NERA
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# 2014 – Asian Nuclear Power Outlook

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## Introduction

Asia has a high level of nuclear power activity. Several Asian countries have built nuclear power plants to meet domestic electricity needs and some are building additional nuclear capacity. Some Asian countries have nuclear industrial capability that is being further developed to compete in the global nuclear power market.

This note[1] provides a perspective on issues in the Asian nuclear power industry. It is not intended to be a comprehensive discussion of the nuclear power industry in Asia and interested readers can find more information Asia nuclear power developments and activities from the WNA, IAEA, and other public resources.

This note has four sections:

**Nuclear industrial countries - China, Japan and South Korea**

China, Japan, and South Korea have generally followed the approach taken by France to establish a nuclear power industry, although the timing and the details are different. These countries are competing in the global nuclear power market.

**India**

India is implementing a three-stage plan to establish a thorium-based nuclear industry and dealing with issues related to the 2008 Indo-U.S. nuclear agreement that allowed India to enter the world nuclear market.

**Asian nuclear market countries**

Some countries in Asia consider imported nuclear power plants to help meeting domestic electricity demand while reducing dependence on imported electricity generation fuels.

**U.S. nuclear export controls**

U.S. nuclear export controls are a factor in the nuclear power industry in Asia, influencing nuclear industry development and nuclear technology imports and exports.

A glossary at the end of this note explains acronyms and terms used in the note.

[1] This note reflects the views of Edward Kee, whose views may not be consistent with the views of others at NERA, the views of NERA's clients, or the views of others in the nuclear industry.

# I. Nuclear Industrial Countries

China, Japan, and South Korea have taken similar paths to establish their nuclear industries, although the timing and details are different. These countries have generally followed the approach taken by France, with a nuclear industrial capability-building process that includes multiple steps:

- Acquire nuclear power technology from outside;
- Build domestic nuclear power plants to provide electricity;
- Build national nuclear industrial capability and companies, by increasing level of involvement in the domestic nuclear power build program;
- Newly established national nuclear industrial companies take a leading role in domestic nuclear power projects to demonstrate capability and build experience;
- Develop indigenous reactor designs; and
- Sell nuclear power plants to other countries, using national nuclear industrial capability and supply chain.

Today, China, Japan and South Korea are competing in the global nuclear power market.

## A. China

China has a large and growing demand for electricity, but also has poor air quality caused in part by emissions from coal-fired power plants. These issues have led to a large and ambitious nuclear power build program in China, with China's government-owned electricity sector providing a large and protected market for Chinese nuclear industrial companies. Few countries have the combination of power needs, government financial commitment, and nuclear industry focus seen in China. The Chinese nuclear sector activity provides an opportunity for Chinese nuclear industrial companies to become world leaders.

China's nuclear power industry followed the strategic playbook by buying foreign nuclear power plants. China also invested in its nuclear power sector, funding universities, research and development centers, nuclear industrial companies, and nuclear supply chain companies.

China developed some indigenous reactor designs, including the CNP-300 built in China and exported to Pakistan, 1,000 MW PWR designs being built at many sites in China and exported to Pakistan, and the CAP1400, based on the AP1000 reactor design. The first CAP1400 unit is expected to start construction in 2014 and will be a reference unit for exports. An even larger 1700 MW version is being considered.

China is also building prototypes of multiple small and advanced reactor designs, and the long-term nuclear power plan includes fast reactors to help close the nuclear fuel cycle. If one or more of these small and advanced reactor designs offer significant benefits, China has the potential to build multiple units in China that will demonstrate performance and build experience for even large domestic fleets and potential exports.

In addition to its ambitious domestic nuclear plant build program and nuclear technology development activities, China has plans to export nuclear power plants in the future. Chinese activity in the export market is an indication of these plans.

**Pakistan** - China has completed two CPR300 plants and is building two more of these units at Chasma in Pakistan. China has also sold two 1,000 MW PWR units to Pakistan to be built near Karachi and there are reports that additional large PWR units may be built in Pakistan. China is also offering Pakistan loans to help pay for the nuclear units.

Building the Pakistan nuclear power plants will help Chinese nuclear companies gain experience and demonstrate the Chinese capability to build nuclear power plants outside China.

**CAP1400 -** The plans for the CAP1400 reactor call for sales into the export market after units are built in China. A large passive-safety Gen III+ unit with a completed and operational reference unit in China, Chinese costs and supply chain, and Chinese financing may be a strong product offering in the global nuclear power market.

**Turkey** - In 2012, CGN submitted a proposal for a BOO project at the Sinop site in Turkey. CGN would invest in up to eight ACPR1000+ nuclear power units at the Sinop site. CGN planned to be the majority owner of the project and to arrange project financing without sovereign guarantees from Turkey. CGN also offered to form Sino-Turkish consortiums for localization of equipment manufacturing, construction and operations management.

CGN's approach for Sinop was similar to the Rosatom approach for the Akkuyu project, showing that China is willing to adopt a nuclear export strategy similar to that being followed by Rosatom.

**Romania** – In November 2013, CGN signed a letter of intent with the Romanian national nuclear company Nuclearelectrica regarding the development of two additional units at its Cernavoda nuclear power plant. The CGN involvement in the Cernavoda expansion is a part of a new global strategy.

**UK – Hinkley Point C** - CGN has agreed to invest in the Hinkley Point C nuclear plant in the UK, an opportunity for the Chinese government to leverage its availability of capital and its relatively successful experience with the Taishan EPR projects. CGN will take a significant, but non-controlling share of Hinkley Point C (i.e., less than 50%), but this investment was conditional on an assurance that China could take a controlling interest in a future UK nuclear power projects. The UK government expects that the Hinkley Point C project will proceed and that it will be a template for additional UK nuclear projects. The EU has initiated an investigation into the Hinkley Point C incentive package to determine whether the incentives are illegal State Aid. The State Aid investigation is expected to be completed before the end of 2014.

***Turkish BOO nuclear projects***

*China, Japan, and South Korea were contenders for the second Turkish nuclear project at Sinop. A Japanese-led consortium won the rights to build a 4-unit nuclear power plant at Sinop. Like the earlier Rosatom nuclear project at Akkuyu, the Sinop project will be a BOO project, with a nuclear power plant built, owned, and operated by a vendor-led consortium.*

*There are several potential reasons why a nuclear vendor, normally in the business of selling nuclear power plants and equipment, would take on the additional roles (and risks) of investor, owner and operator:*

***Turkish requirements** - Turkey asked for BOO proposals and only those vendor-led consortium groups that offered a deal meeting Turkey's requirements would be considered. Rosatom agreed to this deal structure in the Akkuyu project and multiple proposals were received for a BOO deal at Sinop project. Apparently, the Turkish BOO approach is working.*

***Potentially profitable** - Turkey, while not offering a sovereign guarantee, is willing to enter into an inter-governmental agreement that includes a power purchase agreement with Turkish utilities for some of the nuclear project output. The remainder of the plant's electrical output would be sold into the Turkish electricity system. While revenue from the sale of non-contracted output is uncertain, high growth for electricity demand in Turkey may mean that these sales are at attractive prices. While project revenue is not fully certain, a BOO nuclear project may have financial upside.*

***Vendor's objectives** - Nuclear export projects may be part of a national nuclear sector growth strategy. Developing a BOO project in Turkey may be consistent with a vendor's market share objectives and may help achieve geopolitical goals of government-owned nuclear vendors. A BOO project may be an effective way for a government-owned and financed nuclear vendor to compete with private nuclear vendors that prefer to focus on equipment sales.*

***FOAK projects** – The BOO project structure may offer a more effective way to manage first-of-a-kind (FOAK) nuclear power plant projects. FOAK nuclear plants are typically sold under a fixed-price turn-key contract that shifts cost and schedule risks to the vendor, but a FOAK reactor design built under a BOO structure may be a better alternative. Under a BOO nuclear project structure, the vendor/builder/owner can streamline project decision-making to accommodate the project/design changes typical in a FOAK nuclear plant project. The BOO owner also has an opportunity to earn returns that may offset higher FOAK project capital costs.*

**Nuclear power imports by China** - In addition to Chinese activity in the nuclear power plant export market, the Chinese nuclear power program presents an attractive market for non-Chinese nuclear industrial companies. Westinghouse, AREVA and Rosatom are already involved in building nuclear power plants in China and other companies are selling nuclear power plant components and services to Chinese customers.

**Summary**

Significant events for the Chinese nuclear power industry in 2014:

- Commercial operation of first AP1000 unit at Sanmen

- EDF and CGN financial arrangements for Hinkley Point C, if EU State Aid investigation is completed
- Commercial operation of multiple 1,000 MW PWR units now under construction
- Progress on several small and advanced reactor designs
- Construction start on the first CAP1400 project
- The recently announced CGN IPO should proceed and will provide a better understanding of the long-term role of the Chinese government

## B. Japan

Japan started the move to nuclear power early, with the first commercial units placed into operation in the mid-1960s. The Japanese nuclear power industry started with and still has a close relationship with US nuclear companies. Japan established a large and capable nuclear power industry and a large fleet of nuclear power plants.

However, today, Japan's nuclear power industry faces significant challenges.

**2011 Great East Japan Disaster -** The March 2011 events at the Fukushima Dai-ichi nuclear power plant have had an impact on the global nuclear power industry, but the impact on Japan has been significant. All nuclear power plants are closed and the cost of imported fuel for electricity generation to replace the closed nuclear power plants has had a significant negative effect on the Japanese economy. The timetable for returning these nuclear power plants to operation is uncertain. The new NRA is reviewing applications for restart, political and public opinion is becoming more favorable for nuclear plant restarts. While the NRA process is moving slowly, some nuclear power plants may get permission to restart in 2014.

**Private Ownership -** Japan's nuclear industry and electricity industry is not owned and controlled by the government, as in China, South Korea, France, and Russia. The level of coordination in the domestic power market and the amount of implicit and explicit government support for nuclear export deals is likely to be lower in Japan, compared to the countries where the nuclear power and electricity industries are owned and controlled by the government.

**Fragmented Nuclear Industry –** Japan has three large nuclear industrial companies, Hitachi, Toshiba, and Mitsubishi. While JINED has represented Japan's entire nuclear industry in negotiating with potential nuclear export markets, Japanese nuclear companies compete with other Japanese nuclear companies in the export market. This type of competition is not likely for Russian, Chinese and South Korean nuclear industrial companies.

**Focus on U.S. Nuclear Market -** Japanese nuclear companies spent significant time and money preparing for and investing in a new wave of nuclear build in the U.S that has been stopped by the unconventional (i.e., shale) natural gas production. Major investments were made by Toshiba in Westinghouse and by Hitachi in a nuclear power joint venture with GE.

**Limits from U.S. Nuclear Export Treaties -** Japanese nuclear power plant designs have U.S. content and are subject to U.S. nuclear export controls, limiting nuclear power exports to countries with a 123 Agreement in place.

**Exports**

Japanese nuclear companies are turning their focus on activity outside Japan. The export of Japanese nuclear components and technology are key elements of Japan's recent economic plans.

**U.S.** – The Westinghouse / Toshiba AP1000 projects at the Vogtle and Summer sites are under construction. Earlier nuclear projects were planned around the ABWR, APWR, and ESBWR reactor designs, but these merchant power plant projects have been placed on hold or cancelled.

**China** – The Westinghouse / Toshiba AP1000 projects at the Sanmen and Haiyang sites are under construction and the first of these units may reach commercial operation in 2014.

**India** - Japanese nuclear vendors are potentially involved in the sale of nuclear power plants to India and non-Japanese reactor designs may include Japanese components. Japan has asked India to make formal commitments to nonproliferation as a pre-condition for Japanese nuclear power exports, but India has not agreed. India wants Japan to do business with India without additional nonproliferation requirements, as the U.S. and other NSG members have agreed to do.

**Vietnam** - Japan is pursuing the second nuclear project in Vietnam, led by JINED. Like the first Russian project, the second nuclear project may be delayed for several years.

**Saudi Arabia** – Japanese nuclear companies are hoping to be involved in the coming Saudi Arabia nuclear power program. Saudi Arabia must obtain a 123 Agreement if Japanese nuclear power plant designs are to be sold there.

**UK** – Both Hitachi and Toshiba have moved aggressively into the UK market, with Hitachi acquiring Horizon and Toshiba acquiring NuGen. If the Hinkley Point C project incentive package is approved and offered to other UK nuclear projects, the Horizon and NuGen projects may be attractive merchant nuclear investments. The UK NDA is considering the GE Hitachi PRISM fast reactor as an option to burn the substantial UK plutonium stockpiles while generating electricity.

**Turkey** - In 2013, a consortium led by Mitsubishi entered into an agreement to build a 4-unit nuclear power plant at Sinop in Turkey. The Sinop consortium has selected the French / Japanese ATMEA1 reactor design for Sinop. The Sinop project could be the reference unit for future Mitsubishi export sales of the ATMEA1 reactor design that are not limited by U.S. 123 Agreements. In Turkey, as in the UK, Japanese nuclear power plant vendors are moving from a traditional strategy of selling nuclear power plants and equipment to a strategy that includes ownership and operation of nuclear power plants.

**Finland** - TVO is evaluating bids for the new OL4 project in Finland that include AREVA (EPR), GE Hitachi (ESBWR), KHNP (APR1400), Mitsubishi (APWR) and Toshiba (ABWR). All three Japanese nuclear companies are competing for the OL4 project.

**Lithuania** - In 2011, Lithuania selected Hitachi-GE to build an ABWR reactor, with Hitachi-GE expected to take a significant "strategic investor" ownership stake in the project. Westinghouse / Toshiba, was the primary competition for the Lithuania project. Like the UK and Turkey projects, this will require nuclear plant investment and ownership.

**Poland** - Poland announced in early 2014 that it would proceed with its nuclear program, despite concerns about the financing of a nuclear power plant in Poland. Westinghouse / Toshiba and GE- Hitachi have signed cooperation agreements for nuclear projects in Poland, setting up a potential future competition in Poland between these two Japanese nuclear vendors.

Significant events for the Japanese nuclear power industry in 2014:

- The new government energy plan that includes a reliance on nuclear power is expected to be approved in March
- The recovery process at the Fukushima Dai-ichi plant should resolve key issues related to the disposition of treated water stored on site and used fuel movement
- TEPCO's restructuring plan anticipates restart of two Kashiwazaki Kariwa nuclear units in mid-2014
- Applications to restart multiple nuclear units have been submitted to the NRA and some restart decisions may come in 2014
- As the Hinkley Point C deal emerges from the EU State Aid investigation in late 2014, a clearer project development and finance strategy for Horizon and NuGen will be possible
- The Mitsubishi-led Sinop project in Turkey should have an approved inter-governmental agreement in 2014

## C. South Korea

South Korea followed the same strategy to become a nuclear industrial country used in France, Japan, and China. Like Russia, France and China, the South Korean electricity industry and key nuclear companies are owned and controlled by the government. After a 30-year effort to establish a national nuclear power industry, South Korea has a large and growing domestic nuclear fleet, indigenous reactor designs, companies that are world leaders in the nuclear industry, and ambitious plans for the nuclear export market.

In 2009, South Korea won the competition to build the 4-unit Barakah nuclear power plant in the UAE. South Korea offered the lowest price, but also had strong support due to South Korea's domestic nuclear build program and the South Korean design and construction of conventional power plants, desalination facilities, and other projects in the Middle East.

**Safety Culture** - The South Korean nuclear industry is recovering from a scandal related to nuclear power equipment safety certificates for thousands of components that were forged.

The South Korean nuclear industry will be stronger and better as these internal troubles are sorted out. KHNP has initiated a company-wide effort to remove corruption and establish a more comprehensive nuclear safety culture.

Another driver of South Korean nuclear safety culture is the UAE Barakah project, which has put South Korean nuclear companies into a high visibility project outside South Korea, with oversight by a non-South Korean owner and safety regulator and close work with international nuclear industry companies.

**123 Agreement** - South Korea is constrained in its nuclear industry strategy by the 1974 123 Agreement that restricts South Korea's activities in uranium enrichment and used nuclear fuel reprocessing. Negotiations to renew the agreement are in progress.

**R&D** - South Korea has developed a significant nuclear power research and development capability. Nuclear industry research and development, led by KAERI, supports national energy and nuclear strategy and provides a technology base to support nuclear exports. South Korea has developed a small and alternate reactor designs, including the SMART integral PWR that has design approval from the South Korean regulator.

**Exports**

South Korea has made nuclear power exports a strategic priority and sees nuclear power plants as products where South Korean companies can major suppliers in the world market, similar to automobiles, electronics and shipbuilding.

After the UAE sale, South Korea announced a goal of exporting 80 nuclear power reactors by 2030. In pursuing this goal, the South Korean nuclear power industry aims to be 100% self-sufficient in the near future, with no remaining reactor design intellectual property constraints or U.S. export control restrictions.

**Finland** – KHNP has proposed the APR1400 for TVO's OL4 project and the bids are under review in early 2014.

**Turkey** – South Korea negotiated with Turkey for the Sinop project between 2010 and 2013, but withdrew in 2013.

**Saudi Arabia** – South Korea is hoping to be involved in the coming Saudi Arabia nuclear power program. Saudi Arabia must obtain a 123 Agreement to buy South Korean nuclear plant designs, unless South Korea successfully develops an APR+ design that is not restricted by U.S. nuclear export controls.

**U.S.** - In 2013, an APR1400 design approval application was submitted to the U.S. NRC. The NRC has required more information before starting the review. Given the state of the U.S. new nuclear market, NRC certification of the APR1400 reactor design is likely aimed at helping sales to other international markets.

**Components and O&M** - In addition to exporting reactors, South Korean nuclear companies also provide nuclear power plant components and O&M. For example, Doosan is negotiating a long-term O&M contract for EDF UK nuclear units and is a key component supplier for AP1000 units under construction in the U.S. and China.

**India** - In early 2014, South Korea was in negotiations with India to provide nuclear power plants and other nuclear industrial services, based on a 2011 bilateral nuclear cooperation agreement.

**Indonesia** - In 2007, KEPCO signed an agreement with Indonesia's PT Medco Energi Internasional, an independent power producer, to conduct a feasibility study for Indonesia's first nuclear power plant. The sale of a small reactor project based on the SMART reactor design has been discussed.

Some key issues and events in 2014 include:

- South Korea’s domestic nuclear build program should be back on track
- KHNP’s corporate safety culture reform efforts should show results
- The existing 123 Agreement will be extended, allowing an additional two years to negotiate a new 123 Agreement
- Progress will continue on the Barakah nuclear project, as work begins on units 3 and 4

# II. India

India aims to be a world leader in nuclear technology in fast reactors and thorium fuel cycle, consistent with the lack of indigenous uranium and large deposits of amounts of thorium. India developed a plan that starts with PHWR reactors, moves to fast breeder reactors, and then to thorium-fueled reactors.

**Three-Stage Plan**

Dr. Homi Jehangir Bhabha, the founding Chairman of India's Atomic Energy Commission, developed India's three-stage nuclear power program, adopted in 1958, as a way for India to develop nuclear power despite limited uranium resources.

- Stage I – PHWR power plants that use natural uranium fuel to produce electricity, with plutonium recovered from spent fuel.

- Stage II - Fast breeder reactors that use Stage I plutonium and natural uranium fuel to produce electricity and breed additional plutonium. When plutonium inventory is sufficient, the fast breeder reactors will convert thorium into uranium-233 for Stage III.

- Stage III – Thorium breeder reactors using uranium-233 produced in Stage II for startup and refueled with natural thorium.

India is now in Stage I of the plan. India's nuclear power fleet, owned and operated by NPCIL, has a large and growing fleet of PHWR reactors of various sizes, up to the current standard 700 MW design. A 500 MW prototype fast breeder reactor is under construction at Kalpakkam is expected to start up in September 2014.

**Light Water Reactors**

Light water reactors, while not part of the three-stage plan, could provide electricity and plutonium that would augment the three-stage plan.

Two 150 MW BWR power plants were built by GE in Tarapur and placed into operation in 1969. Two 1,000 MW VVER units in Kudankulam are entering commercial operation in 2014. Russia is supplying enriched nuclear fuel for the Kudankulam units for the life of the units and India will keep the used fuel as a source of plutonium.

**2008 Indo-U.S. Nuclear Agreement**

The 2008 Indo-U.S. agreement allowed India to re-join the international nuclear industry. This allowed India to import uranium, to retain and reprocess imported nuclear fuel in order to recover the fissile plutonium for use in the three-stage plan and to import non-Indian (foreign) nuclear reactor designs. Reports suggest that the Indian Prime Minister made commitments to buy foreign nuclear power plants to gain support for the 2008 agreement, with several dedicated foreign-reactor sites.

- Jaitapur in Maharashtra – Six nuclear power plants using the French EPR reactor design.

- Mithi Virdi in Gujarat – Six nuclear power plants using the Toshiba / Westinghouse AP1000 reactor design.

- Kovvada in Andhra Pradesh – Six nuclear power plants using a GE Hitachi reactor design (ESBWR or ABWR).

- Kudankulam in Tamil Nadu – Six nuclear power plants using the Russian VVER reactor design, in addition to the 2 VVER units already built at the site.

- Haripur in West Bengal – Four to six nuclear power plants using the Russian VVER reactor design; this site faces strong local opposition and may be moved to Orissa.

Discussions have also been held with KEPCO about importing APR-1400 power plants.

The imported light water reactor nuclear power projects have faced several issues, including the Indian nuclear liability law, public opposition to nuclear power, and high prices. Some in India oppose imported light water reactors because the need for imported nuclear fuel for these reactors would undermine the energy independence goals of the three-stage plan.

**Liability Law**

In 2008, India's nuclear law did not cover third-party liability, inconsistent with the requirements of foreign nuclear vendors that expected India to have a nuclear law consistent with international practices. In 2010, the Civil Liability for Nuclear Damage Act (the 2010 Act) related to third party liability was passed by parliament. The 2010 Act was consistent with international practice in placing responsibility for any nuclear accident with the operator (NPCIL), limiting total liability, and providing that the Indian Government would cover claims above the liability limit.

However, the 2010 Act diverged from international practice because the nuclear plant operator (NPCIL) was allowed to claim damages from suppliers of goods or services if there were a nuclear power plant accident, with potential supplier liability for up to 80 years after the nuclear plant commenced operation.

2011 rules implementing the 2010 Act narrowed the potential liability of suppliers by limiting the supplier liability period (i.e., the longer of the 5-year initial nuclear plant safety license or the product warranty period) and amount (i.e., the lower of NPCIL's limit on third-party liability of Rs 1,500 crore or about US$250 million or the value of the contract for goods or services).

Potential foreign and domestic nuclear suppliers remain concerned about supplier liability and have been reluctant to enter into nuclear industry contracts in India.

**Public Opposition**

There is growing opposition to nuclear power in India that appears to be focused on foreign nuclear power plants and the sites selected for these foreign nuclear power plants. Protests at the Kudankulam site have slowed progress and protests about the other imported reactor sites have led to discussions about relocating the sites.

### Cost

In the political debate leading up to the 2008 Indo-U.S. nuclear deal, NPCIL suggested that the cost of electricity from foreign nuclear power plants would be comparable to the cost of power from the existing fleet of NPCIL nuclear power plants. As the cost and other details of foreign reactor deals become clearer, the price of power from these projects appears to be much higher than the earlier NPCIL estimates. These higher electricity costs raise political and public concern that NPCIL, a government entity, would be subsidizing foreign reactor deals and/or passing higher costs on to Indian ratepayers.

### Inconsistent with three-stage plan

Opposition to foreign reactors also comes from a concern that the large investment in imported light water reactors will delay or diminish the progress on the three stage plan and, if the foreign light water reactors are placed into operation, India's electricity sector will be even more vulnerable to a potential future stoppage of imported enriched uranium nuclear fuel.

## Export Market

Unlike the nuclear power companies in South Korea, Japan and China, India has not focused on nuclear power plant exports, even though there is some interest in selling the locally-designed PWHR nuclear power plants to other countries.

Indian industrial companies see the foreign nuclear power plant projects as a means of entering the global nuclear supply chain. Larsen & Toubro has a forge with the capability to produce large forged nuclear components under its ASME N-Stamp qualification. Reliance Power, NPCIL, and BHEL are investing in industrial capability to supply components for nuclear power plants inside and outside India. GE Hitachi signed a preliminary agreement with Tata Consulting Engineers, Ltd related to future nuclear projects inside and outside India.

Significant events for the Indian nuclear power industry in 2014:

- Continued construction of PHWR nuclear power plants
- The Indian liability law issues may be resolved, allowing nuclear industry suppliers to engage in activity in India
- Negotiations will continue on the foreign reactor deals
- Resolution of the nonproliferation issues with Japan
- Start-up of the Kalpakkam fast breeder reactor

# III. Nuclear Power Market Countries

Other countries in Asia have growing energy needs that might be met by development of civil nuclear programs. Nuclear power programs in these Asia market countries vary, but a consistent theme is the need to diversify electricity generation sources and reduce dependence on imported oil and gas electricity generation fuels. These nuclear market countries have focused on importing nuclear power plants rather than using domestic nuclear power plants to build nuclear industrial capability.

The countries covered in this note are:

- Taiwan
- Pakistan
- Bangladesh
- Vietnam
- Indonesia
- Malaysia
- Thailand
- Philippines
- Singapore
- Australia

There are four different groups in this list.

The first two countries, Taiwan and Pakistan, already have nuclear power plants in operation and under construction.

The third and fourth countries, Bangladesh and Vietnam are close to starting construction of nuclear power plants.

The countries after Vietnam and before Singapore have considered nuclear power but face issues that make nuclear power difficult, including unsettled domestic politics, limited financial resources, and limited nuclear industry bureaucratic infrastructure. Despite ambitious announcements and plans for building nuclear power projects in this middle group of countries, nuclear power programs have been cancelled or postponed.

The last two countries, Singapore and Australia, have a level of political stability and economic viability that would support a nuclear power program, but have no active nuclear plans.

## A. Taiwan

Like South Korea and Japan, Taiwan must import fossil fuel for electricity generation and has turned to nuclear power to lower fuel imports. Taiwan has six operating reactors that are nearing the end of their original 40-year operating licenses.

Two new Lungmen ABWR units have been under construction for some time. After facing setbacks, including a cancellation by the government that was later overturned, the first Lungmen unit is expected to start commercial operation in late 2014.

Taiwan had plans for six additional nuclear power units, but now only one additional unit is planned after both Lungmen units are operational.

## B. Pakistan

Pakistan's first nuclear power plant is a 125 MW PHWR near Karachi that commenced operation in 1971.

Two CPR-300 nuclear plants supplied by CNNC were built near Chashma in northern Punjab and placed into commercial operation in 2000 and 2011. Two additional CPR-300 plants are being built by CNNC at the Chasma site.

In 2013, China agreed to build two 1,000 MW PWR units near Karachi, with construction scheduled to start in late 2014. Announcements suggest that additional Chinese 1,000 MW units may be built in Pakistan as a key part of Pakistan's electricity infrastructure development plans.

## C. Bangladesh

Nuclear power was first considered in 1961 and land was acquired for a nuclear power plant site at Rooppur in 1963. Several feasibility studies confirmed the technical and economic viability of nuclear power as an energy option, eventually leading to a national Nuclear Power Action Plan in 2001. In 2007, the Bangladesh Atomic Energy Commission proposed two 500 MW nuclear units at the Rooppur site.

A Russian proposal to build a nuclear power plant was approved in 2009. Rosatom agreed to build two 1,000 MW AES-92 nuclear power plants at Rooppur and to provide nuclear fuel services, including the return of used nuclear fuel to Russia. The nuclear deal includes government-to-government loans and Russian support and training for the Bangladesh Nuclear Regulatory Commission.

Site work at Rooppur started in October 2013, and construction of the first Rooppur unit is expected to start in 2015.

## D. Vietnam

Vietnam has studied the potential for nuclear power since the 1980s. In 2006, the government announced that the nuclear power program would proceed.

A plan was approved for state-owned EVN to build 2,000 MW nuclear power plants, one in Ninh Thuan and the other in Ha Tinh. Rosatom, Westinghouse, EDF, KEPCO, a Japanese consortium and CGN all expressed strong interest in supplying the first of these plants.

In 2010, Rosatom was selected for the first plant at Ninh Thuan and an intergovernmental agreement was signed with Russia. This plant was to be a turnkey project that would start

construction in 2014, with significant Russian financing and a Russian agreement to supply nuclear fuel for the life of the plant.

A Japanese consortium was selected for the second plant and an intergovernmental agreement with Japan was signed. METI, JINED and other Japanese companies worked with EVN on a study of the nuclear power plant project.

In early 2014, Vietnam announced that it will delay the start of the Russian nuclear power plant at Ninh Thuan by about six years. The delay will allow Vietnam to further develop nuclear regulatory capability and other nuclear capability. The second Japanese nuclear project will likely be delayed.

The Vietnam government decided to build a 5,000 MW gas-fired power plant that would offset the delayed nuclear power plants and signed agreements with Russia related to LNG imports and a new offshore gas field near Vietnam.

Vietnam's long-term plan to build multiple nuclear plants will be facilitated by an approved 123 Agreement. This will allow nuclear companies from the U.S. and countries with U.S. reactor designs (i.e., Japan and South Korea) to participate in the Vietnam nuclear power market.

## E. Indonesia

Indonesia has developed plans for several nuclear power projects, but none of these nuclear power projects have moved forward. Negative public opinion towards nuclear power, reinforced by the 2011 Great East Japan Disaster, is a significant factor in Indonesia.

Indonesia's 2007 Long-Term National Development Plan envisioned the construction of four new reactors that would be operational by 2024, with the first reactor to be under construction in 2010. Japan and Indonesia signed a nuclear power cooperation agreement in 2007.

In 2011, Indonesia's new minister for state enterprises, Dahlan Iskan, said he had approved a plan to build the country's first nuclear power plant. However, in mid-2012 the national Energy Council said that nuclear power was an unlikely last resort in the country and a government spokesman said the government will continue to study possible development of nuclear power, but it would not be a priority.

In 2013, the head of the National Nuclear Energy Agency said he expects the construction of a nuclear power plant to begin no earlier than 2015.

Indonesia has studied projects involving the South Korean SMART reactor and Russian floating nuclear power plants. In early 2014, a news story reported that a 30 MW nuclear power plant would be built in Indonesia, but without details.

## F. Malaysia

Malaysia has considered nuclear power since the 1970s and several Malaysian nuclear organizations have studied the potential for nuclear power.

In 2008 the government announced a commitment to nuclear power, directed TNB to study the feasibility of nuclear power, and started work on a national energy policy that included nuclear power.

In 2009, the government decided to consider nuclear power and announced in 2010 that Malaysia was planning to build two 1,000-megawatt nuclear power plants. A nuclear site selection process started and the Malaysia Nuclear Power Corporation was established. An initial decision on nuclear power was scheduled for 2013, with construction on the first unit starting in 2016.

The Malaysian government announced in early 2013 that the detailed nuclear feasibility study had been delayed and may not be completed until late 2014. Despite efforts to gain public support, the Energy Minister announced that the project would be placed in a "Keep In View" status (usually indicating that a project has been significantly postponed) due to a lack of public support.

## G. Thailand

Thailand has been considering nuclear power since 1960 and several initiatives to start a nuclear power program were started but all faced political changes, public opposition, and financial issues.

In 2008, Burns & Roe was retained to conduct a 2-year study of siting, technology and size for Thailand's first nuclear power plant.

The latest Thailand Power Development Plan (PDP 2013) includes future options for nuclear power, as did earlier PDPs and PDP revisions.

## H. Philippines

The Philippines started its nuclear program in 1955 under the U.S. Atoms for Peace Program and decided to build a nuclear power plant in the early 1970s.

Construction started on the two-unit Bataan Nuclear Power Plant in 1976, with unit 1 largely completed by 1984 when financial and safety issues stopped the project. Bataan unit 1 has been maintained to allow the option to refurbish the unit and place it into commercial operation.

A 2008 IAEA mission confirmed that Bataan unit 1 could be refurbished with modern safety equipment added and placed into commercial operation. The Philippines National Power Corporation retained KEPCO to do a detailed feasibility study, with the study recommending refurbishment of Bataan 1.

In 2013, National Power Company requested government approval to proceed with the Bataan refurbishment project, but does not expect a decision until 2016.

## I. Singapore

Singapore has a large and growing economy that depends on imported gas and oil to generate electricity. Singapore's energy policy aims to maintain a balance between energy security, environmental sustainability, and economic competitiveness.

In November 2010, the Prime Minister said that Singapore "cannot afford to dismiss the option of nuclear energy altogether." A nuclear pre-feasibility study was done to explore nuclear power options to overcome energy constraints and enhance energy security.

In 2012, the Singapore government discussed the results of a nuclear pre-feasibility study:

- Nuclear energy technologies presently available are not yet suitable for deployment in Singapore;
- Singapore will wait for future nuclear technology and other developments; and
- Meanwhile, Singapore will strengthen nuclear science and technology capabilities and play an active role in global and regional cooperation on nuclear power.

## J. Australia

Australia is one of the largest world suppliers of uranium for nuclear fuel, but has no nuclear power plants and relies heavily on coal-fired power plants.

Australia has considered nuclear power in the past and a nuclear power project at Jervis Bay in NSW was started, but cancelled soon after land was acquired in 1972.

In 2006, an expert taskforce report concluded that nuclear power was more expensive than coal-fired power, but that a moderate price on carbon emissions would make them competitive.

Even if the Australian government were to overcome public opposition to nuclear power, it is unclear how a nuclear power program would be implemented.

The Australian electricity sector was owned by state governments until electricity sector reforms in the 1990s. Today, much of the Australian electricity industry has been restructured, with government-owned utilities replaced with private power plants and market-based investments in a formal electricity spot market.

A new nuclear power plant in Australia would be a merchant generation investment that would require a package of incentives and revenue guarantees similar to the deal offered to the Hinkley Point C project in the UK.

# IV. U.S. Nuclear Export issues

Nuclear cooperation between the U.S. and other countries requires a nuclear cooperation agreement ("123 Agreements"). These agreements include the terms, conditions, duration, nature, and scope of nuclear cooperation and must meet nonproliferation criteria.

U.S. nuclear export controls are an important factor in the nuclear power industry in Asia for at least three reasons:

- Some countries in Asia are parties to 123 Agreements that restrict their nuclear power industry activities (e.g., the current 123 Agreement with South Korea prohibits uranium enrichment and spent nuclear fuel reprocessing);
- Any country that wants to import nuclear power plants with U.S. content must have an active 123 Agreement; and
- A non-U.S. country that wants to export a nuclear power plant with U.S. content is restricted by U.S. nuclear export laws (e.g., South Korean sale of APR1400 reactors to the UAE required a 123 Agreement with the UAE).

Asian countries with active 123 Agreements:

- Australia
- China
- India
- Indonesia
- Japan
- South Korea
- Taiwan
- Thailand

A 123 Agreement with Vietnam has been negotiated, but has not yet completed the required U.S. legislative review process.

South Korea's sale of APR1400 nuclear power plants to the UAE was only possible because the UAE had negotiated a 123 Agreement. Without the UAE 123 Agreement, South Korean, Japanese, and U.S. companies would not have been able to participate in the UAE nuclear procurement process.

The UAE 123 Agreement is seen by U.S. members of Congress and others as an example of how the U.S. can achieve nonproliferation objectives because the UAE 123 Agreement included a legally-binding UAE government commitment not to engage in uranium enrichment or spent fuel reprocessing. Some in the U.S. Congress want all future 123 Agreements to include the same nonproliferation restrictions as the UAE 123 Agreement.

The U.S. President has suggested that a flexible approach to nonproliferation requirements in 123 Agreements, but this is not popular with the U.S. Congress which has started a process to modify U.S. law to make it more difficult for any 123 Agreement without nonproliferation restrictions to gain approval.

The Vietnam 123 Agreement is now under review by the U.S. Congress and will provide a test of the President's more flexible approach.

**South Korea**

South Korea is now negotiating a renewal of the existing 123 Agreement that was to expire in March 2014. In 2013, the parties agreed to extend the existing 123 Agreement by two years, pushing the expiration date to March 2016. The extension was approved by the U.S. Congress at the end of January 2014 and the President is expected to sign the law prior to the expiration of the existing 123 Agreement in March.

South Korea wants to reprocess used nuclear fuel and enrich uranium. These activities, prohibited by the existing 123 Agreement, would allow South Korea to develop an indigenous nuclear fuel cycle capability for its domestic nuclear fleet and to offer full nuclear fuel cycle services to potential nuclear reactor export customers.

South Korea is developing a version of the APR-1400 that is slightly larger, referred to as the APR+ design. The APR+ reactor design is reported to have no U.S. content and could be sold to countries without a 123 Agreement.

**Vietnam**

The U.S. and Vietnam negotiated a nuclear cooperation agreement that was submitted to the U.S. Congress in early 2014 for review.

The Vietnam 123 Agreement includes a preamble that says any foreign reactors built on Vietnamese soil will use foreign fuel, rather than domestically enriched uranium or reprocessed plutonium. This commitment is not in the main text of the agreement and is not considered legally binding. In 2014, the reaction of U.S. Congress to this more flexible approach to 123 Agreements will be seen.

**Taiwan**

In early 2014, a new 123 Agreement with Taiwan was submitted to the U.S. Congress for review. The Taiwan 123 Agreement replaces an earlier 123 Agreement that expires in June 2014.

The Taiwan 123 Agreement includes a legally binding commitment not to enrich uranium or reprocess spent nuclear fuel, consistent with the 2009 UAE agreement. It expected that the U.S. Congress will approve the Taiwan 123 Agreement, with the nonproliferation provisions providing bipartisan support.

**Japan**

With Japanese nuclear new built projects cancelled or delayed, the Japanese nuclear industrial companies are looking at opportunities to build nuclear power plants outside Japan. The nuclear power plant designs offered by Japanese nuclear companies have U.S. content, limiting Japanese nuclear power exports to countries with a 123 Agreement.

Some major potential nuclear power markets, including Saudi Arabia and some of the Asian countries discussed above, do not have a 123 Agreement.

Mitsubishi has selected the ATMEA1 reactor design for the Sinop project in Turkey. The ATMEA1 reactor design, without U.S. content, may provide Mitsubishi with a reactor design that can be sold to countries without 123 Agreements.

**China**

The Chinese CAP1400 reactor design, a larger version of the AP1000, is expected to be offered into the export market, consistent with the AP1000 technology rights agreement with Westinghouse.

However, if U.S. nuclear export restrictions apply to the CAP1400, China may be limited to selling the CAP1400 reactor design to countries with a 123 Agreement.

# V. Glossary

This glossary provides more information on acronyms and terms used in this note.

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| **123 Agreement** | Bilateral nuclear cooperation agreements with the U.S. under Section 123 of the United States Atomic Energy Act of 1954. |
| **ABWR** | Advanced Boiling Water Reactor; a 1,350 MW (or larger) advanced BWR reactor design developed by GE, Hitachi, and Toshiba; variants of the ABWR reactor design are offered by GE Hitachi and by Toshiba. |
| **AP1000** | Advanced Passive reactor design, a 1,000 MW passive safety PWR developed by Westinghouse / Toshiba |
| **APR+** | A larger version of the South Korean APR1400 reactor design, expected to have no U.S. content |
| **APR1400** | Advanced Power Reactor; a 1,400 MW advanced PWR reactor design developed in South Korea; an advanced version of the South Korean OPR1000 reactor design |
| **APWR** | Advanced Pressurized Water Reactor; a 1,500 MW advanced PWR reactor design developed by Mitsubishi Heavy Industries for the Japanese market; a 1,700 MW version was developed for the U.S. and other markets |
| **ASME** | American Society of Mechanical Engineers; a non-profit organization that, among other activities, develops codes and standards that define the requirements for fabrication and testing of nuclear components; the ASME "N-Stamp" is awarded to nuclear component manufacturers and fabricators that meet ASME's criteria |
| **ATMEA & ATMEA1** | ATMEA is a joint venture between AREVA and Mitsubishi Heavy Industries; the ATMEA1 reactor design is a 1,100 MW advanced PWR reactor design developed by the ATMEA JV |
| **Barakah** | Barakah is the site, west of Abu Dhabi on the coast, where the UAE's first nuclear power plant is located |
| **BHEL** | Bharat Heavy Electricals Limited; an equipment manufacturer and engineering company based in New Delhi, India |
| **BOO** | Build, Own, and Operate; a project development approach where the developer builds, owns and operates a project in a host country, with the host country buying the electrical power output of the project |
| **BWR** | Boiling Water Reactor; a reactor design that uses boiling water as the moderator, with steam directly produced in the reactor that drives steam turbines |
| **CANDU** | CANada Deuterium Uranium reactor; Canadian-invented pressurized heavy water reactor design |
| **CAP1400** | China Advanced Passive reactor design, a larger version of the AP1000 reactor design developed in China |
| **CGN** | China General Nuclear Corporation, formerly known as China Guangdong Nuclear Corporation |

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| **CNNC** | China National Nuclear Corporation |
| **CNP-300** | China Nuclear Power reactor design; China's first domestic commercial reactor design; a two-loop 300 MW PWR; first unit located at the Qinshan |
| **EDF** | Électricité de France; the French government-owned electric utility; the EDF Group also has significant activities outside France (e.g., in the UK) |
| **EPR** | Evolutionary Pressurized Reactor (also known as the European Pressurized Reactor); a 1,600 MW advanced PWR reactor design developed by AREVA |
| **ESBWR** | Economic Simplified Boiling Water Reactor; a 1,500 MW advanced boiling water reactor design with passive safety developed by GE Hitachi Nuclear Energy |
| **EU / EC** | European Union / European Commission |
| **EVN** | VietNam Electricity; state-owned EVN is the largest power company in Vietnam |
| **FOAK** | First Of A Kind; in the nuclear industry, this usually refers to the first unit of a reactor design to be built and placed into commercial operation, where FOAK risks including technology, construction and operating risks. However, the term may also be used to refer to the first nuclear plant built in a country, where FOAK risks include nuclear licensing and regulation or to the first nuclear plant built by a vendor, where FOAK vendor risks include experience, management and quality control issues |
| **Gen III / III+** | Gen is short for Generation, a term referring to generations of reactor designs. The early designs are Gen I, most operating reactors are Gen II, and more modern designs are Gen III. Some in the industry considering only reactor designs with passive safety as Gen III+, while others consider modern reactor designs with active safety systems as Gen III+ |
| **Hinkley Point C** | Hinkley Point C is a new nuclear power project at the Hinkley Point site that will have two EPR reactors; EDF Energy is the lead developer; an incentive package was offered by the UK government in late 2013, an EC State Aid investigation of the arrangements is in progress |
| **Horizon** | Horizon Nuclear Power is a UK energy company developing new nuclear power stations at the Wylfa and Oldbury sites; a wholly owned subsidiary of Hitachi, Ltd. |
| **IAEA** | International Atomic Energy Agency; www.iaea.org/ |
| **IPP** | Independent Power Producer; a term that typically refers to a power project that depends on long-term power purchase agreement revenue for returns |
| **IPO** | Initial Public Offering, where some or all of the shares in a company are sold to the public for the first time |

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| **JBIC** | Japan Bank for International Cooperation; a government-owned financial institution and export credit agency |
| **JINED** | International Nuclear Energy Development of Japan Co., Ltd; a Tokyo-based consortium of thirteen Japanese companies focused on proposal and research activities for nuclear power plant export projects |
| **KEPCO** | Korea Electric Power Corporation; the largest electric utility in South Korea and the developer of nuclear power projects; South Korean government is the majority owner of KEPCO |
| **KHNP** | Korea Hydro & Nuclear Power Co. Ltd; a subsidiary of KEPCO, a wholly government-owned corporation |
| **LNG** | Liquefied Natural Gas; this is natural gas that has been cooled to a liquid state for storage and transport |
| **Merchant plant** | A merchant generation plant typically refers to a power plant project investment that depends on electricity market revenue for returns |
| **MW** | Megawatt, a measure of power output; in this note, the term refers to nuclear power plant electrical power output (sometimes referred to as MWe) rather than reactor thermal output (MWth) |
| **NPCIL** | Nuclear Power Corporation of India, Ltd; the entity that owns and operates the nuclear power plants in India; owned by the Indian government |
| **NRA** | The Japanese Nuclear Regulatory Authority |
| **NRC** | The U.S. Nuclear Regulatory Commission |
| **NSG** | The Nuclear Suppliers Group, a group of nuclear supplier countries that contribute to the nonproliferation of nuclear weapons through Guidelines for nuclear exports |
| **NuGen** | NuGen is a UK nuclear company originally owned by GDF SUEZ and IBERDROLA developing new nuclear projects in West Cumbria; in later 2013 and early 2014, Toshiba acquired a controlling interest in NuGen |
| **O&M** | Operation & Maintenance; O&M generally refers to the activities and costs of operating and maintaining a power plant |
| **OL3 / OL4** | The Olkiluoto Nuclear Power Plant is owned by TVO and consists of two older BWR units (OL1 and OL2), a new EPR unit under construction (OL3), and another new nuclear unit that is in the procurement phase (OL4) |
| **OPR1000** | Optimum Power Reactor; a 1,000 MW advanced PWR reactor design developed in South Korea; based on the U.S. Combustion Engineering System 80 PWR reactor design |
| **PHWR** | Pressurized Heavy Water Reactor; a reactor design that uses a heavy water moderator and, typically, natural uranium fuel |

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| **PWR** | Pressurized Water Reactor, a reactor design that uses pressurized water as the moderator and primary coolant, with a steam generator to convert primary coolant energy into steam that is used to drive steam turbines |
| **SMART** | System-integrated Modular Advanced Reactor; a South Korean reactor small integral PWR reactor design with an output of about 100 MW |
| **State Aid** | State Aid is a term used in Europe to refer to activities of a government to intervene in an industry or market; some State Aid activities are not allowed by the EU |
| **TNB** | Tenaga Nasional Berhad; the largest electricity utility in Malaysia |
| **TVO** | Teollisuuden Voima Oyj is a Finnish power company organized under the Finnish Mankala principles and owned by a consortium of energy using companies; TVO owns and operates the Olkiluoto Nuclear Power Plant |
| **U.S.** | The United States of America |
| **UAE** | United Arab Emirates |
| **UK** | United Kingdom of Great Britain and Northern Ireland; with Great Britain consisting of England, Wales, and Scotland |
| **VVER** | Any one of the pressurized water reactors developed in the Soviet Union and Russia; from the Russian Водо-водяной энергетический реактор (Vodo-Vodyanoi Energetichesky Reactor, translates into English as Water [moderated]-Water [cooled] Power Reactor) |
| **WNA** | World Nuclear Association; www.world-nuclear.org/ |

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