IEA /NEA Nuclear Energy Technology Roadmap

Stakeholder Engagement Workshop

Paris, 1 April 2014

Workshop Summary (final)

On 1 April, 2014 the IEA and NEA hosted in Paris its third stakeholder engagement workshop in support of the update of the nuclear energy technology roadmap. Participants included experts from academia, government, NGOs and industry.

The objectives of this workshop were as follows:

- Share views of stakeholders on future prospects for nuclear and expectations for technology evolution.
- Review preliminary milestones and metrics for technology development, policy, regulation, finance, training and capacity building to accelerate nuclear energy development and deployment.
- Discuss and review draft recommendations for policy, regulatory, market, and finance to accelerate nuclear energy development and deployment.
- Articulate recommendations for actions and milestones related to communication and public acceptance for nuclear.

This document reflects the key points that emerged from the discussions held at this workshop. The views expressed in this paper do not necessarily represent those of the IEA/NEA or IEA/NEA policy.

Session 1: Reactor technology (including supply chain)

This session focused on technological changes and innovations in the area of reactor technology and operation, including Generation IV and non-electric applications of nuclear energy, as well as industrial issues such as supply chain, standardisation, etc. A presentation by Westinghouse on lessons learnt during new build projects kicked off the session.

- Long Term Operation of existing reactors, provided safety requirements are met, is needed to maintain capacity in low carbon generation and is a way to produce low carbon electricity in the most cost-effective way. The importance of the role and organisation of the operator to reach this target were highlighted. R&D in ageing and improved safety is needed to support this objective. Research into the backfitting requirements for 60+ year operation is required.
- Power uprates have contributed to a significant increase in capacity over the last two decades, at a time when new build rates were low (Sweden's current 10-reactor fleet capacity for instance was increased to compensate for the closure of

two units). However, the potential for further uprates in the US and in a number of other countries is now limited, but there is still a potential to exploit in some other countries.

- Following the Fukushima Daiichi accident, the safety of existing reactors was assessed by regulators for the type of events that led to the accident as well as for other beyond design accident conditions, and safety upgrade measures taken to improve the resistance of these plants. For Generation III reactors, very few design changes were recommended, since these plants already take severe accidents into account in their design. More attention is paid however to the qualification of systems designed to mitigate severe accidents, and more research on severe accident management is being performed.
- Cost reduction of Gen III reactors is an objective shared by all vendors and operators: this can be achieved through a number of options including design simplification, standardisation, improved constructability, modularity and supply chain optimisation and by taking full advantage of lessons learnt during the FOAK projects.
- Interest in Small Modular Reactors (SMRs) is driven both by the need to reduce the impact of capital costs and to provide power in small grid systems.
- There are different types of Small Modular Reactors (SMR), some already under construction in Argentina (CAREM) and China (HTR-PM) - (light water reactor and high temperature reactor technologies), others with near-term deployment such as mPower and NuScale in the US, and SMART in South Korea, and others with longer-term deployment prospects (liquid-metal cooled reactor technologies). SMRs can address complementary markets (countries with small grids, and/or geographical constraints, or cogeneration applications), and could be competitive against other form of generation suitable for those markets, depending on the manufacturing and construction rates. The competitiveness of SMRs compared to large nuclear reactors, in countries where both could be accommodated, needs to be assessed in a systems approach, where both generation and grid investments are accounted for.
- Two other types of SMRs were mentioned: floating SMR barges such as the KLT-40S (for electricity generation, heat processing, and possibly desalination) under construction in Russia for isolated coastal regions, and concepts for dedicated burners for countries having to dispose of plutonium stockpiles.
- Generation IV reactors, in particular fast neutron reactors, can improve waste management in the long term by further reducing long-term radiotoxicity of the ultimate waste. Gen IV designs have ambitious safety and non-proliferation targets as well.
- Nuclear cogeneration, in particular but not exclusively with high temperature reactors, has a lot of potential and nuclear energy could target other markets than just electricity production, and offer low carbon heat generation alternatives to fossil-fired heat production, thereby improving security of energy supply in countries that import fossil fuels for industrial applications. Cogeneration can also provide “energy storage” services by allowing nuclear power plants to switch from electricity to heat production while maintaining baseload operation.

- Potential for desalination to become a new market for nuclear power was also mentioned. The production of fresh water during off-peak hours would allow NPPs to operate economically well above usual baseload levels.
- In terms of operation, it was agreed that baseload power production was the most cost efficient of operating a nuclear power plant. Having large shares of variable renewable electricity production will require more thermal plants to deal with greater need for flexibility. Thus, there needs to be a better integration of nuclear, thermal and renewables from an electricity system and market perspective, taking into account the peculiarity of each technology to avoid loss of production and cost efficiency. One must keep in mind that operators supply electricity to customers on a competitive marketplace, where overall cost is an important parameter.
- Also, in the long term, there is a need to take into account possible changes in the climate to ensure that nuclear power plants are resilient both in the face of extreme weather events as well as under higher ambient air and warmer cooling water conditions.

In terms of industrial issues associated with new build:

- Vendors are aware of the necessity to build on time and to budget, and to reduce costs of new designs and licensing. Integrating lessons learnt from recent FOAK projects is an essential part of that strategy, applied to project management and planning, human resource allocation, supply chain set up and oversight, and reactor design and construction simplification and optimisation as well.
- There needs to be a good balance between supply chain localisation and globalisation, which depends on the extent of the past and future nuclear programme in the country of localisation. Guidance on how to reach this balance would be beneficial. Qualification of a new supply chain remains a challenge.
- Improved standardisation and harmonisation of codes and standards are seen as effective ways to improve new build performance and to reduce costs.

Session 2a: Nuclear fuel cycle and decommissioning

This session focused on some issues related to the front end (for example fuels with increased tolerance to accidents) and to the back end of the fuel cycle as well as decommissioning. A presentation from AREVA described the two possible strategies for the back-end of the fuel cycle, the once-through route and the recycling route, and the possible benefits of the latter in terms of uranium savings, volumes of generated waste and timeframes for decay heat reduction.

- Uranium supply is currently more than adequate to meet demand up to 2035 and beyond. However, given the long lead time of mining projects, it is recommended that investments continue to be made to develop environmentally-safe mining operations.

- In terms of enrichment, laser enrichment is a technology that could potentially bring costs down but this needs to be proven at industrial scale. Currently, there is no clear push at present to accelerate its deployment.
- Since the Fukushima accident, there has been a renewed interest in the development of so-called accident-tolerant fuel, that are designed to offer additional coping times to operators in case of a severe loss of coolant accident. However, there is a long way ahead to develop and qualify these fuels – and this will depend on the level of budgets devoted to this research.
- Deep geological disposal (DGD) is the recommended strategy for dealing with high level waste, but it requires long term planning, political commitment and strong engagement with local communities. Finland and Sweden (operating once-through cycles) and France (operating the recycling route) will be the first countries to have operational DGDs in the early to mid 2020s.
- The concept of regional repositories should be discussed more, as it would offer countries the possibility to pool resources, and also to find the most appropriate site if there are geological or other limitations to siting DGDs in a given country. The EU directive on radioactive waste does not exclude the concept of regional repositories.
- Because of delayed decisions on implementing DGDs, there is a need to address extended storage of spent fuel. However, this cannot be considered an alternative to DGD.
- Recycling of spent fuel has advantages in terms of resource management (for instance through the use of MOX fuel) but also in terms of conditioning of the high level waste (vitrification process), and hence the sizing of the DGDs. Further progress is expected with the development of multi-recycling in Fast Neutron Reactors (FNRs), and later on with the industrial-scale demonstration of use of minor actinide-bearing fuels, or targets in FNRs.
- Alternative routes to recycling spent fuel can be offered by heavy water reactors operating in synergy with LWRs, as currently being demonstrated in China.
- The current world market for fuel services (uranium supply, conversion, enrichment services, fuel fabrication) provides a considerable degree of security of supply and thus can play a major role in supporting the further development of nuclear energy. Increased security of supply can also be achieved through inter-governmental or international agreements dealing with fuel leasing, fuel banks, etc.
- Maintaining the highest levels of nuclear security for transport of nuclear material from providers to customers is essential.
- Finally, decommissioning will become an increasingly important part of the nuclear sector activity in the coming decades, as dozens of reactors will be shut down. Industry must provide further evidence that it can dismantle safely and cost-effectively these plants. Further improvements in technology (for instance robotics) and adaptation of regulations (for instance in the clearance of non-radioactive material from a power plant as waste) can help reach these objectives.
- It is important that decommissioning activities are covered by sufficient funds, and governments have a responsibility to ensure that this financial security is in place.

Session 2b: Safety, licensing and regulation

This session essentially addressed safety and regulation issues, with a discussion on the consequences of the Fukushima Daiichi accident on safety requirements.

- Following the Fukushima Daiichi accident, governments across the world requested safety evaluations (called stress tests in the EU) which underwent peer reviews by regulators. The IAEA also put in place its "Safety Action Plan" which was unanimously endorsed, and calls on implementing fully lessons learnt from the accident. Although the nuclear power plants which were assessed were found to be sufficiently safe, upgrades were requested and are currently being implemented, to improve resistance to extreme external events and overall safety, including in the case of multiple events affecting multi-unit sites.
- In parallel, enhanced safety requirements were put in place by regulators, to ensure that nuclear plants operate to even higher safety standards.
- Safety assessment methodologies, such as Probabilistic Safety Assessment methods are also being improved and further developed, recommendations for level two (2) and three (3) PSAs of external events, fire and flooding have been revised and their use encouraged also as a tool to improve on site and off site emergency planning. In general, more efforts should be devoted to safety research, and results communicated to a wider audience.
- Countries choosing to develop nuclear power should follow the IAEA "milestones" approach which provides a guide to set up all the necessary infrastructures, including the regulatory body.
- Regulators, whether in newcomer countries or established nuclear countries, should be strong and independent. They need to have sufficient, well-qualified and resourced staff to carry out their missions.
- There is some concern about the risk of over-regulating the nuclear industry, through the multiplication or duplication of regulatory requirements. Coordination and harmonisation of these requirements should lead instead to efficient regulation.
- Safety culture needs to be enhanced across the nuclear sector (operators, industry including supply chain, regulators) and at all levels of staff.
- There is an important role for international organisations to promote efficient regulation, harmonise requirements, share experience. In particular, peer-review processes, whether among operators or among regulators is seen as an effective process to improve the overall level of safety.
- Assurance of compensation for trans-boundary issues in the event of an accident must be improved through international conventions and greater adherence by States to liability regimes.

Session 3a: Training and capacity building

The session reviewed the preliminary milestones and metrics for training and capacity building needs for the nuclear industry. This included human resource and training

needs for the nuclear regulator, for new build construction, operation of existing and new plants, decommissioning and for replacing the nuclear workforce who will retire in the coming decades. The discussion also highlighted the following points.

- In addition to quantify the human resource requirements for the future nuclear industry, the roadmap should also provide guidance on the skills requirement (i.e. level of education) for training. This should cover both the construction and operation stages.
- With respect to regulators, requirements for compensation are less relevant. Focus should be on maintaining and attracting highly skilled regulators. In addition to the skills requirement at the regulator there is also a need to ensure adequate skills and expertise amongst the licensees.
- A recommendation for training the trainers was also highlighted. This emphasised the need to develop sufficient local education capacity in countries undertaking a nuclear programme.
- Investment in R&D to improve operation and safety was seen as a priority. Even in countries that are planning to phase out nuclear, additional R&D will be required to maintain a skilled work force to oversee decommissioning and waste management.
- Industry has very well developed training programmes which are shared across countries and provide an important source of nuclear training. Government action to support universities programmes for nuclear science, engineering and law was highlighted as a gap to be addressed.
- Mobility of nuclear literate workers across borders is critical. UK skills passport and French ticketing system provide a good basis for developing mutual recognition from one country to another on qualifications. This would help mobility of workforce. In particular skilled nuclear welders were identified as a skill requiring greater mobility.
- The NEA international school of nuclear law was identified as a good example which could perhaps be extended to other areas.
- The IAEA also offers training opportunities, especially aimed at newcomers.
- There is a need to develop programmes aimed at knowledge transfer from the highly skilled and experienced workforce that will soon be retiring, in the form of "mentoring".

Session 3b: Nuclear financing

A presentation from Rosatom Overseas on the Akkuyu project set the scene for the discussion on nuclear financing. One of the key messages on the investment and financing behind the Akkuyu project was strong commitment from both the Russian and Turkish governments.

According to the IEA's Energy Technology Perspectives 2°C scenario, over USD 4.3 trillion will be needed to finance investments in nuclear new build and for life time extensions by 2050. The bulk of this investment will be needed in non-OECD countries/regions such as China, India, the Middle East and ASEAN. This session

reviewed the draft milestones and recommendations and also highlighted the additional points.

- Long-term government policy support is key in the financing of new nuclear projects. Given the large capital investment required, long construction and operation timeframes it is important to have a clear long term strategy which supports the development of nuclear power. The UK experience was highlighted as a good example.
- Islamic bonds could be a potential financing instrument to support investments in nuclear projects in certain regions.
- Refinancing strategies once the construction phase has been completed are available and should be implemented.
- Significant government involvement in the financing of nuclear projects will likely be limited to the first two or three projects and hence alternative financing models will be needed. The Mankala model used in Finland could be a potential financing model where no government support is available.
- There is a need for greater cost transparency in nuclear power plant investments. Currently some project costs appear to be excluded from reported projects or different boundary conditions are used when reporting figures (i.e. overnight costs vs costs including financing).
- Role of development banks in financing of nuclear projects should be evaluated within the roadmap. Although they will unlikely fund entire projects, there could be certain aspects such as training and capacity building, early planning which could be funded based on benefits related to energy security and climate change. Development banks could play an important role in catalysing higher levels of private finance in part by providing a degree of insurance against political risk.

Group Discussion 4: Communication and public acceptance

During the Hong Kong workshop, participants highlighted the key role of communication and public acceptance in the development of nuclear particularly in new comer countries. This session began with a presentation from Burson-Marsteller on the Swiss case for effective communication and public acceptance of nuclear. Followed by a discussion aimed at identifying lessons learned and recommendations for improved communication and public acceptance for nuclear.

- For the Swiss case, the three most important factors include i) building trust through transparency, integrity and competence; ii) focus on evidence based communication; and iii) communicate often through various forms such as newsletters, public debates and online media.
- In Poland education of children was seen as critical in helping to improve public acceptance amongst adults. Education centres can be effective forms of improving public knowledge about the benefits of nuclear.
- Teachers and doctors were also highlighted as another stakeholder group to which improved communication and understanding about the benefits and risks of nuclear could help to support improved communication and public acceptance.

- Focus should be aimed at informing and raising acceptance amongst decision makers as achieving 100% public acceptance was seen as an unrealistic goal. Mayors of communities where nuclear facilities operate were identified as good communicators of the benefits of nuclear power for the local community.
- Finland and France were identified as two examples where communication and public acceptance for nuclear has been successful. In Finland significant time and resources were invested in educating local communities with respect to local benefits and risks for repositories. In France, LCIs (Local Commissions of Information) have been operating for several decades around nuclear facilities. They provide an efficient framework for all stakeholders to meet and for the public to have access to information.
- A successful strategy for nuclear communication will vary depending on the local situation. However understanding the concerns and needs of the local community will be key, in devising a successful communication strategy. Project developers need to be sensitive and responsive to stakeholder concerns, for example, farmers whose livelihoods are threatened by a new plant need to be provided with the means to secure an alternative livelihood and fishermen who believe that cooling water discharges might contaminate their catches need to be given visible assurance that this is not the case.
- Educating the media will be an important part of any communication strategy. They have a lot of influence on public opinion and in some cases can miss-communicate the issues due to either inadequate information or through over simplification which can lead to a confused public.
- Improving public acceptance for nuclear should be achieved via fact-based information and not ideology based. Education should be the focus of communication.

Session 5: Recommendations for key messages and final suggestions for the roadmap

- The roadmap should address the key challenges of competitiveness and public acceptance, and discuss how industry and governments are working to ensure that safety remains the highest priority, through technology, organisational practices, and regulatory oversight.
- The roadmap should provide a good overview of small modular reactors (SMRs), including current technology status and potential for market development. Current debate on SMRs is not very well informed. The development of the SMR technology deserves to be continuously monitored, updating both technical and economical aspects.
- Gen IV technologies and their potential role should be included in the roadmap as well as non-electric applications for nuclear (whether with Gen IV or other reactor technologies) such as high temperature heat process heat, desalination and co-generation. The potential role that nuclear energy can play in supporting electrification of transport should also be assessed.

- Government and industry must improve their communication and outreach on nuclear. This should be done by better informing the public and media about the benefits and risks of nuclear power. Governments must clearly define the objectives of their energy policies (e.g.: economics, CO_2 emissions, security of supply, technology options) and the political decisions shall be consistent with those targets.
- The UK model in support of nuclear under a strategy for a transition to a low carbon energy system was identified as a good model for others to learn from. Of particular note are activities around development of a local supply chain and programmes focused on training and capacity building, as well as the contract for different (CfD) proposal to support nuclear financing.
- There is a need to define more carefully electricity market designs in which nuclear power plants can operate most effectively, whether as baseload or as flexible capacity and to more carefully distinguish between nuclear operating in baseload and as flexible capacity.
- In additional to international organisations focused on nuclear development, there is also a role for the development of regional cooperation amongst countries. Regional collaboration may be more effective at facilitating the development of nuclear and in particular could be important for new nuclear countries.
- Research and development should focus on the following three areas: i) facilitating the deployment of existing GEN III/III+ technologies; ii) adapting nuclear technologies for use in other non-electric applications; and iii) breakthrough technologies for GEN IV and innovations for LWRs such as accident protected fuels.
- The important role of the operator, utilities and industry should be highlighted in the roadmap, perhaps in the form of a case study. Case studies should also include less favourable examples to highlight important lessons learned from failed examples.
- The role of nuclear in improving energy security and diversity of supply should be emphasised and not just with respect to climate change.
- Technologies and options for management of spent fuel should also be covered in the roadmap. One case study could cover the different options for managing spent fuel.
- The outlook for nuclear given current cheap gas, rapid expansion of renewables and low CO_2 prices is extremely challenging. The roadmap should also explore nuclear development realities under the current business as usual scenario.

Next Steps

- Development of case studies for inclusion in the roadmap to illustrate good examples and lessons learned in the construction, operation, fuel cycle management, licensing, regulation and safety, financing, training and capacity building and communication and public acceptance for nuclear. A list of potential cases studies discussed during the workshop is summarised in the table below.
- The full draft of the roadmap will be circulated for expert review in mid 2014.

Proposed case studies

Topic	Case study
Lessons learned from new build	Feedback from construction – Westinghouse AP1000 experience
	Setting up and qualification of a local supply chain – China
	Building on time and on budget – Japan's ABWR experience
Operational feedback for increased safety and performance	The architect-engineer model - EDF
Long term operation	Materials research on extended life times of NPPs – USA
Fuel cycle	Reprocessing of spent fuel and vitrification of high level waste – Areva
	Geological disposal of long term waste – Sweden or Finland (including stakeholder involvement)
Decommissioning	Case study Germany – E.On
Licensing, regulation and safety	UAE model for setting up of a regulator
	International collaboration amongst regulators – WENRA or MDEP
	Peer review process amongst nuclear operators – WANO
	New enhanced safety standards – Japan
	Good practices in siting and environmental impact assessments (country)
Guidance for new comer countries	IAEA milestones in the development of a national nuclear infrastructure
Financing	Akkuyu build own and operate – Rosatom
	Innovative financing mechanisms in liberalised electricity markets (i.e. Mankala, CfD, other)
Training and capacity building	UK programmes for education and training
Communication and public acceptance	Lessons learned from India on communication