China's Nuclear Restart

Opportunities and Challenges in a Modernizing Market

This report is presented by Nicobar Group in Cooperation with the U.S. Department of Commerce

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Nuclear Power in China: Restarted

The October 2012 announcement that China will resume approvals of new nuclear power plants and will invest significantly in safety upgrades to its existing fleet has reopened the door to the world's fastest growing nuclear new build market. Two years after the disaster at Japan's Fukushima Daiichi nuclear power plant, which prompted China to suspend new approvals of nuclear projects in order to review its nuclear expansion plans, a renewed commitment to an aggressive new build plan ensures China's nuclear market will become the focus of global nuclear leaders for years and indeed decades to come.

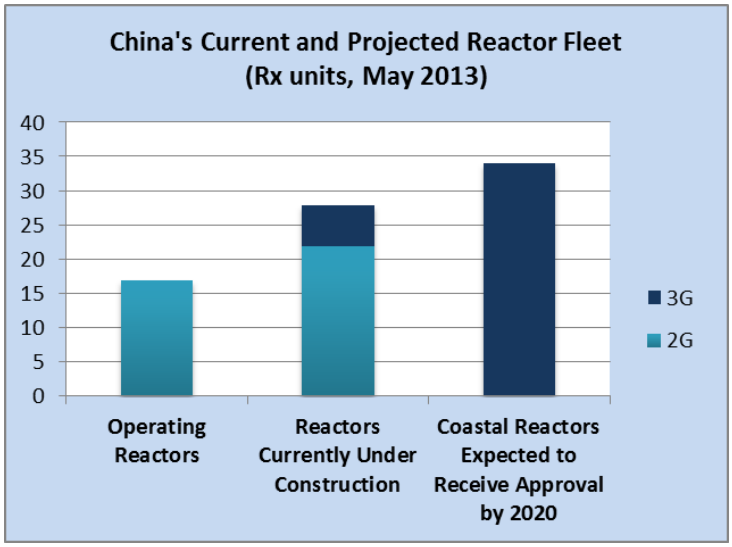

Figure 1

Over the next three years, China plans to approve only coastal projects utilizing third generation (3G) technology, with the Westinghouse AP1000 and 3G evolutions of China's indigenous CPR reactor seeing the widest deployment. While planned inland projects in China prior to Fukushima likely will not proceed before the end of 2015, many industry insiders expect the pace of expansion to accelerate again after 2015 as industry-wide improvement measures are implemented as outlined in the *Nuclear Safety Radioactive Pollution Prevention 12th Five Year Plan and Vision for 2020* approved on October 16th, 2012 by China's State Council.

Summary: China's Expanding Nuclear Fleet

Reactor Model	Operating Units	Under Construction Units
CNP-600	4	2
Framatome PWR-1000	4	-
CPR 1000	4	18
AECL Candu-6	2	-
VVER-1000 (AES-91)	2	1
CNP-300	1	-
EPR	-	2
AP1000	-	4
HTR-PM	-	1
TOTAL	***17***	***28***

Reactor Model	Coastal Units Planned (pre-2020 construction start)	Inland Units Planned *(suspended)*
ACPR1000 / ACP1000	14	-
AP1000*	14	*12*
VVER-1000 (AES-91)	3	-
CAP1400	2	-
EPR	2	-
BN-800	2	-
ACP100	1	*1*
TOTAL	***38***	***13***

**Chinese indigenous adaption*

Figure 2

China's current operating fleet is a mix of imported and indigenous second-generation (2G) reactors. Over two dozen 2G and 3G reactors that are currently under construction will be gradually brought online over the next few years, increasing China's installed nuclear power generating capacity to more than 40GWe from 14.5GWe as of May 2013. With plans to reach approximately 58GWe of generating capacity from mostly 3G reactors by 2020, China will become home to one of the largest and most advanced nuclear fleets in the world.

Building, operating, and maintaining this fleet will put tremendous pressure on China to develop the technical resources and train the human capital necessary for safe, efficient nuclear power generation. With decades of experience, advanced technologies, and strong quality and performance pedigrees, U.S. nuclear companies are well positioned to successfully fill many of the gaps in China's commercial nuclear market.

China's Post-Fukushima Nuclear Safety Plan

Shortly after the disaster at Fukushima Daiichi in March 2011, China suspended approvals of new nuclear power projects and announced plans to conduct comprehensive safety reviews of all nuclear facilities in operation and under construction, as well as a review of all projects in the planning stages. Safety reviews on all operating units concluded in May 2012.

On October 16th, 2012, China's State Council released the long-awaited *Nuclear Safety Radioactive Pollution Prevention 12th Five Year Plan and Vision for 2020* (henceforth referred to as the 'new nuclear safety plan'). The purpose of the plan was to identify safety gaps in China's nuclear power plants and fuel cycle facilities, its regulatory capacity as well as certification and verification systems, domestic R&D of nuclear safety technology, radioactive waste storage and management, and environmental radiation monitoring capabilities.

China's Post-Fukushima Investment in Nuclear Safety

By 2015, China is calling for the investment of nearly RMB¥80 billion (USD$13 billion) in nuclear safety improvement measures, including:

- Safety equipment upgrades at China's nuclear facilities
- Improvements in radioactive waste management and environmental radiation monitoring
- Increased research and development of nuclear safety technology
- Development of disaster monitoring and emergency response capabilities
- Nuclear regulatory capacity building

The new nuclear safety plan outlines measures for upgrading the safety of China's nuclear facilities and improving radioactive contamination control by 2015. China intends to bring its nuclear safety standards in line with international best practices by 2020.

Foreign Nuclear Companies in the Post-Fukushima China Market

The extensive upgrades and retrofits China will carry out over the next few years and the decisive shift to 3G technology in its new build plans will challenge China's nuclear expansion program. China's renewed emphasis on safety in domestic nuclear projects will continue opening market segments to American companies with solid performance track records. While some foreign firms have found lucrative commercial opportunities in China, many others have found identifying a suitable point of entry into the world's fastest growing nuclear market a challenge. Developing a sharp strategy to this dynamic market is a challenge requiring a sound grasp of the local landscape and how it continues to evolve in the aftermath of the disaster at Fukushima Daiichi nuclear power plant.

Chinese Nuclear Regulatory Structure

The State Council is the chief administrative authority in China, under which exists a web of ministries, commissions, and other organizations responsible for nuclear policymaking and regulation.

National macroeconomic energy policy is shared by the National Development & Reform Commission (NDRC) and its sub-organ the National Energy Administration (NEA), as well as the National Energy Commission (NEC). The China Atomic Energy Authority (CAEA) is primarily responsible for exchanges and cooperation with foreign governments and international organizations in the nuclear field, such as the IAEA, as well as emergency response planning. The

State-owned Assets Supervision and Administration Commission (SASAC) also exercises influence over nuclear planning through its investment in and supervision of some of China's largest nuclear firms. The National Nuclear Safety Administration (NNSA) is responsible for licensing and permitting, and currently is working with the U.S. Nuclear Regulatory Commission (NRC) on the AP1000 projects sharing regulatory best practices.

China's Regulatory Challenges & Improvement Measures

- Regulatory decision-making fragmented across many government bodies
- Regulatory capacity has not kept pace with speed and scale of nuclear development in China
- Investment in technical enforcement capabilities of regulators
- Construction of nationwide network of 31 radiation monitoring stations

Regulatory Challenges and Improvement Measures

Investment in regulatory capacity has not kept pace with the scale and pace of nuclear development in China. There is a shortage of experienced nuclear safety regulatory personnel, and regulators lack sufficient analytical capability and the ability to evaluate test data efficiently. The new nuclear safety plan emphasizes a need to strengthen the independence, authority, and effectiveness of China's nuclear regulatory bodies through increased investment in technical enforcement capabilities. The plan also outlines an ambitious development effort building a nationwide environmental radiation monitoring system, including the construction of 31 provincial disaster monitoring stations and the deployment of radiation detection devices at China's many seaports.

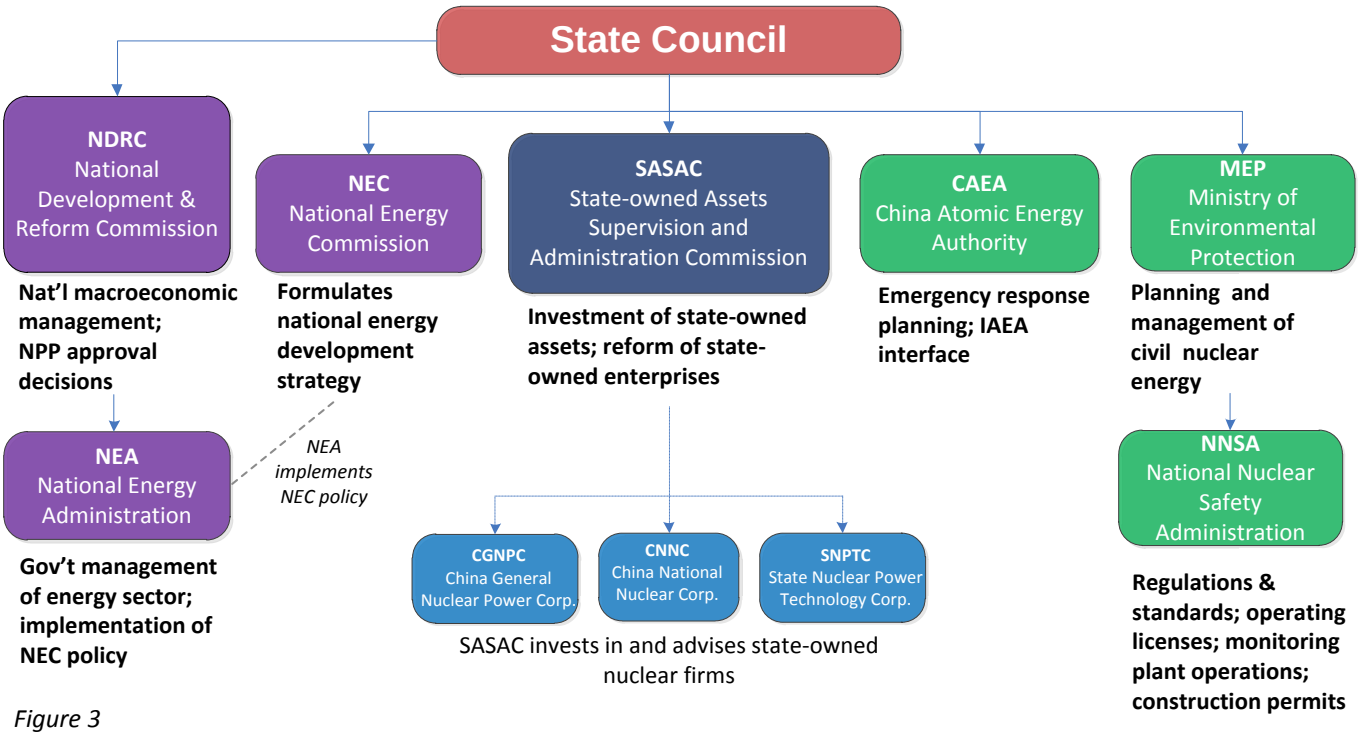

Figure 3

China's Nuclear Fuel Cycle

Fuel cycle activities in China remain controlled by China National Nuclear Corp. (CNNC) and China General Nuclear Power Group (CGNPC; formerly named China Guangdong Nuclear Power Group). Through its subsidiaries, CNNC controls all conversion, enrichment, fuel fabrication, reprocessing, storage, and disposal activities. Recently, CGNPC has begun making moves to become more independent of CNNC through acquisition of numerous overseas and domestic uranium assets. CGNPC and its subsidiaries have acquired mines in Africa and Central Asia, and CGNPC-Nuclear Fuel Co. Ltd. will soon undertake development of a uranium mine in northwest China. Despite an announcement in November 2012 of the discovery of a large uranium deposit in China's Inner Mongolia Autonomous Region, China will remain dependent on imported uranium in the coming decades.

Looking Ahead in China's Nuclear Fuel Cycle

- CGNPC pushing for greater independence from CNNC in fuel cycle activities
- Accelerated decommissioning of fuel cycle facilities
- Aggressive construction of radioactive waste disposal sites
- Expansion of uranium mining and processing infrastructure

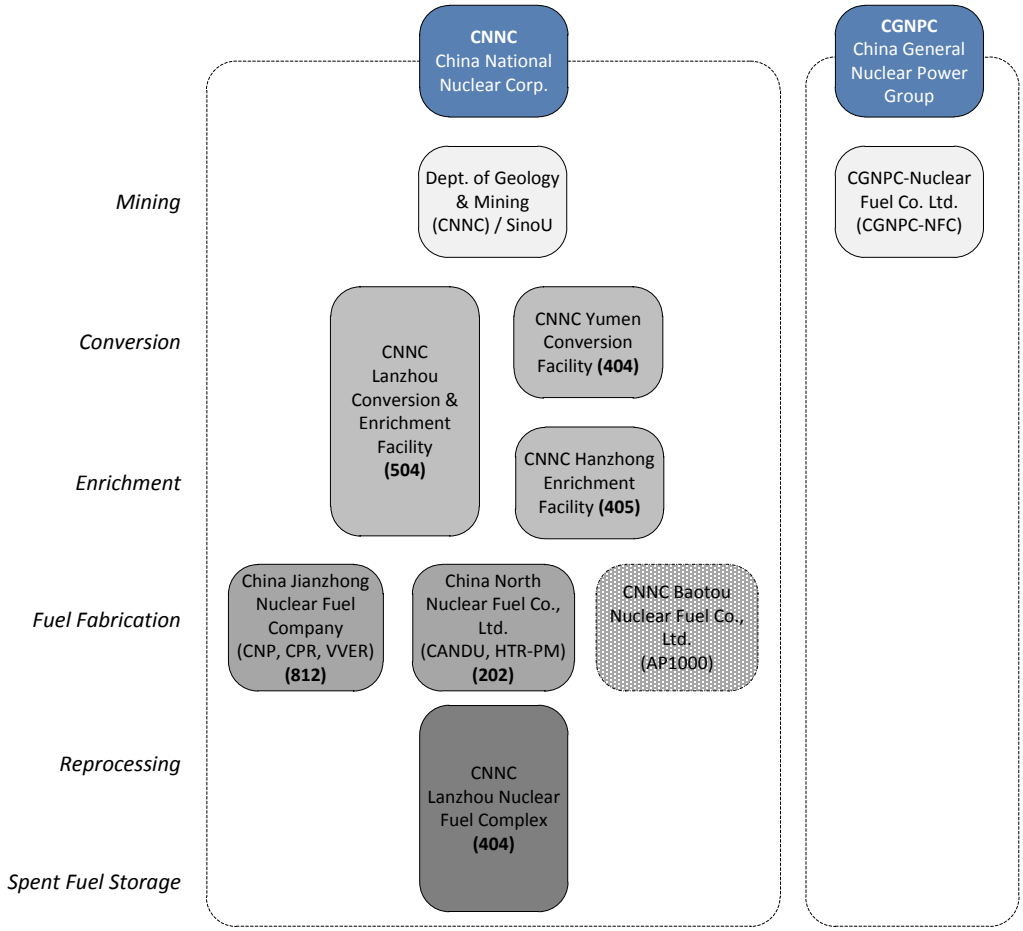

Figure 4

Fuel Cycle Challenges and Improvement Measures

China's rapid new build program will put significant pressure on the domestic fuel cycle, and China will continue to look to foreign expertise in both the front-end and back-end it builds out its fuel cycle infrastructure to support this growth. China

plans to invest in uranium mining and processing facilities, the construction of two or three regional radioactive waste disposal sites, and the accelerated decommissioning of fuel cycle facilities and equipment. The management of fuel cycle infrastructure, including technical, storage, logistics, and staffing aspects, is one of the biggest challenges facing the Chinese nuclear industry in the coming years.

China's Evolving NPP Ownership Landscape

- Gradual liberalization of NPP ownership
- Suspension of inland project approvals will slow expansion of majority ownership rights
- New players moving are taking on minority ownership stakes in China NPPs

Nuclear Power Plant Ownership

While most of China's power industry (coal, hydro, wind) is dominated by China's "Big 5" power generation companies, the nuclear power sector has historically been and continues to be largely controlled by two separate nuclear-specific owner-operators: CNNC and CGNPC, the same SOEs that control fuel cycle activities in China.

The industry is gradually liberalizing in terms of ownership: One of the "Big 5" players, China Power Investment Corp. (CPI), after taking minority stakes in several earlier nuclear power plants, joined CNNC and CGNPC as China's third authorized nuclear power plant majority owner-operator. CPI currently owns a 65% stake in the new Haiyang nuclear power plant, the site of two of the first four AP1000 units in China (the other two China AP1000 units are located at Sanmen in Zhejiang province under CNNC's ownership).

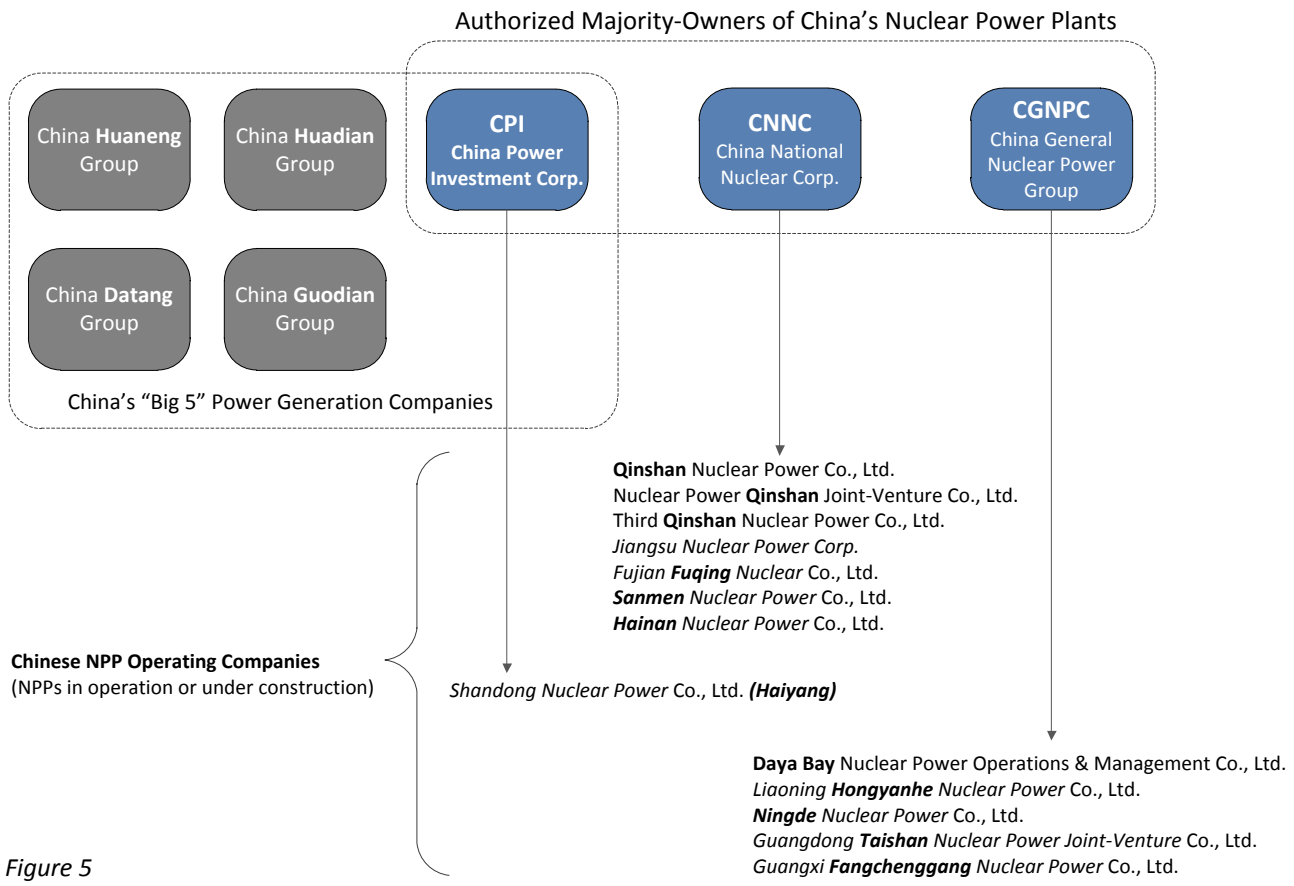

Figure 5

Ownership in China Two Years after Fukushima

Aside from CPI's transition into a majority ownership role in addition to its minority stakes in several nuclear power plants, each of the other four of the "Big 5" generators, Huadian, Datang, Huaneng, and Guodian, now also own minority stakes in Chinese nuclear power plants. The trend towards liberalization of nuclear power plant ownership was more pronounced prior to Fukushima as these firms sought to expand their ownership stakes in planned inland plants. With the recent suspension of these inland projects, it now appears likely that this trend will slow. In the coming years, the nuclear operations of these other "Big 5" generators may face competition from national power companies such as Three Gorges Group, China Resources Holdings Company, and other companies, who have been slowly moving in to claim minority ownership stakes in China's new nuclear power plants.

Construction in China's Post-Fukushima Nuclear Market

- Only 3G generation nuclear projects will be approved post-Fukushima
- No inland projects to be approved before the end of 2015
- Cooperation with U.S. NRC on AP1000 construction and supplier inspection
- Ambition to use new build as demonstration of advanced 3G construction capability

New Build & Procurement

China Nuclear Engineering & Construction Group (CNEC) holds a monopoly on nuclear power plant construction. CNEC deploys one of its five daughter nuclear construction companies on a per-project basis for the required civil construction and installation work. These daughter companies are in turn responsible for the procurement of construction materials and services from both domestic and international suppliers. The majority of nuclear power plant equipment and components procurement, whether local or foreign, is handled by one of three EPCs contractors: SNPEC, CNPE, or CNPEC (see Figure 6 below), with involvement dependent on plant type and ownership. Regional Chinese construction companies not directly affiliated with CNEC have participated in turbine-island and balance-of-plant construction, and are now pushing for greater involvement in other aspects of nuclear power plant construction.

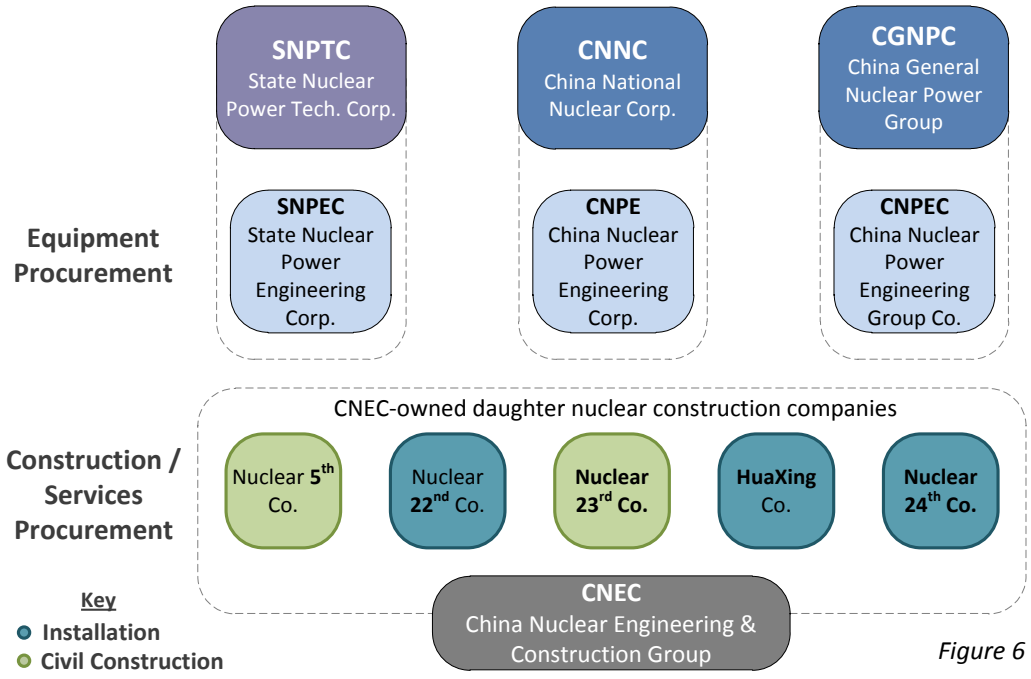

Figure 6

Construction in the Post-Fukushima Era

The rapid pace of construction over the past few years has raised concerns about the safety of China's nuclear projects. The decision to postpone all inland projects and proceed with 3G coastal new build over the next few years was, in part, a nod to such concerns. China aims to achieve the highest global safety standards in nuclear construction, and is working closely with the U.S. NRC on AP1000 construction and vendor inspection. As evidence of China's expanding EPC capabilities, SNPTC announced in October 2012 that they will provide Shaw Group (now CB&I) with technical support for the AP1000 units underway at Vogtle. China hopes to showcase its expertise in nuclear power plant construction and serve as a counterpoint to the delays and cost overruns that have been encountered in Finland and France during deployment of Areva's EPR reactor.

Verification and Certification in the Post-Fukushima China Market

- China regulates safety-related equipment with HAF 601 and HAF 604 certifications
- 217 foreign firms certified to export nuclear safety-related equipment to China
- Increased investment in technical enforcement capabilities
- China to adopt stringent international safety standards to raise threshold for entry into industry

Regulation and Certification of Nuclear Safety-Related Equipment

In order to ensure the quality of nuclear safety-related equipment procured for use in China's growing reactor fleet, China's National Nuclear Safety Administration (NNSA) issues certifications covering the design, manufacture, installation, and non-destructive testing of electrical and mechanical nuclear safety-related equipment. A company must apply for and be granted certification for each category of nuclear-safety component it aims to sell into China.

HAF 601/604 Certification

HAF 601 certification is required for all firms seeking to manufacture, design, install, or test safety-related equipment at a facility based in China. As of May 2013, there were 191 companies with a HAF 601 certification and more applications are in process. While the majority of these firms are wholly Chinese-owned enterprises, numerous Sino-foreign joint ventures and wholly foreign-owned enterprises have been successfully certified as well.

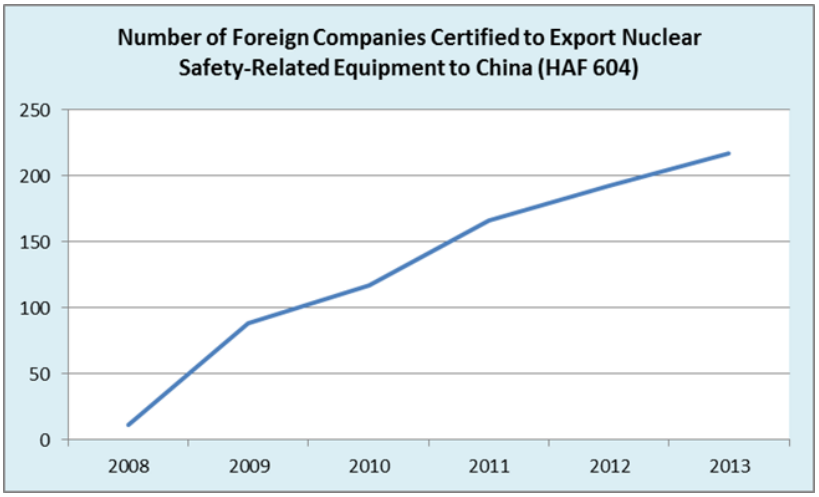

Figure 7

HAF 604 certification is required of firms exporting nuclear safety-related equipment and components into China. In 2008, the first 11 foreign firms received HAF 604 certification. That number has grown rapidly over the past four years; American, French, and German firms now collectively account for approximately two-thirds of the 217 foreign companies with HAF 604 certification (Figure 7; as of May 2013). The table in Figure 8 summarizes the safety-related equipment categories that are covered under NNSA's HAF 601 and 604 regulatory structure.

Nuclear Safety-Related Equipment Categories Requiring HAF 601/604 Certification

Safety-Related Mechanical Equipment			Class 1E Equipment	
Steel Containment	*Fans*	*Supports*	*Sensors*	*Equipment Cabinets*
Containment Liners	*Compressors*	*Bellows & Expansion Joints*	*Cables*	*Control Consoles & Displays*
Pressure Vessels	*Valves*	*Gates*	*Electrical Penetrations*	*Emergency Diesel Generators*
Tanks	*Pumps*	*Mechanical Penetrations*	*Storage Batteries*	
Heat Exchangers	*Core Internals*	*Flanges*	*Valve Actuators*	
Pipes and Pipe Fittings	*CRDM*	*Forgings*	*Electric Motors*	

Figure 8

Inspection, Verification, and Certification in Post-Fukushima China

The new nuclear safety plan states that China's nuclear regulators possess insufficient technical means for conducting effective verification and certification work. China has expressed preference for technology and services from firms with established commercial and performance track records, and the new nuclear safety plan intends to 'raise the threshold' for entry of Chinese equipment suppliers into the nuclear industry by improving inspectors' verification capabilities. As stated in the plan, China intends to adopt the most stringent international nuclear safety standards and will continue to build upon international cooperation with the U.S. NRC on AP1000 supplier inspection as well as participation in the Multinational Design Evaluation Program (MDEP) as the next-generation of nuclear reactor construction is pioneered in China.

Foreign Technology in China's Nuclear Market

Since the early years of its civil nuclear program, China has aggressively sought opportunities for cooperation in the global nuclear industry, such as those with Framatome (now part of Areva), Westinghouse, Electricité de France (EDF), Atomic Energy of Canada Ltd. (AECL), and Atomstroyexport.

China's reliance on imported nuclear technology in the 1980s and 1990s over time has given way to a more balanced approach characterized by a mix of both domestic and foreign provision of technology and services. However, the new nuclear safety plan points to China's low level of domestic R&D in nuclear safety technology as a major challenge to China's ambitious nuclear expansion plans. As China upgrades its existing fleet and moves forward with approval and deployment of 3G reactors, a balance will need to be struck between the desire for greater local procurement and the renewed emphasis on safety and quality in a post-Fukushima market.

Technology in Post-Fukushima China Market

- Low levels of domestic investment in nuclear safety technology R&D
- Imbalance between increasing localization requirements and demand for high quality technology
- Western quality and safety records are key advantages in China's nuclear market

Fukushima's Effect on Foreign Firms' Export Strategies

The gap between foreign and domestic nuclear technological capabilities is expected to lead to increased commercial demand for advanced technologies and services from foreign companies with proven commercial track records. This may relieve some of the pressure on such firms to localize, at least in the short term. However, the time necessary to process the expected influx of equipment certification applications from foreign firms may lengthen as China implements more stringent inspection procedures. This uncertainty, coupled with the improving capabilities of the domestic nuclear industry, will challenge foreign companies' abilities to design export strategies that provide the necessary flexibility to remain competitive in China's dynamic commercial nuclear market.

Future of International Cooperation on 3G Technology

- China plans to boost joint technology development with international players
- Western firms are establishing platforms for broad cooperation with China
- Successful participation in China's nuclear market increasingly requires a robust and innovative local presence

New Forms of Sino-Foreign Partnership

The new nuclear safety plan highlights cooperation and joint-development of nuclear technology with international players as a key focus for China's nuclear sector in the coming years. Western companies with an eye toward the Chinese and other global markets have begun exploring new ways of leveraging their strengths to cooperate and partner with domestic Chinese players. Notable recent examples of Sino-Foreign cooperation on nuclear projects can be found in Figure 9.

There are numerous resources available to assist foreign firms in cooperating with Chinese partners. The US – China Energy Cooperation Program's (ECP) recently announced Nuclear Power Working Group (NPWG) is currently the most prominent private bilateral platform for Sino-American joint development of nuclear technology. It is co-chaired by General Electric and Westinghouse, with Curtiss Wright, Duke Energy, and Emerson Rosemount also as founding members. It aims to develop opportunities for American participation in China's nuclear projects. Besides sharing best practices and cooperating on technical standards and specifications, the NPWG also provides support for the development of nuclear liability protection protocol in China. The NPWG is expected to play an important role shaping Sino-US partnerships in the years to come.

Sino-Foreign Nuclear Cooperation

Project	Partner Companies	Year
Development of global AP1000 supply chain	Westinghouse and SNPTC	2013
Development of recycled uranium and thorium-fueled reactors	Candu Energy Inc. and CNNC subsidiaries	2012
JV for production of crane components and fuel handling equipment	PaR Nuclear and Taiyuan Heavy Machinery	2012
JV for production of zirconium sponges	Westinghouse and SNZ	2012
Technical support for AP1000 construction	SNPTC and Shaw Group	2012
AP1000 engineering, design, and data management solutions	Intergraph and SNPTC	2011
Development of safety I&C platforms and reactor protection systems	Lockheed Martin and SNPAS	2010
Nuclear power training	Duke Energy and China Huaneng Group	2010

Figure 9

While companies can benefit from participating in China's nuclear market, there are significant risks as well. China's fast-changing nuclear market is very complex, and a lack of local knowledge can lead to poor planning and execution. Whether pursuing an export-only approach to the China nuclear market or choosing to localize marketing, design, manufacturing, logistics, installation, or after-sales service, practical concerns on the part of the Chinese customer regarding accessibility, communication, time, and cost must receive consideration.

The push for next-generation new build in China is expected to propel the global development of this technology, and the innovations in nuclear technology and services that occur in China over the next decade may well end up defining the rules of the game in the future global nuclear industry. American firms with a robust approach to world's most promising nuclear market can use the platforms they establish in China to fundamentally enhance their advantage in international nuclear markets.

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