The Research Councils' objectives are to:

- fund basic, strategic and applied research
- support postgraduate training (PhDs and masters students and fellows)

- advance knowledge and technology and provide services and trained scientists and engineers to contribute to the economic competitiveness, the effectiveness of public services and policy, and quality of life
- support science in society activities.

These organisations support academic level research through open and targeted calls for proposals. These projects of cutting edge science and commissioning world class facilities are funded through an open peer review process.

Several Research Councils fund activities related to civil nuclear energy, with the majority of funding flowing through the Engineering and Physical Sciences Research Council (EPSRC) led Energy Programme[7], which also includes research commissioned by the Natural Environment Research Council (NERC), and the Science and Technology Facilities Council (STFC). The Energy Programme includes both nuclear fusion and fission research.

UK Research and Innovation (UKRI) - proposed

The Higher Education and Research Bill 2016/17 proposes the creation of UKRI, a single, strategic NDPB that will bring together the seven Research Councils, Innovate UK and the research funding from Higher Education Funding Council for England (HEFCE). The Bill transfers to UKRI the roles, functions and responsibilities of these bodies. The Bill protects and maintains their remits and autonomy by establishing nine statutory councils within UKRI: the seven discipline research councils, alongside Innovate UK and a new Council – Research England.

UKRI will build on, and protect, the strengths and values of the current system, while creating a strong and unified voice, acting across disciplines. Its aim will be to improve collaboration and sharing of expertise, avoiding duplication and thus maximising the effectiveness of the system, improving value for money.

As of February 2017 the Bill is at the Report stage in the House of Lords.

Nuclear Decommissioning Authority (NDA)

NDA is an executive NDPB sponsored by BEIS, responsible for the safe and efficient clean-up of the UK's nuclear legacy. NDA owns 17 UK nuclear sites including their assets and liabilities. NDA primarily delivers its mission through SLCs and their supply chains, although the NDA does commission research directly where there is a cross-site benefit or need to do so. The budget for the NDA is formed from a combination of public funding and income from commercial contracts.

A significant change since publication of the previous Landscape is the shutdown of the last Magnox reactor at the NDA owned site at Wylfa, Anglesey, which represented the end of reactor operation at any NDA site.

National Nuclear Laboratory (NNL)

NNL is the UK's national laboratory for fission covering the whole of the nuclear fuel cycle. It is a government owned and operated public corporation and operates on a commercial basis, receiving no direct grant funding. By agreement with Government, NNL invests in

[7] http://www.rcuk.ac.uk/research/xrcprogrammes/energy/

areas of strategic national importance from its operating profits including into facilities, critical skills, innovation and R&D.

United Kingdom Atomic Energy Authority (UKAEA) and Culham Centre for Fusion Energy (CCFE)

CCFE is the UK's national laboratory for fusion research. CCFE is owned and operated by the UKAEA. UKAEA is an executive NDPB, sponsored by BEIS.

Fusion research at CCFE is funded jointly by Euratom and EPSRC.

Since the previous Landscape review in 2013, CCFE has increased the amount of research it carries out which is relevant to nuclear fission. CCFE is one of the host organisations for the National Nuclear User Facility (NNUF) and hosts the Materials Research Facility (MRF) which has been established to analyse material properties. MRF provides academic and industrial users with the resources to carry out micro-characterisation of neutron-irradiated materials (see Details of selected Government funded research facilities in section 7). UKAEA also hosts the Remote Applications in Challenging Environments (RACE) facility (see Details of selected Government funded research facilities in section 7).

Department for Work and Pensions (DWP)

Office for Nuclear Regulation (ONR)

ONR is responsible for regulation of nuclear safety and security across the UK. Its mission is to provide efficient and effective regulation of the nuclear industry, holding it to account on behalf of the public.

At the time of publication of the previous Landscape, ONR was an agency of the Health and Safety Executive (HSE), an NDPB sponsored by the Department for Work and Pensions. ONR was established as a statutory Public Corporation on 1 April 2014 under the Energy Act 2013. The Secretary of State for Work and Pensions has principal responsibility for ONR.

ONR uses research to support its independent regulatory decision making. Where necessary it commissions research to support this function.

Department for Environment, Food and Rural Affairs (Defra)

Environment Agency (EA)

EA is an executive NDPB, sponsored by Defra. It works to create better places for people and wildlife, and support sustainable development. EA is responsible for regulating major industry and waste management and the treatment of contaminated land. It is therefore responsible for granting site permits to operators, ensuring compliance with radioactive waste disposal regulations. It has limited funds for commissioning its own research, but as a key user of research output, it publishes its research priorities to inform external researchers and research funders[8].

[8] https://www.gov.uk/government/publications/collaborative-research-priorities-for-the-environment-agency-2015-to-2019

Department of Health (DoH)

Public Health England (PHE)

PHE is an executive agency, sponsored by the Department of Health. It aims to protect and improve the nation's health and wellbeing, and reduce health inequalities. It is a research-informed organisation that is driving forwards the provision and use of evidence for decision-making across the UK's public health system. PHE contributes to research into radiation protection issues.

The Health Protection Agency, which was listed as funding civil nuclear research in the previous Landscape review, became part of PHE in 2013.

Food Standards Agency

The Food Standards Agency is a non-ministerial Government department responsible for food safety and food hygiene in England, Wales and Northern Ireland. Part of its research portfolio investigates the impact of radiological discharges in the UK on foodstuffs, and the safety and detection of irradiated food. The majority of its 2015/16 radiological research funding was spent on food sampling and analysis with the remainder on research related to developing capability for assessing the impact to the public from radioactivity in food.

Coordination of Civil Nuclear R&D in the UK

NIRAB's remit included fostering greater cooperation and coordination across the whole of the UK's nuclear research and innovation capability.

5 Coordination of Civil Nuclear R&D in the UK

Coordination between public sector research funders

In 2013 Government formed the Low Carbon Innovation Coordination Group Nuclear Sub-Group (LCICG NSG) to coordinate public funding of nuclear research. There was no mechanism in place at the time of the previous Landscape review. The LCICG NSG consisted of members of BIS, DECC, Innovate UK, RCUK, NDA, MoD, FCO and was co-chaired by the Government Office for Science and DECC.

In November 2016, the Government announced the formation of the Energy Innovation Board to provide strategic oversight of all energy innovation programmes and coordination of energy innovation activity. This replaces the LCICG. It is Government's intention to continue to have a nuclear focussed sub-group consisting of similar members as the LCICG NSG.

The Government established the Nuclear Innovation and Research Advisory Board (NIRAB) in January 2014 to advise Ministers, Government Departments and Agencies on issues related to nuclear research and innovation in the UK. NIRAB was established as a temporary advisory board for a period of up to three years and concluded at the end of December 2016. Part of the role of NIRAB was to foster greater cooperation and coordination across the whole of the UK's nuclear research and innovation capability, portfolio and capacity.

NIRAB has, in part, fostered cooperation and coordination by providing a forum at which Government Departments and Agencies have been able to discuss priorities and share plans for funding research. The Nuclear Innovation and Research Office (NIRO) has also supported NIRAB in attending other coordinating bodies such as the NDA Research Board, the National Nuclear User Facility (NNUF) steering group and the Nuclear Waste and Decommissioning Research Forum (NWDRF).

Coordination between research performers

There are a number of mechanisms, bodies and groups which act to facilitate coordination between research performers in the nuclear field. Some have a specific nuclear focus and others include nuclear as part of a more extensive portfolio. These include:

- The Nuclear Waste and Decommissioning Research Forum (NWDRF) is a cross industry group that aims to enhance coordination of R&D and technical programmes across UK Site Restoration and Integrated Waste Management activities. Its membership includes representatives from NDA, Radioactive Waste Management (RWM), Site Licence Companies, regulators and organisations with significant nuclear decommissioning liabilities.
- The Nuclear Universities Consortium for Learning, Engagement and Research (NUCLEAR) is funded by the EPSRC to widen academic and industrial collaboration and enhance knowledge transfer. The NUCLEAR group is responsible for organising national meetings to support the nuclear universities in the UK.
- The NNUF steering committee, which coordinates access to NNUF equipment suitable for conducting research on radioactive or activated materials. This committee reports to BEIS on usage of the NNUF facilities.

Coordination between public and privately funded research

There are no formal mechanisms for coordination of public and privately funded research.

NIRAB's remit included fostering greater cooperation and coordination across the whole of the UK's nuclear research and innovation capability, including members and observers from the public and private sector.

The Nuclear Industry Council (NIC) was established in February 2013 as a partnership between Government and industry with a view to providing high-level strategic direction to the UK's nuclear industry. The NIC aims to develop and maintain a single, coherent strategy and vision for the civil nuclear industry and also work with the research community and industry to underpin those actions needed to realise industry and government's long-term vision for the sector. In December 2016 it was announced by BEIS that the NIC is to be reformed, with the first meeting of the reformed Council to take place in February 2017[9].

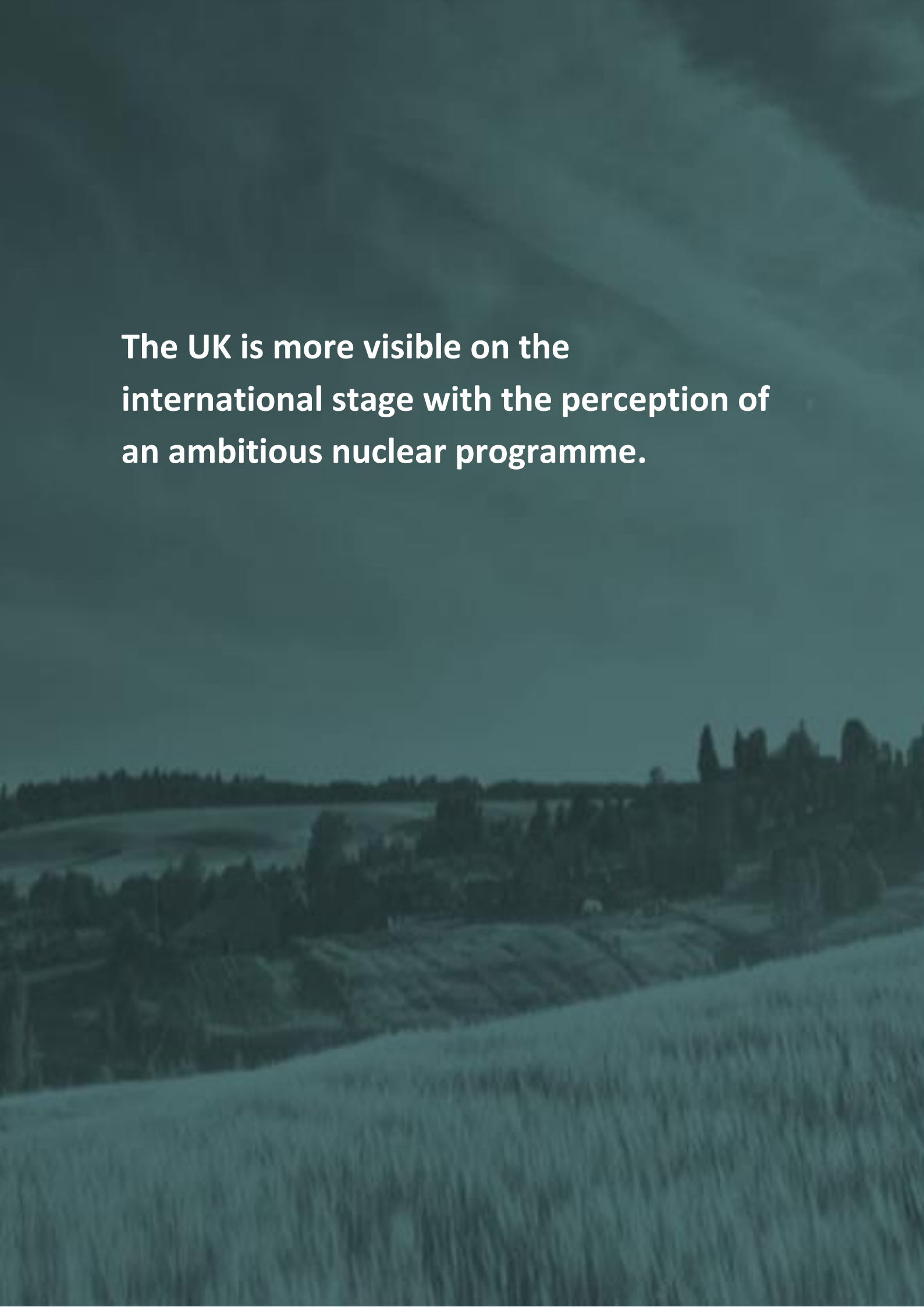
NIRAB and NIRO have worked closely with the NIC since 2014; NIRO, for example, has collaborated with the relevant NIC sub-groups and work streams on innovation to coordinate specific R&D activities across the two organisations.

There are good examples of coordination in some areas; for example, RCUK and industry have come together to fund collaborative programmes:

- New Nuclear Manufacturing (NNUMAN) - The programme focuses on early-stage research into a range of manufacturing technologies. The programme, managed by the Dalton Nuclear Institute at The University of Manchester and supported by the Nuclear Advanced Manufacturing Research Centre (NAMRC) at the University of Sheffield, has £4 million funding from Engineering and Physical Sciences Research Council (EPSRC), with the two universities committing a further £4 million, and further financial and in-kind support coming from industry.
- Decommissioning, Immobilisation and Storage Solutions for Nuclear Waste Inventories (DISTINCTIVE) - the £5 million DISTINCTIVE programme coordinates the EPSRC supported research in decommissioning and waste disposal, undertaking fundamental scientific research to address the decommissioning and waste disposal challenges that the UK faces. The programme is supported by additional funding from NDA, Sellafield Ltd and NNL.

[9] https://www.gov.uk/government/news/uk-business-to-benefit-from-new-nuclear-projects

International Collaboration in Civil Nuclear R&D


The UK is more visible on the international stage with the perception of an ambitious nuclear programme.

6 International Collaboration in Civil Nuclear R&D

International collaboration is the main route for developing nuclear technologies, such as advanced reactors, due to the substantial investment required by such programmes. International engagement and collaboration are therefore important and afford a number of benefits:

- Access to international best practice to challenge and benchmark the UK's research capability
- Access to facilities to enable the UK to meet its research objectives, for example, research reactors and irradiation facilities
- Leverage on investment in nuclear R&D
- Access for UK industry to overseas markets
- Improved understanding of political and legislative developments.

The UK is more visible on the international stage with the perception of an ambitious nuclear programme which has been created through investment in new research facilities, ambitions for deploying a small modular reactor (SMR) and the role of NNL in representing the UK on various international fora. The provision of research facilities, for example, provides credibility and a basis for finding mutual benefit in international research collaborations.

There is, however, no overarching international collaboration strategy for nuclear research in the UK. Since publication of the previous landscape review, a number of Government sponsored Memoranda of Understanding, Nuclear Cooperation Agreements and other declarations have been made that state the UK's intent to collaborate with international partners in the field of nuclear energy, for example:

- The UK and South Korea signed two Memorandums of Understanding in November 2013 to develop closer cooperation in the fields of commercial civil nuclear energy and nuclear decommissioning[10]
- UK and France signed a declaration on nuclear energy in January 2014[11]
- In June 2015 the UK and Canada signed a Memorandum of Understanding concerning enhancing cooperation in the field of civil nuclear energy[10]
- UK and China signed a Statement of Cooperation in the field of civil nuclear energy in October 2015[12]. This was followed by a signing of a Heads of Terms Agreement for a UK–China Joint Research and Innovation Centre (JRIC). NNL and China National

10 https://www.gov.uk/guidance/guidance-for-operators-of-new-nuclear-power-stations#history

11 https://www.gov.uk/government/news/uk-and-france-sign-declaration-on-nuclear-energy-and-agree-cooperation-on-ambitious-climate-change-action

12 https://www.gov.uk/government/publications/statement-of-cooperation-in-the-field-of-civil-nuclear-energy-2015

Nuclear Power Co Ltd (CNNP) are respectively the lead organizations for the UK and China.

- In December 2016 the UK and Japanese governments signed a Memorandum of Cooperation across a range of civil nuclear activities, including decommissioning, research and development and new nuclear. The Memorandum stimulated creation of the EPSRC sponsored network for Japan – UK Nuclear Opportunities (JUNO) which is forging new and deeper collaboration between academic researchers in the nuclear fission landscape.

There are good examples of where the UK is working as a respected partner and contributing to international research programmes, for example, EU funded projects (such as SACSESS, ASGARD, CEBAMA, SOTERIA, RoMaNs, EUROfusion). There is also international academic engagement through Research Councils UK funding of programmes supporting collaboration with Japan, India, South Korea and the US.

The UK actively engages in International Atomic Energy Agency (IAEA) Coordinated Research Projects (CRPs). UK organisations are currently participating in over 30 active CRPs which include research in the areas of Food and Agriculture, Human Health, Nuclear Power, Nuclear Security and Nuclear Fuel Cycle and Materials Technologies. The following are a selection of active CRPs with UK involvement:

- Spent Fuel Performance Assessment and Research
- Management of Severely Damaged Spent Fuel and Corium
- Modular High Temperature Gas Cooled Reactor Safety Design
- Accelerator Simulation and Theoretical Modelling of Radiation Effects - SMoRE-II
- Sustainable Education in Nuclear Science and Technology.

The UK remains an inactive member of the Generation IV Forum (GIF), and only participates indirectly through the subscription of Euratom – a low level of involvement. Additionally, the UK is a member of the Jules Horowitz Reactor project being built in France, and continues to be a member of the OECD Nuclear Energy Agency (NEA) Halden research reactor in Norway.

The UK leaving the EU, and Euratom, will inevitably have an impact on the UK's nuclear R&D activity and international collaboration. It is too early to fully understand what this will be, and Government will need to assess the potential implications and mitigate accordingly.

There remains a need, as recommended in the 2013 landscape review, for the UK to develop and implement a comprehensive and coordinated international collaboration strategy for nuclear research and innovation to enable research to be implemented to the greatest effect.

Facilities for Civil Nuclear R&D in the UK

Government has invested around £60m in new UK nuclear research facilities since the last landscape review in 2013.

7 Facilities for Civil Nuclear R&D in the UK

The UK requires access to world-leading facilities to deliver the nuclear R&D necessary to underpin the UK's nuclear ambitions. The UK has a range of facilities, across both the public and private sector, which are capable of undertaking work related to nuclear R&D. This chapter focuses on new Government investment in research facilities, for nuclear R&D, since the previous review of civil nuclear R&D landscape in the UK published in 2013. In addition to these there are a variety of existing facilities within universities, national laboratories and industry that add to a national capability.

BIS, DECC and Research Councils UK have collectively invested approximately £60 million in research facilities for nuclear R&D since March 2013; Figure 19 provides an overview of the breadth of these new, Government funded, facilities and their location. Further details of these facilities are provided in Section 7.1.

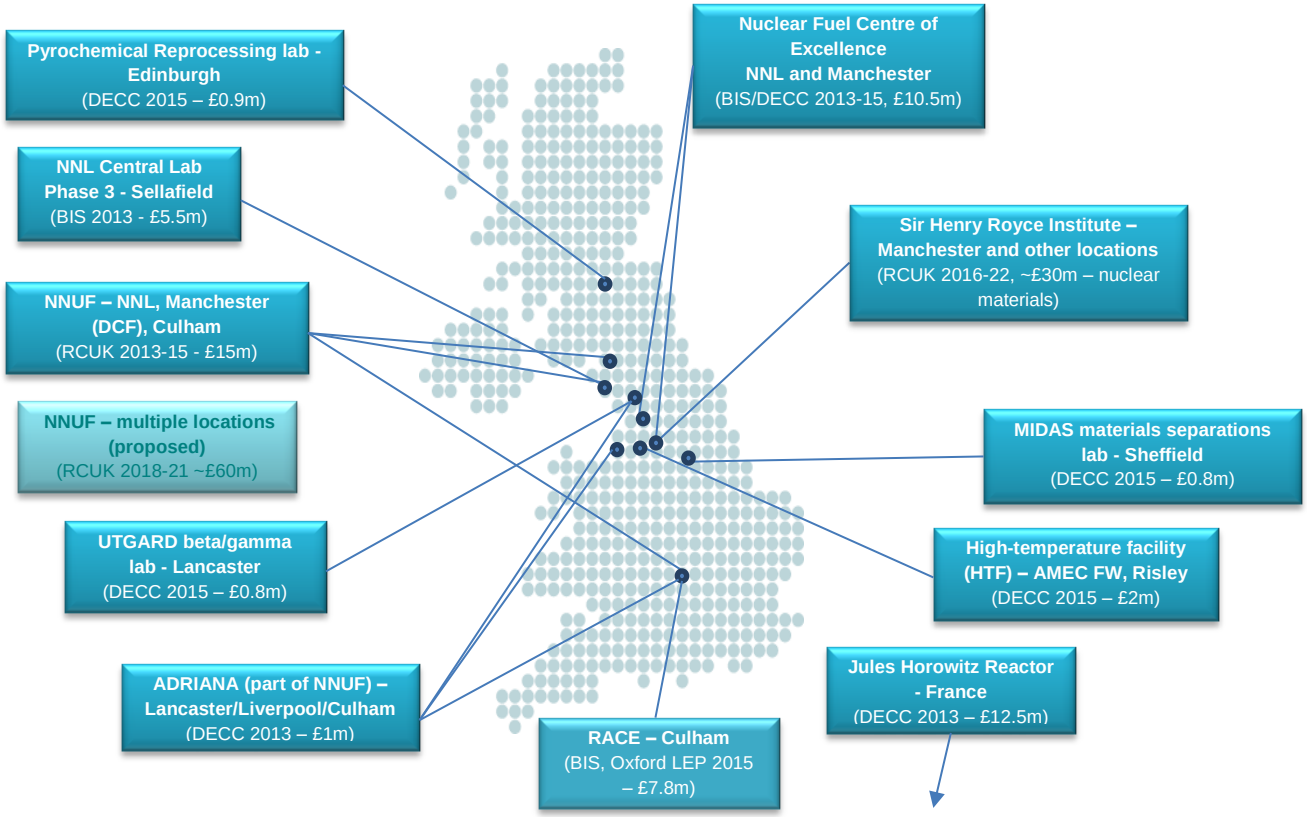


Figure 19. Map of new Government funded nuclear research facilities

Figure 19 identifies a number of facilities associated with the National Nuclear User Facility (NNUF). The NNUF was established in March 2013 to provide greater accessibility to facilities for handling, testing and inspection of radioactive/irradiated materials as a collaborative effort from four complementary hubs: the NNL Central Laboratory, the Culham Centre for Fusion Energy (CCFE), the Dalton Cumbrian Facility (DCF) (part of The University of Manchester) and Lancaster University.

In addition to the investment in facilities delivered since 2013, announcements of further public funds for nuclear research facilities have been made:

- £60 million to extend the capabilities of the NNUF, announced in December 2014[13]
- Nuclear materials research infrastructure is one of the nine research areas that form part of the £235 million Sir Henry Royce Institute for Advanced Materials, announced in December 2014[13]

This additional funding and extension to UK nuclear research capabilities, if delivered, will continue to improve the facilities landscape supporting nuclear R&D in the UK.

Government has looked to address the paucity of facilities for handling radioactive materials described in the 2013 landscape review through investment in new facilities; in addition, the commissioning of the DCF and also investment in the Jules Horowitz Reactor (JHR) Consortium aims to address gaps in facilities to irradiate materials – the JHR is anticipated to be operational by 2022 (the UK currently is also a member of the NEA Halden reactor project in Norway). However, availability and accessibility of active facilities for the widest possible user community is still a key challenge for the UK. Some progress is being made, but this needs to continue to rebuild the UK capability.

7.1 Details of selected Government funded research facilities

Figure 19 shows a range of research facilities that have been developed between 2012/13 and the end of the 2015/16 financial year. This section provides brief descriptions of each of these facilities.

Research Facility	Research Facility Description
High Temperature Facility (HTF)	The HTF Alliance has built an open access materials testing laboratory using a grant from DECC. It was established to investigate, develop and advance structural materials technology for future systems applications such as Generation IV nuclear fission, nuclear fusion, advanced gas turbine materials and other advanced energy concepts. The HTF is housed in dedicated facilities at the Amec Foster Wheeler Technology and Innovation Centre, Warrington. The HTF offers rigs capable of testing materials at temperatures up to 1000°C and with temperature cycling in a range of novel, demanding environments.

[13] Autumn Statement 2014, Cm 8961, December 2014 (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/382327/44695_Accessible.pdf)

Research Facility	Research Facility Description
Materials Research Facility (MRF)	The MRF has been established to analyse material properties in support of both fission and fusion research. It is part of the NNUF initiative, funded by EPSRC and has recently moved to a purpose built facility at Culham. The MRF provides academic and industry users with a unique resource for micro-characterisation of materials. With hot cells for processing and micro-characterisation of neutron-irradiated samples, it has the capacity to cut, polish and encapsulate individual samples up to the Tera-Becquerel level for analysis either on-site or back at the user's institute. The facility supports research in lifetime extension, nuclear new build, Generation IV and fusion. The MRF is also part of the Sir Henry Royce Institute for Advanced Materials, which is investing in the facility in the years 2016-2019.
UTGARD (U/Th/beta-Gamma Active process chemistry R&D) Laboratory	The UTGARD Laboratory has been established for the study of chemical processes in support of spent nuclear fuel recycle and waste management. Funded by DECC, it is part of the EPSRC supported NNUF initiative and is an open access laboratory housed in dedicated facilities at Lancaster University. UTGARD Laboratory provides academic and industry users with a unique resource for the study of the chemistry and engineering of spent fuel recycle and waste management processes. With glove boxes for the study of aqueous and non-aqueous samples, it has the capacity to study fully nuclear hydrometallurgical separations processes. It is licenced for work on β/γ active fission products, uranium, thorium and low level alpha tracers.
Nuclear Fuel Centre of Excellence (NFCE)	The NFCE is hosted by the Dalton Nuclear Institute and NNL. NFCE's purpose is to create an advanced fuel R&D capability within existing facilities to enable the UK to be a world leader in fuel technology. A key focus is on growing UK talent specialising in advanced fuels. Supported by £10.5 million of funding from Government to strengthen the existing fuel R&D facilities at NNL and The University of Manchester and create an integrated UK capability, the NFCE builds unique fuel fabrication and performance experience from decades of research and development on past, present and future fuel types. It will support the creation of improved fuel for current reactors, a new Generation III+ fleet, small modular reactors and ultimately Generation IV fast reactor systems.
Remote Applications in Challenging Environments (RACE) Research Centre	2015 saw the completion of the RACE research centre based at the UKAEA's Culham site. The centre will be involved in exploring many areas of remote operations including inspection, maintenance and decommissioning and will be instrumental in developing new remote tools and techniques with academia and industry. RACE occupies a dedicated new building at the Culham Science Centre which opened in 2016.

Research Facility	Research Facility Description
Materials for Innovative Dispositions from Advanced Separations (MIDAS) Laboratory	In 2015 investment from the University of Sheffield in conjunction with a grant from DECC was used to establish the state of the art MIDAS laboratory to support world leading research in the management and disposal of radioactive wastes from the nuclear fuel cycle. The MIDAS laboratory has been established as a national user facility and is part of a network of facilities which enable the UK to deliver internationally competitive R&D in nuclear waste management. The facility is operated as an open facility, available for use by academic, public and private sector organisations and is staffed by an experienced team of researchers who provide advice and guidance on utilising the equipment. The facility is capable of working with high active alpha and beta/gamma materials. Investment by DECC in this asset has supported delivery of a research portfolio in excess of £15 million, with grant awards to use the facility in excess of £8 million.
Pyrochemical Reprocessing Laboratory (PRL)	The PRL at the University of Edinburgh provides the facilities to develop and demonstrate integrated pyrochemical reprocessing of nuclear fuel using fuel relevant inactive compositional mixtures at laboratory scale, along with the required process monitoring. The laboratory consists of a suite of interconnected integrated controlled atmosphere dry-boxes, equipped with the necessary furnaces, cell systems and electrochemical and spectroscopic characterisation equipment required for research into and development of each of the essential elements of pyrochemical reprocessing at the laboratory scale. The PRL is an open access laboratory and is affiliated to the NNUF.

The UK's Civil Nuclear R&D Landscape 2016:

Appendices and Glossary

Appendix 1 Methodology for Data Collection

The national laboratory, industry and academic R&D data presented in this report has been acquired using a data collection process using a questionnaire agreed by NIRAB. This questionnaire was designed to collect data which could be compared directly to that collected in 2012 and used in the review of the civil nuclear landscape published by Government in 2013.

A questionnaire was sent to national laboratories, industrial organisations carrying out research and universities engaged in civil nuclear research. The number of national laboratories is limited and these were contacted directly. Questionnaires were sent to all of the industrial organisations that responded in 2012, all organisations that have received research funding from Innovate UK and all of the organisations holding research contracts with NDA and RWM. Finally questionnaires were sent to all of the academics belonging to the nuclear academics meeting, a total of approximately 300 people.

The academic questionnaire is replicated in Appendix 2. The industrial and national laboratory questionnaires were almost identical to the academic questionnaire. The only difference was that they did not seek information on numbers of PhD students and postdoctoral researchers.

In common with the previous review the list of organisations responding to the request for data is significant, but not definitive. There are almost certainly organisations engaged with civil nuclear R&D that have not responded.

Appendix 2 Civil Nuclear R&D Landscape Survey Questionnaire 2016 - Universities

About Your Organisation

1. Organisation Name
2. Organisation point of contact and contact details

R&D Funding

3. Complete the table for R&D Projects which your organisation undertook in FY15/16 (Add more rows as required).

Project Title	*Total Project Value*	*Funding source*				Research Theme (See Guidance)
		Internal funding	*UK industry funding*	*Public funding*	*Overseas funding*	

Guidance - The research themes include the following programme areas:

Themes

Fuel Fabrication

Uranium conversion and enrichment, fuel development, fuel manufacture, fuel cycle assessment

Reactors

Reactor technology/design, reactor component manufacture, reactor operation including materials degradation and structural integrity, activation and structural integrity

Advanced Reactors

Advanced reactor systems (GEN IV), fuel recycle / reprocessing for advanced systems

Spent Fuel Handling

Spent fuel storage, fuel recycle / reprocessing for current operations, nuclear materials management

Waste

Waste retrieval, legacy clean-up, effluent management, geo-science, earth science

Decommissioning

Decontamination, structure demolition, asset management, post operation clean out

Fusion

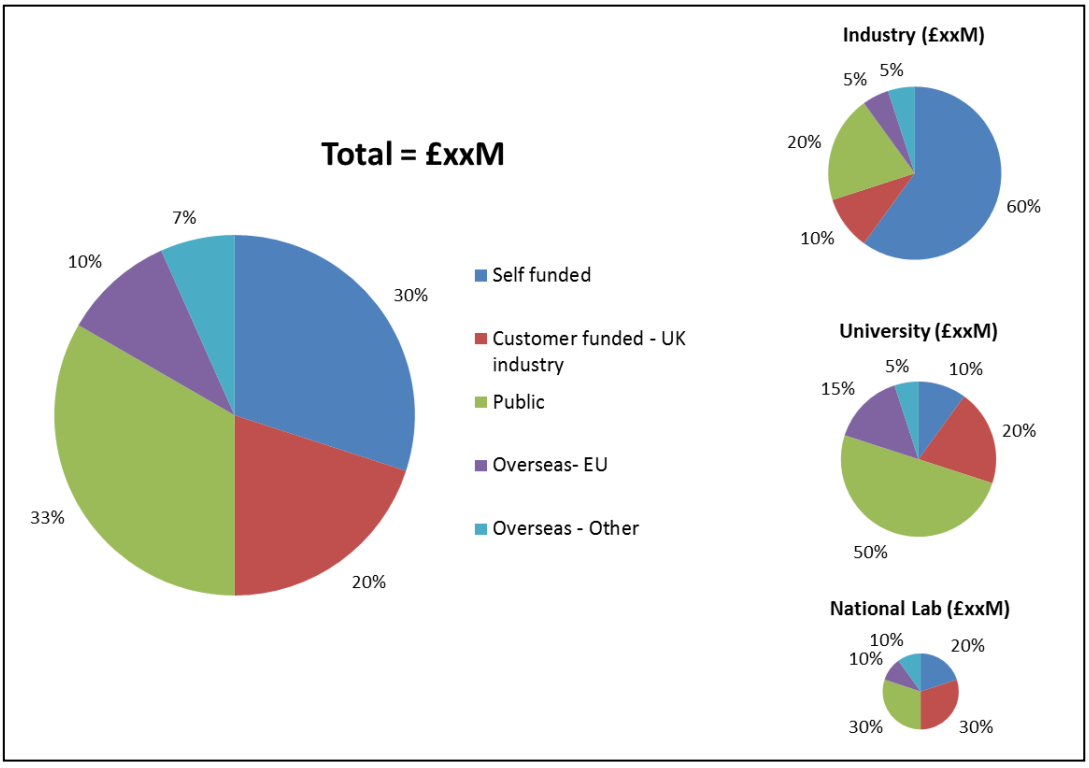
Plasma, advanced materials for fusion, tritium handling in fusion, activation studies for fusion, nuclear data for fusion, remote handling for fusion

Cross-cutting technologies

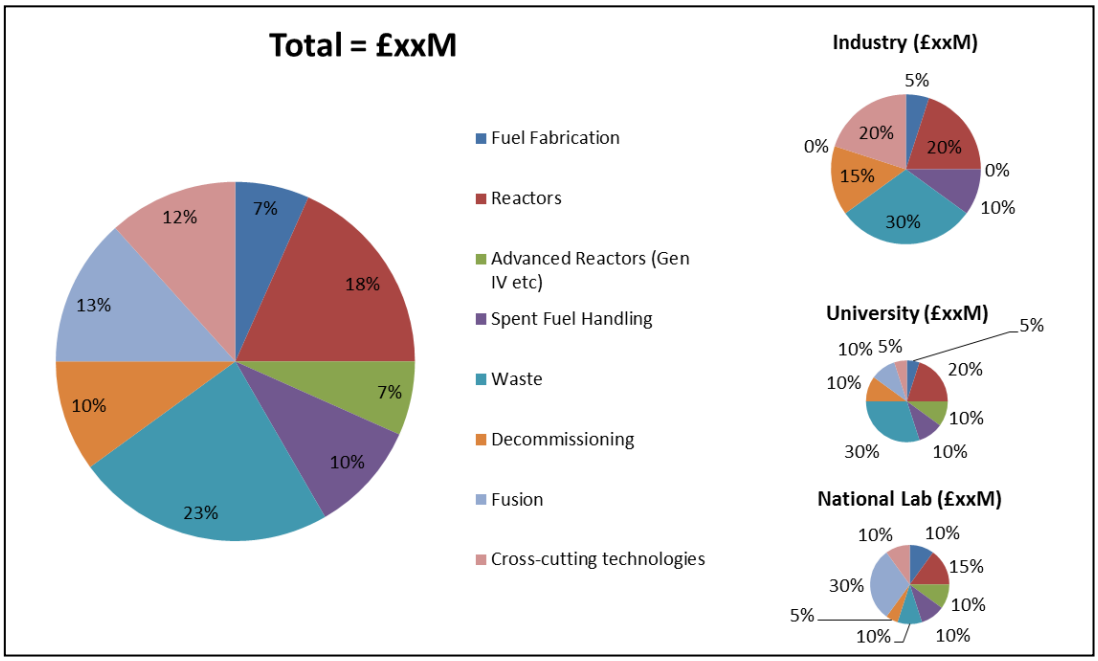
Advanced computational methods, neutronics, safety, security, social studies, public engagement, regulatory, economic

Guidance - The R&D funding data received will be used to generate a series of figures showing the breakdown of funding per source for research done in academia, industry and national labs, and the breakdown of funding per research theme as shown in the figures below.

Example chart - Breakdown of funding per source:



Example chart - Breakdown of funding per research theme:



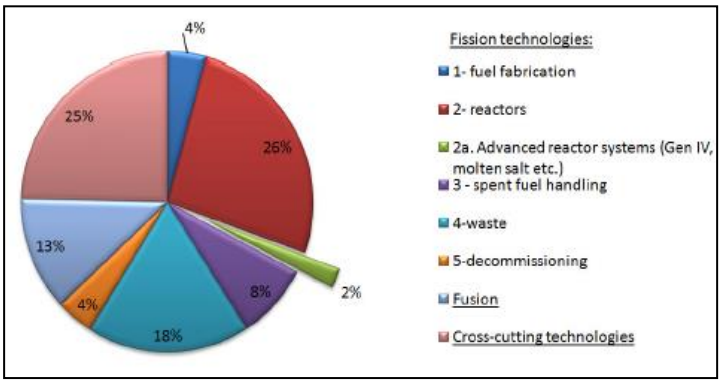
Research Capacity and Focus

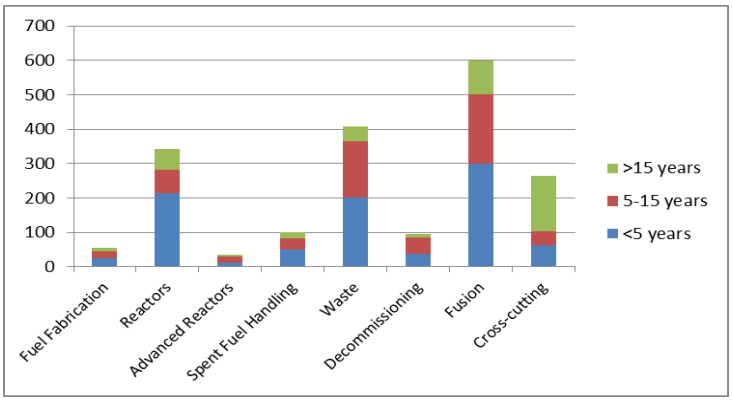
4. Please complete the table for the number of Full Time Equivalents (FTE) in your organisation that were deployed on nuclear R&D projects in FY2015/16, their area of expertise and number of years experience. Please note that an FTE can be split across a number of themes if applicable.

If you have more than one location, please estimate the number of researchers based at each site.

Themes	PhD Students	Post Doc Researchers	Academic staff with less than 5 years experience	Academic staff with 5 to 15 years experience	Academic staff with more than 15 years experience
Fuel Fabrication					
Reactors					
Advanced Reactors (Gen IV etc)					
Spent Fuel Handling					
Waste					
Decommissioning					
Fusion					
Cross-cutting technologies					

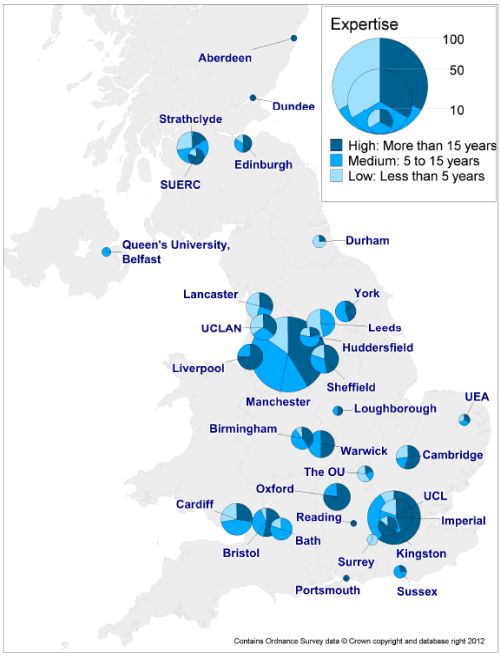
Guidance - It is intended that the data will be used to generate figures illustrating the distribution of research across the research themes for each sector (academia, industry and national labs). It is not intended to publish data on the distribution of research themes on an organisation by organisation basis. The figure below is taken from the 2013 Review and illustrates the distribution of research effort across the academic sector.





Guidance - The data may be used to compile figures illustrating the varying distributions of experience of researchers working on different research themes as illustrated in the figure to the left (NB not based on real data).

Guidance - The data received will be used to generate a series of figures showing the distribution of experience across the country for researchers in academia, industry and national labs. The university data from the 2013 Review is reproduced on the right.



Have Your Say

5. Please provide any additional comments you have on strategic issues facing the UK's civil nuclear R&D landscape. Your comments will not be attributed in the summary report but will help inform the qualitative analysis.

Thank you for completing the Civil Nuclear R&D Landscape Survey Questionnaire 2016.

Glossary

AWE	Atomic Weapons Establishment
BEIS	Department for Business, Energy and Industrial Strategy
BIS	Department for Business, Innovation and Skills
CCFE	Culham Centre for Fusion Research
CNNP	China National Nuclear Power Co Ltd
CORDIS	Community Research and Development Information Service
DCF	Dalton Cumbria Facility
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food & Rural Affairs
DoH	Department of Health
DWP	Department for Work and Pensions
DISTINCTIVE	Decommissioning, Immobilisation and Storage Solutions for Nuclear Waste Inventories
DSRL	Dounreay Site Restoration Ltd
EA	Environment Agency
EC	European Commission
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
FCO	Foreign and Commonwealth Office
FSA	Food Standards Agency
FTE	Full Time Equivalent
GDA	Generic Design Assessment
GIF	Generation IV Forum
HEFCE	Higher Education Funding Council for England
HMRC	HM Revenue and Customs
HSE	Health and Safety Executive
HTF	High Temperature Facility
IEA	International Energy Agency
JET	Joint European Torus
JHR	Jules Horowitz Reactor
JRIC	Joint Research and Innovation Centre
LCICG	Low Carbon Innovation Coordination Group
LLWR	Low Level Waste Repository Ltd
MIDAS	Materials for Innovative Dispositions from Advanced Separations
MoD	Ministry of Defence
MRF	Materials Research Facility
NAMRC	Nuclear Advanced Manufacturing Research Centre
NDA	Nuclear Decommissioning Authority
NDPB	Non-Departmental Public Body
NERC	Natural Environment Research Council
NFCE	Nuclear Fuel Centre of Excellence
NIC	Nuclear Industry Council
NIRAB	Nuclear Innovation and Research Advisory Board
NIRO	Nuclear Innovation and Research Office

NNL	National Nuclear Laboratory
NNUF	National Nuclear Users Facility
NNUMAN	New Nuclear Manufacturing
NPL	National Physical Laboratory
NUCLEAR	Nuclear Universities Consortium for Learning, Engagement and Research
NWDRF	Nuclear Waste Decommissioning Research Forum
OECD-NEA	Organisation for Economic Co-operation and Development – Nuclear Energy Agency
ONR	Office for Nuclear Regulation
PHE	Public Health England
PRL	Pyrochemical Reprocessing Laboratory
R&D	Research and Development
RACE	Remote Applications in Challenging Environments
RCUK	Research Councils UK
RWM	Radioactive Waste Management Ltd
SLC	Site Licence Company
SMR	Small Modular Reactor
STFC	Science and Technology Facilities Council
UKAEA	United Kingdom Atomic Energy Authority
UKRI	UK Research and Innovation
USA	United States of America
UTGARD	U/Th/beta-Gamma Active process chemistry R&D

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Further information about NIRAB is available at:
www.nirab.org.uk

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