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Nuclear Power:
its role in shaping energy policies in Asia Pacific

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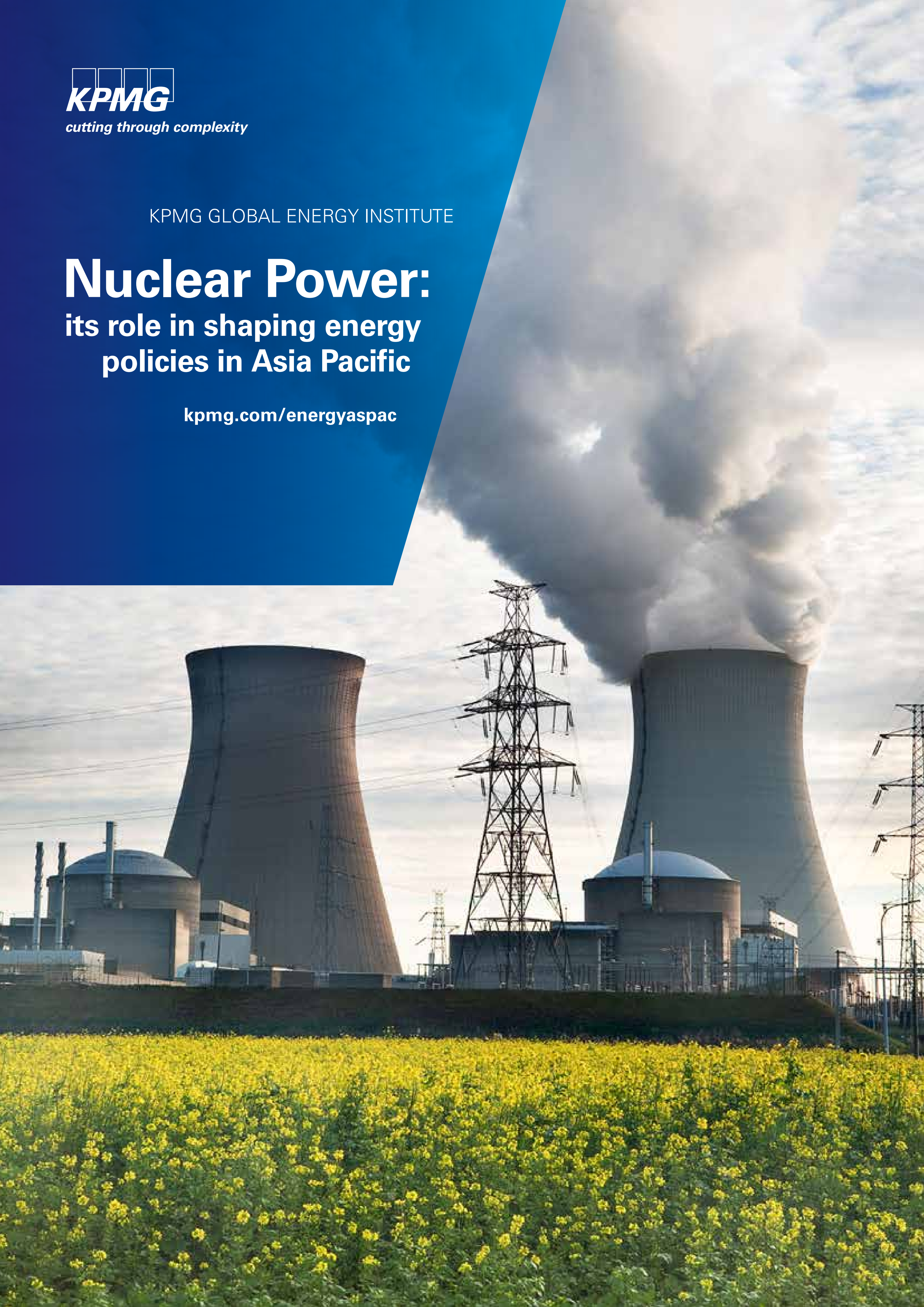

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FOREWORD

The World Energy Outlook 2013 by the International Energy Agency (IEA) presents the view that by 2035 global energy demand will grow by one-third from 2011. The demand from emerging countries will account for more than 90 percent of this growth.

While China has been leading energy demand growth for the last decade, the Outlook predicts that demand will shift towards India and Southeast Asia after 2025.

Without doubt, Asia is leading global energy growth. While China, India and ASEAN countries are trying to secure energy, Japan and Korea are facing increasing competition from them and others. To ensure that they have adequate energy to sustain national growth for the future, the significance of each country's energy policy, which dictates a nation's energy mix, is greater than ever.

In addition to growing energy demand, the world is also challenged by the necessity to secure power affordability and to act against the effects of climate change. To achieve these mid-to-long-term objectives, there is no surprise that many countries still see nuclear power generation as key part of their energy mix. Many important challenges remain in safety and economic viability.

This report provides an overview of the current Asian nuclear power market, noting growing demands for nuclear power in the region. It also focuses on two of the major challenges for those considering nuclear power development: safety and finance.

To provide insights for Asian countries which plan to construct nuclear power reactors in the near future, our report outlines the United Kingdom's (UK) new nuclear program; particularly focusing on assuring operational safety and organizational governance. This approach reflects the lessons learnt from the Fukushima accident and the process of securing funding for construction.

Key authors of this report include Vicky Parker and Darryl Murphy, both partners in KPMG in the UK who are deeply involved in the UK Government's design of policies around the nation's new nuclear. Other major contributors to this report are Tim Rockell, director of the KPMG Global Energy Institute in Asia Pacific and Dr Glenn George, principal in KPMG in the United States (US).

Also we would like to express our special thanks to Mr. Nobuo Tanaka, Global Associate for Energy Security and Sustainability, Institute of Energy Economics, Japan and former executive director of International Energy Agency for providing insights on lessons learned from Fukushima.

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Global context of nuclear power

The current global challenge to ensure long-term, sustainable access to secure, cost-effective and lower carbon power has provided fresh impetus to develop the global nuclear industry.

World energy consumption is expected to grow by 41 percent between 2012 and 2035, with around 95 percent of that coming from emerging economies, in particular China and India[1]. Nuclear power generation is effectively placed to meet this need as it is seen by many as the only readily available large-scale alternative to fossil fuels for production of continuous, reliable supplies of electricity.

The nuclear market is well established and accepted as a core element of the global energy mix, making up 4.5 percent of total energy consumption[1]. Within certain developed countries this is much higher, with nuclear power making up a significant proportion of the overall energy mix.

For example nuclear power accounts for 75 percent of the energy mix in France, 38 percent in Sweden, 30 percent in South Korea and 19 percent in the US[2].

The increasing attention on reducing carbon emissions has driven steady growth in investments in renewable power sources globally. However, concerns over intermittency and cost, as well as the challenge of identifying suitable land area have limited the impact on total energy consumption; in 2012, 4.7 percent of global power generation came from renewable sources[1].

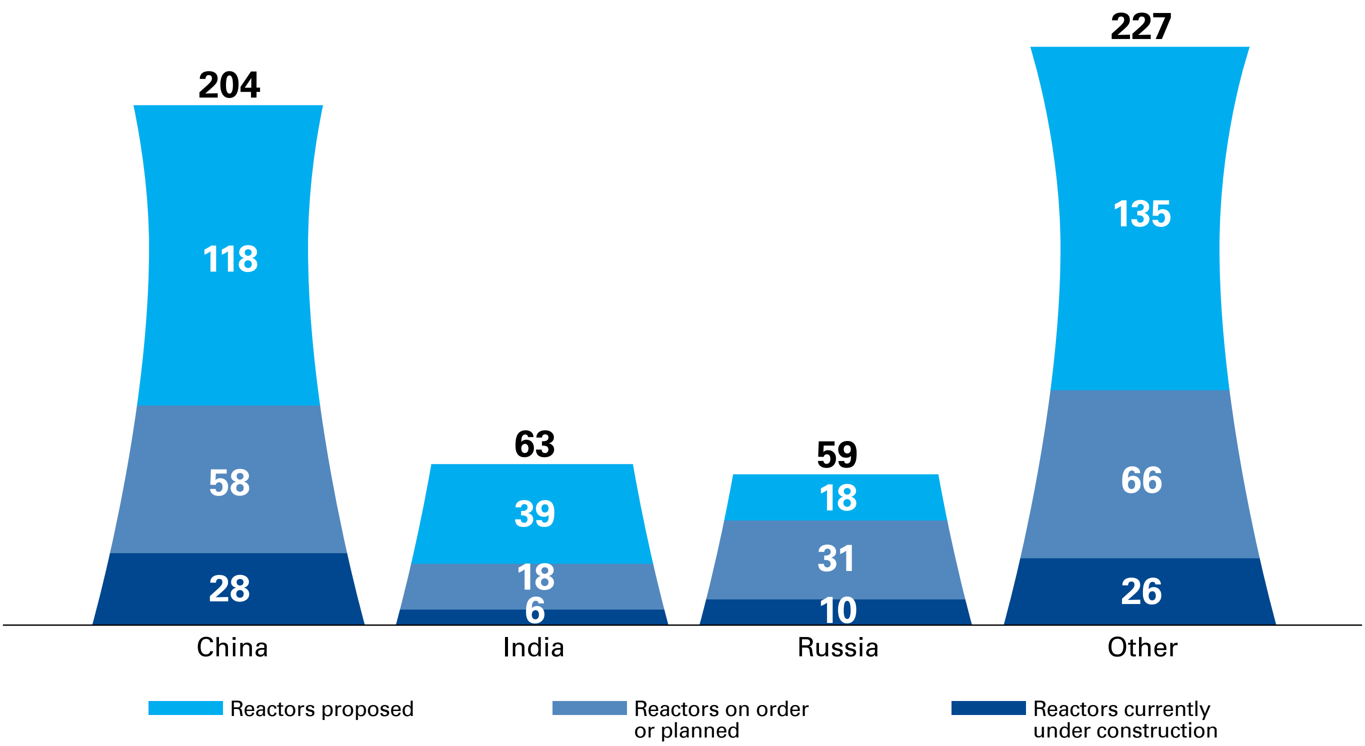
Shale gas has also made gas power generation attractive from an economic standpoint in certain regions, particularly in the US.

Suffering from relatively higher gas prices from the Middle East, countries in Asia, especially Japan at the moment, welcome lower priced gas from the US. However, longer term this presents the risk of overreliance on fossil fuel imports. Therefore, many countries continue to consider nuclear as part of a balanced energy mix which will support secure generation and provide flexibility to respond to changing economic and political circumstances.

As a result, more than 550 new reactors are expected to become operational globally by 2035[3]. Of these, there are very ambitious new build plans for China (204), India (63) and Russia (59), coupled with 18 countries embarking on new nuclear programs for the first time.

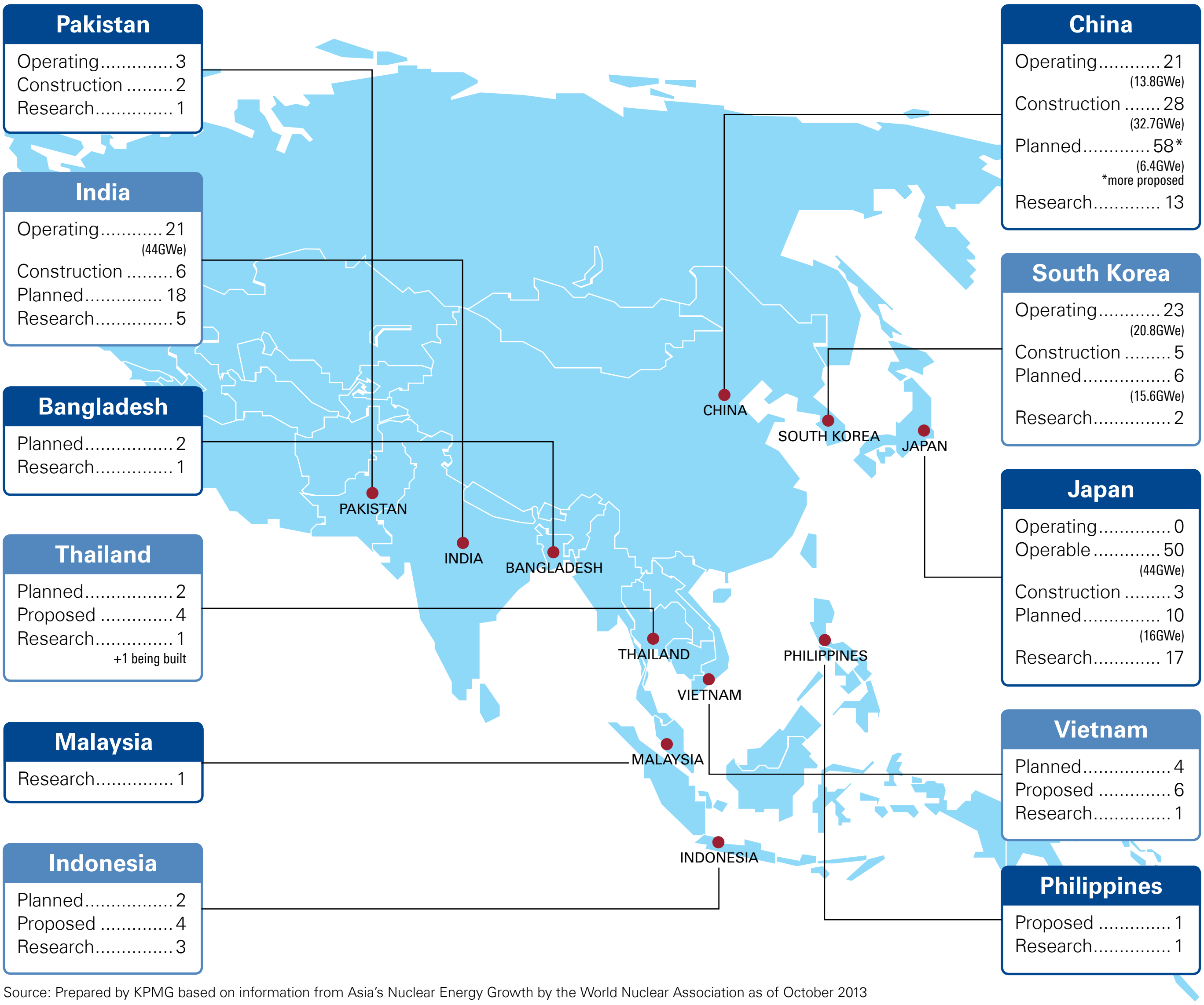
[1] BP: http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/Energy_Outlook_2035_booklet.pdf).
[2] IAEA Nuclear Share of Electricity Generation in 2012 -http://www.iaea.org/PRIS/WorldStatistics/NuclearShareofElectricityGeneration.aspx
[3] World Nuclear Association - http://world-nuclear.org/NuclearDatabase/Default.aspx?id=27232

Reactors planned or proposed to be operational by 2030[3]



Source: World Nuclear Association 2013 - http://world-nuclear.org/NuclearDatabase/Default.aspx?id=27232

Asian context of nuclear power



Source: Prepared by KPMG based on information from Asia's Nuclear Energy Growth by the World Nuclear Association as of October 2013

The existing 119 nuclear power reactors in Asia have a combined capacity of 85 gigawatt (GW) in 2012. A total of 331 terawatt hours (TWh) of electricity is generated by these facilities, down from 460 TWh in 2011.

This is due to a near 100 percent decrease of power generation in Japan's nuclear power plants which have been taken offline since the Fukushima accident in 2011. Despite Fukushima, the regional nuclear development trend seems less pronounced. Nuclear power is growing in traditional markets of China and India, and emerging in Southeast Asia – most notably in Vietnam, and also in Indonesia.

There are a total of 55 research reactors in 14 countries in Asia including eight countries (six are in Southeast Asia) that do not currently operate nuclear power on a commercial scale. Many of these started nuclear power research and development in collaboration with mainly Russian technical assistance, in response to the oil shocks of the 1970s.

Increasingly, nuclear power is being seriously considered in Southeast Asia where surging electricity demand, and fossil fuel prices driven by a growing population and economy have made nuclear a more realistic option. However, moving from research into commercial scale generation has proven to be a difficult process in the developing countries of Asia. These governments face protracted negotiations on financing especially with the newly added costs for safety measures after Fukushima.

Research Reactors and Fuel Cycle by Country in Asia	
Country	Stage(s) of Fuel Cycle
Australia	Mining
Bangladesh	Research*
China	Mining, conversion, enrichment, fuel fabrication
India	Mining, fuel fabrication, reprocessing, waste management
Indonesia	Fuel fabrication
Japan	Conversion, enrichment, fuel fabrication, reprocessing, waste management
Malaysia	Research*
Mongolia	Mining
North Korea	Conversion*, fuel fabrication*, reprocessing
South Korea	Conversion, fuel fabrication
Pakistan	Mining, enrichment, fuel fabrication
Philippines	Research*
Taiwan	Research*
Thailand	Research*
Vietnam	Mining*

* Limited information available
Source: International Energy Agency 2013

Economics and financing of new nuclear

There are currently two dominant methods (or a combination of these two methods) for financing nuclear new-build projects. The first is through government support, where the government provides the required financial resources, typically through a nationalized utility.

Alternatively, governments may use private sector financed method where a commercial entity or consortium of entities, funds the project using equity, corporate borrowing and government-provided state guarantees to underpin the project. The apportionment of financial risk among governments, operators and vendors typically represents a key area for negotiation and may pose a greater challenge than that of the technology itself.

The attractiveness of a new nuclear project, like any other major infrastructure investment, will be increased if it can be demonstrated that the nuclear plant has been properly established and resourced, has a sound business case, and that risks have been recognized and minimized.

Nuclear new build is characterized by significant risk, including upfront construction cost and time risk, potential decommissioning liabilities for an undefined period as well as political and regulatory risks. In addition, an initial new build program will be subject to "first of a kind" costs and must provide assurance that the program would remain sufficiently attractive.

Therefore, balancing the interplay of construction, market, regulatory, legal and political, environmental, safety and operational risks is critical for a new nuclear program to achieve its potential as the most economical alternative for low-carbon electric power generation.

Given these risks and uncertainties, it is therefore unlikely that the private sector alone would be willing to provide the required levels of capital to support new build programs without government support.

Without some form of government support, a standardized and clear approach to technology, clear revenue and payback mechanisms, and ensuring cost targets set by project owners and contractors are not overly ambitious, will be the key challenges for the 18 countries that are embarking on nuclear new build for the first time.

The UK Government has achieved some success in attracting investment through a raft of initiatives including an agreed "strike" price for electricity, as well as providing financial guarantees to debt providers.

In the coming years many will be watching with keen interest, to ascertain whether the industry can deliver new nuclear power plants on time and on budget, with cost control and payback certainty the big issues. This will be required to demonstrate that the nuclear industry has fully learnt from its past experiences.

Safety and the impact of Fukushima

Following the Fukushima accident in 2011, nuclear safety continues to a major focus both within and outside of Japan. Japan's new nuclear regulator, the Nuclear Regulatory Authority (NRA), introduced a regulatory regime with significant improvements to safety standards and monitoring of nuclear operators.

The NRA imposed certain restrictions, including mandatory installation of defenses that can prevent meltdowns caused by natural disasters or terrorist attacks, installation of multiple 'off-site power supply' to prevent disruption of power supply to the core cooling system of the particular nuclear reactor, and the setting up of emergency control rooms[4].

Outside Japan, all countries that have signed up to the Convention on Nuclear Safety have initiated reviews of the measures that defend nuclear power stations against the consequences of complex and severe accidents.

These include both enhancements to existing nuclear power plants, as well as to the design of new nuclear power plants. Independent safety reviews, such as those undertaken by Russia, Germany, Spain, Switzerland, the UK and the US, have examined the Fukushima accident in the context of their own national nuclear programs.

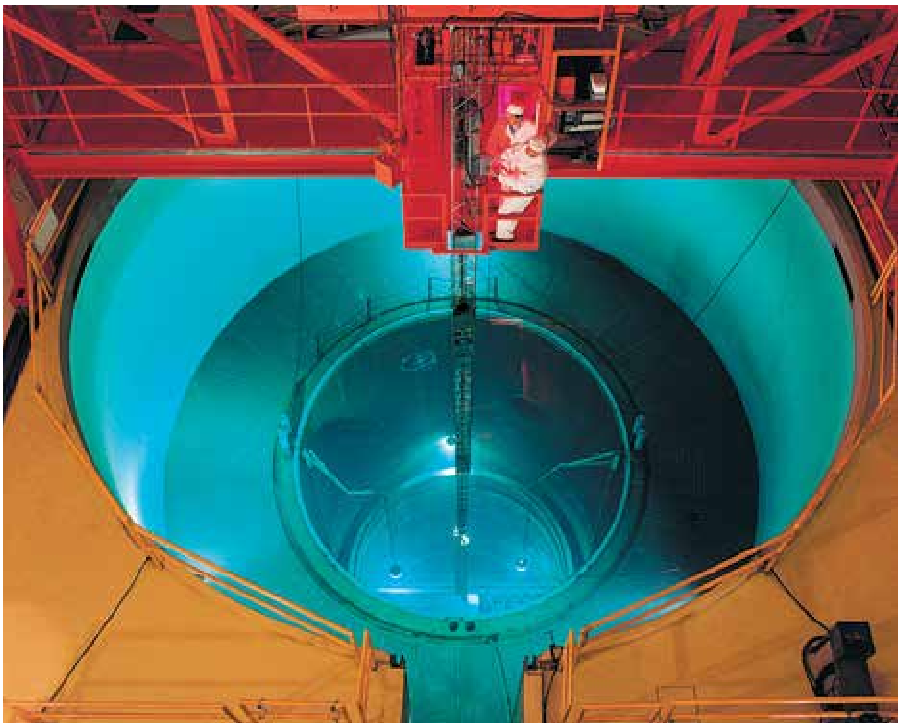
Stress tests in a number of countries have determined that while there are lessons to be learned, fundamentally the same events would not have occurred under the same extreme conditions with the modern 3rd and 4th generation designs. Therefore there was not a significant backtrack on nuclear power with the majority of countries concluding that new build nuclear is still a viable option.

European investments and decommissioning

There have been closures in a number of European countries such as Germany, Switzerland and Belgium, which have either aborted their plans to replace aging nuclear power stations or cancelled switching to nuclear as a source of energy. While the primary explanations behind these closures lie in the risks involved in producing nuclear energy, changing public sentiment in these countries where nuclear power has become increasingly unpopular post-Fukushima has also played a part.

Fukushima also had an impact on the economics of nuclear energy, increasing safety and compliance costs, as well as potentially giving rise to a tougher financing environment for nuclear facilities.

However, there remains a strong belief in certain European countries, such as the UK and across Central and Eastern Europe, that nuclear power will be a vital component of the future energy mix. Therefore, in Europe between 2025 and 2050, the projected level of investments is expected to surpass the decommissioning of nuclear capacity. By the end of the projection period, installed nuclear capacities are expected to be almost equal to 2010 levels across Europe[5].



Outside of Europe, very few countries have stopped or deferred nuclear programs in the wake of Fukushima, with 20 nations currently building or planning for new nuclear[3]. In the Asia Pacific alone, Bangladesh, Indonesia, North Korea, Malaysia, Thailand and Vietnam are all considering nuclear new build for the first time. Developing countries may have even more compelling drivers for nuclear power than their advanced industrialized neighbours due to the faster growth in energy demand, resulting in a greater need to provide a low-cost alternative as fossil fuel and carbon prices rise.

3 World Nuclear Association - http://world-nuclear.org/NuclearDatabase/Default.aspx?id=27232
4 IDSA - http://idsa.in/idsacomments/FukushimaImpactinJapan_sakhan_220713
5 EU Energy, Transport and GHG Emissions: Trends to 2050 - the EC presents a new 'EU Reference Scenario 2013'. - http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2050_update_2013.pdf

The United Kingdom. A case study on nuclear resurgence

As governments around the world look to dramatically adjust their power generation mix, many are closely watching the UK's new nuclear program to see whether lessons have been learnt and new best practices established.

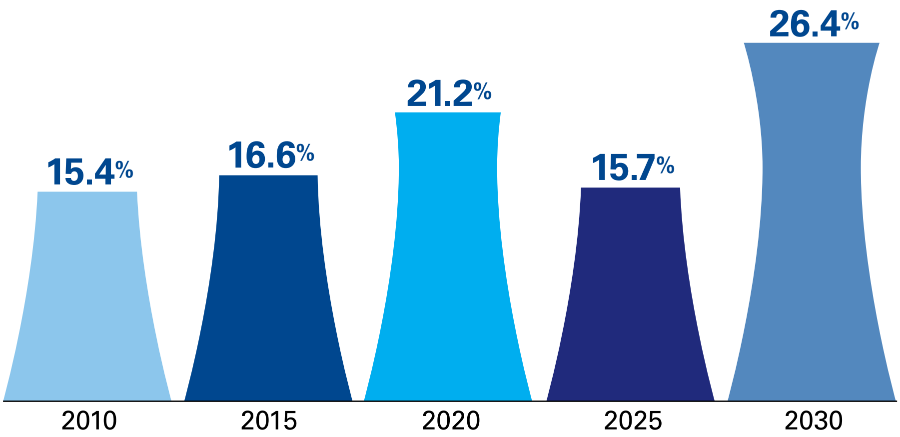
The UK Government's sentiment towards nuclear has shifted significantly over the last decade in the context of Government forecasts that power demand could double by 2050[7]. This has been exacerbated by aging power infrastructure (a fifth of power plants are expected to close by 2020[6]) and commitments to affordably decarbonize the economy, which have contributed increasing pressure on future energy security.

With traditional fossil fuels considered too polluting and concerns over the security of gas and renewables, there is now widespread acknowledgment that nuclear power has a key role to play in the UK's future energy market.

There are currently three major new build programs in the UK, with EDF's NNB Generation Company the most advanced. EDF is the only one of the (UK) Big Six utilities to have a stake in the new build program following the exit of RWE, E.ON, Centrica, SSE and Iberdrola*. The remaining two programs - Horizon Nuclear Power and NuGeneration are now led by technology providers (Hitachi and Toshiba/ Westinghouse* respectively), with operators and supply chain participants still to be identified.

If all programs go ahead, more than 10 GW of nuclear capacity will be expected to come online by 2030, with ambitious targets that nuclear could make up between 16 GW-75 GW of a possible total of 160 GW of total installed capacity by 2050[6].

DECC Reference Scenario – proportion of UK electricity generation from Nuclear[7]



Source: Department of Energy & Climate Change (DECC) forecasts 2013 – https://www.gov.uk/government/organizations/department-of-energy-climate-change. Based on outputs electricity (TWhs) instead of capacity

Safety and public sentiment

Safety represents the top priority for both the UK Government and new nuclear participants. The tragic events of Fukushima were met with an immediate and comprehensive review of the UK nuclear industry by UK's Office for Nuclear Regulation (ONR), which operates at the forefront of nuclear safety.

The report concluded that there were no fundamental safety weaknesses at existing plants, which are designed differently from those at Fukushima. The report did however recommend a number of improvements that should be made at current and future plants. ONR's role will be vital as it continues to consult widely across the globe to ensure that the UK's new build program adheres to international safety best practice.

Perhaps surprisingly, the events of Fukushima have not significantly changed public sentiment towards nuclear power in the UK. Polls have indicated similar levels of support (32 percent) and opposition (29 percent) to nuclear power in 2013[7], representing an increase in support for nuclear power since 2005. This may be partially due to the success that successive UK Governments have had in clearly articulating nuclear's key role in ensuring an affordable, low-cost and future-secure UK energy mix.

Investment challenges

Attracting capital to the UK remains a key challenge, with the UK Government keen to encourage private sector and not Government financing. Steady progress has been made to date, although it is clear that overseas investment will be vital in order to maintain the impetus within the new build program.

Within an increasingly global nuclear market, there is recognition that the UK investment opportunity will be evaluated relative to other global prospects.

There are some clear benefits in the UK market. These include access to innovation, a stringent regulatory environment, an increased focus on safety and the credibility of operating in the UK. However, these benefits may not be enough.

[6] Department of Energy & Climate Change (DECC) forecasts – https://www.gov.uk/government/organisations/department-of-energy-climate-change
[7] UK Energy Research Center – http://www.nerc.ac.uk/press/releases/2013/71-nuclear.asp?cookieConsent=A
* The exit by Iberdrola from NuGeneration is being finalized, the resulting company being a joint venture between Toshiba/Westinghouse and GDF Suez.

Introduction of incentives

The UK Government has therefore introduced measures to incentivize new investment. For example, the Electricity Market Reform (EMR) provides long-term revenue stability, lowering risk to investors through an agreed "strike price" of electricity over a fixed time period. However, this policy is currently subject to a European Commission approval. The Commission's initial assessment raised a number of concerns and many will be watching closely to see whether the deal can win approval without any major revisions. In addition, the UK is proposing to provide financial guarantees to debt providers on a commercial basis to enable sufficient financing to be raised. However, uncertainty remains for the financial guarantee program as a result of the European Commission's investigation into whether this Government support breaks European state aid rules. The Commission's initial assessment raised a number of concerns and many will be watching closely to see whether the deal can win approval without any major revisions.

Continued dialog

Regardless of the outcome, continued dialog among the Government, investors and industry players will be vital to ensure that the nuclear program remains an attractive investment opportunity.

In addition, certain overseas investors are seeking increased participation in the future – therefore distinction between the strategic nature of many of these investments versus purely financial investments must be recognized if the UK is to secure the capital injection that it requires.

Filling the skills shortage

Another key challenge for the UK is to fill the skills gaps that exist for the first new build program in the country for a quarter of a century (the last time ground was broken for a reactor in the UK was in 1988). The UK Nuclear Industry Association estimates that the UK has the capacity to supply between 40 and 60 percent of supply chain requirements, representing a significant fillip to the UK economy.

In addition, the nuclear program also brings significant opportunities for both UK and overseas supply chain companies to enter into new, and innovative, forms of partnership, with the potential for replication within international markets.

Conclusion

With energy demand continuing to grow in most parts of the world, nuclear is still viewed as a key part of the overall energy policy required to sustainably serve this growth in a carbon-effective manner.

Within the Asia Pacific region, nuclear power has an important future role, although safety and economic viability will remain key challenges.

The experience within the UK should provide a platform to demonstrate that nuclear power is a credible technology. However, the support of governments is vital to the success of such projects.

There are a number of lessons which can be applied in how this has been achieved to both create an attractive environment for investors and secure private sector investment to reduce the burden on government financing requirements'.

Beyond the role of governments in securing project financing, any country keen on developing nuclear power capabilities must generate greater awareness and build up knowledge of the nuclear sector. Doing so will go a long way to towards obtaining support from its citizens.

Appendix: An overview of Asian nuclear markets

Traditional Markets

JAPAN

At the time of writing, the 50 nuclear reactors of 42 GW have been standing idle since Fukushima in 2011. At its height nuclear energy provided up to 30 percent of total electricity demand. The shortfall since then has been made up for by fossil fuel – mainly LNG.

Since the crippling of its domestic nuclear market, Japan Atomic Power Co. and International Nuclear Energy Development of Japan Co Ltd (JINED) were established to finance and export nuclear products and services abroad, notably to Vietnam, Turkey, Kazakhstan and the United Kingdom.

CHINA

China has been seeking to secure energy supply for its domestic energy demand with a predicted continuous GDP growth ranging from five to eight percent over the next few years.

China's cities have been inundated with serious air quality issues from huge operations of coal-fired power plants. As a result, China has been actively pursuing a new alternative energy mix. Nuclear power has been identified as a sustainable and zero emission energy source for China. In October 2012, the State Council released a white paper on Energy Policy where China's installed capacity of nuclear power will achieve around 40 GW by 2015.

Currently, with a total nuclear power plant operating capacity of 12 GW, China has 21 nuclear power plants in operation. In order to accommodate the future growing electricity demand at 8 percent per year, China has 28 nuclear power plants under construction (33 GW) and 58 nuclear power plants planned (64 GW).

China's nuclear power industry has been dependent on overseas reactor technologies which mainly come from France, Russia and United States. The State Nuclear Power Technology Corporation (SNPTC) is responsible for the technology selection of new nuclear plants from overseas. Local fuel assemblies for China's nuclear plants are fabricated locally to meet the needs of China's nuclear policy.

Currently, China relies on foreign suppliers for all stages of the fuel cycle, from uranium mining through fabrication and reprocessing. The Chinese Government has selected several parties to be responsible for developing this value chain. China National Nuclear Corporation (CNNC) is the sole current supplier of domestic uranium and China Guangdong Nuclear Uranium Resources Co Ltd (CGN-URC) is responsible for all fuel cycle operations in China.

The World Nuclear Association has placed China's role in the research and development of nuclear technology as second to none. Their nuclear research program plays an important role in building domestic capabilities in the value chain of nuclear power reactors (technology, uranium mining, conversion, enrichment, fuel fabrication, reprocessing and waste management). In the near future, China is expected to become a top nuclear power player in Asia.

SOUTH KOREA

As a major nuclear power producer in Asia, South Korea has 23 nuclear power plants, with a capacity of 21 GW, five nuclear power plants under construction and six nuclear power plants planned. By 2030, the country's national nuclear plan is to expand to 35 nuclear power plants. The nuclear sector currently meets 35 percent of total electricity power demand.

In 2010, the South Korean Ministry of Knowledge Economy aimed to achieve exports of nuclear reactor technology worth US$ 400 billion by 2030 and become the world's third largest supplier of nuclear power. Korea has successfully developed a 95 percent domestically made nuclear power reactor, 1000 MW OPR -1000, which can supply reactor technology to Southeast Asia and Middle East clients. Furthermore, South Korea intends to be independent from the constraints of licensing or intellectual property. With such capabilities, South Korea aims to attain around 20 percent share of the world market.

Since the 1980s, South Korea has transformed from a supplier to an exporter of complete nuclear powered solutions. Korea Electric Power Corporation (KEPCO) has played a significant role on this transformation journey by collaborating with the US. Their collaboration, focused not only on reactor design but also human capital and financial support for the nuclear power sector.

INDIA

India has 21 operational reactors, six under construction and 18 being planned. The total capacity is relatively small because reactors have an average size of 200 MW compared to reactors used in other countries. For example, the average capacity of reactors in China is 900 MW.

India is expected to have 150 GW nuclear capacity online by 2020. The country also aims to supply 25 percent of electricity from nuclear power by 2050. The recent membership to the non-proliferation treaty brings import of fuel and technology and is expected to boost nuclear power in India. The country largely employs indigenous technology that uses thorium and aims to export this technology in the future.

TAIWAN

As a country that imports 97.5 percent of its energy, Taiwan has six operational nuclear power reactors that generate one quarter of the base-load power with capacity of 5 GW.

The technology used by Taiwan's nuclear power plants comprises General Electric boiling water reactors and Westinghouse pressurized water reactor. These plants are operated by the utility Taipower, under the Ministry of Economic Affairs.

Since the shutdown and decommissioning of four research reactors, Taiwan's research and development has slowed down. Taiwan has signed and cooperated with China and the US on nuclear safety, technology and managing aging plants.

PAKISTAN

Pakistan has three reactors in operation with 725 MW capacity that generates around four percent of Pakistan's total electricity supply.

The Pakistan government will be increasing their nuclear power capacity to reach eight GW for ten sites by 2030. Currently, there are two reactors under construction.

Appendix: An overview of Asian nuclear markets

Emerging Markets

VIETNAM

Vietnam had originally planned to start building the Ninh Thuan 1 nuclear plant in 2014 and start operations in 2023, with help from Russia's state nuclear firm Rosatom.

This plan could be delayed for six years according to reports in early 2014. Russia plans to finance and build a 2 GW Ninh Thuan 1 plant with four reactors near Ho Chi Minh City. Japan has also agreed to finance the second 2 GW also in Ninh Thuan.

Vietnam plans to produce 15 GW of electricity, or 10 percent of total generating capacity, through nuclear power by 2030. South Korea has proposed more collaboration on nuclear plants in Vietnam. Vietnam's power utility company, EVN, expects to own and run these plants.

Uranium deposit exploration is currently underway in Quang Nam province.

INDONESIA

The country's 2001 power generation strategy proposed a nuclear plant on the 500 kV Java-Bali grid in 2016 generating 2 GW. This will go up to between six and seven GW in 2025.

However, these plans have been put on hold. In December 2013, on the 55th anniversary of the National Atomic Energy Agency (BATAN), the Ministry of Energy said that a non-commercial power reactor and a gamma irradiation facility would be built by BATAN at Serpong, the site of its largest research reactor.

In February 2014, a 30 MW nuclear power plant has been proposed to be built by BATAN at Serpong, near Jakarta.

BANGLADESH

As an emerging player in the nuclear power sector, Bangladesh Atomic Energy Commission plans to build two 1 GW Russian technology nuclear reactors by 2020. Construction has started in 2013, according to the World Nuclear Association. Currently, Bangladesh has one research reactor under operation.

Appendix: An overview of Asian nuclear markets

Potential Markets

AUSTRALIA

Australia's known uranium resources are the world's largest – 31 percent of the total reserve globally. It is the world's third-ranking producer, behind Kazakhstan and Canada. The Australian Nuclear Science & Technology Organization (ANSTO) owns and runs the modern 20 MW Opal research reactor.

Infrastructure exists to support nuclear development but economic and political will so far remains elusive.

THAILAND

Thailand has well-developed plans but commitment is pending. Two commercial reactors have been planned since 2007 but progress was stalled due to Fukushima. A research reactor has been operating since 1977, and one more is being built.

Some 70 percent of electricity is generated from natural gas. Given the depleting domestic gas resources and the burden of gas imports, nuclear power can play a role in Thailand.

MALAYSIA

In Malaysia, a research reactor has been in operation since 1982. The Government is developing plans, and is currently undertaking feasibility, site selection and regulatory studies. It is also contemplating the construction of two to four reactors.

PHILIPPINES

Philippines built the Bataan nuclear power reactor in the early 1980s. However, this reactor never went into operation because of safety issues. Although a 2008 inspection by the International Atomic Energy Agency (IAEA) revived plans to refurbish the plant, Fukushima has put the project on the backburner once more.

Commentary: Nuclear power after Fukushima

It has become a totally different world for nuclear power after the accident at the Fukushima Daiichi Nuclear Power Plant. Safety has become issue number one everywhere. No reactors are currently running in Japan because each reactor needs to pass new safety standards test set by the independent Nuclear Regulatory Commission (NRC) to restart after its regular maintenance shut down.

Japan's basic energy plan is a qualitative policy document rather than a quantitative plan because nobody can predict when the NRC will approve the restart of reactors, much less the long-term future of nuclear power. The risk of nuclear power was revealed by the Fukushima accident but the risk of no nuclear power is not explained well to the public. If reactors do not restart soon, some regions may face a shortage of electricity supply this summer, depending on how hot it becomes. Japan is wasting USD 40 billion a year for extra purchases of gas and oil for thermal power. Old mothballed oil-fired power plants are utilized at full power with enormous efforts by maintenance staff while facing possible shutdowns. The Middle East situation continues to be unstable while Iranian nuclear talks seem to be moving forward. But there always remains a risk of Israeli attack against Iranian nuclear facilities when the P5+1 talk may not deliver expected consequences. Japan depends on free navigation at the Strait of Hormuz for 85 percent of its oil and 20 percent of its LNG. Without nuclear power plants running, Japan is as vulnerable as it was 40 years ago when the first oil shock hit her.

The shale revolution would enable the United States to export gas and to substantially reduce its oil imports from the Middle East. So-called 'energy independence' is within reach in coming years. Its industrial competitiveness is strengthened by cheap gas input for the petrochemical industry (the IEA calls this the "Petrochemical Renaissance" of the US), and cheap electricity from gas power plants will help the American manufacturing sector. How can Japan compete with the US in addition to emerging economies like China, India and Brazil, without economical and secured energy sources like nuclear power? The pain of higher electric fees and loss of jobs have not yet been felt by the public. But sooner or later this will happen just as Europe has been experiencing higher cost of energy and lack of competitiveness relative to the US.

The difficulty for Japan in maintaining "First Tier Nation" status with nuclear power as Joe Nye and Richard Armitage mentioned two years ago in the CSIS report comes from loss of public trust in politicians, government officials, utilities and the nuclear community as a whole. Public concern expands from the safety of reactors to that of high-level waste disposal. The delay of demonstration of Japan's FBR, Monju, as well as Rokkasho Reprocessing plant triggers doubt about the appropriateness of back-end fuel cycle technologies. Nuclear fuel cycle options are essential if we continue to use nuclear power. Sometimes Japan's nuclear policy is criticized as a condominium without toilets. New solutions are needed which warrant peaceful use (non-proliferation), safety and ease of waste disposal. The solution does exist! It is called Integral Fast Reactor (IFR) and Pyroprocessing. This technology has been developed and tested at the Argonne National Laboratory in the US. The passive safety feature of this technology was demonstrated in the total plant blackout experiment held in 1986. The recent movie "Pandora's Promise" directed by Robert Stone picked it up as the Fukushima-like experiment. Unfortunately, development of IFR was crowded out by Light Water Reactors (LWRs) and was eventually aborted prematurely by politics. The LWR technology paradigm has been hastily established and developed because of urgent need for military use, in particular, for nuclear submarines without establishing passive safety when it is built on shore and a complete waste disposal solution.

Before the Fukushima accident, nuclear power was considered to be a safe and cheap electricity source, but the world has changed. Post-Fukushima Japan is responsible for developing a new paradigm. Japan has been an excellent model of peaceful use of nuclear power. Japan is uniquely authorized to reprocess LWR spent fuels even though she is not a nuclear weapon state. Korea is eager to follow a Japanese model using IFR and Pyroprocessing by renewing a so-called "1-2-3 agreement" with the US. An international research consortium comprising the US, Korea and Japan for the IFR development should be established.

Fukushima would be the best location for such a project to "turn the devil to the fortune" (Wazawai tenjite Fuku to nasu). We need a big picture to convince the Japanese public to regain lost trust.

Written by **Nobuo Tanaka**,
Global Associate for Energy Security and Sustainability, Institute of Energy Economics, Japan and former Executive Director of International Energy Agency

Commentary: Potential role of small modular reactors

– a response from the United States against the challenges posed to new nuclear

As discussed in the main body of this report, new nuclear shows significant promise across the Asia Pacific region and, indeed, around the world. Despite the global challenge to nuclear power posed by events at Fukushima, new construction programs in the US, UK, China, Russia, the Middle East, and a dozen or more countries globally continue to make good progress.

Yet the picture is clouded by a variety of challenges, especially for large-scale reactors: a moribund US Government loan guarantee program focused on new nuclear, more-stringent regulatory requirements (largely driven by Fukushima) in certain jurisdictions, a scaling-back or abandonment of nuclear power in some geographies, slow load growth in much of the OECD, a low (or zero) price of carbon in the US and some other key countries, significant cost overruns at many ongoing nuclear construction projects, premature shut-down of four nuclear units in the US, and persistently cheap natural gas in North America, among others. From a global perspective, the market for large new nuclear power plants is cloudy, at best.

There is a view in the market that the sheer size of large new reactors – the "lumpiness" of the required capital investment – magnifies the costs and risks of new nuclear plants and makes it difficult for even the largest global utilities to finance nuclear projects. Small Modular Reactors (SMRs) offer the opportunity to overcome many of these issues.

The International Atomic Energy Agency defines SMRs as those reactors with a capacity of less than 300 MW, although, in general parlance, any reactor with capacity less than 500 MW is an SMR. Over time, more than 100 SMR designs have been put forth by a diverse set of players across virtually every country active in the commercial nuclear market.

Despite their inherent diseconomy of scale and lack of immunity to many of the same challenges (e.g. cheap natural gas) facing large reactors, SMRs offer a variety of advantages relative to full-size nuclear plants. SMRs' small size may make it easier to obtain financing. Series production in a factory setting can create learning-curve effects, lowering capital cost, while reducing the risk of construction cost overruns associated with custom-built projects. It may be easier to achieve a degree of passive safety when power output is relatively low, components and systems are integral, and the physical envelope of the plant is small. Siting and licensing could, in principle, be easier for an SMR than for a large reactor.

Consequently, a number of vendors are developing modern SMR designs (in part with government support) in order to compete in this market. These span the gamut of technologies like their full-size cousins. Among current SMR designs are the following:

- Babcock & Wilcox mPower (US) – an integrated PWR, approx. 180 MW per module
- CAREM (Argentina) – a simplified pressurized water reactor (PWR) design
- Encapsulated Nuclear Heat Source (US) – a liquid metal design which uses lead or lead-bismuth (Pb-Bi) coolant
- Flibe Energy (US) – a molten-salt reactor which uses liquid fluoride thorium
- Hyperion Power Module (US) – a liquid metal design which uses lead-bismuth coolant
- International Reactor Innovative & Secure (IRIS) (US) – a 50 MW modular PWR which can run five years between refueling
- Korea Atomic Energy Research Institute SMART design (Korea) – a 100 MW class integral PWR
- Modified KLT-40 (Russia) – a small PWR based on the reactors used on Russian icebreakers
- NuScale (US) – a light-water design that uses one to twelve modules, each producing 45 MW
- Pebble Bed Modular Reactor (PBMR) (South Africa) – a modernized version of a design first deployed in the 1960s in Germany, which uses spherical fuel elements coated with graphite and silicon carbide filled with up to 10,000 particles which contain uranium fuel and safety layers
- Purdue Novel Modular Reactor (PNMR) (US) – a small boiling water reactor that does not require refueling for ten years
- TerraPower Traveling Wave Reactor (TWR) (US) – a design that is based on a chain reaction moving slowly through a core in a "wave," over a period of 50 to 100 years
- Toshiba Super Safe, Small & Simple (4S) (Japan) – a sodium-cooled design with a moveable neutron reflector
- Westinghouse SMR (US) – a scaled-down version of the AP1000 reactor, with some unique features

As discussed in the body of this report, concerns over global climate change and other drivers have the potential over time to create significant demand for nuclear generation generally. In my view, they may drive demand for SMRs to a disproportionate degree. If this is true, the challenge for SMR vendors is to make tangible progress on their technology and licensing efforts for a number of years, primarily through public-private partnerships and niche deployments, until broader market conditions become more favorable, perhaps in several years' time.

Three particular global sub-markets for SMRs are promising in the short- to medium term: desalinization and industrial process heat applications (e.g., for oil sand processing), remote population concentrations (as is common throughout Oceania) without easy access to cheap natural gas, and replacement of retiring fossil-fired power plants in some countries. In geographic terms, the most promising markets for SMRs include the Middle East, China, India, Russia, Korea, and Southeast Asia.

I remain upbeat regarding the prospects of nuclear power generally and SMRs in particular. Nuclear remains the only dispatchable source of electric power with no direct carbon emissions. There is a growing recognition of the value of generation diversity and its role in reliability and resilience. If SMR vendors can demonstrate that learning curve effects are real and significant, that construction cost risk can be managed, and that SMRs are safe, reliable, and licensable without significant regulatory changes, then SMRs are likely to play a major role in the generation mix over time in Asia-Pacific and around the world.

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