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### *China's Nuclear Industry After Fukushima*

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### Summary

The March 2011 Fukushima nuclear accident has had a significant impact on the future of China's nuclear power. First, it highlights the importance of safety as China builds more nuclear power plants. The challenges Beijing faces include the range of different types of nuclear reactor designs, hence making safety standardization a daunting task; lack of sufficient numbers of personnel with the training and experience to manage, run, and inspect nuclear power plants across the country; and a need for better inter-agency coordination to ensure efficient management and speedy responses to Fukushima-like and other unexpected emergency situations. Second, the accident has resulted in a modified mid- to long-term nuclear power development plan that puts on hold inland construction of power plants while requiring that all new plants meet international safety standards and adopt Generation-III reactor technology. Third, there is growing recognition that the rapid expansion of China's nuclear industry requires a well-developed legal framework and accompanying regulatory procedures.

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## **CHINA'S RESPONSE TO FUKUSHIMA**

In the aftermath of the Fukushima nuclear accident, the Chinese government made a series of decisions, including comprehensive safety inspections of all nuclear facilities, both in operation and under construction; temporary suspension of approval of all new nuclear power plant applications; review of nuclear safety regulations; and revision of nuclear power development plans. Nuclear safety was placed front and center of the government response measures. Teams of officials and inspectors drawn from the National Nuclear Safety Administration (NNSA) and other government agencies focused on a number of key areas such as nuclear plants' preparedness and abilities in the event of major natural disasters, quality controls of construction, and power backup in emergency situations. The inspections reportedly uncovered 14 safety areas that need to be addressed and remedied within three years, but overall, China's nuclear facilities have received a relatively clean bill of health. None have suffered an incident higher than Level-2 on a 7-level scale (Fukushima was Level-7).

The safety inspections have revealed deep structural problems facing China's growing nuclear industry. Inter-agency coordination lacks clarity, with the presumed lead agency, NNSA, half a rank lower than a ministry and supervised by the rather weak Ministry of Environmental Protection. NNSA is woefully understaffed, compared to staffing of other advanced nuclear power states such as France and Japan. Furthermore, China still does not have legislation on nuclear energy even though its drafting was initiated 27 years ago and has undergone three drafts so far. Another concern is that in the rush for indigenous innovation and localization of foreign technology and key components, quality, as well as safety, could be ignored.

Despite these concerns and challenges ahead, it is most likely that China will move forward with implementing its nuclear energy development plan, albeit with some modifications that take into

consideration the various issues raised since the Fukushima nuclear accident. Chief among them would be safety, quality control in construction and running of nuclear reactors, human resources, waste management, and nuclear fuel supplies, among others. But given the growing demands for energy and environmental concerns, moving away from coal-fired power plants to renewable and clean energy has become imperative and nuclear power will play a key role in implementing that strategy. However, China may re-think the GEN-II plus reactors that have been the mainstay for many of the planned nuclear power plants and turn to the Westinghouse AP1000 out of safety concerns, and to speed up its own efforts in developing third-generation reactors. Indeed, the government has recently approved the resumption of nuclear power plant construction but decided not to consider any inland projects in the next three years. In addition, all new power plants must meet nuclear safety standards and adopt third-generation nuclear reactor technology. The projected costs for upgrading existing facilities to international safety standards would be around CNY 80 billion (USD 12 billion). And the capacity target for new plants has been adjusted to 40GWe by 2015.

## **KEY PLAYERS**

China's nuclear industry is highly concentrated in the hands of a few state-designated corporations. At the corporate level, the China National Nuclear Corporation (CNNC) controls most of the country's nuclear business and is the government-designated entity involved in nuclear exports and technology transfers. In addition to CNNC, China Power Investment Corporation (CPI) and the China Guangdong Nuclear Power Company (CGNPC) are the only other entities permitted by the Chinese government to build and operate nuclear plants. In May 2007, the State Nuclear Power Technology Corporation (SNPTC) was established with investments from the Chinese government (the State Council) and four major Chinese power companies. Other key companies and research organizations include China Nuclear Engineering and Construction Group (CNEC),

China Institute of Atomic Energy, China Nuclear Engineering Academy, Shanghai Nuclear Energy Research and Design Institute (SNERDI), Beijing Institute of Nuclear Engineering, and China Nuclear Power Engineering Corporation.

There is no question that first among equals is the CNNC. It currently operates the Qinshan and Tianwan sites, with nine units in total. Out of its 100,000 employees, there are 36,000 technologists, 8,000 senior professionals, and 34,000 technicians. Between 2008 and March 2012, CNNC's total assets grew from CNY 165.6 billion to 268.4 billion. CNNC aims to achieve total revenues of CNY 100 billion by 2015, with 10 billion in profits, and a further target of 200 billion in total revenues by 2020.

CGNPC was established in 1994, with a registered capital of CNY 10 billion. By June 2012, it had total assets of 280 billion, with net assets of 75 billion. It has about 20 member companies and currently owns Guangdong Daya Bay Nuclear Power Station and Ling Ao Nuclear Power Station (LNPS) Phase I with nearly 4,000 MWe of installed generating capacity. LNPS Phase II, Liaoning Hongyanhe Phase I, Yangjiang Nuclear Power Station Phase I and Ningde Nuclear Power Station Phase I, all of which are currently under construction, involve over 10,000 MWe of installed generating capacity.

CNEC was incorporated in 1999, after it was separated from the CNNC as part of the restructuring of China's key defense industrial corporations. CNEC has undertaken construction work on pressurized water reactors, experimental fast breeder reactors, and heavy water reactors, and is capable of undertaking construction of various types of reactors with different capacities of 300MWe, 600MWe, 700MWe, and 1000MWe. CNEC has completed construction of Chashma NPP Phase I and Phase II (and is currently involved in Phase III) in Pakistan and has the capabilities to construct advanced AP1000 and EPR pressurized water reactors. CNEC has been involved in nuclear island construction tasks of all the in service and ongoing nuclear power plants in China.

Established in 2007, SNPTC is authorized by the Chinese government to negotiate with foreign suppliers for the importation of third-generation

nuclear power reactors and technologies, to develop nuclear engineering design, and to manage projects. SNPTC currently is the principal organizer of the Sanmen (Zhejiang) and Haiyang (Shandong) nuclear power projects. Westinghouse AP1000 third-generation reactors will be installed in both sites. In 2011, SNPTC realized CNY 7.5 billion in revenue, lower than the 8 billion originally targeted due to the post-Fukushima impact, with profits of 670 million. Still, these represent growth of 10.3 and 28.8 percent, respectively, over the previous year.

## **NUCLEAR TECHNOLOGY AND FUEL CYCLES**

China's currently running nuclear reactors and planned ones under construction are primarily based on two designs: the CPR1000 and the AP1000. However, after the Fukushima nuclear accident, the push is clearly toward third-generation designs such as the AP1000. AP1000s will serve as the basis for China to acquire and master third-generation nuclear technology and reactor design, with the goal of developing China's own third-generation nuclear technology. Westinghouse, together with SNPTC and SNERDI, would jointly develop the CAP1400, a passively safe, larger design based on the AP1000.

Indigenization in the development of nuclear engineering, design, and components remains an important goal for Chinese nuclear industry, and in that respect, some noticeable progress has been made in recent years. The Nuclear Power Institute of China, for instance, has successfully designed reactor containment electrical penetrations and the CPR1000 reactor pressure vessel with complete Chinese indigenous intellectual property rights for the Hongyanhe I power plant. These are critical steps toward indigenization and many years in the making. However, indigenization will remain a major challenge for China's nuclear industry. CPR1000 reactors, for example, still depend on foreign suppliers to provide key components such as instrumentation and control systems, and mainstream isolation valves. Such dependence on core nuclear components and technologies will subject it to continued restrictions imposed by foreign

suppliers for either export control or intellectual property rights reasons.

China has developed and mastered the key nuclear fuel cycle technologies from uranium prospecting, mining, and purification, to conversion, enrichment, and fuel element fabrication. The government has also given priority to research and development on the next generation technologies such as fast breeder reactors (China Experimental Fast Reactor, or CEFR) and high temperature gas cooled reactors. CEFR has achieved criticality and passed review for acceptance. These represent major breakthroughs as part of the three-step development strategy of nuclear technology: “pressurized water reactor—fast reactors—fusion reactor,” further elevating China’s advanced international standing in fourth-generation nuclear power technology research and development. In addition, China is also seeking to reprocess civilian spent fuel and to recycle plutonium in MOX (mixed oxide) fuel for its light water and fast breeder reactors. Chinese scientists have tested the world’s first fully superconducting tokamak device, a new fusion reactor called the Experimental Advanced Superconducting Tokamak (EAST).

## NAVAL PROPULSION

Like most advanced nuclear power states, developments in China’s nuclear technology can (and indeed, some would argue, already) benefit its nuclear submarine propulsion. For instance, both Westinghouse and France’s AREVA Group have been critical players in the designs and development of both U.S. and French nuclear propulsion programs. The benefits and potentials of civil-military integration have been an important consideration in this regard. Indeed, the design of China’s first civilian nuclear power plant was based on the naval submarine nuclear reactor. There have been various reports, in both Chinese-language and Western sources, that suggest that the new naval nuclear propulsion has benefited from the civilian nuclear research and technology over the past decade, including, some would argue, Western technology transfers as part of the growing Chinese nuclear power programs. One such technology is

the high temperature gas-cooled reactor (HTGR). Research on the HTGR started in the 1970s, well before the civilian nuclear industry was launched. HTGR would allow submarines to achieve faster speeds and lower noise levels. However, major technical hurdles still exist and need to be overcome for an HTGR to be compatible with a submarine. Indeed, as suggested by some analyses, the new generation of Chinese nuclear submarines continues to suffer from relatively high noise levels, exposing them to detection and disarming first attacks.

## CONCLUSION

In the aftermath of Fukushima nuclear accident, China’s nuclear industry has undergone comprehensive reviews. The government has carefully reviewed and revised its mid- to long-term nuclear power development plans, adjusted the target for nuclear-generated electricity by 2015, and placed more emphasis on nuclear power safety and the adoption of third-generation nuclear technology. The reviews have also drawn attention to the need for legislation on nuclear energy and greater autonomy and authority, in addition to better staffing, of the country’s regulatory bodies for more efficient enforcement. Despite Fukushima, China will continue to pursue nuclear expansion as part of an energy strategy that aims to increase clean and renewable energies (solar, hydraulic, wind, and nuclear) to 15 percent of total generated electricity. This would require continued efforts in both introducing, absorbing, and integrating third-generation nuclear technology, and indigenization, such as the ability to manufacture core components. These will remain the challenges and imperatives as China’s nuclear industry expands in the coming decades.

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