IAEA BULLETIN

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Nuclear power for a clean-energy future

IAEA 60 Years *Atoms for Peace and Development*

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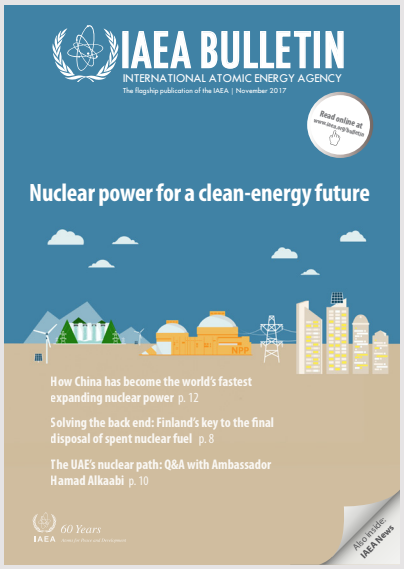

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IAEA

The International Atomic Energy Agency's mission is to prevent the spread of nuclear weapons and to help all countries — especially in the developing world — benefit from the peaceful, safe and secure use of nuclear science and technology.

Established as an autonomous organization under the United Nations in 1957, the IAEA is the only organization within the UN system with expertise in nuclear technologies. The IAEA's unique specialist laboratories help transfer knowledge and expertise to IAEA Member States in areas such as human health, food, water, industry and the environment.

The IAEA also serves as the global platform for strengthening nuclear security. The IAEA has established the Nuclear Security Series of international consensus guidance publications on nuclear security. The IAEA's work also focuses on helping to minimize the risk of nuclear and other radioactive material falling into the hands of terrorists and criminals, or of nuclear facilities being subjected to malicious acts.

The IAEA safety standards provide a system of fundamental safety principles and reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards have been developed for all types of nuclear facilities and activities that serve peaceful purposes, as well as for protective actions to reduce existing radiation risks.

The IAEA also verifies through its inspection system that Member States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements to use nuclear material and facilities only for peaceful purposes.

The IAEA's work is multi-faceted and engages a wide variety of partners at the national, regional and international levels. IAEA programmes and budgets are set through decisions of its policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States.

The IAEA is headquartered at the Vienna International Centre. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.

Clean energy for a sustainable future: the role of nuclear power

By Yukiya Amano, Director General, IAEA

Energy is the engine of development and prosperity. All countries need to secure sufficient energy to drive economic growth while working to mitigate the effects of climate change.

Renewable sources of energy such as wind and solar power will play an important role in the future. At the same time, use of nuclear power will need to increase to provide the steady supply of baseload electricity. As one of the lowest-carbon technologies for generating electricity, nuclear power will also help countries meet their goals of reducing greenhouse gas emissions.

This edition of the *IAEA Bulletin*, published for the International Ministerial Conference on Nuclear Power in the 21st Century, covers some of the most relevant topics on nuclear power and its role in contributing to sustainable development.

We highlight the way in which operators of nuclear power plants in the United States of America are seeking licence renewals to extend operation beyond 60 years; how China is undertaking the largest expansion of a nuclear power programme of any country; and why the United Arab Emirates has embarked on a nuclear power programme.

Nuclear power plants require significant upfront capital investment, but once they are up and running, they are comparatively inexpensive to operate. We examine the United Kingdom's model for financing nuclear power plant construction as one example of how financial risks can be managed.

Remarkable research is under way on a new generation of nuclear reactors, which will have inherent safety features, will be more efficient and will generate less waste. The latest developments in the field of small modular reactors are explored on page 18.

The nuclear industry has been managing waste disposal successfully for more than half a century. Dozens of facilities for low-level and intermediate-level nuclear waste are in operation throughout the world. As far as the long term management of high level radioactive waste and spent fuel is concerned, good progress has been made in recent years. You can learn about Finland's construction of the first deep geological repository for spent nuclear fuel, which is likely to become operational early in the next decade.

In many countries that are considering launching a nuclear power programme, public acceptance remains an important issue. The story on page 6 summarizes the approach taken by Ghana and Kenya. Investing in young people is important to bridge the skills gap and sustain nuclear power in the future. You can read about how the United Kingdom is implementing programmes in this area.

Women in nuclear

This edition includes a special section featuring eight exceptional women working in the nuclear field. We are proud to highlight their achievements and present their perspectives.

I am confident that nuclear power will make a growing contribution to sustainable development in the coming decades. The IAEA will play its part to assist countries in the safe, efficient and sustainable use of this remarkable resource.

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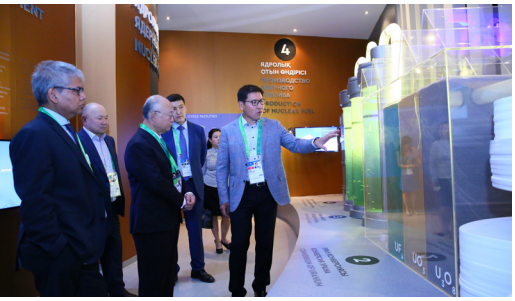
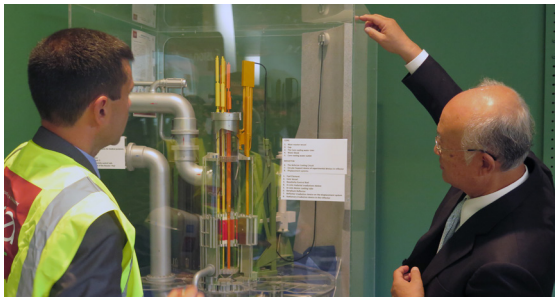
— Yukiya Amano, Director General, IAEA



(Photo: Expo 2017 Astana)

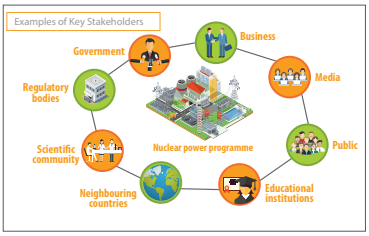


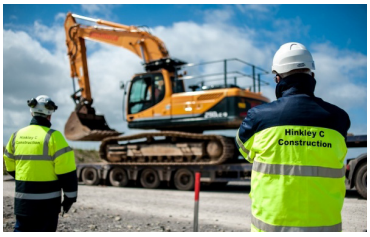
(Photo: C. Brady/IAEA)

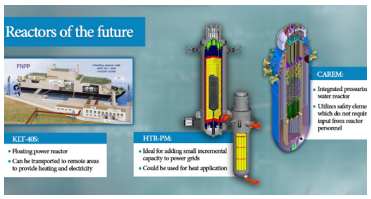
(Photo: ITER)

Foreword

Nuclear power for a clean-energy future







World View

IAEA Updates

Going long term: US nuclear power plants could extend operating life to 80 years

By May Fawaz-Huber

Surry Power Station was the first plant to notify the US Nuclear Regulatory Commission of plans to submit an application for subsequent licence renewal.
(Photo: NEI)

"If a subsequent renewal is granted and plants are allowed to operate for 80 years, NRC could see increased interest by other utilities."

— Allen Hiser, Senior Technical Advisor for Licencing Renewal Ageing Management, NRC

The last couple of decades have witnessed increased interest in the extension of the operating life of nuclear power plants. Extending the life of a plant is more economical than building a new one, and where it makes business sense, many plant operators in the United States are seeking licence renewals. This helps avoid supply shortages and support the country in reducing carbon emissions.

"It is very important for us as a world community to care how electricity is produced," said Maria Korsnick, President and Chief Executive Officer of the Nuclear Energy Institute. "You can produce electricity of an intermittent nature, like wind and solar, but you are going to also need 24/7 baseload energy supply that is kind to the environment, and nuclear is just that."

The US Nuclear Regulatory Commission (NRC) issues licences for nuclear power plants to operate for up to 40 years and allows licences to be renewed for up to 20 years with every renewal application, as long as operators prove that the effects of ageing on certain plant structures and components will be adequately managed.

About 90 percent of US plants have already renewed their licences once, extending their operation to 60 years. But most of these will soon reach the end of their 60-year term. If they cease to operate or are not replaced by new plants, the percentage of energy generated from nuclear will drop. A subsequent renewal extends a plant's operation from 60 to 80 years.

Nuclear provides 20 percent of the United States' electricity supply and more than 60 percent of the country's CO_2 emissions-free generation. Electricity demand is expected to rise by more than 30 percent by 2035.

To obtain licence renewal, a plant must provide the NRC with an assessment of the technical aspects of plant ageing and show how any issues will be managed safely. This includes review of system metals, welds and piping, concrete, electrical cables and reactor pressure vessels. It must also evaluate potential impact on the environment, assuming the plant will operate for another 20 years. The NRC verifies evaluations through inspection and audits, and its reviews of licence renewal applications can last anywhere between 22 and 30 months.

"In the very beginning, an NRC review took years to complete," Korsnick said. "Now that the process is better understood, we are just under two years. For subsequent licence

renewal, we will probably get the process down to 18 months."

While there have not been any subsequent licence renewals yet, three plants have already expressed their intent to submit an application for such renewal.

"If a subsequent renewal is granted and plants are allowed to operate for 80 years, NRC could see increased interest by other utilities," said Allen Hiser, Senior Technical Advisor for Licencing Renewal Ageing Management at NRC. "NRC experienced a similar trend when the original licence renewals were granted back in 2000."

Coping with government and market challenges

Most US Government policies favour renewables over nuclear, and according to Korsnick the market does not value all of the attributes that the nuclear plants bring. Three plants in the past six years have already shut down even before their original licence expired because they could not make sufficient money in the current market place. Korsnick maintains that the markets must be improved so that they value the products that nuclear is bringing — products that include clean air, constant 24/7 power and continuous operation for at least 18 months before needing to refuel. Full recognition of these benefits would prevent additional plants from shutting down prematurely.

"Fundamentally we want an electricity grid that boasts a diversity of generating technologies and that appropriately values the core attributes of each technology and the benefits they deliver to society," Korsnick said.

WOMEN IN NUCLEAR

Maria Korsnick

President and Chief Executive Officer, Nuclear Energy Institute (NEI)

Drawing on her engineering background, hands-on experience in reactor operations and a deep knowledge of energy policy and regulatory issues, Ms. Korsnick aims to increase understanding of nuclear energy's economic and environmental benefits among policymakers and the public. Before joining NEI, she was Senior Vice President of Northeast Operations for Exelon and had served as chief nuclear officer and acting chief executive officer at Constellation Energy Nuclear Group. She began her career at Constellation in 1986 and held positions of increasing responsibility, including engineer, operator, manager, site vice president, corporate vice president and CNO.

"I am proud to have been a member of Women in Nuclear for more than a decade — an organization with more than 25,000 members from 107 countries. Women in Nuclear members come from all areas of the nuclear industry — major power utilities, reactor design firms, universities, laboratories and government agencies — and draw on their passion for this industry to advocate for nuclear science and technology."

The IAEA and long-term operation

The IAEA has benefited from NRC support in its long-term operation (LTO) activities. The NRC was an early funder and active participant in the IAEA International Generic Ageing Lessons Learned (IGALL) programme, which used technical information from the NRC's Generic Ageing Lessons Learned report as its starting point. Other IAEA Member States added data for their plants to that US information, including information for pressurized heavy water reactor designs.

The USA has been an active participant in other IAEA activities related to LTO, including the development of safety guides on ageing management and LTO and presenting LTO workshops for international regulators and plants. The US also continues to provide expertise during IAEA Safety Aspects of Long-Term Operation (SALTO) missions to countries in Europe, Asia, North and South America.

Making the case for nuclear power: why stakeholder involvement matters

By Elisabeth Dyck

"Kenya undertook early public opinion polling to identify the main interests and concerns of stakeholders, including the public, regarding nuclear power. The results helped in developing a comprehensive communication strategy, including activities, messages and preferred media."

— Basett Buyukah, Director for Publicity and Advocacy, Kenya Nuclear Electricity Board

One of the biggest challenges that nuclear power programmes face is securing and sustaining the support of key stakeholders, including the public. This is also applicable to countries considering a possible role for nuclear power in their energy mix to ensure energy sustainability and enhance economic and industrial development.

Embarking on a nuclear power programme requires years of preparatory work and long term national commitment throughout the development, construction, operation and, ultimately, decommissioning, of nuclear facilities. To advance a strong case for nuclear power and to gain sustained public acceptance, it is essential to engage all stakeholders at every stage of the planning process and during the life cycle of nuclear facilities.

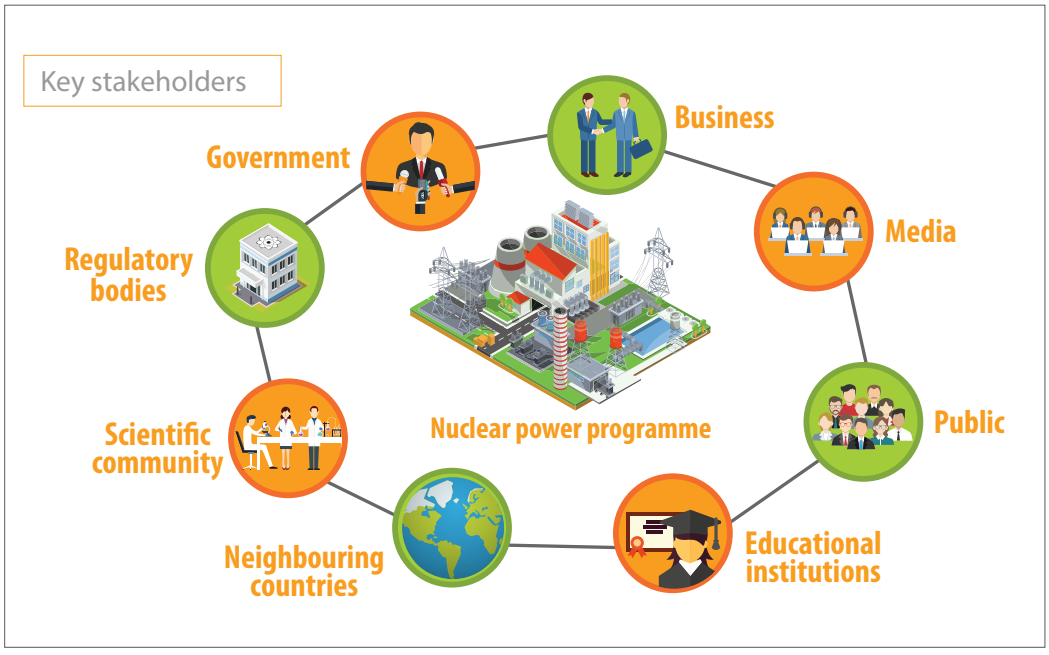
"Transparent and fact-based communication with the society at large not only contributes to the introduction and acceptance of nuclear power programmes, but also enhances safety and security," says Mikhail Chudakov, IAEA Deputy Director General and Head of the Department of Nuclear Energy.

Stakeholder involvement is one of the 19 infrastructure issues covered in the IAEA's Milestones approach, a structured guidance document that Member States use for the development of infrastructure for a nuclear power programme. The IAEA publishes guidance documents and organizes discussions on common challenges and good practices to facilitate the exchange of knowledge, experience and best practices on how to communicate with all interested parties.

"Engaging stakeholders is more than promoting the benefits of nuclear power or explaining its risks or complexities," said Brenda Pagannone, a stakeholder engagement expert who chaired a recent meeting on Stakeholder Involvement and Public Information at the IAEA. "It is about creating dialogue and taking into account the role and inputs of all interested parties in the decision-making process."

Ghana's example

Ghana, for instance, is cooperating with the IAEA on developing a national nuclear power programme. It has established a national organization — the Ghana Nuclear Power Programme Organization (GNPPO) — to coordinate all preparatory activities related to nuclear infrastructure development and hosted an IAEA Integrated Nuclear Infrastructure Review.



(Infographic: F. Nassif/IAEA)

"We have recognized that this undertaking is of a national dimension, requiring the buy-in of a wide range of interested parties," said Ben Nyarko, Deputy Chairman of GNPPO. "We have engaged with stakeholders from the very onset of the programme. This has enabled the GNPPO to effectively communicate the requirements and benefits of the programme to industry, policymakers and the general public."

Kenya's case

Kenya, which has also sought IAEA guidance on the development of a nuclear power programme, established the Kenya Nuclear Electricity Board (KNEB) in 2012 to coordinate all preparatory activities related to nuclear infrastructure development.

"Kenya undertook early public opinion polling to identify the main interests and concerns of stakeholders, including the public, regarding nuclear power," said Basett Buyukah, Director for Publicity and Advocacy at KNEB. "The results of the poll were pivotal for KNEB in developing a comprehensive communication strategy, including activities, messages and preferred media." KNEB has subsequently rolled out a strong public education programme, including for schools, colleges and universities, and hosted meetings, conferences and workshops for different stakeholders.

Non-stop communication

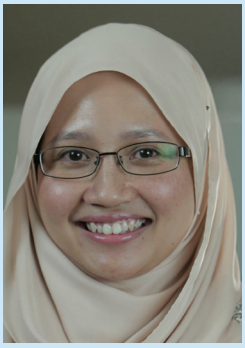
Stakeholder involvement activities do not stop once a nuclear power plant is in operation. They need to be maintained throughout the life cycle of nuclear facilities, including operating reactors, temporary spent fuel storage facilities and final radioactive waste repositories.

"Forging a positive and open relationship with local communities — workers, families, representatives of other industries, leaders, students and teachers — is paramount to maintaining a trustworthy and positive environment," said Pagannone.

WOMEN IN NUCLEAR

Myra Liyana Razali

Manager, Stakeholder Engagement, Malaysia Nuclear Power Corporation (MNPC)



Ms. Razali is responsible for stakeholder engagement and corporate communications for the nuclear power programme development in Malaysia. Over recent years she has participated in and contributed to IAEA meetings and expert missions, as she aspires to be among those raising the bar for stakeholder involvement in the nuclear industry. She has worked in the nuclear energy field since 2007, when she joined the Malaysian Nuclear Agency as a publication officer.

"To move forward with the pursuit of nuclear power, we need to address negative perceptions of nuclear etched in the hearts and minds of the public. To do that effectively, trust — as the new currency of stakeholder involvement — is foundational. Trust requires a genuine approach to communication — one that involves deep listening, meaningful dialogue and mutual understanding. As challenging as this may be, we have to find our voice in the midst of the noise and remain committed in order to keep the public engaged."

More than 60 participants from 19 newcomer countries to nuclear power and 16 operating countries attended the IAEA Technical Meeting on Stakeholder Involvement and Public Information, held on 13-16 June 2017 in Vienna.
(Photo: A. Evrensel/IAEA)

Solving the back end: Finland's key to the final disposal of spent nuclear fuel

By Irena Chatzis

Entrance to ONKALO, Finland's repository for spent nuclear fuel
(Photo: Posiva)

"Since the decision was made 40 years ago on the overall waste management strategy and on a deep geological repository as the primary option for spent nuclear fuel, all the stakeholders have stood by it. Governments and people have changed, but the decision and the vision for the future have remained the same."

— Tiina Jalonen, Senior Vice President for Development, Posiva

Countries operating nuclear power plants store their spent nuclear fuel either at reactor sites or away from them. Spent fuel can be dangerous to people and the environment if not properly managed; therefore, a publicly acceptable, permanent solution for its disposal is needed (see box). While a number of countries are considering deep geological disposal repositories, Finland is the only country that has begun the construction of a repository for the final disposal of its spent nuclear fuel.

Finland's recipe for success

At a depth of 400-450 metres and with about 70 km of tunnels and shafts, the ONKALO repository in Olkiluoto on Finland's west coast will house copper canisters filled with spent fuel from nuclear power reactors. It is expected to receive waste for about 100 years, after which time it will be sealed.

"Since the decision was made 40 years ago on the overall waste management strategy and on a deep geological repository as the primary option for spent nuclear fuel, all the stakeholders have stood by it," said Tiina Jalonen, Senior Vice President for Development at Posiva, the company in charge of the project. "Governments and people have changed, but the decision and the vision for the future have remained the same."

Another reason why Finland's model has worked is the timely involvement of all the stakeholders in the project, who worked as one team, targeting the same goal.

"The roles between the different stakeholders have been clear. The decision makers have developed legislation in parallel to introducing nuclear energy, and the Radiation and Nuclear Safety Authority of Finland (STUK) has developed safety guides, regulations and competences to review and inspect our documentation and applications," said Jalonen.

Moreover, involving STUK from the beginning was crucial to building the trust in the project. "It wouldn't have worked if any of the stakeholders were missing from the process," explained Petteri Tiippana, Director General at STUK. "Active participation of the safety regulator provided the local community with additional assurances."

In fact, public acceptance was crucial for the success of the project. The selection of the Olkiluoto site — home to three nuclear reactors — as the repository site was made, not only for the geological suitability of this area, but also for the acceptance of the people living there. Finland conducted many studies about local and national attitudes toward the project, which showed that people living around nuclear power plants tend to have more trust in nuclear projects.

"Trust has been one cornerstone in being able to proceed according to the Government's schedule," Jalonen said. "Building trust has required extensive and open communication with local people, the authority and the decision makers."

The project is based on the "multiple barriers" concept, which aims to provide needed containment and isolation to prevent spent fuel from leaking and spreading, according to Posiva. The combination of bedrock, disposal canisters surrounded by clay, tunnels filled with clay containing backfilling materials and plugging the tunnel's mouth will all serve as protective multiple barriers.

Who's next?

Two other countries have made progress towards building repositories for high-level radioactive waste or spent fuel declared as waste. In June 2016, the Swedish Radiation Safety Authority endorsed the licence application for the future spent fuel deep geological repository at Forsmark. Review by the Swedish Land and Environment Court for environmental licencing of the project started in September 2017.

In France, the licence application for the deep geological disposal facility, Cigéo, is under preparation; it is planned to be submitted by the end of 2018, with construction starting in 2020. The pilot phase of disposal could start as soon as 2025. It will contain waste from the reprocessing of spent fuel from France's current fleet of nuclear power plants and other long-lived radioactive waste.

WOMEN IN NUCLEAR

Laurie Swami

President and CEO, Nuclear Waste Management Organization (NWMO)

Ms. Swami is responsible for implementing Canada's plan for the long-term management of used nuclear fuel. She previously served as Senior Vice-President of Decommissioning and Nuclear Waste Management at Ontario Power Generation (OPG), where her responsibilities included overseeing operation of OPG's nuclear waste management facilities, as well as implementing OPG's deep geological repository for low and intermediate-level nuclear waste. She began her career at OPG in 1986 and held various roles with increasing responsibility in the Nuclear Division.

"The safe, long- term management of used nuclear fuel is an important responsibility we have towards future generations. Fortunately, nuclear waste management organizations around the world, including ours in Canada, are building momentum and taking concrete action to implement plans in a manner that protects both people and the environment."

THE SCIENCE

High-Level Radioactive Waste (HLW) is produced from the burning of uranium fuel in nuclear power reactors. It is of two kinds: spent fuel, declared as waste and ready for disposal, or waste resulting from the reprocessing of spent fuel.

Due to its high radioactivity and very long half-life (the time it takes for a radioactive substance to lose half its radioactivity), HLW has to be well contained and isolated from the human environment. Intensive research has identified the suitability of various rock types to host deep geological repositories and engineered barrier systems to isolate the waste. These repositories are constructed in suitable geological formations at a depth of several hundred meters and designed to contain high-level waste for hundreds of thousands of years.

The UAE's nuclear path: Q&A with Ambassador Hamad Alkaabi

By Shant Krikorian

The United Arab Emirates is expected to bring its first nuclear power reactor into operation in 2018. The country started building the first unit of the Barakah Nuclear Power Plant in 2012 and currently has four units under construction. We sat down with Ambassador Hamad Alkaabi, Permanent Representative of the UAE to the IAEA, to talk about his country's nuclear power programme.

Q: Why did the UAE choose to embark on a nuclear power programme?

A: The UAE's decision to pursue a nuclear power programme was based on the need to meet the country's increasing energy demand. We chose nuclear power for its commercial and environmental competitiveness. The early phase of the programme included a detailed road map addressing all infrastructure requirements and associated costs. The decision to go ahead with the programme was based on full understanding of its financial implications. The development of a nuclear power programme requires solid investment and risk mitigation strategies. What makes our programme successful is our Government's robust commitment, a viable business model, high public acceptance and strong international cooperation and support, including with and from the IAEA.

We chose nuclear power for its commercial and environmental competitiveness. What makes our programme successful is our Government's robust commitment, a viable business model, high public acceptance and strong international cooperation and support, including with and from the IAEA.

— Hamad Alkaabi, Ambassador and Permanent Representative of the UAE to the IAEA

Q: How has the IAEA helped with this process?

A: The IAEA has provided guidance on the development of our national nuclear infrastructure. Our planning was based on the IAEA's Milestones approach, whereby eight IAEA review missions were conducted covering various areas and stages of the programme. Moreover, the reports from these review missions were made public, which contributed to increased confidence in the programme among stakeholders and the public at large.

Barakah nuclear power plant, UAE
(Photo: IAEA)

Q: How will cooperation with the IAEA evolve once the Barakah Plant is connected to the grid?

A: The focus of our cooperation will naturally shift to more advanced areas of commissioning and safety of operation, but

we will continue to be interested in technical support and peer review missions.

The UAE's commitment to the highest standards of operational transparency, safety, security and non-proliferation, as well as our cooperation with the IAEA has enabled our programme to serve as a model for many countries embarking on nuclear power. We look forward to sharing our experience with other IAEA Member States.

Q: How can a country develop a strong nuclear regulator when it is developing a nuclear power programme?

A: A competent nuclear safety regulator is the cornerstone of any successful nuclear programme. First, we established the right framework through a comprehensive nuclear law that gives the regulator the power, independence and resources it needs to carry out its mandate. Second, we have established the regulatory capabilities by focusing on maintaining the needed skills. This is done on the one hand by acquiring external experts with global experience, while training local experts and developing their skills on the other. We also coordinate with the industry so that building regulatory capabilities becomes a gradual process directly linked to the progress of the project and its schedule. Not to mention the valuable support received from the reactor's country of origin and other internationally recognized technical support organizations.

Q: A foreign workforce has played an important role in the UAE's nuclear push. How will the country secure a skilled and sustainable workforce in this sector for the long term?

A: Building a sustainable national capacity is a challenge for any country using nuclear. In newcomer States, nuclear projects necessarily dictate a reliance on a foreign workforce and expertise, particularly at the beginning of a project. To address the challenge of ensuring the availability of sufficient manpower throughout all phases of the nuclear programme, the UAE developed a robust human resources strategy that identifies the scale and type of expertise needed. It is an integrated approach that includes scholarships and on-the-job training and mentoring. Youth empowerment and capacity building are key priorities in our policy.

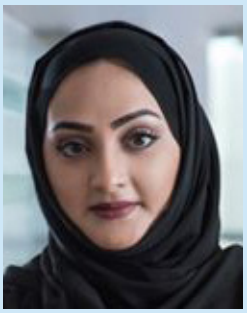
Q: What is the UAE's rationale for hosting the IAEA's International Ministerial Conference on Nuclear Power in the 21st Century?

A: In 2012, the UAE became the first newcomer State in almost three decades to start the construction of a nuclear power reactor. This makes it a uniquely relevant case to many Member States. The support we received for hosting this Conference is recognition of the UAE's successful efforts and responsible approach in developing a peaceful nuclear programme. Moreover, the Conference is an important forum to discuss the current and future role of nuclear power in sustainable development and climate change mitigation. The UAE is happy to host such a timely discussion, given our strong commitment to clean energy, where nuclear, solar and other clean sources will play an important role in our nation's future energy mix.

WOMEN IN NUCLEAR

Shaima Al-Mansoory

Director, Education and Training, UAE's Federal Authority of Nuclear Regulation (FANR)

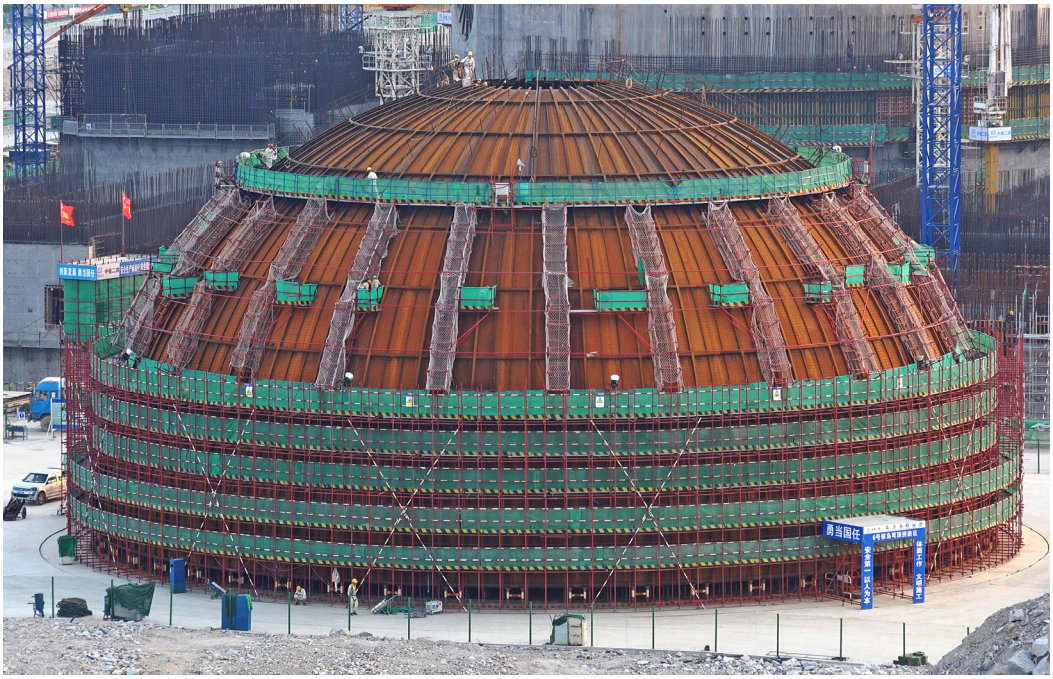


Ms. Al-Mansoory is responsible for capacity building, knowledge management and operations training at FANR. Under her leadership, the Education and Training Department has progressed in developing the capacities of the Emirati staff and experts in the areas of competency development, succession, research and development, knowledge management, technical certifications and career development. Ms. Al-Mansoory joined FANR in 2009 and played an important role in the establishment of the department alongside experts in the field of capacity building.

"Empowering women in nuclear serves a vital part of our work at FANR. We have developed specific programmes to ensure our women are well equipped with the skills and knowledge required to perform at their peak. Currently, Emirati women comprise more than 38 percent of FANR's total workforce of 213 employees, with around 42 women taking up leading roles in nuclear safety and security, safeguards and others."

How China has become the world's fastest expanding nuclear power producer

By Laura Gil



This huge round structure, called 'the dome', is only one piece in China's Fuqing Nuclear Power Plant, which is currently under construction.
(Photo: M. Klingenboeck/IAEA)

"We have a well-established, complete system in place, not only from the point of view of design, but also manufacturing, quality assurance, safety and construction."

— Zheng Mingguang, President, Shanghai Nuclear Engineering Research and Design Institute

It has 38 nuclear power reactors in operation and 19 under construction[1]. It has increased its number of operating reactors by more than ten times since 2000 and plans to bring five units into commercial operation this year alone. It is China, the fastest expanding nuclear power generator in the world.

"China is a big country. We have higher energy demand than other countries, but also more room for nuclear power," said Zheng Mingguang, President of the Shanghai Nuclear Engineering Research and Design Institute (SNERDI).

In the list of 'expanding countries' in the world, China stands at the very top, followed by Russia with seven reactors under construction, India six and the Republic of Korea three. Currently, the countries with most reactors in operation are the United States, France, Japan and China.

Trying to curb its reliance on coal, which pollutes the air and is hard to transport from the coal mines in the west and north of the country to the economically developed southeast coast, China is building most of its reactors along this coast. With nuclear, it plans to increase energy security, lower its reliance on coal and oil and limit CO_2 emissions while keeping up with its economic growth.

A test for the world

China's 19 reactors under construction include several advanced models. "The nuclear industry is watching China put the first AP1000 reactors in Sanmen and Hiayang in operation," said Nesimi Kilic, nuclear engineer at the IAEA. Out of these, Sanmen-1 is expected to be finished by 2018. The EPR reactor in Taishan is also expected to enter commercial operation in 2018. With the commissioning of Sanmen-1, more of such reactors could be built in other countries, according to Kilic. "China has become a pilot for the world," he remarked.

[1] *These figures do not include six units in operation and two units under construction in Taiwan, China.*

The economics of nuclear

China's energy regulator, the National Energy Administration, is expected to set the country's nuclear capacity target to 120-150 gigawatts by 2030, up from about 38 in 2017. Thanks to this scale, nuclear is economically competitive, Chinese experts have said.

"We have a well-established, complete system in place," Zheng said. "Not only from the point of view of design, but also manufacturing, quality assurance, safety and construction. This is why nuclear power in China is economically feasible."

Localizing the technology — design and manufacturing in China — is what is giving the Chinese an advantage and making this expansion possible, Kilic said. China has the facilities, the technology and the human capability.

Expansion abroad

China's ambitions are also global as it plans to export nuclear power reactors in the future.

"With technological development, the economy of nuclear power could be better in the future," Zheng said, adding that countries need to support each other. China is already sharing best practices from its experience, using the IAEA as a platform.

WOMEN IN NUCLEAR

Rong Fang

Chief Economist, State Nuclear Power Technology Corporation (SNPTC)

For the past 32 years, Ms. Rong has devoted herself to the development of China's nuclear industry and has assumed executive positions in nuclear research and design institutes, nuclear power plants, nuclear equipment manufacturers and national nuclear corporations. She completed the design of several major nuclear engineering projects, contributed to the planning of nuclear industry expansion in China and facilitated the establishment of several professional nuclear enterprises, including engineering, operation and fuel management for AP1000 nuclear power projects. She is the first woman from mainland China to receive the Women in Nuclear award in 2017.

"China's efforts to develop nuclear energy are necessary to safeguard energy security, improve energy structure and combat climate change. I believe China will continue to adhere to the three-step strategy, i.e. pressurized water reactor, fast reactor and fusion reactor in the path of nuclear energy development. Moreover, the advanced GEN III passive pressurized water reactor technology will be the mainstream model in mainland China for decades to come."

Staff receive instructions at China's Fuqing Nuclear Power Plant.

(Photo: China National Nuclear Corporation, Fuqing Nuclear Power Company)

Financing and managing nuclear energy risks: The UK model

By Jennet Orayeva

Workers at Hinkley Point C construction site
(Photo: EDF Energy)

"It is instructive that the UK government has concluded, based on years of analysis, that even in a market that has a long history with civilian nuclear power, government support is still needed to facilitate nuclear power development."

— Paul Murphy, Managing Director, Gowling WLG

Nuclear Power Plants (NPPs) have long lifetimes and low running costs, but they require high up-front capital expenses and a long planning and construction time. This means the economics of NPPs are sensitive to the cost of financing and overruns, and project delays can be costly. Successful financing is a major challenge and typically requires significant government involvement.

Traditionally, the costs of constructing and operating nuclear power plants were mostly passed on to electricity consumers in the form of regulated tariffs, minimizing the risk to lenders, investors and operators of exposure to price fluctuation. This traditional approach characterized most pre-liberalization electricity markets, where many of the utilities were integrated monopolies combining generation, transmission, distribution and retail, and the level of government involvement in regulation was high.

However, the market liberalization that started in the developed world in the 1990s has led to increased price and revenue uncertainty, causing reluctance among lenders and investors to commit the significant resources needed for NPP construction.

In an attempt to address this reluctance, stakeholders have come up with innovative approaches to risk sharing in nuclear power projects that aim to give additional assurance to potential lenders and reduce capital costs. These include reducing revenue volatility by guaranteeing electricity prices and providing various forms of government guarantees.

Replacing nuclear with nuclear: Why the UK model matters

Around 20 percent of the UK's electricity supply today is produced by nuclear.

Within the broader context of its Electricity Market Reform, the Government has decided to continue to rely on nuclear rather than only on gas or renewable energy sources, and is seeking to replace its existing nuclear fleet.

Currently, developers have up to 11 reactors proposed or planned at six sites. The power plant at Hinkley Point C has already passed through several stages of the decision-making process and is expected to be commissioned in the early 2020s.

The UK model features three main mechanisms in support of nuclear: a price guarantee scheme known as contract for difference (CfD); a government guarantees scheme; and a mechanism for limiting investor exposure to the costs of disposing of higher activity waste, including spent nuclear fuel.

Contract for Difference

The CfD features a ratepayer-backed guaranteed price for electricity generated by low-carbon technologies. According to

the terms of its CfD, Hinkley Point C, once operational, will be paid the difference (on a 'per megawatt hour' basis) between a 'strike price' (the electricity price that reflects the cost of investing in a particular low-carbon technology) and the 'reference price' — a measure of the average price for electricity in the UK market. When the average market price (the price that a generator such as Hinkley Point C might expect to receive directly from the sale of its electricity in the market) is lower than the strike price, the generator receives a 'top up' payment to make up the difference. When the average market price is higher than the strike price, the generator must pay back the difference.

"In the Hinkley Point C project, the CfD substantially mitigates the so-called 'market risk' faced by lenders and investors," said Anurag Gupta, Director and Global Sector Head for Power Infrastructure and Corporate Finance at KPMG.

This gives electricity generators greater certainty and stability of revenues by reducing their exposure to volatile wholesale prices, while protecting consumers from paying for higher than necessary support costs when electricity prices are high.

"By creating greater certainty, investors and lenders are able to model the project, which in turn allows them to make more informed decisions," explained Paul Murphy, Managing Director of Gowling WLG. "Furthermore, taking a 35-year tenure, as opposed to a classic 20-year tenure, facilitates further long-term equity investment as well as refinancing options."

The UK Guarantees Scheme

The UK Guarantees Scheme (UKGS) is a mechanism developed by the UK Government to provide credit enhancement through debt guarantees. The scheme was introduced in 2010 with a budget of £40 billion in guarantees to be invested across a range of UK infrastructure categories, including energy, transport and social infrastructure. Support from this scheme has been made available to the Hinkley Point C project (for up to £2 billion worth of debt).

"It is instructive that the UK Government has concluded, based on years of analysis, that even in a market that has a long history with civilian nuclear power, government support is still needed to facilitate nuclear power development," Murphy commented.

Limiting investor exposure to the costs of disposing of higher activity waste

One of the key issues associated with nuclear power is uncertainty with regard to the costs of disposing of higher activity waste, including spent nuclear fuel. The UK Government has put in place a mechanism to effectively cap such costs, thereby reducing operators' exposure to the risk of cost escalation. The mechanism operates by setting an upper limit (or 'cap') on the 'waste transfer price' that an operator will have to pay in return for the UK Government taking 'ownership' of the higher level waste (and thus responsibility for its disposal).

"By effectively capping the ultimate waste transfer price, the UK Government has provided reassurance to potential investors regarding a very 'difficult to quantify' project risk," explained Paul Warren, IAEA Senior Nuclear Engineer for Nuclear Power.

WOMEN IN NUCLEAR

Helen Cook

Counsel, Shearman & Sterling LLP

Ms. Cook advises clients on the establishment and implementation of civilian nuclear power programmes and on the procurement, construction and financing of new nuclear power plants and associated nuclear fuel facilities and transactions. She is the author of *The Law of Nuclear Energy* and the Chair of the Law Group of the World Nuclear Association. Ms. Cook was recently named to the National Law Journal's 2017 D.C. Rising Stars list, which recognizes the Washington, D.C. area's 40 most promising lawyers aged under 40.

"The future of the global nuclear industry requires that new sources of finance are attracted to nuclear power projects. This means managing the unique and highly complex risk profile presented by nuclear power plants, which encompasses both financial and reputational risks, and recognizing that the character of these risks changes over the lifetime of a project."

Encouraging careers in nuclear: The UK's strategy for a sustainable nuclear workforce

By Oleksandra Gudkova

Workers at Sellafield
(Photo: NDA)

"[The NDA's] strategy covers a range of aspects, from attracting young people into the industry through targeted skills interventions at schools and developing fit-for-purpose apprenticeship programmes, right through to the development and redeployment of skills to ensure that they stay within the sector."

— Beccy Pleasant, Head of Skill and Talent, NDA

In order to address the widening skills gap caused by the retirement of an ageing workforce in the nuclear industry, the United Kingdom is devising strategies to develop the skills of its young people and encourage them to pursue careers in this sector.

"The United Kingdom is experiencing a nuclear renaissance," said Lynne Matthews, Education and Skills Strategy Manager at EDF Energy. "In order to build, operate and decommission current and future stations, we need to ensure we have the skills needed."

One of the ways of addressing this gap, Matthews added, is to support public understanding and acceptance of nuclear through programmes and activities and inspire the young to choose careers in this industry.

Nuclear for children

The Pod is an education programme promoted by EDF Energy, the largest producer of low-carbon electricity in the UK. The programme provides free resources for teaching children and adolescents aged between 4 and 14 years about topics in energy, waste, water, transport, biodiversity and climate change.

EDF Energy developed the Pod in 2008 to help meet its goal of engaging 2.5 million children by 2012 in education programmes about the sustainable use of energy. Today, it has more than 22 000 registered schools, with more than 10 million children and 32 000 teachers registered in the programme. More than 200 schools from 54 other countries have also joined.

"The Pod provides ideas for teachers to use in the classroom, such as games and competitions. This interactive approach helps students have fun while learning about sustainable development and energy saving, Matthews explained.

"We are starting with primary schools and working all the way to university level. We also have nuclear site tours to help dispel any myths about nuclear. We want to encourage openness, transparency and trust."

Within the scope of its educational activities, EDF Energy also provides opportunities for young people to enrol in training workshops and graduate and post-graduate programmes. These opportunities give students the chance to develop their academic qualifications while gaining field experience. They also equip them with the skills necessary to build a successful career in the nuclear industry.

Focused national strategies

Other activities are being carried out on the national level. The United Kingdom's

Nuclear Skills Strategy Group (NSSG) was established to coordinate the efforts of all the major nuclear players in the sector. It has developed a clear action plan of collaborative initiatives which address the attraction, development and mobilization of a nuclear workforce. Each of these initiatives is sponsored by organizations within the sector, with Government agencies also playing a role.

Feeding into the NSSG Strategic Plan is the National Decommissioning Authority's (NDA) People Strategy, which is designed to ensure that the UK's decommissioning sector has the skills and capability to deliver its mission.

"This strategy covers a range of aspects, from attracting young people into the industry through targeted skills interventions at schools and developing fit-for-purpose apprenticeship programmes, right through to the development and redeployment of skills to ensure that they stay within the sector," said Beccy Pleasant, Head of Skill and Talent at the NDA.

Another programme has been developed by Sellafield, the country's fuel reprocessing and nuclear decommissioning site. "It offers nuclear degree apprenticeships for young people who are looking for an alternative to going to university," Pleasant said. "This is just a selection of the work being developed by the NDA to ensure the ongoing availability of a talented workforce for decommissioning."

WOMEN IN NUCLEAR

Helena Zhivitskaya

Vice-Rector, Belarusian State University of Informatics and Radioelectronics, Scientific Secretary of the Regional Network for Education and Training in Nuclear Technology STAR-NET

With more than 15 years of managerial experience, Dr. Zhivitskaya oversees quality control and development of educational curricula, including the 'Instrumentation and Control Systems for Nuclear Power Plant' degree programme, among others. She is a core contributor to the 'Belarus educational programme for Nuclear Energy 2008-2020'. She is also the author of more than 170 scientific works and publications, including four monographs and 11 textbooks. She is one of the initiators and leaders of the creation and operation of the Regional Network for Education and Training in Nuclear Technology STAR-NET.

"Safe development of nuclear energy is key to solving the energy problems facing society. In the era of globalization and fast-paced development, a new generation of nuclear technology professionals must continuously develop their knowledge, creativity and propensity for innovation. Increasing public awareness of the immense benefits of nuclear energy, and therefore improving its image amongst non-professionals, is crucial to attract highly qualified personnel."

An IAEA curriculum for nuclear science

A career in nuclear can be made more attractive thanks to the Compendium, an IAEA tool that aims to increase awareness and appreciation of nuclear science among young people.

The Compendium, which is being tested by the IAEA and education experts from several countries, devises unique teaching strategies and materials to introduce science and technology in education systems.

Prepared under an IAEA technical cooperation project, the Compendium was developed with technical input from experts in Australia, Finland, India, Israel, Japan, the Republic of Korea, the United Kingdom and the United States. The projects involved putting together a collection of extracurricular programmes and activities for secondary school teachers and students aimed at increasing curiosity, awareness and knowledge among students.

The Compendium proposes nuclear topics for secondary education, while the modular nature of the materials allows teachers and students to choose activities that meet their specific needs.

The Compendium was launched in 2015 as a pilot in Indonesia, Malaysia, Philippines and the United Arab Emirates, with prospects of applying it in more countries, including Jordan, Sri Lanka and Thailand, at their request.

Next generation reactors: safe and economical tools for sustainable energy

By Matthew Fisher

"The concept of small modular reactors is that smaller units, modular construction, simplification of design and demonstrated safety are sought in order to add flexibility and make the investment decision easier."

— Francois Gauché, Nuclear Energy Director, French Atomic Energy Commission

The nuclear industry could benefit from a new generation of reactors designed to create inherently safer and more efficient nuclear power plants. These reactors may contribute to the development of more sustainable nuclear energy and may also be used in a variety of industrial applications.

Advanced reactors with unique performance and safety features

The next generation of reactors are made to meet several benchmarks in performance, safety and reliability. Small modular reactors (SMRs), for example, are advanced reactors that can generate up to 300 MW of electricity and whose parts can be transported to installation sites as prefabricated modules.

"Thanks to their prefab construction model and their smaller size, the capital cost is lower for SMRs than for the typical large reactors currently under construction or in operation," said Stefano Monti, Section Head for Nuclear Power Technology Development at the IAEA. "The construction period is also expected to be shorter as the modules are prefabricated and then brought to the installation site for construction. SMRs are also inherently much less prone to severe accidents, as they are designed to have reduced core damage frequency."

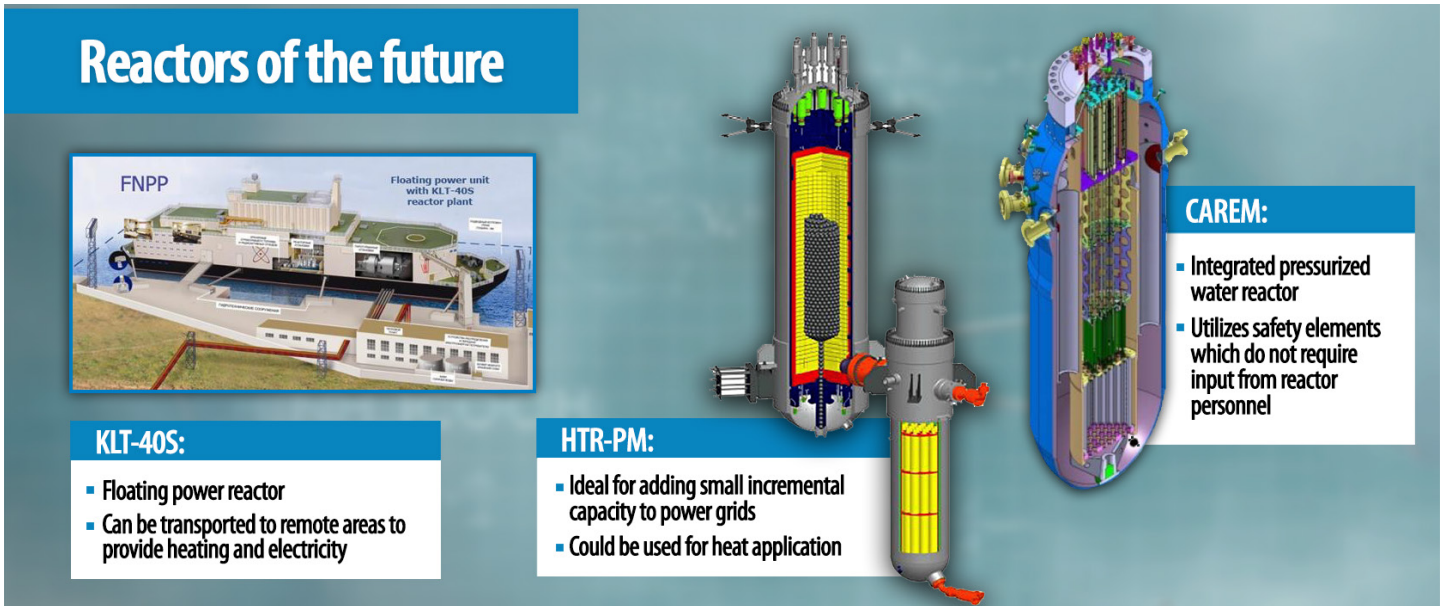
With these advanced reactor designs comes the possibility of an expanded role for nuclear energy. So far, nuclear energy has primarily been used for electricity generation, but there is a wide variety of other, non-electric applications for which the new generation of reactors could be well suited.

"The benefits of nuclear energy should not be limited to electricity production, but should also target other applications, such as heat production," said Francois Gauché, Chair of the Gen IV International Forum Policy Group and Nuclear Energy Director at the French Alternative Energies and Atomic Energy Commission. "The concept of small modular reactors is that smaller units, modular construction, simplified design and demonstrated safety are sought in order to add flexibility and make the investment decision easier."

Several countries are in the process of developing and designing the next generation of reactors, and construction has already begun on four SMRs in Argentina, China and Russia.

Innovative reactors for sustainable energy

The most advanced gas-cooled reactor to date, the High Temperature Reactor-Pebble-bed Module (HTR-PM), is currently



(Infographic: F. Nassif/IAEA)

under construction in China. This modular reactor is designed to optimize energy efficiency and is ideal for adding small incremental capacity to power grids, said Yuliang Sun, Deputy Director and Deputy Chief Engineer at Tsinghua University's Institute of Nuclear and New Energy Technology. This reactor type is also well suited for the application of power and heat co-generation, in particular for heat application at higher temperature levels.

An integrated pressurized water reactor (PWR), the CAREM, is in the works in Argentina. It is scheduled to come online by the end of 2018. The design of this SMR incorporates safety elements which do not require input from reactor personnel, including the capability to automatically shut down if a problem with the reactor is detected.

A very particular case is KLT-40S, a floating power reactor under construction in Russia. This reactor type has potential applications in heating and electricity and in power supply to isolated consumers in remote areas. The RITM-200, also under construction in Russia, is intended for marine propulsion of an icebreaker ship, but it can also be used as a land-based or barge-mounted SMR for heat and electricity.

Fast reactors for more efficient nuclear energy

Fast reactors are designed to produce as much as 60 to 70 times more energy from uranium than the current generation of thermal reactors. By recycling spent fuel and utilizing "fast" neutrons (neutrons produced by fission which are not slowed down by a moderator), these reactors are highly efficient, produce far less nuclear waste, and may have great potential for non-electrical applications of nuclear energy, particularly for industrial processes.

The only fast reactor currently used in commercial operation is the Russia BN-800 reactor. Connected to the grid in December 2015, it runs on mixed oxide fuel and has advanced safety characteristics. The BN-800 is also highly fuel efficient.

"The BN-800 reactor is another step towards a full commercialization of fast reactors, which will be able to compete with PWRs on cost," said Vyacheslav Pershukov, Deputy Director General at Rosatom.

WOMEN IN NUCLEAR

Patricia Paviet

Director, Office of Materials and Chemical Technologies, US Department of Energy

Dr. Paviet oversees R&D activities related to the back-end of the nuclear fuel cycle, which include material recovery and waste-form development, material protection, accountability and control technologies. Prior to joining the US Department of Energy, she was the Deputy Director of the Institute of Nuclear Energy Science and Technology for fuel cycle research and education at the Idaho National Laboratory, where she was responsible for strengthening and expanding the university's partnerships to areas such as actinide science, separations, safeguards and instrumentation. Dr. Paviet is the Chair of the Gen IV International Forum - Education and Training Task Force.

"The future vigour, prosperity and sustainability of the nuclear fuel cycle depend on the formation of specialized nuclear engineers, scientists and radiochemists. New ideas and innovative solutions will be needed as well. Education and training should be priorities, not only to respond to the challenge of maintaining a strong well-educated workforce, but also to meet the projected growth in this field."

The IAEA has been supporting the progress of these innovative technologies, in particular by hosting a series of conferences on new reactor technologies for sustainable development. In June 2017, the IAEA held the third iteration of the International Conference on Fast Reactors and Related Fuel Cycles in Yekaterinburg, Russia. These events bring together a wide range of professionals in this field to discuss how best to apply new reactor designs to providing clean and sustainable energy.

New designs that help overcome challenges

Though SMRs may provide numerous benefits, there are still some challenges associated with their implementation. "As advanced SMRs have yet to be deployed, a regulatory infrastructure for these reactors has yet to be consolidated," Monti said. "Another challenge is to have a single control room for all modules in an SMR facility. This has not been done before, and if successful, could help streamline reactor operations." He added that though licensing of SMRs could take longer initially, this process should be sped up considerably once a regulatory framework is well established.

The seven secrets to cheap nuclear energy

By Michael Shellenberger

Michael Shellenberger is President of Environmental Progress, an independent research and policy organization based in Berkeley, California, USA. This article is drawn from its new report, "Seven Secrets to Cheap Nuclear Energy."

Energy ministers and other policymakers often face a bewildering array of sales pitches from nuclear plant promoters, which has resulted in many countries making poor decisions, leading to long construction delays and large cost overruns in the United States, Finland, France, China, India and the United Kingdom, among others.

The good news is that there is overwhelming consensus among economists and energy experts about what it takes to make nuclear energy competitive. This consensus draws on construction and operation cost data from countries around the world over a period of more than 40 years.

Build national consensus around a long-term energy plan. Successful nuclear programmes require *decades,* not just a few years. This means they must enjoy strong national support across the political spectrum, so that nuclear plant construction is not interrupted by changes of government on the way to a country's goal of achieving 20, 40 or even 80 percent of its electricity from nuclear. Building that consensus requires establishing the *need* for nuclear energy for economic, security and environmental reasons. There also needs to be consensus around the relative safety of nuclear, since this is the top concern for all parties.

Engage the public. Like all technologies, nuclear energy must have popular support to survive and thrive. Most people, whether in developed or developing countries, know little about energy and are wary of nuclear despite the fact that it is the safest way to produce electricity. Public engagement is therefore not optional, but essential. Engagement efforts must be science based, informed by the best psychological, sociological and public opinion research available.

Standardize to a single design. What France and South Korea have proven is that for construction crews to reduce the time and cost of building reactors and power plants, they must gain experience — which only comes from repetition. While modest changes can be made to designs — such as moving to a larger reactor, or adding safety features — the core design must be the same.

Centralize construction with a single, experienced builder. A single person must have the authority to oversee all aspects of construction in a single institution. This person should have experience and the trust of policymakers, must be held accountable, and in turn, should have the authority to hold everyone involved in the project accountable. All parties must also be held accountable in order to control costs.

Civeaux nuclear power plant, France
(Photo: EDF)

Experienced managers overlooking the construction of multi-unit Shin-Kori nuclear power plant.
(Photo: M. Shellenberger)

Build as big as possible. Despite some recent enthusiasm for smaller plant designs, evidence shows that nuclear plants with higher output produce cheaper electricity than ones with lower output. This is mostly because the additional workers required to produce power from bigger reactors are outweighed by the higher output. This rule holds true even when larger reactors modestly increase the cost of construction — the higher output simply makes up for the higher building cost. Smaller plants may be more appropriate for smaller countries or those with lower electricity demand. But if these plants are pursued, buyer countries must understand they will come at the price of higher operating costs per unit of electricity produced.

Fix the price, and don't allow changes during construction. The key to low-cost construction is low risk — not the estimated total cost. It is better for countries to go with a slightly more expensive builder who has significantly more experience — and who agrees to a fixed price in exchange for a no-changes rule — than one who offers a lower price at a "cost-plus" basis. The key is to avoid disputes between buyer and builder since it is ultimately impossible to resolve who is right and who is wrong, and the construction delays will only hurt everyone. For this to work, transparency is required: the buyer must be able to check the books of the vendor.

Finance with low-cost loans. Some of the highest costs that result from construction delays are simply paying the interest on loans. Avoiding high costs requires both avoiding delays and low-interest financing, whether from the government, the ratepayers (in the form of a fee on electric bills), or an international development bank. The riskiest phase of the project is in the planning, with risk decreasing once construction has begun. Buyer countries should, therefore, have different financing for different phases.

These are the only seven secrets for cheap nuclear energy for which strong, supportive data is available. While nuclear plant promoters may talk about other elements, such as recycling the fuel, manufacturing more of the plant in factories and using non-light water designs, the advantage these bring is not at all clear cut.

Nuclear energy is facing significant challenges, but it can still achieve its goal of providing a growing share of cheap and clean electricity to the world.

Innovation in nuclear is key for a sustainable energy future

By William D. Magwood, IV

William D. Magwood, IV is the Director General of the OECD Nuclear Energy Agency (NEA).

For most countries, a successful energy policy is one that fulfils the three pillars of sustainability — security of supply, environmental protection and affordability. In the rapidly evolving electricity market, the value of nuclear power to the energy mix will depend on its capacity to meet current and future energy needs — as reflected by these three pillars. It is evident that meeting these expectations will require innovation in nuclear technology.

Nuclear power plants provide reliable dispatchable power generation that is transmitted as needed by electricity grid operators day and night, all year around, and in all weather conditions. Moreover, nuclear power plants are deployable on a large scale to meet the expected increase in demand for carbon-neutral electricity. It is likely that with the share of variable renewable energy increasing substantially, nuclear generation will need to be flexible beyond its traditional baseload operation mode. Increased flexibility will imply a need for optimization and innovation in areas such as: reactor and fuel designs; enhanced load-following capacity of nuclear reactors; the deployment of small modular reactors (SMRs); and the development of co-generation strategies that can provide additional demand and revenue streams to plant operators.

While there is general consensus that nuclear is a clean, low-carbon technology that can address environmental concerns, its ability to adapt to today's very challenging market conditions is in question. Such market conditions include a decrease in the costs of renewable energy coupled with very favourable government policies and subsidies towards renewables, as well as a growing share of non-conventional sources of fossil fuels such as shale gas without carbon pricing in the market. Because electricity markets are not structured to reflect these changes in technology and policy, these factors reduce the profitability of many existing baseload electricity plants, particularly nuclear power plants. To be sustainable, the electricity markets must be modernized to ensure long-term reliability; but whatever path the future takes, nuclear power's future will require innovation to decrease the overall cost of generation while maintaining high levels of nuclear safety.

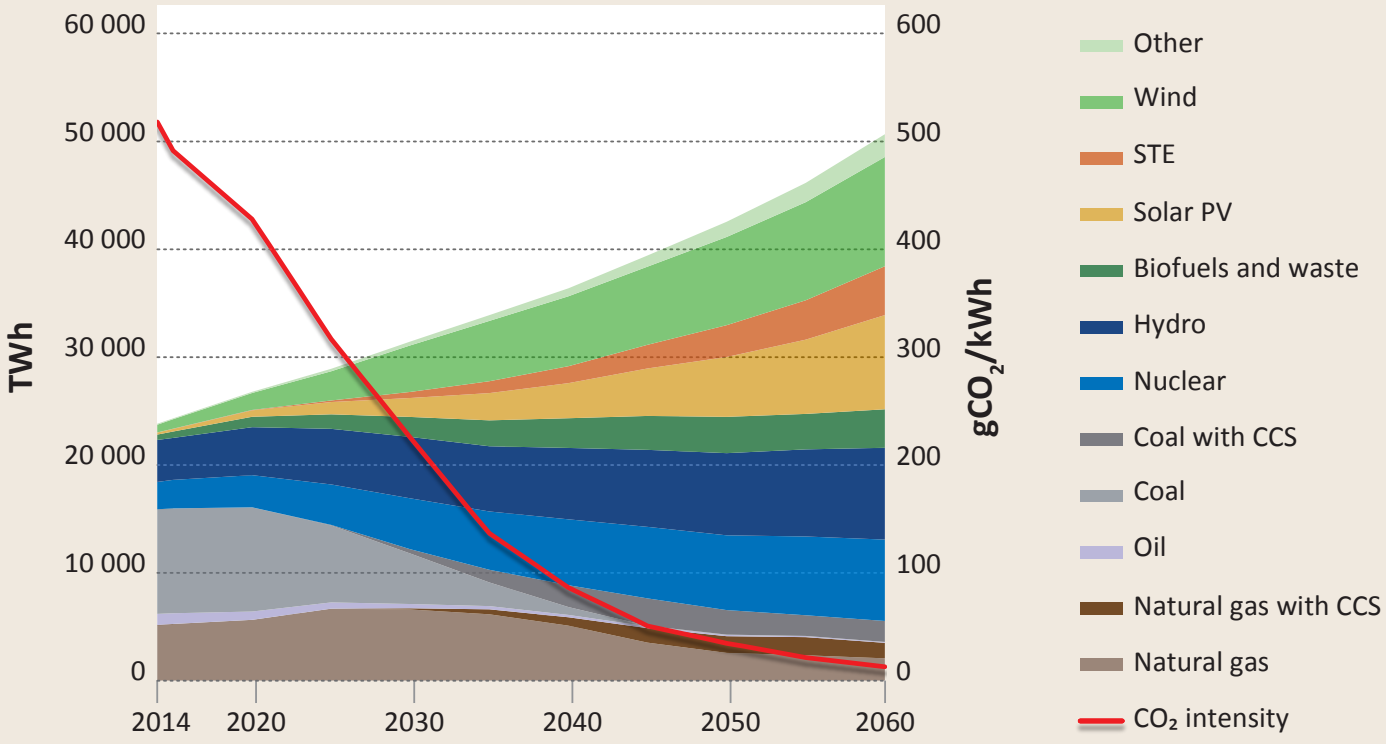
The importance of international cooperation

The Nuclear Energy Agency (NEA) launched the "Nuclear Innovation 2050" (NI2050) initiative to encourage new cooperative approaches among countries for the purpose of furthering research and the deployment of innovative nuclear technologies that contribute to a sustainable energy mix. This goal is also supported by other NEA initiatives, such as an ongoing study on advanced reactor systems as well as work jointly carried out with the International Energy Agency (IEA) on the electricity market.

The core of NI2050's approach is to apply multilateral strategies to support more effective deployment of innovative nuclear technologies. Multilateral approaches can create the confidence needed for the worldwide deployment of innovative technologies through the identification of priorities, the establishment of solid common foundations based on scientific validation of technologies and the definition of shared qualification methods to support robust licensing processes.

Because safety is a priority to be "built in" at the early design stages of any technological evolution, some level of interaction with authorities and regulators is necessary. International collaboration among safety bodies is probably one of the most effective ways to get early insight into the safety aspects of any innovation without compromising regulatory independence. The NEA already offers such a framework by providing a broad platform for discussion through its various specialized committees. NI2050 has now selected a set of topical areas to develop "10-year programmes of action" on accident-tolerant fuels, severe accident knowledge management, passive safety systems, the management of ageing

Global electricity generation by source



(Data from Energy Technology Perspectives 2017*, International Energy Agency)*

Today one third of generated electricity comes from low-carbon sources. If global targets for CO_2 emissions are met, this share would increase to nearly 85 % by mid-century.

Source: NEA

structures, advanced fuels and materials, advanced components, fuel cycle chemistry/recycling, heat production and cogeneration, modelling and simulation, digitalization and measurements, infrastructures and demonstrations. By gathering stakeholders around shared priorities, NI2050 could trigger innovation in nuclear technology, which is the most important condition for nuclear energy to play a role in the sustainable energy mix of the future.

Many countries are faced with the challenge of simultaneously dealing with an electricity market growing in complexity, increasing demand for electricity and the need to establish national policies to reduce carbon emissions. Without sufficient innovation capacities, countries using nuclear technology may be forced to rely on more technologically innovative countries, with implications regarding their sovereignty in the energy field. For this reason, governments need to pay close attention to the overall strategic dimension of nuclear power beyond the economic and environmental dimensions.

Innovation in nuclear technology today requires increased involvement and cooperation among countries and actors in the nuclear sector to harness collective skills and means, to create sound and robust confidence in new technologies, to open the international market and to attract investment.

Harmony — the future of electricity

By Agneta Rising

Agneta Rising is the Director General of the World Nuclear Association.

The World Nuclear Association's Harmony programme sets out the global nuclear industry's vision for the future of electricity. It aims to help the world meet the energy challenges arising from the increase in demand for electricity and the need to reduce greenhouse gas emissions and air pollution. For this purpose, the nuclear industry has set the Harmony goal of 25 percent of global electricity in 2050 to be provided by nuclear energy. This will require the construction of approximately 1000 GWe of new nuclear capacity.

The Harmony goal is based on the International Energy Agency's 2 degree scenario, which aims to avoid the most damaging consequences of climate change and, thus, requires a large increase in the production of nuclear energy. To meet this goal, Harmony envisages a mix of low-carbon generating technologies working together.

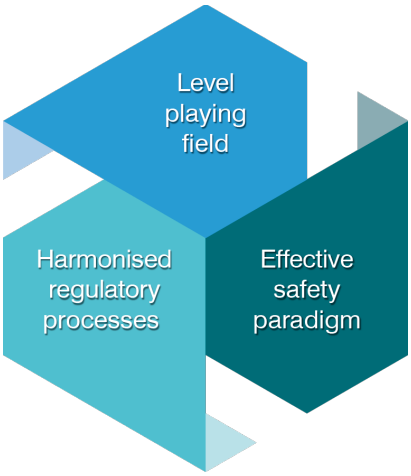
Governments' current Intended Nationally Determined Contributions — the climate actions that countries declared they would take under the Paris Agreement to curb greenhouse gas emissions — fall significantly short of the 2 degree target, let alone the aim of reaching 1.5 degrees. The current plan to address climate change is, therefore, not on track, and urgent additional action is needed to reduce emissions. However, achieving the Harmony goal will only be possible if the following objectives are met.

Level playing field

Nuclear is a proven source of reliable, clean, baseload power with significant benefits. However, nuclear power plants are facing financial challenges, resulting in early closures of plants that were performing well operationally and limited investment in new ones. A combination of factors, including subsidies and priority of dispatch for renewable energy, has led to market failure for nuclear power.

The Harmony objective is to support the establishment of a level playing field in energy markets that recognizes existing low-carbon energy resources already in place and drives investment in additional clean energy resources where nuclear energy is treated on an equal level with other low-carbon technologies and is recognized for its values in a reliable low-carbon energy mix. As the only low-carbon generating resource that can be scaled to meet actual demand, nuclear power should also receive recognition and compensation for its contribution to system reliability and for other public benefits.

Harmony goal: ready to deliver more nuclear to ensure the 2 degree scenario

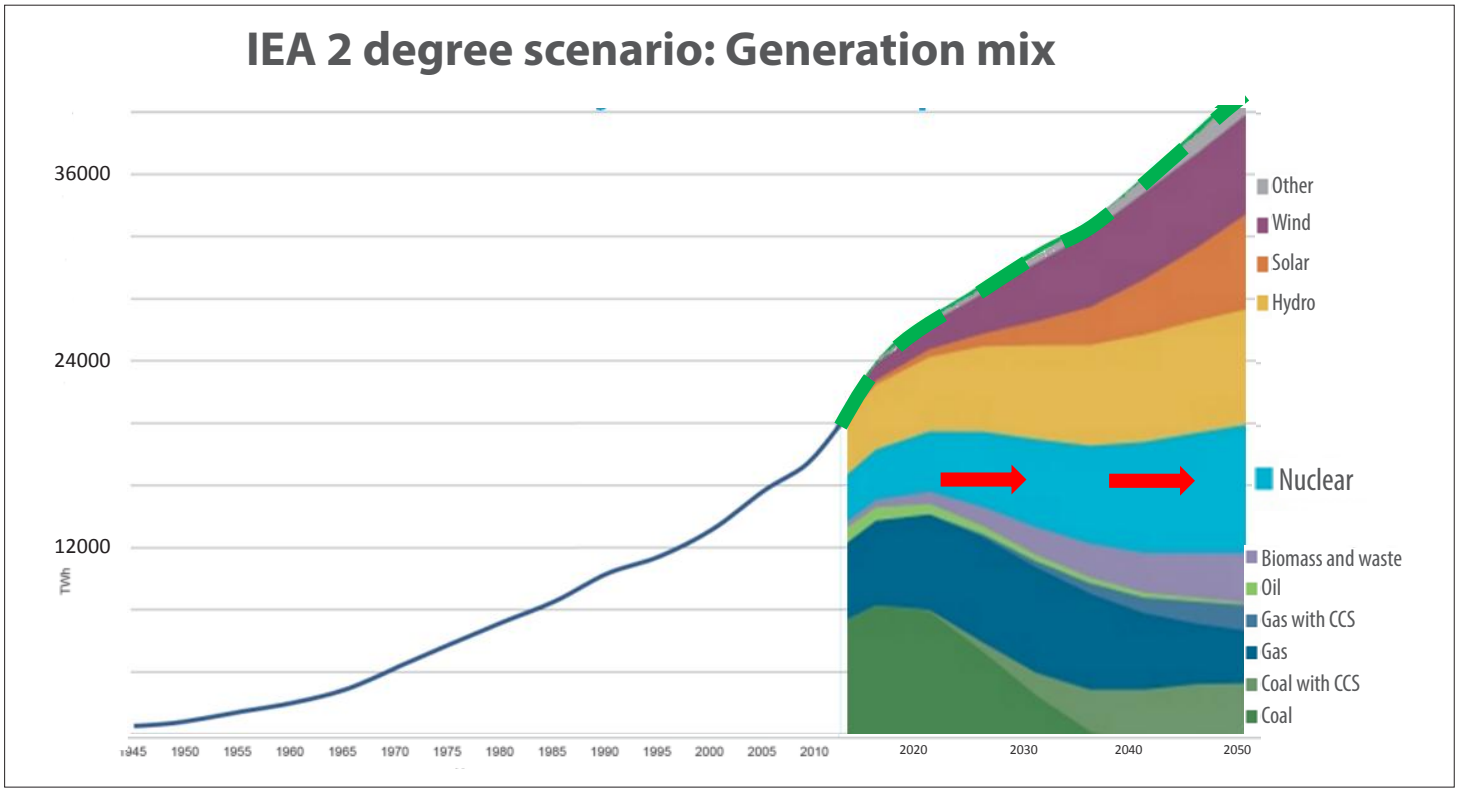


1000 gigawatt new nuclear capacity by 2050

25% of electricity supply 2050

Nuclear energy to deliver reliable, affordable and clean electricity

Source: WNA



Source: 1945-1979, International Energy Agency databases and analysis; 1980-1912, Energy Information Administration

Harmonized regulatory processes

Nuclear safety is a national responsibility, and this has led to significant differences in licencing arrangements, with each State developing its own regulatory framework, licencing process and safety requirements. While there is a globalized market for new nuclear projects and supply chain, this internationalization has not spread to regulation and licencing. The harmonization of regulatory processes, safety requirements and codes and standards would result in significant benefits for improved new build investment, project delivery, reduced costs, accelerated innovation and increased safety.

Harmony aims to promote harmonized regulatory processes to provide a more internationally consistent, efficient and predictable nuclear licencing regime that allows for standardized solutions to facilitate significant growth of nuclear capacity, without compromising safety and security.

Effective safety paradigm

Despite nuclear energy's good safety record, a lack of public confidence and trust in some countries is restricting its development. Nuclear energy has one of the lowest overall impacts on human health and the environment, but this is not reflected in public understanding. Therefore, we need to create an effective safety paradigm that focuses on genuine public well-being, where the health, environmental and safety risks and benefits of nuclear are recognized and assessed objectively alongside those of other power generation technologies.

The need for action

While the Harmony goal is ambitious, it is achievable. In order for nuclear energy to reach the Harmony goal and to support the world in meeting its 2 degree target, a rapid ramp-up of new nuclear builds to an annual connection rate of 33 GWe within the next decade is required, which is comparable to the rate achieved in the 1980s. The main challenges are not in the production — although significant strengthening and building of capability would be required — but in securing the necessary policy support and building confidence.

The World Nuclear Association's Harmony programme is a cooperative effort by the whole nuclear community, working with key stakeholders to take the action necessary for nuclear energy to be able to play its crucial part in meeting the global energy challenge.

Revamping food safety in Costa Rica with nuclear technology

Costa Rica no longer depends on laboratories abroad to guarantee food safety and to stay competitive thanks, in part, to nuclear technology and to the support of the IAEA and the Food and Agriculture Organization of the United Nations (FAO).

"We analyse 310 samples a month, 25 percent more than we did two years ago," said Yajaira Salazar, food safety expert at Costa Rica's National Laboratory for Diagnosis and Research in Animal Health (LANASEVE). Salazar and her colleagues have participated in several IAEA training courses and fellowships and can now perform marine biotoxin analysis and quality management, among others.

Pesticides, veterinary drug residues, heavy metals, marine biotoxins, and other organic and inorganic pollutants can all contaminate our food. "To detect these, Costa Rica needs the finest, newest technology manned by well-trained personnel," said Marietta Ureña Brenes, Director of LANASEVE. "We need to stay ahead of the game."

Since 2015, LANASEVE's experts have been learning the latest nuclear and conventional analytical technology to detect contaminants and residues in food, receiving state-of-the-art equipment and expertise through an IAEA technical cooperation project. This food safety facelift has helped Costa Rica's consumers, producers and exporters alike.

Fish & cows

To Costa Rican fish producers, sending samples for analysis to LANASEVE instead of abroad means less money and a shorter turnaround time. While they used to send almost 200 samples a year to laboratories in Ecuador and Chile to check for suspicious harmful substances and comply with EU rules, now LANASEVE analyses these in Heredia north of San José, saving each producer at least EUR 27 000 per year. Meat producers are also benefiting from these new analytical services. CIISA, a Costa Rican company that sells beef and pork in the country, the USA, Russia and Europe, among others, also depends on LANASEVE's precise nuclear and isotopic analytical technology to ensure its products are innocuous and meet market requirements.

LANASEVE's enhanced capacity to monitor veterinary drug residues and related contaminants in animal products using nuclear or isotopic techniques has not only boosted the country's ability to maintain its food export markets to the EU, the USA and other Latin American countries, but also assisted in capturing newer markers such as China.

International standards

Having the capacity to ensure food safety locally is a game changer for exporters, too. Besides affecting public health, food contamination can have a devastating economic impact on international trade.

"Globally, technology is getting better at detecting very small traces of residues in food," said Mauricio González, another food safety expert at LANASEVE who has also been trained through the IAEA's technical cooperation programme. "Which is a good thing for consumers, but which means that codes are getting stricter for exporters." With today's rapidly evolving international food safety laws, Costa Rica has had to adapt.

Using the newly learnt nuclear analytical techniques and equipment, experts at LANASEVE can detect very small traces of contaminants, medicine residue and pesticides in food samples, meeting international requirements. "The more sensitive the equipment, the better we can guarantee the absence of any unwanted products in our food," González said.

The new capacities have also helped LANASEVE open up to other areas, such as analysing a wider variety of animal products and imported food. Thanks to the nuclear techniques, for example, the team at LANASEVE detected malachite green, a dye that is both potentially carcinogenic and could damage the DNA, in imported fish products. After these findings, Costa Rica stopped imports from these providers. Examples like these demonstrate why it is necessary to build national laboratory food-testing capabilities, said James Jacob Sasanya, food safety specialist at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

"Costa Rica has always made efforts to protect public health," said Bernardo Jaén Hernández, Director General of Costa Rica's National Animal Health Service (SENASA), which LANASEVE is part of. "And to protect public health you need to have strong capacities in place to check what the country is producing, exporting and even importing."

A new IAEA technical cooperation project will support LANASEVE in further improving its technical and analytical capabilities, said Raquel Scamilla Aledo, manager of these projects at the IAEA. "As one of its national development priorities, Costa Rica has asked for more support in analysing marine biotoxins, pesticides and veterinary drugs that are not included in its current range of tests," she said. "It also aims to increase laboratory services to meet new European Union and other food export market regulations."

Jointly with the FAO, the IAEA assists countries in adopting nuclear and related techniques that provide a science-based solution to regulating food safety — making analytical methods available in laboratories worldwide. This also includes food irradiation, analysis of various food and environmental contaminants as well as food authenticity.

— By Laura Gil

Supporting nuclear non-proliferation: Ghana converts research reactor from HEU to LEU fuel

Ghana has successfully completed the conversion of its only research reactor from the use of high enriched uranium (HEU) fuel to low enriched uranium (LEU) fuel, in an international project supported by the IAEA to help decrease the proliferation risks associated with HEU fuel.

HEU is an ingredient that can be used to create a nuclear device intended for malicious use, and since 1978 various national and international activities have been underway to convert research and test reactors from the use of HEU to LEU fuel, with the aim of minimizing and eventually eliminating the civilian use of HEU.

The HEU fuel was repatriated to China

The three-year project, which was a joint undertaking of the Ghana Atomic Energy Commission (GAEC), the China Atomic Energy Authority (CAEA), the US Department of Energy's National Nuclear Security Administration (DOE/NNSA) and the IAEA, was completed last week. Ghana has become the first of the five countries operating a Chinese-supplied Miniature Neutron Source Reactor (MNSR) to successfully convert and repatriate its irradiated HEU core to China.

"With this pioneer engagement Ghana demonstrated the feasibility of the MNSR conversion outside China," said Kwame I. J. Aboh, Project Manager at GAEC. "We hope our model of conversion and repatriation can be applied in similar operations in other countries operating such facilities."

The conversion from HEU to LEU reduces the enrichment level from over 90 percent uranium to below 20 percent, without affecting the reactor's research capabilities. Therefore, GAEC is still able to maintain its scientific research, education, training and industrial applications based on nuclear facilities following the conversion.

"Ensuring the sustainability of MNSR operation with a LEU core was a key success factor of this project," said Christophe Xerri, Director of the IAEA Division of Nuclear Fuel Cycle and Waste Technology. "This experience offers a good example of international cooperation to foster nuclear science and practical training while addressing non-proliferation concerns and delivering capacity building."

To ensure successful knowledge transfer for future conversion projects, a mock-up MNSR vessel was built for operator training at the GHARR-1 facility. This has since been further developed into a full-scale MNSR Core Removal Training Centre (CRTC), available for training operators from other MNSR countries. "The National Nuclear Security Administration is a strong supporter of the CRTC concept," said Dave Huizenga, Acting Deputy Administrator of Defense Nuclear Non-proliferation at NNSA. "This helps harness experience gained from the pilot project in Ghana and offers full-scale training possibilities for the MNSR operators facing similar challenges in the future."

Two meetings were held in the summer of 2017 to capture lessons learned from the implementation of the project – which could benefit other reactors looking to convert to LEU fuel. "Outcomes of these meetings will build up the Ghana model and support similar operations in the future," said Lixin Shen, Deputy Director General of China Atomic Energy Authority.

Chinese-designed MNSRs

MNSR type research reactors were designed and manufactured by the China Institute of Atomic Energy, and the original design had a compact core with 30 kW thermal powers, containing about 1 kg of 90 percent enriched HEU.

Nine Chinese-designed MNSR facilities exist: four in China – one of which has been converted to LEU fuel – and one each in Ghana, Iran, Nigeria, Pakistan and Syria. They are used primarily for education and training purposes.

Upon the commitment of the Chinese Government, the China Atomic Energy Authority undertook the responsibility of MNSR conversion first for the prototype MNSR in China, and then worked with GAEC to complete the conversion of GHARR-1 and take back the HEU.

IAEA assistance

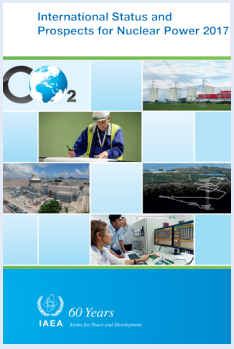
The IAEA's cooperation with the MNSR community began in 2006 with a coordinated research project to determine the technical feasibility of converting them to LEU fuel.

Upon request from Ghana in 2014 for assistance in securing a LEU core for the country's GHARR-1 facility, the IAEA's Research Reactor Section provided support for the conversion and removal, carried out review missions at the GHARR-1 research reactor focusing on safety, offered regulator training on cask licencing and held workshops on transport security.

Nigeria and Syria have also requested IAEA assistance for conversion and HEU core removal. The Nigerian project is scheduled to be accomplished in 2018.

In Beijing, where the HEU fuel has just arrived, Mary-Alice Hayward, IAEA Deputy Director General, head of the Management Department, represented the Agency at HEU return event that the Chinese authorities organised today. She stated that "The IAEA was pleased to support our Member States with the conversion of Ghana's MNSR and the return of its HEU fuel to China. This project represents a significant milestone in the broader endeavour to minimize the use of HEU in civilian facilities while ensuring continued access to nuclear research and training capabilities."

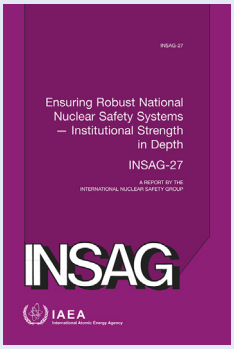
— By Sandor Tozser



International Status and Prospects for Nuclear Power 2017

analyses the factors which could influence the future of nuclear power, such as funding and financing, electricity markets and public acceptance. It states that if nuclear power's potential as a low-carbon energy source grows in recognition and advanced reactor designs further improve both safety and radioactive waste management, the use of nuclear power could grow significantly.

https://www.iaea.org/About/Policy/GC/GC61/GC61InfDocuments/English/gc61inf-8_en.pdf

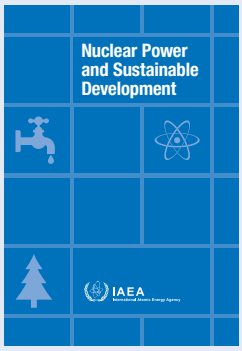


Ensuring Robust National Nuclear Safety Systems — Institutional Strength in Depth

is intended to provide a philosophy to guide the thinking about the institutional structures necessary to assure nuclear safety. It refers to the three important institutional subsystems – the industry regulator and stakeholders – and describes the interfaces that should be nurtured among these as well as within each subsystem. The publication is intended to serve as a fundamental tool in the continuing efforts to strengthen nuclear safety.

INSAG Series No. 27; ISBN: 978-92-0-102317-9; English Edition; 24.00 euro; 2017

http://www-pub.iaea.org/books/iaeabooks/11148/National-Nuclear-Safety-Systems

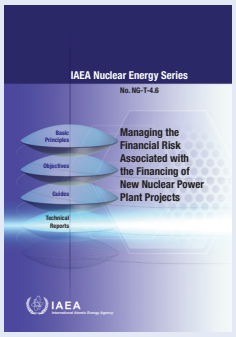


Nuclear Power and Sustainable Development

explores the possible contribution of nuclear energy to addressing the issues of sustainable development through a large selection of indicators. It reviews the characteristics of nuclear power in comparison with alternative sources of electricity supply, according to economic, social and environmental pillars of sustainability. The findings summarized in this publication will help the reader to consider, or reconsider, the contribution that can be made by the development and operation of nuclear power plants in contributing to more sustainable energy systems.

Non-serial Publications; ISBN:978-92-0-107016-6; English Edition; 45.00 euro; 2016

http://www-pub.iaea.org/books/IAEABooks/11084/Sustainable-Development



Managing the Financial Risk Associated with the Financing of New Nuclear Power Plant Projects

emphasizes how various risks — including those typically considered to be 'engineering risks' — will give rise to financial risks. It then introduces the linkage between efficient financial risk allocation/mitigation and the cost of capital, and sets out a range of mechanisms which can be used to manage and allocate risks efficiently, thereby minimizing the cost of capital and enhancing project economics. At a practical level the publication provides an insight into the concerns, modes of thinking and language which a nuclear new-build proponent may expect to encounter within the financing community as they seek to develop their project.

IAEA Nuclear Energy Series No. NG-T-4.6; ISBN:978-92-0-100317-1; English Edition; 32.00 euro; 2017

http://www-pub.iaea.org/books/IAEABooks/11140/Financial-Risk

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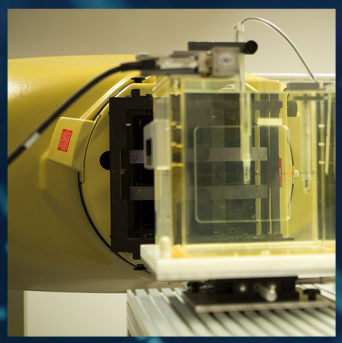

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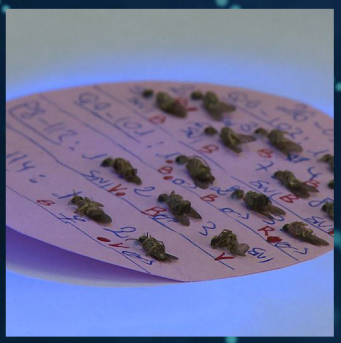

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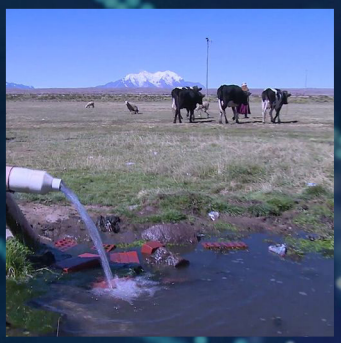

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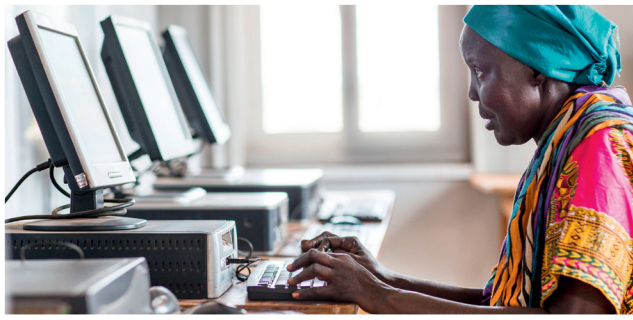

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