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# Potential Secure, Low Carbon Growth Pathways for the Chinese Economy

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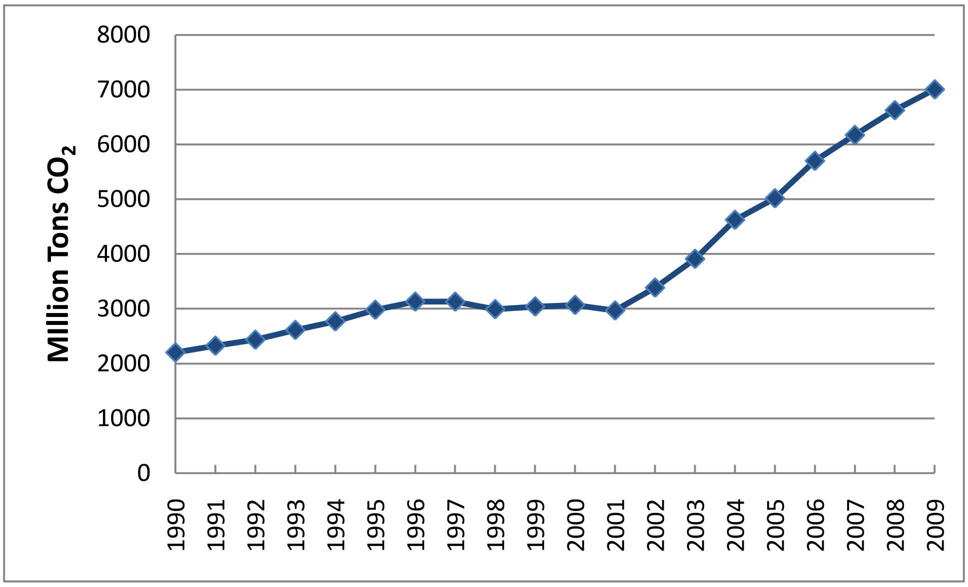
## 1. Background

After the long time process over the scientific validity of climate change, countries are now getting more consensus to reach a period for further actions. The recently published Fourth Assessment Report by the Intergovernmental Panel on Climate Change's (IPCC AR4) , together with the Stern Review, again confirmed that climate change is happening and that it is in society's interest to act sooner rather than later to mitigate its long-term effects. Interesting funding also is given to low cost for reaching 550 PPM target. Outside the United Nations Framework Convention for Climate Change (UNFCCC) process, international talks on climate change, including G8+5, the Asia Pacific Economic Cooperation (APEC) summit, Asia-Pacific Partnership on Clean Development and Climate, and bilateral discussions, are becoming much more rigorous than before. Several countries in the European Union are proposing their own emission reduction targets for 2020 and 2050, including the United Kingdom and Germany. Japan is also taking measures to implement a low carbon society by 2050 by setting targets of 60 percent to 80 percent emissions reduction. These developments present opportunities for much more action to be taken by the world, with some countries beginning to take the lead.

In recent years, China's rapidly growing energy consumption has exerted great pressure on energy supplies and the environment. Total primary energy consumption increased from 400 million tons oil equivalent (mtoe) in 1978 to 2040 mtoe in 2008, with an annual average growth rate of 4.7 percent (China Energy Year Book 2009; China Year Book 2009, 2009). Coal is the major energy source, providing 70.7 percent in 1978 and 71 percent in 2008 of total primary energy use. Recent years have witnessed a dramatic surge in Chinese energy use and associated widespread energy shortages. The increased energy use in China brought with it a large increase in $CO_2$ emissions. Figure 1 presents a recent history of $CO_2$ emission in China. In 2007, China overtook the United States to become the largest emitter of greenhouse gases (GHG) in the world (Jiang et al, 2008).

**Figure 1 $CO_2$ Emissions in China, 1990-2009**




Source: Calculated by author

This sudden increase pressured China to find a way to control future GHG emissions in order to enable the international community to meet the UNFCCC's larger goal of reducing emissions and limiting global warming to "safe levels." Even before this pressure, China adopted policies, and was considering even stronger policies, to set domestic energy efficiency targets and renewable energy targets. All these policies are consistent with China's emission mitigation policies. Most importantly, the Chinese government considers climate change one of its major issues for action. In 2007, the National Program on Climate Change was released. This is an important document in China, which guides the future national and provincial policies on climate change (State Council, 2007).

An important question is, if countries like the UK and Japan, achieve GHG emission reduction by 60 percent to 80 percent in 2050, what would happen to China? What is the possibility for China to reduce its GHG emissions? The purpose of this scenario analysis is to explore China's low carbon pathway options in the context of aggressive near-term emissions reduction in other countries and to explore some of the technological leaps China could choose to institute in order to achieve low carbon development and avoid the high-carbon development pathways of other industrialized economies.[1] It is understood that technologies and policy actions

[1] Modeling work for this study is based on previous work in Integrated Policy Assessment for China (IPAC) modeling team, for domestic energy and emission scenarios, IPCC scenarios, Energy Modeling Forum studies, etc (Jiang et al, 1998; Hu et al, 2001; Jiang et al, 2008; Jiang

could play a very important role on future GHG emissions cuts. The possibility for China to achieve deep cuts could be explored by looking at the pathways in developed countries.

This paper will discuss the future potential for low carbon development for China. First, the low carbon emission scenarios will be presented. The paper then explores key factors for low carbon development, including economic structure, technology progress, cost and benefit, and key policies.

## 2. Emission Scenarios

Three scenarios were defined for the emission scenario analysis.[2] Key assumptions for these three scenarios are given in Table 1.

**Baseline Scenario**: The Baseline Scenario reflects existing policies and measures, including current efforts of the Chinese government to increase efficiency and control emissions.

**Low Carbon Scenario**: The Low Carbon (LC) scenario assumes China will make an effort to achieve a relatively low carbon future, by making $CO_2$ emission control one of its domestic environmental targets and by implementing domestic policies such as economic structural reform away from energy intensive industries; the widespread dissemination of currently available energy efficiency technologies; and the aggressive diversification of the electricity generation mix. By 2020, the energy efficiency level of major high energy consuming industries in China would reach or surpass that in developed countries, and new building construction would need to obtain a high level of energy efficiency standards. In general, this would reflect a shift towards highly efficient and clean production in the industrial sector, and aggressive standards that would encourage a public focus on energy efficiency in the home and the workplace.

**Enhanced Low Carbon Scenario**: The Enhanced Low Carbon (ELC) scenario assumes that by partaking in global efforts to achieve low GHG concentration targets, China will make much a bigger effort on GHG emission control. The potential of lower carbon emission technologies would be further explored. Zero emission vehicles, low emission buildings, renewable energy and nuclear power would reach their maximum potential. Decentralized power supply systems would be widespread, and some coal fired power plants would employ carbon capture and storage (CCS). Under this scenario, China becomes one of the global leaders on low carbon technology.

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et al, 2009). A description of the modeling process can be found in Annex 1.

[2] Jiang et al, 2009

**Table 1 Details of the Three Scenarios in 2050**

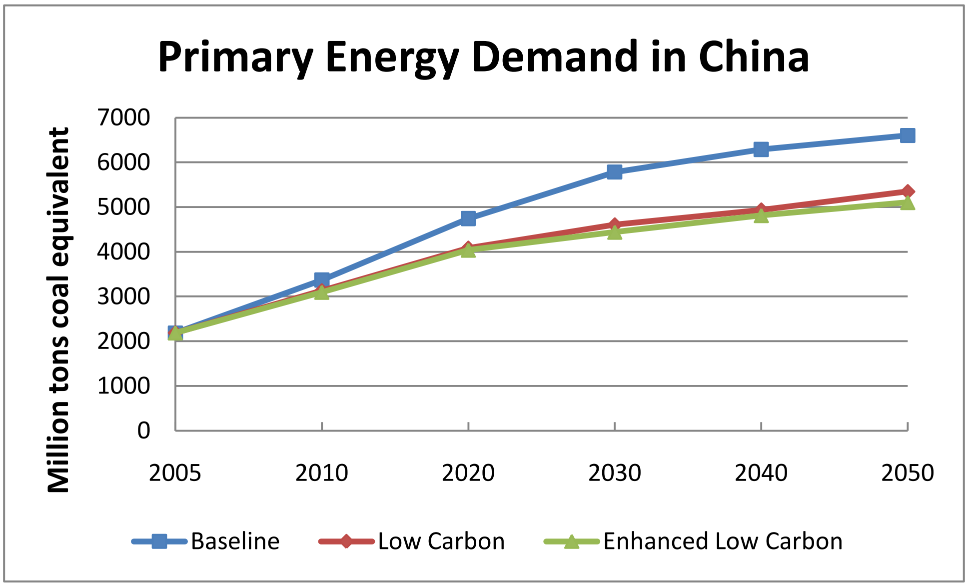
| | Baseline | Low Carbon (LC) | Enhanced Low Carbon (ELC) |
|---|---|---|---|
| GDP | Realizing the national target of three-step development.<br>Annual average growth rate is 9% between 2005 and 2020; 6% between 2021 and 2035; 4.5% between 2036 and 2050.<br>Annual average growth rate is 6.4% between 2005 and 2050. | Similar to baseline | Similar to baseline |
| Population | Reaching maximum of 1.47 billion. In 2050, the population decreases to 1.46 billion. | Similar to baseline | Similar to baseline |
| Per capita GDP | About 270,000 yuan in 2050 (USD38,000). | Similar to baseline | Similar to baseline |
| Industry structure | Economic structure is optimized to a certain extent. The tertiary industry is the main component.<br>The development of secondary industry has great consumption. The heavy industry still holds an important role. | Economic structure is further optimized, similar to the pattern of developed country today.<br>New industries and tertiary industry develop fast.<br>IT industry plays an important role. | Similar to LC |
| Urbanization | 70% by 2030;<br>79% by 2050. | Similar to baseline | Similar to baseline |
| Configuration of export and import | Primary products begin to lose competitive power at 2030.<br>Energy intensive products mainly satisfy domestic demand, rather than export. | Primary products begin to lose competitive power at 2020.<br>Energy intensive products mainly satisfy domestic demand, rather than export.<br>The exports by high added value and service industries increase. | Similar to LC |
| Energy Intensive Manufacturing | Reaches maximum output in 2030, and begin to decrease subsequently. | The maximum output is attained between 2020 and 2030, followed by a decrease. The maximum is lower than baseline. | Similar to LC |
| Demands of the primary | About 6.5 billion tons of coal equivalent (tce) in 2050. | About 5.3 billion tce in 2050. | About 5.1 billion tce in 2050. |

| | | | |
|---|---|---|---|
| energy sources | | | |
| $CO_2$ emissions by 2050 | About 3.4 billion tons of carbon (12 billion tons of $CO_2$). | About 2.2 billion tons of carbon (8 billion tons of $CO_2$). | Peaking by 2030 and 5.5 billion tons of $CO_2$ by 2050. |
| Domestic environment problem | Much improvement in local environment, could reach environment standard similar with developed countries, but the pathway for local environment improvement still follow pollution first then reduction pathway, as a result of environment Kuznetz curve. | Similar to baseline | Fully improve local environment by 2020, better pathway for local pollutant emission, follow the effects of environment Kuznetz curve. |
| Energy technology progress | Advanced energy technology is widely available in 2040. China becomes the technology leader; there will be 40% higher energy efficiency than present. | Advanced technology is widespread in 2030. The state of industry and technology in China are the highest in world. China becomes the technology leader; there will be 40% higher energy efficiency than present. | Similar to LC |
| Application of non-convention al energy resources | Exploitation of non-conventional oil and gas after 2040. | Similar to baseline | Almost do not need to exploit non-conventional oil and gas. |
| Electricity generation from solar energy and wind energy | The cost of solar energy is 0.39 yuan/kWh in 2050; the land wind generating sets are widely deployed. | The cost of solar energy is 0.27 yuan/ kWh at 2050. The land wind generating sets are widely deployed. The offshore generating sets are constructed in large scale. | Similar to LC |
| Nuclear power generation | Generating capacity is more than 200 million kW in 2050. The cost is lowered from 0.33 yuan/kWh in 2005 to 0.24 yuan/kWh in 2050. | Generating capacity is more than 330 million kW in 2050. The cost is lowered from 0.33 yuan/kWh 2005 to 0.22 yuan/kWh in 2050. Large scale construction of 4th generation nuclear power plants begins after 2030. | Generating capacity is more than 380 million kW in 2050. The cost is lowered from 0.33 yuan/kWh in year of 2005 to 0.2 yuan/kWh in 2050. Large scale construction of 4th generation nuclear power plants begins after 2030. |
| Electricity generation by coal | Mainly supercritical (SC) and ultra-super critical (USC). | Mainly the SC and USC before 2030, and subsequently integrated gasification combined cycle | Mainly IGCC after 2020. |

| | | | |
|---|---|---|---|
| | | (IGCC). | |
| CCS | No consideration | The typical projects begin in 2020 and some low cost CCS subsequently.<br>Matching the newly built IGCC plants from 2050. | Integrated with IGCC plants; CCS is also used in industry of iron, cement, electrolytic aluminum, synthesis ammonia, ethylene, coal chemical, extensive use after 2030. |

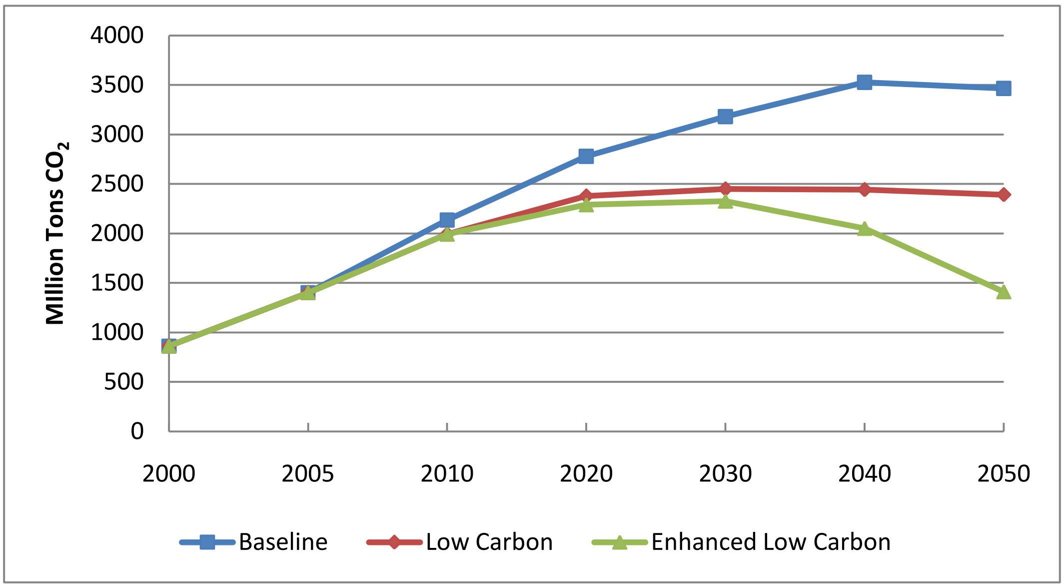
Figure 2 shows the results of the three scenarios with regard to primary energy demand. Both of the low carbon scenarios yield significant energy savings starting in 2005 and extending out to 2050. There is not, however, a significant difference in primary energy demand between the LC and ELC scenarios because alternative energy technologies such as renewable, nuclear and CCS are assumed to be more cost-effective in the LC and ELC cases and therefore much of the demand destruction or more expensive energy efficiency gains are not necessary and higher energy consumption is allowed. Both the LC and ELC scenarios have assumed energy efficiency could reach peak level around 2030. ELC scenario has higher energy efficiency in end use sectors, but ELC scenario also adopts much more CCS which will increase energy use, which makes the difference between LC an ELC not big.

**Figure 2 Primary Energy Demand in China, 2005-2050**




Equivalent Figure 3 outlines the main trend lines for emissions under the three scenarios. $CO_2$ emissions increase until 2030 in the two low carbon scenarios. The pace of emission reductions after 2030 are driven by various policy options (discussed below). By 2030, $CO_2$ emissions will increase to 2.63 billion t-C in mitigation scenario, 3.13 times of that in 2000. By 2050, it is possible for the emission level to go down to 1.73 billion t-C, 66 percent of that in 2030, and 2.05 times of that in 2000.

**Figure 3 $CO_2$ Emissions in China, 2000-2050**




Many of the enhanced policies in the low carbon scenarios are found to be well matched to the policies for the sustainable development strategy (i.e. increasing efficiency, promoting low carbon energy sources, and encouraging structural economic reform). Especially during the early period, because of the lack of experience to combat climate change, focusing on sustainable development will be the major way for China to contribute to climate change mitigation.

## 3. Key Factors for Low Carbon Development

### 3.1 Economic structure change

China's future economic development is expected to follow China's long-term development plan--the three-step target in the national development plan[3], which aims to reach by 2050 a GDP per capita level similar to that of OECD countries in the 1990s. China's long-term economic development is expected to follow that of developed countries, where the tertiary sector has a greater share in the total economy. However, China is now in a period of further industrial development. Industry represents nearly half of its total GDP and its share is continuing to grow. Due to the change of the domestic and international market environment, China's industrial structure will need to be adjusted, especially after China entered the World

[3] The three-step target: first step, by 1990, compared with that in 1980, GDP will be doubled; second step, from 1990 to 2000, GDP will again doubled; third step, after 2000, by taking 30 to 50 years, GDP will be four times, which is middle level of developed countries.

Trade Organization and Chinese industries became more international. In the coming decades, China will be the center for international manufacturing and exports will be the main driver of economic growth.

After 2030, however, domestic demand will become the main driver for economic growth. International competitiveness of the manufacturing sector will decrease due to the quick increase in labor cost. China will need to take a series of effective measures to improve the economic structure, upgrade the industrial structure, and enhance the international competitiveness of its advanced industry. It is estimated that from 2000 to2050, the Chinese economy will have an annual average growth rate of 6.4 percent. The estimated economic growth by sector for each period is shown in table 2.

**Table 2 Structure of GDP**

| | 2005 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| Primary industry | 12.4% | 10.0% | 6.7% | 4.7% | 3.6% | 3.0% |
| Secondary industry | 47.8% | 49.0% | 46.6% | 42.9% | 37.6% | 33.4% |
| Tertiary industry | 39.8% | 40.9% | 46.7% | 52.5% | 58.8% | 63.7% |

In 2030, industry will still constitute the major portion of GDP, and industry will be the main consumer of energy. The range of future changes in China's energy-intensive industries is difficult to analyze because there are only a few in-depth studies in this area with large differences in the potential scenarios, thus leading to a great uncertainty in energy demand forecasts. In order to further understand the future development in industrial sectors and better predict the future of energy-intensive and other sectors, several analytical methods are used in this study to supply better data for analysis.

Even if the industrial sector in China continues to grow quickly, there is still room for internal structures to be optimized. A large amount of energy intensive products are already being manufactured and China's future GDP will continue to grow rapidly. Such a large amount of GDP growth may not be supported by traditional industry. High value added industry has to be much further developed. There is little space for the output of energy intensive products to growth in the next decades; and the growth will hopefully peak in 5 to 10 years. Today, energy use in energy intensive industry accounts for around 45 percent of total final energy use in China. The future output scenario is given in Table 3.

**Table 3 Production of Main Energy-Intensive Products, Low Carbon Scenarios**

| | Unit | 2005 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| Iron and steel | $10^8$ tons | 3.55 | 6.1 | 5.7 | 4.4 | 3.6 |
| Cement | $10^8$ tons | 10.6 | 16 | 16 | 12 | 9 |
| Glass | $10^8$ weight cases | 3.99 | 6.5 | 6.9 | 6.7 | 5.8 |

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|---|---|---|---|---|---|---|
| Copper | $10^4$ tons | 260 | 700 | 700 | 650 | 460 |
| Aluminum | $10^4$ tons | 851 | 1600 | 1600 | 1500 | 1200 |
| Lead and zinc | $10^4$ tons | 510 | 720 | 700 | 650 | 550 |
| Sodium carbonate | $10^4$ tons | 1467 | 2300 | 2450 | 2350 | 2200 |
| Caustic Soda | $10^4$ tons | 1264 | 2400 | 2500 | 2500 | 2400 |
| Paper and paperboard | $10^4$ tons | 6205 | 11000 | 11500 | 12000 | 12000 |
| Chemical fertilizer | $10^4$ tons | 5220 | 6100 | 6100 | 6100 | 6100 |
| Ethylene | $10^4$ tons | 756 | 3400 | 3600 | 3600 | 3300 |
| Ammonia | $10^4$ tons | 4630 | 5000 | 5000 | 5000 | 4500 |
| Calcium carbide | $10^4$ tons | 850 | 1000 | 800 | 700 | 400 |

### 3.2 Technology roadmap

The scenario analysis includes nearly 600 technologies to simulate future energy demand and emissions, and identifies key technologies for the low carbon scenarios, especially the enhanced low carbon emission scenario, which is presented in table 4. The 28 key technologies or technology groups given in table 4 are those with the largest $CO_2$ emission reduction potential. The learning curve for key technologies is presented based on a review of recent studies, an original independent study[4] and the curve for several key technology where Chinese manufactures lead is analyzed based on engineering cost in China(Jiang et al, 2009; Jiang, 2007) (see figure 4). The specific penetration rates of technology under different scenarios are listed in Table 5. Some technologies have lower penetration rates due to higher penetration rates for more advanced technologies in the same manufacturing process or energy service.

**Table 4  Key Technologies for Enhanced Low Carbon Scenario**

| No. | Sector | Technology | Description | Note |
|---|---|---|---|---|
| 1 | Industrial technology | High energy efficiency equipment | High efficiency furnace, kiln, waste heat recovery system, high efficiency process technologies, advanced electric motor | Nearly in market |
| 2 | | New manufacturing process technology for cement and steel | | |

[4] In order to understand the perspective of these key technologies, with the support from National Natural Science Foundation, the author developed a study on technology learning curves (see figure 4) which presents the index of cost change for selected technologies.

| | | | | |
|---|---|---|---|---|
| 3 | | CCS | In cement, steel making, refinery, ethylene manufacture | |
| 4 | Transport | Super high efficiency diesel vehicle | Advanced diesel hybrid engine | |
| 5 | | Electric car | | |
| 6 | | Fuel cell car | | |
| 7 | | High efficiency aircraft | 30% higher energy efficiency | |
| 8 | | Bio-fuel aircraft | | |
| 9 | Building | Super high efficiency air-conditioner | With coefficient of performance (COP)>7 | |
| 10 | | LED lighting | | |
| 11 | | Residential renewable energy system | Solar PV/Wind/Solar hot water and space heating | |
| 12 | | Heat pumps | | Mature |
| 13 | | High heat isolation building | | Mature |
| 14 | | High efficiency electric appliance | TV(60% higher efficiency), refrigerator, etc. | Mature before 2030 |
| 15 | Power generation | IGCC/Poly-Generation | With efficiency above 55% | |
| 16 | | IGCC/Fuel cell | With efficiency above 60% | |
| 17 | | On shore wind | | Mature |
| 18 | | Off shore wind | | Mature before 2020 |
| 19 | | Solar PV | | |
| 20 | | Solar thermal | | |
| 21 | | Advanced generation nuclear | | |
| 22 | | Advanced NGCC | With efficiency above 65% | |
| 23 | | Biomass IGCC | | |
| 24 | | CCS in power generation | | |
| 25 | Alternative fuels | Second generation bio-ethanol | | |
| 26 | | Bio-diesel | Vehicles, ships, vessels | |

| | | | | |
|---|---|---|---|---|
| 27 | Grid | Smart grid | | |
| 28 | Circulating technologies | Recycle, reuse, reducing material use | | |

**Figure 4　Technology Learning Curve in IPAC Model**

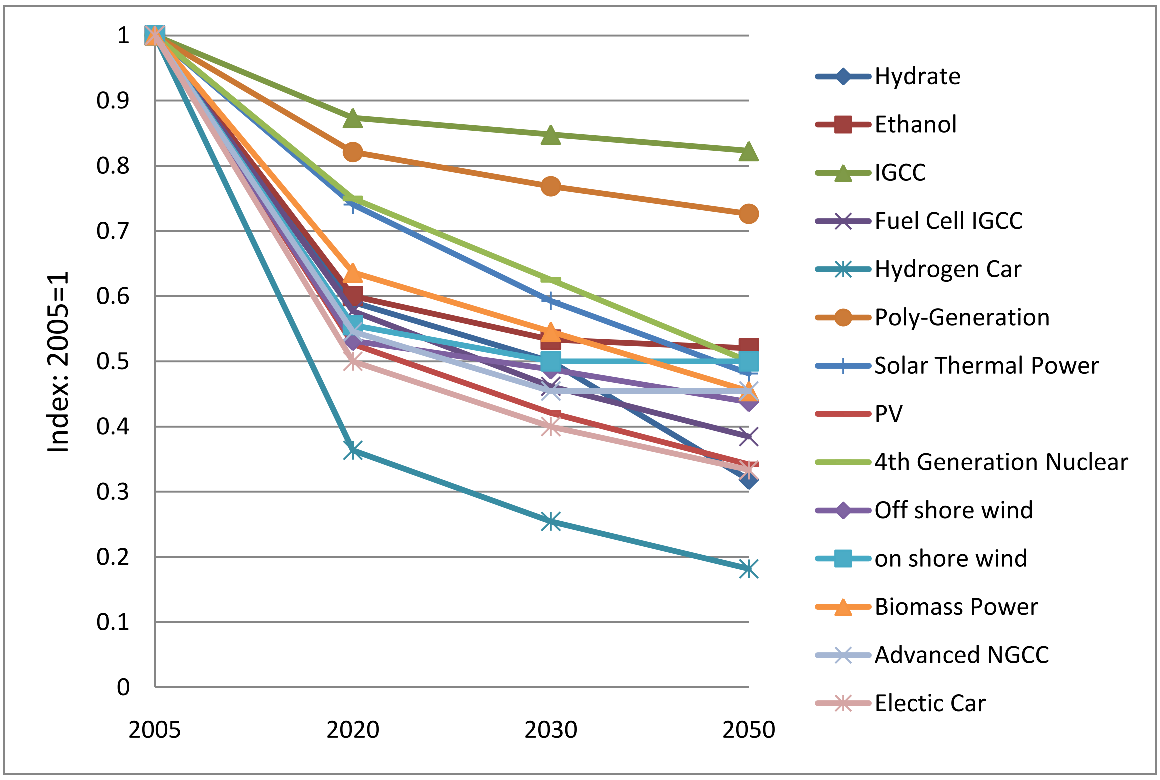


**Table 5　Penetration Rate of Key Technology**

| Technology | Efficiency | Penetration rate in 2030 | | Penetration rate in 2050 | | Note |
|---|---|---|---|---|---|---|
| | | Reference scenario | Low carbon scenario | Reference scenario | Low carbon scenario | |
| Advanced coke oven | 11900 Mcal/ ton coke, with gas production of 1340 Mcal | 58% | 50% | 77% | 42% | Full domestic manufacture |
| New generation coke oven | 10300 Mcal/ ton coke, with gas production | 17% | 47% | 23% | 58% | |

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|---|---|---|---|---|---|---|
| | of 1420Mcal | | | | | |
| Dry quenching | 2.4 Mcal/ton Recovery | 80% | 100% | 90% | 100% | Full domestic manufacture with promising prospects for market potential |
| Sintering furnace of international advanced level | 390 Mcal/ ton sinter lump, Energy savings of 42% | 45% | 85% | 67% | 90% | Need localization |
| Blast furnace of international advanced level | 3750 Mcal/ ton hot metal, energy savings of 21% | 40% | 65% | 64% | 87% | |
| Blast gas recovery /TRT | Heat and electricity recovery 0.7 Mcal/ ton hot metal | 44% | 70% | 85% | 100% | |
| Continuous casting and rolling | Energy savings of 86% | 90% | 98% | 85% | 95% | |
| Large-scale converter (Oxygen enrichment, negative pressure) | 170 Mcal/ ton molten steel, energy savings of 23% | 34% | 30% | 60% | 0% | |
| Advanced converter (Oxygen enrichment, negative pressure, gas recovery) | 218 Mcal/ ton molten steel, recovering 286Mcal/ ton molten steel | 37% | 70% | 40% | 100% | |
| Hot transportation and hot charging | Energy savings of 44% | 70% | 95% | 95% | 100% | |
| New dry cement + | 102 kgce/ton clinker | 75% | 100% | 90% | 100% | |

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|---|---|---|---|---|---|---|
| waste heat recovery | | | | | | |
| Advanced copper melting furnace | 0.5tce/ton | 75% | 100% | 90% | 100% | |
| Alumina energy saving technique | Energy savings of 8% | 85% | 100% | 95% | 100% | |
| New lead and zinc smelting technique(SKS) | 0.379 tce/ ton, energy savings of 21% | 80% | 100% | 93% | 100% | |
| Large scale synthetic ammonia | 8500 Mcal/ ton, with the most advanced level of 6926 Mcal/ ton | 70% | 96% | 85% | 100% | |
| Ionic membrane caustic soda | 3744 Mcal/ ton, energy savings of 34% | 80% | 98% | 95% | 100% | |
| Ethylene raw material and high- efficiency heat match | 6517 Mcal/ ton, energy savings of 38% | 66% | 95% | 83% | 100% | |
| Rapid displacement heating, continuous cooking | | 80% | 100% | 95% | 100% | |

## 4. Policy Roadmap

### 4.1 Policies implemented

To achieve sustainable development in China, the national energy development strategy includes policies to prioritize energy efficiency improvements and conservation while vigorously developing renewable and nuclear energy in China (NDRC, 2007; Jiang et al, 2007).

China has instituted a series of economic and technological policies on energy conservation. Also in the 1980s China established a three-tier system of energy saving in the central government, local governments, and industry and enterprises. The “Energy Conservation Law”, passed in 1998, further established a system for managing the implementation of energy conservation measures. In addition, China has implemented a series of policies on energy saving technologies. These policies and efforts include a national “Energy Conservation Propaganda Week”, energy efficiency standards, a labeling and verification system, and effective advancement of energy saving practices.

To promote the application of nuclear and renewable energy in the long term, China has given financial subsidies and support to their technological development and deployment into the market. Discount loans are provided for the development and use of small hydropower and wind power, in addition to preferential taxation and a protective price policy (Li Junfeng, 2007). There is a 0.25yuan/kWh subsidy for biomass power generation, and the price of wind power generation is established to cover cost and provide a consistent profit. Small scale hydropower generation is developed with government financial support made available for rural development.

As a result of these policies, energy efficiency has improved significantly since 1980. From 1980 to 2000, the average annual energy efficiency improvement rate was 5.4 percent. However, due to rapid development of industry manufacturing, particularly energy intensive products in China after 2000, the energy efficiency improvement rate compared to GDP is negative. The share of GDP coming from energy intensive industries has increased, and in the whole economy, production capacity and output expansion have surprisingly gained speed after 2003. China’s economy is heavily reliant on exports and is generally becoming a manufacturing center for the world. Energy intensive sectors keep expanding, and major changes are not foreseeable during the 11th Five Year Plan (2006-2010). Such trends have made it very difficult to reach the energy intensity targets set out in the 11th Five Year Plan.

After 1980, energy intensity made great progress, to which structural changes of the economy contributed nearly 70 percent (decreasing GDP share of industrial sectors where energy use per GDP is much higher than in other sectors, especially tertiary sector and agriculture) and technology contributed around 30 percent (Feng Fei, 2007). However, it is hard to see further positive change in the economic mix to support energy intensity reduction in the 11th Five Year Plan. If the $11^{th}$ Five Year Plan energy intensity targets are achieved, the contribution from economic change will be smaller than 50 percent; and a larger contribution has to come from technological progress (Jiang, et al, 2007a).

In 2005, the government set a target of reducing energy intensity by 20 percent between 2005 and 2010 in the 11th Five Year Plan (State Council, 2006). In order to reach the target, several programs were introduced, including 10 key energy conservation projects (Table 5) and a monitoring program of 1,000 large energy users. A package of policies focusing on energy conservation was also announced.

The long-term energy conservation plan (NDRC, 2004) identified and set energy efficiency targets for key sectors and products. Table 6 presents energy efficiency targets set for selected energy intensive products in China that are included in the long-term energy conservation plan, as guidance for energy efficiency targets of key industries. The energy efficiency targets of the 11th Five Year Plan are a first step to implementing the long-term energy conservation plan.

**Table 5 Energy Conservation Projects Approved by the Chinese Government in 2005**

| Program | Description | Potential Annual Energy Savings |
|---|---|---|
| Coal-fired industrial boiler conversion and increase of energy efficiency | Transform or replace existing medium and small coal-burning boilers (furnaces and kilns) by burning high quality coal, screened lump coal and sulfur fixed coal, and adopting advanced technologies such as circulating fluidized bed and pulverized coal burning and establishing scientific management and operation mechanisms. | 70 Mtce (conversion)<br>35 Mtce (efficiency) |
| Heat-power cogeneration | Establishing 300 MW cogeneration units with environmental protection features in areas where thermal loads for space heating are heavy and thermal loads are relatively concentrated or there is more development potential. | 5 Mtce |
| Residual heat and pressure usage | In key sectors such as steel making, cement, and other energy intensive sectors, residual heat and pressure will be fully utilized. | 2.66 Mtce (steel industry)<br>3 Mtce (cement industry)<br>1.35 Mtce (coal-mining industry) |
| Oil conservation and substitution | In the electric power, petrochemical, metallurgical, building materials, chemical, and transport industries, replace fuel oil (light oil) with clean coal, petroleum coke and natural gas. | 35 Mt oil |
| Electrical machinery system energy conservation | Popularize high-efficiency energy saving motors and rare-earth permanent magnet electric motors. | 20 billion kWh electricity |

| | | |
|---|---|---|
| Energy system optimization | Improve energy system efficiency to reach the highest level of the same industry or approach the advanced international level by system optimization design, technological transformation, and management improvement. | Strive to achieve international benchmarks of energy efficiency in steel, petrochemical, and chemical industries. |
| Construction energy conservation | Residential buildings and public buildings meet strict standard of 50% or higher energy saving for new constructed building. Accelerate the reform of heat supply systems and promotion of energy-saving construction technologies and products. | 50 Mtce |
| Green lighting | Spread highly efficient and energy-saving lighting systems and tri-phosphorus fluorescent lamps in public facilities, hotels, commercial buildings, office buildings, stadiums and gymnasiums and residential buildings; carry out automation retrofit for the production assembly lines of high-efficiency lighting appliances. | 29 billion kWh electricity |
| Energy conservation by government organizations | Carry out energy conservation retrofits for government buildings and their space heating, air conditioning and lighting systems. The area of government buildings that is renovated according to the building energy saving standard will represent 20% of the total area of government buildings. Popularize application of highly efficient and energy-saving products, and include these products into government procurement lists. Reform public service cars, and take a lead to procure low oil consuming cars. | Reduce energy consumption per capita and per area of office space by 20% between 2002 and 2010. |
| Energy conservation monitoring and technology | Take measures such as updating monitoring and testing equipment, strengthening personnel training, and adopting new market-oriented | Start implementation in 2006. |

| | | |
|---|---|---|
| services system construction | mechanisms. | |

Source: NDRC, 2004

**Table 6 Energy Efficiency Targets for Selected Products**

| Item | Unit | 2000 | 2005 | 2010 | 2020 |
|---|---|---|---|---|---|
| Coal consumption of power supply | gce/kWh | 392 | 377 | 360 | 320 |
| Comprehensive energy consumption per ton of steel | kgce/t | 906 | 760 | 730 | 700 |
| Comparable energy consumption per ton of steel | kgce/t | 784 | 700 | 685 | 640 |
| Comprehensive energy consumption of 10 types of non-ferrous metals | tce/t | 4.809 | 4.665 | 4.595 | 4.45 |
| Comprehensive energy consumption of aluminum | tce/t | 9.923 | 9.595 | 9.471 | 9.22 |
| Comprehensive energy consumption of copper | tce/t | 4.707 | 4.388 | 4.256 | 4 |
| Energy consumption of unit energy factor of oil refining | kgoe/t factor | 14 | 13 | 12 | 10 |
| Comprehensive energy consumption of ethylene | kgoe/t | 848 | 700 | 650 | 600 |
| Comprehensive energy consumption of large scaled synthetic ammonia | kgce/t | 1372 | 1210 | 1140 | 1000 |
| Comprehensive energy consumption of caustic soda | kgce/t | 1553 | 1503 | 1400 | 1300 |
| Comprehensive energy consumption of cement | kgce/t | 181 | 159 | 148 | 129 |
| Comprehensive energy consumption of plate glass | kgce/ weighting box | 30 | 26 | 24 | 20 |
| Comprehensive energy consumption of architectural ceramics | $kgce/m^2$ | 10.04 | 9.9 | 9.2 | 7.2 |
| Comprehensive energy consumption of railway transportation | tce/ million t-km | 10.41 | 9.65 | 9.4 | 9 |

Source: NDRC, 2004

Since 2006, a number of policies focusing on energy conservation have been announced in order to support the implementation of the energy intensity targets of the 11th Five Year Plan. The original plan to reach the 20 percent energy intensity reduction target was a 4.3 percent improvement per year from 2006 to 2010. Due to a failure to reach the annual target in 2006 (energy intensity was only 1.6 percent lower in 2006), further effort was made in 2007. The resulting policies cover nearly all aspects of energy-related activities.

To support the 20 percent energy intensity reduction goal of the 11th Five Year Plan, China has enacted a strategy for the 1,000 top energy consuming enterprises. It is estimated that 70 percent of the final energy consumption of China comes from industry, and the energy consumption of these 1,000 enterprises accounts for 60 percent of all energy consumed by industry. Consequently, it was decided that the energy consumption practices of these enterprises would be guided by a series of energy monitoring measures. Under this policy, local governments can expand the number of top energy users to be monitored in their region, allowing for a positive effect on energy savings by larger energy users. Previously, local governments in some regions that had experienced energy shortages initiated similar policies, to constitute an “energy conservation society” in Beijing in 2005. Governmental agencies should take the lead in demonstrating such practices.

So far the government has implemented the following major actions:

- Allocate targets to all provinces.
- Monitoring program on the top 1,000 large energy-intensive enterprises at the national level, with local governments extending the number of enterprises to be monitored.
- Government investment in energy saving projects was 23.5 billion RMB in 2007 from national budget.
- Energy saving and emission reduction are key performance indicators for local government officials.
- Shutting down small coal-fired power plants, steel production plants, coke production plants, etc.
- Strong implementation of 10 energy conservation programs under the long-term energy conservation plan.
- Establishing statistical data system on energy conservation.
- Linking national target with performance evaluation of government officials.

The most remarkable policy is the Implementation Scheme of Energy Intensity per GDP, announced in November 2007, which links the energy intensity targets to the evaluation of local government performances. Such linkages of a policy and performance evaluation are unusual, and had previously happened for a very few national strategic policies, such as population control. This policy makes the energy efficiency goal a political target and local governments have to make full effort to achieve it. A regime on responsibility allocation and a monitoring system were established. In recent years, the government has issued related policies with unprecedented frequency and intensity. Table 7 shows the major policies announced recently. A target for closure of small industry has been allocated to each province, in a way similar to the 20% energy intensity target.

Compared to energy conservation efforts in the last couple of decades as well as efforts in many other countries, China is now taking major actions on energy conservation. This can be seen from the following:

- Energy conservation policy was made a top national policy priority.
- The energy intensity target was made a key performance evaluation indicator for local government officials.
- The frequency of policymaking is extraordinarily high. In 2007, the central government alone issued nearly one new policy per week on energy conservation,(there were more when including local government energy conservation policies).
- The closure of small-scale power generation facilities and other industries is a very brave action that may cause social instability due to unemployment and loss of profit for stockholders.

**Table 7 Major Policies Announcements**

| Classification | Policies |
|---|---|
| Administration | Establishing energy conservation and emission reduction steering group chaired by the Prime Minister (June 2006); Allocating targets to each province (Sept 2006) |
| Overall National Policies | Synthesizing Working Program for Energy Conservation and Emission Reduction (June 2007); Revised Energy Conservation Law (Oct 2007); Integrated Resource Utilization Guidance (Jan 2007); Guidance for Accelerating Energy Conservation Service Industry (2008); Guidance Catalog for Industry Structure Change (annual) |
| Monitoring | Implementation Program of Energy Intensity Per GDP Statistic Index System (Nov 2007), Implementation Program of Unit Energy Use Per GDP Exam (Nov 2007), Implementation Program of Unit Energy Use Per GDP Monitoring (Nov 2007) |
| Pricing/Financing | Differentiating energy prices for key energy-intensive industries |
| Standardization | Second catalog of energy efficiency labeling for consumer products (Sept 2006); Third catalog of energy efficiency labeling for consumer products (Jan 2008) |
| Industry | 1000 large energy users monitoring program by national government (April 2006); extending provincial large energy user monitoring program (April 2006); closure of small-size industry in energy intensive sectors including cement, steel, non-ferrous, and chemistry (June 2006); approval for new projects based on energy efficiency standards (Jan2007) |
| Transport | Light Vehicle Fuel Efficiency Standards (Sept 2007) |
| Buildings | 11$^{th}$ Five Year Plan for Energy Conservation in Buildings (February 2006); Building Efficiency Standard Implementation |

| | |
|---|---|
| | (June 2007) |
| Power Generation | Closure of small power plants (Jan 2007); regulation for newly installed coal-fired power plants to be most advanced power plants (super critical units, ultra-super critical units) (2007); power dispatch based on energy efficiency (Dec 2007) |
| Public Involvement | Eliminating cost-free use of plastic bags (June 2008); Energy Conservation Week (annual) |

### 4.2 Low carbon scenarios

The scenario study paints a wide range of futures even without climate change-oriented policies. It is interesting to explore the key drivers of a low carbon future. Key driving forces used in the scenario study include economic development (GDP growth), social efficiency change, and technology progress. Factors and relative policies considered in social efficiency change and technology progress are explained in Annex 2

Technology plays a key role in climate change mitigation, as shown in several studies (IPCC, 2007; Jiang et al, 2008). As a large country in a stage of sustained economic growth, technologies are very important in meeting targets related to energy, environment and climate change. Technology progress plays a key role in GHG emission reduction in China, while most of these technologies are also viable in meeting the demand for energy conservation, both in the short-term and long-term. Therefore, the technology strategy could combine well with energy and environment policies. Detailed technology studies on the sectoral level to reduce $CO_2$ emissions are well matched with technology progress desired by sectors without consideration of climate change (see table 5) (Jiang et al, 2003, Jiang et al, 2009).

Many of these technologies already appeared in sector development plans by the government or enterprises. What we should do is to further develop these technologies by including climate change as a factor that would raise the demand for these technologies (see table 9).

**Table 9 Technologies Contributing to GHG Emission Reduction in Short and Medium-Term**

| Sector | Technologies |
|---|---|
| Steel Industry | Large size equipment (coke oven, blast furnace, basic oxygen furnace ,etc.), Equipment of coke dry quenching, continuous casting machine, TRT<br>continuous rolling machine, equipment of coke oven gas, OH gas and BOF gas recovery , DC-electric arc furnace |
| Chemical Industry | Large size equipment for chemical production, waste heat recovery system, ion membrane technology, existing technology |

| | |
|---|---|
| | improving |
| Paper Making | Co-generation system, facilities of residue heat utilization, black liquor recovery system, Continuous distillation system |
| Textile | Co-generation system, shuttleless loom, high speed printing and dyeing |
| Non-ferrous Metal | Reverberator furnace, waste heat recovery system, QSL for lead and zinc production |
| Building Materials | Dry process rotary kiln with pre-calciner, electric power generator with residue heat, colburn process, hoffman kiln, tunnel kiln |
| Machinery | High speed cutting, electric-hydraulic hammer, heat preservation furnace |
| Residential | Cooking by gas, centralized space heating system, energy saving electric appliances, high efficient lighting |
| Service | Centralized space heating system, centralized cooling and heating system, co-generation system, energy saving electric appliance, high efficient lighting |
| Transport | Diesel truck, low energy use car, electric car, natural gas car, electric railway locomotives |
| Common Use Technology | High efficiency boiler, FCB technology, high efficiency electric motor, speed adjustable motor, centrifugal electric fan, energy saving lighting |

The long-term scenario study for China suggested the following key technologies for meeting climate change goals [Nakicenovic, 2000, Jiang at al, 1999]:

- Modern renewable energy production (e.g., solar energy)
- Advanced nuclear power generation
- Fuel cell
- integrated gasification combined cycle (IGCC) /advanced clean coal technologies
- Advanced gas turbine
- Unconventional natural gas and crude oil production technologies
- Syn-fuel production technology

These technologies are listed for government consideration for additional support, including some unconventional energy technologies such as coal bed gas, shale oil, shale gas etc. Because of lack of investment on technology R&D, most of these technologies are expected to be developed in other countries. However, some of the technologies could be made in China, provided there is more R&D investment in China. For example, IGCC and clean coal technologies have large market potential domestically, while the market for technology developers in countries with small coal use is uncertain. If China can be a leader on development of these technologies, it could enjoy their environment and economic benefits. In such a case, policy for technology development could be bolstered by the added incentive of addressing climate change concerns. International collaboration on development of these technologies is necessary (Jiang, 2007).

Given the insights provided by the scenario analysis, the following actions are necessary in order to bring about secure, low carbon development:

- Change the composition of economy to one that is much more service sector and low-energy-use-industry sector oriented. Energy intensive production should be actively controlled to prevent economic loss brought about by overcapacity and environmental costs. The scenario shows that while the desired structural change for the Chinese economy is achievable, urgent efforts are needed in the near-future.

- Continue energy conservation policies implemented in 11$^{th}$ Five Year Plan in the future five year plans. Such kind of effort is crucial if the energy efficiency in major industry in China is to peak by 2030, which is a key component for China's low carbon future.

- Develop renewable energy and nuclear power production at a larger scale. The scenarios shows that the low carbon development needs 400GW to 500GW of new capacity for wind, hydro and nuclear, respectively, by 2050, and 300GW to 400GW for solar by 2050. Recent policy direction is moving to support the development of renewable energy and nuclear energy (NDRC, 2007; NDRC, 2008), but this needs long-term effort.

- CCS is crucial for China's long term emissions reduction given the predominant role of coal. By 2050, more than 2 billion tons of coal will be used in China. The cost analysis for CCS shows that electricity prices will increase by 0.15-0.25 yuan/kWh for CCS; the average electricity price will increase by 0.03 yuan/kWh by 2030, and by 0.15 yuan/kWh by 2050, to reach the capacity of CCS in the low carbon scenario. The assumption for investment for CCS is 3000yuan-5600 yuan/kW. With this investment, IGCC with CCS efficiency loss could go down from 9 percent to 6 percent. However, CCS development requires urgent, concrete and long-term policy support if it ever going to play a role in the Chinese energy sector.

- Public awareness and involvement are very important. Scenario analysis shows the need for changes, such as public consumption and travel patterns.

## 5. Conclusions

For China, as a large developing country with a growing economy, technology is vital to energy savings, environmental protection, and climate change. In China, not only will technology improvements play an important role in mitigating climate change, but most of these technologies can also meet the requirements of energy savings and non-climate related environmental protection in the short and long term. Therefore, the technology strategy should be combined with energy and environment policies. The analysis of future technology development in various sectors of the Chinese economy shows that many existing technologies can not only contribute to energy saving and also decrease GHG emissions, but also these technologies can be deployed before 2020.

Climate change strategies could provide China with a good opportunity to promote existing goals of economic restructuring towards low-energy-intensity and high-value-added sectors' development. It is not practical to carry out large scale emission reductions in China in the short term. However, the current domestic energy policies, agriculture policies and land use policies could consider to some extent their emissions profile in light of emissions reduction goals, as a way to help transform the mode of economic development for China.

The scenario study found that advanced technology will play a significant role in helping China reach a low carbon energy future. A group of key technologies could contribute for a significant reduction of GHG emissions by 2050. These key technologies cover both end-use technologies and energy supply-side technologies. End-use technologies play an important role before 2030, while energy conversion technologies are much more important after 2030. CCS is also very crucial for China's low carbon future.

Clean coal technologies should be emphasized to mitigate emissions from coal combustion. Only a few countries in the world consume coal in a large scale; therefore, the development of clean coal technology depends on them. China is the biggest country to use coal, and in future the coal use will increase quickly, possibly accounting for more than 40 percent of world's total coal use in 2020. Therefore, clean coal technology is crucial for China. China should have clear development plans to promote these technologies. China should work in close coordination with other countries to develop new generations of clean coal technologies.

Clean energy utilization technologies should be further diffused in China. Some transportation technologies, such as hybrid cars and direct injection diesel vehicles, already show a large commercial potential in other countries; they should be introduced in China as soon as possible.

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## Annex 1 – About the Models

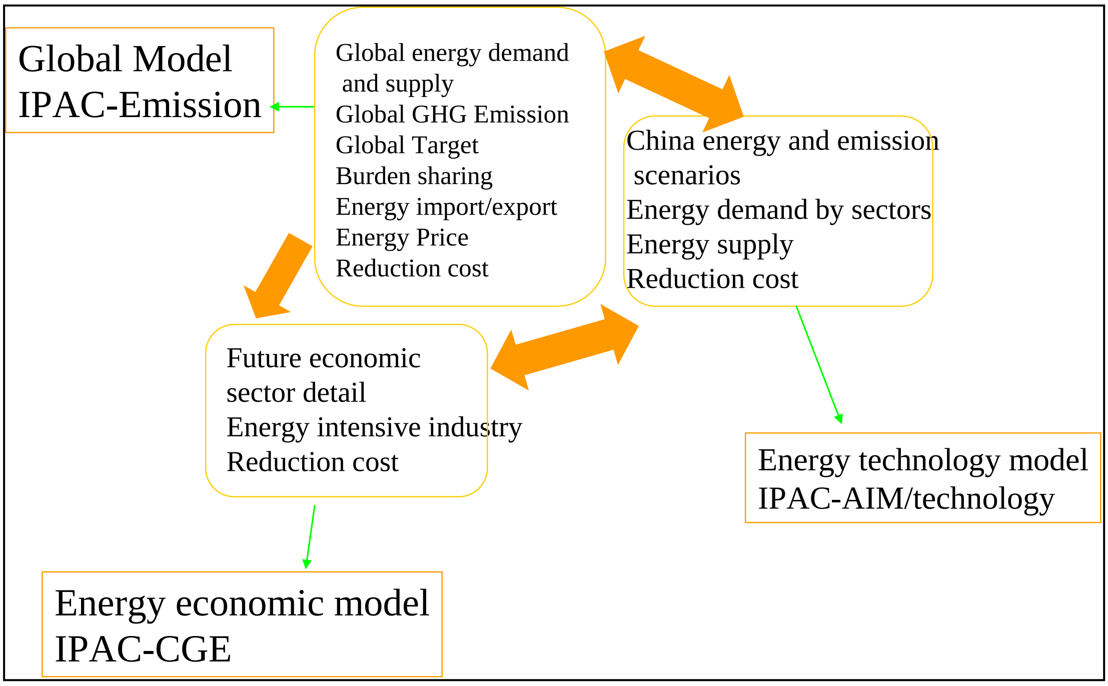
IPAC-Emission model is an extended version of the AIM-Linkage model used in Integrated Policy Assessment for China (IPAC) Special Report on Emission Scenarios (SRES). This model links social and economic development, energy activities and land use activities, and forms the emission analysis across a spectrum of activities. The timeframe of the IPAC model can be up to 100 years. The former 50 years have a more detailed analysis, with the time interval of 5 years. The latter 50 years have the time interval of 25 years (Jiang et al, 2000).

As the main component of the IPAC model, the function of IPAC-AIM/technology is to give a detailed description to the current status and future development of the energy service and the technologies, and to simulate the energy consumption process sequentially. Under different scenarios, the model can calculate the future demand of different types of energy in every energy end-use sector, and further calculate their $CO_2$ emissions. One of the important functions is to evaluate the effect that different technology policies would have on the introduction of technologies and GHG reduction. The current version of IPAC-AIM/technology model deals with 42 sectors, their products, and nearly 600 technologies, including existing and potential technologies (Hu, et al, 2001; Jiang et al, 2009).

IPAC-SGM is a general equilibrium model (CGE model), modeling the impacts and interactions among various economic activities. This model is used primarily to analyze the economic impacts of different energy and environmental policies, as well as the mid- and long-term energy and environment scenarios. IPAC-SGM divides the whole economic system into household, government, agriculture, energy and other production sectors; the sectors could be further divided when necessary. The decision makers of economic behaviors include households, government and producers. The primary factors in the production sectors include capital, labor and land. The production sectors produce goods according to the combinations of factors (Jiang et al, 2000; Jae et at, 1994).

The timeframe of this study is from 1990 to 2050. This study will focus on the years that are deemed important to the development of low-carbon economy in China in the future.

Three models from the IPAC model were used in the analysis. The figure below presents the model framework (Jiang et al, 2009).


Global Model
IPAC-Emission
Global energy demand
and supply
Global GHG Emission
Global Target
Burden sharing
Energy import/export
Energy Price
Reduction cost
China energy and emission
scenarios
Energy demand by sectors
Energy supply
Reduction cost
Future economic
sector detail
Energy intensive industry
Reduction cost
Energy technology model
IPAC-AIM/technology
Energy economic model
IPAC-CGE

**Annex 2 Factors for Key Driving Force**

| Driving Forces | Sectors | Factors | Policies to Promote the Change |
|---|---|---|---|
| Social Efficiency Change | Industry | Value added change within the sector.<br>Products structure change within one sector. | Various policies relative to value added, such as price policy; national plan for key industry; promote well working market; market oriented policies; and national development policies. |
| | Residential and Commercial | Energy activity change within the sector. | Public education and price policies. |
| | Transport | Change of transport mode<br>Traffic volume conservation. | Transport development policies and public education. |
| Technology progress | | Efficiency progress for technology, and technology mix changes, fuel mix changes. | Technology R&D promotion, market oriented policies, international collaboration, market oriented policies, environmental regulation, national energy industry policies, import & export policies, and tax system. |