Development of Civil Nuclear Power Industry in China*

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ABSTRACT

The paper details China's present energy situation. Including rising energy demands and the disparity of energy supply locations between the east and the west. The Chinese development plan includes the goal to reduce energy consumption per unit GDP by 2010, increase the share of renewable energies and call for a considerable development of nuclear power with an aimed increase between 4% to 5% from present 2%. This makes China one of the last nations in the world where considerable development of nuclear industry is expected.

In China, the development of nuclear energy as a CO_2 emission free energy resource is often mentioned alongside renewable energies as a form of "clean energy" and in international negotiations has been consequently a strong supporter for the proposal to include nuclear energy into the Clean Development Mechanism. The main players of the nuclear energy program are detailed, including influential supporters in the Chinese government. Within China, safety details regarding the nuclear program remain unclear and have not been made public. Therefore, as long as transparency and access to information is not given, environmental NGOs are not fully able to address issues of nuclear safety and authorities in charge are severely short of trained specialists, concerns remain about adequate handling of nuclear accidents, the handling of nuclear wastes and the safety in uranium mines, enrichment facilities and disposal sites.

Keywords: Peoples Republic of China, energy policy, nuclear power

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1. CHARACTERISTICS OF CHINA'S PRESENT ENERGY SITUATION

China's rapid economic development has been accompanied by a huge increase in energy demand. From 2000 to 2005, China's primary energy consumption has risen by more than 70%, equalling to 2.2 billion tons coal equivalent (tce). In the first decade of the 21st century, China became the world's second largest energy consumer (after the United States) and the third largest energy producer (after the United States and Russia). Low energy efficiency and rising living standards contribute to a steady increase of consumption. On the one hand, according to estimates by the Asian Development Bank, China uses four times the amount of energy to produce a unit of GDP than the Group of Seven developed countries. On the other hand, compared to western countries the average per capita energy consumption is still low: the average Chinese citizen consumes only one eighth of a U.S citizen, but consumption is expected to grow fast. The ongoing trend of urbanization and motorization and the aim to quadruple the economy by 2020 will result in a further increase in energy, mainly coal consumption.[1]

The dependence on conventional fossil fuels, namely coal and crude oil, has created severe environmental pollution problems and a rapid increase of greenhouse gas (GHG) emissions. As soon as in 2009 China is expected to overtake the United States as the world's largest emitter of CO_2. At present seventy percent of China's CO_2 emissions are derived from coal combustion. China's energy resources are not well distributed with respect to economic development and demand. Coal and natural gas reserves are mainly concentrated in the western provinces, hydropower in the southwest. Energy demand, on the other hand is highest in the eastern coastal provinces of Guangdong, Zhejiang and Jiangsu, and especially in the mega-cities Shanghai, Beijing and Tianjin, where in recent years power cuts during peak seasons have become a frequent problem. In view of the mentioned problems related to fossil fuels, the Chinese government has in recent years shown serious commitment to improve energy efficiency and develop renewable and so-called "clean energies", including nuclear energy. For the first time, the present 11th Five-Year Plan (2006-2010) includes the goal to reduce energy consumption by 20% per unit GDP by 2010, and to increase the share of renewable energies in the energy portfolio to up to 15%. China is planning to invest US $ 185 billion to meet this goal (SZYMANSKI 2006). Development plans also call for a considerable development of nuclear power. So the aimed increase of the share of nuclear energy between 4% to 5 % from present 2% compared to some western nuclear nations remains relatively modest the increase will equal the construction 30 new nuclear plants by 2020, making

1Between 2000 and 2005 coal consumption increased by 75% and is expected to increase further. For example, China plans to build more than 500 additional coal-fired power plants in the coming 15 years. (Szymanski 2006).

China one of the last nations in the world where considerable development of nuclear industry is expected.

CHINA'S NUCLEAR ENERGY PROGRAMME

Present Status

In China, the development of nuclear energy as a CO_2 emission free energy resource is often mentioned alongside renewable energies as a form of "clean energy" and in international negotiations has been consequently a strong supporter for the proposal to include nuclear energy into the Clean Development Mechanism (CDM). China's civilian programme for nuclear power generation was initiated in the 1980s, with the indigenous design and construction of a 300 MW pressurized water reactor (PWR). Construction of the Qinshan Unit 1 plant about 100 km southwest of Shanghai started in 1985, operation began in 1991. In the mid-1980s, the Daya Bay project near Hong Kong was started. Daya Bay Units 1 and 2 are equipped with PWR units of 984 MW, supplied by the French company Framatome. The two reactors began commercial operation in 1994. About 70% of their power is transmitted to Hong Kong and 30% to Guangdong Province. During the planning phase, environmental activists in Hong Kong collected about one million signatures, protesting against Daya Bay, but their protests were ignored by Beijing authorities.

Since the beginning of this millennium, another seven nuclear plants have been connected to the power grid: Qinshan Units 2A and B with Chinese designed reactors started operation in 2002 and 2004, respectively, Qinshan Units 3A and B began operating in 2003 using Canadian CANDU units, and in 2002, Lingao Units 1 and 2, also located in Guangdong Province, and equipped with 990 MW Framatome units similar to those in Daya Bay went into operation. In 2007, both units of Russian AES-91 power plants (equipped with 1060 MW VVER light water pressurized reactors) were connected to the grid in Tianwan (Lianyungang). The total capacity of all operating nuclear power plants amounts to 7587 MW.

Organisation

A number of institutions are in charge of the civilian nuclear program. The National Development and Reform Commission (NRDC) sets the targets for energy development (and the share of nuclear energy) and approves nuclear projects. The China Atomic Energy Authority (CAEA) is in charge of civil nuclear programs and international cooperation in this field. The CAEA is also responsible for feasibility studies for planned nuclear power plants. The

Table 1. Nuclear power reactors in operation and under construction

Name	Technology	Location (Province)	Capacity (MW)	Start of Commercial Operation
Operational				
Qinshan 1	PWR, China	Zhejiang	300	1994
Qinshan 2 A	PWR, China	Zhejiang	642	2002
Qinshan 2 B	PWR, China	Zhejiang	642	2004
Qinshan 3 A	PHWR, Canada	Zhejiang	728	2002
Qinshan 3 B	PHWR, Canada	Zhejiang	728	2003
Daya Bay 1	PWR, France	Guangdong	984	1994
Daya Bay 2	PWR, France	Guangdong	984	1994
Lingao 1	VVER, Russia	Guangdong	990	2002
Lingao 2		Guangdong	990	2003
Tianwan 1		Jiangsu	1,060	2007
Tianwan 2		Jiangsu	1,060	2007
Under construction				
Lingao 3	PWR, France	Guangdong	935	2010
Lingao 4	PWR	Guangdong	935	2011
Qinshan 6	PWR, CPR	Zhejiang	610	2011
Qishan 7	1000,	Zhejiang	610	2011
Hongyanhe 1–4	PWR, CPR 1000	Liaoning	4 x 1080	
Ningde	(China/France)			

Source: World Nuclear Association (2008), www.world-nuclear.org/info/inf63.html

National Nuclear Safety Administration oversees safety regulations and their compatibility with international agreements, whereas Department for Nuclear Safety of the Chinese Environmental Ministry (former SEPA) is charge of nuclear safety, environmental impact assessment of nuclear power plant projects and monitoring radioactive pollution.

Today there are several Chinese corporations active in the nuclear power sector. The China National Nuclear Corporation (CNNC) is involved in R & D, uranium exploration and mining, enrichment, fuel fabrication, reprocessing and waste disposal. CNNC's subsidiary China Nuclear Energy Industry Corp. (CNEIC) is in charge of uranium fuel trading. The China Nuclear Engineering and Construction (CNEC) group is responsible for plant construction. Another leading company in this field is the Guangdong Nuclear Power Group (CGNPG) that runs the Daya Bay plant and will be in charge of the Yangqiang project. The China Huaneng Group (CHNG) one of the five leading power companies in China is not involved in the nuclear business so far but helds a major share in a consortium for the Shidaowan demonstration plant for small scale high-temperature gas cooled reactors. The Institute for Nuclear Energy

Technology (INET) at Qinghua University in Beijing is the leading research institution for China's nuclear research and has developed the first pilot HTR gas cooled reactor, a technology that is seen to be the future of China's nuclear industry.

The Chinese nuclear industry has influential supporters in the Chinese government. Former premier Li Peng, an engineer and energy expert, was one of the strong promoters of the early nuclear power projects. He also managed to find for some of his family members key positions in the nuclear power business and the power industry. For many years Mr. Li Peng's wife Zhu Lin hold the position of a general manager of the Guangdong Nuclear Power Group. Today Mr. Li Peng's son Li Xiaopeng is the director general of the China Huaneng Group, a company that recently joined the nuclear club.

URANIUM EXPLORATION, MINING, ENRICHMENT, FUEL ELEMENT FABRICATION, TEMPORARY FUEL STORAGE AND REPROCESSING

China has uranium resources of estimated 70,000 tU, which is probably not enough for the supply of an expanding nuclear industry. The current annual production of 840 t uranium from local mines in Western China (Xinjiang Autonomous Region, Shaanxi, Guangxi, Liaoning) supplies about half of the current demand, the remaining half having to be imported from Kazakhstan, Russia and Namibia. In April 2006, prime minister Wen Jiabao's state visit to Australia, which holds 40 percent of the world's uranium reserves, resulted in the Nuclear Transfer Agreement and Nuclear Co-operation Agreement that allows Australia to supply uranium to China (South China Morning Post April 4, 2006). The China Nuclear International Uranium Corp (SinoU) is active in exploration in Niger, Kazakhstan, Mongolia and Algeria. Canada and South Africa are two other potential suppliers. Chinese national uranium mines, most of them located in the less developed western regions, are reported to be causing environmental pollution and health risks to local residents. Cases of radiation poisoning affecting local residents have, for example, been reported from uranium mine No. 792 in Diebu County, Gansu Province. The mine opened in 1967, run by the military, annually milled between 140 and 180 tons of uranium bearing rocks. In 2002, the mine officially was closed down owing to ore exhaustion and outdated equipment. However, it continues operation as a private owned mine operated by Longjiang Nuclear Ltd. Since 1988, Sun Xiaodi, a former employee repeatedly travelled to Beijing and met with foreign journalists to make the case public. In early 2005, he was detained by public security forces. He was released later that year, but ever since remains under police surveillance. In 2006 Sun Xiaodi was awarded with the international Nuclear-Free Future Resistance Award. (www.nuclear-free.com/english/frames7.htm).

Uranium enrichment is mainly undertaken either within China or by the

company Urenco in Europe. Within China, facilities in Chengdu (Sichuan Province), Lanzhou (Gansu Province) and Hanzhong (Shanxi) provide uranium enrichment for civilian purposes. Fabrication of PWR fuel is done at a plant in Sichuan Province, another plant in Inner Mongolia will provide PHWR fuel to the CANDU type plants. Spent fuel activities include at-reactor storage, away from reactor storage as well as reprocessing. A centralized storage facility with a capacity of 550 tons of fuel has been in operation since 2000 in Lanzhou (Gansu Province). As many other nuclear power nations China so far has not yet established a site for permanent disposal of nuclear waste.

Assessments are underway at six locations, most of them located in remote desert areas in western China (world-nuclear.org). In 2005, Chinese experts with German experts from the Technical University of Clausthal began assessing potential repository sites in the Gobi desert (Gansu Province) (e.g. of the Beishan granite site) (SPIEGEL ONLINE May 14, 2005). Repository sites are planned to be fully operational by around 2030. No information how the fuel will be transported to reprocessing and repository sites is available.

4.3. The Future of Chinese Nuclear Power Industries

Up to the late 1990s, China's nuclear industry saw only modest development. Starting in 1997 and for the following six years, as a result of the Asian crisis many potential projects were put on hold because of concerns of excess capacity, safety and the high costs of nuclear power. Nuclear plans were resumed with the 10th Five-Year Plan (2001-2005), which explicitly incorporated the development of nuclear energy as one major goal within China's energy strategy. Under pressure because of severe power shortages that have affected China's main industrial centres in the eastern coastal regions in recent years, the nuclear development plans had been adjusted. The latest plans as stated in March 2008 by the newly established State Energy Bureau call for China's nuclear power industry to provide 5 % of the overall power supply 2020 and an increase of installed capacities up to 50 GW. Earlier in May 2007 the National Development and Reform Commission even announced that the target for 2030 could be as high has 160 GW. This would make China the leading nuclear power country in the world.

Almost all of the proposed sites are located in the densely populated eastern coastal regions. As many as 16 provinces have announced intentions to built nuclear power plants during the twelfth 5 year plan (2011-2015).

According to EIA projections, in 2025, China will become one of the world's leading nuclear power nations:

International suppliers of nuclear technologies that have been suffering from a worldwide slowdown of nuclear development are now eagerly looking at China's ambitious nuclear power plans and for new business opportunities.

Table 2. Planned nuclear power stations in China

Name	Technology	Location (Province/ Municipality)	Capacity (MW)
Approved for construction			
Sanmen1, 2	AP 1000 USA	Zhejiang	2 x 1,000
Yangjiang 1,2	PWR France	Guangdong	2 x 1,650
Haiyang	AP 1000 USA	Shandong	1,000
Shidaowan	HTR–PM China	Shandong	200
Huian/Fuqing	N	Fujian	2 x 1000
Hongyanhe/Dalian	CPR 1000	Liaoning	2 x 1080
Hongshiding	N	Shandong	2 x 1000
Taishan	PWR France	Guangdong	2 x 1080
Planned or proposed			
Heyuan	PWR	Guangdong	4 x 1000
Ningde	PWR	Fujian	2 x 1080
Tianwan–2	AES–91, Russia	Jiangsu	2 x 1060
Qinshan –5	CNP 1000	Zhejiang	2 x 1000
Hongyanhe–2	N	Liaoning	2 x 1000
Rongcheng or Weihai	AP1000	Shandong	8 x 200
Haiyang	CPR 1000	Shandong	6 x 1000
Tianwei	N	Guangdong	4 x 1000
Bailong	CPR 1000	Guangxi	4 x 1000
Hui'an/Fuqing 2	N	Fujian	4 x1000/1500
Yangjiang 2,3	N	Guangdong	4 x 1080
Haijia	N	Guangdong	2 x 1000
Jinzhouwan	N	Liaoning	2 x 300
Taohuajiang	N	Jiangsu	2 x 600
Taohua	CPR 1000	Hunan	4 x 1000
Yiyang	HTR–PM	Chongqing	2 x 900
Fuling		Anhui	4 x 1000
Bamaoshan		Jilin	2 x 1080
Shidaowan		Shandong	18x 200

Source: World Nuclear Association 2008, www.world–nuclear.org/info/inf63.html

This is especially the case for US American companies, which have only since 1997 been allowed to export civilian nuclear technologies to China as a result of previous American trade restrictions. At present, more than 300 international companies, including companies from Canada, Germany, Japan, Spain and the USA are supplying technologies or know-how to Chinese nuclear power projects. In September 2005, the Atomic Energy of Canada (AECL) signed a technology development agreement with the China National Nuclear Corporation (CNNC), which opened up new opportunities for

Table 3. Projected nuclear-generated electricity consumption 1990-2025 (in billion kilowatt hours)

Country	1990	2000	2001	2010	2015	2020	2025
USA	577	754	769	794	812	816	816
France	298	394	401	447	478	520	550
Germany	145	161	163	137	107	15	0
Japan	192	294	309	369	394	426	411
Canada	69	69	73	108	110	118	98
Russia	115	122	125	141	154	129	99
S. Korea	50	104	107	141	171	209	220
India	6	14	18	46	55	66	66
China	0	16	17	66	129	142	154

Source: Energy Information Administration (EIA)

supplying more Candu-6 reactors. Germany had talks on delivering a MOX uranium-plutonium plant (which had originally been built for Germany, but following public protests has never been operated in Germany). The talks came to a halt due to strong opposition within the German government and the public. In November 2007, CNNC signed an agreement with French Areva for construction of a MOX fuel fabrication plant.

Since 2004, the bidding process for the Sanmen (Zhejiang) and Yanjiang (Guangdong) plants had the US Westinghouse, the French Areva and the Russian Atomstroyexport involved, with the US, French and Russian governments reported to having been giving support. The US Export-Import Bank approved 5 billion US $ loan guarantees for the Westinghouse bid, and the French Coface gave similar guarantees for the support of Areva's bid. The US Nuclear Regulatory Commission gave approval for Westinghouse to export the respective equipment. The final decision was a kind of surprise. In December 2006 the Chinese announced a tentative agreement with Westinghouse. But after a strong intervention by France, the decision was altered and the projects divided between the two western competitors. Westinghouse Electric won a US $ 6 billion worth contract to build four of its AP 1000 reactors in Sanmen and in Haiyang north of Shanghai (another projected plant, which was not part of original bidding. The French Areva won US$ 5 billion worth contract to built two plants in Yanjiang (Guangdong). Construction is planned to start in 2009, the first plants are expected to be completed in 2013. In addition Areva also agreed to supply uranium to China (www.chinaview.cn 2007.02-06, www.post-gazette.com March 2, 2007).

In the long run, China aims to rely more on home-grown nuclear technologies. This will on the one hand include the duplication of imported technologies, but on the other hand also the development of its own technologies, such as the CNP (China Nuclear Power) 1000 and 1500 models.

The CNP 1000 technology will be used for the two 1,000 MW reactors built in Fangjiashan, Zhejiang province. (www.chinaview.cn 2007.02.06) China's nuclear research institutes and companies have already achieved high standards. Qinghua University's Institute of Nuclear Energy (INET) has developed a test 10 MW high-temperature gas-cooled reactor (HTR-10), also called pebble bed modular reactor PBMR, which remains the only operational PBMR in the world (Durnim 2007). In 2006, the China Huaneng Group, the country's largest power company launched the construction of the first nuclear power plant with using these high temperature gas-cooled reactors (HTR-PM) developed in China. The demonstration plant Shidaowan, located in Rongcheng, Shandong province will have an installed capacity of 200 MW and is scheduled to be operational by 2013. 18 further units with a total capacity of 3800 MW shall be built either in Rongsheng or in Weihai, Shandong province. On the long run HTR reactors could be factory built and installed all over the country. They are especially regarded as useful support for the energy intensive process of seawater desalinisation plants. Analysts see good chances for the widely introduction of PMBR technology in China since it is compared to traditional nuclear power technology relatively affordable, simpler and regarded as safer. Also gas cooled reactors could be of advantage in water scare regions (Durnim 2007). With Russian assistance China is also working on the development of fast reactors. The development of a domestic nuclear industry will enable China to export their technologies to other countries. China has already been involved in the construction of a smaller plant in Chasma in Pakistan, and in November 2006, during a state visit of president Hu Jintao to Pakistan talks were held to cooperate on more nuclear power projects in the future.

Despite these impressing results of Chinese nuclear research, the country at present still severely lacks trained engineers and researchers to adequately staff research institutes and planned power plants and monitoring stations – a deficit which is of some concern for safety issues. According to the Science and Technology Commission the country needs to train at least 13,000 specialists to adequately staff the nuclear power sector in the near future.

NUCLEAR DEVELOPMENT AND THE CIVIL SOCIETY

In the past, the Chinese media have reported about anti-nuclear protests and accidents in nuclear power plants in foreign countries. Therefore the Chinese public is relatively well informed about Chernobyl, about accidents in Japanese nuclear power plants as well as about anti-nuclear rallies in Taiwan, international protests against Taiwan's nuclear waste shipments to North Korea and the Stop-castor campaign in Germany. However, when it comes to the planned massive development of national nuclear industries within China, local media are quick to assure that nuclear power is a clean and safe energy

source. Although China has seen a promising development of environmental NGOs in recent years, with countless groups mushrooming all over the country, none of them so far openly addresses concerns related to nuclear safety. Only recently some citizens also have raised their voice against nuclear power projects. Wen Bo, an environmental activist himself, reports about protests against the planned Hongheyan Nuclear Power Plant in Changxing Island, Liaoning province. The project will be built on an island that so far has been the breeding ground of the endangered spotted seal and a stopover for migratory birds. The local environmental bureau was not consulted by the company in charge of the project. Local officials leaked information to environmentalists that no adequate environmental impact assessment (EIA) report had been submitted. Nevertheless authorities obviously lack power to put the project on hold (Wen Bo 2007, p. 106).

In another case concerned citizens initiated a petition campaign against three proposed nuclear plants in the vicinity of a popular seaside resort Silver Beach in Shandong province. The campaign managed to collect several hundred signatures, which were sent to prime minister Wen Jiabao and the State Environmental Protection Administration (Wen Bo 2007, p.108). In this case protests were heard. In December 2007, SEPA informed on their website that the planned Hongshiding nuclear power plant had not yet submitted the application for the EIA and demanded that developers should organise a public hearing (SCMP 2.12.07).

CONCLUSION

According to the China Atomic Energy Authority "China established a safety and supervision and management system and nuclear safety standards in line with international standards. A three-level nuclear accident emergency management system is in place..." (CHINA ATOMIC ENERGY AUTHORITY 2004: 3). Details about this system have not been made public. There are also regulations on the safety of radioactive isotope and radiation devices, which require immediate and accurate reports on accidents. However, as long as transparency and access to information is not given, environmental NGOs are not fully able to address issues of nuclear safety and authorities in charge are severely short of trained specialists, concerns remain about adequate handling of nuclear accidents, the handling of nuclear wastes and the safety in uranium mines, enrichment facilities and disposal sites.

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ABBREVIATIONS:

CAEA	China Atomic Energy Authority
CDM	Cleaner Development Mechanism

CNNC	China National Nuclear Corporation
CPI	China Power Investment Corporation
HTR	High Temperature gas cooled reactor
NDRC	National Development and Reform Commission
NNSA	National Nuclear Safety Administration
PWR	Pressurized Water Reactor
SEPA	State Environment Protection Administration
VVER	Russian Version of light water pressurized reactor