China's Nuclear Industry in 2015

Moving Forward

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Industry Overview

First Chinese Plant Approvals Post-Fukushima

- **Hongyanhe 5 & 6 are the first NPP units approved for construction since the Fukushima disaster, four years earlier**
- **Policymakers are pushing ahead with 3G reactor deployment plans**
- **Pace of reactor construction will significantly ramp up in 2015 and 2016**

In March 2011, the Fukushima disaster brought plant approvals and construction in China to a halt, and a moratorium on construction was put in place while domestic plants underwent a series of safety inspections that resulted in mandatory safety upgrades to plants throughout the fleet. Construction resumed in 2012, but it was four years after Fukushima before the Chinese government announced approval of any new projects to begin construction.

In March 2015, the National Development and Reform Commission (NDRC) officially announced the first new approvals for construction since the 2011 moratorium was put in place: Hongyanhe units 5 and 6 in Liaoning province. Preliminary regulatory approval documents for Hongyanhe 5 and 6 indicate these units will utilize the 2G+ ACPR1000 design, a predecessor to China's new flagship indigenous 3G PWR design, the Hualong 1.

Earlier this month, the State Council issued final approval for Fuqing 5 and 6, which will utilized the Hualong 1 design. This is a significant endorsement by Chinese nuclear policymakers and State-owned Enterprises (SOEs) of China's first indigenous 3G design.

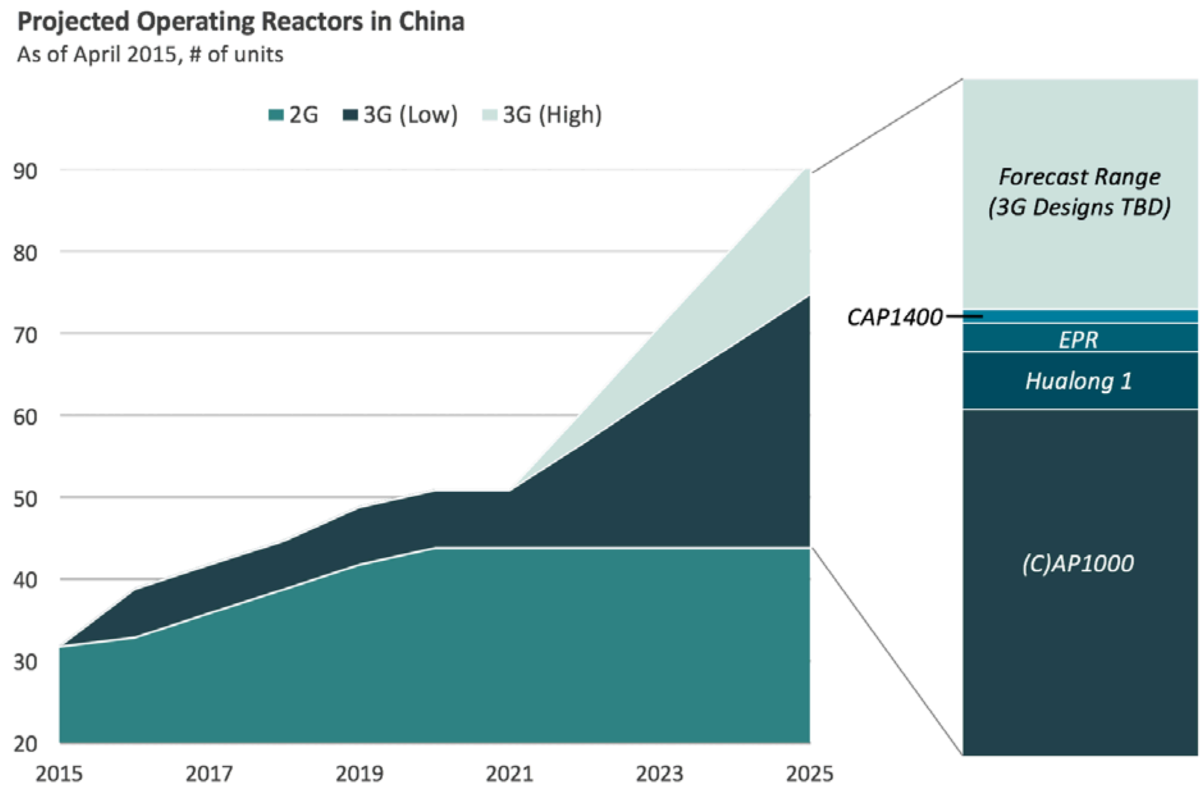
Despite that the country's first 3G projects at Sanmen, Haiyang, and Taishan, are still under construction, the newest approvals at Hongyanhe and Fuqing plants represent major milestones in the effort to advance China's ambitious plans for nuclear power plant construction. The rate of reactor construction starts is expected to significantly increase throughout 2015 and into 2016, which is aligned with Chinese policymakers' target of 58 GWe of operating nuclear power capacity in place by 2020 outlined in the 12th Five Year Plan.

Current Deployment Plans and Emphasis on 3G

China's current operating fleet contains a variety of imported and indigenously designed 2G reactors. In the next five years, the country will need to construct over two dozen reactors, the majority of which will be 3G designs, including the indigenous Hualong 1 design and the Chinese variation of the Westinghouse AP1000, known as the CAP1000. After the Fukushima disaster China committed to deploying only 3G reactors, but there still remain 6 sites whose owner-operators have yet to determine which 3G design will replace the initially planned 2G designs. Whichever designs are selected, the shift to 3G is underway.

Total nuclear generating capacity in China is 20 GWe as of April 2015, with a further 26 GWe of capacity under construction. Coastal power plant construction has increased in pace since resuming in 2012 following the completion of China's post-Fukushima safety review. In both 2013 and 2014, slightly over 3 GWe of generating capacity came online annually. Our baseline forecast projects new construction starts will jump from an average annual increase of approximately 3 GWe in 2011-2015 to 8 GWe in 2016-2020. Some predict the pace of new plant construction starts will reach as high as 11 GWe per year during the 2015-2017 period and perhaps more if the Sanmen AP1000 project is finished before 2016.

Inland power plant construction is expected to restart at the end of 2015 or the beginning of 2016. Construction start dates of the first inland projects also will impact the pace of overall nuclear capacity expansion.



The 13th Five Year Plan, expected to receive approval in the spring of 2016, may lower China's 2020 operating nuclear power capacity target to 53 GWe from the current 58 GWe target. This potential adjustment will depend in part on NPP construction progress made in 2015, especially at sites where China's first 3G units are being built. Whatever the new target, the rate of construction must markedly increase from its current level to meet a goal within that range.

CPI-SNPTC Merger to Create Third Major Nuclear Owner-Operator

Announced on February 2, 2015, the merger of SNPTC and CPI, one of China's "Big 5" power utilities, will have a major impact on China's nuclear industry by forming a large and highly capable competitor of CGN and CNNC, as well as likely streamlining procurement and freeing up additional resources for new reactor research. Negotiations between the two companies as well as with the State-owned Assets Supervision and Administration Commission (SASAC) were publicly remarked upon by the presidents of SNPTC and CPI in April 2014; talks are thought to have begun as early as 2012. CNNC lobbied unsuccessfully against the merger and instead called for closer collaboration and coordination among CNNC, SNPTC, CPI, and CGN while maintaining the status quo.

The most recent draft plan for the CPI-SNPTC merger includes the creation of a parent company called State Power Investment Group Corporation (SPI).

Nominally and functionally, SNPTC and CPI will remain separate while the two companies form a reorganization team and plan the restructuring. SNPTC is expected to take the lead in the reorganization process, with its president Wang Binghua named director of the reorganization team and CPI president Lu Qizhou serving as deputy director. The precise details of the restructuring will be announced as part of the final reorganization plan.

	CNNC China National Nuclear Corp.	SPI State Power Investment Group Corp.	CGN China General Nuclear Power Corp.
NPP Owner-Operators	• Qinshan Nuclear Power Co. • Nuclear Power Qinshan Joint Venture Co. • Third Qinshan Nuclear Power Co. • Jiangsu Nuclear Power Co. • Fujian Fuqing Nuclear Power Co. • Sanmen Nuclear Power Co. • Hainan Nuclear Power Co.	• State Nuclear Power Demonstration Plant Co. • Shandong Nuclear Power Co.	• Daya Bay Nuclear Power Operations & Management Co. • Liaoning Hongyanghe Nuclear Power Co. • Ningde Nuclear Power Co. • Guangdong Taishan Nuclear Power Joint Venture Co. • Guangxi Fangchenggang Nuclear Power Co.
In Operation	• Qinshan Phase I, 1 (CNP300) • Qinshan Phase II, 1-4 (CNP600) • Qinshan Phase III, 1-2 (Candu 6) • Fangjiashan 1-2 (CPR1000) • Tianwan 1-2 (WER1000) • Fuqing 1 (CPR1000)		• Daya Bay 1-2 (M310) • Ling Ao Phase I, 1-2 (M310) • Ling Ao Phase II, 1-2 (CPR1000) • Yangjiang 1-2 (CPR1000) • Ningde 1-3 (CPR1000) • Hongyanhe 1-3 (CPR1000)
Under Construction	• Sanmen 1-2 (AP1000) • Tianwan 3-4 (WER1000) • Changjiang 1-2 (CNP600) • Fuqing 2-4 (CPR1000)	• Haiyang 1-2 (AP1000) • Shidaowan 1-2 (CAP1400)	• Yangjiang 3-4 (CPR1000) • Taishan 1-2 (EPR) • Fangchenggang 1-2 (CPR1000) • Yangjiang 5-6 (ACPR1000) • Ningde 4 (CPR1000) • Hongyanhe 4 (CPR1000) • Hongyanhe 5 (ACPR1000)
Approved	• Sanmen 3-4 (CAP1000) • Tianwan 5-6 (ACPR1000) • Taohuajiang 1-4 (CAP1000) • Haixing 1-2 (CAP1000) • Changjiang 3-4 (CNP650 or ACP600) • Xudabao 1-2 (CAP1000) • Fuqing 5-6 (Hualong 1) • Putian 1-2 (ACP100) • Zhangzhou 1-4 (CAP1000)	• Haiyang 3-4 (CAP1000) • Pengze 1-2 (CAP1000) • Xiaomoshan 1-2 (CAP1000)	• Fangchenggang 3-4 (Hualong 1) • Fangchenggang 5-6 (CAP1000) • Shanwei (Lufang) 1-2 (CAP1000) • Huizhou 1-2 (CAP1000) • Taishan 3-4 (EPR) • Xianning (Dafan) 1-2 (CAP1000) • Ningde 5-6 (Hualong 1) • Hongyanhe 6 (ACPR1000)
Planned	• Hongshiding 1-2 (ACPR1000) • Longyou (Zhexi) 1-2 (CAP1000) • Yanjiashan 1-2 (CAP1000) • Sanming 1-2 (BN800)	• Bailong 1-2 (CAP1000) • Zhanjiang 1-4 (CAP1000) • Guidong (Pingnan) 1-4 (CAP1000) • Fuling 1-4 (CAP1000)	• Ningde 5-6 (ACPR1000) • Wuhu 1-2 (CAP1000) • Shaoguan 1-4 (CAP1000) • Lianyungang 1-2 (ACPR1000)

Notes: 1) NPPs listed above are classified according to the owner-operator holding the largest equity share, and most plants also have one or more minority shareholders; 2) The Shidaowan HTG-PM demonstration fast reactor is currently under construction. China Huaneng Group holds the largest share (47.5%); 3) Only nearer-term planned NPPs are listed in 'Planned'; 4) This list is up to date as of April 2015

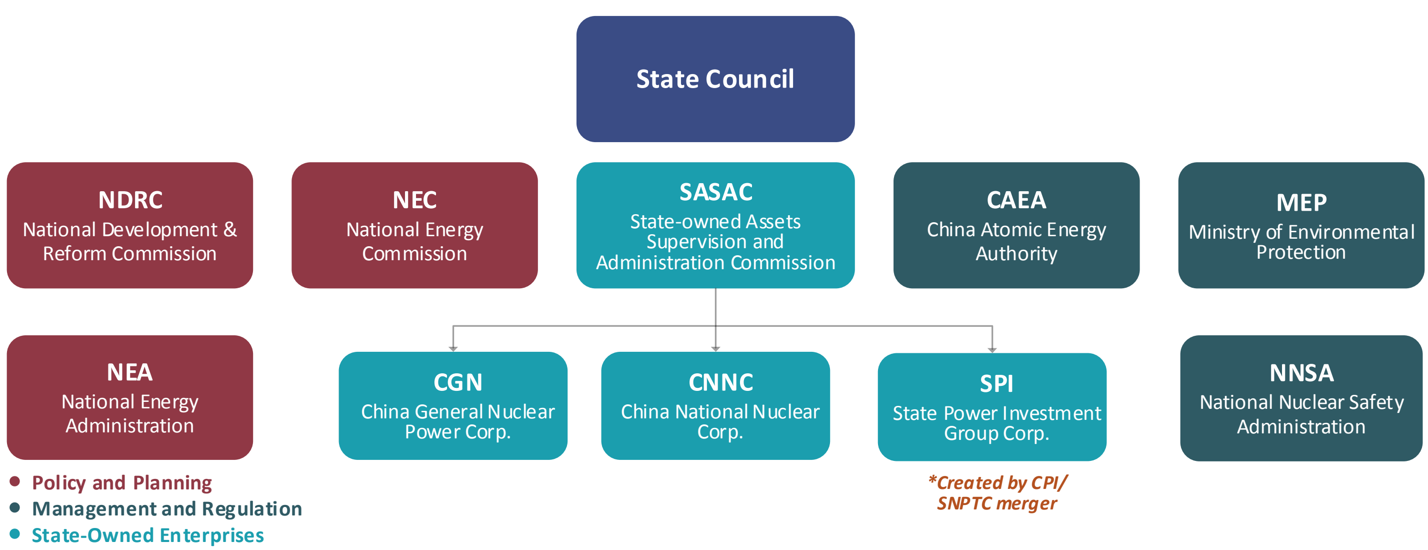
By combining SNPTC's technological advantages with CPI's strong finances and NPP operating certificate, the merger will have synergistic effects. CPI will gain design capabilities and SNPTC will have access to new site locations for the deployment of its reactors designs. These respective capabilities will make the new company, SPI, comparable in size and scope to CGN and CNNC, as each firm will have its own design institute, reactor technology, technical services company, operating company, and EPC. Each large nuclear SOE is more likely to use their proprietary designs and services.

The deal is also a merger of China's conventional power industry and the nuclear power industry as it will be the first time a Chinese "Big 5" power company has successfully owned nuclear power assets through a merger. On a larger scale, SNPTC's conventional design institutes will likely receive more contracts to support CPI's massive conventional power fleet. While unlikely to significantly influence progress toward localization of CAP1000 components or design development, the merger may help expedite development of China's indigenous CAP1400 reactor and strengthen efforts to export it and other designs.

As a result of the merger, SNPTC should benefit from more stable revenues from CPI's large power generation portfolio, some of which could be directed towards R&D projects. Shanghai Nuclear Engineering Research and Design Institute (SNERDI), SNPTC's design subsidiary, is developing a small-scale CAP-150 and CAP-FNPP designs, but also has plans to develop a full range of CAP reactors from 40MWe to 1700MWe. With SNERDI's resources, CPI may reconsider developing their own SMR design as well.

Industry Structure and Oversight 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 China's largest nuclear firms. Similar to the U.S. Nuclear Regulatory Commission (U.S. NRC), the National Nuclear Safety Administration (NNSA) is responsible for licensing, permitting, and oversight. NNSA is currently working with the U.S. NRC on the AP1000 projects to share regulatory best practices. Unlike the NRC, however, NNSA also issues certifications for both foreign and domestic safety-related components supplied to plants.



Regulatory Challenges and Improvement Measures

Following the 2011 Fukushima disaster and China's subsequent country-wide nuclear safety review, the State Council passed the Nuclear Safety Radioactive Pollution Prevention 12th Five Year Plan and Vision for 2020 in October 2012. The plan contained industry-wide improvement measures that allowed the country to resume its rapid build program while reducing risk, identifying safety gaps in nuclear power plants and fuel cycle facilities, regulatory capacity, certification and verification systems, domestic R&D of safety-related technology, waste storage and management, and environmental radiation monitoring. The safety plan emphasized the need to strengthen the independence, authority, and effectiveness of China's nuclear regulatory bodies through increased investment in technical enforcement capabilities.

Investment in regulatory capacity has not kept pace with the scale and pace of nuclear development in China. The country is experiencing a shortage of experienced nuclear safety regulatory personnel – regulators lack sufficient analytical capacity, experience, and the ability to evaluate test data efficiently. Philippe Jamet, Commissioner of the French Nuclear Safety Authority, testified before the French National Assembly in June 2014 that "the Chinese security authority does not meet our expectations currently, and an explanation for this difficulty in our relationship is that the Chinese authority lacks the means. They are overwhelmed."

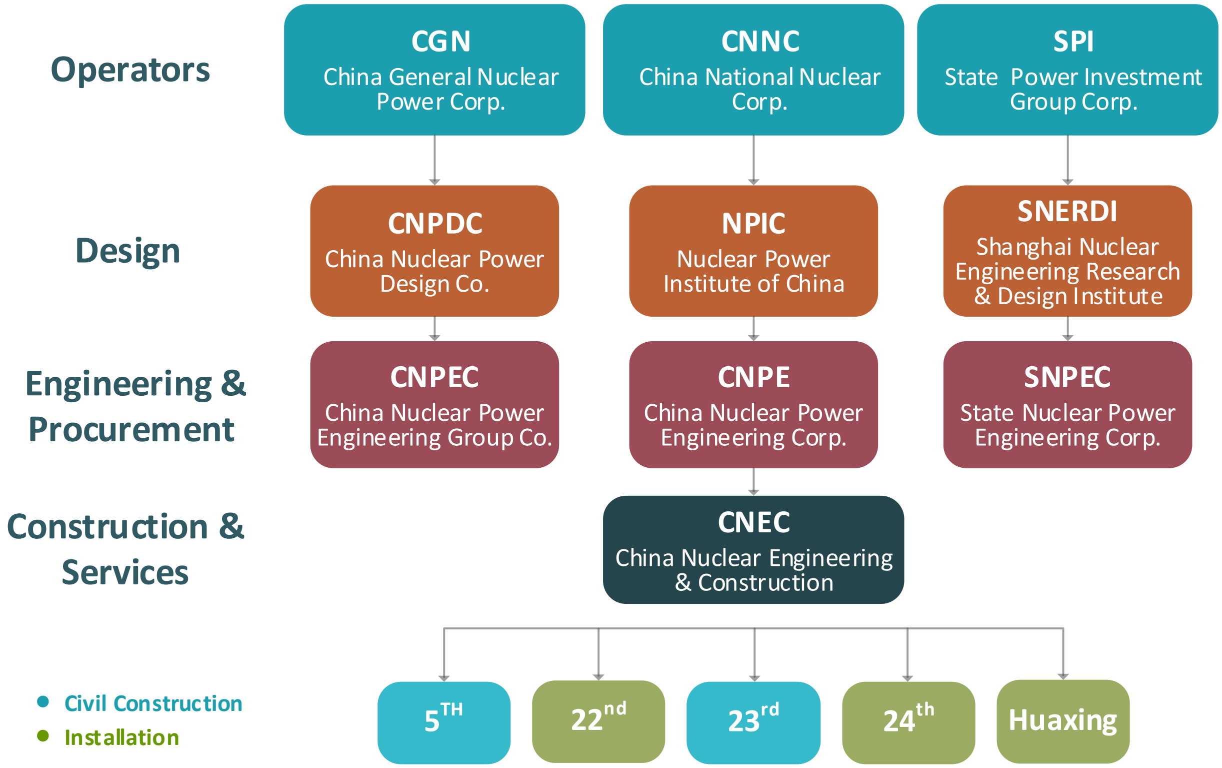
Building upon the recommendations in the October 2012 safety plan, China's State Council Research Office recommends the NNSA expand to four times its current size by 2020 in order to enforce heightened safety requirements as the Chinese operating fleet continues to grow. According to industry sources, the NNSA recently increased the pace of hiring and subcontracting to independent technical experts to offset insufficient in-house staffing.

New Build & Procurement

China Nuclear Engineering & Construction Group (CNEC) controls 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, 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 have been pushing for greater involvement in other aspects of nuclear power plant construction.

The CPI-SNPTC merger also will substantially alter China's procurement landscape. While EPC activities for the nuclear island and conventional island are typically delivered separately in China, after the merger it will be possible for the newly-formed SPI to perform all design, engineering, and procurement functions for both the nuclear and conventional islands.

For the Sanmen AP1000 units, CNNC has been contracting with SNPEC for procurement, but following a July 2014 memorandum of understanding signed between CNNC subsidiary CNPE and CB&I dealing with site management, it is expected CNNC will use its own EPC company, CNPE, for future AP1000 projects. The deal may indicate an industry trend toward companies relying exclusively on their own subsidiaries for procurement in the future.



AP1000 Localization

China's nuclear firms have also been working to achieve near-full indigenous production of the AP1000 reactor and its key components. According to SNPTC, locally produced components will account for 55% of the cost of China's first four AP1000 reactors, rising from 31% for Sanmen 1 to over 72% for Haiyang 2. In August 2014, for example, China First Heavy Industries (CFHI) delivered China's first domestically produced AP1000 reactor pressure vessel, a part that previously had been produced by Doosan Heavy Industries. Doosan is producing the reactor pressure vessels for Sanmen 1 and Haiyang 1, while CFHI and Shanghai Electric are producing the pressure vessels for Sanmen 2 and Haiyang 2, respectively. Table 1 below indicates which key AP1000 nuclear island components are locally produced for each unit.

Recognizing the continued need to develop indigenous production and project management capabilities in order to reach the 2020 localization and capacity targets, Chinese firms have signed further cooperation agreements with Westinghouse and CB&I. In September 2014, Westinghouse and China's State Nuclear Power Automation System Engineering Company (SNPAS) agreed to expand collaboration on I&C systems for future Chinese AP1000 reactors, both in China and abroad. CB&I also signed a memorandum of understanding with CNNC, the majority owner of Sanmen 1 and 2, for future cooperation on construction management.

TABLE 1 – Localization Progress of Key AP1000 Components Bold=Chinese Supplier				
Main Equipment	Sanmen 1	Haiyang 1	Sanmen 2	Haiyang 2
Canned Motor Pump	*EMD*	*EMD*	*EMD*	*EMD*/**SBW/HE**
Squib Valves	*SPX*	*SPX*	*SPX*	*SPX*/**SV**
Reactor Pressure Vessel	*Doosan*	*Doosan*	**CFHI**	**SENPE**
Steam Generators	*Doosan*	*Doosan*	**SENPE/ENSA**	**SENPE**
Reactor Internals	*Doosan*	*Newington*	**S1stMT**	**S1stMT**
Control Rod Drive Mechanism	*Newington*	*Newington*	**S1stMT**	**S1stMT**
Integrated PV Head	*PCC*	*PCC*	**SDNPE**	**SDNPE**
Polar Crane	*PaR*	**TaiHeavy**	**DHI-DCW**	**TaiHeavy**
Refueling Machine	*Westinghouse*	**DHI-DCW**	**SCCW**	**DHI-DCW**
PRHR Heat Exchanger	*MANGIAROTTI*	**DHM**	**HECHE**	**DHM**
Steel Containment Vessel	*WEC*/**SDNPE**	**SDNPE**	**SDNPE**	**SDNPE**
Main Coolant Pipe	**BSIC**	**ErZhong**	**ErZhong**	**BSIC**
Pressurizer	**SENPE**	**DF**	**SENPE**	**DF**
Accumulator Tank	**SEPGE**	**SEPGE**	**SEPGE**	**SEPGE**
Core Makeup Tank	**SENPE**	**HE**	**SENPE**	**HE**
RPV/SG/PZR Support	**ErZhong/DF/DF**	**ErZhong/DF/DF**	**ErZhong/DF/DF**	**ErZhong/DF/DF**
Note: Table omits certain advanced components that have yet to be localized, such as reactor I&C systems				

Construction Delays for China's Flagship 3G Plants

China's first deployments of 3G reactors at Sanmen 1 (AP1000), Haiyang 1 (AP1000), and Taishan 1 (EPR) originally were scheduled to begin operation in 2014, but several delivery and onsite issues have caused delays. Initially, the Fukushima-related safety screenings slowed progress, but management and manufacturing-related issues have since had an impact as well. Being the first reactors of their kind, the Sanmen and Haiyang AP1000 units serve as test projects for China's ambitious AP1000 construction plans. The completion and start of operation of those units are key thresholds to cross before additional AP1000 projects may move forward.

Working closely with international firms and the U.S. NRC, SNPTC had hoped to avoid further delays of the type that have negatively impacted 3G plant construction projects worldwide. However, the Sanmen and Haiyang AP1000 projects have been delayed by nearly two years due to a number of factors, including on-site management issues and potential quality problems revealed during testing of the U.S.-made reactor coolant pumps.

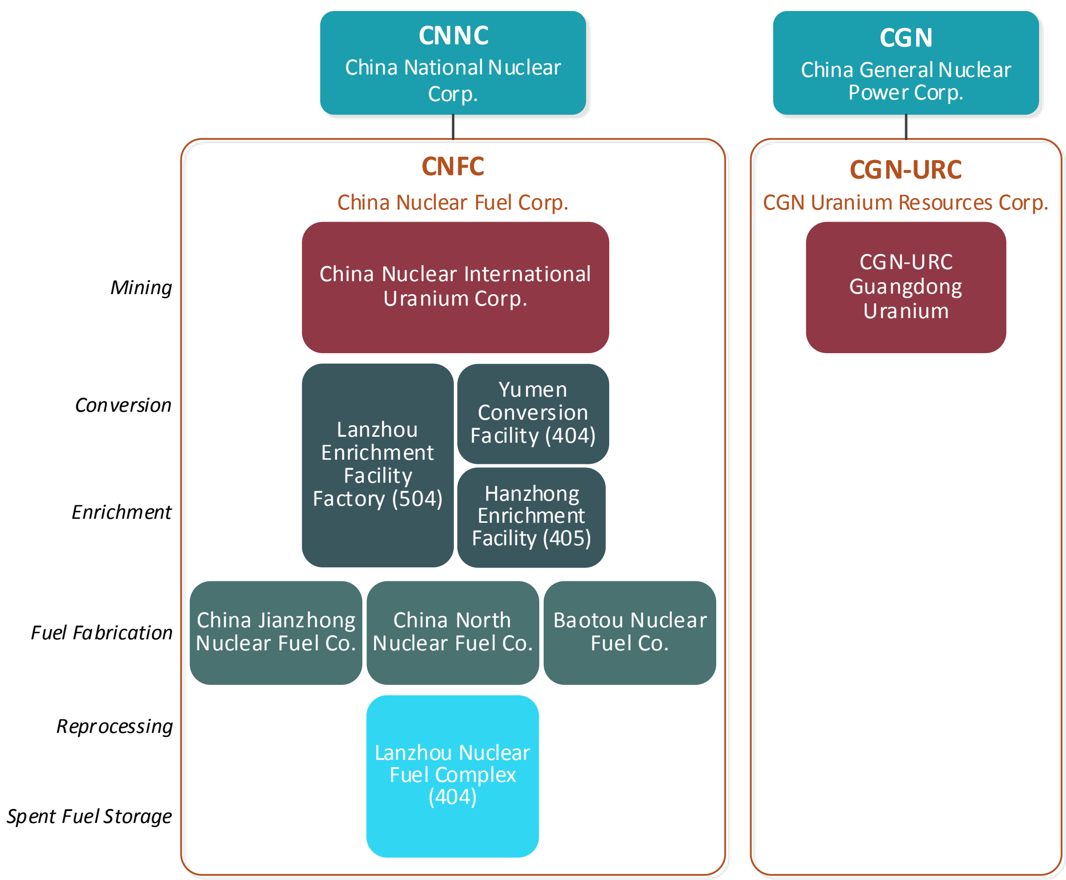
Westinghouse began a global corporate reorganization effort in 2010 with the goal of boosting project management efficiency. The Sanmen plant is continuing to make progress toward commercial operation, and the Site Project Management Office (SPMO) is gradually transferring responsibilities to the startup group while it finalizes installations and resolves finances. Westinghouse has noted that productivity and efficiency will improve as lessons are learned, stating that manpower requirements in Sanmen 2 and Haiyang 2 have thus far been 30% less than those for the first units at each site.

Areva's Taishan reactor project may have suffered from an over-reliance on domestically produced components coupled with a lack of appropriate scrutiny. In February 2015, for example, the NNSA discovered two instances in which the Taishan project had procured safety-related components from a Xi'an-based firm lacking the proper certification. With the completion date for

Taishan 1 still unclear, Areva has stated that its Flamanville, France EPR, slated to begin operation in 2016, may in fact be completed before the Taishan reactor

China's Nuclear Fuel Cycle

China's nuclear fuel cycle has seen few changes over the past several years. CNNC still owns the majority of the front- and back-end fuel cycle activities, including conversion, enrichment, fuel fabrication, reprocessing, storage, and disposal activities. CNNC and CGN are the only two firms sanctioned to engage in fuel cycle activities in China. It remains unclear if and how SPI, the newly formed firm following the merger of SNPTC and CPI, will attempt to enter the fuel cycle value chain; however, Wang Binghua, the president of SNPTC has stated that the firm hopes to do so in the future. In the last few years, SNPTC has gained experience in this area through cooperation with CNNC to establish CNNC Baotou Nuclear Fuel Company. CGN has been slowly building capabilities in the fuel cycle, including purchasing mining assets abroad and conducting exploration in northwest China, but CGN still defers to CNNC and contracts with CNNC'S subsidiaries on many fuel cycle activities. While China has expressed the goal of and has been making progress towards becoming more self-sufficient, the country continues to be dependent upon imported uranium and technology from foreign countries and firms in all aspects of the fuel cycle.



Fuel Cycle Challenges and Recent Developments

Management of fuel cycle infrastructure continues to be a significant challenge, and Sino-foreign cooperation is extensive on both the front and back end. Planned steps for mitigation include the development of domestic and foreign exploration and extraction-related assets; increasing capacity of fuel fabrication as well as spent fuel reprocessing and recycling facilities; and experiments in spent fuel storage by CGN near reactor sites. In uranium mining, CNNC has signed multiple deals with subsidiaries of non-nuclear firms, including SINOPEC in 2013 and Shenhua Group in 2014. Other progress includes the February 2013 commissioning of the first domestically produced centrifuge at Lanzhou and a new initiative by CGN-URC in Kazakhstan on fuel fabrication services which began in April 2014.

Mid- and low-level waste processing continues to be an area of relative weakness for Chinese firms. CNNC and Candu Energy renewed a strategic agreement in 2014 to develop uranium-recycling technology at the Qinshan PHWR, and both companies have been in discussions over mining and the potential addition of an Advanced Fuel CANDU Reactor (AFCR) to China's existing fleet. Spent fuel storage issues are a large challenge as well as China has yet to designate a dry spent fuel repository.

Areva's Strategic Shift

Desiring to maintain a strong position in China after losing out to Westinghouse's AP1000 in the bid to supply China's mainstream 3G reactor design, Areva announced a strategic shift for its China business by deciding to focus more heavily on fuel cycle-related activities. In the past year, the company has signed multiple agreements with CNNC, including a strategic cooperation agreement in March 2014 and a memorandum of understanding in December 2014 to support the development of Chinese fuel cycle capabilities. These agreements also include significant transfers of both front- and back-end fuel cycle technology.

On the front end, Areva and CNNC signed a memorandum of understanding to build a new JV with CNNC cooperating on fuel assembly manufacturing and design. Areva and CNNC had also planned to build new enrichment and fabrication facilities in Jiangmen, Guangdong, yet due to popular resistance to facility construction, Chinese local governments have been in conflict over where to locate the site and thus the project has stalled. The companies are also discussing cooperation in Uranium mining and transportation.

On the back end, Areva and CNNC have signed agreements to build a commercial reprocessing facility with a target operation date of 2025, and are also discussing further cooperation in decommissioning.

While Areva comes from a position of strength in China having a successful track-record of major cooperation dating back to the early 1990s, the firm also owes its deals in the fuel cycle to more accommodating Chinese policies. The Ministry of Commerce's newest draft guideline on Foreign Direct Investment indicates that restrictions on foreign investment in the some areas of fuel processing and assembly will be lifted, which is why Areva was able to pursue the previously mentioned cooperation agreements with CNNC.

Development of Indigenous 3G Reactor Technology

CAP1000

As Westinghouse and SNPTC cooperate on the construction of China's first AP1000s, Westinghouse has also been transferring the reactor design and intellectual property rights for future Chinese indigenization and deployments to SNPTC. The indigenized AP1000 design being adopted by SNPTC is referred to as the CAP1000, which effectively will be identical to the AP1000 design but contain an even greater proportion of localized components than Haiyang 2, the last of the four AP1000 units deployed by the Westinghouse-led consortium with the highest percentage of local content. After completion of Sanmen 2 and Haiyang 2, all future AP1000-equivalent reactors in China will be CAP1000s.

CAP1400

The AP1000 also serves as a basis for China's indigenous 3G design, the CAP1400. Under the agreement between Westinghouse and SNPTC, Westinghouse maintains the right to limit the sale and export of AP1000 derivative designs up to 1399 MWe generating capacity. The motivation behind the development of the CAP1400 is that China will own the intellectual property assuming that capacity is achieved. The CAP1400 design has been approved and pre-construction of the first two units in at Shidaowan in Shandong Province began in April 2014. These units will also be the first nuclear power generation assets owned and operated by utility giant Huaneng, and SNPTC estimates that, measured by their proportion of the total nuclear island cost, 80% of the nuclear island components for these first two CAP1400 reactors will be locally produced.

The CAP1400 demonstration project has been prioritized as one of 16 key strategic projects under China's National Science and Technology Development Plan, and policymakers' eventual aim to deploy the plant in large numbers nationwide. CAP1400 components being produced by foreign vendors so far include a reactor coolant pump prototype shipped from German firm KSB in July of 2014.

The reactor development effort has crossed several milestones in recent years on the path to becoming operational and locally produced. In 2010, the CAP1400's concept design passed an initial review by China's NEA, and in 2014 the reactor completed the NEA's preliminary design review. By the middle of 2014, the plant's nuclear island construction design was 65% complete, while procurement contracts have been given out for key equipment such as steam turbines and power generators. Construction of a key safety-related system verification and testing platform also successfully concluded in 2014. The reactor's prototype steam generator and pressure vessel are currently being manufactured, and the CAP1400's largest-diameter squib valve prototype passed preliminary engineering testing in August 2014, according to SNPTC. In November 2014, the Shidaowan CAP1400 construction site completed final product warehouse facilities and confirmed its readiness for a first concrete date. Units 1 and 2 are currently targeted to begin operation in 2019.

Hualong 1

As part of China's broader strategy to promote the use of its nuclear energy technologies in overseas markets, the country's large nuclear firms have developed the Hualong 1 indigenous reactor design, previously referred to as the Hualong 1000 and the ACC1000. The Hualong 1 design effort came into existence after the NEA ordered CGN and CNNC to combine their ACPR1000 and ACP1000 designs in order to have a single Chinese reactor design for export. The first Hualong 1 projects for CGN are slated to be Fangchenggang 3 and 4, and for CNNC the first Hualong 1's will be Fuqing 5 and 6, all set for completion after 2018.

The Hualong 1 will have two variations on the same reactor design: one sold by CGN that incorporates some auxiliary features of the ACPR1000 reactor, and one sold by CNNC which retains elements of its ACP1000 design. Both Hualong 1 versions currently feature an upgraded core design from the ACP1000. The two designs will also have slightly different safety systems: CNNC's design will have one passive and two active systems, while CGN's will have no passive and three active systems.

Chinese firms and policymakers are working to make Hualong 1 the safest reactor in China, if not worldwide, and to hold complete intellectual property rights for its design. According to information provided by CGN and CNNC, features of the reactor include a double-layer containment, a maximum core damage frequency of 1.7×10^{-7} per year (compare with the AP1000's 2.4×10^{-7} per year, according to Westinghouse), a large release frequency of less than 1×10^{-7} per year, three separate engineered safety systems, a 60-year reactor life, a reported localization ratio of 85% for the first units and 95% for subsequent deployments. The Hualong 1 will also utilize CF3, China's first indigenous fuel design, which will make the export of fuel technology possible for the first time as well. Although CGN and CNNC hope to achieve such high localization ratios for the

Hualong 1, China will need to continue developing the technology for at least another decade before its suitable for large-scale export, according to NNSA ex-director Zhao Chengkun.

Continuing Pressure to Localize

Nuclear power plant operators and companies have been under continuous pressure from policymakers to localize production of nuclear components. Chinese manufacturers have become increasingly capable of producing high-quality equipment to compete with their Western counterparts, and the newest Chinese reactor design is projected to contain approximately 85% locally-produced components. For the Ningde 2 CPR1000, completed in January 2014, the reported localization ratio was estimated at 75%, with ratios of 85% projected for units 3 and 4. The Fangjiashan 1 CPR1000, connected to the grid in December 2014 currently has the highest localization ratio in China, at approximately 80%. Policymakers target a localization ratio of 90% for future CPR1000 reactors, including ACPR1000s.

The push for localization presents implementation challenges, yet as a policy effort it has not abated and should be factored into any foreign firm's China market entry strategy. For example, Shenyang Blower Nuclear Power Group ("Shenyang Blower"), a Chinese nuclear pump supplier, was found by the NNSA in 2013, to have quality issues with its class II and class III safety-related pumps supplied to two power plants under construction. Shenyang Blower previously had been part of a JV with Clyde Union to produce nuclear pumps and transfer the related technology, but Clyde Union subsequently withdrew from the JV. Shenyang Blower continued to pursue the technology and produced the pumps for multiple plants in China. After the quality issues were discovered, Shenyang Blower was restricted from supplying any safety-related pumps for a three-month period. Now, however, Shenyang Blower is still actively supplying components to advanced reactors, and in February 2014 announced that it had successfully completed China's first indigenous CAP1000 reactor coolant pump testing circuit. Thus, poor performance by a locally made product in safety testing may not reduce medium term pressure for that component to be localized or for the local firm to succeed commercially.

Chinese Firms Invest and Sell Abroad

China's first reactor exports were to Pakistan, with CNNC supplying the Chashma 1 and 2 reactors based on the Qinshan Phase One, 300 MWe PWR design. CNNC is also currently constructing two more CNP300 reactors at the Chashma 3 and 4 sites, and talks are underway on the construction of two Hualong 1 reactors at Pakistan's Karachi coastal location. However, China's status as a member of the Nuclear Suppliers Group may limit its ability to deal with Pakistan in the nuclear sphere, so Chinese firms must also look elsewhere for opportunities.

In the past few years, China has seen its reactor technology export prospects improve. On February 3, 2015, China and Argentina signed an agreement that could make Argentina the first overseas buyer of a Chinese nuclear power plant besides Pakistan. The new plant would be the CNNC variant of China's Hualong 1 reactor design. As of April 2015, however, the agreement is only preliminary: according to the cooperation agreement, CNNC will provide Argentina's Nucleoeléctrica Argentina SA (NASA) with a proposal by mid-2015, and NASA will have three months to respond after which the Argentine and Chinese national nuclear regulatory authorities will review the deal for approval. Both sides aim to have a commercial contract and finance agreement signed by the end of 2016.

Chinese companies have also signed multiple agreements to participate in the construction of CANDU reactors in Argentina and Romania. The Argentine Candu deal, signed in July 2014 and separate from the Hualong 1 export agreement with NASA, included the provision of technical services, equipment, and financing by CNNC for the Atucha 3 reactor project. China's Qinshan 3 PHWR units will serve as the reference design. As the CANDU design uses Candu Energy's intellectual property, this company is also included in the deal as a subcontractor to CNNC – an example of China's "going out" strategy also benefiting foreign partners of Chinese firms. In Romania, CNPEC has signed an agreement with Candu Energy to construct two CANDU 6 reactors, Cernavoda 3 and 4, which are projected to begin operation in 2019 and 2020, respectively.

CGN and CNNC both are actively investing in nuclear plant projects abroad. Alongside EdF and Areva, CGN and CNNC are equity investors in Britain's Hinkley Point C project where two EPR reactors will start generating electricity between 2023 and 2025.

Making Strides

China's nuclear energy industry is becoming increasingly developed, and this means opportunities for foreign firms are also in the process of evolving. The fuel cycle remains nearly monopolized by CNNC, yet is also a key area of need where foreign companies have reached multiple deals for cooperation. The regulatory environment must continue to make investments in human capital, and relevant entities will need to continue cooperation with international firms and organizations in order to ensure that China's ambitious new build program can successfully and safely meet its targets. Reactor technology is also rapidly developing as China emphasizes its transition to 3G and other new reactor designs, and safety and quality of foreign-made components that companies wish to market in China will be all the more crucial as operators strive to raise the proportion of locally-produced components in new builds. Increasingly, foreign producers operating in and marketing to China's nuclear industry will be competing with highly capable domestic firms whose products China also hopes to eventually export worldwide.

Running the world's largest new build program safely and successfully continues to require significant investment in all areas. Opportunities for U.S. nuclear firms with experience, advanced technologies, and strong quality and performance reputations exist and should be pursued aggressively. The Chinese industry will face challenges as the country pushes to build the first-of-a-kind units of new 3G reactor designs while quickly localizing the production of major components. Western firms able to allow the Chinese to overcome these challenges can profit from engaging with the China's nuclear industry. More and more, however, meaningful success in China requires a long-term commitment to the market and the ability to adapt to changing strategic conditions.

This white paper is presented by Nicobar Group in cooperation with the U.S. Department of Commerce – Commercial Service.

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Nicobar Group is a Shanghai-based strategy and operations consulting firm that specializes in China market entry strategy development and commercial support for US nuclear companies competing in China's nuclear power market. With 10 years of experience in China, Nicobar can drive success in China nuclear with robust, pragmatic, and carefully thought-out strategies and deliver results with crisp in-country execution. To learn more about how Nicobar Group can help your company succeed in the Chinese nuclear industry, please contact nuclear@nicobargroup.com.

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