Evidence to the House of Lords
Science and Technology Select Committee

UK Nuclear Energy Research & Development Capabilities

Tony Roulstone MA CEng FIMechE MIET

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Summary

The main thrust of the Energy Research Partnership argument on nuclear R&D is supported - that there will be large investment in new nuclear power stations in the next 20 years and nuclear will be a major contributor to decarbonising the UK economy in the period up to 2050. Though the accident at Fukushima that resulted from the Tohoku earthquake and the consequential tsunami will have a major effect on the nuclear industry, the focus will be on older plants. Committed nations such as the UK, China, UAE, and India will, after a pause continue with their nuclear investment plans, driven by climate change and energy security requirements and objectives.

The UK nuclear new build programme is one of the largest firm programmes in the world, outside China. Because of its technological capability, experience of operating nuclear power stations and position in the nuclear renaissance, the UK is well positioned to exploit and grow the large market for nuclear services and products that will develop.

The UK now needs to invest in its nuclear capability and infrastructure for four reasons, to:

- Continue to be a responsible host for nuclear power;
- Gain the benefits from the investment in new reactors in the UK;
- Enable exploitation of the nuclear export market;
- Access the developments and improvements in light water reactors (LWR) that the UK is to build and will be important in the period up to 2050.

After a long period of decline nuclear R&D objectives, funding and structures need to be re-visited.

R&D funding should be first directed towards thermal reactors, rather than fast reactor systems. Fast neutron systems have undoubted advantages in enabling closed fuel cycles and hence the efficient use of uranium resources, but it seems that they probably will not be required for at least 50 years. Their technological difficulties and cost make them a topic for long term collaborative study. Hence, the UK should focus on the future of LWRs rather than fast reactors and their fuels.

New objectives for nuclear R&D should to be laid out and agreed after many years of a policy of ‘no new nuclear’. A set of prioritised objectives for nuclear R&D is proposed below (see box).

UK Nuclear R&D Objectives:

a. Maintain its ability to be a responsible host of current and planned power reactors;
b. Gain the benefit from on-going LWR developments and their ability to burn actinide wastes and convert/breed nuclear fuel;
c. Use UK’s early position in the nuclear renaissance to rejuvenate its nuclear industry and gain a share of the export growth in nuclear;
d. Maintain a position in the international fast reactor technology programme.

Funding and structures follow from objectives. A form of public-private partnership for nuclear R&D funding is contemplated, both to discharge UK responsibilities as a host for nuclear power and to provide the impetus for development in what is likely to be a rapidly evolving sector.

UK Nuclear Energy Research & Development Capabilities

Introduction

1. In response to the call by the House of Lords Science & Technology Select Committee for evidence on Nuclear Research & Development Capabilities [1], the views on fission R&D and its associated capabilities are presented below. No evidence is provided on nuclear fusion.
2. The author is the Course Director for the MPhil in Nuclear Energy at the University of Cambridge, is an affiliated lecturer in the Department of Engineering, has long experience in the nuclear industry and is a former MD of Rolls-Royce Group of civil and military nuclear businesses.
3. The views presented are those of the author however, I had have input from other members of Cambridge Nuclear Energy Centre, including Drs W Nuttall, Ian Farnan and Geoff Parks.
4. Cambridge Nuclear Energy Centre is a major initiative across the University of Cambridge to unite the wide range of specialist disciplines in nuclear energy research and technology. It coordinates nuclear energy research across the Departments of Materials Science & Metallurgy, Physics, Earth Sciences, Engineering and the Judge Business School. This collaboration has led to the establishment of a new postgraduate master's level course in Nuclear Energy, combining teaching of nuclear science & engineering and business management.

Fukushima & Nuclear Renaissance

5. It is too early to be clear about the effects on the nuclear industry of the Fukushima accident resulting from the Tohoku earthquake and the related tsunami. This is because the accident while it appears to being brought under control, is not fully stable and there is not yet a plan for returning the site to a more normal state.
6. Also, detailed analysis of the accident has yet to be done - how the reactor systems responded both to the initial event and the sequence of failures that followed. It is very important to the re-building of confidence in the nuclear industry that a detailed, open, independent and international review is conducted of the accident. That review should ensure that all facts about the accident are laid out and a full understanding is gained. If done properly, this process should ensure that the remedial measures have wide international and public support.
7. Even though our understanding of the accident is currently incomplete, it is expected that the older plants that will be challenged most by the lessons of this accident. There will be questions about their response to very infrequent external hazards (earthquake, flood(including tsunami), fire, airplane crash, terrorism etc.) with their propensity of common cause failures that cut across what are considered highly reliable systems. Also, there will be a need to consider the adequacy and the robustness of reactor cooling and containment systems.
8. In the UK, the utilities that plan to build large new nuclear power stations wish to learn the lessons of Fukushima, but they are not being diverted from their plans. Other countries like Germany and Austria are more doubtful about nuclear. Countries with access to low cost gas such the US may slow their nuclear plans. Countries that had firm intentions for nuclear such as: China, UAE and India etc. will, after a pause, continue with their large plans for investment in nuclear energy.

9. The emergence of a world-wide nuclear renaissance, though inevitably delayed by the events in Japan, is unlikely to be halted. There will be significant ramifications for the nuclear industry from the accident at Fukushima but the broad case for nuclear energy remains strong.

Energy Research Partnership Analysis

10. The Energy Research Partnership (ERP) Report [2] provides a very good background for the discussion of nuclear energy in the UK. The nadir for nuclear was in the early years of this century when the policy was 'no new nuclear'. This has changed completely in response to the demands of climate change, energy security and the increasing cost of energy. We agree with much of ERP's argument that the choice of Gen III+ light water reactors and their variants will predominate for many years both in the UK and worldwide and that support is required for UK industry to maximise their contribution to new build by supplying components and services.
11. ERP points out that the current R&D programme is still at a level and with a scope that is consistent with the past policy of nuclear phase-out. Also, the limited R&D is well not directed to obtain the best value over the next 50 years from the planned investment in new nuclear reactors.
12. The UK has one large light water reactor generating electricity (Sizewell B). After many years of very low funding, the UK now has a limited capability for new nuclear research, design and development. It can be said that the UK is living on its past investments and these capabilities are being eroded by the passage of time and by retirements from the industry.
13. In recent years the power reactor industry has become more global. Now only a small number of companies have the scale, capability and technology to design and support new reactors. The main centres of nuclear energy technology are currently in US, France and the Far East.
14. For these reasons, the UK has decided to import the best available international technology - pressurised water reactors - with two somewhat different designs being considered. The choice of the designs is also a matter for the private companies that will invest in and operate the power stations.
15. Though the nuclear technology is being imported it does not mean that the UK can neglect light water reactor technology. Also, there is definitely still a role for British companies in the new nuclear build programme.

A Responsible User of Nuclear Energy

16. The UK nuclear new build programme is a major undertaking. The planned 12 reactors will require an investment of about £50bn by 2030. Though the prime responsibility for nuclear safety is always held by the operator, the UK must as a responsible user of nuclear energy ensure that suitable conditions exist for the operator to succeed. The Government retains the ultimate responsibility for protecting its citizens and therefore needs to consider:
    a. **Education & Research -** Re-invigorate and then maintain the education, research community:
        i. Nuclear technology and business is best taught at a post graduate level (masters or doctorate) after a student has gained a broad understanding of the constituent elements of mathematics, physics, engineering and materials etc.

Because nuclear technology runs across these disciplines it can be understood properly only once a base education is established by an undergraduate degree. Similarly, the business knowledge for nuclear energy needs to be built upon a broader undergraduate understanding of related management and engineering subjects.

ii. Several postgraduate nuclear engineering and nuclear energy courses are being established. However, there is currently an inadequate understanding of the need for this type of training by students and there is little or no support in funding such courses, either funding for universities, or for students.

iii. PhD and Eng Doc programmes exist at a number of UK universities to prepare specialists either for research or for work in industry.

In the past, the large R&D programmes in Government bodies like the UKAEA and BNFL ensured that post degree and research training was available to meet the broader needs of research and industry. With the break-up of these organisations this is not now the case. Also, student numbers in universities still reflect the 'no new nuclear' policy of the early 21st century. The number of taught and research programmes needs to increase well before the time when the UK industry will need to harness this intellectual capital.

b. **Facilities -** As well as an expansion of the volume of education the facilities should also be considered. Nuclear energy is a practical technology. Universities have only a small amount of the test and development facilities required for a sound education. There are opportunities to work with industry by using their facilities and working on problems relevant to industry. Similarly, NNL provides an excellent facility for working on trans-uranic substances. Some new facilities for low activity work are being brought into use but the state of the art high activity cells remain unused.

Some specific weaknesses in the provision of UK nuclear R&D facilities provision include:

i. After the planned shut-down of Consort, Imperial College's reactor there will be no university research reactor in the UK unlike the situation in many US and Europe universities. Students requiring the experience of operating a reactor will have to travel to Europe where there are several facilities. Similarly, there will be no reactor for practical research;

ii. The lack of a materials testing reactor impedes reactor materials development. Because irradiation is essential for proving new materials, either such development is precluded, or must be in collaboration with the other countries that have retained their materials testing capabilities;

iii. Much of operator training can be done on plant simulators. These are expensive and are much in demand for training of operators by the electricity utilities that have built them. A shared generic reactor and plant simulator facility or model universities would be of great benefit to nuclear education;

iv. Development facilities for reactor research and development (see below for research and development plans).

The high costs of both constructing and operating such new facilities mean that

US Doe Nuclear University Funding 2010/11

- NE R&D facilities $62m
- Infrastructure grants incl. research reactors $20m
- Scholarships & fellowships $8m

these costs will have to be shared between universities and other government and commercial users. There are costs for universities associated with accessing such facilities which are currently not funded except in the context of research.

c. **Training and preparation** of nuclear operators, regulators and engineers. This is in our view largely the responsibility of industry and the government bodies that employ regulators and other specialists. Some training will be collective and some will be company specific. NSAN (National Academy for Nuclear) which is directed at apprentice and technician skills and other similar initiatives are a good model.

b. **Safety Regulation** is an area where developments are required. The nuclear industry is a global industry. An accident or a problem in one country quickly affects other countries either because of worries about the spread of radiation or because of public concerns about safety. Safety regulation varies in its approach and standards between countries. This is not a healthy position for a renaissance in nuclear. The methods and techniques of nuclear safety have developed only slowly over the past 20 years following the inclusion of probabilistic methods. In the 21st century the general public expects a more open and transparent approach to assure them that nuclear energy is safe.

c. **Proliferation -** The UK as an original signatory of the Nuclear Proliferation Treaty and the holder of the largest stock of civil plutonium has obligations which it currently does not appear to be discharging. The establishment of the NNCE in 2009 seemed to be a step in the right direction but that is now suspended. In our view there is a need for a wider range of research activity relating to nuclear non-proliferation and nuclear security.

    i. The growing adoption of nuclear energy by countries that have little previous experience of the technology will require wider control of nuclear materials and nuclear fuel chains that ensure civil application of nuclear energy can expand without the number of weapons states increasing;
    ii. There are strong overlaps between nuclear counter-terrorism and issues of health physics and nuclear safety;
    iii. Nuclear proliferation research is highly interdisciplinary involving physics, chemistry, statistics, engineering and law. The issues of international law, states' rights and sovereignty are interesting relating as they do to the law of international institutions and the United Nations;
    iv. There would be benefit in creating a national nuclear archive and research. This could be a monitored-access facility providing access to declassified and unclassified items as well as providing more secure (non-governmental) archive capacity (politicians papers etc.) This facility would cater to researchers from around the world with a very wide range of disciplines and interests. There is a need for improved and expanded nuclear forensics capability. This activity may be developed entirely within government, but might benefit from outside contributions;
    v. There is also scope for open work on issues of nuclear verification and monitoring for nuclear disarmament. The UK has led in this area via the UK-Norway Initiative managed by Vertic, but more could be built upon this foundation.

d. **Emergency Response** - Ensure adequate emergency preparedness. Fukushima has thrown a sharp light again onto emergency preparation. It is expected that the reviews which are being started in the UK and elsewhere into the lessons of the accident in Japan will demonstrate the need for old plans to be revised and some national infrastructure to be established or modified.
e. **Nuclear Decommissioning & Waste** - Continue to implement waste disposal and decommissioning strategies. NDA has the responsibility for these areas and within the funding that is made available to them is making progress (but see g. below). Their recent Strategy Document [3] makes clear that its prime focus is site remediation and all other themes support or enable this delivery. It has been widely noted by many observers that in the light of plans for new reactors and the need to demonstrate that the UK has solution to nuclear waste problems:
   i. Progress has been slow on many fronts;
   ii. Little decommissioning of nuclear facilities completed to green-field conditions has been completed;
   iii. The National Waste Repository has neither a defined plan nor planned timescale.
f. The NDA's R&D needs for decommissioning and waste management [4] (see box for summary) cover the scope of their remit but are somewhat dated.

NDA R&D Topics
- Materials Characterisation
- Waste Processing
- Management of SNF
- Plant termination (decommissioning)
- Site remediation

g. **Management of Special Nuclear Materials** - The NDA responsibility for managing uranium and plutonium stocks is confusing. The Government has recently launched a consultation on the management of its stock of plutonium [5]. Recent studies [6] show these materials can have a significant value as fuel for either thermal or fast reactors. Also, plutonium represents a proliferation hazard with the UK having one of the largest civil stocks in the world. The material can be burned in many existing LWRs as MOX fuel but this strategy will reduce the level of stocks only slowly. Dedicated plutonium burner LWRs can be designed which would be better suited to the reduction or elimination of this large stock and would provide an economic benefit in the form of the generation of electricity.
   There have been many studies and consultations about plutonium management, but a coherent policy has eluded the NDA. Perhaps DECC should reconsider whether the management of special nuclear materials over-complicates the responsibilities of the NDA. This includes commercial reprocessing of spent fuel, MOX fuel fabrication and management of the plutonium fuel stocks. DECC should consider whether a more focused organisation could better provide focus and leadership in fuel management while operating through contracts with Sellafield Ltd and others.

Gaining the benefit from UK Investment in LWRs

17. The designs of Light Water Reactors (LWR) that are to be ordered over the next few years are considered as a mature technology. They represent the best available designs and are based on many years of experience with fuel irradiation and operation of similar reactors. In that sense

they are evolutionary developments. However, it is incorrect to say that LWRs are at the end of their development cycle. There remains much scope for innovation and improvement of LWRs. Authorities in the US recognise the potential and new LWR development programmes are being discussed.

18. By its nature nuclear technology development is conservative. The need for certainty, the time taken to gain meaningful information about performance coupled with the scale of development means that the pace of development is necessarily slow. However, if the UK is to gain the full benefit of the large investment in LWR it needs to use the opportunity to underpin some of the claimed but not yet demonstrated enhancements – such as vessel life-time exceeding 60 years – and also contribute to the lines of thermal reactor research and development which include:
    a. Bringing down the costs of large LWR construction;
    b. More robust & cooler fuels: advanced zircalloy and silicon carbide cladding, annular fuel forms, nitride fuels, beryllium doping of oxides;
    c. Advanced modelling/methods: mixed probabilistic and deterministic methods made possible by advanced computers, multi-physics etc;
    d. Passive systems developments – AP1000 is only the first, concept needs to be expanded;
    e. Integral reactors – all components in one vessel – to be developed and demonstrated;
    f. High temperature reactors for process heat and hydrogen conversion;
    g. Small and mobile reactors – for smaller grids and for marine applications;
    h. LWRs as plutonium burner or as converter/breeders with different neutron spectrums – (see also Appendix B of [7]) ;
    i. Energy storage for supply demand matching – daily variations & renewable volatility.
19. The merits of such developments need each to be argued on a cost benefit basis. Any such developments would necessarily be conducted in collaboration with other countries and with the main reactor vendors. It is clear that there is much scope for development in LWRs which have the best potential for delivering enhanced value in the coming years. Other types of thermal reactor system are likely to follow addressing higher temperature and process heat applications.
20. These reactor and other developments are being planned now by other countries. They are relevant to the UK nuclear energy programme. In our view, these developments are low risk and would have greater benefit to the UK in the period up to 2050, than some of the proposed programmes in the ERP Report [2].

UK Nuclear Business Case

21. The UK has an opportunity to develop a new global and commercially driven nuclear industry because of its particular history and the timing of new nuclear investment. The UK entry was one of the first to build nuclear power stations (in 1960s) and these stations are now coming to end of their operating life-times. This loss of assured supply together with the planned closure of coal plants in response to the EU Large Combustion Plant Directive, require the UK to invest in new base load generation. Following the Energy Reviews of 2006-8 the UK now has the largest committed nuclear build programme outside China.

22. Many UK companies involved in the nuclear industry have the capability to contribute to the domestic nuclear construction programme. Some have strongly relevant light water reactor knowledge and capability derived from the UK military programmes. Also, several major UK engineering companies and consultancies also have the global presence to exploit the ensuing global nuclear renaissance. Before Fukushima, estimates of the growth of global nuclear industrial activity were to $50bn pa by about 2025.

UK Export Opportunities

- High value component manufacture;
- Nuclear fuel supply;
- Nuclear I&C systems;
- Regulation & Safety Case consultancy;
- Nuclear systems installation services;
- Engineering services;
- Waste & Decommissioning services
- Project Management services
- Investment & Legal services.

23. There are uncertainties about the effects of the Fukushima accident on the timing of the market development. It is clear that the UK's position at the head of this international movement to invest in nuclear energy provides opportunities found in few other sectors in the economy. Involvement in the construction and operation of LWRs in England and Wales will allow UK companies and consultancies to gain a prominent position in the global LWR systems and services market.
24. The UK needs to be part of the continuing LWR international R&D programme to capitalise on this opportunity. In our view, this forward-looking and market-focused view of UK nuclear capabilities is more important than preserving past capabilities which may not be required for several decades (see Fission R&D below).

Longer term Fission R&D

25. The case is made strongly in the ERP Report [2] that in the longer term nuclear developments will need to turn to closed fuel cycles. Nuclear fuel removed from the reactor is reprocessed and re-cycled making use of fast reactor systems to convert the maximum amount of energy stored in the structure of large atoms such as uranium and thorium. Also, fast reactor systems are well suited to the reduction of higher actinides – neptunium, plutonium, americium, curium, berkelium, californium – reducing much longer term activity of high level stored nuclear wastes.
26. There is a range of views about the timing of the changeover from the current thermal reactor systems to fast reactors. They have been studied since the building of DFR in the 1950s because of their ability to breed fissile material for power reactors. Both test reactors such as DFR and larger demonstration fast reactors have been built in the UK, France, US, India, Russia and Japan. New fast reactors are being constructed or are planned in Russia, India and probably France. While the this type of reactor has been shown to be a stable source of heat and the principle of breeding fuel has been demonstrated, they have yet to solve some important technological problems (see box).

Fast Reactor Technology Development

- Weakening of the clad and core materials during irradiation;
- Thermal fatigue of structural components;
- Compatibility of the sodium coolant with construction materials and water,
- Reliable refuelling under sodium,
- Proliferations concerns of separated plutonium in civil reactors
- Dose associated with re-fabrication of plutonium-based fuels.

27. The ERP Report plan suggests that fast reactors will be adopted as soon as they are proven. European plans led by the French are to build one or

more demonstration plutonium fuelled fast reactor in about 2020 and that reactor will provide the evidence for commercial fast reactors to be built after 2040. Even if this is technologically feasible there are still the considerations of need and costs. The US views on this topic are instructive.

US DoE Nuclear Funding Objectives

- Develop technologies and other solutions that can improve the reliability, sustain the safety and extend the life of current reactors;
- Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals;
- Develop sustainable nuclear fuel cycles;
- Understand and minimise the risks of nuclear proliferation and terrorism.

28. Recent MIT Fuel Cycle studies [7] demonstrate that nuclear fuels are much more abundant than had been thought and can be extracted at cost below those of re-cycle fuel. There is scope for some conversion of uranium and thorium using LWRs to extend the energy that can be generated in a once-through fuel cycle. The authors argued that an extended life open fuel cycle will be much cheaper than using fast reactors and their associated reprocessing plants. Therefore in their view it will not be necessary or economic to change technology to closed fuel cycles and hence fast reactors during the 21st century, unless the growth in nuclear energy greatly exceeds current expectations.
29. US priorities for nuclear R&D [8] (see box above) are focused mainly on existing thermal reactor types (LWRs) and more affordable small and modular thermal reactors for power generation and propulsion. The US is funding a technology programme (CASL) to improve design methods - high performance computing with integrated physics, computations fluid mechanics, heat transfer and chemistry models to develop better computer codes. The programme is worth $122m over five years.
30. Closed nuclear fuel cycles are included in their plans. These involve the study of spent fuel reprocessing and closed fuel cycles. Even so the US has a strong preference for efficient use of uranium in open/once through fuel cycles. MIT has recommended (see table below) R&D spend of $670m pa plus $300m pa for supporting facilities for ten years, with $250 pa on fast reactors and related fuels and much of the remainder on thermal reactors.
31. Therefore in a similar manner to fusion, fast reactor R&D should be pursued by the UK because of the long term value to UK in its ability to use fission energy resources with the maximum efficiency. In the longer term nuclear fuel resources will become depleted. Only fusion and fast fission of the foreseeable energy technologies have the capability to provide low carbon energy on a global scale for period exceeding a century.

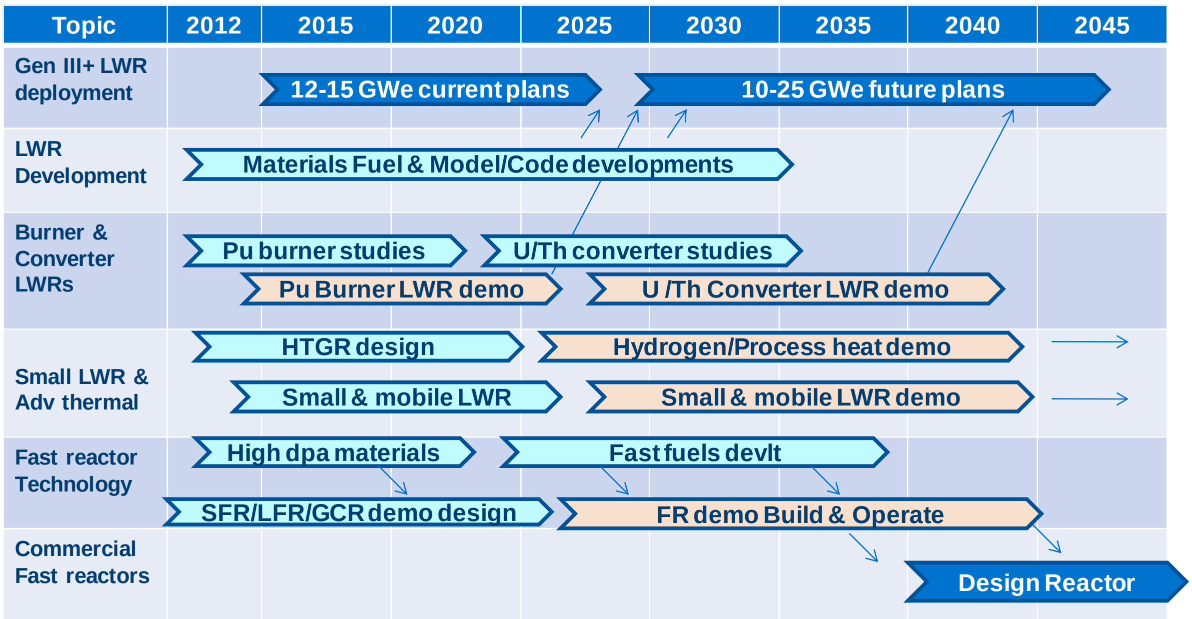
ITEM	$ 10^6 PER YEAR
Uranium Resources	20
LWR Nuclear Power Reactor Enhanced Performance	150
SNF/HLW Management	100
Fast reactors and closed fuel cycles	150
Modeling and Simulation	50
Novel Applications and Innovative Concepts	150
Nuclear Security	50

US R&D from MIT Fuel Cycle

32. Because of the huge costs of fast reactor and their associated reprocessing developments they will be conducted only through international collaboration. These developments should have a lower priority than thermal reactor R&D because of the lower benefits to UK in the period before 2050.
33. UK has run-down its participation in EU and other international nuclear programmes. As argued above this should be reversed in line with the needs of the new UK nuclear energy plans.

R&D Priorities

34. As argued above, the priority both for UK energy generation and for trade is LWRs and other thermal reactors. These priorities are different from those in the ERP report [2]. A suggested outline R&D programme is given as Figure 1 below.
35. The programme links LWR developments to a second tranche of reactors built after 2025 to meet the 2050 climate change targets. However, the continuity of water reactor technology means that many improved aspects of technology (fuel, materials, models, codes etc) may also be applicable to older types of reactors.



Outline Long Term UK Fission R&D Programme **Figure 1**

36. The option of fast reactor development for the UK can and should be preserved by participation in the EU SNETP programme (and subsequent variants) which will proceed, but probably on slower timescales than currently forecast.

Developing a UK R&D Programme

37. R&D capability has to be seen in the context of a set of objectives and priorities. While the drivers in terms of government policy and investment plans have become clear, there is no similar clarity about specifically nuclear R&D.
38. It is suggested that the objectives for the UK in order of priority should be:
    j. UK to maintain its ability to be a responsible operator of current and planned reactors in areas of: Education, Infrastructure including research reactor, Waste disposal, Decommissioning, Regulation, Non-proliferation, and Emergency preparedness;
    k. Gain the benefit from UK investment in LWRs – from on-going LWR developments and their ability to burn and convert/breed fuel and waste, with an assured life-time of 60 years;
    l. Use UK's early position in the nuclear renaissance to rejuvenate the nuclear industry and gain a share of the major global growth in nuclear;
    m. Maintain a position in the international fast reactor technology developments for the longer term – when fuel re-cycle and/or actinide elimination become a necessity and economic.
39. If the objectives for UK nuclear R&D are agreed, this would provide guidance for the various programmes and hence for planning and prioritising nuclear R&D capability and the associated infrastructure.

R&D Funding

40. Without a clear strategy for nuclear R&D and a significant funding stream, it is not possible to say what decision making structure might be appropriate for nuclear fission R&D.
41. Funding is a critical issue both because the level of nuclear R&D funding is so low and the financial climate for the next four years is so tight that large increases in funding are unlikely. Also, in the current circumscribed funding situation any attempt to seek re-allocation of funding from one area to another is going to be resisted with vigor by potential losers of funding..
42. Other countries are providing increased funds for nuclear R&D. The US has recently added $120m pa and is considering raising this up to $1bn pa. Figures for France are less readily available but last year the French Government announced an additional €1bn for new demonstrators for advanced reactors.
43. It can be argued that the current level of funding which owes much to the 'no nuclear future' policy. The current funding level is probably below what is necessary for continuing to be a responsible user of nuclear and it being a significant element of UK's energy strategy.
44. The business case for an increase in nuclear R&D is strong, with three main reasons for Government support:
    a. Expected increase in the contribution of nuclear energy to the economy;
    b. Scope for increased benefit from improved nuclear reactors in the period to 2050;
    c. Export opportunities for UK businesses and consultancies.
45. Longer term increases in UK nuclear R&D programmes can be funded in only one of three ways:
    a. Government funding;
    b. Industry funding;
    c. Public private partnership.

Even so the UK Government is unlikely to fund all of the necessary increase in nuclear R&D.

46. Nuclear operating utilities such as EDF Energy and the future operators such as Horizon and NuGen, are the probable contenders. These companies will benefit from the UK investment in education, infrastructure and any new developments. However, they are unable to lead new development because their prime focus is the managing their investments in nuclear power stations. Also, many of the nuclear developments will be open research (rather than proprietary) either because they will be done by universities or through international collaboration. A 'laissez faire' approach will mean that UK participation in new R&D and hence its nuclear capability will continue at is low level.
47. While industry policy otherwise might be to leave such investments to the market, the long timescales of nuclear R&D together with the need to exploit UK investments and position mean that the UK Government needs to consider whether to increase its funding. Such an increase would be consistent with the idea of re-balancing of the UK economy by investing in high value and specialist manufacturing. As argued earlier, the nuclear industry is well placed as a potential growth point for manufacturing and associated engineering and commercial services.
48. It is proposed that a form of public-private partnership, such as exists in ETI, be considered for nuclear R&D. This would fund some or all future nuclear R&D with industry providing funds through a small but long term levy on nuclear-generated electricity. These new funds would be matched by the Government.

Structures & Responsibilities

49. The current responsibilities and structures for nuclear R&D and leadership of nuclear energy development appear to be unsatisfactory in a number of ways:
    d. The creation of **DECC** brings together the energy supply and back end responsibilities but the current fission budget is very small;
    e. **NDA** responsibilities for management of decommissioning and waste management are clear. Their responsibilities for the management of fuel reprocessing, MOX fuel fabrication and the disposal of plutonium and other heavy metals seems to be a significant diversion from their main role;
    f. The role of **NNL** is either so circumscribed, or is conflicted, or it is confused. It is called a national laboratory but its role is that of a service provider and is funded by contract R&D with customers that are largely government departments – NDA, AWE, MoD etc. each with rather restricted objectives and narrow programmes. None of these has a remit to develop civil nuclear power. Whilst, this structure provides good financial discipline for NNL ensuring that it performs in a commercial manner, NNL does not appear to have any funding to provide ideas or leadership in its areas of competence (see box). These skill areas are only a part of those required to meet the UK's nuclear R&D needs;

> **NNL is a nuclear technology services provider**. The business specialises in providing customers with tailored solutions in a number of key areas:
> - Nuclear Science
> - Waste and Residue Management
> - Plant Process Support
> - Modelling and Simulation
> - Materials and Corrosion
> - Environmental Management
> - Homeland Security and Non-Proliferation
> - Specialist Analytical Services
> - Knowledge, Data and Laboratory Management

g. **NNCE** creation was aborted because of the lack of support for its different and disparate objectives across Government Departments – MoD, FCO, DECC and BIS;
h. **Fusion** budget is managed by Department of Business, as part of its science budget with little relationship to other nuclear or energy R&D;
i. UK nuclear R&D will inevitably have a strong **international dimension** working with other governments and with reactor vendors – EU & US.

50. In these circumstances, it is unsurprising that any attempt to exercise oversight of nuclear R&D will continue to be problematic. Once national objectives for nuclear are agreed, the responsibilities and organisational roles for discharging them can be addressed. The delivery new national nuclear R&D programme should be transparent and done in manner that commands wide industry and public support.

Conclusions

51. One can say that the UK nuclear capability is living on its past investment. The current low level of R&D and the age profile in the industry together mean that skills are being lost faster than they are being created. The low level of nuclear R&D funding is a product of the past 'no new nuclear policy' and this needs to change to:
    a. Maintain UK ability to be a responsible host of current and planned power reactors:
    b. Gain the benefit from on-going LWR developments and their ability to burn actinide wastes or convert/breed nuclear fuel;
    c. Use UK's early position in the nuclear renaissance to rejuvenate its nuclear industry and gain a share of the export growth in nuclear;
    d. Maintain a position in the international fast reactor technology programme for the longer term.

    These suggested objectives for nuclear R&D need to be debated widely and agreed in manner that gives long term commitment consistent with the scale of the need and the timescales of the new nuclear technology.
52. Other countries are building up their nuclear R&D programmes with increased funding announced in both US and France. The emphasis for US and EU nuclear R&D programmes is somewhat different with US exploiting and developing the relatively mature technology of LWRs while led by France, EU programmes are seeking to accelerate the development of fast reactors and closed fuel cycles. While there is no difference about fast reactors being the long term objective the need for them before 2050 is being questioned.
53. There is a strong case for increased nuclear R&D funding and it proposed that increased funding should be by public-private partnership, perhaps managed by an arrangement such as ETI.
54. Once the R&D objectives and priorities are agreed the responsibilities of parts of the nuclear industry should be re-considered to provide better focus and to ensure the leadership and capabilities for the UK to respond to the emerging nuclear renaissance in the UK and around the world.

Tony Roulstone **April 2011**

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