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UKERC ENERGY RESEARCH LANDSCAPE: NUCLEAR FISSION

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1. Overview

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Characterisation of the Field

The UK's civil nuclear fission interests cover a number of aspects; these are summarised below:

Legacy waste clean-up and decommissioning – providing means to support the skills base, develop innovative solutions to enable the clean-up programme to be delivered cheaper, faster and safer. This is one of the major aspects of the UK's nuclear programme at present. There is a significant challenge in cleaning up historic facilities, packaging wasteforms and remediating sites. The estimated cost of this programme is currently set at £100bn (source : House of Commons Committee of Public Accounts – Nuclear Decommissioning Authority: Managing risk at Sellafield. Report HC 746, page EV2, Q10) and is scheduled to last for over 100 years, with the end point being remediated sites and packaged wasteforms. The Nuclear Decommissioning Authority was established in April 2005 to drive forward this programme with private sector organisations competing to run site management contracts. There is a significant R&D programme associated with this activity as the NDA is keen to drive forward innovation to reduce cost timescale and improve safety. However clean-up cost estimates since 2005 have risen by £30bn, mainly due to the complex nature of decommissioning the site at Sellafield.

- Support existing operations – ensuring UK's operational plants (both reactors and fuel cycle facilities) can be safely and efficiently operated through to the end of their life. Whilst the UK has a significant decommissioning programme there are still major on-going operations underway. In 2012 the UK generated 19% of its electricity from nuclear (source : Digest of UK Energy Statistics, Chapter 5: Electricity), the reactors are now mainly Generation II AGR stations as Generation I Magnox have now reached their end-of-life, except for Wylfa which will be shut down when its fuel runs out in late 2014. The Lifetime of two of the AGR fleet is currently 2018, for two others 2019, with the remainder currently due to come offline in 2013. The Sizewell PWR is expected to operate until 2035. However, the operator of all these plants, EdF Energy, is seeking lifetime extensions.

- In addition there are on-going fuel cycle and infrastructure activities in the UK. For example the THORP reprocessing plant at Sellafield is operational until 2018 (source : NDA : Oxide Fuels Credible Options: November 2011). On 3 August 2011 the Nuclear Decommissioning Authority announced that the MOX Plant would close, due to the loss of Japanese orders following the Fukushima Daiichi nuclear disaster. The UK also has front-end fuel conversion, enrichment and fabrication facilities. These on-going operations require R&D to support operations and ensure plants are operated in a safe manner.

- New Nuclear Build - The UK has undergone major consultation in recent years over the future of nuclear new build. A number of sites have been shortlisted; currently this number stands at 8. In 2012 Hitachi made the decision to purchase the 'Horizon' venture from E.On and RWE power, with the aim of constructing two or three new power plants over the next few decades. EDF Energy also plans to build 4 new reactors; in March 2013 it received permission to build Hinkley Point C. In 2013 the

Government also published a Nuclear Industrial Strategy, which sets out plans for 16GWe of electricity to come from nuclear by 2030. R&D will be required to support the deployment of these systems, although the UK will not indigenously develop its own technology but purchase from an overseas vendor such as Westinghouse or Areva. R&D will help ensure the UK has the sufficient "intelligence" to act as an informed buyer and there is a supply chain of skilled individuals able to join the industry. A number of new programmes are underway to help prepare for this expansion of the current fleet, as well as increased funding for nuclear Doctoral Training Schemes, and new centres for nuclear design, manufacturing and materials testing.

- Advanced Reactor technology – keep abreast of the development of advanced reactor technology being developed overseas though international collaborations, such as fast reactors and high temperature gas-cooled reactors for electricity and heat applications such as hydrogen generation. The Generation IV international programme is being led by the US and involves a number of key countries interested in developing next generation systems. Currently the UK Government has plans to resume active participation in Generation IV in 2014, after having backed out in 2005. In 2013, the UK has joined the International Framework for Nuclear Energy Cooperation (IFNEC). It is also looking into the possibility of becoming involved with a Small Module Reactor (SMR) programme, and decisions on this are expected by the end of 2014.(source : Press Release : March 2013 : Press release : Long-term partnership to help UK compete in £1 trillion global nuclear industry).

- Geological Disposal - In 2006 the Committee on Radioactive Waste Management (COWRM) concluded that deep geological disposal is the most appropriate way forward for managing the UK's inventory of intermediate and high level waste and spent nuclear fuel. The COWRM report identified the importance of R&D to support the geological disposal programme. After a 2008 white paper on managing waste, Government nominated the NDA to be responsible for planning and delivering geological disposal. The work is being undertaken within NDA's Radioactive Waste Management Directorate (RWMD) at their offices in Harwell, Oxfordshire. Currently, research is underway to find and procure a suitable site on which to set up a geological disposal facility, taking into account levels of community support as well as local rock type.

- The UK also has a major naval nuclear power propulsion programme. Although not considered here there are common technological issues to be shared with civil nuclear power reactors. Strong synergies exist for example in materials research, structural integrity, reactor physics etc.

All the above require supporting R&D activities to ensure activities are carried safely, timely and to cost. In addition to science and engineering R&D activities, a wide range of disciplines are required such as social, risk perception, human factors, safety analysis, socio-economics etc.

One of the additional aspects of the UK's nuclear programme that does receive significant attention is the work on contributing to international safeguards and non-proliferation. Whilst R&D activities specifically related to this field may be limited, it is still necessary to have expertise and knowledge which often is generated through R&D. In addition this area does drive future R&D in terms of development of new detection techniques, proliferation resistance fuel cycles and reactors.

In a similar manner to this is work on emergency preparedness to understand what impact a release of radionuclides would have on flora,

fauna and up-take into the food chain. Research on emergency preparedness also involves communication systems, infrastructure requirements and social aspects in terms of how individuals respond and decisions are made.

The majority of R&D to support the industry is used to help underpin the industry's knowledge base to ensure appropriate judgements and decisions related to whether this is on safety assessment, cost reduction or performance/operational related issues. There are very few occasions when it is possible to specifically identify a new product taken through the innovation chain to commercial deployment. It is more a case of R&D helping to progress understanding and resolve issues. Market pull will come from aspects such as ensuring safety, economic competitiveness, performance, environmental impact, etc are all appropriately factored in to different aspects of nuclear operations

The role of underpinning R&D to support safety case development is key to having a mechanistic understanding of nuclear processes, this not only helps support operational issues but improves understanding of the processes thus helping to gain public confidence. Closely associated with this is maintenance of an expert authoritative skill base of key experts that can act independently and ensure integrity of operations and the approach to safety. Such a skill base can only be generated through underpinning R&D and experimentation, it cannot be generated by passive engagement in activities carried out overseas and simply reading about technological developments.

The volume of nuclear R&D carried out in the UK has declined substantially since the 1970s when approximately £500m per annum was invested. By 2000, direct publicly funded R&D was virtually zero. This came about partly due to the change in UK energy policy as a result of the discovery of North Sea gas and a move away from nuclear energy and partly as a result of the divestment of the Atomic Energy Authority with no national entity taking forward fundamental R&D. Back in the 1970/80s the UK saw nuclear as a means of providing energy security of supply and the country was developing the AGR reactors, supporting deployment of PWRs, developing the fast reactor and deeply involved in fuel processing operations (hence the historic levels of investment). With the discovery of North Sea Gas, loss of the AEA and move away from nuclear energy, by the 1990s, British Nuclear Fuels assumed the de facto role as national champion for backstopping fundamental R&D and maintained a corporate investment programme, roughly £10m per annum, directed at longer-term R&D and capability management.

However, as the Government considered ways to meet its ambitious climate change targets set out in May 2007, nuclear power seemed increasingly likely to play a substantial role in the UK's energy future. The new build confirmed in January 2008, accompanied by a series of Government reports, helped increase R&D funding as Government and industry alike recognised the need for increased investment to keep R&D in line with new nuclear policy. It should be noted that although R&D spending rose between 2000 and 2009 it remained in 2009 at only 7% of the level spent in 1980. (source : A review of the civil R&D landscape , page 22).

Starting with a white paper entitled 'Meeting the Energy Challenge' in 2007, investigations into the nuclear industry began, including nuclear R&D. Notable publications include a House of Lords Inquiry into Nuclear R&D Capabilities in the UK (2011), followed by a review of the civil R&D landscape (March 2013) which presented an overview of current nuclear R&D in the UK, and contained recommendations for further action in areas where funding was lacking. Furthermore, the 'future pathways' report outlined a number of potential options for the future of nuclear new build, and suggested R&D strategies to match each possible route. This series of reports has culminated in the creation of several new committees, groups, research boards and councils, as well as prompting significant investment in new and

existing laboratories and research programmes in order to support the expected expansion of the nuclear sector over the next decade.

Several reports highlighted funding gaps in nuclear R&D, particularly R&D involving future reactor generations and fuels, suggesting where there was cause for concern and prompting the Government to undertake further discussion on funding and expansion of some current facilities.

Most recently, EDF Energy have started preparations for nuclear new build at Hinkley Point C, with plans to build two further reactors on a second site at Sizewell. The Government recognises that the UK must advance its R&D capabilities in order to reduce costs and increase safety whilst carrying out new build.

Primarily funded by EPSRC, and mostly carried out by National Nuclear Laboratory and the Dalton Nuclear Institute, the following new initiatives have been set up:

- £7.1m for the 'Nuclear FiRST' Doctoral Training Centre lead by University of Manchester
- £3.6m for an Industrial Doctoral Centre in nuclear engineering (Sheffield and Manchester Universities) (expanded from a Doctoral Training Centre established in 2006)
- £15.5m for the Nuclear Universities Consortium for Learning, Engagement And Research (NUCLEAR), a network which aims to 'facilitate the effective UK academic engagement in nuclear research programmes'
- £4.1m for a New Nuclear Manufacturing programme, which conducts research to help improve current manufacturing techniques.
- Two new advisory boards: Nuclear Innovation and Research Advisory Board (NIRAB) and Nuclear Innovation Research Office (NIRO), which will oversee public R&D and influence the direction and funding levels to align them with industrial needs.

The academic sector has responded to these new opportunities with several new centres opening at Manchester, the John Tyndall Institute for Nuclear Research (JTI) at UCLAN (University of Central Lancashire), the Centre for Nuclear Engineering at Imperial, plus the expansion of the existing University Alliances at Leeds, Sheffield and Manchester. In addition there are other positive signals such as the development of a National Skills Academy for Nuclear (NSAN), from which has come the National Nuclear Gateway project (2012), helping to equip companies with the skills needed to carry out new build. A Nuclear Advanced Manufacturing Research Centre (NAMRC) has also been established (2012) with the help of a £15m grant from the Department of Business, Innovation and skills (BIS), £7 million from the regional development agency Yorkshire Forward (now defunct). And funds from the European Regional Development Fund. It aims to 'enhance the capabilities and competitiveness of the UK civil nuclear manufacturing industry' through development of manufacturing processes and technologies.

The commercially operated National Nuclear Laboratory has taken on a substantial amount of nuclear R&D since its opening in 2009, taking over and expanding from the work of Nexia Solutions. With 6 sites, 400 R&D staff and funding of around £57m (2011 figures), it currently receives the overwhelming majority of UK funding for nuclear R&D. NNL's customers to date have included the NDA, Sellafield Ltd and EDF Energy amongst others. It has quickly become one of the UK's main research assets, allowing both industry and academia access to world class facilities.

Research Challenges

The nuclear industry is somewhat unusual in that R&D does not necessarily lead to development of completely new products. Whilst funding levels may be similar to other R&D intensive industries such as aerospace, chemical, pharmaceutical, the end-products are very

different. Research to support the nuclear industry is typically associated with taking existing technology found in other industries and adapting it for use in a nuclear environment. Alternatively research and development is aimed at helping judgements and decisions to be made associated with safe and effective operational practices.

Indeed, the role of nuclear R&D has changed over the years and expectations have increased. Scientific credibility now requires a predictive capability based on mechanistic understanding ("Why does it happen?"), rather than the much simpler empirical studies ("What happens?") of reactions, processes and materials. Gaining a mechanistic understanding will be key for developments such as geological disposal and winning public support.

The research and development requirements associated with the nuclear industry can therefore be summarised as follows:

Support to existing reactor and fuel cycle infrastructure operations

R&D is required for the continued safe and reliable operation of the UK's existing nuclear fleet and supporting fuel cycle infrastructure. This requires assessment of materials performance issues such as graphite cores in Magnox and AGR reactors or steels in structural components; both of which are subject to effects such as thermal ageing, corrosion mechanisms and radiation damage etc. Research is also required to help plant lifetime and performance predictability which requires R&D into inspection and condition monitoring techniques. Chemistry related issues are also important such as effect of radiation on reactor coolants, spent fuel processing operations or radiolytic oxidation of graphite. Continued research is also required on reactor core physics and fuel performance as well as fuel cycle assessment.

Support to legacy waste management, decommissioning and clean-up

The Nuclear Decommissioning Authority has stated clearly that research and innovation play a key role in helping to drive forward the clean-up programme such that it can be delivered "quicker, cheaper and safer". This requires research on waste form characterisation, separation and segregation techniques. Means to immobilise and encapsulate waste are also required. Concerning decommissioning there is a need to assess structural integrity, radionuclide inventory analysis, remote handling and use of robotics, for example. The NDA also conduct research into environmental impact assessments, land remediation and epidemiology.

Ensuring readiness for new nuclear build in terms of reactor selection, licensing & deployment

Although new reactor systems likely to be deployed in the next ten years are regarded by the vendors as standardised and "ready to go", it is still likely that some supporting research and development will be necessary. Advanced Generation III systems such as the European Pressurised Water Reactor or the AP1000 have novel features such as passive safety or digital control and instrumentation. Whilst research is not needed to "deconstruct" these systems before they are built, it is still necessary that the UK regulatory authorities can make informed expert judgements to support assessment and deployment. The ability to make this judgement relies on underpinning research and development. Research is therefore needed to maintain UK capability in reactor related issues such as reactor physics and fuel performance studies, materials performance, criticality, coolant chemistry, materials performance, thermal hydraulics and transient analysis etc.

Keeping abreast of advanced reactor technology as part of long term energy policy

Concerning long-term policy the UK needs to maintain an informed status regarding more advanced reactor designs that are being developed worldwide. These include novel Generation III+ systems such as high temperature gas-cooled reactors or Generation IV systems such as fast reactors, supercritical water or molten salt reactors. Currently there are active international collaborative projects investigating such systems. The UK needs to ensure it retains involvement in such activities in order to be able to assess whether or not such systems are appropriate for the UK. Also the UK already has some historic R&D experience associated with such systems given past developments like the Dounreay sodium-cooled fast reactor. R&D is necessary on issues such as fuel technology, reactor core design, spent fuel treatment process etc.

As of early 2013, there were no active advanced reactor R&D programmes beyond some work conducted in academia funded by the Research Councils. However there are signs of change: In 2014 the UK is set to resume active participation in the Generation IV programme, as well as investing £12.5m to join the Joules Horowitz Test Reactor in France (see page 75 of "The UK's Nuclear Future"), and a decision on a new small module reactor programme is expected by the end of the year.

Support to implementing deep geological disposal

On geological disposal CoWRM did recommend there is a need for "an intensified programme of research and development into the long-term safety of geological disposal aimed at reducing uncertainties at generic and site-specific levels as well as into improved means for storing wastes in the longer term". Research topics are likely to cover issues such as materials performance and integrity of the waste canisters, rock geology in terms of siting, radiochemical issues concerning migration of radionuclides through ground water, structural integrity and mechanical engineering associated with a repository. Also biological related research concerning the possible uptake of radionuclides into the environment and pathways back to man. The RWMD have made a start in this area by setting up their own geological disposal R&D programme. Together with EPSRC, the RWMD have awarded funding of £4m for "innovative R&D projects to addressing research challenges" in this area. These funds are split between five major projects.

In summary the UK has significant demand on nuclear R&D covering waste management through to advanced reactor development. This broad requirement is met through industrial and commercial research as well as the academic sector.

2. Capabilities Assessment

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The UK capabilities in nuclear fission power generation vary widely and have been much decreased over the past few decades following the termination of reactor design and build in the UK as well as the reduction in investment in R&D. This decrease is also evident in the university sector with very limited capability in the 1990s until BNFL and more recently EPSRC started more targeted investment and re-invigoration. Specifically in reactor technology capability still exists to support current operations, although the ability to select, license and deploy advanced systems could prove more difficult due to lack of familiarity with such systems. Critical skills include:

- Materials performance
- Reactor Physics and Fuel Assessment
- Water Chemistry
- Criticality and shielding
- Thermal hydraulics and transient analysis
- Safety assessment
- Nuclear systems engineering
- Nuclear Data

Vulnerable capabilities are not just those associated specifically with reactor engineering but also include other aspects such as environmental and social assessment as well. For environmental work funding on research activities (such as dispersion of radionuclides into the environment and uptake into the food chain, for example) have declined markedly over the past decade. International collaborative efforts and EU projects are a means to retain some of the funding in this area.

Capabilities to support legacy waste management and clean-up activities are much healthier given the focus of UK activities. The UK has very strong capability in areas such as spent fuel management, fuel reprocessing, waste separation, waste characterisation and waste management. The UK has fully developed the capability to manufacture fuel including enrichment of uranium, plus examine irradiated fuel in special hot cell facilities and conduct all necessary tests on spent fuel. In addition the UK has independently developed the capability to manufacture MOX fuel (mixed Plutonium, Uranium Oxide fuel) and to load into reactors. Past strengths of the UK have been in fuel technology and also materials performance assessment with an extensive suite of facilities for conducting spent fuel tests and materials properties assessment. Also given the focus of the UK programme on legacy waste management and decommissioning, the UK has built up significant capability in technologies associated with engineering decommissioning such as remote handling, remote sensing, safety case assessment, hazard control, controlled demolition etc.

Given the historic UK capability in developing reactor systems, front end fuel manufacture, fuel processing and spent fuel management, it has significant capability that can support overseas developments. The UK is one of only a few countries that has deployed the technology to close the fuel cycle and take spent fuel from thermal reactors, reprocess and re-fabricated fuel and load into fast reactor systems. Thus with international collaborative programmes such as the Generation IV programme and the International Framework for Nuclear Energy Co-operation, the UK could potentially offer significant know-how and experience to further these programmes. However there is currently a political unwillingness to support active UK involvement in these programmes.

However in general nuclear energy still remains at risk given combined issues such as:

- Reduction in popularity of science and engineering degree courses amongst young people, though recently (as in 2013) this does seem to be changing as students are now seek courses which will lead to clear career paths
- Difficulty of attracting those that takes sciences and engineering into the industry
- Current age profile of the industry with many individuals with experience and expertise being close to retirement, though this is now (as at 2013) being modified by recent increases in students studying nuclear energy.

In general there has been a short term approach to R&D funding, often because of priorities set by the industry and this has led to some skills being vulnerable. In the past BNFL sought to address some of the needs by funding R&D to support advanced reactor systems. Now in the absence of Government funding for industrial R&D (beyond that of the Research Councils) some capabilities remain vulnerable. One of the roles of the National Lab will be to protect and revitalise these critical capabilities.

There are many international organisations involved in nuclear energy research, and these are investing and collaborating with UK programmes such as through the IAEA, OECD and EU Framework programmes. This type of activity helps to support the UK's interests and activities.

Table 2.1 Capability Assessment

UK Capability	Area	Market potential
High	Radionuclide separation	More generally referred to as reprocessing, the UK is one of the few countries that has built up significant experience and know-how both of aqueous and non-aqueous (molten salt) reprocessing.
	Actinide chemistry	UK has strong capability in radiochemistry and an understanding of actinide behaviour
	Spent fuel handling	Growing markets especially for R&D activities given the international collaborative ventures such as Generation IV and the International Framework for Nuclear Energy Cooperation.
	Fuel Reprocessing	As for "spent fuel handling", the UK has significant historic capability given it has fully developed the closed fuel cycle. This technology will be of benefit in the future as international interest grows in advanced reactors and fuel cycle technology.
	Waste encapsulation	Growing market given legacy waste issues in UK and similar decommissioning activities in other countries plus drive for geological disposal. Lack of UK experience of geological disposal is an inhibiting factor, though being offset by membership of the EU-funded Implementing Geological Disposal Technology Platform (IGDTP).
	Decommissioning engineering	A growing global market with the UK having strong industrial capabilities.
	Waste characterisation	A growing global market given legacy waste management programmes. UK industry and academia have strong capabilities.
	Fuel cycle assessment & evaluation	A growing global market, with strong US interest. The UK is one of few nations that has a strong industrial capability supported in niche areas by academia.
	Fuel manufacture	Global market depends on a nuclear revival. UK has strong industrial track record supported by academia. This includes the ability to enrichment uranium and also manufacture MOX fuel

	Materials performance	To support the UK's capability in fuel technology, reactor systems and spent fuel handling, there is an extensive capability in materials performance assessment including handling of active samples. This is a growing market given a lot of nuclear engineering issues are associated with materials issues. A growing global market related to structural integrity, lifetime extension and safety case production. Strong UK capability in industry and academia.
	Criticality and safety assessment	Good UK capability in industry and academia – however this capability is very much in demand worldwide.
	Nuclear Information Security	The UK is also leading on nuclear information security through an FCO initiative. An additional UK-sponsored multinational statement (also known as a "gift basket") on nuclear information security was supported by over 30 countries at a Summit in Seoul in Korea. They will report on this gift basket at the 2014 Summit. https://www.nss2014.com/
Medium	Enrichment technology	Level global market, possibly growing dependent on global new nuclear build. UK still active but has lost its R&D capability.
	Nuclear data and physics code development	Global market depends on new nuclear build. Good UK capability in industry and academia.
	Systems Engineering	Global market depends on new nuclear build. UK has only pockets of capability.
	Geological disposal engineering	A growing global market. Lack of UK experience of geological disposal is an inhibiting factor due to the fact the UK has not properly initiated an implementation programme. However in specific technical areas the UK has made substantial contribution to international know-how, for example on canister welds and ground water flow modelling.
	Human and other biota risk assessment	Human risk assessment is well established, but non-human biota may be a growth area if EU or international standards are set in the future.
Low	Reactor design Reactor construction Thermal hydraulics	Global market depends on nuclear revival. The UK is no longer able to compete but needs to retain some indigenous capability to understand reactor systems.

3. Basic and strategic research

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The UK has an extensive civil nuclear fission programme covering all aspects of the fuel cycle such as fuel manufacture, reactors, spent fuel treatment, reprocessing, waste management, disposal and decommissioning.

The research base exists within private sector industry, public sector organisations and academia. Obviously the academic work is more focussed on fundamental underpinning science whereas public sector and private sector research is closer to end –user application.

The majority of R&D to support the industry is used to help underpin the industry's knowledge base to ensure appropriate judgements and decisions related to whether this is on safety assessment, cost reduction or performance/operational related issues. There are very few occasions when it is possible to specifically identify a new product taken through the innovation chain to commercial deployment. It is more a case of R&D helping to progress understanding and resolve issues.

Here academia provides the underpinning fundamental science and this is often then used by industrial research organisations in terms of application. Key industrial research organisations are discussed in detail in section 4 with the remainder of this section focusing on academic capability.

For the majority of research projects, the avenues open for funding include UK Research Councils, direct support to Government, private industry, EU framework activities and broad international collaborative ventures.

University based nuclear fission research falls into several different categories ranging from materials performance, civil engineering and waste disposal. The research in each category focuses on improving the efficiency, reliability, safety and sustainability of the reactor systems. Negligible research falls under advanced reactor systems or design of new fuels suitable for such systems. Research is broadly in line with Government civil nuclear policy, and so focuses on decommissioning and safety and efficiency of current systems. Hence R&D is carried out in areas such as materials performance, modelling and spent fuel, but very little R&D goes into new reactor systems or fuels.

Despite previous dramatic cut backs in nuclear fission funded research, funding for some expertise and capabilities have been maintained. There are several university research alliances which have links to the NDA as well as the NNL. These centres at Manchester, Sheffield and Leeds attract funding from a variety of sources including industry, research councils and Government grants, and each centre has a different area of expertise. Manchester University in particular receives substantial funding for its work on nuclear energy, and has expanded to include several new centres and programmes, most of which are overseen by the Dalton Nuclear Institute.

The Dalton Nuclear Institute (DNI) opened in 2005, and has been a valuable resource to the nuclear industry. Advanced nuclear research is carried out at the Institute, and partnerships with industry keep research topics broadly in line with the current needs of the nuclear sector. The DNI has received significant funding from research councils and several industrial partners and now supports the following groups within the University: control systems, acceleration science, graphite research, thermal hydraulics and computational fluid dynamics. Additionally it runs, or is closely linked with, a number of important centres, including the Centre for Nuclear Energy Technology, the Centre for Radiochemistry Research, the Materials Performance Centre,

and the Nuclear Advanced Manufacturing Research Centre. The roles of these centres are outlined in Table 3.2.

Furthermore, the construction of the Dalton Cumbrian Facility has significantly helped research; housing state-of-the-art irradiation equipment and analysis tools, it allows academics and industry alike unique opportunities to use specialist equipment, including a Cobolt-60 gamma irradiator.

Other universities also are developing their capability in nuclear research. For example Imperial College in Materials Modelling and Reactor Physics / Criticality related research, Lancaster University in Environmental Assessment, Birmingham through its Centre for Nuclear Education and Research, UCLAN through the Westlakes Research Institute, and UCLan Nuclear, Liverpool in Radiometrics, and the University of the Highlands and Islands in Decommissioning support work to Dounreay and further afield.

Also EPSRC has funded an Engineering Doctorate Training Programme in Nuclear Engineering: this is led by the University of Manchester in partnership with Imperial College London and 6 supporting universities (Birmingham, Lancaster, Leeds, Sheffield, Strathclyde and Surrey) covering specific topics and skill areas, and carried out in direct collaboration with industry. Total funding to date (since 2006) from EPSRC for this Doctorate Programme is £7.6m further supplemented by industry sponsorship in excess of £2.5m. It is aimed at developing future technical leaders for the nuclear industry. Similarly a Nuclear Fission Research, Science and Technology (Nuclear FiRST) doctoral training scheme has also been introduced (2009).

Research into long term solutions for nuclear waste has received increased attention, with EPSRC and NDA RWMD putting forward a collective £4 million in 2010 for a call into Geological Disposal of Nuclear Waste. Five projects from different universities were selected to benefit from this funding.

The UK Nuclear University Network maintains a list of current nuclear energy research.

Table 3.1: Research Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Nuclear Engineering Doctorate	EPSRC	Engineering Doctorate (EngD) carried out in collaboration with industry to develop high-level skills in: Reactor Technology, Waste Management, De-commissioning, Materials, Socio-economic aspects and Safety Systems. Led by the University of Manchester	£7.6M (EPSRC) plus industry contribution of at least £2.5M	09/2006 – 09/2017	£1M (approx)

		University in partnership with Imperial College London and supported by the Universities of Birmingham, Lancaster, Leeds, Sheffield, Strathclyde and Surrey.			
Doctoral Training Centre for Nuclear Fission Research, Science & Technology (Nuclear FiRST), University of Manchester and University of Sheffield	EPSRC	Nuclear FiRST was established in January 2009, with investment from EPSRC. It is a national training centre for postgraduates who wish to pursue nuclear fission science and technology careers and training. Nuclear FiRST is a collaboration between The University of Manchester and The University of Sheffield.	£7.1m	10/09 – 03/18	
Decommissioning, Immobilisation and Storage soluTIons for NuClear wasTe InVEntories (DISTINCTIVE)	EPSRC	This consortium of 10 Universities (Leeds, UCL, Strathclyde, Loughborough, Sheffield, Lancaster, Manchester, Bristol, Imperial College and Birmingham) and three companies (National Nuclear Laboratory Ltd, Nuclear Decommissioning Authority, and Sellafield Ltd) builds upon and consolidates the work of a previous EPSRC funded programme known as Diamond (Decommissioning, immobilisation and management of nuclear wastes for disposal, EP/F055412/1 – July 2008 to March 2013). It addresses the broad area of nuclear waste and decommissioning. The consortium includes 30 separate research projects clustered into 4 major themes, viz.: Spent Fuels, Plutonium Oxide & fuel residues, Legacy ponds & silo wastes, and Structural Integrity. With the overall aim of providing new and innovative pathways to better (that is safer and cheaper)	£4.9m	02/14-1/18	£1.0m

		management of both legacy and future nuclear wastes.			
NDA direct portfolio	Nuclear Decommissioning Authority	Support for four university Centres (Leeds, Sheffield and two at Manchester) in particle science and engineering, immobilisation science, Radiochemistry and materials performance, respectively. NDA also fund epidemiological research at UCLAN. Also individual projects, e.g. at Imperial College See Table 3.2 for details.			£3.2m in 2012/2013 (variable)
Decommissioning related research	Nuclear Decommissioning Authority & Manchester University	Joint £20m strategic fund for agreement between Manchester University and NDA, also there is investment by EPSRC in establishing two new chairs at Manchester University in decommissioning engineering and radiation sciences etc	~£20m	2007 onwards	~£3m
Waste management, decommissioning and Geological Disposal	EPSRC, RWMD	Programme covering legacy waste management and clean-up activities. Funding split between five projects	£4m	2008 onwards	
Nuclear Safety Research	Health & Safety Executive	Direct funding of basic research in key areas such as Graphite through the Nuclear Graphite Research Group at Manchester University			
Dose estimation	Health Protection Agency (which on 1 April 2013 became part of Public Health England)	Development of assessment tools for radiological impact on individuals and population in general.			
Dose estimation for non-human biota	Environment Agency	Development of assessment tools for estimation of internal and external doses to plants and animals. Current focus on waste and new build.	~£1m	2003 onwards	
Basic nuclear research at universities	Private & Public Sector Organisations such as Rolls Royce, NDA,	A range of basic research activities are funded by public and private sector organisations through agreements with UK			

	AMEC-NNC, AMEC, EDF Energy etc	academia.			

Table 3.2: Key Research Providers

Name	Description	Sub-topics Covered	No of staff	Field
Construction and Remediation, Chemistry, School of Natural and Computing Sciences, University of Aberdeen	Aberdeen has a long history of research excellence in cement science. Current activities include: • Fundamental studies of cement hydration and durability • Applications to waste management, including nuclear decommissioning	• Nuclear waste management and decommissioning	3 academics	Chemistry
Nuclear Energy Group, University of Bath	The Nuclear Materials Group at the University of Bath is recognised for its expertise in nuclear materials (especially graphite). More recently it has expanded to include expertise in decommissioning, mechanical design and energy systems analysis.	• Nuclear materials		Metallurgy and Materials
The Birmingham Centre for Nuclear Education and Research, University of Birmingham	The Birmingham Centre for Nuclear Education and Research brings together a multidisciplinary team from across the University to tackle fundamental nuclear industry problems. The team actively engage with industry, other universities, and international partners.	• Nuclear Engineering • Waste Management • Decommissioning	4 academics	Mechanical, Aeronautical and Manufacturing Engineering Physics
University of Bristol	The Nuclear-Systems Performance Centre (Nuclear-SPC) is a Research Alliance between the University of Bristol and British Energy The Nuclear-SPC is one of four British Energy Research Alliances. The Safety Systems Research Centre is a research centre established in 1995. It conducts research into the challenges of safe and reliable design, operation and maintenance of computer-based systems. The SSRC has a broad appreciation of safety issues across various industry sectors such as nuclear,	• Reliability		Metallurgy and Materials Physics

Name	Description	Sub-topics Covered	No of staff	Field
	naval and aviation industries The Universities of Bristol and Oxford have a joint nuclear research centre. It has been established to provide leading edge and innovative research to support the safe operation of current and future generation nuclear systems	• Safety		
Cambridge Nuclear Energy Centre, University of Cambridge	Encompassing the departments of earth sciences, physics, Metallurgy and materials, engineering and the Judge Business school, the Nuclear Energy Centre supports a broad range of research into all areas of nuclear power. These include waste disposal, reactor systems, energy security and nuclear policy, radiation damage and materials, as well as research on fusion energy.	• Materials science • Thorium reactors • Fuel design • Systems modelling		Metallurgy and Materials Physics
Geoenvironmental Research Centre, Cardiff university	The Geo-environmental Research Centre (GRC) is a pioneer in the field of geo-environmental engineering. Established in 1996, the Centre provides research support in a new and emerging area of land-based environmental problems; and directly translates its research for the benefit of industry.	• Geo-environmental engineering		Earth Systems and Environmental Sciences
UCLan Nuclear, University of Central Lancashire	UCLAN Nuclear specialises in a number of areas : • Nuclear Safety, Security and Safeguards – Regulation • Nuclear Materials and Processing Technology – including decontamination (e.g. bio-availability of radionuclides in i-graphite) and advanced separation science (e.g. continuous chromatographic separation of metals). • Internal and External Hazards - current projects include impact on honeycomb structures, model development for auxetic materials, fire modelling capability and realistic temperatures for prediction of waste package boundary conditions • Nuclear Decommissioning and Waste Management	• Nuclear Regulation • Nuclear Safety • Nuclear Security • Nuclear Materials • Internal and external hazards • National and international nuclear energy strategy • Effective management	5 academics	Business and Management Studies
CEFAS	Scientific research working in fisheries management, environmental protection and aquaculture with specific links to understanding radionuclide up-take	• Ecosystem interactions • Organism health		Biological Sciences Earth Systems and

Name	Description	Sub-topics Covered	No of staff	Field
				Environmental Sciences
Centre for Nuclear Engineering, Imperial College London	"The Centre brings together a number of disciplines including mechanical, chemical and materials engineering, modelling and radio ecology to create one of the most comprehensive research and teaching groups dedicated to nuclear engineering and science." Imperial College London is one of four British Energy Research Alliances.	• Modelling • Structural integrity and life assessment • Geomechanics for waste • Materials transport • Materials performance and ageing • Reactor hydraulics • Waste	~30	Metallurgy and Materials Physics
Department of Materials, Imperial College London	Research is centred around four main types of material: Biomaterials; Ceramics and Glasses; Metals; and Nanotechnology. Energy conversion is one of the key application sectors identified.	• Atomistic simulation of Fission Product concentration with burn up of UO2 Fuel • Atomistic simulation of encapsulation of legacy ILW	~20	Metallurgy and Materials
Complex Flow Systems Research Group, Faculty of Science, Engineering and Computing, Kingston University	The Complex Flow Systems Research Group conducts multi-disciplinary researches on a wide range of topic including aerodynamics, thermo-fluids, energy systems and granular flow. Its work is characterised by the diversity in methodology and approach: theoretical, simulation and modelling and analysis/experiment. One active research area is the application of computational fluid dynamics (CFD) for a Gen-IV thermodynamics study in collaboration with researchers from China.	• Computational Fluid Dynamics (CFD)		Mechanical, Aeronautical and Manufacturing Engineering
Radiometrics, Instrumentation and Control Group,	A multidisciplinary team of engineering researchers working on the combination of instrumentation and generic control in the context of a broad spectrum of autonomous platforms. Our research is almost entirely collaborative with the engineering	• Control and instrumentation		Electrical and Electronic Engineering

Name	Description	Sub-topics Covered	No of staff	Field
Engineering Department, Lancaster University	sector and other leading academic institutions around the world. Has delivered solutions to nuclear industry.			
Environmental Radiochemistry Group, Chemistry Department, Loughborough University	The Group's research work is largely, but not exclusively, centred on the Geochemistry of nuclear waste disposal, and requires an interdisciplinary approach to solve this world-wide problem. Research Topics : • Water chemistry (speciation, stability constants, kinetics, modelling). • Surface interactions (metal and metal-complex interactions with mineral and clay surfaces in the presence and absence of humic materials). • Mobility of aqueous species. • Predictive computer modelling. • Land remediation.	• Nuclear waste disposal		Earth Systems and Environmental Sciences Chemistry
Metals Research Group, Institute of Polymer Technology and Materials Engineering, Loughborough University	The focus of the activity is twofold: to understand, and direct, metallurgical behaviour through modelling microstructural evolution and to engineer surface coatings for enhanced performance.	• Irradiation assisted stress corrosion cracking associated with the chromium depletion • Earlier models for neutron induced grain boundary phosphorus Segregation in Ferritic pressure vessel steels is being expanded to cover such effect as stress, site competition, grain boundary	13	Metallurgy and Materials

Name	Description	Sub-topics Covered	No of staff	Field
		character.		
Particle Science and Engineering, University of Leeds	Based on the disciplines of Chemical and Mineral Process Engineering, addressing the engineering science of particulate processes	• Modelling • Measurement • Manufacture	22	Metallurgy and Materials
Centre for Radiochemistry Research, University of Manchester	Established in 1999 with support from BNFL (BNFL is now part of NDA). The centre is part of Manchester's Dalton Institute, and mainly investigates the chemistry of radioactive elements. Funded by the NDA and UK research councils.	Research Programmes: • Environmental Radiochemistry • The Chemistry of Nuclear Waste Disposal • Actinide Coordination Chemistry		Chemistry
Dalton Nuclear Institute, University of Manchester	"Established in 2005, the Dalton Nuclear Institute (DNI) has built a broad nuclear research capability that is addressing the major issues associated with nuclear power today and in the future: plant life extension, new nuclear build, decommissioning and radioactive waste management. The Dalton Cumbrian facility is the main research base for the DNI, and allows industry and academia access to top facilities. The DNI is home to many research centres, draws from expertise across the schools of materials, earth and atmospheric sciences, chemistry and physics."	• Manages the NNUMAN programme (see Table 4.1) Groups/ centres: • Accelerator Science • Modelling and Simulation Centre • C-NET • Materials Performance • Nuclear AMRC • Graphite Research Group • Radiation Science • Control Systems • Thermal hydraulics and computational		Metallurgy and Materials Physics Chemistry Earth Systems and Environmental Sciences

Name	Description	Sub-topics Covered	No of staff	Field
		fluid dynamics		
Materials Performance Centre, University of Manchester	A research centre for materials for the nuclear, power and chemical industries. The activity of this Centre is based across three host sites at the University of Manchester: the Corrosion and Protection Centre in the School of Materials, the Materials Science Centre also in the School of Materials and the Nuclear Graphite Research Group in the School of Mechanical, Aerospace & Civil Engineering. The University of Manchester is one of four British Energy Research Alliances	• Support on materials issues to NDA-operating companies and other external chemical and power industry companies • Expertise in key areas including: materials degradation, structural integrity and graphite	18	Metallurgy and Materials
Materials Engineering Group, The Open University	The Group's research focuses on the use of advanced metal alloys in demanding applications, including nuclear energy. Research expertise is in the fields of Residual Stress Measurement and Analysis, High Temperature Materials Behaviour and Mechanics of Materials.	• Metallurgy and materials		Metallurgy and Materials
Materials Department, Oxford University	The materials department works in partnership with NNL and Rolls-Royce to study of the effects of thermal ageing and irradiation on reactor pressure vessel (RPV) steels.	• Performance and Reliability of Metallic Materials • Characterization of the atomic scale structure of yttria-based particles in oxide dispersion strengthened steels • Zirconium alloys for high burn-up fuel in current and advanced light water-cooled reactors		Metallurgy and Materials
Public Health England (before 1	Independent national organization charged with protecting the health and well-being of the United Kingdom citizens from	• Capability to assess impact of different		Biological Sciences

Name	Description	Sub-topics Covered	No of staff	Field
April 2013 was known as the Health Protection Agency)	infectious diseases and in preventing harm and reducing impacts when hazards involving chemicals, poisons or radiation occur	radiation types on individuals and population as a whole.		Agriculture, Veterinary and Food Science Earth Systems and Environmental Sciences
Immobilisation Science Laboratory, University of Sheffield	Science of nuclear waste immobilisation. Also the Sheffield hub of the Nuclear FiRST DTC (Doctoral Training Centre)	• Immobilisation of toxic and radioactive waste in phosphate glasses • Application of ceramics and glass ceramics for immobilisation of plutonium containing legacy wastes • thermodynamic database for advanced nuclear fuel • Immobilisation of Intermediate Level Nuclear Wastes in Cement	24	Metallurgy and Materials
Materials Science and Engineering, University of Sheffield	Research covers many topics, waste immobilisation being the one most heavily linked to nuclear. The department is home to the Immobilisation science laboratory, which examines radioactive immobilisation.	• Advancement of Castings in the Nuclear Supply Chain • Designing ceramic Coatings for Zr-alloy Cladding • Effects of radiation on materials • The Development of		Metallurgy and Materials

Name	Description	Sub-topics Covered	No of staff	Field
		Nuclear Manufacturing Techniques for Nuclear Applications		
EDF Energy Advanced Diagnostic Centre Department of Mechanical Engineering, University of Strathclyde	Primary drivers for the research in the centre has been on AGR (Advanced Gas Cooled Reactor) nuclear power plant lifetime extension The University of Strathclyde is one of four British Energy Research Alliances.	Research focused on: • automated data analysis • diagnostics and decision support • modelling and simulation and sensors • sensor systems within the nuclear power industry		Metallurgy and Materials Electrical and Electronic Engineering
Westlakes Science and Technology Park	Capabilities in areas of Genetics, Epidemiology, Environmental Science and Policy studies	• Genetics and Epidemiology, • Environmental Science • Policy studies		Biological Sciences Earth Systems and Environmental Sciences

4. Applied research

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Beyond university based research, the National Nuclear Laboratory (NNL), formerly Nexia Solutions, conducts research for customers such as the site license companies that run sites for the NDA. As well as these Tier 1 organisations, NNL also does work for Tier 2 and Tier 3 supply chain companies. It also has contracts with the MoD and EDF Energy. However, much of the output is commercially confidential or directly related to plant support activities.

Work directly funded by NDA relating to R&D is available to any contractor with much of the outcome placed in the public domain. Major R&D activities conducted by NNL cover the whole breadth of the nuclear industry: Measurement and Analysis, Environmental Services, Waste Residues and Processes, Waste Management Technology, Fuel and Radioisotope Technology, Spent Fuel Technology, Safety Management, Asset Care and Security.

The majority of research in the UK is concerned with maintaining current reactors, fuel cycle operations plus, as noted earlier, the decommissioning and legacy waste management. With new reactors set to be built over the coming decades, the expectation is that research focuses will undergo a shift, as Government aims to increase funding for R&D to help maintain the new fleet and keep construction/running costs down. There is also increased spending on R&D into long term storage of legacy waste and waste being produced by the current fleet. At present there is still negligible investment in the new generation of reactor systems and fuels.

To help with the forthcoming new build, The Nuclear Advanced Manufacturing Research Centre was opened in 2012, and carries out specific R&D projects for individual companies, as well as participating in externally funded research projects. The centre also has an industry-lead training scheme which aims to help equip the nuclear manufacturing supply chain with the skills it needs for new build construction and safety. Its research primarily focuses on ensuring companies overcome any manufacturing problems.

Not highlighted in Table 4.1 below, due to low level of funding but some involvement include funding organisations such as the Home Office, the DTI non-proliferation and safeguards work, the Health Protection Agency (which since 1 April 2013 is part of Public Health England) and the Environment Agency. The MOD also funds nuclear R&D but this is not classed as civil related work, although work on naval propulsion does overlap with civil reactor systems work.

Table 4.1: Research Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Operations Support	Tier 1 Site License Companies, contracted by the NDA	Support to site management activities, decommissioning work, waste characterisation and encapsulation. Also includes R&D to support continued operation of Magnox stations (such as graphite monitoring)			
	Other Engineering Companies	Other engineering companies support applied research as part of business operations associated with management and clean-up activities at UK sites			
Generation	EDF Energy	Support to current AGR fleet including graphite and performance other materials, instrumentation and control and lifetime extension			£300m
Naval Propulsion	MoD AMEC Rolls Royce	Support to continued operation and maintenance of UK naval nuclear propulsion fleet			
Waste Disposal	NDA, CoWRM	Support to waste disposal			
Nuclear Safety Research	Health and Safety Executive	Nuclear safety research requirements			£53m
New Nuclear Manufacturing (NNUMAN)	EPSRC, Universities of Sheffield and Manchester	NNUMAN has R&D capabilities for supporting nuclear new build over the coming decade. It concentrates on development of manufacturing processes in areas such as materials, fuels and components.	£8m	2012 onwards	

Table 4.2: Key Research Providers

Name	Description	Sub-topics Covered	No of Staff	Sector
Academia	UK academic institutions support applied research delivery to industry such as Manchester, Leeds, Sheffield, Imperial, Bristol, Strathclyde, UHI etc	• General capabilities as covered by academic sector (see earlier)		
AMEC-NNC	Reactor operations support firm including desk based research on advanced systems. In 2010 AMEC were awarded an 11 year contract with EDF to help engineer the four new reactors to be built at Hinkley point and Sizewell. In 2008, the Serco's Technical Services was contracted (under a 5 year contract) to be a provider of nuclear data codes and radiation transportation analysis software to British Energy. In June 2012 Serco's nuclear Technical Services business was acquired by AMEC	• Materials • Radiochemistry • Systems Engineering • Reactor Physics • Fuel Assessment • Engineering design • Safety Assessment • Thermal Hydraulics • Operations	~500 ~ 3000 nuclear specialists	Consulting engineers
National Nuclear Laboratory	As the main nuclear lab in the UK, research into all areas of basic and advanced R&D are carried out. The NNL conducts R&D for a range of companies and organisations.	• Measurement and Analysis • Environmental Services • Waste Residues and Processes • Waste Management Technology • Fuel and Radioisotope Technology • Spent Fuel Technology • Safety Management • Asset Care • Security	~500 (not including facilities operations)	R&D science and engineering
Nuclear Advanced Manufacturing Research centre	Launched in 2012, the Nuclear AMRC supports industry with manufacturing issues. It is owned by universities, and receives support from EDF, NIA, NNL and carries out research in	• Machining • Welding and cladding • Materials • Laser processing		Manufacturing

Name	Description	Sub-topics Covered	No of Staff	Sector
	machining, welding and cladding, materials, and laser processing. NAMRC was funded £22m Department for Business, Innovation and skills, and the former Yorkshire Forward.			
Rolls Royce Power	Nuclear materials and structural integrity R&D for supporting naval propulsion	• Nuclear data • Materials performance		Manufacturing

5. Development and Demonstration Funding

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There are no nuclear fission demonstration projects in the UK in the same sense as those for demonstrating other energy technologies such as wave, wind or tidal. Test rigs are developed to support specific research projects and occasionally these could be classed as demonstration facilities. For example the Vitrification Test Rig at Sellafield. There are also demonstration fuel fabrication facilities at Springfields for advanced fuels research, although these are not currently utilised.

6. Research Facilities and other Assets

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Current research reactor facilities are limited, and when this is broadened to neutron sources the list expands little. There are several universities which have the facilities to consider waste encapsulation and conduct simulation experiments, however the equipment is often generic and as such the facilities are generally limited to the staff expertise present at the institutions. Very few laboratories have the capability of handling highly radioactive samples at present. The NNL holds most capability in this area, with its Sellafield Laboratories equipped to deal with hot cells, amongst other radioactive materials. As of 2013, the NNL is in the process of completing 'phase 2' of its laboratories which will give it the ability to handle plutonium active 'gloveboxes'. This should be project ready by April of 2014. The NNL is also waiting for the go ahead for 'phase 3' plutonium laboratory complex to be built. This will enable the lab to handle High Active Cells.

Table 6.1: Research Facilities And Assets

Name	Description	Type of asset	Scale of operation	Annual Operating Budget
Dalton Cumbria Facility	Nuclear Research complex, part of the Dalton Nuclear Institute. The DCF, is a core component of the new National Nuclear User Facility (see below), and is designed to complement and significantly expand the nuclear research and education capability of the UK's nuclear R&D sector	Research laboratories, cobalt 60 source	50 postgrad researchers	
HMS Sultan	Defence School of Marine Engineering, which trains engineering officers and ratings.	Neutron source and teaching facilities		
National Nuclear Gateway	The National Nuclear Gateway was designed to help equip businesses with the skills needed to help deliver the new nuclear programme. Announced in December of 2012 and funded by the UK Commission for Employment and Skills (2 year funds), it is overseen by NSAN.	Training centre		
National Nuclear Laboratory	The largest nuclear laboratory in the UK, with its own R&D portfolio, as well as carrying out work for Tier 1, 2 and 3 companies. Capabilities in advanced reactors, fuel manufacture, specialist analytical services and process chemistry. Several laboratories: Central Laboratory, Sellafield Preston laboratory – Uranium active Windscale Laboratory – highly active materials Workington – 'non active' research.	Research laboratories	Largest nuclear labs in UK: ~250 full time equivalent (FTE) (source : p28 of "A Review of the Civil Nuclear R&D Landscape in the UK "	In 2011, NNL received over £32m from UK industry, with ~£9m coming from other sources including Government, EU, research councils, and self-funding.
National Nuclear User Facility	In March 2013 the Government announced the award of £15 million to set up a new world class National Nuclear Users Facility for universities and companies carrying out research into nuclear technology. The facility will have centres at Sellafield (within the Dalton Cumbria Facility – see above), the Culham Centre for Fusion Energy in Oxfordshire and the University of Manchester's Dalton Cumbrian Facility.			

National Skills Academy for Nuclear	Launched in 2008, the NSAN was initially Government funded, but has since become self-sustaining. It is an employer lead organisation, representing industry, and training in skills to support the nuclear industry.	Training centre	Over 100 employer members	
Nuclear Advanced Manufacturing Centre	Nuclear AMRC supports industry with manufacturing issues. It is owned by universities, and receives support from EDF, NIA, NNL amongst others, with an aim to 'help businesses become suppliers of choice to the global civil nuclear industry'. Its core facility is situated near Sheffield at the Advanced Manufacturing Park. It also uses the Manufacturing Technology Research laboratory at the University of Manchester.	Research Laboratories, Training centre	40 member companies	
Other	There are a range of academic based research facilities– a few universities are able to handle active materials			

7. Networks

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Until recently there have been few UK activities. However, new networks are beginning to emerge, particularly following the 2013 Government reports on the review and expansion of the nuclear industry. The Nuclear Institute has been formed as a merger of the longstanding British Nuclear Energy Society and Institution of Nuclear Engineers. The Nuclear Innovative Research Advisory Board (NIRAB) and the Nuclear Innovation Research Office (NIRO) oversee R&D as the nuclear sector expands. A list of current UK Educational Networks can be seen on the UK page of the European Nuclear Society's www

There are a number of EU and international activities in which the UK participates, see Sections 8 and 9.

Table 7.1 Networks

Network	Established	Description	Membership	Activities
COGENT	2008	**Cogent** is the UK's industry skills body for chemicals, pharmaceuticals, nuclear, oil and gas, petroleum and polymer businesses. As an employer-led Sector Skills Council (SSC), Cogent works with industry to research and forecast skills needs and develop fit-for-purpose standards and qualifications and other skills solutions. Employers and national and regional partners work with Cogent and the National Skills Academies to ensure that individuals and the companies they work for can develop higher skills and achieve higher productivity.	Employers	• Cogent works with industry to research and forecast skills needs and develop fit-for-purpose standards and qualifications and other skills solutions.
COMARE		Committee on aspects of radiation in the environment. Offers independent advice to Government regarding the health effects of radiation.	Independent Medicals University academics	• To assess and advise Government and the devolved authorities on the health effects of natural and man-made radiation and to assess the adequacy of the available

				data and the need for further research
Co-ordinating Group on Environmental Radioactivity (COGER)	1976	COGER's principle role is to bring together specialists from the nuclear and related industries, academics from Universities and NERC institutes, nuclear industry regulators and interested parties including non-Government organisations (NGOs) whose interests are in the broad area of environmental radioactivity (from both natural and anthropogenic sources) and is highly multi-disciplinary in nature with scientists from botany, zoology, chemistry, soil science, ecology, geochemistry, geology and oceanography to name but a few disciplines.	Researchers, regulators, consultancies - highly multi-disciplinary in nature with scientists from botany, zoology, chemistry, soil science, ecology, geochemistry, geology and oceanography	• To ensure effective coordination of information exchange between research groups involved in basic scientific research and those involved in programmes of directed research in the field of environmental radioactivity • To organise an annual Open Meeting involving all those concerned with research on environmental radioactivity • To ensure effective coordination of basic research and applied research for environmental radiological impact assessment • To provide advice and support in general to those carrying out environmental radioactivity research • To advise on the adequacy of research on radioactivity in the environment and in particular to highlight any deficiencies/gaps in the research programmes • To provide links between COGER and the activities of other groups with responsibility for matters

				related to environmental radioactivity
National Dose Assessment Working Group (NDAWG)	2002	Brings together people and organisations with responsibility for, and/or an interest in, the assessment of radiation doses to the public from the operation of the nuclear industry and from minor users of radioactivity. The main focus of the work of NDAWG is to be past, present and future authorised discharges and direct radiation; initially the Group's scope will not include accidents or solid waste disposal.	Regulators/agencies Industry Specialists/NGOs	• To facilitate the exchange of data and views between all parties on assessment methodologies. • To advance the understanding between groups who are likely to have differing objectives and views on dose assessment methods. • To facilitate the development of coherent transparent methods for the assessment of radiation dose to the public from all pathways which arise as a result of the operations at nuclear and non-nuclear sites. • To meet on a regular basis (every 6 months) to discuss matters of mutual concern, and developments arising out of research, case histories (e.g. recent consultations) or changes in Government policy. • To identify, discuss and evaluate research which will progress dose assessment methods. • To initiate debate beyond the group on key issues, as necessary (for example via the Society for Radiological

				Protection). • To keep abreast of international developments on dose assessment methodologies, and to provide feedback to the appropriate UK authorities for input into EU bodies.
National Skills Academy for Nuclear, NSAN	2008	The National Skills Academy for Nuclear, NSAN, was established in 2008 with a role to create, develop and promote world class skills and career pathways to support a sustainable future for the UK Nuclear industry. It is an employer led organisation established to ensure that the UK Nuclear Industry and its Supply Chain has the skilled, competent and safe workforce it needs to deal with the current and future UK nuclear programme	Nuclear Industry	• to create, develop and promote world class skills and career pathways to support a sustainable future for the UK Nuclear industry.
Nucleargraduates	2007	nucleargraduates is a national two year graduate scheme that is backed by over twenty different organisations who work within the nuclear industry. Initially established by the Nuclear Decommissioning Authority in 2007 it has now been expanded to cover all aspects of the nuclear industry in the UK.	Nuclear Industry	• Creation of graduate training programme for Engineers, scientists, business minds, talented managers and financial experts .
Nuclear Industry Association	1963	Main body in the UK for acting on behalf of the collective nuclear industry	260 + member companies	• Promotion of the nuclear industry

Nuclear Industry Council	February 2013	Aims to provide 'high level strategic direction to the UK's nuclear Industry'. Set up as part of the Government's Nuclear Industrial Strategy, the NIC replaces the Nuclear Development Forum (NDF). The NIC helps industry capitalise on the opportunities that new build presents.	Jointly chair between Government and industry. (DECC and NIA) Members are senior representatives from the nuclear industry, including developers, vendors, operators, key suppliers, contractors and unions.	• To act as the leading engagement body between the UK nuclear industry and Government, as well as providing a forum for dialogue between different parts of the industry. • To develop and maintain a single, coherent strategy and vision for the civil nuclear industry in the UK to guide decision-making in Government and business. • To agree, and oversee the implementation of, work programmes to strengthen the capability and competitiveness of the UK nuclear industry at home and internationally. • To work with the Research community and industry to underpin those actions needed to realise industry and Government's long-term vision for the sector.
Nuclear Innovation Research Office	2013	NIRO, which is hosted by the National Nuclear laboratory (NNL) will "respond to Nuclear Innovation Research Advisory Board (NIRAB) recommendations and provide advice to Government, its organisations and industry on R&D / innovation opportunities (including commercial) and programmes." (source p22 of "The UK's Nuclear Future"		• Advise Government and industry on nuclear innovation and R&D into future nuclear energy technologies • Coordinate UK involvement in international nuclear programmes • Ensure public R&D

				programmes align with industrial and energy policy aims • Explore how funding can be secured, not only from Government, but also from the private sector, EU and other international organisations and programmes related to future nuclear energy systems • Review at regular intervals the status of UK nuclear innovation and R&D
The Nuclear Institute	2009	Works with members to provide training, run events, offers services and develop expertise. Offers a range of memberships to match the experience and expertise of each member. Covers all aspects of nuclear energy. The nuclear Institute is a merger of British Nuclear Energy Society and Institute of Nuclear Engineers. The **Nuclear Academic Industry Liaison Sub-Committee of the NI, NAILS**, is a forum in the UK at which representatives from both the academic and industrial nuclear sectors meet to discuss trends, implications and opportunities. Meetings occur twice a year and have representatives from most of the major academic institutions, companies and public sector organisations. It is also responsible for organising the annual Universities Nuclear	Three main types of members: Professional members, Learned Society members and Company members.	• provides information on nuclear energy issues. • provides opportunities for members to meet and debate issues • provides opportunities for members to publish and present papers. • promotes increased public understanding of the issues surrounding the use of nuclear energy • Promotes nuclear energy specific training in the United Kingdom.

		Technology Forum, UNTF, (www.untf.org.uk)		
Nuclear Universities Research Consortium	2007	A grouping of UK universities interested in nuclear R&D	23 HEIs	• Networking • Joint assessment of research opportunities • Response to consultations • Promotes international opportunities

8. UK Participation in EU Framework Programmes

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EU Framework funding in the area of nuclear research is covered separately as the EURATOM programme to the rest of EU funded activities. It was originally ring-fenced given the need to take forward essential nuclear research for safety etc but recognised that the topic was one that consensus amongst the EU nations was difficult to achieve. For FP6 the total funding was €1.3billion with €824m for the fusion programme, €209m for the fission R&D programme and €319m contribution for running the EU Joint Research Centres. The fusion funding supports domestic research programmes in member countries, plus the JET facility in Oxfordshire which is the EU's leading facility and also preparation for ITER.

The FP7 budget for nuclear was €2.75b to be spent between 2007 and 2011. In FP7 Euratom there were two associated specific programmes, one covering *indirect actions* in the fields of fusion energy research and nuclear fission and radiation protection, the other covering *direct actions* in the nuclear field undertaken by the Commission's Joint Research Centre (JRC). The JRC was initially established by the Euratom Treaty and has since become a leading institute of nuclear research in Europe.

Euratom indirect actions are managed by the Commission's Directorate-General for Research (DG RTD). The specific programmes allocate €1,947 million to fusion energy research and €287 million for nuclear fission and radiation protection. €517 million are reserved for nuclear activities of the JRC. The JRC is also a partner in many of the consortia implementing indirect actions in the fission area.

FP7 Euratom aimed to address the major issues and challenges in nuclear research and to contribute to the further consolidation of the European Research Area in the nuclear energy sector. It also supported existing Community policies while at the same time responded to new policy requirements.

Fission research funding splits into five categories:

- Management of Radioactive Waste – includes geological disposal and partitioning and transmutation
- Reactor Systems – includes reactor safety and advanced reactor R&D
- Radiation Protection – include medical radiology, dosimetry and safety
- Research Infrastructure
- Human training & resources

Clearly not all the Euratom investment is associated with advanced reactor development, only a fraction of the €209m. This is partly because of the contentious nature of nuclear R&D in some countries obtaining EU Council unanimity can prove difficult and greatly influences the programme.

The UK is active in all areas of research. Some of the research on topics such as partitioning & transmutation which as a conceptual fuel cycle strategy and not factored into UK energy policy, provide useful research topics to ensure critical skills and capabilities remain available. The UK tends to get value for money from the EU programmes by receiving back in funding at least the level of contributions made, for fission this is approximately £5m. However the UK tends to be less well coordinated than other EU countries such as France where CEA take a natural lead on a number of projects. In the UK, fewer institutions are prepared to act as Co-ordinator for research programmes and most of the time the UK has partner status.

Table 8.1: EU Framework Programme Participation

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
EBSSYN: A joint EC/NEA EBS project synthesis report	This project will involve the preparation of a synthesis report on Engineered Barrier Systems (EBS) and the safety of deep geological repositories for high-level radioactive waste. The objective of the report will be to bring together the main conclusions from a series of key thematic international workshops organised by the OECD/NEA on the Engineered Barrier Systems (EBS).	FP7-EURATOM-FISSION	Support actions	Terrasalus Limited	Terrasalus Limited	€25,000	€25,000	From 2008-12-01 to 2009-11-30	€25,000
GOFASTR European Gas Cooled Fast Reactor	This proposal concentrates on the gas-cooled fast reactor (GFR) with a view to developing the GFR as a more sustainable version of the very high temperature reactor (VHTR). This project will contribute EURATOM's contribution to the Generation IV system research programme. As such, it is strongly aligned with the goals and structure of the latter.	FP7-EURATOM-FISSION	Small or medium-scale focused research project	AMEC Nuclear UK Ltd NNL Imperial College Rolls Royce	AMEC Nuclear UK Ltd 23 participants	€5.4m	€3m	From 2010-03-01 to 2013-02-28	€1m
RISK - IR:	In this project, techniques emerging from stem cell	FP7-EURATOM-	Collaborative project	Public health England	Co-ordinator: Public Health	€8.6m	€6.7m	From 2012-	€1.7m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
Risk, Stem Cells and Tissue Kinetics Ionising Radiation	biological and tissue kinetics research will be used to address several major areas of uncertainty in low dose (<100 mGy) cancer risk estimates.	FISSION	(generic)	University of Sussex Medical Research Council	England 10 participants			11-01 to 2016-10-31	
CTB The Chernobyl tissue bank coordinating international research on radiation induced thyroid cancer	Maintain high quality tissue samples from patients who have developed thyroid tumours following exposure to radiation from the Chernobyl nuclear accident. The project will provide an unequalled resource for research on the health consequences of exposure of a population to radiation from a nuclear accident.	FP7-EURATOM-FISSION Fission-2007-4.1-03	Coordination (or networking) actions	Imperial College of Science, Technology and Medicine	Co-ordinator: Imperial College	€1.7m	€0.2m	From 2008-05-01 to 2012-12-31	€0.05 m
RAPHAEL: ReActor for Process heat, Hydrogen And ELectricity generation	The Project addresses the viability & performance of the Very High Temperature Reactor (VHTR). This innovative system is not only meant at competitive & safe power generation, but also at industrial process heat supply, in particular for hydrogen production.	FP6 EURATOM NUCTECH-2004-3.4.1.1-1 High/Very High Temperature Reactors	Integrated Project	Nexia Solutions Limited National Nuclear Corporation Ltd University of Manchester	Framatome Anp Sas, France 34 partners	€19.82m	€9.0m	Apr 05 – Apr 09	€2.25 m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
				Serco Ltd (now part of AMEC)					
ESDRED: Engineering Studies and Demonstrations of Repository Designs	The overall objective is to demonstrate the technical feasibility at an industrial scale for activities carried out to construct, operate and close a deep geological repository, and at the same time comply with requirements on long-term safely, operational salty, irretrievability and monitoring.	FP6 EURATOM NUWASTE-2003-3.2.1.1-4 Development and testing of disposal concepts and technologies in Underground Research Laboratories	Integrated Project	NDA	Agence Nationale Pour La Gestion Des Dechets Radioactifs, France 12 partners	€18.13	€7.32	Feb 04 – Jan 09	€1.48 m
PERFECT: Prediction of Irradiation Damage Effects on Reactor Components	The aim is to develop faulty-scale numerical tools capable of simulating the effects of irradiation on mechanical and corrosion properties of materials. They will be used to solve issues related to Light Water Reactor pressure vessels and internal structures (PWR and WWR types).	FP6 EURATOM NUCTECH-2003-3.4.3.1-1 Prediction of irradiation damage effects on reactor components	Integrated Project	University of Liverpool Serco Ltd (Now part of AMEC) UKAEA University of Edinburgh	Electricite de France, France 27 partners	€17.75m	€7.5m	Jan 04 – Dec 07	€1.87 m
RISC-RAD: DNA damage responses, Genomic	This project aims to understand the various steps involved in the multistage process of radiation-induced	FP6 EURATOM RAD PROT-2003-3.3.1.1.-1	Integrated Project	Medical Research Council, Gray Laboratory	Commissariat A L'energie Atomique,	€15.88m	€10m	Jan 04 – Dec 07	€2.5m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
instability and Radiation-Induced Cancer: The problem of risk at low and protracted doses (RISC-RAD)	tumorigenesis through detailed analysis of DNA damage responses, genomic instability as well as mechanisms/genetics and modelling of radiation tumorigenesis.	Cellular and molecular biology research on the effects of low and protracted doses		Cancer Research Trust, University Of Sussex, University Of Cambridge, Brunel University, National Radiological Protection Board, Imperial College	France 28 partners				
FUNMIG: Fundamental Processes of Radionuclide Migration	Main objectives are the fundamental understanding of radionuclide migration processes in the geosphere, the application to performance assessment and communication of the results. The project tackles the scientific and social credibility of geological HLNW disposal.	FP6 EURATOM NUWASTE-2004-3.2.1.1-1 Understanding and numerical modelling of the key processes for radionuclide migration through the geological environment for different repository	Integrated Project	Loughborough University UK Nirex Ltd University of Manchester	Forschungszentrum Karlsruhe GMBH, Germany 50 partners	€15.01m	€8.0m	Jan 05 – Dec 08	€2.0m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
		host rocks							
EURANOS: European approach to nuclear and radiological emergency management and rehabilitation strategies	Through the commitment of fifty operational emergency management organisations, "stakeholder groups" and competent RTD institutes this project will build a fully interactive framework for initiating and promoting practical improvements of emergency management and rehabilitation strategies in Europe.	FP6 EURATOM RAD PROT-2003-3.3.4.1-1 Off-site emergency management	Integrated Project	Natural Environment Research Council National Nuclear Corporation Ltd	Forschungszentrum Karlsruhe GMBH 49 partners	€14.17m	€7.05m	Apr 04 – Mar 09	€1.41 m
EC - SARNET: Sustainable Integration of European Research on Severe Accident Phenomenology and Management	SARNET will tackle the fragmentation existing in defining/carrying out research programmes in severe accident research.	FP6 EURATOM NUCTECH-2003-3.4.3.1-2 Sustainable integration of European research on severe accident phenomenology and management	Network of Excellence	AEA technology PLC National Nuclear Corporation Ltd	Institut de Radioprotection et de Surete Nucleaire, France 50 partners	€14m	€6.28m	Apr 04 – Mar 08	€1.57 m
ACTINET-6: Network for Actinides Sciences	One major issue for nuclear energy, requiring intensive R&D programs, remains a broadly agreed approach to waste management, in particular long-lived waste	FP6 EURATOM NUWASTE-2003-3.2.1.1-2 Sustainable integration of European	Network of Excellence	University of Manchester University of Sheffield	Commissariat à l'Energie Atomique, France		€6.35m	Mar 04 – Feb 08	€1.59 m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
	components. R&D is also needed to explore new concepts for nuclear energy generation that make better use of fissile material and generate less waste. Actinide science is one central theme to respond to these needs.	research on actinides		University of Cambridge Imperial College	26 partners				
EUROPART: EUROpean research program for the PARTitioning of minor actinides and some long-lived fission products from high active wastes issuing the reprocessing of spent nuclear fuels	The research to be done within EUROPART concerns the Partitioning of long-lived radio nuclides (Lars) contained in the nuclear wastes issuing the reprocessing of nuclear spent fuels. After separation, the Lars will be destroyed in short-lived or stable nuclides by nuclear means (P&T strategy) or conditioned into stable dedicated solid matrices (P&C strategy)	FP6 EURATOM NUWASTE-2003-3.2.2.1-1 Partitioning of actinides and fission products from high-level nuclear waste for their transmutation or conditioning in stable matrices	Integrated Project	University of Reading British Nuclear Fuels Plc Nexia Solutions Ltd	Commissariat à l'Energie Atomique, France 23 partners	€11.5m	€6.0m	From 2004-01-01 to 2007-06-30	€2.0m
TIMODAZ: Thermal Impact on	The TIMODAZ project will focus on the study of the combined effect of the EDZ (Excavation	Euratom Framework Programme	Specific Targeted Research	Applied Seismology Consultants	ESV Euridice GIE - European	€3.95m	€2.64m	2006-10-01 to	€0.66m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
the Damaged Zone Around a Radioactive Waste Disposal in Clay Host Rocks	Damaged Zone) and the thermal impact.	FP6-EURATOM-NUWASTE	Project	Ltd	Underground Research Infrastructure for the Disposal of Waste in a Clay Environment 24 partners			2010-09-30 Duration: 48 months	
ERICA: Environmental Risk from Ionising Contaminants: Assessment and Management	The objective of ERICA is to provide an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of contaminants emitting ionising radiation, with emphasis on biota and ecosystems. The final outcome of the project will be the ERICA integrated approach to assessment and management of environmental risks from ionising radiation, using practical tools.	FP6-EURATOM RAD PROT-2004-3.3.3.1-1 Assessment and management of the impact of radionuclides on man and the environment	Specific Targeted Research Project	Natural Environment Research Council University of Liverpool British Nuclear Fuels plc Environment Agency	Statens Straalskyddsinstitut, Sweden 14 partners	€3.91m	€1.5m	Mar 04 – Feb 07	€0.5m
PUMA: Plutonium and Minor Actinides Management by Gas-	The objective of the project is to provide additional key elements for the utilisation and transmutation of Pu and MA in current and future (high-temperature) gas-cooled	Euratom Framework Programme FP6-EURATOM-	Specific Targeted Research Project	Nexia Solutions Limited, National Nuclear	Nuclear Research and Consultancy Group	€3.7m	€1.85m	2006-09-01 to 2009-08-31 Duratio	€0.62m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
Cooled Reactors	reactor designs, contributing to the reduction of Pu and MA stockpiles, and to the development of safe and sustainable reactors for CO_2-free multi energy generation.	NUWASTE		Corporation Limited, Serco Ltd (Now part of AMEC)	17 partners			n: 36 months	
GCFR: The Gas Cooled Fast Reactor Project	This GCFR FP6 project is directed at the ambitious long term goals of the Generation IV Gas-cooled Fast Reactor (GFR) R and D Project: self-generating cores, robust refractory fuel, high operating temperature, direct conversion with a gas turbine and full actinide recycling possibly associated with integrated on-site fuel reprocessing.	Euratom Framework Programme FP6-EURATOM-NUCTECH	Specific Targeted Research Project	National Nuclear Corporation Limited, British Nuclear Fuels Plc	National Nuclear Corporation Limited, UK 10 partners	€3.6m	€2m	2005-03-01 to 2009-02-28 Duration: 48 months	€0.5m
RED-IMPACT: Impact of P and T and Waste Reduction Technologies on the Final Nuclear Waste Disposal (RED-IMPACT)	The objective of the RED-IMPACT project is to assess the effects of reduction nuclear waste generation and partitioning and transmutation expressed in technical terms of the benefits and disadvantages for waste management and geological disposal.	Euratom Framework Programme FP6-EURATOM-NUWASTE	Specific Targeted Research Project	British Nuclear Fuels Plc, United Kingdom Nirex Ltd	Kungliga Tekniska Hoegskolan, Sweden 23 partners	€3.51m	€2m	2004-03-01 to 2007-02-28 Duration: 36 months	€0.67m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
LWR-DEPUTY: Light Water Reactor fuels for Deep Burning of Pu in Thermal Systems	LWR-DEPUTY is conceived to fit in a portfolio of experimental research on novel fuels for deep burning of plutonium in existing nuclear power plants (NPPs). It studies to what extent the existing NPPs in Europe can create markedly less nuclear waste by moving to inert matrix fuels. In GEN IV and ADS- research, programs are launched to conceive new reactors and fuels to achieve these objectives, too. With LWR-DEPUTY an alternative route is followed, where one enrols the existing LWRs in the advances to reduce nuclear waste.	Euratom Framework Programme FP6-EURATOM-NUWASTE	Specific Targeted Research Project	Nexia Solutions Limited,	Studiecentrum Voor Kernenergie, Belgium 16 partners	€2.43m	€1.25m	2006-08-01 to 2010-07-31 Duration: 48 months	€0.31m
COWAM 2: Community Waste Management 2 : Improving the Governance of Nuclear Waste Management and Disposal	The objective is to contribute to the actual improvement of the governance of Radioactive Waste Management (RWM), by better addressing and understanding societal expectations, needs and concerns and developing best practices and benchmarking on practical and sustainable decision making processes	FP6 EURATOM NUWASTE-2003-3.2.1.1-5 Improving the governance of geological waste disposal	Specific Targeted Research Project	Syncho Ltd University of Lancaster National Radiological Protection Board (now Health Protection Agency)	Mutadis Consultants Sarl, France 18 partners	€2.33m	€1.2m	Jan 04 – Dec 06	€0.4m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
in Europe									
GENE-RAD RISK: Radiation exposures at an early age: impact of genotype on breast cancer risk	N/A	FP6 EURATOM RAD PROT-2004-3.3.1.1.-2 Epidemiological studies of exposed populations	Specific Targeted Research Project	University of Wales Swansea University of Cambridge University of Birmingham Imperial College Institute of Cancer Research	International Agency for Research on Cancer, France 11 partners	€2.04m	€2m	Jun 05 – May 08	.1.1 € 0.7m
MICADO: Model uncertainty for the mechanism of dissolution of spent fuel in a nuclear waste repository	The proposed coordinated action attempts to assess the uncertainties in models describing the dissolution mechanism of spent nuclear fuel in a repository for geological time periods.	Euratom Framework Programme FP6-EURATOM-NUWASTE	Coordination action	Quintessa Ltd	Gesellschaft fuer Anlagen- und Reaktorsicherheit (GRS) MBH 19 partners	€1.75m	€1.3m	2006-10-01 to 2009-09-30 Duration: 36 months	€0.43 m
RACE:	N/A	FP6 EURATOM	Specific	University of	Karolinska	€1.44m	€1.00m	From 2005-	€0.33 m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
Radiotherapy For Breast Cancer And Subsequent Risk Of Cardiovascular Events		RAD PROT-2004-3.3.1.1.-2 Epidemiological studies of exposed populations	Targeted Research Project	Oxford Oxford Radcliffe Hospitals NHS Trust	Institutet, Sweden 3 partners			08-01 to 2009-10-31	
NEPTUNO: Nuclear European Platform of Training and University Organisations	The aim is to better integrate European education and training in nuclear engineering and safety to combat the decline in both student numbers and teaching establishments, thus providing the necessary competence and expertise for the continued safe use of nuclear energy and other uses of radiation in industry and medicine.	FP6 EURATOM NUCTECH-2003-3.4.2.1-1 Education and training in nuclear engineering and safety	Coordination action	University of Manchester Ministry of Defence	Commissariat à l'Energie Atomique, France 34 partners	€0.84m	€0.83m	Jan 04 – Jun 05	€0.55m
SNF-TP: Sustainable Nuclear Fission Technology Platform	The overall objective of the proposed Sustainable Nuclear Fission Technology Platform (SNF-TP) is to develop a coherent European strategy and to provide the mechanisms for consolidating and deciding future joint undertakings within the EURATOM Treaty. The SNF-TP would also consolidate the European and EURATOM	Euratom Framework Programme FP6-EURATOM-NUCTECH	Coordination action	Nexia Solutions Ltd	Commissariat à l'Energie Atomique, France 22 partners	€0.795m	€0.6m	2006-10-01 to 2008-09-30 Duration: 24 months	€0.3m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
	positions within the GIF-initiative, including waste management related to closed fuel cycles involving fast neutron reactors.								
SENTINEL: Safety and efficacy for new techniques and imaging using new equipment to support European legislation.	N/A	FP6 EURATOM RAD PROT-2004-3.3.2.1.-1 Safety and efficacy of diagnostic imaging techniques other than CT	Co-ordination action	Northumberland, Tyne & Wear Strategic Health Authority Lanarkshire Health Board	Northumberland, Tyne & Wear Strategic Health Authority 22 partners	€0.71m	€0.7m	Feb 05 – Apr 07	€0.3m
CARD: Co-ordination of research, development and demonstration (RD and D) priorities and strategies for geological disposal	The proposal is aimed at assessing the feasibility of a Technology Platform that would provide a European framework for networking and cooperation in the field of RD and D for geological disposal of radioactive waste in the EU. The study will seek inputs from partners in the project, which are radioactive waste management organisations (disposal implementers) and key stakeholders. The project	Euratom Framework Programme FP6-EURATOM-NUWASTE	Cost-sharing contracts	NDA	Posiva Oy Finland 10 partners	€0.54m	€0.35m	From 2006-11-01 to 2008-03-31	€0.18m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
	will analyse these inputs so as to develop a proposal for such a Technology Platform to be implemented in PF7.								
CND: Co-ordination Network of Decommissioning of Nuclear Installations	The purpose of the project is to organise, develop and operate a Network with organisations from the EU and candidate countries, involved in decommissioning activities. The aims are to encourage continuous improvement in capability and effectiveness that should lead to increased competitiveness, and to cluster and co-ordinate projects that were started under earlier FP's, aiding to improve the added value of these projects.	Euratom Framework Programme FP6-EURATOM-NUWASTE	Coordination action	RWE Nukem Limited	Colenco Power Engineering AG 11 partners	€0.83m	€0.75m	2004-12-15 to 2007-12-14 36 months	€0.25m
EISOFAR: Roadmap for a European Innovative Sodium cooled Fast Reactor	The SSA named "Roadmap for a European Innovative SOdium cooled FAst Reactor - EISOFAR" aims enabling the European Community to define its specific R&D strategic objectives on sodium cooled fast reactors embedded in the on-going discussions performed within the CA on the SNF-TP; it has the ambition to be a key component of the European	Euratom Framework Programme FP6-EURATOM-NUCHORIZ	Specific Support Action	Nexia Solutions Limited, National Nuclear Corporation Limited	Commissariat à l'Energie Atomique, France 13 partners	€0.49m	€0.25m	2007-01-01 to 2007-12-31 Duration: 12 months	€0.25m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
	Strategic Research Agenda.								
ENETRAP: European Network on Education and Training in RAdiological Protection	The objectives are of the project are to launch a European Master In Radiation Protection, to establish a network dedicated to the E&T and to provide the necessary competence and expertise for the continued safe use of radiation in industry, medicine and research.	FP6 EURATOM NUCTECH-2004-3.4.2.1-1 Education and training in radiation protection	Coordination action	North Highland College Health Protection Agency	Studiecentrum Voor Kernenergie, Belgium 10 partners	€0.46m	€0.40m	Apr 05 – Mar 07	€0.20m
ERA-PRO: Promotion of the European Radiobiological Archives ERA	This proposal for specific support is designed only to maximise the exploitation of the resource, making European Radiobiology Archives (ERA) accessible to the greatest number of end-users. This will be done by making the archive accessible on line (e.ERA), while assuring controlled user access. The dissemination of e.ERA will then be promoted by presentations at major scientific conferences and by two training workshops. In addition, e.ERA will be made compatible to and interoperable with other relevant radiobiological databases, namely JRA, NRA, PATHBASE,	FP6-EURATOM-NUCHORIZ: Information, Media, Nuclear Fission, Nuclear Fusion	Specific Support Action	The Chancellor, Masters and Scholars of the University of Cambridge	Bundesamt fuer Strahlenschutz 2 partners	€0.39m	€0.38m	2006-04-01 to 2009-03-31 Duration: 36 months	€0.127m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
	and other mouse phenotype projects.								
CETRAD: Co-ordination Action on Education and Training in Radiation Protection and Radioactive Waste Management	The objective of this project is to develop proposals for structuring and delivering both education and training in the management of the geological disposal of high-level and long-lived radioactive wastes and spent fuel in geological formations, and radiation protection.	FP6 EURATOM NUCTECH-2003-3.4.2.1-2 Education and training needs for radiation protection and radioactive waste management	Coordination action	University of Wales, Cardiff Nirex Ltd	University of Wales, Cardiff, UK 19 partners	€0.30m	€0.25m	Jan 04 – Mar 05	€0.20m
CATT: Co-operation and Technology Transfer on long-term radioactive waste management for Member States with small nuclear programmes	This project will investigate the feasibility of Member States with small nuclear programmes (Recipient Member States, RMS) implementing long-term radioactive waste management solutions within their national borders, through collaboration with Member States with advanced disposal concepts (Donor Member States, DMS).	Euratom Framework Programme FP6-EURATOM-NUCHORIZ	Specific Support Action	United Kingdom Nirex Ltd	United Kingdom Nirex Ltd, UK 7 partners	€0.25m	€0.21m	2006-01-01 to 2007-06-30 Duration: 18 months	€0.14m
HOTLAB: European	The general objective is to assess the European of hot	FP6 EURATOM NUCTECH-	Coordinati	British Nuclear Fuels	Studiecentrum Voor	€0.23m	€0.20m	Jan 04 – Jun	€0.13m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
Hot Laboratories Research Capacities and Needs	laboratories capacity and its aptitude for supporting the nuclear industrial and research community both at present and in the future. The ultimate goal is to preserve appropriate nuclear research infrastructure in Europe.	2003-3.4.2.1-3 Infrastructures for nuclear fission and radiation protection research	on action	Plc	Kernenergie, Belgium 18 partners			05	
EURAC: Securing European Radiological Protection and Radioecology Competence to meet the Future Needs of Stakeholders	The objectives of EURAC are to strengthen the scientific academic competence and analytical skills within radiological protection, radioecology and radiochemistry and to secure the future recruitment of appropriately skilled post-graduates to meet the needs of European stakeholders.	FP6 EURATOM NUCTECH-2003-3.4.2.1-2 Education and training needs for radiation protection and radioactive waste management	Coordination action	Westlakes Research Ltd, UK	Westlakes Research Ltd, UK	€0.17m	€0.10m	Sep 04 – Sep 05	€0.10m
CONFIRM: Uranium free fuels for accelerator driven systems: collaboration on oxide and nitride fuel irradiation and	Accelerator driven systems are candidates for burning of uranium free fuels like nuclear waste. This proposal suggests a program for modelling, development and irradiation of oxide and nitride uranium free fuel s under normal operating conditions as well as under power transients. The objective is to identify a reference oxide	Euratom Framework Programme FP5-EAECTP C	Cost-sharing contracts	Serco Ltd (Now part of AMEC), AEA Technology plc, British Nuclear Fuels plc	Royal Institute of Technology 8 partners	€2.06m	€1m	2000-09-01 to 2005-12-31 64 months	€0.1875m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
modelling	fuel for an ADS demo facility, and to investigate safety properties of nitride alternatives.								
HTR-M1: European project for the development of HTR technology - materials for the high temperature reactor	The development of Advanced High Temperature Reactor (HTR) concepts requires material data information and an understanding of material behaviour under react or operating conditions and environment. For components important to the safety and feasibility of modular designs such as the turbine and the graphite structures (core), investigation of the different materials to be used with respect to long term damage and behaviour in the reactor environment is necessary. This work identifies and investigates the most promising materials in these areas with respect to time dependent damage and behaviour and provides information that can be used for feasibility investigations of the most promising options for future application.	Euratom Framework Programme FP5-EAECTP C	Cost-sharing contracts	National Nuclear Corporation Ltd	National Nuclear Corporation Ltd, UK 7 partners	€1.39m	€0.7m	2001-10-01 to 2005-03-31 42 months	€0.2m
HTR-N1:	HTR core analysis will be made	Euratom	Cost-	National	Forschungsze	€1.09m	€0.55m	2001-10-01	€0.157 m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
High temperature reactor, nuclear, physics, waste and fuel cycle studies	for this symbiosis of LWR and HTR. Special treatments for purification of contaminated carbonaceous material from the core structures are intended to improve the disposal or re-use. Data for long-term geochemical modelling of directly disposed spent HTR fuel will be generated by leaching tests on the matrix, coating and kernels of fuel elements.	Framework Programme FP5-EAECTP C	sharing contracts	Nuclear Corporation Limited, British Nuclear Fuels Plc	ntrum Juelich GMBH 12 partners			to 2005-03-31 42 months	
INDOOR DOSE: Quantification of the distribution of radiation doses received by humans through the various pathways in a contaminated indoor environment	The influence of range of factors on the potentially highly significant doses received from contaminant deposition to humans is currently not well understood. The objective of the proposed project is to generate extensive and wide-ranging data to address this problem. A collaborative experimental programme involving new techniques is designed, which will be used to achieve this objective.	Euratom Framework Programme FP5-EAECTP C	Cost-sharing contracts	Imperial College London	Risoe National Laboratory, Denmark 3 partners	€0.59m	€0.4m	2004-02-01 to 2007-07-31 42 months	€0.11 m

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
ITEM: Improvement of techniques for multiscale modelling of irradiated materials	The objective of the proposed Thematic Network is to ensure that the developments required to simulate quantitatively irradiation effects in materials are performed rapidly and in a co-ordinated way in Europe.	Euratom Framework Programme FP5-EAECTP C	Thematic network contracts	The University of Liverpool, University of Edinburgh, King's College London	Electricite de France (EDF) Service National, France 42 partners	€0.44m	€0.39m	2001-11-01 to 2005-10-31 48 months	€0.0975m

9. International Initiatives

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The EU and IAEA are active internationally with collaborative projects which consider the promotion and enhancement of nuclear technology. Much consideration is given to Gen IV reactor systems through the Generation IV International Forum (GIF). This has many aims some of which are to improve safety, reliability, efficiency and non-proliferation.

The UK's direct involvement in international programmes is extremely limited at present. There are signs that this is set to change following the House of Lords Select Committee's recommendations for nuclear R&D funding, and as of 2013, the Government plans to resume active participation in GIF. It is also looking into launching a small module reactor programme, and has invested £12.5m in the Joules Horowitz test reactor in France. These investments point towards an upward trend in level of spending on international nuclear R&D, as the UK seeks to remain a leading nuclear nation, and keep up to date with new nuclear technologies.

The UK Research Council's Energy Programme has funded a number of international collaborative projects with partners in other countries – for example, India. It is suggested that the reader uses the UKERC Research Register to search for relevant projects.

Table 9.1: International Activities

Name	Type	Description	UK Contact Point
European Energy Research Alliance	EERA has a 'nuclear materials' branch	Aim to "to identify key priority topics and funding opportunities with the purpose of supporting in an efficient way the development and optimisation of a sustainable nuclear energy."	UKERC HQ
European Nuclear Society	Federation of 23 nuclear societies from 23 countries — stretching from the Atlantic to the Urals and on across Russia to the Pacific.	ENS is the largest society for nuclear science, research and industry in Europe. Ever since its foundation in 1975 it has been promoting the advancement of nuclear science, research and engineering to its members, decision makers and the general public. The Society's membership includes national nuclear societies from 22 countries in Europe plus Israel.	UK Board Member : Norman Harrison
European Nuclear Society (ENS) Education and Training (E&T) Platform.		The Platform provides an overview of available university courses, as well as the training and education programmes offered by industry and other institutions. The E&T Platform places special emphasis on collaboration between stakeholders, on the sharing of available infrastructure and resources and on the promotion of existing networks.	The UK rep on the Higher Scientific Council is Prof Laurence Williams of UCLan
European Nuclear Education Network (EWEN)		The main objective of the ENEN Association is the preservation and the further development of expertise in the nuclear fields by higher education and training. UK Members : University of Manchester, University of Birmingham, Imperial College London, University of Hertfordshire, and University of Central Lancashire (UCLAN)	UK Board Member : Dr John Roberts, The University of Manchester
Generation IV International Forum (GIF)	US-led forum.	Set up in May 2001 to lead the collaborative efforts of the world's leading nuclear technology nations to develop next generation nuclear energy systems. In February 2005, five of the forum's member countries (including the UK) signed the world's first agreement aimed at the	Department of Trade and Industry

		international development of advanced nuclear energy systems. The UK Government has plans to actively resume participation in this forum in 2014.	
IAEA Department of Nuclear Energy	Funding for collaboration and research in all member states	Nuclear Power, Nuclear Fuel cycles and materials technology, Waste management	UK mission at the IAEA in Vienna
IAEA Department of Nuclear Science and Applications	Fosters collaboration and research in all member states	Provision of scientific and analytical services, research and development. including Assessments and Management of Marine and Terrestrial Environments and Supporting Quality in Environmental Analytical Techniques in Member States	UK mission at the IAEA in Vienna
Implementing Geological Disposal of Radioactive Waste Technology Platform		The technology platform will be implementer-driven. Members will be organisations either being responsible for implementing a waste management programme or being formally responsible for the RD&D programme needed for implementation. In addition, research organisations with significant autonomous budgets and/or available funding that can contribute to the work of the technology platform have an advisory role	NDA
International Framework for Nuclear Energy Cooperation	International forum	IFNEC was previously the Global Nuclear energy partnership (GNEP). It discusses civil nuclear power and related matters. Promotes safe use of nuclear power, as well as looking for ways to reduce waste and proliferation.	NDA attend. DECC funds.
Organisation for Economic Cooperation Nuclear Energy Agency (OECD-NEA)	Forum for R&D discussion. Helps run joint projects	The Nuclear Energy Agency (NEA) is a specialised agency within the Organisation for Economic Co-operation and Development (OECD), an inter-Governmental organisation of industrialised countries based in Paris, France. Currently 12 on-going experimental projects overseen by OECD.	NDA
Sustainable Nuclear Energy Technology Platform	Research support and R&D coordination	The SNETP aims to promote nuclear fission as a long term energy source across Europe. It has put together a 'strategic research agenda' which helps researchers achieve short, medium and long term research goals.	Industry, Academia, National representatives,

(SNETP)			safety organisations Education, Training and Knowledge Management Committee is chaired by Dr John Roberts, The University of Manchester
World Nuclear Association		Promotes nuclear energy and supports companies. Within the WNA, a group called Cooperation in Reactor Design Evaluation and Licensing has been set up (CORDEL). "CORDEL facilitates dialogue among industry, regulators and Governments on the benefits of international standardisation of nuclear reactor designs"	UK companies involved with Nuclear