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China in the Transition to a Low-Carbon Economy

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Summary

China, from its own perspective cannot afford to, and from an international perspective, is not allowed to continue on the conventional path of encouraging economic growth at the expense of the environment. The country needs to transform its economy to effectively address concern about a range of environmental problems from burning fossil fuels and steeply rising oil import and international pressure to exhibit greater ambition in fighting global climate change. This paper first discusses China's own efforts towards energy saving and pollutants cutting, the widespread use of renewable energy and participation in clean development mechanism, and puts carbon reductions of China's unilateral actions into perspective. Given that transition to a low carbon economy cannot take place overnight, the paper then discusses China's policies on promoting the use of low-carbon energy technologies and nuclear power and efforts to secure stable oil and gas supplies during this transition period. Based on these discussions, the paper provides some recommendations on issues related to energy conservation and pollution control, wind power, nuclear power, clean coal technologies, and overseas oil and gas supplies, and articulates a roadmap for China regarding its climate commitments to 2050.

Keywords: Energy Saving, Renewable Energy, Clean Development Mechanism, Nuclear Power, Power Generation, Oil and Gas, Post-Copenhagen Climate Negotiations, China

JEL Classification: Q42, Q48, Q52, Q54, Q58

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China in the Transition to a Low-Carbon Economy[1]

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Abstract
China, from its own perspective can not afford to, and from an international perspective, is not allowed to continue on the conventional path of encouraging economic growth at the expense of the environment. The country needs to transform its economy to effectively address concern about a range of environmental problems from burning fossil fuels and steeply rising oil import and international pressure to exhibit greater ambition in fighting global climate change. This paper first discusses China's own efforts towards energy saving and pollutants cutting, the widespread use of renewable energy and participation in clean development mechanism, and puts carbon reductions of China's unilateral actions into perspective. Given that that transition to a low carbon economy cannot take place overnight, the paper then discusses China's policies on promoting the use of low-carbon energy technologies and nuclear power and efforts to secure stable oil and gas supplies during this transition period. Based on these discussions, the paper provides some recommendations on issues related to energy conservation and pollution control, wind power, nuclear power, clean coal technologies, and overseas oil and gas supplies, and articulates a roadmap for China regarding its climate commitments to 2050.

JEL classification: Q42; Q48; Q52; Q54; Q58

Keywords: Energy saving; Renewable energy; Clean development mechanism; Nuclear power; Power generation; Oil and gas; Post-Copenhagen climate negotiations; China

1. Introduction

Since launching its open-door policy and economic reform in late 1978, China has experienced spectacular economic growth. Hundreds of millions of the Chinese people have been raised out of poverty. In this course, China has been heavily dependent on dirty-burning coal to fuel its rapidly growing economy. This gives rise to unprecedented environmental pollution and health risks. On top of these environmental stresses, projected global climate change is expected to pose the additional threats to China.

Given the fact that China is already the world's largest carbon emitter and its emissions continue to rise rapidly in line with its industrialization and urbanization, China is seen to have greater capacity, capability and responsibility. The country is facing great pressure both inside and outside international climate negotiations to exhibit greater ambition. There are renewed interests in and debates on China's role in combating global climate change.

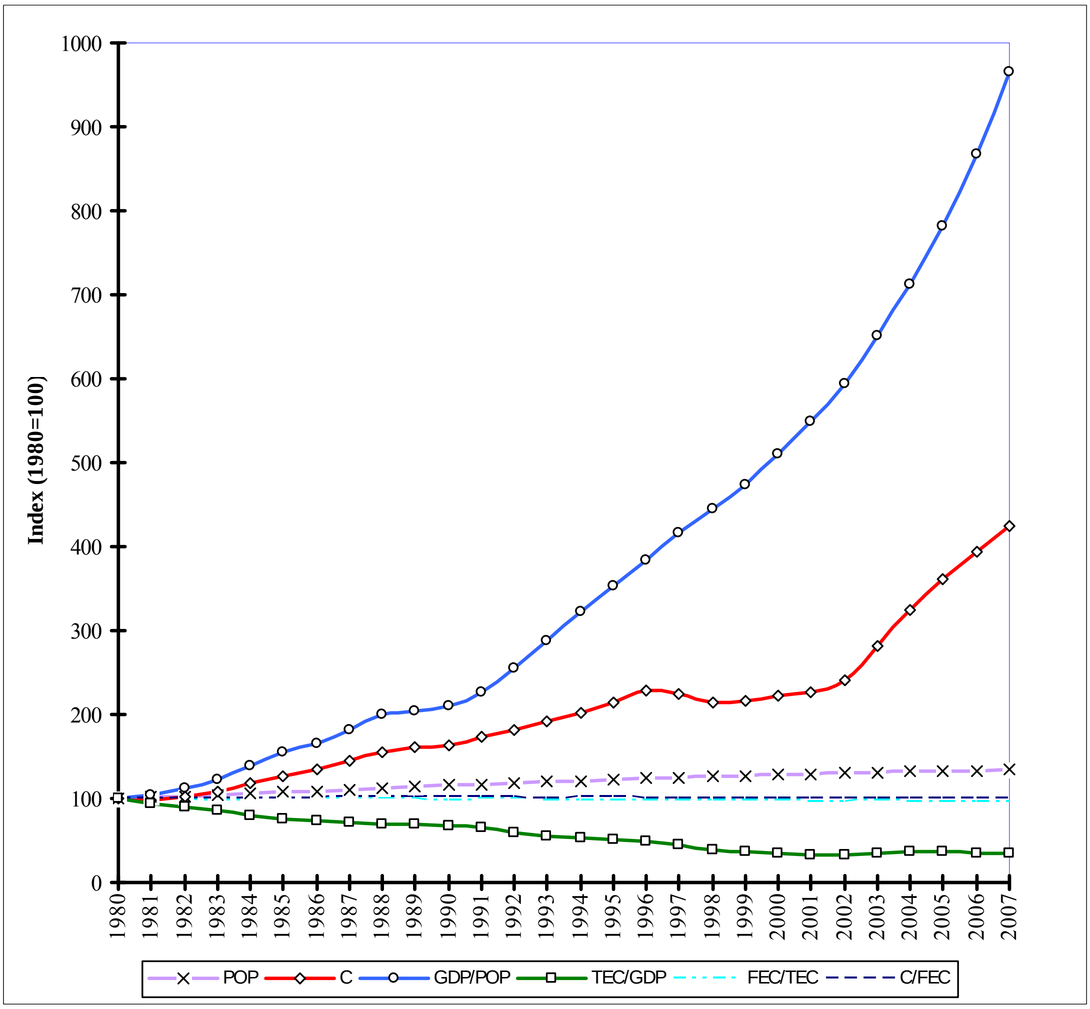
Clearly, China, from its own perspective can not afford to, and from an international perspective, is not allowed to continue on the conventional path of encouraging economic growth at the expense of the environment. Instead, China needs to transform its economy to effectively address concern about a range of environmental problems from burning fossil fuels and steeply rising oil import and international pressure on it to exhibit greater ambition in fighting global climate change. These concern and pressures have sparked China's determination to improve energy efficiency and increase the use of clean energy in order to help its transition to a low carbon economy.

Improvements in energy efficiency are particularly important in reducing energy consumption and greenhouse gas emissions as they offer win-win options at a relatively low cost compared to other options. Figure 1 and Table 1 show the historical contributions of inter-fuel switching, energy conservation, economic growth and population expansion to China's CO_2 emissions during the period 1980-2007.[3] China achieved a quadrupling of its GDP with only a doubling of energy consumption between 1980 and 2000 (Zhang, 2003). As a result of energy conservation, a reduction of 576 million tons of carbon (MtC) were achieved in 2000. In other words, without efforts towards a reduction in energy intensity, China's CO_2 emissions in 2000 would have been 576 MtC higher, or about 38% higher, than its actual CO_2 emissions. On the trends of the 1980s and 1990s, the U.S. EIA (2004) estimated that China's CO_2 emissions were not expected to catch up with the world's largest carbon emitter until 2030. However, China's energy use had surged since the turn of this century, almost doubling between 2000 and 2007. Despite similar rates of economic growth, the rate of growth in China's energy use during this period (9.74% per year) has been more than twice that of the last two decades in the past century (4.25% per year) (National Bureau of Statistics of China, 2009). As a result, China became the world's largest carbon emitter in 2007, instead of *until 2030* as estimated as late as 2004. Instead of pushing CO_2 emissions down as it had

[3] See Zhang (2000a) for discussion on the methodology to decompose the contributions of these factors to CO_2 emissions.

been the case over the period 1980-2000, this change in energy intensity was even responsible for an increase of 20 MtC during the period 2000-2007.

Figure 1
Decoupling CO_2 Emissions from Economic Growth in China, 1980-2007



C - the amount of CO_2 emissions; *FEC* - the total carbon-based fossil fuel consumption; *TEC* - the total commercial energy consumption; *GDP* - the gross domestic product; *POP* - the population.

Table 1
Breakdown of the Contributions to CO_2 Emissions Growth in China, 1980-2007 (MtC) [a]

	Due to change in fossil fuel carbon intensity	Due to penetration of carbon free fuel	Due to change in energy intensity	Due to economic growth	Due to population expansion	Total change in CO_2 emissions
1980-2000	-1	-16	-576	+896	+138	+441
2001-2007	+7	+2	+20	+640	+39	+708

[a] A positive sign indicates an increase; A negative sign indicates a decline.

This paper will first discuss China's own efforts towards energy saving and pollutants cutting, the widespread use of renewable energy and participation in clean development mechanism (CDM). Next, the paper puts carbon reductions of China's unilateral actions into perspective by examining whether the estimated greenhouse gas emission reduction from meeting the country's national energy saving goal is achieved from China's unilateral actions (namely, actions outside the CDM projects in China) or mainly with support from the CDM projects. Given that that transition to a low carbon economy cannot take place overnight, the paper then discusses China's policies on promoting the use of low-carbon energy technologies and nuclear power and efforts to secure stable oil and gas supplies during this transition period. Finally, the paper provides some recommendations on issues related to energy conservation and pollution control, wind power, nuclear power, clean coal technologies, and overseas oil and gas supplies, and articulates a roadmap for China regarding its climate commitments to 2050.

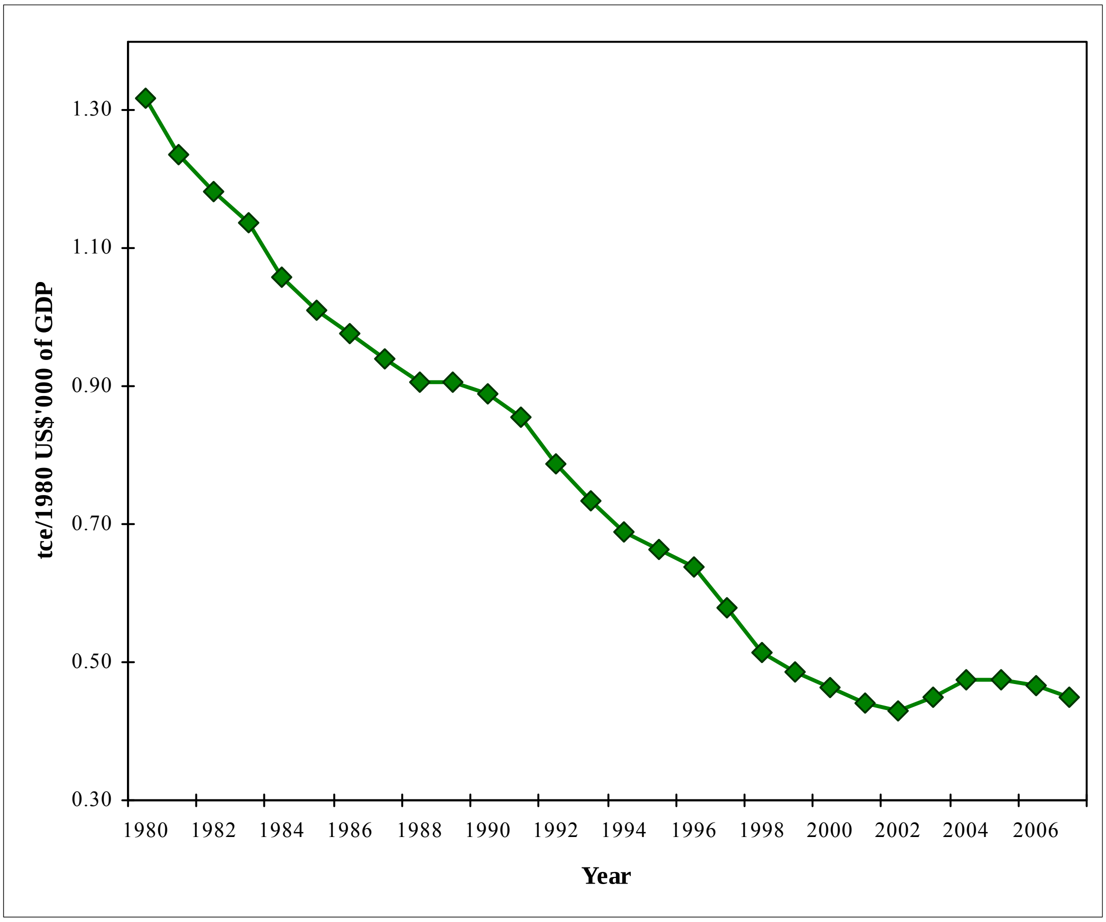
2. Increasing energy efficiency and cutting pollutants

While China has been calling for energy saving since the early 1980s, the country has set, for the first time, the goal of cutting energy use per unit of GDP by 20% in its current five-year (2006-10) economic plan. China achieved a quadrupling of its GDP with only a doubling of energy consumption between 1980 and 2000, as indicated in Figure 2, but since 2002 China has experienced faster energy consumption growth than economic growth (Zhang, 2005 and 2007d). Clearly, this is a very challenging goal in light of the recent increase in energy intensity in China. Given that industry accounts for about 70% of the country's total energy consumption (Zhang, 2003), this sector is crucial for China to meet its own set goal. So the Chinese government has taken great efforts towards changing the current energy-inefficient and environmentally-unfriendly pattern of industrial growth. To that end, China is exploring industrial policies to promote industrial upgrading and energy conservation. With a surge in energy use in heavy industry, the Chinese government started levying export taxes in November 2006 on energy- and resource-intensive products to discourage exports of these products that rely heavily on energy and resources and to save scarce energy and resources. This includes a 5% export tax on oil, coal and coke, a 10% tax on to non-ferrous metals, some minerals and 27 other iron and steel products, and a 15% tax on copper, nickel, aluminum and other metallurgical products. From July 2007, China eliminated or cut export tax rebates for

2831 exported items. This is considered the boldest move to rein in exports since China joined the World Trade Organization (WTO). Among the affected items, which account for 37% of all traded products, are 553 "highly energy-consuming, highly-polluting and resource-intensive products", such as cement, fertilizer and non-ferrous metals. The export tax rebates on these products were completely eliminated. This policy will help to enhance energy efficiency and rationalize energy and resource-intensive sectors as well as control soaring exports and deflate the ballooning trade surplus (Zhang, 2008).

On the specific energy saving front, China established the "Top 1000 Enterprises Energy Conservation Action Program" in April 2006. This program covers 1008 enterprises in nine key energy-supply and consuming industrial subsectors. Each of them on the list consumed at least 0.18 million tons of coal equivalent (tce) in 2004, and all together consumed 33% of the national total and 47% of industrial energy consumption in 2004. The program aims to save 100 million tce cumulatively during the period 2006-10, thus making a significant contribution to China's overall goal of 20% energy intensity-improvement (NDRC, 2006a). In May 2006, empowered by the State Council, the National Development and Reform Commission (NDRC), China's top economic planning agency, signed energy-saving responsibility agreements with these enterprises. To ensure the goal to be met, achieving energy efficiency improvements has become a criteria for job performance evaluations of heads of these enterprises. This will help them realize that they should take their jobs seriously because they have a very real stake in meeting energy-saving goals. The first-year's results of the program's implementation are encouraging. More than 95% of these enterprises appointed energy managers, and the program achieved the energy saving of 20 million tce in 2006 (NDRC and NBS, 2007). In 2007, the energy saving of 38.17 million tce was achieved, almost doubling the amount of energy saving in 2006. If savings continue at the 2007 rate, the top-1000 program will exceed its target (NDRC, 2008c). For power generation, China has adopted the policy of accelerating the closure of thousands of small, inefficient coal- and oil-fired power plants and encouraging the construction of larger, more efficient, cleaner plants (See Section 5 for detailed discussion).

Figure 2 Energy use per unit of GDP in China, 1990-2007 (tons of coal equivalent per US$ 1000 in 1980 prices).
Source: Drawn based on *China Statistical Yearbook*, various years.



For residential buildings, China has taken three steps to improve energy efficiency. The first step requires a 30% cut in energy use relative to typical Chinese residential buildings designed in 1980-1981. Second, China requires that new buildings have to be 50% more efficient by 2010. Third, the energy-saving goal is to be increased to 65% for new buildings by 2020 (Zhang, 2005 and 2008). Tianjin is the first metropolitan city in China to embark on reform for heat supply and charge. As indicated in Table 2, by the end of 2006, 73.49 million m^2 energy-efficient residential buildings were built in this city, accounting for 47.8% of the total residential buildings (Zheng and You, 2007). In Beijing, the building sector consumed 28% of total energy use in 2004. By the end of 2004, 175.2 million m^2 energy-efficient residential buildings were built in China's capital, 37.1% of which met with the 30% more energy-efficient standards and the remaining 62.9% met with the 50% more energy efficient standards (see Table 2). All these energy-efficient buildings in Beijing accounted for 65.1% of its total residential buildings. Beijing plans that all new residential buildings have to meet with the 65% more energy-efficient standards by 2010, one decade ahead of the national schedule (BMCDR, 2006).

Table 2 Residential Buildings by Energy Efficient Standards in Beijing and Tianjin, China

Region	Non-Energy-Efficient Buildings	Energy-Efficient Buildings in the First Step	Energy-Efficient Buildings in the Second Step	Energy-Efficient Buildings in the Third Step
Beijing by 2004	35%	24%	41%	0%
Tianjin by 2006	52%	23%	15%	10%

Sources: BMCDR (2006); Zheng and You (2007).

In the transport sector, the excise tax for vehicles has been adjusted over time to incentivize the purchases of energy-efficient cars. The excise tax levied at the time of purchase was first introduced in 1994 when China reformed its taxing system, and the rate increases with the size of engines, setting at 3% for cars with engines of 1.0 liter or less, 8% for cars with engines of more than 4 liters, and 5% for cars with engines in between. These tax rates for cars remain unchanged. The new vehicle excise tax implemented since April 2006 has broadened the tax base from the existing range of 3-8% to 3-20%, and has increased to the six categories of engine size instead of the existing three ones. Since April 1, 2006, the rate for small cars with engines of 1.0 to 1.5 liters decreased to 3%, two percentage points lower than before. Cars with engines of 1.5 to 2.0 liters continue to enjoy a tax rate of 5%, and consumers who buy cars with engines of no less than 2 liters but no larger than 4 liters are required to pay a consumption tax of 9–15%. In the meantime, the tax on cars with engines of larger than 4 liters more than doubles from 8% to 20% (see Table 3). To further rein in the production and use of gas-guzzler cars and promote the production and use of energy-efficient small cars, China announced on August 13, 2008 that since September 1, 2008, the rate for small cars with engine of 1.0 liter or less further decreases to 1%, whereas the rate for cars with engines of no less than 3 liters but no larger than 4 liters goes up to 25%, 10% higher than the existing rate. Cars with engines of larger than 4 liters are now taxed at the highest rate of 40%, 20% higher than the existing level.[4] This large, upward adjustment in consumption

[4] China lost its first-ever dispute with WTO on July 18, 2008, when a panel on the WTO compliance of its auto part tariffs found in favor of the complainants - Canada, the EU and the U.S.. China imposed in April 2005 a 25% tariff on imported auto parts, if the parts made up 60% or more of the value of a whole vehicle (Sina Net, 2008; WTO, 2009). This tariff rate equals the duty that China applies on imported automobiles but exceeds its 10% tariff ceiling on imported auto parts. China had contended that the higher tariff was necessary to prevent tax evasion by companies that import whole cars as spare parts and then assemble them together inside China to avoid the higher tariffs applicable to entire automobiles. However, the three complainants in the case maintained that these higher charges unfairly discriminate against the use of foreign auto parts and effectively subsidize domestic production. The complainants argued that the tariff not only

tax for gas-guzzler cars clearly reflects the Chinese government’s determination to use consumption taxation as an important economic instrument to promote the production and use of energy-efficient small cars and enhance its policy guidance on energy conservation and environmental protection.

Table 3 Consumption Tax Rates for Cars in China

Engine (liters)	Excise Tax Since 1 January 1994 (%)	Excise Tax Since 1 April 2006 (%)	Excise Tax Since 1 September 2008 (%)
1.0 or less	3	3	1
1.0 < engine ≤ 1.5	5	3	3
1.5 < engine ≤ 2.0	5	5	5
2.0 < engine ≤ 2.5	5	9	9
2.5 < engine ≤ 3.0	5	12	12
3.0 < engine ≤ 4.0	5	15	25
Greater than 4	8	20	40

Sources: Sina Net (2006); People Net (2008a).

China has set even more stringent fuel economy standards for its rapidly growing passenger vehicle fleet than those in Australia, Canada, California and the United States, although they are less stringent than those in Japan and the European Union (see Figure 3). Implemented in the two phases, the standards classify vehicles into 16 weight classes, covering passenger cars, SUVs and multi-purpose vans. Converted to the U.S. CAFF (Corporate Average Fuel Economy) test cycle, the average fuel economy standards of new vehicles in China are projected to reach 36.7 miles per gallon in 2008 (An and Sauer, 2004).

Figure 3 Comparison of Fuel Economy Standards for Vehicles

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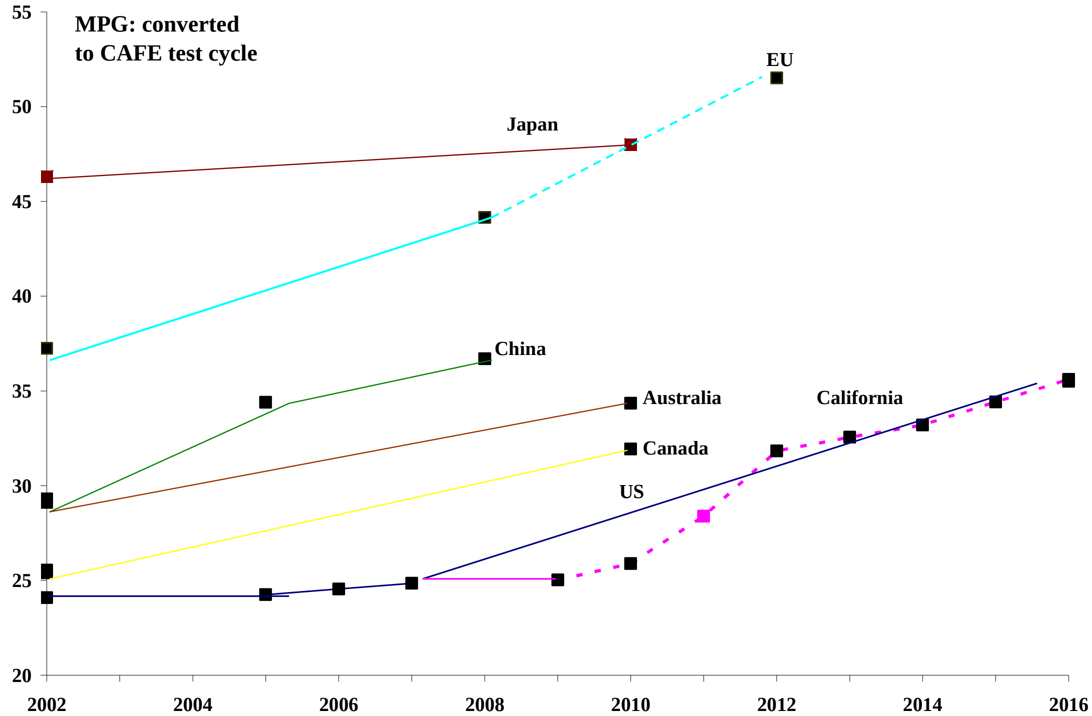
discouraged auto manufactures in China from using the imported parts, but also that the higher tariff put pressure on foreign producers of auto parts to relocate manufacturing facilities to China. On September 15, 2008, China notified its decision to appeal to the Appellate Body. On December 15, 2008, the Appellate Body reports were circulated to Members, upholding the Dispute Settlement Panel’s findings (WTO, 2009). As a response to the WTO decision, China decided since September 1, 2009, to give up this practice that had been implemented for the past four years and to impose a uniform 10% tariff on all imported auto parts (NDRC et al., 2009). Given the fact that Chinese auto manufactures tend to produce cars with engines smaller than 2.5 liters and an amazing coincidence of timing (Time to decide to introduce this green tax is less than a month after China lost its WTO dispute), this big upward adjustment in consumption tax for gas-guzzler cars may be seen as a way for China to cut car imports without offending the WTO.

Notes: Dotted lines denote proposed standards; MPG – Miles per gallon.
Source: Adapted from An and Sauer (2004).



In the meantime, growing Chinese cities are prioritizing public transport and are promoting efficient public transport systems. However, given an inevitable increase in the number of vehicles on road, China has also taken significant steps to control vehicle emissions. Following the phasing out of leaded gasoline nationwide in July 2000, the State Environmental Protection Agency of China requires all new light duty vehicles sold after April 2001 to meet State Phase I (similar to Euro I) vehicle emission standards and after July 1, 2004 to meet State Phase II (similar to Euro II) standards across China. Beginning July 1, 2007, China started implementing State Phase III (similar to Euro III) vehicle emission standards, with State Phase IV (similar to Euro IV) vehicle emission standards scheduled to be introduced on July 1, 2010 (see Table 4). Pollution from State Phase III standards is 30% lower than that from State Phase II standards. Pollution from State Phase IV standards even goes down below 60% of that from State Phase II standards (Xinhua Net, 2007b). Clearly, more stringent vehicle emission requirements by these new standards will help to reduce substantially the environmental stress in China.

Table 4 Vehicle Emission Standards and the Time to Enter into Force in China, ASEAN and European Union

	Euro I	**Euro II**	**Euro III**	**Euro IV**	**Euro V**
European Union	July 1992	January 1996	January 2000	January 2005	September 2009 (proposed)
China	April 2001	July 1, 2004	July 1, 2007	July 1, 2010	
Beijing	1999	August 2002	December 30, 2005	1st half of 2008	
India	2000	2005	2010		
ASEAN		December 2005 (targeted)		December 2010 (targeted)	
Indonesia		Early 2006	1st Q 2007	2012	
Malaysia		Mid 2006		2010	
Philippines		Dec 2006		2010	
Singapore		2005		Oct 2006 (Diesel)	
Thailand			Early 2005	2010	
Vietnam		July 2007		2012	

Source: Zhang (2008).

New vehicles that do not comply with the new standards cannot be sold in China. Clearly, vehicle emission standards in China have become increasingly stringent over time. While the time schedules to implement these regulations in China are a couple of years ahead of the schedules of India and most of ASEAN (Association of Southeast Asian Nations) countries that have about the same levels of vehicle emission standards as China does, China still lags behind the European Union's emissions requirements for new vehicles. However, China's gap with the EU requirements has gradually reduced from about nine years in 2001 to five and a half years in 2010. With the population of registered vehicles in China reaching 148 million by the end of March 2007 (Xinhua Net, 2007b) and continuing their explosive growth, and the emissions from vehicles as the main source of air pollution in many Chinese cities, these cities have been proactive in controlling vehicle emissions. With the largest population of registered vehicles in China (Xinhua Net, 2005),[5] Beijing took the lead. China's capital started a pilot program to stop sales of leaded gasoline by July 1997, three years ahead of the nationwide ban, and enforced State

[5] It took 48 years for the population of registered vehicles in Beijing to reach one million in February 1997 from 2300 in the early 1950s. It took six and a half years to reach two millions in August 2003. But it took only 3 years and nine months to reach three millions on May 27, 2007, much quicker than experts expected (Xinhua Net, 2007c).

Phase II standards two years ahead of the national schedule and State Phase III standards one and a half years ahead of the national schedule. By enforcing State Phase III standards ahead of the national schedule and speeding up the elimination of existing vehicles with lower standards, total pollution from vehicles in Beijing was estimated to be cut by 20% by 2008, compared with the existing level of pollution (Xinhua Net, 2005). As commitments to the Green Olympic Games, Beijing introduced State Phase IV fuel standards on January 1, 2008, and required all pump stations to supply State Phase IV fuel by March 1, 2008. Cars with State Phase IV vehicle emission standards and powered by State Phase IV fuel emit half as much pollution as cars with State Phase III vehicle emission standards and powered by State Phase III fuel (People Net, 2008b). China's capital also introduced State Phase IV vehicle emission standards in the first half of 2008, prior to the Beijing Olympic Games on August 8, 2008 (Xinhua Net, 2007a).

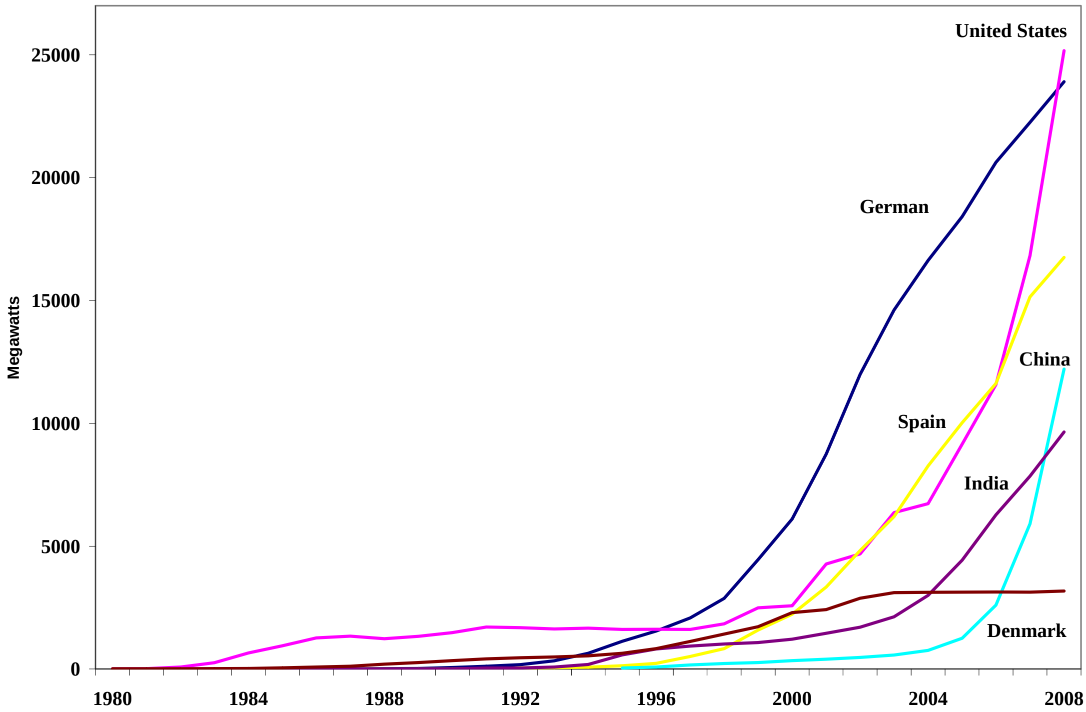
3. The use of renewable energy

Concerns about a range of environmental problems from burning fossil fuels and steeply rising oil consumption have sparked China's plans to pursue alternative energy sources to meet the country's increasing energy needs. China has targeted alternative energy sources to meet up to 15% of the nation's energy rwequirements by 2020, up from 8.9% in 2008. This is a big step up from the previous goal of 10% by 2020. Under this ambitious government plan, China aims to have an installed capacity of 300 gigawatts (one gigawatt equals one million kilowatts, GW) for hydropower (including large hydropower), 30 GW for wind power and 30 GW for biopower (power generated from biomass), and produce 10 million tons of ethanol and 2 million tons of biodiesel by 2020 (Zhang, 2007b).

The European Union is widely considered to be the world's leader in renewable energy. Let us look at the EU to put China's renewable energy goals into perspective. The EU aims at renewable energies meeting 12% of its primary energy by 2010 and 20% by 2020 from its current level of 6.5% (European Commission, 2007a and 2007b). At first glance, the EU's goal of tripling the share of renewable energy from the current level to 20% by 2020 seems even more ambitious than China's renewable energy goal. But because energy demand in China grows at least three times faster than EU does, doubling renewable energy in China's total energy mix by 2020 requires that renewable energy in China grows at a rate of four times that the rate of the EU.

Not only is China setting the ambitious renewable energy goals, more importantly it is taking dramatic efforts to meet these goals. China invested $12 billion in renewable energy in 2007, which trails the leader Germany, who invested $14 billion (REW 21, 2008). Given that the size of the Chinese economy was only slightly smaller than that of the German economy in 2007, this suggests that, in terms of renewable energy investment as a percentage of GDP, China probably scored as well as Germany. Take wind power as an example. In 1986, the first wind farm in Shandong Province, China, was connected with the electric grid. In 1995, the then Ministry of Electric Power set up the target of having total wind power capacity installed of 1 GW by the year 2000. However, by the end of 2003, the wind power capacity installed only totaled 0.56 GW, falling short of the target (Zhang, 2005). China had been suffering from power shortages from 1980s and to mid-1990s, and was able to achieve the first time the balance between power demand and supply in 1997. This crisis would have provided a unique opportunity to adjust the power generation mix and to encourage the development of wind power. But unfortunately, the opportunity was lost without notice.

Figure 4 Cumulative Installed Wind Power Capacity by Country, 1980-2008
Sources: Drawn based on data from Global Wind Energy Council (2009) and Earth Policy Institute (2008).



The turning point for wind power development occurred in 2003. In that year, the government put in place a series of policies favorable to wind power development. These policies include value added tax for wind power being cut in half, from the normal rate of 17% to 8.5%; low duty rate for domestic investment being levied for wind power (6%), in comparison with the normal rate of 23%; and duty free for equipments imported for renewable energy technologies in joint ventures. Some local governments provided even more favorable policies. For example, in Inner Mongolia, value-added tax of 6% is levied on wind power. With these favorable policies in place, the total wind power capacity installed doubled between 2003 and 2005, rising to 1.26 GW in 2005. With China's Renewable Energy Law entered into force in January 2006, the pace of installations accelerated considerably. The total installed wind power capacity rose to 2.60 GW in 2006, with new installations in that year alone more than the combined total over the past 20 years. Wind power capacity in China has doubled for the past consecutive three years (see Figure 4). With 5.9 GW of total installed capacity at the end of 2007, China has already surpassed its goal to achieve 5 GW in 2010. With new installations of 6.3 GW and a total installed capacity of 12.2 GW in 2008, China overtook India in wind power installations. During this process, local wind turbine makers, such as Sinovel Wind, Goldwind Science and Technology, and Dongfang Electric, accounted for an increasing share of total new installations. Together they now supply over 50% of a market once dominated by foreign firms until 2008. Clearly, speeding up the development of wind power in China not only helps to green the Chinese economy, but also creates green jobs.

In its response to the financial crisis, the Chinese government has identified the development of wind power as one of the key areas of economic growth. With an estimated new installations of 10 GW expected to come on line in China in 2009, relative to that of 6 GW in wind power in the U.S., China will overtake the U.S. as the top world wind power market in 2009 (Isensee, 2009). At this growth rate of new capacity installations, China would overtake Germany and Spain to reach the second place in total wind power installations in 2009 and surpass the U.S. in 2010, and would have met its 2020 target of 30 GW ten years ahead of schedule (Global Wind Energy Council, 2009).

This achievement has come because of a wind policy change. Since 2003, China has adopted the so-called Wind Power Concession Program as its primary strategy to further promote wind power development. Feed-in tariffs enacted in 2005 took effect on January 1, 2006 in China. Contrary to the wide expectations, the standard feed-in tariff model did not apply to wind power, only to biomass power.[6] Instead, China has been implementing the Wind Power Concession Program aggressively. This government-run program auctions off development rights for wind power projects of 100 MW or more for a 25 year period, which include a guaranteed tariff for the first 30,000 hours, as well as concession operation agreements. Such on-grid tariff of wind power is decided through a competitive bidding process. If such a tariff is higher than the reference on-grid tariff of desulfurized coal-fired power, then the difference will be shared in the selling price at the provincial and national grid levels. For the remainder of the period (namely, after the first 30,000 hours until the ending of the total concession period of 25 years), the tariff of wind power is set to be equal to the average local on-grid tariff.

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[6] Wind power industry and policy analysts in China recommended the Chinese government to adopt a feed-in tariff. That will oblige the utilities to purchase electricity from renewable energy sources at a fixed rate. But to the surprise of many who expected a "coal-fired power indexed tariff plus subsidy" as the tariff model for wind power, the Chinese government decided on a competitive bidding mechanism to determine the proposed wind power grid tariff. Simply put, bidding to determine the price at which a unit of electricity will be provided to the grid. The reason for not choosing the expected model is the Chinese government's belief that under the feed-in tariff model, the wind power tariff in the southeast coastal areas would be almost double those in the western regions of the country because of the higher coal prices in the former, despite the fact that much of the wind resources are located in the western provinces. That would make it unlikely that investors would be interested in the western regions where their return would be much smaller, an outcome that is not beneficial to the country's overall sustainable development objectives.

China completed in 2006 the fourth round of bidding for three wind power concession projects of total capacity of 700 MW. The Chinese government took the lessons learned from the pervious bidding processes and made efforts to ensure that this program works effectively to promote a robust and sizeable wind power industry in China. No doubt, the bidding-based program has introduced competition to both the construction and management of wind farms. However, it is not without its own problems. One is that investors underbid to win a project. For example, the winner in the first round of bidding offered the unprecedented grid tariff of 390 Yuan per 1,000 KWh, whereas the other offers were in the range of 600 to 700 Yuan per 1,000 KWh. Another problem is that the grid tariff is not known until after the bidding, which makes it difficult for firms to secure bank loans as the banks cannot assess the rate of return on the project without knowing the tariff (Zhang, 2005). To prevent irrational bidding that could endanger overall project quality and investor return, the Chinese government has lowered the weight of the grid tariff in the bidding assessment process and assigned more weight to other factors, such as local content, investment and financial ability, financial plan, and technical plan. In the first round of bidding in 2003, the tariff was the only criteria determining the winner. Those who offered the lowest grid tariff won. But, the weight of the grid tariff in the overall bidding decision has been declining. It accounted for only 40% by the third round in 2005, and only 25% in the current fifth round of bidding. With these modifications, the bidding tariff is now ranked as the second key criteria under a 100-point bidding evaluation system, after the 70% local content requirement that accounts for 35% in the current round of bidding.[7] However, simply lowering the weight of the grid tariff in the bidding process is not the answer because that will simply increase the transaction costs (Zhang, 2005). To lower transaction costs and at the same time ensure project quality, competitive bidding needs to be coupled with a mechanism that would hold bidders

[7] While China sets itself on a course of rapid development of wind power, its technology and manufacturing capacity can hardly match its demand. China has to rely on foreign turbine manufacturers. Generally speaking, huge order of turbines from China helps to expand these manufacturers' scale of production and thus reduces their cost and price of wind turbines. However, there have been the so-called phenomenon of the "China factor". When China needs something, the prices go up; when China sells something, the prices then go down. The monopoly behaviors of these foreign turbine manufacturers keep the prices of turbines rising as China's order size is growing. China has indeed seen itself subsidizing foreign manufacturers. This "China factor" may be okay with the increasing oil prices because it is a depletable natural resource. But China cannot accept this for wind turbines. This has promoted the top Chinese policymakers to add the 70% local content requirement. This requirement means that wind power projects must have over 70% of their turbine components locally made, and that the wind turbine generator must be assembled in China. The aim is to encourage technology and manufacturing industry for wind turbines in China. This requirement was originally proposed in relation to wind concession farms in China, but was extended to include ordinary wind farm projects as well in 2005. The bidding mechanism, coupled with the 70% local content requirement, speeds up the localization of wind turbines. 2008 was the first year in which the installed capacity of domestically made turbines exceeded that of foreign ones.

accountable for the implementation of project, robust technical standards for design and construction to avoid downward pricing pressure leading to substandard technology and implementation,[8] and/or a floor price to prevent unrealistic low bids from jeopardizing the bidding process (Zhang, 2005; Baker & McKenzie et al., 2007).

With both power demand and new installations of wind power capacity increasing faster than planned, and further deterioration of the environment, China is set to raise its wind power target. The country now aims to have at least 100 GW of wind power capacity in operation by 2020. This revised target is 70 GW more than the 30 GW target set in 2007, eight times its current total wind power capacity, and more than the Great Britain's entire current power capacity. In company with this, on July 22, 2009, the NDRC enacted feed-in tariffs for wind power, which took effect on August 1, 2009. This means the ending of the controversial bidding-based program that had been in place since 2003. According to the quality of wind energy resources and the conditions of engineering construction, four wind energy areas are classified throughout China. Accordingly, on-grid tariffs are set at 0.51, 0.54, 0.58 and 0.61 yuan/kWh as benchmarks for wind power projects across the nation, respectively (NDRC, 2009). The rates are in line with tariffs that the NDRC has approved in the past. By letting investors know the expected rate of return on their projects through announcing on-grid tariffs upfront, the Chinese government aims to encourage development of wind energy resources of good quality, thus promoting the development of wind power in proper order. In the meantime, this will encourage wind power plants to reduce the costs of investment and operation and increase their economic efficiency, thus promoting the healthy development of the whole wind industry in China.

However, many consider that the new set wind tariffs provide only small profit margins. The wind power plants have to bundle with clean development mechanism (CDM) to increase their profit margins by selling the certified carbon reductions generated. Indeed, the CDM has to date played an important role in driving wind power expansion in China.[9] As of August 1, 2009, China hosts 371 wind power CDM projects that are at the public validation stage or beyond. The total installed capacity of these CDM projects is projected to be 20.7 GW (UNEP Risoe Center, 2009), much higher than the current total installed capacity of 12.2 GW in China. Currently, the certified carbon reductions generated are sold at a price ranging from the lowest end of 0.036 yuan/kWh from one plant in Inner Mongolia to the highest end of 0.11 yuan/kWh from one plant in Beijing

[8] This is the lesson learned in India's competitive bidding regime. It was a lack of turbine standards or production requirements that led several early projects to poorly perform, despite significant technology advances. As a response, in 2003, certification of design and performance became mandatory in its bidding regime (Baker & McKenzie et al., 2007).

[9] The recent CDM Executive Board's decision to reject 10 Chinese wind power CDM projects has cast doubt on this. China has been accused by critics of gaming the CDM system. The Executive Board said that China deliberately set power tariffs so that the 10 wind power CDM projects, with a combined investment of some six billion yuan, could not be profitable without the subsidies.

(Wang et al., 2009). This will boost the internal rate of return by 6-20%, relative to wind power stand-alone projects.

4. Participation in clean development mechanism

The CDM is an innovative mechanism built into the Kyoto Protocol. The CDM allows industrialized countries to generate emission credits through investment in emission abatement projects in developing countries while helping developing countries to meet their sustainable development objectives. While many Annex I countries have put and continue to put pressure on developing countries to take on emissions limitation commitments, the CDM so far is the only mechanism with an authentic global reach.

China was a slow starter of CDM projects.[10] However, since mid 2005, China has rapidly increased the number of CDM projects. Part of this can be attributed to the extensive capacity building exercises between late 2001 and 2006 supported by many donor agencies, with each of these exercises having different focus. For example, the World Bank project focuses on the methodological aspects of the CDM, the Asian Development Bank project on small-scale CDM energy projects, the Canadian International Development Agency-funded project on an operational model and case studies in the areas of urban transportation and renewable energy, and the United Nations Development Programme project on capacity building needs of industry and three CDM pilot projects in the areas of renewable energy, energy efficiency and coal bed methane. In the meantime, China has prioritized the areas of the CDM investment, and put in place clear institutional structures, streamlined and transparent CDM procedures and sound governance of clearer lines of responsibility and functions to facilitate the smooth implementation of CDM projects without making a lengthy administrative and legislative procedure a precondition for project approval (Zhang, 2006a).

Table 5 Pipeline of CDM Projects at the Validation Stage or Beyond (as of 1 August 2009)

Region	CDM projects at validation or beyond		Projected certified emission reductions by 2012	
	Number	%	Million tons CO_2	%
Latin America	805	17.5	393.6	14.2
Asia & Pacific	3582	78.1	2254.7	81.1
China	**1804**	**39.3**	**1541.3**	**55.4**
India	1168	25.5	427.4	15.4
Europe & Central Asia	46	1.0	18.5	0.7
Africa	105	2.3	80.6	2.9
Middle-East	50	1.1	34.0	1.2

[10] See Zhang (2006a,b) for detailed discussion on the reasons.

Total	4588	100.0	2781.3	100.0

Source: UNEP Risoe Center (2009).

As the biggest host country, as of August 1, 2009, China hosts 1804 CDM projects that are at the public validation stage or beyond, accounting for 39% of the world's total CDM projects (Table 5). In terms of the number of projects, hydropower, wind power, and energy efficiency projects in the energy sector are the three most popular types of CDM projects in China. The number of CDM projects in the three types is 819, 371 and 277, respectively, accounting for 81% of the total CDM projects in China. Their share in expected emissions reductions in China accounts for 46% of the total estimated emissions reduction. If operated as planned, all these currently known CDM projects in China are projected to generate reduction of 1541 $MtCO_2$ equivalent by 2012, accounting for 55.4% of the world's total estimated carbon credits by 2012.[11] To put into perspective, this amount of the total emissions reductions by 2012 is more than the current greenhouse gas emissions of Germany and the United Kingdom (the first and second largest emitters in the European Union) combined.

Putting CO_2 reductions from China's unilateral actions into perspective

If the goal of 20% energy intensity reduction in China would be met, that would translate into a projected reduction of its 2010 CO_2 emissions by 1500 $MtCO_2$ (NDRC, 2007). The Top 1000 Enterprises Energy Conservation Action Program would lead to a cumulative CO_2 reduction of 220 $MtCO_2$ during the period 2006-2010. For comparison, energy-related CO_2 emissions in all Annex 1 countries committed to participating in the Kyoto Protocol are projected to be reduced by 422 $MtCO_2$ relative to the reference case in 2010 (EIA, 2006). This is just about 30% of the estimated CO_2 reduction from meeting the aforementioned 20% energy saving goal in China.

Let us put it aside for a moment whether that energy intensity target is going to be achieved and assume that it will. The question then arises: is that estimated reduction achieved from China's unilateral actions (namely, actions outside the CDM projects in China) or mainly with support from the CDM projects? As of August 1, 2009, China hosts 1804 CDM projects. All these currently known projects lead to annual reduction of 357 $MtCO_2$ equivalent. HFCs and N2O decomposition and landfill gas types of CDM projects only have climate benefits but do not offer energy saving and other social and environmental benefits to host countries. Moreover, China's CDM regulations require that solely Chinese or Chinese-controlled enterprises are eligible for project development, indicating that the foreign company undertaking a CDM project could not be allowed to own more than 50% of equity in the project (Zhang, 2006a). Taking out contributions from HFCs, N2O, landfill gas types of CDM projects and factoring in the Chinese

[11] This is very in line with the economic model-based estimates of Zhang (1999, 2000b, 2001, 2004), which show that about 60% of the total CDM flows in 2010 go to China. Once that results of the Asian Development Bank study (Zhang, 1999) were released, some people dubbed CDM China Development Mechanism.

company owning more than 50% of equity in a CDM project, portion of that reduction from foreign investment in the CDM projects in China is estimated to only contribute about 5% of China's projected CO_2 reduction in 2010. This clearly indicates that CDM does not make much of a difference to China, but China is definitely making a difference to CDM. The overwhelming majority of the estimated CO_2 reduction from meeting the aforementioned 20% energy saving goal in China is expected to be achieved through its own domestic actions, rather than support from the CDM projects. China clearly does more than what the world thinks. It is unfair to criticize China without acknowledging what the country has done.

5. Low-carbon energy and technology and nuclear power

China relies heavily on coal to fuel its economy. As the world's largest coal producer and consumer, China produces and consumes about twice as much coal as the U.S., the world's second largest coal producer and consumer. Coal has accounted for over two-thirds of China's primary energy consumptions for several decades. For a considerable period of time to come, China's energy mix will continue to be dominated by coal (Zhang, 1990; IEA, 2008a). Coal-fired power plants dominate total electricity generation in China, accounting for about 75% of total capacity and more than 80% of total power generation. Power and heat generation is consuming over half of the total coal use. As a result, China's total installed capacity of coal-fired power plants is more than the current total of the U.S., the United Kingdom and India combined. While nuclear and renewable power will gain in importance of China's power mix in the long term, coal-fired power is still expected to account for more than 70% of total power generation in China over the next two to three decades (Zhang, 1990; IEA, 2009). Given this trend of continued coal use, the key issue is to how China can use it more efficiently and environmentally friendly in order to limit its impacts.

5.1. Accelerating the closure of small, inefficient coal- and oil-fired power plants

As the largest coal consumer, power generation is currently consuming over half of the total coal use in China. This share is expected to rise well above 60% in 2020, given the rapid development of coal-fired power generation. In this regard, efficient coal combustion and power generation is of paramount importance to this endeavor. To that end, China has adopted the policy of accelerating the closure of thousands of small, inefficient coal- and oil-fired power plants. Units facing closure include those below 50 MW, those below 100 MW and having in operation of over 20 years, and those below 200 MW and having reached the end of their design life, those with a coal consumption of 10% higher than the provincial average or 15% higher than the national average, and those that fail to meet environmental standards. The total combined capacity that needs to be decommissioned is set at 50 GW during the period 2006-10. By the end of 2008, China had closed small plants with a total capacity of 34.21 GW, relative to a total capacity of 8.3 GW decommissioned during the period 2001-05 (NDRC, 2008b). According to Zhang Guobao, Administrator of China's National Energy Administration, the total capacity of decommissioned smaller and older unites had increased to 54 GW by the end of the first half year of 2009, having met the 2010 target of decommissioned 50 GW one and half years ahead of schedule (Sina Net, 2009).

5.2. Encouraging the construction of large, more efficient, cleaner units

In the meantime, the Chinese government policy has focused on encouraging the construction of larger, more efficient, and cleaner units. China has completely mastered design and manufacturing technologies for subcritical units with the capacities of 300 MW and 600 MW (Yu, 2006). This technology will remain a dominated generation technology in the foreseeable future. By June 30, 2009, 64% of coal-fired units comprised units with the capacities of 300 MW or more (Wang and Ye, 2009). On the other hand, due to higher thermal efficiency and relatively low unit investment cost, China's power industry has listed super critical power generation technology as a key development focus. To date, this generation technology is the only advanced, well established and commercialized clean power generation technology in the world. As a result, an increasing number of newly built plants are more efficient supercritical (SC) or ultra-supercritical (USC) plants. Until the end of 2003, all SC units installed in China were imported from abroad. In 2004, the first domestically designed and manufactured SC unit with the capacity of 600 MW at Qinbei power station in Henan Province was successfully put into parallel operation with grids (Yu, 2006). Now 600 MW units dominate among new power generation plants. In November 2006, the first two of four 1000 MW USC units at Yuhuan power plant in Zhejiang Province were put into operation by China Huaneng Group, the country's largest state-owned electric utility. Units 3 and 4 went on line in 2007 and 2008, respectively. This is China's first commercially operated power plant built based on domestically made 1000 USC pressure boilers. This plant has a generation efficiency of as high as 45%, with a coal consumption of 285.6 gce/kWh, 53.4 gce/kWh less than the national average of 339 gce/KWh in 2006. This means that it can cut carbon emissions by more than a third compared with the least efficient plants in China with a generation efficiency of 27-36% (Bradsher, 2009). With cost comparative advantages over other cleaner coal technologies, such as IGCC and polygeneration technologies, SC and USC technologies will be developed and deployed in China. By 2007, the share of SC and USC units in total coal-fired generation capacity was about 12% (See Table 6). In comparison, the corresponding share is about 70% in Japan and 30% in the U.S.. However, as over 40% of the new-builds in China are large, SC and USC units by 2010, and all new units of 600 MW and more are required to be SC and half of the new-builds will be USC between 2010 and 2020, their share in total coal-fired generation capacity is expected to grow to 15% by 2010 and 30% by 2020 (Huang, 2008; Table 6).

5.3. Mandating coal-fired units to be equipped with FGD facilities and to pay pollution charges

With one-third of China's territory widely reported to be affected by acid rain, the formation of which SO_2, along with NO_2, contributes to, reducing SO_2 emissions has been the key environmental target in China. In its current economic blueprint for 2006 to 2010, China incorporated for the first time the goal of reducing SO_2 emissions by 10% by

2010. The Chinese government is taking concerted efforts to meet its goals. With burning coal contributing 90% of the national total SO_2 emissions and coal-fired power generation accounting for half of the national total, the Chinese central government has mandated that new coal-fired units must be synchronously equipped with a flue gas desulphurization (FGD) facility and that plants built after 1997 must have begun to be retrofitted with a FGD facility before 2010. Empowered by the State Council (the Chinese Cabinet), the Ministry of Environmental Protection (then State Environmental Protection Agency) in May 2006 signed SO_2 emissions-cutting responsibility agreements with seven provincial governments and six top national power-generating groups, which together account for two-third of total SO_2 emissions in China. And, policies favorable to FGD-equipped power plants are being implemented, e.g., the on-grid tariff incorporating desulphurization cost, priority given to be connected to grids, and being allowed to operate longer than those plants that do not install desulphurization capacity. Some provincial governments provide even more favorable policies, leading to priority dispatching of power from units with FGD in Shangdong and Shanxi provinces. Moreover, the capital cost of FGD has fallen from 800 yuan/kW in the 1990s to the current level of about 200 yuan/kW (Yu, 2006), thus making less costly to install FGD facility.

Table 6 Coal-fired Power Generation Technologies in China, 2005-2030 (GW)

	2005	**2006**	**2007**	**2020**	**2030**
Total generation capacity	**517**	**624**	**713**	**~1500**	**2000 - 2300**
Coal-fired	368	454	524	1040	1200
subcritical	355	419	464	700	440
supercritical	13	32	~50	200 - 220	300 - 330
ultra-supercritical	0	3	10	80 - 90	270 - 280
IGCC	0	0	0	44	170
Gas-fired and oil-fired	22	30	40	60	200
Total thermal capacity	**390**	**484**	**564**	**1100**	**1400**
Installed FGD capacity	53	162	270	700 - 800	1000 -1100

Source: Compiled by IEA (2009) based on a number of sources.

As a result, newly installed desulphurization capacity in 2006 was greater than the combined total over the past 10 years, accounting for 30% of the total installed thermal (mostly coal-fired) capacity. This helped to slow down the growth rate of SO_2 emissions significantly in 2006, which was 11.3% less than that in 2005. By 2007, the coal-fired units installed with FGD increased to 266 GW from 53 GW in 2005. Generation units with FGD further rose to 379 GW in 2008. Accordingly, the portion of coal-fired units with FGD rose to 51% in 2007 and 66% in 2008 of the total installed thermal capacity from 13.5% in 2005 (Sina Net, 2009).

To encourage technical progress and strengthen pollution control to meet the energy-saving and environmental control goals set for the 11th Five-Year Economic Plan, the Chinese government plans by three steps to double the charges for SO_2 emissions, which started being levied in 1996 in the so-called Two Control Zones[12] and since July 1, 2003, was applied nationwide, from current level of 0.6 yuan per kilo of pollutant equivalent to 1.2 yuan per kilo of pollutant equivalent within the next three years. Local governments are allowed to raise their own pollution charges above the national levels. Since 1999, Beijing levied charges of 1.2 yuan per kilo of pollution equivalent for SO_2 emissions from coals of high sulfur content. Jiangshu Province raised charges for SO_2 emissions from current level of 0.6 to 1.2 yuan per kilo of pollution equivalent from July 1, 2007 onwards, three years ahead of the national schedule (Zhang, 2008). However, the pollution charges have been set too low, relative to the cost of abating pollution. Even in the case of Jiangshu Province, this charge is still less than half of the real abatement cost, which is reported to be 3 yuan per kilo of pollution equivalent for abating SO_2 emissions from coal-fired power plants (Zhang, 2008).

Table 7 Levels of Charges for Atmospheric Pollutants in China

Pollutants	Staring Time	Levels of Charge (yuan/kilo pollution equivalent)
SO_2 emissions	July 1, 2003	0.2
	July 1, 2004	0.4
	July 1, 2005	0.6
	July 1, 2010	1.2
NOx emissions	July 1, 2003	0
	July 1, 2004	0.6

Source: Zhang (2008).

5.4. CCS research and demonstration projects

With China still dependent on coal to meet the bulk of its energy needs, carbon capture and storage (CCS) has been identified as a crucial element in the country's efforts to reduce greenhouse gas emissions. PetroChina has operated China's first CO_2 storage and injection pilot tests at the Jilin Oil Field since 2006. In partnership with Australia and Xi'an Thermal Power Research Institute, the Huanneng Group commissioned a post-combustion carbon capture pilot facility at the Gaobeidian power plant in Beijing in July

[12] The so-called Two Control Zones refer to the acid rain control zone and the SO_2 control zone. The former mainly covers the southern and southwestern parts of China where precipitation is acidic most of the time, whereas the latter covers the northeastern and eastern parts of the country where SO_2 emissions are very intensive but the acid rain is not apparent partly because of the alkaline soils in these areas.

2008. Designed and developed by Xi'an Thermal Power Research Institute, with all of its equipments made in China, this pilot project is capable of recovering more than 85% of the CO_2 with a purity of 99.99% from the power plant flue gases, and can trap 3000 tons of CO_2 a year. In July 2009, the Huaneng Group started building China's first commercial-scale IGCC demonstration power plant in Tianjin. This 250 MW plant is planed in three phases, with hydrogen production and CCS expected to be completed by around 2015 and trapping 5000 tons of CO_2 per day. The Shenhua Group, China's biggest coal producer, is planning to launch the country's first commercial-scale CCS facility. It will be built at the company's 24.5 billion yuan ($3.58 billion) coal-to-liquids plant at Ordos in Inner Mongolia, according to the State-Owned Assets Supervision and Administration Commission. This project will likely inject 100,000 tons of CO_2 underground by the end of 2009 and ultimately aims to capture three million tones of CO_2 annually (Friedman, 2009). China also established a partnership with the EU on climate change. It aims to develop CCS demonstration projects based on the EU advanced, near-zero emissions coal technology by 2020.

Thus far, CCS has not been commercialized anywhere in the world, and it is unlikely, given current trends, that this technology will find large-scale application either in China or elsewhere before 2030. However, the commercialization and widespread deployment of CCS is a crucial option for reducing both China's and global CO_2 emissions. As a critical first step, IEA (2008b) recommends 20 large-scale CCS demonstration projects by 2020. To that end, cooperation among countries will reduce both the costs and risks of CCS research and demonstration projects. Given that China is building one to two large coal-fired power plants per week, China has cut costs substantially through economies of scale. Now building a USC unit in China can cost a third less than building a less efficient coal-fired plant in the U.S. (Bradsher, 2009). To take advantage of the high level of manufacturing and low costs of manufacturing, labor and other factors in China, the U.S., the EU, Japan and other key players should cooperate with China in such a way to build more joint demonstration CCS projects in China using its currently proven technologies to achieve economies of scale enough to bring down the costs. In the meantime, these countries should initiate a major new initiative to jointly develop more advanced and innovative CCS technologies with shared intellectual property rights.

5.5. Development of nuclear power

In 1983, China started constructing the first domestically designed nuclear power unit with a capacity of 300 MW in Qinshan, Zhejiang Province. On December 15, 1991, this unit was successfully put into parallel operation with the East China Power Network (Zhang, 1997). This marked the end of an era without nuclear power in China. China has mastered PWR nuclear power generation technology with unit sizes of 300 MW and 600 MW, with 60% of components manufactured domestically. China's own CPR1000 nuclear technology is used for all four units of 4320 MW Red River nuclear power plant in Liaoning Province, the first in the current 11th Five-year Plan period.

In the mid-1980s, the then Ministry of Energy, which was abolished in March 1993 as a result of the restructuring of governmental organization, set an ambitious target for nuclear power, aiming to have total installed capacity of 10 GW by 2000. However, by 2008, the total installed capacity of nuclear power was only 9.1 GW, with 11 power stations in operation. The speed of nuclear power development is much slower than planned. This slow pace of nuclear power development is to a large extent the result of nuclear power policy: the Chinese government was unable to make up its mind as to what a role nuclear power should play in the country's overall energy policy.

In early 2004, at the meeting to celebrate the 50th anniversary of the establishment of the nuclear industry in China, then Vice Premier Huang Ju emphasized that special attention should be paid to nuclear power. Soon after that, Xu Kuangdi, President of the Chinese Academy of Engineering, told the media that the Chinese government had planned to adopt an active development policy of nuclear power to replace the current moderate development. On March 2, 2005, the Premier Wen Jiabao instructed to adjust China's energy mix and vigorously develop nuclear power. This is widely viewed as the signal that China was going to step up the development of nuclear power.

With this policy change, in June 2007 the NDRC issued China's medium- and long-term development plan for nuclear power. According to Cao Shudong, Deputy Director-General of China's National Energy Administration, the plan aims to have total installed capacity of 40 GW, with another 18 GW under construction by 2020. This requires the addition of 2 GW every year and the total expected investment of 450 billion yuan (Ye, 2009). With power demand rising faster than the reference on which the current target is set and further deterioration of the environment, the tone of the nuclear power policy was further adjusted in 2009 to ramp up the development of nuclear power to the extent possible. Accordingly, China's National Energy Administration now aims to have 70 GW or more of nuclear power capacity in operation, with another 30 GW under construction by 2020 (Yang, 2009).

Increasing manufacturing capability, breaking the monopoly in construction and installation, and reducing the high cost of imported equipments are seen as crucial for achieving the revised goal. Also, limited uranium resources in China will be a key factor constraining the development of nuclear power. China's *in situ* uranium resources totaled 100,000 ton (tU) in 2007, with up to 48,000 tU being reasonably assured and recoverable. Production was estimated to be 750 tU, and consumption for power generation was about 1500 tU in 2007 (NEA, 2008). Current uranium resources in China are reported only to meet the expected consumption for 40 GW capacity in 2020 (Yang, 2009). With nuclear power capacity being increased significantly, securing the supply of uranium resources becomes even more important for China, at a time when many countries, even including Australia the world's second largest exporter of uranium resources, are now considering increasing nuclear power generation in their total power production.

China's planned development of nuclear power sets a pace that is unprecedented elsewhere. However, even if by 2020, China has commissioned the planned 40 reactors or so and reached that revised 70 GW target, nuclear power will still only account for 5% of national power capacity at that time. In percentage terms, this is only slightly higher than 4%, which corresponds to the 40 GW nuclear capacity target set in 2007.

6. Securing a stable oil and gas supply during the transition to a low-carbon economy

We should first put China's overall energy demand and supply in context as these factors are often overlooked in discussing the issue of China's importation of oil.

China is indeed a large energy consumer. In the mean time, China is also the world's largest energy producer. With total domestic primary energy production of 2600 million tce and total domestic energy consumption of 2850 million tce in 2008, domestic supply provides about 91% of the total energy consumption in China, meaning that the overall energy dependence (namely, the ratio of the energy that a country imports to the total it consumes) is about 9%. In the future, China will continue to rely mainly on domestic supply to meet its growing energy demand. With a variety of policies and investments that have been and continue to be made to further expand domestic supply capacity, domestic, conventional energy is estimated to supply 2400 million tons of coal equivalent (tce) by 2020 (Zhang, 2005).

For the current five-year period running from 2006 to 2010, the Chinese government has set a goal of cutting energy use per unit of its gross domestic product by 20%. The government has also established a medium to long term energy conservation plan to keep the country's total energy demand below 3000 million tce in 2020 (NDRC, 2004). This suggests that domestic supply will meet 80% of the total energy consumption. Even if energy demand goes up to 4000 million tce in the worst case scenario as some estimates suggest (e.g., EIA, 2009), China's domestic supply is still able to provide 60% of the total energy demand in 2020. This makes China different from other large energy-using countries like Japan that imports over 80% of its total energy consumption.

That said, this by no means lessens the increased importance of China's growing oil imports. China was traditionally self-sufficient in oil, but since 1993 it has been a net oil importer. China's economic boom and stagnated supply of domestic oil have produced a growing hunger for foreign oil. As of 2003, China emerged second only behind the U.S. in terms of oil imports. At present, China imports over 50% of its oil consumption and this is expected to rise to 60% or more by 2020 (Zhang, 2005). The IEA estimates that by 2030 China is expected to import almost 13.1 mb/d, more than the U.S. imports today, in order to meet its expected oil demand of 16.5 mb/d. This puts China's oil dependence rate at 80% in 2030 (IEA, 2007). Energy security has risen to the height of importance in its foreign policy, and is becoming what has been called a "transforming" factor in the relations between China and the Middle East, Russia, and energy-rich Central Asian, African and Latin American countries (Yi, 2005).

China has relied on the majority of its oil imports from the Middle East. Thus, it will continue to consolidate its base there. A noticeable move is that China National Petroleum Corp (CNPC) joined in the BP-led consortium to win the rights to develop Iraq's giant Rumaila oil field on June 30, 2009. While the awarded payout for increasing current production at a US$2 per barrel is much smaller than what the consortium asked for, contracts are seen as a way for Chinese oil majors to get their foot in the door in Iraq, which is thought to have the world's third largest oil supplies, with about 115 billion barrels in proven reserves (Chon, 2009). In the meantime, China is concerned about the security of its sea-lanes for imports and desires to diversify its oil supplies from the Middle East in order to sustain economic growth. These concerns have sparked China's interest in trying to ensure oil supplies from as many sources as possible and in reducing its overwhelming reliance on seaborne imports of oil, which, in China's view, is considered less vulnerable to disruption than oil arriving by tankers (Zhang, 2007e). Given their closeness and accessibility through pipelines, China has been keen to invest in Central Asian and Russian oil and natural gas field development projects and in the construction of pipelines in order to bring oil and natural gas from these regions. On April 16, 2009, CNPC signed a deal with Kazakhstan's state-owned oil and natural gas corp KazMunaiGas. The CNPC will provide a US$ 5 billion loan in return for steady oil supply from KazMunaiGas (Wang, 2009). The CNPC also agreed to buy Kazakh oil producer MangistauMunaiGas in partnership with KazMunaiGas. On June 25, 2009, China signed a 30-year deal to increase by 30% purchases of natural gas from Turkmenistan, which sits on the world's fourth largest reserves of natural gas. This contract, which increases gas deliveries to 40 billion cubic meters annually, is seen as a landmark agreement as China's ongoing push into Central Asia is challenging Russia's dominance in the region (Asian Wall Street Journal, 2009). The deals come amid strained relations between Turkmenistan and Russia, who usually buys most of the Turkmen gas for less than US$ 200 per 1000 cubic meters (it was only half this amount two years ago) for onward sale in Ukraine and Western Europe (where gas traded is around US$ 350 per 1000 cubic meters) but early 2009, reduced gas imports from Turkmenistan because of plunging demand and prices in Europe. China and Russia have been discussing a cross-border pipeline for crude oil since early 1990s, but weren't able to finalize a deal. Leveraging its relative financial strength at a time when most other big economies are in recession, China eventually struck this largest, long-awaited loan-for-oil deal with Russia on February 17, 2009. Under this long-term deal, China lends US$ 25 billion to Rosneft, Russia's biggest oil producer, and Transneft, its oil pipeline operator. In exchange, Russia will provide China with an additional 15 million tons of crude oil a year between 2011 and 2030, which represents about 300,000 barrels a day for 20 years, or nearly 10% of China's current volume of oil imports. The deal not only provides the two Russian oil companies with the much needed credit, but also helps Russia to secure customers and reduce its dependence on Western Europe.

In the recent years, China has also turned its eyes to the emerging oil and gas fields in Africa. Top Chinese leaders frequently paid the visits to oil-producing countries in the region. This high-profile, goodwill-based energy diplomacy has helped China to make remarkable inroads in striking energy deals with oil-rich African countries in the Gulf of Guinea, Central African Republic, Chad, Congo, Libya, Niger, and Sudan. At present, there is no direct competition between China and Japan for African oil resources, largely because Japan has almost ignored Africa as a source of its badly needed oil. This may change in the future, because Japan has stepped up its Africa diplomacy in recent years. While China aggressively pursuing oil and gas interests in Africa plays a part, this has been mainly promoted by a strong desire for Japan to gain support from the continent's

53 countries in its bid for a permanent United Nations Security Council seat (Masaki, 2006). While cooperating with each other occasionally,[13] China and India already compete directly for energy resources in Africa as well as in other regions. In the meantime, China's oil diplomacy in Africa has been roundly criticized in Western capitals. Critics accused China of fueling conflicts and human-rights violations in Africa (Zhang, 2007e).

China's search for oil has recently taken it to Central and South America, America's backyard which the U.S. perceives as its turf and within its traditional sphere of influence. China already struck the two loan-for-oil deals with Venezuela. China provided US$ 8 billion to Venezuela's state-owned oil corporation PDVSA. In return, PDVSA agreed to supply 230,000 barrels a day to the CNPC. In July 2009, China struck the third loan-for-oil deal with Venezuela, providing an additional US$ 4 billion loan to PDVSA. The CNPC also struck a deal with Ecuador's state-owned oil company. The CNPC in August 2009 will provide an upfront payment of US$ 1 billion to receive 288,000 barrels a month for two years (Y. Zhang, 2009). The biggest deal in this region is a US$10 billion loan agreement made with the Brazilian state-owned oil giant Petroleo Brasileiro SA, known as Petrobras. Under the terms of the 10-year loan from China Development Bank, which has been at the center of China's resources policy, Petrobras will supply China Petroleum and Chemical Corporation, known as Sinopec, 150,000 barrels of oil a day in 2009, rising to 200,000 barrels a day for another nine years from 2010 to 2019 (Ma, 2009).

Currently depressed oil prices and the global credit crises have left oil companies scrambling for cash, creating an opportunity for the Chinese oil majors, which still have access to financing from China's robust banking sector. The Chinese oil majors have taken this opportunity to pick up their overseas M&A pace in 2009. On June 24, 2009, Sinopec made a C$ 8.27 billion (US$7.22 billion) takeover bid for the international oil and gas exploration company Addax Petroleum. The takeover would give Sinopec access to Addax's stakes in oil fields off the coast of West Africa, as well as in Iraq. Addax is based in Switzerland but has shares listed in Toronto and London. By 2008, this company held estimated reserves of 536 million barrels, and produced 140,000 barrels of crude oil a day. This deal, if completed, will be the largest overseas takeover by a Chinese company. The CNPC has entered into talks to buy the majority of YPF of Argentina from its Spanish parent Repsol YPF. YPF produces about a third of Argentina's oil and a quarter of its gas. The CNPC aims to purchase a 75% stake in YPF at US$17 billion (Tucker et al., 2009). If the YPF deal goes ahead, it will be the largest acquisition ever by a Chinese company. Analysts say that this Argentine business is not the world's most enticing asset. YPF's reserves are declining. Its profitability is limited by domestic price regulation and a crippling export tax. Labor disputes and an increase in fixed costs also

[13] In the first instance of Sino-Indian cooperation, the CNPC and India's state-owned Oil and Natural Gas Corp (ONGC) won a joint bid in December 2004 to buy PetroCanada's 37% stake in Syrian oilfields for US$ 573 million. India and China also work together in Sudan, where the CNPC operates the Greater Nile oilfield, in which ONGC has a 25% stake (Zhang, 2007e).

make Western investors wary of Argentina's oil and gas sector. So, the instant reaction in the oil industry to this CNPC bid was that the Spaniards would be delighted, and the Chinese in danger of being fleeced (Crooks, 2009). Seen from the CNPC's point of view, however, YPF is an important oil and gas producer in Argentina, one of the biggest economies in South America. The CNPC sees itself able to help stabilize production by using techniques honed at its flagship but aging Daqing field in northeastern China (Winning, 2009). Such an acquisition helps to achieve its ambition to grow and build global businesses, and for that they need to make acquisitions. China National Offshore Oil Corp (CNOOC), meanwhile, has discussed with Repsol a proposal that could lead the Chinese group to invest at least US$15 billion in a joint venture that would house some of Repsol's main exploration and production assets outside Argentina. The CNOOC is also interested in a minority stake in YPF (Tucker et al., 2009).

The Chinese oil companies have a history of overpaying for equity positions (Balfour, 2002). Because China has viewed paying a higher price than competitors to secure energy resources to be more of a national security issue than a pure business decision (Bradsher, 2005), such bidding wars between Chinese companies and their rivalries have further intensified the tendency of Chinese oil companies to pay far above what other competitors offer. Prior to the credit crisis, China had grabbed these deals by overbidding at least 10% more than its competitor India had bid. In January 2006, the CNOOC bought a 45% stake in the Akpo offshore oil and gas field in Nigeria for US$ 2.27 billion by outbidding the competitor, the ONGC that submitted a bid of US$ 2 billion but withdrew after India's cabinet raised concerns about the risks involved (Aiyar, 2006; Masaki, 2006). In August 2005, the CNPC paid US$4.18 billion to acquire Canadian oil company PetroKazakhstan, making it China's largest foreign acquisition ever by that time (Bradsher, 2005). Originally, the CNPC offered US$ 3.6 billion. With the Indian consortium's (ONGC-Mittal) bid of US$ 3.8 billion, the CNPC hiked its offer to US$4.18 billion to secure the deal (Basu, 2005).

Now, the credit crisis and the decline in global oil demand have turned the oil industry into a buyer's market. Should the Chinese oil majors be able to make better M&A deals than those prior to the credit crisis? In the aforementioned deal with Addax, the Korea National Oil Corp (KNOC) also bid for USS$ 6.9 billion (The Chosun IIbo, 2009). The Sinopec offered US$ 7.2 billion to win the deal. So, the Sinopec only overbid its competitor by 4.6%, far less than the overbidding of at least 10% it had made in those aforementioned deals prior to the credit crisis. Measured in other indicator, however, the story differs. Sinopec's offer is equivalent to US$34 a barrel of proved reserves and US$14 a barrel of proved and probable reserves. The African transaction average in 2007, when the average crude price is similar to current prices, was $14.40 a barrel for proved reserves and $9.90 for proved and probable reserves, respectively. On a proved basis, the 2007 average suggests US$3.1 billion total value for the deal. Therefore, US$7.2 billion implies a 135% premium (Xu, 2009). However, it is important to note that the higher bid does not always win in a politically charged industry like energy. The CNOOC failed to acquire Unocal for US$ 18.5 billion, although it topped Chevron's bid of US$ 16.4 billion. In the end, Chevron won the deal based on other factors. China's willingness to overpay is to a large extent because these state-own oil majors are obligated to guarantee

China's energy security, given that the country's demand for oil will grow faster than its domestic output. This overpaying may also partly reflect a need to overcome the kinds of political difficulties that hampered Chinese state-owned companies' overseas takeover attempts in recent years.

7. Recommendations

Based on the preceding analysis and discussion, I will provide some recommendations on issues related to energy conservation and pollution control, wind power, nuclear power, clean coal technologies, and overseas oil and gas supplies, and articulate a roadmap for China regarding its climate commitments to 2050.

Energy conservation and pollution control

China needs to continue to set energy-saving and pollutant control goals in the subsequent national five-year economic blueprints as challenging as the current 11th five-year blueprint does and to increase investment in energy conservation and improvement in energy efficiency. Moreover, achieving such goals should transform from current reliance on command and control regulations to a policy based on market-oriented policy instruments.

Calling future goals as challenging as the current ones requires establishment of why the current 20% energy saving goal is considered very challenging. As discussed earlier, China set a goal of cutting energy use per unit of GDP by 20% by 2010. In 2006, the first year of this energy efficiency drive, while China reversed a rise in its energy intensity in the first half of that year, the energy intensity only declined by 1.79% over the entire year. Although this decline is a first since 2003, it was far short of the targeted 4%. Among the 31 Chinese provinces or equivalent, only Beijing met that energy-saving goal in 2006, cutting its energy use per unit of GDP by 5.25%, followed by Tianjin, another metropolitan city in China, with the energy intensity reduction of 3.98%, Shanghai by 3.71%, Zhejiang by 3.52% and Jiangsu by 3.50% (NBS et al., 2007).[14] In 2007, despite concerted efforts towards energy saving, the country cut its energy intensity by 4.04% (NBS et al., 2009). There are still big variations in energy-saving performance among the 31 Chinese provinces or equivalent. Beijing still took the lead, cutting its energy intensity by 6%, followed by Tianjin by 4.9% and Shanghai by 4.66% (NBS et al., 2008). This clearly indicated Beijing's commitments to the 2008 Green Olympic Games. In the meantime, however, there were seven provinces whose energy-saving performances were below the national average. 2008 was the first year in which China exceeded the overall annualized target (4.4%) of energy saving, cutting its energy intensity by 4.59% (NBS et al., 2009). This is partly due to the economic crisis that reduced overall demand, in particular the demand for energy-intensive products. Overall, the energy intensity was cut by 10.1% in the first three years of the plan relative to 2005 levels. This suggests that the country needs to achieve almost same overall performance in the remaining two years as

[14] Beijing is the first provincial region in China to establish in 2006 the bulletin system to release data on energy use and water use per unit of GDP, quarterly releasing these and other indicators by county. See Zhang (2007a,c,d) for detailed discussion on why Beijing met but the country missed the energy-saving goals.

it did in the first three years in order to meet that national energy intensity target. It will certainly not be easy to achieve that.

China needs to further strengthen existing policies and measures towards energy saving. For example, China cut its total energy subsidies to around US$ 11 billion in 2006 (IEA, 2007). This corresponds to a reduction of 58% compared to its 2005 level of around US$ 26 billion (Zhang, 2008). On June 20, 2008, China further increased its producer prices of gasoline and diesel by about 20% (NDRC, 2008a). Although this is encouraging, removing such subsidies is but a first step in getting the energy prices right. Further steps include incorporating the cost of resources themselves to reflect their scarcity and internalizing the costs of externalities. More importantly, China needs to significantly scale up its efforts towards strengthening industrial restructuring to keep the frenzied expansion of highly energy-consuming, highly-polluting and resource-intensive industries under control. While the decline in real energy intensity was the overwhelming contributor to the decline in China's industrial energy use in the 1980s and 1990s (Zhang, 2003), structural change in the next two years will be a decisive factor in determining whether China will meet its energy saving goal by 2010.

Moreover, shifting control over resources and decision making to local governments and enterprises, a result of the economic reforms in China over the past three decades, has led to insufficient investment in energy saving, with its share in the total investment in the energy industry in China declining from about 13.4% in 1983 to the level of about 3% in 2005 (Zhang, 2007d). China needs to increase investment in energy conservation and improving energy efficiency. Faced with the prospect of not meeting the ambitious energy intensity target, the central government embarked Yuan 10 billion in mid 2007, in addition to Yuan 11.3 billion already allocated in earlier that year (the total of Yuan 21.3 billion, about US$ 3.2 billion, or 4.5% of the total investment in the energy sector in 2005) specifically for energy saving, of which Yuan 9 billion to support the Ten Key Energy-saving Programs, 13 times that of the funding support in 2006 (Yuan 0.68 billion). While this is a helpful step in promoting energy conservation, funds allocated for energy saving need to be further increased. To encourage local governments to eliminate outdated production capacities, I repeatedly called for payment of transfer both from the central government to provincial governments in the less developed regions and from the provincial governments to those cities and counties in which a large amount of outdated production facilities have been closed down. Moreover, the amount of that transfer needs to be indexed with the real energy saving as the result of closing down the production facilities. The Chinese government has gradually recognized the importance of the payment of transfer in getting local government's cooperation. This is reflected by the central government's decision in November 2007 to transfer Yuan 2 billion to provincial governments. This is a very positive development, but this amount of payment transfer is far short of the needs. There must be a further increase, in particular given that the central government only accounted for about 25% of the country's total government expenditure but received over 50% of the total government revenue in China (see discussion below). The good news is that the Chinese government has recognized these needs, increasing the funds allocated for energy saving to Yuan 41.8 billion in 2008 (including funding support for urban sewage treatment that was allocated to Yuan 4 billion in 2007) from Yuan 23.5 billion in 2007 (The State Council, 2008).

In addition to the distorted evaluation criterion for officials on which they typically have been promoted based on how fast they expand their local economies, objectively speaking, the current fiscal system in China plays a part in driving local governments to seek higher GDP growths at the expense of the environment because that tax-sharing system makes it difficult to reconcile the interests of the central and local governments. Since the current tax-sharing system was adopted in China in 1994, taxes are grouped into taxes collected by the central government, taxes collected by local governments, and taxes shared between the central and local governments. All those taxes that have steady sources and broad bases and are easily collected, such as the consumption tax, tariffs, and vehicle purchase tax, are assigned to the central government. The VAT and income tax are split between the central and local governments, with 75% of VAT and 60% of income tax going to the central government. As a result, the central government revenue increased by 200% in 1994 relative to its 1993 level. This led the share of the central government in the total government revenue to go up to 55.7% in 1994 from 22.0% in the previous year (see Table 8). In the meantime, the share of the central government in the total government expenditure just rose by 2%. By 2008, local governments accounted for only 46.7% of the total government revenue, but their expenditure accounted for 78.7% of the total government expenditure in China. In order to pay for culture and education, supporting agricultural production, and social security subsidiary, etc., local governments have little choice but to focus on local development and GDP. That will in turn enable them to enlarge their tax revenue by collecting the urban maintenance and development tax, contract tax, arable land occupation tax, and urban land use tax, etc.

Table 8 Shares of the Central and Local Governments in the Government Revenue and Expenditure in China

	Government Revenue		**Government Expenditure**	
	Central Government (%)	Local Governments (%)	Central Government (%)	Local Governments (%)
1993	**22.0**	**78.0**	**28.3**	**71.7**
1994	**55.7**	**44.3**	**30.3**	**69.7**
1995	52.2	47.8	29.2	70.8
1996	49.4	50.6	27.1	72.9
1997	48.9	51.1	27.4	72.6
1998	49.5	50.5	28.9	71.1
1999	51.1	48.9	31.5	68.5
2000	52.2	47.8	34.7	65.3
2001	52.4	47.6	30.5	69.5
2002	55.0	45.0	30.7	69.3
2003	54.6	45.4	30.1	69.9
2004	54.9	45.1	27.7	72.3

2005	52.3	47.7	25.9	74.1
2006	52.8	47.2	24.7	75.3
2007	54.1	45.9	23.0	77.0
2008	53.3	46.7	21.3	78.7

Source: National Bureau of Statistics of China (2009).

Another example of the unbalanced tax-sharing scheme in China is related to the differentiated tariffs for eight energy-intensive industries. The NDRC (2006b) ordered provincial governments to raise power tariffs for eight energy-guzzling industries from October 1, 2006 onward (see Table 9), but many local governments failed to implement the differentiated tariffs that charge more for companies classified as "eliminated types" or "restrained types" in these industries, with 14 of them even continuing to offer preferential power tariffs for such industries (Zhang, 2007a,c,d). The reason for this failure is the lack of incentive for local governments to implement this policy as all the revenues collected from these additional charges go to the central government (Zhang, 2007d). To provide incentives for local governments, these revenues should be assigned to local governments, but the central government requires local governments to use the revenues specifically for industrial upgrading, energy saving and emissions cutting.

Table 9 Differentiated Tariffs for Eight Energy-guzzling Industries in China

		Existing Additional Charge (Yuan/kWh)	Additional Charge since October 1, 2006 (Yuan/kWh)	Additional Charge since January 1, 2007 (Yuan/kWh)	Additional Charge since January 1, 2008 (Yuan/kWh)
Eight energy-guzzling industries	Eliminated types	0.05	0.10	0.15	0.20
	Restrained types	0.02	0.03	0.04	0.05

Source: NDRC (2006b).

Wind power

China needs to significantly improve its power grids and to coordinate the development of wind power with the planning and construction of power grids. Many local power grids are simply too small to carry all the wind power being generated today. Wind turbines often have to wait 4 months or more before they are hooked up with the power grid. Of 5.9 GW of total installed capacity at the end of 2007, only 4 GW were plugged into the grid (Cyranoski, 2009). Thus, new transmission lines will have to be constructed simultaneously as more wind power farms are built. Moreover, given the significantly scaled-up wind power capacity planned for 2020, China should now place more emphasis on companies ensuring the actual flow of power to the grid rather than just meeting capacity. In this regard, improving the quality of increasingly-used, domestically-made turbines is seen as crucial for this endeavor, given that Chinese-made turbines break down more often and are much less efficient at generating power than more costly foreign models.

Clean coal technologies

Currently, China is set to decommission thousands of small, inefficient coal-fired power plants with a unit capacity of 50 MW or less. To increase the benefits of energy saving and the environment, China should consider doubling or even quadrupling that unit capacity to 100 MW or 200 MW below which inefficient coal-fired plants need to be decommissioned. In the meantime, the country needs to accelerate the construction of large, more efficient, supercritical or ultra-supercritical coal-fired units.

China needs to strengthen the enforcement of FGD operation to ensure that those generation units with FGD facility always use it. It was reported that "up to 40% of those generation units with FGD facility did not use it" (Liu, 2006). Given that FGD costs are estimated to account for about 10% of the power generation cost (Peng, 2005), this should not come as a surprise, unless there is adequate enforcement. With the portion of coal-fired generation capacity with FGD increasing, the government desulphurization policy should switch from mandating the installation of FGD to focusing on enforcing units with FGD to operate through on-line monitoring and control. There are encouraging signs that the Chinese government is taking steps in this direction. For example, in its 2008 assessment of the total volume reduction of major pollutants, the Ministry of Environmental Protection found that FGD facilities of five coal-fired power plants are either in improper operation or their on-line monitoring and control data are false. These plants were ordered to return the compensation for their desulphurization costs in proportion to the time of their FGD facilities were not in operation and to make necessary adjustments in the specified period (K. Zhang, 2009).

Given that the commercialization and widespread deployment of CCS is a crucial option for reducing both China's and global CO_2 emissions, the U.S., the EU, Japan and other key players should take advantage of the high level of manufacturing and low costs of manufacturing, labor and other factors in China and cooperate with China in such a way to build more joint demonstration CCS projects in China using its currently proven technologies to achieve economies of scale enough to bring down the costs. In the meantime, these countries should initiate a major new initiative to jointly develop more advanced and innovative CCS technologies with shared intellectual property rights. Thus far, CCS has not been commercialized anywhere in the world, and it is unlikely, given current trends, that this technology will find large-scale application either in China or elsewhere before 2030. Until CCS projects are developed to the point of achieving economies of scale and bringing down the costs, China will not feel confident about committing to absolute emissions caps.

Nuclear power

China should give careful consideration of the suitability of foreign nuclear power technology for use domestically and avoid importing multiple examples of similar foreign nuclear technologies. That will ease China's ability to assimilate any particular nuclear power technology, reduce the high costs and increase its ability to see widespread deployment. This is the lesson that China should have learned from importing coal gasification technologies from abroad. Chinese companies have imported more than twenty variants of such technologies. This has impaired China's ability to assimilate any particular technology (IEA, 2009). Moreover, with nuclear power capacity being expected to increase significantly, securing a supply of uranium resources is seen as crucial for achieving its revised nuclear goal. China needs to enhance cooperation with such uranium-rich countries as South Africa and Australia and establish its strategic reserves of uranium resources. Processing and storing nuclear wastes will become an issue as well as increasing new reactors are commissioned in China. Thus, China is also required to make parallel progress in this area to match the significantly scaled-up development of nuclear power. Furthermore, the scaled up nuclear power construction program has raised safety concerns. In a national business culture where quality and safety sometimes take a back seat, China must keep a close eye on nuclear safeguards to ensure construction quality and operating safety of nuclear power plants.

Oil and gas supplies from overseas

Given that China is already a large oil consumer and its oil use is set to rise rapidly, China needs to continue to invest in adding new capacity to its world oil supplies via loan-for-oil deals or acquisitions as it has aggressively pursued during the current credit crisis. This should be seen as beneficial for other global consumers because Chinese investments in oil fields help to stabilize the oil prices by pumping more oil out of the fields and enlarging the overall availability of oil on the world market. However, as long as Chinese state-owned oil majors are trying to acquire sensitive oil assets, political issues will be hard to avoid. To better serve China's interest, Chinese majors should team up with Western oil majors in pursuing overseas acquisitions and takeover. Furthermore, partly because the Western powers have gained control over the best oil fields available, as a late entrant to the international oil game, China has little choice but to strike deals with the so-called rogue states, and to take risks to make acquisitions in oil-rich but politically-unstable countries or regions. However, China should be very cautious in pursuing oil diplomacy and business in these countries and regions, giving proper consideration of the international community's concerns and avoiding coming into direct conflict with Western countries.

Climate commitments to 2050: A roadmap for China[15]

With governments from around the world trying to hammer out a post-2012 climate change agreement, no one would disagree that a U.S. commitment to cut greenhouse gas emissions is essential to such a global pact. However, despite U.S. president Obama's

[15] See Zhang (2009d,e) for detailed discussion.

recent announcement to push for a commitment to cut U.S. greenhouse gas emissions by 17% by 2020, in reality it is questionable whether the U.S. Congress will agree to specific emissions cuts. Although these are not ambitious at all from the perspectives of both the European Union and developing countries, they probably cannot be met without imposing carbon tariffs on Chinese products to the U.S. market, even given China's own recent announcement to voluntarily seek to reduce its carbon intensity by 40-45% over the same period.[16] China is also expected to face increasing pressure from the European Union, who will find it increasingly hard to convince its citizens in general and the companies in particular why the EU has taken the lead but does not see China following, because overall competitiveness concerns mean that no country is likely to step out too far in front.

Given the fact that China is already the world's largest carbon emitter and its emissions continue to rise rapidly in line with its industrialization and urbanization, China is seen to have greater capacity, capability and responsibility. The country is facing great pressure both inside and outside international climate negotiations to exhibit greater ambition. There is no question that China eventually needs to take on binding greenhouse gas emissions caps. The key challenges are to decide when that should take place and to determine the credible interim targets that would be needed during the transition period. These results will no doubt be a combination of China's own assessment of its responsibility, economic and political benefits, and climate change impacts, taking also into consideration the mounting diplomatic and international pressure and the give and take of international negotiations.

In response to these concerns and to put China in a positive position, I propose that at current international climate talks China should negotiate a requirement that greenhouse gas emissions in industrialized countries be cut at least by 80% by 2050 relative to their 1990 levels and that per capita emissions for all countries by 2050 should be no more than the world's average at that time. Moreover, it would be in China's own best interest if, at the right time (e.g., at a time when the U.S. Senate is going to debate and ratify any global deal that would emerge from Copenhagen or later), China signals well ahead that it will take on binding absolute emission caps around the year 2030.[17] While this date is later than the time frame that the U.S. and other industrialized countries would like to see, it would probably still be too soon from China's perspective. Overall, this proposal is a balanced reflection of respecting China's rights to grow and recognizing China's growing responsibility for increasing greenhouse gas emissions as its standards of living increases over time.

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[16] See Zhang (2009a,b,c) for detailed discussion on the WTO scrutiny of emissions allowance requirements (EAR) under a cap-and-trade regime proposed in the Lieberman-Warner bill in the U.S. Senate and in the Waxman-Markey bill in the U.S. House of Representatives, whether an EAR threat would be effective as an inducement for major emerging economies to take climate actions that they would otherwise not, and methodological challenges in implementing EAR.

[17] See Zhang (2009d,e) for detailed discussion on why China should take on absolute emission caps around the year 2030.

It is hard to imagine how China could apply the brakes so sharply as to switch from rapid emissions growth to immediate emissions cuts, without passing through several intermediate phases. After all, China is still a developing country right now, no matter how rapidly it is expected to grow in the future. Taking the commitment period of five years that the Kyoto Protocol has adopted, I envision that China needs the following three transitional periods of increasing climate obligations, before taking on absolute emissions caps.

Further credible energy-conservation commitments starting 2013
China has already committed itself to quantified targets on energy conservation and the use of clean energy. It needs to raise its level of ambition, making further credible quantified domestic commitments in these areas for the second commitment period.

Voluntary "no lose" emission targets starting 2018
During this transition period, China could commit to adopting voluntary emission reduction targets. Emissions reductions achieved beyond these "no lose" targets would then be eligible for sale through carbon trading at the same world market price as those of developed countries whose emissions are capped, relative to the lower prices that China currently receives for carbon credits generated from clean development mechanism projects, meaning that China would suffer no net economic loss by adhering to the targets.

Binding carbon intensity targets starting 2023, leading to emissions caps around 2030
While China is expected to adopt the carbon intensity target as a domestic commitment in 2011, China adopting binding carbon intensity targets in 2023 as its international commitment would be a significant step towards committing to absolute emissions caps during the subsequent commitment period. At that juncture, having been granted three transition periods, China could then be expected to take on binding emissions caps, starting around 2030 and to aim for the global convergence of per capita emissions by 2050.

The commitments envisioned for China are basic principles. They leave ample flexibility for China to work out the details, as international climate change negotiations move onward. The value of this proposal lies in the format and timeframe under which China would be included in a post-2012 climate change regime, not in the numerical details. It should not be taken for granted that China can take on such increasingly stringent commitments, because that would entail significant efforts to cut China's projected emissions below its baselines. Political reality may limit the U.S. ability to take on the significant emissions cuts by 2020 that developing countries called for, but as a tradeoff, the U.S. should significantly scale up its technology transfer and deployment, financing and capacity building to enable China to meet the goals. This is the least that the U.S. can and should do, and by example, can encourage other developed counties to do the same. As Winston Churchill said, "[you] can always count on the Americans to do the right thing – after exhausting every other alternative." After what is viewed as eight years of lost time under President Bush, the whole world bets that U.S. will not disappoint us this time. Only history will tell us whether that will be a case.

In the meantime, commitments by China would send a signal well in advance that China is seriously committed to addressing climate change issues. They will also alleviate, if not completely remove, U.S. and other industrialized country's concerns about when China will join them, an indication that the world has long awaited from China, and help the U.S. take on long-expected emissions commitments, thus paving the way for reaching an international climate agreement at Copenhagen and beyond.

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