CHINA – NUCLEAR POWER FOR GHG MITIGATION AND SUSTAINABLE ENERGY DEVELOPMENT

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Introduction: Coal-fired power plants are the major source of electricity in China, accounting in 1998 for 73% of total installed capacity. However coal-fired plants create serious air pollution problems, and their fuel transport requirements place a heavy burden on the transportation system. Nuclear power plants (NPPs) are therefore a potentially attractive option for China, particularly in the coastal regions, which are both more economically developed and far from the main coal mines in northern and western China.

Currently, China has no capability to build large-scale nuclear power plants. Nor would nuclear power plants in China be financially competitive with coal-fired plants under fair market conditions. China does have three NPPs currently in operation, built partly with French and British expertise and assistance, and eight more under construction. These have all benefited from a number of favourable government policies – i.e. exemptions from taxes on imported equipment and from value-added taxes, and an electricity purchase agreement at an artificially high price.

The Electric Power System in China and the Potential for Nuclear Energy

Current status: From 1980 to 1998 China's electric power industry grew rapidly. Installed capacity grew at an average of 8.15% annually and electricity generation at an average of 7.83%. In 1997 and 1998, however, there was a drop in electricity demand growth to 4.8% and 2.8% respectively[7], due to energy efficiency improvements, economic restructuring associated with market reforms, and the Asian financial crisis. At the end of 1998, total installed electricity capacity was 277 GW. Annual electricity generation was 1,158 TW·h.

China's electricity generation mix is dominated by coal, which accounts for 73% of total installed capacity. Nuclear capacity is only 2.1 GW, or 0.9% of total power capacity.

Future plans: The long-term planning targets for China's electric power sector for 2010 are 500–550 GW of total installed capacity, with around 20 GW of new capacity added annually. For electricity generation, the 2010 target is 2,500 TW·h, with 6% annual growth. For 2020 the target for total installed capacity is 750–800 GW, with around 25 GW of new capacity each year. For electricity generation, the target is 3,200 TW·h, with 4% annual growth.

These targets may yet be adjusted downwards. Electricity shortfalls due to tight supplies have declined remarkably in the past few years, given the recent slowdown in electricity

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7 *Source: the State Statistics Bureau, 1999.*

demand growth. But even with lower targets, there would remain large opportunities for investors and suppliers in the power sector to provide financing and equipment.

Need for nuclear power: China's existing subsidies for nuclear are motivated by several national interests that would not be reflected in a private economic assessment of nuclear power. These include energy supply security, a cleaner and more efficient energy mix, the promotion of high technology innovation, and stimulating growth and demand in industries related to NPP construction and operation. In addition there are now several environmental concerns that might justify further subsidies, including international subsidies, for nuclear power.

1. Global environmental concerns: The electric power sector in China is a growing significant source of CO_2 emissions.
2. Local environmental concerns: It was estimated by World Bank[8] that China's economic losses due to air pollution and acid rain were about 37 billion US$ in 1995, over 5% of overall GDP.
3. National transportation concerns: Long distance transportation of coal from northern and western China, where the principal coal mines are, to eastern and southern coastal areas, where electricity demand is growing fastest, imposes a heavy burden on the national transportation system. This, in turn, exerts upward pressure on the coal price, which reduces the competitiveness of domestic coal against imported coal. In contrast, the burden of nuclear fuel transportation for new NPPs would be almost negligible.

However, even with its environmental and transportation advantages, nuclear power remains a very capital- and technology-intensive electricity supply option. As is the case in many other developing countries, these financial and technological barriers still hold back the pace of nuclear power development in China.

Current developments are therefore limited to three operating reactors (with a total installed capacity of about 2.1 GW), plus eight NPPs under construction (Table 2). Looking further into the future, China has formulated nuclear power targets for 2010 of 20 GW(e) of total installed capacity, rising to 40 GW(e) by 2020. Whether or not these targets can be met will depend on financing, market liberalization, and the evolution of electricity rate structures.

Table 2. Nuclear Power Plants in China

Nuclear Power Plant	Project Phase	Capacity MW(e)	Type	Operation Time
Qinshan	Phase-I	300 × 1	PWR	1991
Daya Bay	Phase-I	900 × 2	PWR	1994
Qinshan	Phase-II	600 × 2	PWR	2001 and 2002
Qinshan	Phase-III	700 × 2	CANDU	
Ling'Ao	Phase-I	900 × 2	PWR	
Lian Yungang	Phase-I	900 × 2	PWR	
Total		8.3 GW(e)		

[8] *World Bank : " China in 2020", Sept. 1997.*

The need for sustainable development in China: China is a large developing country with a very low national income (769 US$ GDP per capita in 1998) and low energy consumption (1.09 tce, or 0.763 toe, per capita in 1998[9]). Despite rapid economic growth over the past two decades, China still ranks among the low and middle income countries in the world. As indicated in the UNFCCC, the top priorities for non-Annex I, low-income, developing countries such as China are economic and social development and poverty eradication. In full recognition of these priorities, the UNFCCC and Kyoto Protocol do not impose any GHG mitigation commitments upon developing country Parties.

Nonetheless China has devoted substantial attention to the mitigation of GHG emissions and has adopted domestic policies and measures that are compatible with the national sustainable development plan. "*The Agenda for 21 Century Development in China*" is one principal example of China's national strategies to abate GHG emissions and climate change. It puts forward preferential action plans and development projects in various priority areas.

However, China has been constrained by barriers that hinder further development, such as the country's huge population and limited natural resources per capita, its poor ecological environment and its vulnerable capability for mitigating and adapting to climate change. As a result, China very much needs assistance, including the CDM, in pursuing sustainable development options. There is a large potential in China for CDM projects, including nuclear power, and such assistance is vital for China achieving sustainable development.

Baseline Project — Coal: Coal-fired power is the preferred option for the next generation of investments in China. The capital investment ratio for a nuclear power plant in China relative to a coal-fired power plant of the same capacity is about 2.5 to 1, rather high by the standards of industrialized countries. The fuel costs of nuclear power are also high, due to the high price of domestic nuclear fuel. Table 3 calculates the incremental costs of emission reduction for Ling'Ao's two 900 MW(e) nuclear units relative to a comparable coal-fired power plant. The coal-fired plant is assumed to be located in Guangdong Province, a region of high expected electricity demand growth. This is where the Ling'Ao nuclear power plant is located, so that the comparison provides a fair reflection of the incremental cost of emission reduction associated with shifting from a baseline coal-fired alternative to a CDM nuclear power plant of the same size and serving the same market.

Additionality: Table 3 shows that a nuclear power plant would lead to long-term measurable GHG reductions of 2.85 MtC/yr relative to the baseline coal project, thus satisfying the CDM criterion of environmental additionality.

Table 3 shows that the nuclear plant also meets the criterion of financial additionality as it is more expensive than the coal-fired baseline project and thus would not be built under fair market conditions. Indeed without subsidies, tax breaks, or other financial support, the nuclear power plants necessary to meet China's future targets will not be

[9] *Source: The State Statistics Yearbook by State Statistics Bureau, 1998. Exchange rate: 1 US$: 8.29 Yuan RMB.*

Table 3. Comparison of baseline and CDM project technologies – China

Characteristics	Units	Baseline Coal	CDM Nuclear
Technical			
Plant lifetime	year	30	30
Net capacity	MW(e)	1,800	1,800
Load factor	%	75	75
Net efficiency	% (LHV)	37	35
Sulfur abatement (SO_2)	%	70	–
Nitrogen oxide abatement (NO_x)	%	0	–
Particulate abatement	%	99.5	–
Economics			
Investment costs	US$/kW(e)	734	1,800
Interest during construction	US$/kW(e)	197	644
Total capital investment[1)]	Million US $	1,676	4,400
Localization rate	%	100	15
Real discount rate	%	10	10
Fix O&M costs	US$/kW(e).yr	34.24	55.27
Variable O&M	US$/MW·h		
Fuel purchase costs	$/GJ	2.16	0.416
Total levelized generating costs	mills/kW·h	41.26	52.16
Emissions & Wastes			
Ash	g/kW·h	50.66	
Sludge from abatement	g/kW·h	n.a.	
I & L level radioactive waste[2)]	m^3/MW·h		$1.735 * 10^{-5}$
High level radioactive waste	g/kW·h		n.a.
Heavy metals	g/kW·h	n.a.	
Particulates	g/kW·h	0.49	
Sulfur dioxide SO_2	g/kW·h	4.79	
Nitrogen oxides NOx	g/kW·h	3.92	
Carbon monoxide CO	g/kW·h	n.a.	
Methane	g/kW·h	n.a.	
Nitrous oxide N_2O	g/kW·h	0.02	
Carbon dioxide CO_2	g/kW·h	241	0
Total GHG emissions	g C/kW·h equiv.	n.a.	
GHG abated	g C/kW·h equiv.	0	241
Total GHG emissions	Mt C / year	2.85	0.00
Total annual GHG reductions	Mt C / year		2.85
Mitigation costs based on levelized generating costs			
Incremental generating costs	mills/kW·h		10.84
Mitigation costs (generation)	US$/t C		45
Mitigation costs (generation)	US$/t CO_2		12.3
Mitigation costs based on levelized capital costs			
Incremental capital costs	Million US $		2,724
Mitigation costs (capital)	US$/t C		101.4
Mitigation costs (capital)	US$/t CO_2		27.7

1) Total plant capital investment including interest during construction
2) Intermediate and low level radioactive waste data based on Daya Bay nuclear power station operation report.

built. This is partly because electricity pricing in China incorporates social goals as well as purely financial considerations. But it will also be true in an increasingly liberalized electricity market in the future, with coal-fired power plants remaining the most attractive alternative to nuclear.

Nuclear power further satisfies the criterion of technology additionality given, first, China's current domestic inability to develop large-scale nuclear technology and, second, the reality that electricity generation costs using imported technologies would, in the absence of CDM, be too high relative to coal-fired plants to be justified.

Table 3 shows the resulting mitigation costs, based on the difference in levelized generating costs between the nuclear and coal-fired alternatives. For a CDM nuclear power project to compare favourably economically to the coal-fired baseline, payments from an Annex I partner to cover the difference between nuclear and coal generating costs would be on the order of US $45/tC (about US $12/t$CO_2$).

Concluding Remarks: Because nuclear power is not financially competitive with coal-fired power plants in China, the government has subsidized the initial stages of nuclear development due to national concerns about secure energy supplies, a cleaner and more efficient energy mix, the promotion of high technology innovation, and stimulating growth and demand in industries related to NPP construction and operation. These, plus concerns about the environment and a transportation system overburdened by coal in the absence of imports, have led China to set targets for the expansion of installed nuclear capacity to at least 40 GW by 2020, which would avoid 63 MtC of CO_2 emissions annually.

To meet such targets, however, China will need financial support through the CDM or some other mechanism to cover the difference between nuclear power plants costs and coal-fired power. Assistance through the CDM would assist in meeting the goals of the UNFCCC, would contribute to cost-effective GHG reductions on the part of Annex I countries, would reduce air pollution from coal-fired electricity generation in China, and by increasing the technological and financial resources available to China, would contribute significantly to sustainable development in China.