***IEA /NEA Nuclear Energy Technology Roadmap***
***Stakeholder Engagement Workshop***
**Hong Kong, 25 February 2014**
***Workshop Summary***

On 25 of February, 2014 the IEA and NEA hosted in Hong Kong its second stakeholder engagement workshop in support of the update of the nuclear energy technology roadmap. Participants included experts from government, industry and other related organisations.

The focus of this workshop was to address nuclear development issues relevant to Asia with the objective to:

- Discuss the latest developments in Asia and how they are influencing the nuclear energy sector globally.
- Identify barriers for Newcomer Countries and discuss possible solutions.
- Identify game changers, technological improvements, R&D that can lead to:
    - Faster deployment rate of new build;
    - Wider implementation of geological disposal solutions for high level waste;
    - Safe and cost-efficient decommissioning of shut down facilities;
    - Improved economics while maintaining highest levels of safety.
- Share views of industry, utilities and nuclear organisations on future prospects for nuclear and expectations for technology evolution in Asia.
- Develop recommendations to policy makers, investors and utilities.
- Articulate policy, regulatory, market, public acceptance and finance related actions and milestones to accelerate nuclear energy development and deployment.

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

**Background**

In 2010, the International Energy Agency (IEA) and the Nuclear Energy Agency (NEA) released a *Nuclear Energy Technology Roadmap* which outlined the steps needed to accelerate the development of nuclear power and its role in achieving large-scale greenhouse-gas emissions reduction. Both the global energy sector and the outlook for nuclear have changed significantly since then and an update of this roadmap is currently underway.

The IEA roadmaps provide guidance to stakeholders on the technology pathways needed to achieve energy security, economic growth, and environmental goals. The roadmaps include a vision guided by the IEA Energy Technology Perspectives 2-Degree Scenario (2DS). Each roadmap represents international consensus on milestones for technology development, legal and regulatory needs, investment requirements, public engagement and outreach, and international collaboration.

**Introduction Session: Role of nuclear in Asia and drivers for nuclear development**

Participants highlighted the following aspects with respect to accelerating development of nuclear in Asia:

- Public acceptance and communication, i.e. how to best communicate the benefits of nuclear power, are some of the biggest challenges facing nuclear development in Asia. Public support in a decision to develop nuclear requires confidence in the safety of nuclear energy and trust in the regulatory body and government to ensure the safe operation of nuclear power plants. Thinking at the beginning of a nuclear power programme about developing a sustainable fuel cycle solution, especially with respect to spent fuel management, helps to gain public confidence;
- Training and skills development of a nuclear workforce able to fill the various requirements needed during construction, operation and of the regulator is a high priority for newcomer countries. International cooperation is needed to support nuclear workforce development.
- Even for developed countries, preservation and dissemination of knowledge learnt by the retiring workforce and the manufacturing experience gained by the nuclear vendors need to be kept alive.
- There is a need for a strong and independent nuclear regulator (safety authority), to promote safety culture and to overcome cultural barriers which could hinder transparency and possibly compromise safety. International collaboration and sharing of lessons learned with respect to operation and safety are critical to ensure a high global standard for safety.
- Newcomer countries should balance the greater certainty achieved by pursuing mature/proven nuclear technologies against the benefits of advance/innovative designs, considering all aspects of the project including risk allocation and knowledge transfer.
- A number of different models for the development of nuclear power in Asia are being pursued with different vendors providing a varying degree of additional services. Some include financing, support for operation, training and localisation.
- In Asia, projects are financed with government guarantees from both vendor (during construction phase) and government, through long term power purchase agreements and government guarantees, or indirect ownership to secure financing. It is also expected that Export Credit Agencies (ECAs) in Asia will play key roles in the export of nuclear technology from their respective countries.
- Nuclear power is seen as a reliable, low carbon source of base load electricity. For many countries in Asia with limited local energy resources, nuclear also provides enhanced energy security and clarity on long term costs as nuclear fuel costs represent a very small share of total costs.
- Good support for the development of case studies highlighting good practice examples and lessons learnt to promote the dissemination of existing solutions, including best practices in construction and quality assurance in the supply chain.

**Session 1a: Reactor technology**

This session focused on technological changes and innovations in the area of reactor technology and operation, as well as non-electric applications. Two presentations on reactor development in China were given, the first by Mr Gu from SNERDI, who presented the current Chinese nuclear development plans. He focused in particular on the development of the CAP1400 reactor, derived from the AP1000, but also a SMR type reactor (CAP150) and a sodium-cooled fast breeder reactor. Mr Xin presented the developments of CNNC's ACP series, ACP100 to ACP1000, which are PWR type reactors with both active and passive safety systems.

- There were questions on some of the problems that the AP1000 construction project encountered, in particular the main coolant pumps which were sent back to the manufacturer in the United States after defects were observed. This raised the issue of quality control in manufacturing safety-related equipment. It was emphasised that manufacturing of components should always be carried out under high quality assurance and monitoring, and suppliers need to be aware of nuclear quality requirements and generally, overall safety culture.
- The development of SMRs in China addresses domestic niche markets such as desalination or district heating, and for export markets, countries that have small electricity grids that would not be able to accommodate large nuclear power plants.
- In terms of competitiveness, economies of scale mean that the cost of nuclear reactors of capacities lower than 1000 MWe can be an issue, especially since the safety requirements for large and small plants are the same, hence it is believed that it will be very difficult for SMRs to be competitive outside of niche markets.
- Cost reduction is a driver for reactor designs in China.
- China like other countries (France, Japan, Russia or India) is pursuing a strategy of closing the fuel cycle. Hence it is interested in developing Fast Breeder Reactor technologies which will be able to recycle spent fuel.

**Session 1b: Fuel cycle and decommissioning**

The second part of the session on "technology development needs for nuclear" focused on the nuclear fuel cycle. It was recalled in the introduction that there is currently an oversupply of uranium, in part due to the fact that the Japanese nuclear fleet is off-line as it awaits authorisations to restart, and to the fact that Germany shutdown 8 reactors of its 17 reactor fleet and is planning to shut down the remaining reactors by 2022. However, in the long term, demand is expected to grow, and this will lead to changes in the fuel market. On the back-end end side of the nuclear fuel cycle, countries operating nuclear power plants need to have established strategies to deal with spent fuel, and ultimately, to manage radioactive waste. R. Autebert of AREVA gave a presentation of possible nuclear fuel cycle strategies.

- There are two ways of managing spent fuel: once-through option whereby fresh fuel is used in a nuclear power plant, and when it is removed, it is considered as waste to be stored for a number decades and then ultimately disposed in a repository. The other option is the recycling option, where spent fuel is reprocessed, useful material (i.e. that has energetic potential) recovered to be used as a component of new fuel. The rest is

considered as waste and is vitrified and stored in universal canisters to be disposed of in a repository. The volume and long term radiotoxicity of waste coming from recycling are substantially reduced compared to waste coming from the once-through option.

- From the point of view of economics, used fuel management represents about 6% of the costs of nuclear electricity generation. According to a recent OECD/NEA study, the costs of both options are comparable.
- In the long term, concerns for uranium resource availability as well as security of energy supply are expected to be drivers for closing the fuel cycle.
- As far as the ultimate disposal of waste in a geological repository is concerned, there may be benefits of recycling spent fuel in terms of cost of the repository since the waste is smaller in volume and in vitrified form.
- The concept of an "international repository" or of "regional repositories" in which waste from several countries could be disposed, with the cost being shared by countries that produce the waste, was also briefly discussed: even though this concept is attractive, it seems that it would be very difficult to establish.
- Three options were identified for nuclear fuel services:
    - The service of reprocessing used fuel produced in a country in another country that has recycling facilities, with the final waste being sent back in vitrified form to the country of origin for disposal, and the separated useful material (plutonium, reprocessed uranium) used to form MOX fuel.
    - Leasing of fuel with the spent fuel to be taken back after use, to be dealt with by the country which provided the initial (fresh) fuel.
    - There are also "fuel banks" which can supply enriched uranium to countries that do not have enrichment capacities but may have uranium resources. Several fuel banks have been set up, including one set up under the auspice of the IAEA, located in Russia, and one set up by Russia and other countries (Kazakhstan, Ukraine, Armenia) in the form of a commercial joint stock company called the "International Uranium Enrichment Center" (IUEC).

**Session 2 – Group I: Financing nuclear**

The development of nuclear energy will depend on its competitiveness, especially with respect to other technologies and low carbon technologies in particular – and on the ability to finance the huge investments which nuclear power plants represent. Paul Murphy from Milbank provided an overview of the current trends and considerations needed for developing and financing nuclear power plants at the start of this session focused on financing nuclear.

- A clear commitment and long term strategy for nuclear development in the country, backed by its government, is important for raising finance.
- A variety of financing models exist to address the variety of risks associated with nuclear investments. Many of the risks are common for all large infrastructure projects such as currency, country and regulatory risk. Government guarantees, tax incentives and different hedging or insurance mechanisms are available to cover these risks.

However, nuclear power projects have a certain set of unique characteristics, which in turn generate particular financing challenges that must be considered.

- Export credit agencies play an important role in providing guarantees and/or direct loans that are needed to make a nuclear project bankable.
- Islamic banking may be a potential source of finance in the future in countries where such a banking structure is available.
- Finance institutions will be interested in projects which demonstrate the capability to reimburse loans. For nuclear, long term fuel supply agreement and power purchase agreements with a clear pricing regime or an equivalent mechanism is required to finance these projects.
- Vendor financing equity is becoming increasingly common for nuclear projects as the ability of the utility to raise large amounts of debt has been reduced due to Basel III regulations which has effectively reduced the availability of long term debt (beyond 6 or 8 years for commercial banks, if not covered an ECA guarantee), Many vendors are supported by ECAs that provide debt and may also be backed by the exporting government via a government-to-government loan.
- Reputational risk considerations such as safety culture, environmental responsibility and commitment to international regimes and standards need to be considered with respect to financing nuclear projects. The Fukushima accident has led many finance institutions to develop or review their lending policies specific to nuclear.
- De-risking of nuclear investments as well as risk diversification (for example by having more equity partners who share the risk) are seen as a priority for all the stakeholders, vendors, utilities and governments, and are looked on favourably by financing institutions. A more comprehensive and uniform international nuclear liability regime is needed, as a means of addressing current gaps in national and international legal structures.
- As construction risks and long development and construction timeframes for nuclear projects have a large impact on financing costs, a refinancing strategy once the construction phase is completed and the nuclear plant is operational can help to lower overall financing costs, considering that NPPs have historically been viewed as an attractive investment for long-term investors (e.g., pension funds and insurance companies) and that, after commercial operation and first outage, the primary deterrents to debt providers have been removed, leading to capital markets and other financing options.

**Session 2 – Group II: Nuclear regulation and safety**

This session was devoted particularly to the set-up of regulatory and other infrastructures that are deemed necessary for new-comer countries choosing to add nuclear power to their electricity mix, and to a discussion on safety measures and "action plan" developed after the Fukushima Daiichi accident. V. Nkong-Njock of IAEA made a presentation of the "Milestones" approach of the agency, which is a phased, comprehensive and integrated approach to help country address the necessary requirements for operating safely one or several nuclear power plants. These requirements include the development of nuclear laws and adherence to

international conventions, and the set-up of a strong, independent safety authority to regulate the country's nuclear activities, and the development of a strong safety culture at all levels among organisations and companies involved in the design, construction, operation, regulation of nuclear power plants. Finally, the fundamental safety principles and the 12 items of the IAEA's "safety action plan" endorsed by all member states following the Fukushima Daiichi accident were recalled.

- Sharing experience and best practices should continue to be promoted. Thus, the role of fora of regulators such as WENRA (Western European Nuclear Regulators Association) or the Senior Regulators' Meetings at the IAEA are essential. Sharing experience among operators is also essential, and that is the role that WANO is fulfilling. Operators should remain responsible for nuclear safety, and liable for nuclear damages suffered by third parties in the event of an accident.
- To fulfil their missions, regulators need to be autonomous, have sufficient staff, with the right competences and skills, and be funded adequately. There was some concern that when regulators are paid by industry to perform work, this might be perceived as undermining the regulators' independence. To prevent that, the rules for such support should be clearly laid out and transparent, as is the case for instance in the UK with the GDA (Generic Design Assessment) process, or in the US where license applicants pay hourly fees to the NRC.
- Even though the mission of regulators is not to promote nuclear energy or to address public acceptance issues, they should (and many do) play a role in providing information to the public (for instance on their websites).
- Safety is of course an utmost priority, but nuclear security and safeguards are equally important, and will become more important as the number of nuclear installations and transport of nuclear material (e.g. fuel, used fuel) between those facilities increase.
- Regulatory frameworks are well established for today's generation of nuclear power plants. But these frameworks will need to evolve continuously to address new types of reactors, such as SMRs, transportable nuclear power plants, and in the longer term, Generation IV reactors.

**Session 3: Overcoming barriers to nuclear build out**

This session was dedicated to the discussion of barriers to the deployment of nuclear energy other than the challenge of financing, such as issues related to training and capacity development, supply chain, standardisation, construction and project management. Didier Cordero of EDF gave a presentation of how an "architect-engineer" organisation can help reduce the industrial risks of building and operating a large fleet of reactors. This implies the integration of the continuous feedback of operational experience in the design of the plant, the manufacture of its components (with appropriate quality control) and its operation. Didier Cordero also explained how this organisation had been well suited to support the construction of the Daya Bay nuclear power plant in 1985. EDF was the technical lead in the construction with the Chinese operator CGN deputy in all positions, and future operators of the plant were trained in France on simulators and in control rooms of EDF's nuclear power plants.

- Experience sharing between established nuclear operators and new nuclear utilities is essential.
- Supply chain issues need to be fully understood when starting a nuclear programme. Localisation requirements by newcomer countries may result in quality control issues and project delays and cost overruns.
- Training of personnel in preparation of the launch of a nuclear programme is an investment for a country, which requires incentives to be put in place to attract young people, train them (including in foreign countries), and ensure they are available when the programme starts.
- Research and development activities, possibly linked to the use of a research reactor, are seen as an effective way to develop and maintain skills and competence. Governments can play a major role in supporting technology development and R&D.

**Group Discussion 4: Key Messages**

- Public acceptance is a key issue, and factual information needs to be communicated to the general public about the benefits as well as the constraints of using nuclear energy.
- Safety culture must be promoted at all levels. Newcomer countries should benefit from past experience with building and operating nuclear plant. The role of a strong and independent safety authority is essential. Support should be provided to assist countries in setting up the necessary regulatory infrastructure.
- Information exchange and experience sharing should continue to be promoted among regulators and among operators of nuclear power plants.
- Additional effort and cooperation is needed to educate and train the future nuclear workforce. Those currently being trained will need to have opportunities to develop and maintain skills so they are operational when new plants become operational in the next decade or later. Clear, transparent and factual information about nuclear energy should also be provided to politicians and policy-makers.
- Newcomer countries will need partners with a solid operational track record and good operational practices to help train and transfer operational skills. Once a country has decided to develop nuclear power. It will take upwards of 15 years or more to set up the necessary institutions train the nuclear workforce and develop local supply chains.
- Clear understanding of quality assurance, monitoring requirements and safety culture is needed to address supply chain localisation. Guidance on what parts of the nuclear supply chain can be developed locally and those that would be better placed to be sourced internationally is required. Requirements for localisation should be carefully evaluated, especially for newcomer countries that are primarily interested in the electricity supplied by nuclear plants.
- Models for nuclear development will vary depending on whether they are in deregulated or regulated markets. The roadmap could highlight these differences and how policies may need to differ to address market differences.
- Stable and technologically-neutral energy policies are needed to ensure a long-term investment framework for capital intensive technologies such as nuclear.

- Financing for nuclear projects should be considered early on in a projects development. This will help to manage certain risks and better allocate risks to those best able to support these risks. Nuclear should be also be given the same carbon credits as other low carbon energy technologies.
- Roles and responsibility of different stakeholders (vendor, utility, host country, local supply chain, regulator etc…) developing nuclear projects needs to be clearly defined.

**Next Steps**

- A 3rd and final workshop will be held at the IEA in Paris on 1 April. The goal of this meeting will be to review milestones, recommendations and key messages of the nuclear roadmap update.
- The full draft of the roadmap will be circulated for expert review in mid 2014.