China's Nuclear Energy Guide

2017

China Nuclear Energy Association

Preparation Instructions



In June 2016, China Nuclear Energy Association (hereinafter referred to as CNEA) visited the UK to take part in the Third Meeting of the Working Group on Sino-British Civil Nuclear Energy Cooperation. During the meeting, CNEA held talks with the British Nuclear Industry Association (NIA), which provided the British Nuclear Industry Guide with a description of the key factors and the best path for the UK nuclear power market. At the same time, NIA expects that CNEA can provide relevant information to help British enterprises to understand the situation of China's nuclear power market and supply and demand information, including the organization, participation, market access and so on.

According to the requirements of this meeting, and based on the actual situation of China's nuclear energy industry, CNEA decided to organize the preparation of *2017 China's Nuclear Energy Guide* (English Version) to help British enterprises and other overseas suppliers, especially SMEs, to understand the development of China's nuclear energy industry and enter the nuclear power market in China. The Chinese Version of *2017 China's Nuclear Energy Guide* will be published simultaneously to help domestic enterprises, especially SMEs members, fully understand the nuclear energy industry.

2017 China's Nuclear Energy Guide is divided into five chapters, including Overview of China's Nuclear Power Development, Government Competent Departments and Related Policies, China's Nuclear Safety Culture and Nuclear Safety Regulation, New Nuclear Power Projects in China and Foreign Cooperation, Introduction of China's Nuclear Power Industry Chain and Major Enterprises. The material used in the report was collected in December 2016. We are grateful to all the experts from China National Nuclear Corporation (CNNC), China Nuclear Engineering & Construction Group Corporation (CNECC), China General Nuclear Power Group (CGN), State Nuclear Power Technology Corporation (SNPTC), China Huaneng Group (CHNG), Nuclear and Radiation Safety Center for their help in the preparation process.

Readers' criticism and corrections are welcomed. The relate contents will be amended in the next version.

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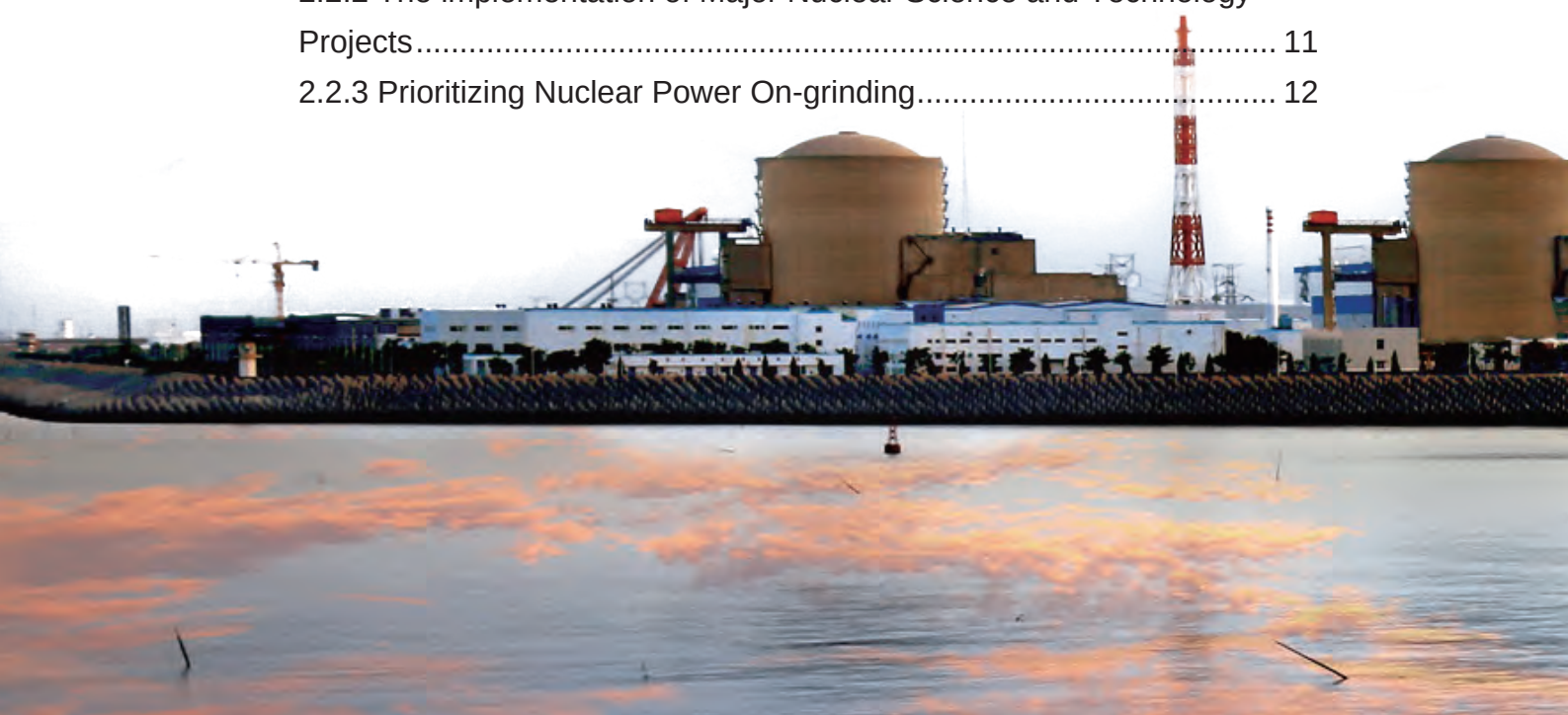


Chapter III: China's Nuclear Safety Culture and Nuclear Safety Regulation

Chapter IV: New Nuclear Power Projects in China

Chapter V: Introduction of China's Nuclear Power Industry Chain and Major Enterprises

Chapter I

Overview of China's Nuclear Power Development

1.1 Overview of China's Energy and Power Development

Since 1979, China has made great strides in its economic development, social development and people's living standard. Energy production and consumption levels have also been improved dramatically.

In 2015, the total energy consumption of China (excluding Taiwan region) was 4.3 billion tons of standard coal; the whole society consumed 5.55 trillion kilowatt-hours of electricity; and the per capita electricity consumption was 4100 kilowatt-hours, which is more than four times of that in 2000. China has become the world's largest producer and consumer of energy for some years. Due to its large population, China's per capita electricity consumption is still relatively low compared to developed countries, and represents about 26% of that of the United States. In the next 20 years, there will be huge room for growth in China's electricity consumption and production.

For a long time, China's energy consumption was dominated by fossil fuels. In recent years, the proportion of non-fossil fuels has increased, but the coal-dominated energy mix has not fundamentally changed. In primary energy consumption, the proportion of coal is as high as 64.4%, which is more than twice the world average level. In the power supply, coal power generation accounts for up to 74.37% (see Figure 1-1). China faces the urgent and arduous task to change its coal-based energy structure and build a green, low-carbon, safe and efficient modern energy system as soon as possible.

In order to cope with global warming and reduce the impact of energy production and consumption on the environment, the Chinese government has set the following development objectives: non-fossil fuels should account for about 15% of primary energy consumption by 2020 and 20% by 2030. The proportion of low-carbon energy such as renewable energy, nuclear energy and natural gas shall be gradually increased. As nuclear power generation does not release greenhouse gases and pollutants into the environment, has more hours of equipment use, low operating cost and provides stable and economic power, it is an important part of the construction of green low-carbon energy system in our country.

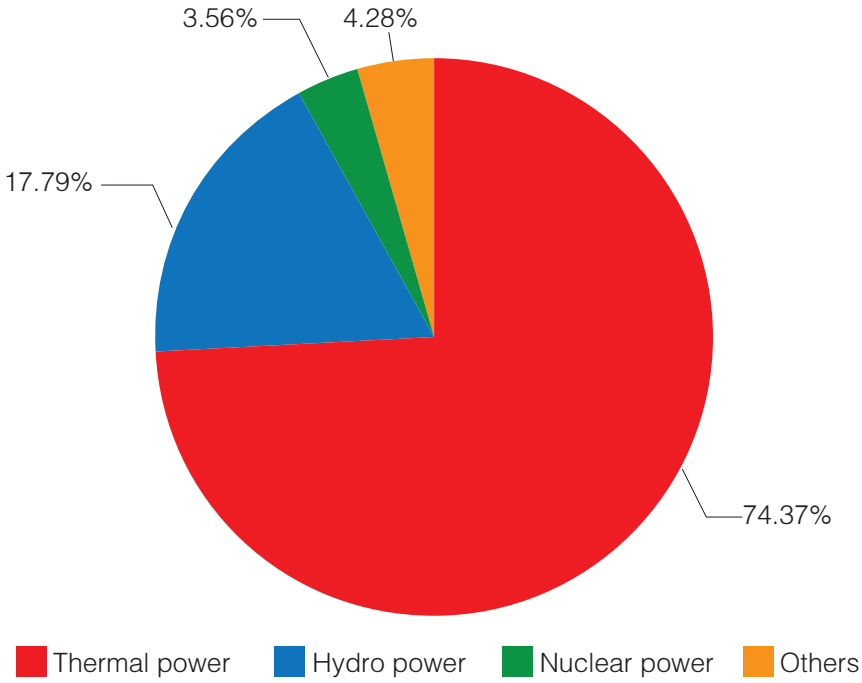


Figure 1−1 Statistical Distribution of Power Generation in 2016 in China (Excluding Taiwan)

1.2 Overview of China's Nuclear Power Development

China launched its nuclear power course in the 1980s. As of the end of 2016, 35 nuclear power units had been put into commercial operation in China (excluding Taiwan); 21 nuclear power units were under construction; 56 units were distributed in 13 nuclear power plants in eight provinces and regions, such as Zhejiang, Guangdong, Jiangsu, Liaoning, Fujian, Guangxi, Hainan and Shandong (see Figure 1-2).

The total installed capacity of 35 nuclear power units was 33.63 million kilowatts, accounting for 2% of the total national installed capacity. In 2016, the gross generating capacity of China's nuclear power units in operation was 210.5 TWh, accounting for 3.56% of the total. Nuclear power generation is equivalent to having reduced standard coal consumption by 65.68 million tons, eliminating emissions of 172 million tons of carbon dioxide, 560 thousand tons of sulphur dioxide and 480 thousand tons of nitrogen oxides, thus having made an important contribution to the green development of China's power industry.

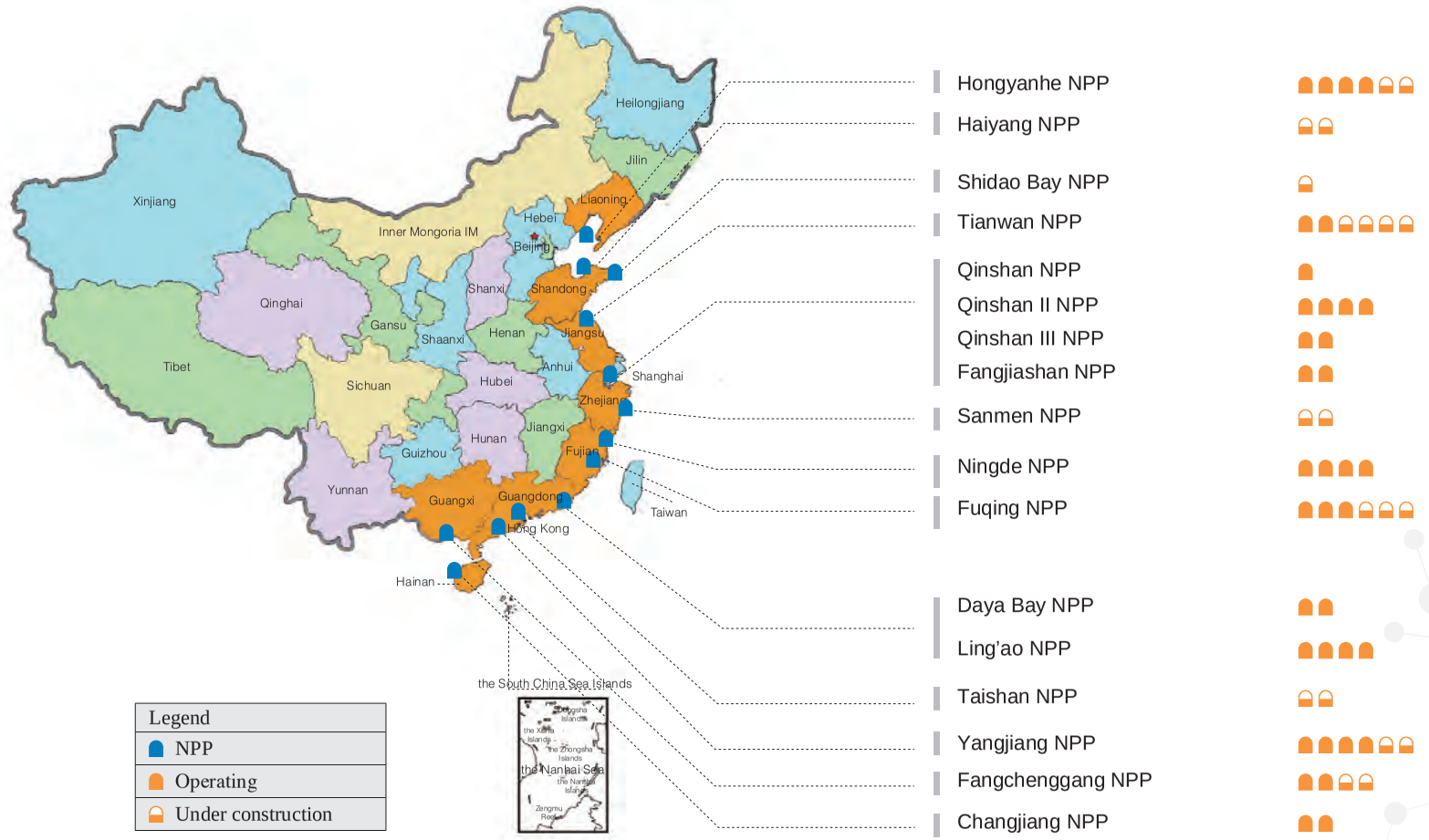


Figure 1−2 Distribution of NPPs in Chinese Mainland (2016)

1.2.1 Overview of In-service Nuclear Power Units

See the name, model, installed capacity, generating capacity and equipment utilization hours and so on of the 35 nuclear power units put into commercial operation in 2016 in Table 1-1.

Table 1−1 Operating NPPs in China in 2016

Operating Unit		Type	Installed capacity (MWe)	Power generation (TWh)	Equipment utilization hours
Zhejiang Qinshan I		CP300	310.0	2.580	8322
Guangdong Daya Bay	Unit 1#	M310	984.0	7.561	7684
	Unit 2#	M310	984.0	7.611	7735
Zhejiang QinShan II	Unit 1#	CP600	650.0	5.044	7760
	Unit 2#	CP600	650.0	4.833	7436
	Unit 3#	CP600	660.0	5.619	8514
	Unit 4#	CP600	660.0	5.310	8045
Guangdong Ling'ao	Unit 1#	M310	990.0	8.619	8706
	Unit 2#	M310	990.0	7.300	7374
	Unit 3#	CPR1000	1086.0	8.512	7838
	Unit 4#	CPR1000	1086.0	7.700	7090
Zhejiang Qinshan III	Unit 1#	CANDU6	728.0	5.932	8148
	Unit 2#	CANDU6	728.0	4.932	6774
Jiangsu Tianwan NPP	Unit 1#	VVER1000	1060.0	7.525	7099
	Unit 2#	VVER1000	1060.0	7.848	7404
Liaoning Hongyanhe	Unit 1#	CPR1000	1118.8	6.520	5828
	Unit 2#	CPR1000	1118.8	5.657	5056
	Unit 3#	CPR1000	1118.8	5.887	5262
	Unit 4#	CPR1000	1118.8	1.211	1082
Fujian Ningde	Unit 1#	CPR1000	1089.0	7.312	6714
	Unit 2#	CPR1000	1089.0	6.262	5750
	Unit 3#	CPR1000	1089.0	6.592	6053
	Unit 4#	CPR1000	1089.0	3.963	3639

Operating Unit		Type	Installed capacity (MWe)	Power generation (TWh)	Equipment utilization hours
Fujian Fuqing	Unit 1#	CP1000	1089.0	7.255	6662
	Unit 2#	CP1000	1089.0	6.611	6071
	Unit 3#	CP1000	1089.0	1.795	1648
Guangdong Yangjiang	Unit 1#	CPR1000	1086.0	7.551	6953
	Unit 2#	CPR1000	1086.0	7.373	6789
	Unit 3#	CPR1000	1086.0	8.118	7475
Zhejiang Fangjiashan	Unit 1#	CP1000	1089.0	8.333	7652
	Unit 2#	CP1000	1089.0	7.783	7147
Hainan Changjiang	Unit 1#	CP600	650.0	4.010	6169
	Unit 2#	CP600	650.0	1.619	2491
Guangxi Fangchenggang	Unit 1#	CPR1000	1086.0	7.746	7133
	Unit 2#	CPR1000	1086.0	1.995	1837
	35 Units		33632.0	210.519	6987

95% of the nuclear power units in service are pressurized water reactors, of which, the M310 and its modified CPR1000/CP1000 account for 70% of the total number of units in service. The nuclear power units known as the "second generation plus" in the industry have relatively low cost and power generation-cost, while meeting safety requirements; they have relatively high cost-performance ratio, thus they are the main forces of nuclear power generation in China at this stage.

Among the 35 units, 24 units were put into operation after 2010, of which 20 units are new nuclear units put into operation in 2013-2016, with an average of five units each year. In 2016, the whole-year nuclear power generation (210.519 billion kWh) and on-grid electricity (196.568 billion kWh) have increased by 25% over the same period of 2015.

China attaches importance to the safety of nuclear power units and places nuclear safety on the premise of ensuring the safety of nuclear power and strictly controlling the safety risk of nuclear power units on nuclear power operation. The nuclear power plants strengthened their nuclear safety culture and system through training, system construction, third-party assessment and other measures, and achieved good results.

China's nuclear power plants under operation have maintained a good record of safe operation. Up to now, no accident of level-II or above according to the INES has occurred and no major environmental incident, radiation incident, fire explosion accident or occupational hazard has occurred. Nuclear energy is one of industries with the best safety record in China.

China's nuclear power operation and management level has been highly recognized by interna-

tional counterparts. In contrast to the operating indicators of the World Association of Nuclear Operators (WANO), the operating indicators of NPPs in China are generally above the global median level, and about half of the indicators are above the international advanced level.

Nuclear power plants strictly control the emission levels of radioactive effluents (liquid and gaseous effluents), and the emission of radioactive effluent from all operating NPPs is far below the requirements of relevant national standards.

The environmental protection departments, where the nuclear power plants are located, continuously monitor the level of ambient radiation in the surrounding areas of a nuclear power plant on a 24-hour basis. The monitoring results show that the ambient air absorption dose rate in the surrounding areas of a nuclear power plant has remained constant within the normal fluctuation range of local radiation level. The construction and operation of nuclear power plants have not brought any adverse impact on local environment.

1.2.2 Overview of Nuclear Power Units under Construction

As of December 31, 2016, China had 21 nuclear power units under construction, with a total installed capacity of about 23.9 million kilowatts (see Table 1-2). China is the country with the largest number of nuclear power units under construction in the world.

Table 1−2 Nuclear Power Units under Construction in China (excluding Taiwan) (as of December 2016)

Unit under Construction		Type	Installed capacity (MWe)	FCD time
Jiangsu Tianwan	Unit 3#	VVER1000	1120	2012/12
	Unit 4#	VVER1000	1120	2013/09
	Unit 5#	CP1000	1080	2015/12
	Unit 6#	CP1000	1080	2016/09
Liaoning Hongyanhe	Unit 5#	CPR1000	1080	2015/03
	Unit 6#	CPR1000	1080	2015/07
Guangdong Yangjiang	Unit 4#	CPR1000	1086	2012/11
	Unit 5#	CPR1000	1086	2013/09
	Unit 6#	CPR1000	1086	2013/12
Zhejiang Sanmen	Unit 1#	AP1000	1250	2009/03
	Unit 2#	AP1000	1250	2009/12
Shandong Haiyang	Unit 1#	AP1000	1250	2009/09
	Unit 2#	AP1000	1250	2010/06

Unit under Construction		Type	Installed capacity (MWe)	FCD time
Guangdong Taishan	Unit 1#	EPR	1750	2009/11
	Unit 2#	EPR	1750	2010/04
Fujian Fuqing	Unit 4#	CP1000	1089	2012/11
	Unit 5#	HPR1000	1150	2015/05
	Unit 6#	HPR1000	1150	2015/12
Guangxi Fangchenggang	Unit 3#	HPR1000	1100	2015/12
	Unit 4#	HPR1000	1100	2016/12
Shandong Shidao Bay		HTR—PM	200	2012/12
	21		24280	

The units under construction include the mature "second generation plus" models and the world's most advanced third-generation nuclear power technology. Among them, the two projects under construction in Sanmen, in Zhejiang, and Haiyang, in Shandong, are AP1000 units imported from Westinghouse Electric Corporation, and European PWR (EPR) units imported from France are adopted by Taishan, in Guangdong. As AP1000 and EPR are the international first or first-batch, there were many difficulties in the construction of AP1000 and EPR, and the construction period was significantly delayed compared to original plans. With joint efforts of both China and foreign countries, current difficulties have been basically solved and the first furnace loading is about to begin.

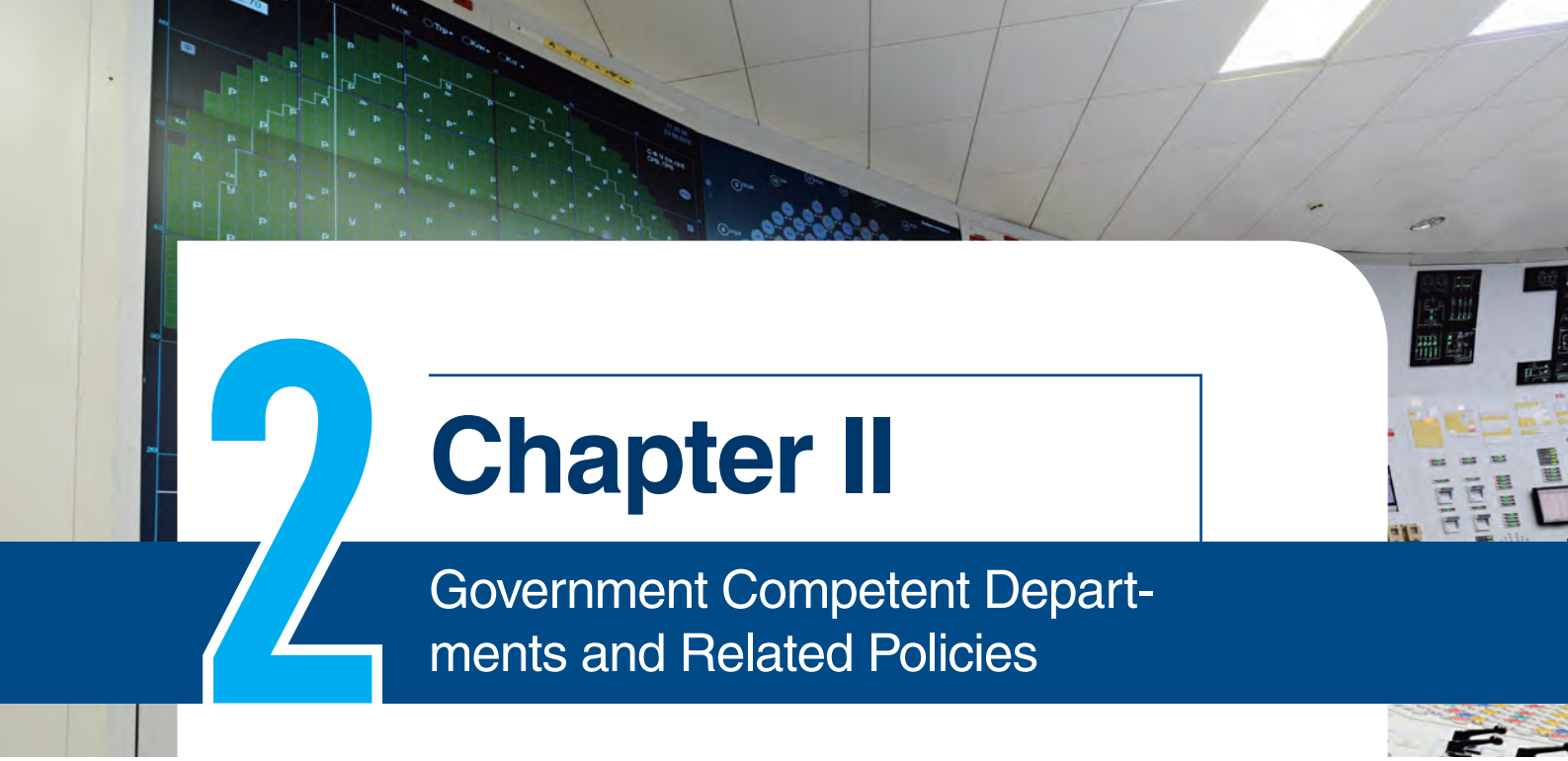
The third-generation units under construction also include HPR1000, which was independently developed by China. The technology is based on 30 years of nuclear power construction and operation experience in China, which draws the advanced design concepts of the international third-generation nuclear power technology, while at the same time integrating technical improvements made both at home and abroad after the Fukushima nuclear accident; the performance indicators meet the international third-generation nuclear power technology requirements. At present, HPR1000 is under construction at the same time in Fuqing, in Fujian (Unit 5/6), Fangchenggang, in Guangxi (Unit 3/4) and Karachi, in Pakistan (K2 / K3), and all projects have made good progress.

1.3 The "Thirteen Five-Year" Development Plan for China's Nuclear Power

China's 13th Five-Year Plan Period started in 2016 and is a crucial period for the development of nuclear power in China. The Chinese government has successively released the China's *13th Five-Year Plan*, *13th Five-Year Plan for Energy Development*, *13th Five-Year Plan for Power Development*, *13th Five-Year Plan for Energy Technology Innovation* and a series of documents, which set forth clear requirements for the construction of new nuclear power projects during the period of the 13th Five-Year Plan, require them to adhere to principles of safely development of nuclear power, increase the construction of independent nuclear power demonstration projects, strive to build the core competitiveness

of nuclear power and accelerate the construction of nuclear power projects in coastal areas.

According to the plan, 30 million kilowatts of new nuclear power plants will be put into operation during the 13th Five-Year Plan; there will be more than 30 million kilowatts of newly-started nuclear power units and 58 million kilowatts of installed nuclear power in China by 2020. The total number of newly-started nuclear power units will reach 25-30 units (5 to 6 units per year), with an annual investment of more than RMB 100 billion.



2 Chapter II

Government Competent Departments and Related Policies

2.1 Government Competent Departments and Main Responsibilities

The competent governmental departments in China, which are directly related to the nuclear power development, include National Energy Administration (NEA), National Nuclear Safety Administration (NNSA), China Atomic Energy Authority (CAEA).

2.1.1 National Energy Administration

National Energy Administration, under the National Development and Reform Commission (NDRC), is the industry authority for China's energy and power including nuclear power.

National Energy Administration is responsible for the national nuclear power industry management, including developing the nuclear power development planning, access conditions, technical standards and implementation; proposing opinions on nuclear power strategic deployment and major project approval; organizing and coordinating nuclear power scientific research; and organizing nuclear accident emergency management of nuclear power plants.

In June 2016, National Energy Administration established China Nuclear Power Development Centre; its business scope includes research on laws and regulations, planning, policies and standards concerning nuclear power; implementation of major nuclear power projects; construction, operation and safety monitoring of nuclear power; accident emergency, fire fighting design review, operator qualification related work of nuclear power plants; research and development, training, publicity and popular science related work of nuclear power; consulting and assessment of nuclear power development, technology and equipment self-reliance; and international exchange and cooperation in the field of nuclear power. China Nuclear Power Development Centre provides technical support to the National Energy Administration in nuclear power management.

2.1.2 National Nuclear Safety Administration

China National Nuclear Safety Administration was established in October 1984 and it is the body of Ministry of Environmental Protection, responsible for the nuclear and radiation safety regulation of nuclear and radiation safety supervision of national nuclear power plants and civilian nuclear facilities. It directly undertakes a total of 20 nuclear and radiation safety administrative licensing matters, involv-

ing construction and operation permits for nuclear power plant, nuclear power plant operators' license, nuclear material permits, nuclear safety equipment design, manufacture, installation and non-destructive testing, etc.

After 30 years of development, the nuclear and radiation regulation in China has formed a regulatory system with the headquarters of the Ministry of Environmental Protection (National Nuclear Safety Administration) as the core, with the nuclear and radiation monitoring stations as the main force, and with the Nuclear and Radiation Monitoring Technology Center as the main technical support body.

The Director of National Nuclear Safety Administration is concurrently served by the Vice Minister of Ministry of Environmental Protection. The specific businesses are handled by three divisions within the Ministry of Environmental Protection, with Division I responsible for the research on the safety supervision of reactors and nuclear facilities, Division II responsible for the safety supervision of nuclear power and Division III responsible for the safety supervision of radiation sources.

The regional supervision station is headquartered in Beijing and has six regional monitoring stations in Shanghai, Shenzhen, Chengdu, Beijing, Lanzhou and Dalian. Regional supervision stations are responsible for dispatching safety inspectors to nuclear power plants and major equipment manufacturers to carry out routine safety inspections of the construction quality, equipment quality, personnel qualification and operational safety of nuclear power plants, and to carry out on-site supervision on important items during the design, manufacturing, construction and operation of NPPs.

Technical support units include more than 10 universities and research institutes, including Beijing Nuclear and Radiation Safety Center, Zhejiang Radiation Environmental Monitoring Station, Nuclear Equipment Safety and Reliability Center, Suzhou Nuclear Safety Center, Beijing Nuclear Safety Review Center, Research Institute of Nuclear Power Operation, China Institute for Radiation Protection, China Institute of Atomic Energy, Tsinghua University, Shanghai Jiao Tong University, etc. Among them, Beijing Nuclear and Radiation Safety Center currently has 600 staff and is mainly engaged in technical review and R&D.

2.1.3 China Atomic Energy Authority

China Atomic Energy Authority is a national bureau administered by Ministry of Industry and Information Technology, and is the industry authority for China's nuclear industry. Major responsibilities in the nuclear power sector include management of nuclear fuel supply (including uranium exploration, natural uranium mining and processing, nuclear fuel processing), the transportation, storage, reprocessing of spent fuel, the treatment of radioactive waste and decommission of nuclear facilities, etc.

The chairman of China Atomic Energy Agency, on behalf of the Chinese government, attends the IAEA activities, responsible for the foreign exchange and cooperation in the nuclear industry field, nuclear export control, nuclear security and national emergency management of nuclear accidents.

National Nuclear Emergency Response Office was established under the State Administration of Science, Technology and Industry for National Defence (SASTIND). SASTIND's leader served as the director of the Nuclear Emergency Office.

Nuclear-related institutions under the State Administration of Science, Technology and Industry for National Defence include Nuclear Technology Support Center, Technical Support Center for Nuclear Emergency, Technical Support Center for Nuclear Security, etc.

2.2 China's Related Policies Encouraging the Development of Nuclear Power

2.2.1 Guidelines for "Active" and "Safe and Efficient" Development of Nuclear Power

On October 11, 2005, the *Proposal of the CPC Central Committee and Central Government on Formulating the 11th Five-Year Plan for National Economic and Social Development* formally put forward the principle of "actively developing nuclear power."In 2007, the State Council Executive Meeting reviewed and approved China's first *Medium and Long-Term Nuclear Power Development Plan (2005-2020),* and proposed that installed capacity of nuclear power in-service will reach 40 million kilowatts and the installed capacity of nuclear power under construction will reach 18 million kilowatts by 2020.

On October 15, 2010, the *Proposal of CPC Central Committee on Formulating the 12th Five-Year Plan of National Economy and Social Development* further clearly put forward the principle of "efficiently developing nuclear power on the basis of ensuring safety".

In October 2012, the State Council approved the revised *Medium and Long-Term Nuclear Power Development Plan (2011-2020).* Compared with the 2007 version, the installed capacity of nuclear power in-service in China will be increased from the original 40 million kilowatts to 58 million kilowatts by 2020; the installed capacity of the nuclear power under construction will be increased from 18 million kilowatts to 30 million kilowatts; and the total capacity of nuclear power will be increased from 58 million kilowatts to 88 million kilowatts by 2020.

In June 2014, the State Council issued and printed the *Energy Development Strategy Action Plan (2004-2020),* clearly proposing the "safe development of nuclear power" and timely launch of new nuclear power projects in the eastern coastal areas under the premise of adopting the international highest safety standards and ensuring the safety. The plan confirmed the objective that "by 2020, the installed capacity of nuclear power in-service will reach 58 million kilowatts, and the installed capacity of nuclear power under construction will reach 30 million kilowatts or more".

The Outline of the 13th Five-Year Plan for National Economic and Social Development of the People's Republic of China published in March 2016 requires to "focus on the coastal nuclear power and construct independent nuclear demonstration engineering and projects in a safe manner." In terms of development goals, the Outline proposes to build two AP1000 relying projects in Sanmen and Haiyang, as well as two demonstration projects using "HPR1000"in Fuqing, Fujianand in Fangchenggang, Guangxi; to start construction of demonstration project CAP1400 in Rongcheng, Shandong; to start the construction of a number of coastal nuclear power projects; to speed up the construction of Jiangsu Tianwan Phase III nuclear power project; and to actively carry out the preliminary work for inland nuclear power projects.

2.2.2 The implementation of Major Nuclear Science and Technology Projects

In February 2008, the State Council approved the overall implementation plan of the major scientific and technological project "Large-scale Advanced PWR and High-temperature Gas-cooled Reactor Nuclear power plant". The goal is to develop CAP1400 technology with independent intellectual property rights by AP1000 technology introduction and digestion as well as relying project construction experience, to create China's independent nuclear power brand, and to establish the related nuclear power technology and standard system.

In January 2014, the CAP1400 completed its preliminary design and was approved by Nation-

al Energy Administration. In February 2016, the preliminary safety analysis report of the CAP1400 demonstration project passed the review of National Nuclear Safety Administration. All the preparatory work for the project construction is ready.

With the support of major project, the localization of CAP1400 equipment has been continuously promoted. At present, except for the main pipeline, the steam generator, pressure vessel, pressure regulator, blasting valve and other nuclear island key equipment have achieved localization.

2.2.3 Prioritizing Nuclear Power On-grinding

In May 2014, the *Guiding Opinions on Strengthening and Improving Regulatory Management of Power Generation Operation* issued by the NDRC specified that "under the premise of ensuring the safety and stability of the grid, the annual power generation plan shall make full arrangement of renewable energy on-grid electric quantity and preferentially arrange the hydropower, nuclear power, cogeneration, comprehensive utilization of resources generating units". The relevant provisions give nuclear power a favourable position in the power generation schedule.

Over the years, the average utilization hours of nuclear power units remained above 7,300. Even in 2016, when the electricity supply was relatively loose, the average annual utilization hours of nuclear power plants still reached 6987 hours, which is far higher than that of other power sources.

2.2.4 Nuclear Power Benchmark Price and VAT Relief Policies

In June 2013, the NDRC issued and published the *Notice on Improving the Mechanism of Nuclear Power On-grid Price* to implement benchmark on-grid price policy for nuclear power units which are put into operation after January 1, 2013. The national benchmark on-grid price for nuclear power approved by the Notice is RMB 0.43 per kilowatt-hour. For areas where the national benchmark on-grid price for nuclear power is higher than the benchmark on-grid price for coal-fired units (including desulfurization and denitrification cost, the same below) where nuclear power units are located, the local benchmark on-grid price for coal-fired units shall be implemented after the new nuclear power units are put into operation. For areas where the national benchmark on-grid price for nuclear power is lower than the benchmark on-grid price for coal-fired units where nuclear power units are located, the scheme for on-grid price of the first or first batch of nuclear power units or demonstration projects which undertake the introduction of nuclear power technology, independent innovation, major special equipment localization shall be proposed by provincial pricing authorities, and the price can be appropriately increased on the basis of the national benchmark on-grid price for nuclear power after being reported to and approved by the NDRC. The benchmark on-grid price for nuclear power as RMB 0.43 per kWh is higher than the cost price of the vast majority of the national nuclear power units, which has ensured the profit margins of nuclear power enterprises.

In April 2008, the Ministry of Finance and the State Administration of Taxation jointly issued the *Notice on Relevant Issues on Tax Policies of the Nuclear Power Industry*.

The Notice stipulates that the value-added tax refund policy shall be implemented for electric power products produced and sold by the nuclear power generation enterprises within 15 years starting from the month after nuclear power units have been officially put into commercial operation; and the return rate is to be decreased in three stages. The specific return rate is: within five years starting from the second month after the official commercial operation, the return rate is 75% of the taxation in storage; within the period from the sixth to the 10th year starting from the second month after the official commercial operation, the return rate is 70% of the taxation in storage; within the period from

the 11th to the 15th year starting from the second month after the official commercial operation, the return rate is 55% of the taxation in storage; after 15 years starting from the second month after the official commercial operation, the VAT refund policy shall not be implemented. The VAT refund policy is implemented for nuclear power units, which reduces the burden on nuclear power companies and improves the profitability of nuclear power companies.

2.2.5 Establishing Spent Fuel Disposal Fund

In July 2010, the Ministry of Finance, NDRC, Ministry of Industry and Information Technology issued and published the *Interim Measures for the Administration of Collection and Use of Spent Fuel Disposal Funds of Nuclear power plant*. The Interim Measures stipulate that the spent fuel disposal fund shall be collected from the PWR nuclear power units which have been put into commercial operation for over five years; the collection standard is RMB 0.026 / kWh. The fund is mainly used for the spent fuel transport, spent fuel storage out-site, spent fuel reprocessing and high-level radioactive waste disposal.

2.2.6 Establishing Nuclear Accident Damage Compensation System

The basis for compensation for nuclear damage is the *Reply of the State Council on the Issue of Damages in Nuclear Accidents* issued in June 2007.

The Reply stipulates that within the territory of the People's Republic of China, the operator of nuclear power plant shall be liable for compensation for human casualties, property damage or environmental damage caused by a nuclear accident. It also stipulates that the maximum amount of compensation for damage caused by a nuclear accident assumed by the operator of nuclear power plant is RMB 300 million. If the total compensation payable for damage caused by a nuclear accident exceeds the stipulated maximum amount of compensation, the maximum amount provided by the state is RMB 800 million. It is required that the operator of nuclear power plant must purchase insurance sufficient to fulfil their liability limits prior to the operation, so as to ensure timely and effective performance of the liability for damage caused by nuclear accidents.

Nuclear accident damage system protects the public interest and enable them to obtain full and reasonable compensation when they suffer nuclear damage; meanwhile, it also protects the interests of investors and it is conducive to the healthy development of nuclear power.

3 Chapter III

China's Nuclear Safety Culture and Nuclear Safety Regulation

3.1 China's Nuclear Safety Concept and Nuclear Safety Culture

In March 2014, Chinese President Xi Jinping elaborated on China's "rational, coordinated and progressive" approach of nuclear safety, emphasized "equal emphasis on development and security, equal emphasis on rights and obligations, equal emphasis on autonomy and coordination, equal emphasis on standardization and permanent cure", and made solemn promise that "China will unswervingly strengthen its own nuclear safety capabilities and continue to make its solemn commitment to strengthening government regulatory capabilities, increasing R&D on nuclear safety technologies and input of human resources and adhering to the cultivation and development of a nuclear safety culture" on the World Third Nuclear Safety Summit held in Hague, Netherlands.

"Nuclear safety" refers to taking necessary and sufficient safety measures, such as monitoring, protection, prevention and mitigation, for nuclear facilities, nuclear activities, nuclear materials and radioactive materials, and preventing any accident due to any technical reasons, human factor or natural disasters, minimizing the radiological consequences of accident and protecting workers, the public and the environment from undue radiation.

On December 19, 2014, the National Nuclear Safety Administration, National Energy Administration, State Administration of Science, Technology and Industry for National Defence jointly issued the *Nuclear Safety Culture Policy Statement* and put forward the eight characteristics of nurturing and practicing a nuclear safety culture:

(1) Decision makers' safety view and commitment

Decision-makers should establish the correct concept of nuclear safety. In the decision-making process of establishing development goals, formulating development plans, establishing a management system, establishing a supervisory mechanism and implementing safety responsibilities, it shall always uphold the fundamental principle of "safety first" and make commitments to ensure safety goals.

(2)Management personnel's attitude and exemplary role

Management should set an example by giving full play to its exemplary and demonstration role in enhancing their own safety and cultural accomplishments, establishing and strictly implementing the safety management system, implementing safety responsibilities, giving sufficient powers to safety posts and providing sufficient resources for safety measures, and taking a prudent and conservative

attitude towards security-related decisions.

(3) Full participation and sense of responsibility

All members shall correctly understand and recognize their respective nuclear safety responsibilities, make security commitments, strictly implement security provisions and create a working atmosphere in which everyone is the creator and defender of safety.

(4) Cultivating learning-based organization

All members should strive to formulate a systematic study and training plan, actively and continuously carry out guidance, training and evaluation, improve employees' professional skills, cultivate a teamwork spirit and form a learning atmosphere of inheriting and carrying forward, continue to make improvement, guard against arrogance and rashness, aim for continuous innovation and pursue excellence and self-transcendence.

(5) Building a comprehensive and effective management system

The government should establish and perfect a scientific and rational management system and a strict regulatory mechanism, and operating units should establish a scientific and rational management system, ensuring that any consideration in setting policies, setting up agencies, allocating resources, planning, scheduling, controlling costs can not override safety.

(6) Creating a suitable working environment

Enterprises should set appropriate working hours and labour intensity, provide convenient infrastructure and hardware conditions, establish a widely accepted incentive mechanism and an open and fair staff promotion mechanism; enhance communication and exchange, create a working atmosphere of mutual respect, high trust, solidarity and collaboration; solve conflicts and contradictions in an objective and impartial way.

(7) Establishing a mechanism for questioning, reporting and experiential feedback on safety issues

Enterprises should advocate a strict questioning attitude towards security issues, establish a mechanism to encourage all employees to freely report safety-related issues and ensure that they will not be subject to discrimination and retaliation; managers should respond promptly and reasonably to solve the potential problems and potential safety hazards reported by employees; and an effective empirical feedback system should be established to prevent human errors.

(8) Creating harmonious public relations

The public's right to know, participate and supervise should be enforced through public information, public participation, popular science promotion and other public communication modes; policy makers and management should listen to different opinions in a multi-channel manner with an open mind and properly treat and deal with the needs of stakeholders.

Facing the rapid development of nuclear power, China will more actively advocate, nurture and disseminate the entire society's nuclear safety culture and continuously improve its nuclear safety culture.

3.2 China's Nuclear Safety Regulation

China's nuclear safety supervision adheres to the fundamental principle of "safety first and quality first" and follows the regulatory principle of "independence, openness, rule of law, rationality and effectiveness". After more than 30 years of supervision and management practice, improved nuclear

safety regulatory system and laws and regulations system that are in line with the international standards and in line with China's actual conditions have been established, which have played an important role in the safe development of nuclear energy applications in China.

3.2.1 Laws and Regulations Concerning Nuclear Safety

China's laws and regulations system includes several levels including laws, administrative regulations, departmental rules, nuclear safety guidance, etc.

Laws are formulated by the National People's Congress and its Standing Committee.

In September 2017, the 29th meeting of China's 12th Session of Standing Committee of National People's Congress deliberated and adopted the *Nuclear Safety Law of the People's Republic of China*, which will be implemented since January 1st, 2018. The Nuclear Safety Law is divided into eight chapters, with a total of 94 articles. Key contents include guidelines, principles, responsibility system and technical and cultural guarantee for ensuring nuclear safety; the qualifications, responsibilities and obligations of the operating agencies of nuclear facilities; the permit system for nuclear materials; the safety system for nuclear and radioactive waste; the emergency system for nuclear accidents; the nuclear safety system; the information disclosure and public participation system, etc. In addition, laws related to nuclear safety also include the .

Administrative Regulations are formulated by the State Council of China. Existing nuclear safety administrative regulations put forward the overall requirements for the safety supervision and management of civil nuclear facilities, the supervision and management of civil nuclear safety equipment and the safety management of radioactive waste.

The departmental rules shall be formulated by the relevant departments of the State Council of China. Nuclear safety department regulations in China are divided into 10 series according to the professional field, namely: general series, nuclear power plant series, research reactor series, non-nuclear reactor fuel cycle facilities, radioactive waste management series, nuclear material control series, civilian nuclear safety equipment supervision and management series, radioactive material transport management series, radioisotope and radiation equipment supervision and management series, and radiation environment series.

Nuclear safety guidelines are specific methods and procedures developed on the basis of the 10 fields of expertise described above, which are guidance documents. The permit holder may use different methods in practice, but must prove that the methods used have at least the same safety level.

3.2.2 Nuclear Safety Permit

China implements the whole-process and full-range nuclear safety permit system for nuclear energy utilization. The whole-process permit refers to the implementation of the permit for various stages, such as site selection, design, construction, operation and decommissioning of nuclear power plants. The full-range permit refers to the implementation of the permit for various aspects, such as personnel qualification, nuclear safety equipment, nuclear material, radioactive waste and radioactive material transportation, etc. Only permit holders granted by the National Nuclear Safety Administration can engage in nuclear safety related activities.

The types and contents of China's nuclear safety permit are as follows:

(1) Nuclear power plant related permits, including the *Nuclear Power Plant Site Selection Review Submissions*, the *Nuclear Power Plant Construction Permit*, the *First Loading Approval for Nuclear Power Plant*, the *Nuclear Power Plant Operation Permit*, the *Nuclear Power Plant Retirement Ap-*

proval, as well as the *Operator License* and *Senior Operator License* of nuclear power plant operators.

(2) Civil nuclear safety equipment related permits, including the design, manufacture, installation and non-destructive testing permits for nuclear safety equipment, nuclear safety equipment non-destructive testing personnel qualification certificate, nuclear safety equipment welder certificate and welding operator qualification certificate.

(3) Nuclear materials related permits. If the quantity of nuclear material held reaches the limited unit stipulated by the state, the nuclear material permit must be applied. The permit is issued by the State Administration of Science, Technology and Industry for National Defence and National Nuclear Safety Administration is responsible for approving the first nuclear material permit.

(4) Radioactive waste related permits. Units engaged in the storage and disposal of radioactive solid waste must apply for a permit issued by the National Nuclear Safety Administration.

(5) Relevant permits for the transport of radioactive material, including the design of class-1 radioactive material transport containers, the manufacturing activities of class-1 radioactive material transport containers and the checking of class-1 radioactive materials, etc.

3.2.3 Supervision and Management of Imported Civilian Nuclear Safety Equipment

3.2.3 .1 The basic requirements of supervision and management

China's laws and regulations on the supervision and administration of civilian nuclear safety equipment mainly include:

Regulation on the Supervision and Management of Civil Nuclear Safety Equipment (Promulgated on July 11, 2007);

Supervision and Management Regulations on the Design, Manufacture, Installation and Non-destructive Testing of Civilian Nuclear Safety Equipment (HAF601-2007);

Management Regulations on Civilian Nuclear Safety Equipment Non-destructive Testing Personnel Qualifications(HAF602-2007);

Management Regulations on Welding Operation Qualification of Civilian Nuclear Safety Equipment Welders(HAF603-2007);

Supervision and Management Regulations on Imported Civilian Nuclear Safety Equipment (HAF604-2007).

Among them, HAF604 is specifically for the import of civilian nuclear safety equipment.

HAF604 consists of seven chapters, with a total of 46 articles, including general provisions, registration of overseas units, supervision and inspection of nuclear safety regulatory authorities under the State Council, supervision and inspection of civil nuclear facilities operating units, pre-shipment inspection, supervision and inspection, safety of imported civilian nuclear safety equipment inspection, legal liability and supplementary rules. Its core content stipulates the specific methods for the registration of overseas units and the safety inspection of imported civilian nuclear safety equipment.

According to the provisions of HAF604, the overseas units, which are willing to provide civilian nuclear safety equipment design, manufacture, installation or non-destructive testing activities for civilian nuclear facilities in China, have the right to submit a registration application to the Ministry of Environmental Protection (National Nuclear Safety Administration). Unregistered overseas units may not design, manufacture, install or conduct non-destructive testing of civil nuclear safety equipment for civilian nuclear facilities in China.

The registration system can effectively guarantee that overseas units engaged in the design, manufacture, installation and non-destructive testing of civil nuclear safety equipment meet the corre-

sponding requirements. Meanwhile, through the registration system, supervision and inspection can be implemented on overseas unit which design, manufacture, install and conduct non-destructive testing of civil nuclear safety equipment if necessary, so as to verify whether the activities of imported civilian nuclear safety equipment engaged in by overseas units meet the requirements of the relevant laws and regulations in China.

The implementation of safety inspection is the basic prerequisite for the fulfillment of the commodity inspection procedures. The entry-exit inspection agency only can perform commodity inspection formalities for the equipment that is qualified for safety inspection; equipment that is unqualified for safety inspection means that it does not meet the requirements and the commodity inspection procedures shall not be performed.

3.2.3.2 The length of time and cost required by the approval process

The National Nuclear Safety Administration shall make the approval decision within 45 working days (excluding time required for technical review, document transmission, etc.) starting from the date of acceptance.

Technical review costs shall be charged for review of registrations according to the relevant provisions of the State and no fee shall be charged before the specific charging standard is formulated. As of the end of 2016, there is no charge for the registration of offshore units providing civilian nuclear safety equipment design, manufacture, installation and non-destructive testing for civilian nuclear facilities in China.

3.2.3.3 The validity of the certificate and how to extend it.

Registration Confirmation is valid for five years. The overseas units which need to continue to engage in relevant activities after the Registration of Confirmation is expired shall submit a registration application to the National Nuclear Safety Administration again according to the same material format requirements as that of the first application 6 months in advance of the expiration of the Registration of Confirmation.

The unit applying for re-application shall not only meet the performance requirements required by the first application and submit the relevant supporting materials, but also shall submit the Usage Evaluation Report if it has engaged in nuclear safety equipment activities related with nuclear facilities in China within the valid registration period; the unit which has not engaged in relevant activities shall additionally submit the procurement demand proof materials for at least 2 units.

The overseas unit which submits an application again shall describe changes in their units (Organizational Structure, Quality Assurance Program and Procedures, Total Number of Technical Staff, Changes in Design and Manufacturing Owners, Design Validation, Plant and Major Equipment, Major Testing Equipment and Instruments, Qualifications, etc.) in the recent five years in the application materials.

The Ministry of Environmental Protection (National Nuclear Safety Administration) shall organize and carry out technical review on the qualified applying units which submit application again; for units with relatively good performance and quality history, the review procedures can be simplified; and for units with no performance but quality problems, the review procedures shall be enhanced to select the best ones and eliminate the inferior ones.

After the technical review unit has completed the technical evaluation, the Ministry of Environmental Protection (National Nuclear Safety Administration) will make review on the company affair meeting and make approval decision after the deliberation has been passed.

The Ministry of Environmental Protection (National Nuclear Safety Administration) will publish the approval information online at the government website of the Ministry of Environmental Protection (http://www.zhb.gov.cn/) on a regular basis.

3.3 Qualified Suppliers Access Procedures

The certification of National Nuclear Safety Administration can be used as a nuclear-level certification, but it will not make a company automatically become a qualified supplier of nuclear power enterprises in China. Overseas enterprises need to submit their application for evaluation in accordance with the relevant provisions of China's nuclear power enterprises. All three nuclear power groups in China have their own independent and qualified supplier evaluation system, and have different qualification requirements for different types of nuclear-level suppliers. Only after the final evaluation is passed, the enterprises providing the products and services can participate in the group's related businesses as suppliers.

3.3.1 China National Nuclear Corporation (CNNC)

To become a qualified supplier of China National Nuclear Corporation, foreign companies must first log in to the China National Nuclear Corporation e-commerce platform (http://epc.cnnc.com.cn) to register and obtain their account number and password. Subsequently, they shall submit their supplier evaluation application to XQCC (http://gys.cnnc.com.cn). After passing the final evaluation, a Qualified Supplier Certificate will be issued to China National Nuclear Corporation; the companies will then be included in the Directory of Qualified Suppliers of China National Nuclear Corporation and become qualified suppliers of China National Nuclear Corporation.

At present, China National Nuclear Corporation has not set up a special English bidding website, but many overseas companies have become qualified suppliers of the group. Overseas enterprises can learn about the relevant information through the China National Nuclear Corporation e-commerce platform or the Xingyuan Certification Center. After registering and passing the qualification examination of qualified suppliers, they can become the first-tier and second-tier suppliers of the group.

3.3.2 China General Nuclear Power Group (CGN)

To become a qualified supplier of China General Nuclear Power Group, the foreign company must log in to the Electronic Commercial Platform (ECP) and register as a member. After being approved by the group's supplier management agency, foreign companies become the potential suppliers. Thereafter, the group's supplier management agency will initiate supplier qualification review as required. The qualification review methods of suppliers include document review, source review and other review. After passing the final examination, the foreign company will become a qualified supplier of China General Nuclear Power Group.

1. Document review: Sending qualification review documents to the supplier and judging whether the supplier has the bidding qualification and the ability to fulfil the contract based on the documents returned by the suppliers, which mainly include confirming the basic qualifications, relevant performance, performance ability, financial status, technical level and safety, quality, environmental conditions of suppliers.

2. Source review: As for the suppliers that need to receive source review, after the document review has been passed, the group company's Safety, Quality and Environment Departments or the

dispatched technical and business personnel shall review the place where the supplier is located as required, adopt corresponding review strategy and issue separate written opinions.

3. Other review: Due to the different businesses of the companies under the group, each company may choose to entrust an external agency to make review, simplify review, be exempted from review, and may choose other special review methods. The corresponding regulations made by the companies in this regard need to be submitted to the Group Bidding Management Center.

The bidding center of China Nuclear Power Engineering Co., Ltd. (CGN) is the engineering company's supplier and the centralized management department of bidding business. According to the group's authorization, the bidding center fulfils the tender public service responsibilities as instructed by the group. In accordance with the operation rules of the engineering company's bidding center, the bidding center of the engineering company is responsible for the bidding of international projects and can help overseas companies to make inquiries.

China General Nuclear Power Group of China General Nuclear Power Group: http://www.cgnpc.com.cn/

3.3.3 State Power Investment Corporation (SPIC)

The evaluation scope of State Power Investment Corporation include suppliers' forensics (such as the nuclear safety license of National Nuclear Safety Administration, the certificate of United States ASME card, etc.), quality assurance system, technical capabilities, economic strength and past performance. Evaluation methods should be implemented in accordance with the evaluation management rules and evaluation criteria of qualified supplier approved by the National Nuclear Power Equipment and Fuel Department.

The responsible department for the supplier evaluation of State Power Investment Corporation is the Materials Procurement Department, and the responsible department is the Commercial and Legal Department. Procurement approach is divided into domestic market procurement and global market procurement. For the procurement in the domestic market, overseas companies need to set up offices in China, with reference to the information published by China Bidding Website (http://www.bidchance.com), and participate in relevant matters as required; for the procurement in the global market, according to the requirements of the Ministry of Commerce, the State Power Investment Corporation and the China National Nuclear Power Co., Ltd. generally entrust SPIC China Power Complete Equipment Co., Ltd. as the acting tender. Specific information is available on the official website.

Website of State Power Investment Corporation: http://www.spic.com.cn/

Website of State Nuclear Power Technology Corporation: http://www.snptc.com/

Chapter IV

4 New Nuclear Power Projects in China

4.1 New Nuclear Power Projects and Their Technical Features

According to the requirements of China's 13th Five-Year Plan, the installed capacity of nuclear power in China will reach 58 million kilowatts by 2020; more than 30 million kilowatts are under construction; and there is an average of five to six newly-built nuclear power plants each year. The main models for the nuclear power plants built during the 13th Five-year Period include HPR1000, CAP1000, CAP1400 and 600-MW demonstration fast reactors and high-temperature gas-cooled reactors. Table 4-1 lists the model selection of some projects.

Table 4−1 Part of New Nuclear Power Projects to Be Built During the 13th Five−Year Plan period

Model	Installed capacity (MWt)	Proposed project
HPR1000	1200×2	Ningde Phase 2; Zhangzhou in Fujian; Taipingling in Guangdong;
CAP1000	1250×2	Haiyang Phase 2; Xudabao in Liaoning; Lufeng in Guangdong; Sanmen Phase 2; Cangnan in Zhejiang; Haixing in Hebei;
CAP1400	1500×2	Shandong Shidao Bay CAP1400 Demonstration Project (2 units)
600-MW Demonstration Fast Reactor	600×1	Xiapu in Fujian;
High-temperature gas-cooled reactor	600	Wan'an in Fujian, etc.;
VVER	1060×2	Tianwan Phase 4
ACP100	100	Changjiang in Hainan

Since a number of new nuclear power projects have not been approved yet, projects and models may change in the future approval process. The reactor type in Table 4-1 is for reference only.

4.1.1 HPR1000

HPR1000 is the third-generation nuclear power technology jointly developed by CNNC and CGN. Its main design features include: 177 fuel assemblies for the reactor core, a combination of "active and passive" multiple redundancies for safety system, single pile arrangement, double containment, all-digital instrument control system (DCS), benchmark ground level acceleration of 0.3g, design life of 60 years, etc. After review, domestic and foreign experts believe that the safety index and technical performance of HPR1000 have reached the advanced level of the international third-generation nuclear power technology.

The equipment manufacturing of HPR1000 is based on China's existing industrial system. Localization rate can reach more than 85%. The construction of the first reactor of HPR1000 has started in Fuqing, Fujian Province (Unit 5, Fuqing) on May 7, 2015. At present, there are six units of HPR1000 under construction, which are units #5/6 in Fuqing, Fujian Province, units #3/4 in Fangchenggang, Guangxi Province and unit K2/K3 in Karachi, Pakistan. In addition, the proposed new nuclear power projects in Fujian Ningde Phase II (No. 5/6), Fujian Zhangzhou (No. 1/2) and Guangdong Taipingling (No. 1/2) will also adopt HPR1000.

4.1.2 CAP1000

CAP1000 is the Chinese localized AP1000 technology formed by Shanghai Nuclear Engineering Research and Design Institute based on the introduction of AP1000 from the United States. At present, AP1000 standard design has been completed; except for a small number of key equipment, CAP1000's key equipment can be manufactured locally, with a localization rate of more than 80%.

The AP1000 is a large commercial PWR developed by Westinghouse Electric Corporation. Its main feature is the use of "passive safety system" to take advantage of the inherent laws of natural convection, gravity, evaporation, condensation and other natural substances to remove the heat from the core and ensure the safety of the reactor during emergency cooling in response to an accident. Within 72 hours after a serious accident, it can rely entirely on passive systems to ensure the safety of nuclear power plants and the environment without the need for external power and personnel intervention.

For AP1000, the single unit power is 1.25 million kilowatts; the designed benchmark ground level acceleration is 0.3g; the designed service life is 60 years; and the availability of nuclear power plan is not less than 93%. AP1000 adopts a fully digital instrument control system (DCS), advanced nuclear fuel assemblies, modular design and construction, which significantly reduce the number of pipes and valves, thus having a number of economic advantages.

The construction of the world's first reactor of AP 1000 was started in Sanmen, China in April 2009. So far, all the work before the first loading has been completed and it will be loaded and put into operation soon.

During the construction process of four AP1000 units in Sanmen, Haiyang, the localization rate of major equipment was continuously increased, from the 25% for the first unit to about 70% for the fourth unit.

The proposed nuclear power projects, such as Haiyang Phase II in Shandong, Xudabo in Liaoning, Lufeng in Guangdong and Sanmen Phase II in Zhejiang have tentatively determined to adopt the CAP 1000 technology, and are planned to start construction in the first half of 2018. The nuclear power projects in Cangnan in Zhejiang and Haixing in Hebei are also prepared to use CAP1000 technology.

4.1.3 CAP1400

According to the AP1000 technology transfer contract reached by China and the United States, China has independent intellectual property rights if the electric power of China's self-developed passive large PWRs exceeds 1.35 million kilowatts. Under the support of major national science and technology projects, the State Nuclear Power Technology Corporation independently developed the CAP1400 nuclear power technology.

The electric power of CAP1400 reaches 15 million kilowatts, with an increase of 20% compared with the AP1000. During the development process of CAP1400, the reactor coolant systems, dedicated safety systems, major nuclear island support systems, main equipment, nuclear island plant layouts and conventional islands were redesigned and systematically optimized. The core fuel assembly load was increased; the number of fuel assemblies was increased from 157 of the AP1000 to 193; the power of nuclear power plant was increased from 1250MWe of AP1000 to 1500MWe, which can ensure that the thermal safety margin is more than 15%. At the same time, the size of the steel containment has also been increased, and the outer layer has the ability to withstand large commercial aircraft impacts (Table 4-2). CAP1400 not only retains the main features of AP1000's advanced design, but also integrates the experience of Fukushima accident feedback, thus having the ability to deal with over-design accidents; and the safety and economy are further improved.

Table 4−2 Main Technical Indicators of the CAP1400

Main Technical Indicator	AP1000	CAP1400
Thermal (electrical) power	3400MWth (1250 MWe)	4058MWth (1500 MWe)
Core damage probability	5×10^{-7}/Reactor * year	4×10^{-7}/Reactor * year
Power plant availability	>93%	>93%
Thermal margin	>15%	>15%
Operator response time	72 hours	72 hours

During the R&D process of CAP1400, China has successively completed a series of research projects including passive core cooling system (ACME), passive containment cooling system (IVR), in-vessel retention (PCS), reactor structural hydraulic simulation, flow-induced vibration simulation of internal components, performance of steam generators and other six key technologies, which laid the foundation for the independent development of CAP1400.

The CAP1400 demonstration project is proposed to be constructed in the Shidao Bay Nuclear Power Base in Shandong Province. The project owner is a national demonstration nuclear power company. The EPC contracting and procurement are undertaken by a national nuclear team formed by State Nuclear Power Engineering Company, Shanghai Nuclear Engineering Research & Design Institute Co., Ltd. and State Nuclear Electric Power Planning Design & Research Institute Co., Ltd. The

civil installation of nuclear island is undertaken by the China's Nuclear Industry Huaxing Construction Company Limited, China's Nuclear Industry 23 Construction Co., Ltd. subordinated to China Nuclear E & C Group and China Engineering Group Zhejiang Thermal Power Construction Co., Ltd.; and the civil installation of conventional island is undertaken by SEPCO Electric Power Construction Corporation and Jiangsu Electric Power Construction Corporation.

In February 2016, the Preliminary Safety Analysis Report (PASR) of CAP1400 demonstration project was reviewed by the National Nuclear Safety Administration. In April 2016, the CAP1400 passed the General Reactor Safety Review (GRSR) of the International Atomic Energy Agency (IAEA); and it is believed that it has reached the latest IAEA safety regulations and requirements in overall. At present, the preliminary work of CAP1400 demonstration project has basically been completed and is pendingapproval by the government.

4.1.4 600-MW Demonstration Fast Reactor Nuclear power plant

The China Experimental Fast Reactor (CEFR) with a thermal power of 65 MW constructed by the China Institute of Atomic Energy was successfully grid-connected in July 2011.

In view of the advantages of the fast reactor in improving the utilization rate of natural uranium resources and transmuting long-lived radioactive waste, the Chinese Government has decided to develop a commercial fast reactor power plant with a capacity of 600,000 kW based on the CEFR. The site is located in Xiapu, Fujian Province. At present, the preliminary work of the Xiapu fast reactor power station is being actively promoted, and the first tank of concrete (FCD) is planned to be poured by the end of 2017.

4.1.5 High-Temperature Gas-cooled Reactor Nuclear Power Plant

In the mid-1980s, China's Tsinghua University conducted a study on a 10-MW high-temperature gas-cooled experimental reactor. In January 2003, it achieved full-power grid-connected power generation.

In January 2006, the State Council listed the high-temperature gas-cooled reactor demonstration project as a major national science and technology project. At the end of December 2012, the 200,000-kWShidao Bay HTR nuclear power plant demonstration project was started; and it is expected to be grid-connected in 2018.

At present, the manufacturing and related tests of key equipment such as pressure vessels, metal reactor components, main helium fans and steam generator heat exchange units in the HTGR demonstration project have been completed and related experiments have been completed. The industrial high-temperature gas-cooled reactor with an annual output of 300,000 fuel balls has been completed and put into production.

With the support of major national projects, the National High-Temperature Gas-cooled Reactor Engineering Laboratory and Engineering Research Center was established. The Engineering Laboratory has set up13 test platforms including large-scale helium test circuit, steam generator test circuit, hot and cold test platform for fuel refurbishment system, hot test and verification platform for absorption ball shut-off system, hot test and verification platform for control rod system, experimental verification platform for main helium fan, etc., and formed a complete, large-scale high-temperature gas-cooled reactor technology research and innovation base. The Engineering Research Center includes simulator laboratory, control rod test bench, nuclear valve verification test bench, simulation design system and three-dimensional collaborative design system, which have initially formed the engineering transformation research and design platform, related experimental verification and equipment identification

platform, demonstration project information management platform, thus providing a guarantee for the R & D verification and follow-up research and development upgrade of HTGR demonstration project.

Tsinghua University is working with relevant parties to actively promote the construction of a new commercial 600,000-kW high-temperature reactor nuclear power project due to its inherent safety and wide range of uses. The 600,000-kW high-temperature reactor nuclear power unit adopts a modular type, and consists of six reactors with a power of 100,000-kW and a 600,000-kW turbine generator set. Its main technical characteristics are consistent with that of Shidao Bay HTR-PM. As a result of the expansion of the scale, the economy of the 600,000-kW HTR nuclear power unit will be improved.

Currently, China Nuclear E & C Group has partnered with Tsinghua University to promote the industrialization of HTGR. The preliminary work on a new 600-MW kWh project has been carried out in Fujian, Guangdong, Jiangxi and Hunan provinces.

4.1.6 Small Nuclear Power Units

Small nuclear power unit refer to the nuclear power units below 300MW. Small reactors have attracted the attention of all countries in the world because of its small initial investment, short construction period, which can effectively solve the transmission problems of small and medium-sized power grids. The small reactors under development in China include ACP100 from China National Nuclear Corporation, ACPR 50S from CGN Group and NHR200-II from Tsinghua University.

The ACP100 from China National Nuclear Corporation uses a number of integrated structures based on typical PWR technology, with small and passive safety features for the physical elimination of large-scale releases of radioactive material. In April 2016, the International Atomic Energy Agency (IAEA) submitted the final report of the ACP100 General Reactor Safety Review to China National Nuclear Corporation. The ACP100 became the first small reactor technology in the world to pass IAEA's safety review. ACP100 has completed all scientific research; reactor pressure vessels and other nuclear island main equipment and turbine generators can all be built independently. China National Nuclear Corporation plans to build ACP100 pilot project in Changjiang, Hainan. The project is scheduled to start by the end of 2017 with a planning capacity of 125MW and a construction period of 36 months.

China General Nuclear Power Group's ACPR 50S is a compact, versatile offshore small pile technology with a single stack of 200 MW, which can provide power for offshore oil and gas field exploitation and island development. ACPR 50S technology is mature, which adopts the long-term refuelling program and is competitive with the conventional energy at sea. At present, China General Nuclear Power Group is carrying out preliminary design of ACPR 50S demonstration project and plans to start construction of demonstration projects in 2017 and generate electricity by 2020.

The NHR 200-II, developed by Tsinghua University, is based on a five-MW low-temperature nuclear reactor and can be combined with heat and power after being scalable and adaptable. Currently, Tsinghua University is cooperating with relevant parties such as China Nuclear Energy Technology Co., Ltd. and is promoting the market application of NHR200-II.

4.1.7 Research and Development of Other Advanced Reactors

Under the framework of the GIF International Forum (GIF), China is cooperating with other countries in the world in terms of the research and development of the fourth generation nuclear energy system.

Nuclear Power Institute of China and Shanghai Jiao Tong University has carried out the research and development of supercritical water-cooled reactor (SCWR), put forward the general technical

route of supercritical water-cooled reactor, completed the overall design scheme and material selection scheme of the highest one million kilowatts supercritical water reactor CSR1000 and built the design and experimental research platform.

Shanghai Institute of Applied Physics, Chinese Academy of Sciences, has taken the lead in research and development of thorium-based molten salt reactor (TMSR) and strives to build the world's first 10-MW solid-state fuel thorium-based molten salt reactor by 2020.

Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences is carrying out the research and development accelerator-driven subcritical system (ADS) and is planning to establish an exemplary ADS transmutation system and China's lead-based reactor (CLEAR) before 2030.

China National Nuclear Corporation, in cooperation with Terra Power, is conducting R&D on travelling wave reactor.

4.2 Other Fields of Foreign Cooperation

4.2.1 Operation and Maintenance of Nuclear Power Plant

—Exchange of experiences in terms of the operation and maintenance of nuclear power plants;

—Joint research and development of new operation and maintenance technologies of nuclear power plants;

—Import and export of operation and maintenance services of nuclear power plants;

—Mutual support in terms of operation and maintenance related human resources of nuclear power plants.

4.2.2 Waste Disposal Safety Assessment

—Site selection, design, construction, scene screening and analysis study during operation and after closure of low and medium level radioactive waste disposal facilities;

—Event classification research and establishment of safety assessment model of disposal site, including model of radionuclide release in near field and far field, nuclide migration and dose estimation model in biosphere;

—Disposal safety analysis methods and safety assessment technical guidelines.

4.2.3 Transport and Storage of Spent Fuel

—Impact analysis and safety assessment of high fuel consumption on spent fuel storage and transportation;

—Research on cladding material properties of high fuel consumption fuel;

—Long-term performance studies of spent fuel storage: long-term performance studies of spent fuel sealed containers in dry storage and long-term performance studies of neutron absorber materials;

—Optimized calculation of spent fuel criticality and burnup trust;

—Storage and handling of damaged spent fuel components;

—Technical research on the spent fuel storage and transportation: including nuclear material tracking management, fuel status monitoring during storage and regular safety assessment of facility operations.

4.2.4 Decommissioning of Nuclear Power Plant

—Nuclear Facilities decommissioning and radioactive waste management standards system;

—Development and upgrading of decommissioning programs for nuclear facilities;

—Retirement related design during the construction process of nuclear facilities;

—PWR main circuit equipment replacement;

—Special technical cooperation in terms of nuclear decommissioning and radioactive waste management;

—Decommissioning and radioactive waste management personnel training;

—Seeking opportunities for decommissioning and radioactive waste management projects.

4.2.5 Technical Requirements for Evaluation of Radioactive Waste Disposal in the United Kingdom

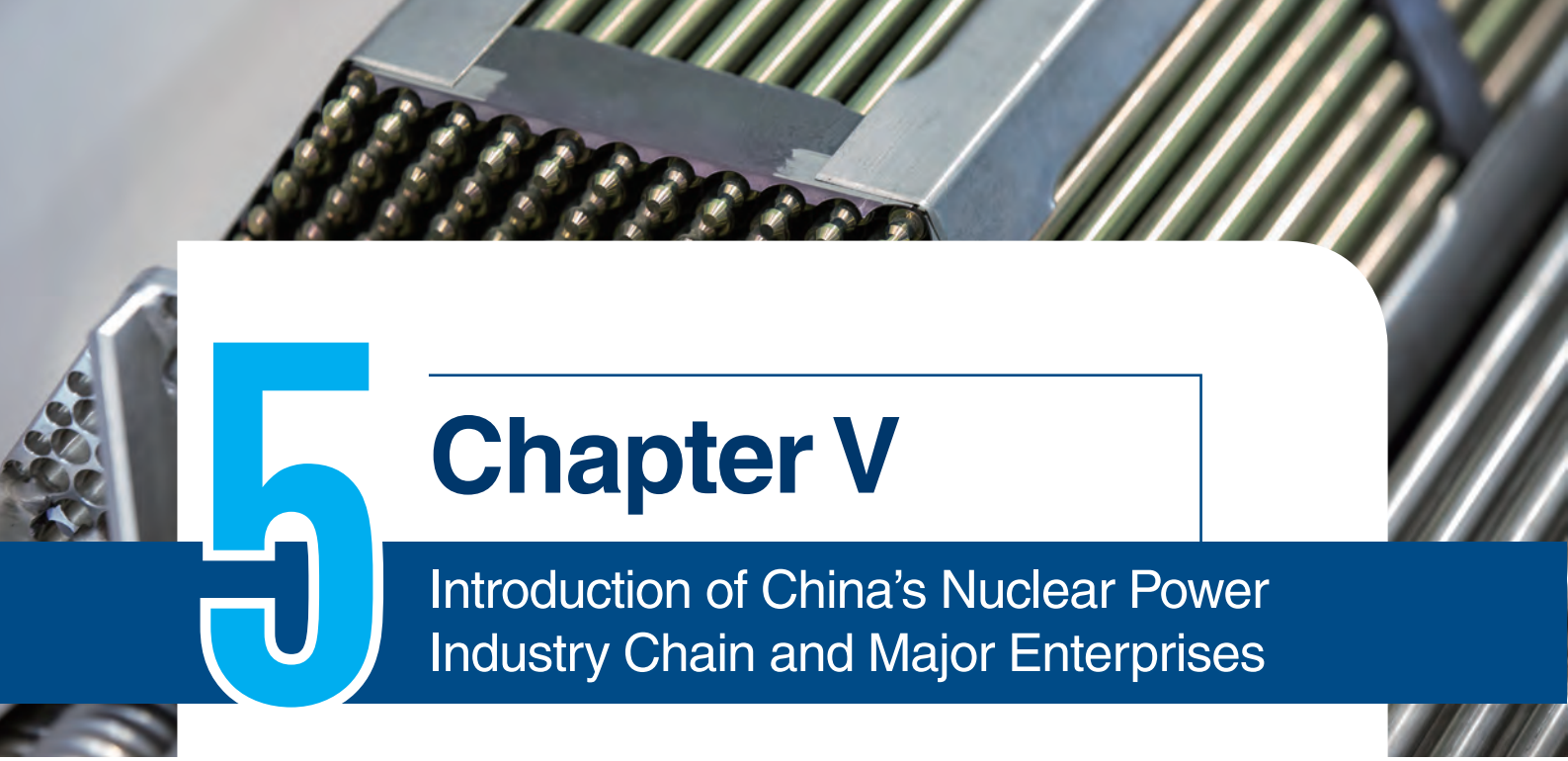
China General Nuclear Power Group has submitted GDA review application of HPR1000 to the UK, wishing to strengthen international cooperation in the area of feasibility assessment of radioactive waste management and disposal:

—Compliance between HPR1000 Radioactive Waste Management Technical Program with the regulations, standards and guidelines relating to radioactive waste management in the United Kingdom.

—Technical requirements, evaluation methods and acceptance criteria of the UK for radioactive waste disposal evaluation, formulating a radioactive waste disposal strategy that meets UK technical requirements.

—The UK's temporary storage facility for medium and high-level radioactive waste meets the design requirements of 100 years of design life, existing technical solutions and operational management measures; developing a medium and high-level radioactive waste repository program that meets UK technical requirements.

—BAT methodology studies factors affecting BAT application throughout the waste management process, demonstrates the radioactive waste management process and optimization of environmental relations, as well as the minimized impact on the public and the environment.



5 Chapter V

Introduction of China's Nuclear Power Industry Chain and Major Enterprises

5.1 China's Nuclear Power Industry Chain

Under the promotion of nuclear power development, China has formed a complete nuclear power industry chain, including project investment, nuclear power operation, nuclear island research and design, project management, supply of nuclear power equipment, nuclear power plant construction, nuclear fuel supply and spent fuel management, operation and maintenance, other social services and other related aspects (Table 5-1). China's nuclear power industry chain has provided strong support for the large-scale development of nuclear power.

Table 5−1 China's Nuclear Power Industry Chain and Major Enterprises

	Industrial Chain Links	Main Enterprises and Public Institutions
1	Project Investment	(Holding) China National Nuclear Corporation, China General Nuclear Power Group, State Power Investment Corporation, China Huaneng Group Corporation (Other shareholders) Local government investment institutions, domestic and foreign power investment companies
2	Nuclear power operation	Qinshan Nuclear Power Company, Nuclear Power Qinshan Joint Venture Co., Limited, The Third Qinshan Nuclear Power Co., Ltd., CNNC Nuclear Power Operation & Management Co., Ltd., Daya Bay Nuclear Power Operation Management Co., Ltd, Jiangsu Nuclear Power Corporation, Fujian Fuqing Nuclear Power Co., Ltd., Zhejiang Sanmen Nuclear Power Co., Ltd., Hainan Nuclear Power Co., Ltd., Liaoning Hongyanhe Nuclear Power Co., Ltd., Fujian Ningde Nuclear Power Co., Ltd., Guangdong Yangjiang Nuclear Power Co., Ltd., Guangxi Fangchenggang Nuclear Power Co., Ltd.
3	Nuclear Island Research and Design	Nuclear Power Institute of China, Beijing Institute of Nuclear Engineering, Shenzhen CGN Nuclear Power Research Institute, Shanghai Nuclear Engineering Research & Design Institute, China Institute of Atomic Energy, Institute of Nuclear and New Energy Technology, Tsinghua University

	Industrial Chain Links	Main Enterprises and Public Institutions
4	Engineering Management	China Nuclear Power Engineering Co., Ltd. (CNNC), China Nuclear Power Engineering Co., Ltd. (CGN), State Nuclear Power Engineering Company, nuclear power owners
5	Nuclear Power Equipment Supply	China First Heavy Industries (CHFI), Shanghai Electric Group Co., Ltd., Dongfang Electric Corporation (DEC), Harbin Electric (main equipment); other nuclear power equipment suppliers;
6	Nuclear Island Civil Installation	China Nuclear E&C Group (CNEC), Guangdong Thermal Power, Shandong Thermal Power;
7	Nuclear Fuel Supply and Spent Fuel Management	China Nuclear Fuel Corporation (CNFC), CGNPC Uranium Resources Co., Ltd., Everclean Environmental Engineering Corporation, CNNC Nuclear Fuel Reprocessing Co., Ltd. (CNFR), etc.
8	Operation and Maintenance	The subordinated nuclear power companies and nuclear power operation companies (same nuclear power operation) of various group companies; equipment suppliers; specialized maintenance companies and technical support units;
9	Social Services	Banks, insurance and other financial institutions; colleges and universities, training institutions and other personnel training bases; legal services, etc.

5.1.1 Investment in Nuclear Power Projects

Most of China's nuclear power projects are invested by a number of investment entities according to a certain share ratio, including an investment entity as the controlling party or the actual controller. The controlling shareholder or actual controller of the project has the primary responsibility for the construction and operation of the NPP.

The Chinese Government has set qualification requirements for controlling nuclear power projects. In the Nuclear Power Regulations (Exposure Draft) drafted by the National Energy Administration, it is required that the controlling shareholder or actual controller of a nuclear power project must have "at least eight years of experience in the construction and operation of nuclear power projects", "undertaken the entire construction cycle of one unit and its three years operational experience" and a sufficient number of "qualified nuclear power related qualifications personnel team" and other conditions. The purpose is to ensure that the key management personnel of nuclear power projects can meet the requirements of project management and nuclear safety regulations in terms of qualification and quality and ensure the construction quality and operational safety of nuclear power units.

There are three companies that have obtained the holding qualification of nuclear power construction projects, namely China National Nuclear Corporation, China General Nuclear Power Group and State Power Investment Corporation. They can declare a new nuclear power project at the state jointly with the local government investment and energy authorities (NDRC, NEA). The State Council also agreed that Huaneng Group act as the controlling shareholder of Shandong Shidao Bay HTGR Demonstration Project (with 47.5% of the shares).

Among the 35 units which have been put into operation currently, the controlling interests of 16 units are held by China National Nuclear Corporation, with a total installed capacity of 13.25 million kilowatts; the controlling interests of 19 units are held by China General Nuclear Power Group, with a total installed capacity of 20.36 million kilowatts.

In 2015, the two groups established China National Nuclear Power Co., Ltd. and CGN Power Co., Ltd. successively, which are listed respectively on the Shanghai Stock Exchange and the Hong Kong Stock Exchange.

Among the 21 units under construction, the controlling interests of nine units are held by China National Nuclear Corporation; the controlling interests of six units are held by China General Nuclear Power Group; the controlling interests of two units (Hongyanhe #5, 6) are held by China General Nuclear Power Group and State Power Investment Corporation with the same ratio; the controlling interests of two units (Shandong Haiyang AP1000 Unit) are held by State Power Investment Corporation; the controlling interest of one unit (Shandong Shidao Bay High-temperature Gas-cooled Reactor Unit)is held by Huaneng Group.

5.1.2 Operation of Nuclear Power Plant

The 35 in-service nuclear power plants belong to 13 nuclear power plants (see Table 1-1). Among them, Qinshan Nuclear Power Operation Company of China National Nuclear Corporation is responsible for the operation of nine units of Zhejiang Qinshan Base (Qinshan Phase I, Phase II, Phase III and Fangjiashan); CGN Daya Bay Nuclear Power Company is responsible for the operation of six units of Daya Bay Base (Daya Bay and Ling'ao); Jiangsu Nuclear Power Corporation (two units), Fujian Fuqing Nuclear Power Co., Ltd. (three units), Hainan Nuclear Power Co., Ltd. (two units), Liaoning Hongyanhe Nuclear Power Co., Ltd. (four units), Fujian Ningde Nuclear Power Co., Ltd. (four units), Guangdong Yangjiang Nuclear Power Co., Ltd. (three units), Guangxi Fangchenggang Nuclear Power Co., Ltd. (two units) are responsible for the operation of the rest of the units.

In accordance with the provisions of China's nuclear safety regulations, nuclear power plant owners assume full responsibility for nuclear safety. For those units commissioned by the operating companies, nuclear power plant owners and operating companies jointly assume nuclear safety responsibilities.

5.1.3 Nuclear Island Research and Design

China's major nuclear power research and design institutes are mainly established under three companies, such as China National Nuclear Corporation, China General Nuclear Power Group and State Power Investment Corporation.

The research design units of China National Nuclear Corporation's nuclear island include Nuclear Power Institute of China (NPIC), Beijing Nuclear Engineering Research and Design Institute (BNERDI) and China Institute of Atomic Energy (CIAE). NPIC is responsible for the design of PWR reactors and primary loop cooling systems; BNERDI is responsible for the overall design, fuel handling system design, nuclear island plant design and auxiliary system (BOP) design of all nuclear power projects of China National Nuclear Corporation. At present, the projects under the R&D of the two institutes include Fuqing #5, 6 units, Karachi K2/K3 unit (HPR1000) in Pakistan, Tianwan #5, 6 units (CP100) and small modular reactors, etc. China Institute of Atomic Energy is responsible for the design of the nuclear island of Xiapu 600-MW demonstration fast reactor in Fujian Province.

CGNPC's major projects are designed by Shenzhen CGN Nuclear Power Research Institute.

The Institute has successively completed the design work for more than ten CPR1000 series nuclear power units such as Hongyanhe, Ningde, Yangjiang and Fangchenggang. Currently, the design of the HPR1000 units and the UK GDA certification work of "HPR1000"are underway.

The Shanghai Nuclear Engineering Research and Design Institute under State Power Investment Corporation undertook the introduction, analysis, integration and re-innovation tasks of AP1000, and completed CAP1000 standard design, CAP1400 research and design work. The currently design projects undertaken include Shidao Bay CAP1400 demonstration project, as well as the design of CAP1000 for Haiyang Phase II, Sanmen Phase II and Lufeng, etc.

Tsinghua University's Institute of Nuclear and New Energy Technology is responsible for the nuclear island design of Shidao Bay 200-MW High-temperature Reactor Project (HTR - PM); and China Energy is responsible for the engineering design of high-temperature reactor nuclear power plant.

5.1.4 Nuclear Power Project Management

At present, China's nuclear power project management has generally adopted the EPC management model of "lean owner plus engineering company general contracting, professional company subcontracting"; the nuclear power engineering companies are responsible for the general contracting of construction projects, and then have qualified specialized companies as the sub-contractors of civil and installation works of nuclear islands and conventional islands.

The project management of the three group's nuclear power projects is undertaken by China Nuclear Power Engineering Co., Ltd., China Nuclear Power Engineering Co., Ltd. (CGN) and State Nuclear Power Engineering Company respectively. China Nuclear Power Engineering Co., Ltd. has successively undertaken the general contracting projects of Fujian Fuqing, Zhejiang Qinshan Expansion (Fang Jiashan), Hainan Changjiang and Jiangsu Tianwan. China Nuclear Power Engineering Co., Ltd. (CGN) has contracted and completed projects of Guangdong Ling'aoPhase II (two units), Liaoning Hongyanhe Phase I (four units), Fujian Ningde Phase I (four units) Guangdong Yangjiang (four units), Guangxi Fangchenggang (two units), etc., and there are eight units under construction.

The State Nuclear Power Engineering Company under the State Power Investment Corporation is the leading general contractor of AP1000, which forms a joint force with companies such as Westinghouse, Shaw and other companies in the United States to manage four units in Sanmen and Haiyang.

5.1.5 Civil Installation of Nuclear Power Plant

The civil construction of nuclear island of China's nuclear plants is mainly undertaken by China Nuclear E&C Group, which has been engaged in construction of nuclear power for more than 30 consecutive years and has completed the construction of different heap types of nuclear power units, such as pressurized water reactors, fast neutron reactors and heavy water reactors. China Nuclear E&C Group has a number of nuclear island civil construction enterprises under it such as China's Nuclear Industry 22nd Construction Co., Ltd., China's Nuclear Industry 24 Construction Co., Ltd. and Huaxing Company, as well as a number of nuclear island installation enterprises such as China's Nuclear Industry 23 Construction Co., Ltd. and China's Nuclear Industry Fifth Construction Co., Ltd. in Shanghai, etc. Thus it has rich engineering experience, and has formed specialized nuclear power construction technology system. In December 2010, China Nuclear Engineering Corporation Limited was established. In June 2016, the stock company was listed on the Shanghai Stock Exchange.

5.1.6 Nuclear Power Equipment Manufacturing

China was a late-comer to nuclear power; the Daya Bay Nuclear Power Plant, for example, was imported from France in the 1980s, and almost all the key equipment were imported from France, with a localization rate of equipment of less than 5%. After years of efforts, the comprehensive localization rate of nuclear power equipment in China has been raised to more than 80% at present, and more than two enterprises are capable of manufacturing all the key nuclear equipment of all nuclear islands. The supply of main equipment for nuclear island has achieved localization and marketization.

China has implemented a safety permit system for the design and manufacture of nuclear safety equipment and enterprises which have obtained the nuclear grade equipment design and manufacturing qualification issued by National Nuclear Safety Administration and related performance include CFHI, CNEG, DEC, SEGC, HEC (large forgings, reactor pressure vessels, steam generators, regulators, etc. for nuclear power equipment); Shanghai First Machine Tool Factory, DEC Wuhan Nuclear Equipment Factory, Sichuan Huadu Nuclear Equipment Co., Ltd. (control rod drive mechanism, internals and other precision equipment); Taihai Group, Jilin Haoyu, double (forging main pipeline), etc., Ten sets of main equipment for third generation of nuclear island can be provided per year. The localization primary circuit coolant main pump which has been relied on import for long time has made a breakthrough; Harbin Electric Power Equipment Company Limited and Dongfang AREVA Company have been able to supply its own main pump for second-generation plus HPR1000 unit; Harbin Electric Power Equipment Company Limited and Shenyang Blower Works Group Co., Ltd. are carrying out joint research on AP1000/CAP1400 shielded main pump. Nuclear fuel replacement systems, electrical penetrations and other key equipment and most of the nuclear-level valves can be manufactured and supplied by China. The self-development of nuclear-grade digital control system (DCS) which has been always relied on import has made major breakthrough. The nuclear-grade digital control system (DCS) developed by China Technology Co., Ltd. has been used in Yangjiang #5,6, Hongyanhe #5,6, Tianwan #5,6 and Shidao Bay High-temperature Gas-cooled Reactor Demonstration Project and other nuclear power projects.

In terms of localization of key materials, the steam generator tube production of heat transfer tube material (nickel-based alloy 690) manufactured by Jiangsu Bao Yin, Zhejiang Jiu Li has been used in nuclear power projects, and with an annual output of 1,300 tons of pipe capacity to meet the need for manufacturing of six to eight nuclear power plant steam generators. Harbin Welding Institute and Atlantic China Welding Consumables, Inc. have successfully developed 26 brands of nuclear grade welding materials, some of which have been used in nuclear power projects.

5.1.7 Nuclear Fuel Supply and Spent Fuel Management

China's natural uranium supply and utilization rely on domestic and foreign markets. Domestic natural uranium production is undertaken by CNNC Jinyuan Uranium Industry Co., Ltd.; and overseas uranium resources development is undertaken by a number of companies including CNNC Overseas Uranium Holding Limited and CGNPC Uranium Resources Co., Ltd. At present, the domestic natural uranium production has reached its highest level in history. The uranium resources available from foreign countries have already exceeded 400,000 tons. With the addition of natural uranium imported from the foreign market, the existing supply channels can fully meet the needs for natural uranium of China's nuclear power development in the next one or two decades.

China's nuclear fuel processing capacities are concentrated in China National Nuclear Corporation. Sichuan Yibin Nuclear Fuel Co., Ltd. and Inner Mongolia Baotou North Nuclear Fuel Co., Ltd. have formed a complete package of manufacturing capabilities for nuclear fuel assemblies. All second

generation plus domestic units, heavy water reactor units and VVER units can be supplied by China. The nuclear fuel assemblies of the AP1000 unit have also been domestically produced. North Nuclear Fuel Co., Ltd. has also built a 300,000-ball HTF fuel pellet production line to supply fuel for HTR nuclear power plants.

5.2 Overview of Major Nuclear Power Enterprises

5.2.1 China National Nuclear Corporation/China Nuclear Power Engineering Co., Ltd.

China National Nuclear Corporation is a key state-owned backbone enterprise directly managed by China's Central Government. It is composed of more than 100 enterprises and institutes and research institutes, and currently employs about 100,000 people, including 36,000 professional technical staff and 16 academicians of Chinese Academy of Sciences and Chinese Academy of Engineering.

Mainly engaged in nuclear power, nuclear fuel cycle, nuclear technology applications, nuclear environmental engineering and other fields of scientific research and development, construction and production operations, foreign economic cooperation and import and export business, China National Nuclear Corporation is currently the main investor of nuclear plants during their operation and construction in China, the main body of nuclear power technology development, an important general contractor of nuclear power design and engineering, a nuclear power operation technology service provider, a nuclear power plant exporter, a domestic nuclear fuel cycle franchise supplier, a pool of nuclear power engineering expertise and the backbone of nuclear technology application.

China Nuclear Power Engineering Co., Ltd. (CNPE) is the subsidiary of China National Nuclear Corporation.

China Nuclear Power Engineering Co., Ltd. is an engineering company with complete professional equipment. The company's business scope covers the pre-planning, feasibility study, project consulting, environmental assessment, engineering design, equipment procurement, construction management, construction supervision, commissioning implementation and management, technical services, tendering agency, personnel training, etc. of nuclear power projects; it has eight Grade A qualifications, including the only engineering design Grade A qualification in the nuclear industry; and it has research and design capabilities in terms of nuclear power, nuclear chemical industry, nuclear fuel and other nuclear energy utilization fields.

China Nuclear Power Engineering Co., Ltd. has undergone continuous development from technical backup to introduction/analysis and integration, independent design and then to self-owned knowledge brand, and has realized the leapfrog development of R&D of China's one million-kilowatt pressurized water reactor nuclear power plant. At present, the R&D and design tasks undertaken by the company include the HPR1000 nuclear power plant with independent intellectual property rights, the R&D and design of the ACP100, the analysis and integration of the AP1000 third-generation nuclear power technology, the R&D and design of the fourth generation of fast reactors, as well as the fission-fusion reactor research project.

China Nuclear Power Engineering Co., Ltd. has also undertaken scientific research and design work concerning spent fuel reprocessing, radioactive waste disposal, retirement of nuclear facilities and other aspects, as well as nuclear reactor fuel element production line of nuclear power plant, professional research and design on the production line of nuclear materials and nuclear parts, the nuclear equipment integration, civil environmental protection and other work; it is rich in engineering experi-

ence and strong technical force; and it is striving to become a world-class engineering company with international competitiveness.

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5.2.2 China Nuclear Engineering & Construction Group Corporation Ltd.

China Nuclear Engineering & Construction Group Corporation Ltd. is the state-owned key backbone enterprise under the direct management of central government and investment agencies and asset management main body approved by the State Council. The main business includes nuclear power engineering, nuclear energy utilization, nuclear engineering technology research and service, clean energy, civil engineering, etc.

China Nuclear Engineering & Construction Group Corporation, the world's leading nuclear power construction enterprise with more than 60 years of development history, is the only enterprise group at home and abroad uninterruptedly engaged in the construction of nuclear power for more than 30 years. In the field of nuclear power engineering construction, it effectively finished the construction of Chinese various pressurized water reactor (including CNP300, CNP600, M310, VVER, CPR1000, AP1000, EPR, HPR1000), heavy water reactor (CANDU-6) and high temperature gas cooled reactor (HTR), experimental fast reactor (CEFR), and other types of nuclear power plants.

In terms of nuclear power construction, China Nuclear Engineering & Construction Group Corporation possesses nuclear engineering contracting qualification, and has formed the service ability for package of the whole-cycle nuclear power construction, and management ability of multiple-reactor nuclear power project, capable of undertaking various nuclear reactor nuclear power plant construction, radioactive chemicals, nuclear fuel element, uranium metallurgy, isotope separation and nuclear defence engineering. It has also undertaken the construction of all nuclear power plants in China and 6 ones exported to Pakistan, ranking first for the number of nuclear power plants under construction in the world for many years. In 2013 when the nuclear power construction booms, it has 35 sets of nuclear power units under construction at the same time, and now has the capability of building 40 nuclear power units.

China Nuclear Engineering & Construction Group Corporation actively develops the clean energy business represented by the industrialization of nuclear energy and the development and utilization of small and medium-sized hydropower. In the nuclear power industry, deepen the manufacture-learning-research cooperation, open up advanced nuclear power business represented by high tempera-

ture gas cooled reactor and low temperature nuclear heating reactor, and gradually achieve industrial upgrading and lift the level of core technology. In the development of hydropower and other clean energy, it has formed a business layout with hydropower investment as the main power, coordinated with power grid, wind power and photovoltaic industry, and kept a relatively fast development speed.

The construction capability of nuclear power also extends to civil and industrial fields, and has been successively used in a large number of key projects in various industries such as municipal administration, transportation, energy and petrochemistry. We actively carry out the investment & financing business, environmental protection water-related affairs, as well as real estate, and gradually form a moderately diversified development pattern.

As of December 31, 2017, China Nuclear Engineering & Construction Group Corporation boasts 20 domestic nuclear power units under construction, and 2 nuclear power units under construction in Pakistan.

China Nuclear Engineering & Construction Group Corporation is actively involved in the construction of the nuclear power project in Hinkley Point, UK, and its member unit Huaxing Construction Company Limited has won the bidding in HXA plant water tank project, with the nuclear island storage tank project and the desalinator project are in the bidding.

Moreover, China Nuclear Engineering & Construction Group Corporation responded positively the "Belt & Road" Initiative, and actively promoted high temperature reactor technology in the international market. Now it has signed a memorandum of cooperation or established connection with Saudi Arabia, United Arab Emirates, South Africa, Indonesia, ASEAN Energy Center and other countries and regions for high-temperature heap promotion.

The two sides can discuss and seek cooperation in the field of technology research & development, industry upgrading and personnel exchanges.

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5.2.3 China General Nuclear Power Group/China Nuclear Power Engineering Co., Ltd.

China General Nuclear Power Group is a central enterprise that has gradually grown with the development of China's reform and opening-up policy and the development of nuclear power industry. It consists of the core enterprise of China General Nuclear Power Group Co., Ltd. and more than 40 major member companies. In September 1994, China Guangdong Nuclear Power Group was officially incorporated. In April 2013, China Guangdong Nuclear Power Group changed its name to China General Nuclear Power Group and China Guangdong Nuclear Power Group Co., Ltd. changed its name to China General Nuclear Power Group Co., Ltd.

China General Nuclear Power Group has made "developing clean energy for the benefit of human society" its mission and "becoming a world-class clean energy enterprise" its vision. As of the end of May 2017, China General Nuclear Power Group owned 20 nuclear power units in operation, with an installed capacity of 21.47 million kilowatts, accounting for 61.8% of China's installed capacity of nuclear power. As a nuclear power operator, it is the largest in China and the fifth largest in the world;

it has 10.93 million kilowatts of holding installed capacity of wind power, 1.96 million kilowatts of holding installed capacity of wind power and solar photovoltaic power generation project and 1.58 million kilowatts of installed capacity of hydropower pumped storage in operation. In addition, good progress has been made in the fields of distributed energy, nuclear technology applications and energy-saving technical services.

Since its establishment, China General Nuclear Power Group has made "safety first, quality first, the pursuit of excellence" its basic principles, insisting on core values such as "Doing things right once". On the basis of the successful construction of the Daya Bay Nuclear power plant, it has formed a virtuous cycle mechanism as "supporting nuclear power by itself and pursuing rolling development" and has established a specialized nuclear power production, construction, science and technology research and development, nuclear fuel supply security system that is in line with the international standards.

Since 2005, the group has entered the new business areas including wind power, hydropower, solar energy, energy-saving technologies, nuclear technology, financial services and public service businesses. It owns eight national R&D Centers and a national key laboratory and it has the capacity to simultaneously construct and operate multiple nationwide, trans-regional and multi-based nuclear power, wind power, hydropower, solar and other clean energy projects on the basis of ensuring safety.

As the main member enterprise of China General Nuclear Power Group, China Nuclear Power Engineering Co., Ltd. (CGN) is China's first specialized nuclear power project management company, which was established in February 2004 and with a registered capital of RMB 1.286 billion. As of May 2017, the company has total assets of about RMB 22 billion and employs more than 6,000 people.

With "specialized AE company" as its strategic positioning, the company has comprehensively mastered nuclear power construction technology, has efficient capabilities in the fields of nuclear power engineering construction resource allocation, project organization and management and scientific and technological innovation, and is committed to become a nuclear power system integrator and a nuclear special technician with excellent performance and first-class brand. With AE core capability as its foundation, the company has formed a business structure that takes nuclear power construction as its business core and takes into account its conventional clean energy projects. It has also expanded its business activities in in-service and retired service nuclear services and non-nuclear projects.

Since its establishment, the company's development vision has been to "become a world-class AE company" and it has adhered to basic principles such as "Safety First, Quality First, Pursuit of Excellence". China Nuclear Power Engineering Co., Ltd. (CGN) has established "six major control" management systems concerning engineering safety, quality, schedule, cost, technology and environment, formed the "matrix-based, project type" operation mechanism, and implemented the comprehensive and coordinated operation mode between internal and external organizations. Since 2010, it has successively constructed 16 units including Ling'ao Phase II, Liaoning Hongyanhe Phase I, Fujian Ningde Phase I, Fangchenggang Phase I, Yangjiang No. 1-4, etc., and put them into operation. As of May 2017, the number of units under construction is eight, with a total installed capacity of 10.27 million kilowatts.

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The General Office of China General Nuclear Power Group is responsible for the overall public relations management and daily reception of the group. The group company can be contacted through the General Office of the group. For investment and business cooperation, you can also contact the group's Capital Operation Department.

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5.2.4 State Power Investment Corporation/State Nuclear Power Technology Corporation

Established in June 2015, the State Power Investment Corporation was reorganized on the basis of former State Power Investment and State Nuclear Power Technology Corporation. After the reorganization, as an industry group company controlled by State Power Investment Corporation, the State Nuclear Power Technology Corporation has continued to undertake strategic tasks of introducing, analysing, integrating and re-inventing the third-generation nuclear power technology in China. It specializes in investment and operation, technology research and development, engineering services of nuclear power and related fields, as well as the power, power grids, new energy engineering and technical services and other businesses.

State Nuclear Power Technology Corporation puts talent building in a prominent position and has firmly enforced its philosophy of "talent is the biggest asset of the company". It vigorously implements the strategy of strengthening the company with qualified personnel, comprehensively promotes the building of qualified personnel, establishes and perfects a personnel training and development system, and attracts and gathers a large number of outstanding talents. Through the implementation of AP1000 relying projects and CAP1400 major projects, it cultivates and established a high-quality nuclear power talent team, which has effectively guaranteed the smooth progress of the national third-generation nuclear power autonomy.

State Nuclear Power Technology Corporation currently employs 11,560 people. It is a dynamic and energetic "knowledge-based, innovative, young and internationalized" professional and technical personnel team. In the Shandong Haiyang AP2000 relying project, Shandong Rongcheng CAP1400 demonstration project and other nuclear power projects, about 2000 nuclear power production and operations personnel has been cultivated. About 9,000 people work in the fields of nuclear power and conventional power station services, covering R&D design, project management, service life, equipment and materials manufacturing and other professional fields of nuclear power and conventional power business. Through cooperating with Westinghouse Electric Corporation to build the AP1000

third-generation nuclear power relying projects in Sanmen and Haiyang, the international capacity of talent team is continuously improved; there are about 170 key internationalized talents who have the capacity of overseas project development and project execution.

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5.2.5 China Huaneng Group/Huaneng Nuclear Power Development Company Ltd.

With registered capital of 20 billion Yuan, the Company is mainly engaged in the following business: development, investment, construction, operation and management of power sources; production and sale of power and heat; development, investment, construction, production, and sale of businesses and products related to finance, energy transportation, renewable energy, and environmental protection; industrial investment, operation and management.

Since its inception in 1985, China Huaneng Group has been providing rich experience for the reform, development and technology advancement of the power industry, and has been playing an exemplary role for power companies in enhancing management level and economic benefits, and has been making great contribution in satisfying power demand for economic and social development, and in ensuring value preservation and increment of state-owned assets. The Company has adhered to the concepts of "clear direction, continuous innovation, extensive cooperation, and mutual benefits", and has cultivated corporate culture with Huaneng characteristics, such as the "three-color" corporate mission of "a Red company serving the need of socialism, a Green company advocating technology advancement and environmental protection, a Blue company emphasizing continuous innovation and internationalization", and the core values of "Integrity, Cooperation, Innovation, Performance-oriented, and Serving the Nation" etc.

China Huaneng Group is committed to building itself into a large enterprise group with international competitiveness. By the end of 2016, the Company had total installed capacity of 165GW, with assets distributed all over China and overseas. The Company is also engaged in sectors of coal, finance, technology R&D, and transportation etc. that support the core business of power. The Company was the first Chinese power producer to join the ranks of Fortune 500 Companies, ranking 217th in 2016.

The 13th Five-year Plan Period is a crucial period for China to comprehensively build a moderately prosperous society and accomplish the first Centenary Goal. It is also a key period for the Company's comprehensive strength to reach world-class level. The Company will continue to hold high the great banner of Socialism with Chinese Characteristics, earnestly study General Secretary Xi Jinping's series of important speeches and the new ideas, new thoughts and new strategies on state governance, center around the concerted endeavor to pursue economic, political, cultural, social and ecological progress and the four-pronged comprehensive strategy in a well-coordinated way, and comprehensively implement the Five Major Development Concepts of "innovation, coordination, green, openness and sharing". The Company will conscientiously practice the "Three-color Company" corporate mission, and strive to transform development mode, and adjust industrial structure. The Company will endeavor to enhance development benefits, improve overall strength and build up world-class management, so

as to make the Company stronger, better and bigger, to take the lead in joining the ranks of World-class Companies with International Competitiveness, and to make greater contributions in comprehensively building a moderately prosperous society.

Huaneng Nuclear Power Development Company Ltd., established in December 30, 2005, is the wholly state-owned company of China Huaneng Group with registered capital of 0.1 billion yuan RMB. As a professional company specializing in nuclear power, Huaneng Nuclear Power Development Company centralizes promoting the national nuclear power construction and optimizing the structure of electric power industry, mainly engaged in R&D and technical services on nuclear power investment, development, production, transmission, and related fields.

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