CO2 mitigation opportunities in China

Wayne Xu
NICE

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CO₂ Mitigation Opportunities in China

Dr. Wayne Xu

National Institute of Clean-and-Low-Carbon Energy (NICE)
Outline: the Picture in China

- Overview of Carbon Emission
- Challenges in Carbon Mitigation
- Opportunities in Carbon Mitigation
- Actions in Carbon Mitigation for China, Shenhua, and NICE
Overview of Carbon Emission in China
Rapid Economic Development in China

**Number of Private Cars in China**

- 1990: 5 Million
- 1996: 8 Million
- 2002: 10 Million
- 2008: 12 Million

**Proportion of Urban Population in China**

- 1990: 30%
- 1996: 35%
- 2002: 40%
- 2008: 45%

**Traffic Operation Mileage in China**

- Railways Length:
  - 1990: 6000 km
  - 1996: 10500 km
  - 2002: 15000 km
  - 2008: 20000 km

- Highway Length:
  - 1990: 5000 km
  - 1996: 9000 km
  - 2002: 12000 km
  - 2008: 15000 km

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National Institute of Clean & low-carbon Energy (NICE)  www.nicenergy.com
Rapid Economic Growth in China

Economy, energy production and consumption in China (1990-2014)

- **In 2014**
  - Energy Production: 3.6 Billion tce
  - Energy Consumption: 4.26 Billion tce

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**GDP (billion yuan)**
- 1990: 15000
- 1992: 16000
- 1994: 17000
- 1996: 18000
- 1998: 19000
- 2000: 20000
- 2002: 21000
- 2004: 22000
- 2006: 23000
- 2008: 24000
- 2010: 25000
- 2012: 26000
- 2014: 27000

**Total energy production/consumption (billion tons of standard coal)**
- 1990: 0
- 1992: 0.2
- 1994: 0.4
- 1996: 0.6
- 1998: 0.8
- 2000: 1.0
- 2002: 1.2
- 2004: 1.4
- 2006: 1.6
- 2008: 1.8
- 2010: 2.0
- 2012: 2.2
- 2014: 2.4

**Energy Consumption**
- 1990: 0.5
- 1992: 0.8
- 1994: 1.2
- 1996: 1.5
- 1998: 1.9
- 2000: 2.3
- 2002: 2.7
- 2004: 3.1
- 2006: 3.5
- 2008: 3.9
- 2010: 4.3
- 2012: 4.7
- 2014: 5.1

**Energy Production**
- 1990: 0.3
- 1992: 0.6
- 1994: 0.9
- 1996: 1.2
- 1998: 1.5
- 2000: 1.8
- 2002: 2.2
- 2004: 2.6
- 2006: 3.0
- 2008: 3.4
- 2010: 3.8
- 2012: 4.2
- 2014: 4.6

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**Chart Notes:**
- GDP (billion yuan)
- Energy Consumption (billion tons of standard coal)
- Energy Production (billion tons of standard coal)

**Source:** National Institute of Clean & low-carbon Energy (NICE)
Rapid Growth in Energy Production and Consumption

**Energy Production Trends in Major Countries**

- **Europe**: Flat trend from 1961 to 2013.
- **China**: Significant increase from 1981 to 2013.
- **USA**: Steady increase from 1961 to 2013.
- **Russia**: Moderate increase from 1961 to 2013.
- **India**: Steady increase from 1961 to 2013.
- **Japan**: Moderate increase from 1961 to 2013.

**Energy Consumption Trends in Major Countries**

- **Europe**: Fluctuating trend from 1961 to 2013.
- **China**: Significant increase from 1981 to 2013.
- **USA**: Steady increase from 1961 to 2013.
- **Russia**: Moderate increase from 1961 to 2013.
- **India**: Steady increase from 1961 to 2013.
- **Japan**: Moderate increase from 1961 to 2013.
The Relationship between energy use and carbon emission in China


Energy Consumption/Billion toe

Carbon Emission/Billion ton
China’s Energy Outlook – Population Growth Driven up More Energy Demand

Relationship between Total Population and Energy Consumption (1971-2011)

China’s Energy Outlook—GDP Growth Driven up More Energy Demand

Energy Demand and per capita GDP (1980-2012)

Note: The per capita GDP calculated by the purchasing power parity (PPP) (constant 2005 International dollar)

Close to the target proposed by the 18th party congress of China
China’s Energy Outlook—Rapid Expansion of Total Energy Demand

China’s Population and Development

Population (100 million)


China Energy Demand Forecast

Population (100 million)

GDP per capita (USD)

5.5 billion tons of standard coal in 2020
3.2 billion tons of standard coal in 2010

GDP

Population

Energy

10 15

0 5000 10000 15000
China’s Energy Challenges — Heavy Pressure on Carbon Emission Reduction

China’s Carbon Emission “Space” Analysis

Hundred million tons

- Developed country
- Developing country

Comparison between CO$_2$ emission in China and that in other countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Global carbon emission in 1990</th>
<th>Global carbon emission in 2011</th>
<th>Global carbon emission in 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>226</td>
<td>340</td>
<td>113</td>
</tr>
<tr>
<td>America</td>
<td>124</td>
<td>140</td>
<td>88</td>
</tr>
<tr>
<td>European Union</td>
<td>101</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Japan</td>
<td>9.7 billion tonne</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

China became the largest CO$_2$ emitter since 2007. 9.7 billion tonne CO$_2$ was released by China in 2014.

The Damages Caused by Climate Change

Average temperature change in China (a) 1996~1998 summer average; (b) 2003~2005 summer average; (c) 2008~2010 summer average; (d) ratio of c/b.
Coal is the dominant energy source.
Coal is dominant in energy consumption.

Energy equaling to 4.2 billion tons of standard coal was produced in 2014.

1990-2014 average growth: 6.2%

Hundred million tons of standard coal

Energy Consumption and Growth in China (1990-2014)

China Statistical Yearbook, 2015
Carbon emissions are mainly from Coal.

<table>
<thead>
<tr>
<th>Fossil fuel</th>
<th>CO₂ emission factor (tCO₂/TJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>87.3</td>
</tr>
<tr>
<td>Oil</td>
<td>71.1</td>
</tr>
<tr>
<td>Natural gas</td>
<td>54.3</td>
</tr>
</tbody>
</table>

- **Coal**: 87.3 tCO₂/TJ
- **Oil**: 71.1 tCO₂/TJ
- **Natural gas**: 54.3 tCO₂/TJ

**Carbon emissions (100 million tons)**

- 2009: 55.3
- 2010: 60.2
- 2011: 66.1
- 2012: 65.1

(Data source: EIA)
Heavy Dependence on Energy Import

Fossil Energy Import Dependence for China

Oil
- 2000: 0%
- 2013: 58.3%

Natural gas
- 2000: -15%
- 2013: 31.6%

Coal
- 2000: 0%
- 2013: 8.13%

It is difficult for China to shake off its dependency on coal.

“We are reducing the proportion of coal in the energy consumption, but coal is still the main energy in a long period of time. Coal is rich in China. We not only develop new energy and renewable energy, but also focus on the coal resource.” — Speech of the central economic work conference, 2014

In 2030, coal consumption is less than 5 billion tons, and try to reach the peak of about 4.5 billion tons, accounting for about 55% of the total energy consumption — Chinese Academy of Engineering, 2013
High Cost of Renewable Energy

- The cost of solar and wind power is much higher than that of fossil fuels.
- For example, the cost of wind power is about 1.7 times as coal power, and the cost of solar power is about 2-3 times as coal power.

Xinjiang, Dabancheng (达坂城，新疆)
Shangyi County, Hebe (尚义县，河北)

Costs of different power sources

资料来源：CEIC
High Cost of Biomass Energy

Cost of Biomass Power Generation

Main Routes of Biomass Power Generation

Fuel Cost of Biomass Power Generation
High Cost of Carbon Capture in the Thermal Power Plant

Benchmarking CCS against Alternative Power Generation Technologies

CNY/kWh = yuan per kilowatt-hour, IGCC= integrated gasification combined cycle, oxy = oxy-fuel combustion, PC=pulverized coal, Note: CO2–EOR assumes a CO2 sales price of CNY 120 per ton of CO2

Total cost for a power plant increases by 25% ~90%

CCS risk is not clear.

Risks:
- Fracture
- Earthquakes
- Others
Nuclear risk is worrisome.

1986 Chernobyl Accident (切尔诺贝利核事故)

2011 Fukushima nuclear accident (福岛核电站事故)
OPPORTUNITY IN CARBON MITIGATION IN CHINA
Modern Energy System

- Cleanness
- Low Carbon
- Modern Energy System
- Security
- High Efficiency
Great Potential in Emission Reduction for China

Comparison between the Energy Intensity of China and that of the World and the Developed Country

TOE/1000$ GDP

China

World

America

Japan

Reduction space

Note: The AGDP is calculated according to the purchasing power parity (PPP) (Constant international dollar in 2011)

Modern Energy System: Low-Carbon

**Fundamental Solutions**

- Clean and efficient conversion of fossil energy
- The fundamental guarantees of low carbon energy
- Enhance the use of non-fossil energy
- Low carbon utilization of high-carbon energy

**Current Focus**

- 56.9% of total carbon emissions can be reduced through energy conservation between 2010 and 2030
- Energy conservation and emission reduction as well as improvement of energy efficiency are the priorities in the process of low carbon for China
Energy Savings:

To firmly establish a systematic energy conservation trend, and take every measure to improve the efficiency of energy use.

To improve the transportation system, and fully tap into the energy conservation and emission reduction potential of modern transport systems.

To develop strict building energy-saving standards, and vigorously implement them in building efficiency improvement projects.

To enhance industrial energy efficiency standards, and limit the expansion of high energy-consuming industries and excess industries.

To implement the energy conservation actions for all people, and restrict the unreasonable energy consumption.

US Quadrennial Energy Technology Report

Energy Consumption Inertia

Energy-Saving Technology
Electric Power Production, Transmission and End Use

Make overall plans and accelerate developing clean, efficient, safe and diversified electric power production system

Integrate advanced technologies, and enhance the power absorption capacity and efficiency of energy utilization of renewable energy sources

Optimize the energy consumption structure, and significantly enhance the proportion of electric power in energy consumption of end users

- Make overall plans for clean, efficient, safe and diversified electric power production system
- Promote energy conservation, water conservation, desulfuration and denitration technologies in thermal power industry
- Adopt international highest safety standards for nuclear power
- Develop gas power generation in eastern prosperous regions in China
- Develop wind power, solar power and focus on the development of thermonuclear fusion power generation

- Establish flexible and intelligent power transmission and distribution network
- Promote the construction of electric power telecommunication network
- Develop distributed power supply and management of distributed energy resources

- Promote the electrification of domestic heat supply, hot water and cooking for urban and rural residents
- Accelerate the construction of power supply and power supply service facilities, and electrification of transportation sector
- Implement demonstration projects of electric heating replacing coal-fired boilers in cities
## Coal Cap, Oil Security

<table>
<thead>
<tr>
<th>Strictly control the output of coal, and effectively push the green development of coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Control the total volume of coal, and implement a rational distribution of coal production</td>
</tr>
<tr>
<td>• Shut-down the small scale coal mines and develop an exit mechanism for old mines</td>
</tr>
<tr>
<td>• Strengthen the large-scale coal bases and establish modern coal mines</td>
</tr>
<tr>
<td>• Promote the green mining technologies (e.g. water-preserved-mining)</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Reduce the output of low efficiency petroleum, proportionally increase oil import, and enlarge the oil reserve capacity</td>
</tr>
<tr>
<td>• Reduce domestic low efficiency petroleum output</td>
</tr>
<tr>
<td>• Cut the output of domestic petroleum and increase oil import from abroad under current low oil prices</td>
</tr>
<tr>
<td>• Increase the national strategic oil reserve, establish and improve the emergency response and safeguard the energy system.</td>
</tr>
</tbody>
</table>
Clean Fuel, Natural Gas:

- Integrate conventional and unconventional developments, and strengthen the domestic gas exploration and development
  - Establish unconventional gas R&D platform, locate and construct the unconventional gas exploration and develop the demonstration areas
  - Prolong the time limit for subsidies and preferential taxes for shale gas and coalbed methane,
  - Develop coal-to-gas and natural gas hydrate technologies

- Formulate a comprehensive plan on the construction of consumer market and on the infrastructures, and make a rational plan on the importation of resources from other countries
  - Diversify the importation of gas sources, and proportionally increase the import of LNG as well as the spot goods
  - Implement the transportation-out and transportation-in of gas, and establish a gas distribution center in East Asia

- Shift the gas pricing mechanism to market based pricing
  - Set a rational end gas price ASAP, and lower the gas prices for industrial and power generation uses
  - Impose the environmental tax or carbon tax properly to reflect the externality of energy utilization

- Rebuild the gas management structure and regulations
  - Improve the natural gas pipeline network
  - Strengthen legislation and supervision
**Renewable Energy and Bioenergy:**

- Solar power and thermal energy
- Geothermal energy
- Economical and large scale applications of renewable energy
- Large wind power and hybrid energy systems
- Ocean power
- Bio energy

**Goal**

- **2016-2020:** Energy structure transformation
  - Promote a shift to low carbon energy use and push to achieve a 5:3:2 composition for coal, oil/natural gas, and non-fossil energy by 2020.

- **2021-2030:** Energy Revolution: To achieving substantially optimized energy structure, push to achieve a 4:3:3 for coal, oil/natural gas, and non-fossil energy by 2030

- **2031-2050:** Harvest of the Energy Revolution
  - To establish a new energy structure, push to achieve 3:3:4 for coal, oil/natural gas, and non-fossil energy by 2050
**Key Clean Technologies**

- **Apply and promote a batch of relatively mature technologies**
  - Ultra low emissions of coal-fired power generating units
  - High-efficiency exploration and development technology for oil and gas fields
  - The third generation of pressurized water reactors
  - Renewable energy sources and building integration system
  - Extra-high voltage AC and DC power transmission

- **Conduct demonstrations for a batch of technologies to be developed**
  - Coal-based polygeneration
  - Enhance the recovery rate of complicated oil and gas fields
  - Large-scale and advanced pressurized water reactors
  - Large-scale development of offshore wind plants
  - Large capacity and flexible DC electricity transmission

- **Cultivate the breakthrough in a batch of advanced technologies**
  - Ultrahigh-parameter coal-fired power generation
  - Highly-efficient development technology of “deep stratum, deep water and unconventional” oil and gas
  - Nuclear fuel reprocessing technology
  - High-efficient power generation technology as well as large-scale grid-connection and integration technology of renewable energy sources
  - Large-scale energy storage

- **Promote the scientific development of coal, and accelerate its clean and efficient conversion and utilization**

- **Realize the high-yield and highly-efficient development of “deep stratum, deep water and unconventional” oil and gas**

- **Design a scientific development scheme; develop safe nuclear power; develop advance technologies for renewable energy resources such as solar energy and wind energy**
Strengthen international energy cooperation and focus on oil and gas

- Strengthen energy cooperation with Central Asia, Russia, Central and Eastern Europe as well as South and Southeast Asia
- Emphasize the fundamental and leading role of oil and gas cooperation in the strategy of “one belt, one road”, and promote the development of oil and gas cooperations in multi-fields, at multi-levels, on multi-subjects and at multi-dimensions along the whole industrial chain
- Accelerate the construction of import oil and gas strategic channels

Steadily promote the construction of infrastructures and supporting facilities based on the important platforms of Asian Infrastructure Investment Bank and Shanghai Cooperation Organization

- Boost the construction of supporting facilities through the already-established four oil strategic channels in the northwest, southwest, northeast and offshore
- Promote the construction of cross-border electricity and power transmission channels, and further enhance the regional energy cooperation
- Strengthen the cooperation along the channels, and improve China’s influence in energy area on the international community.
ACTIONS IN CARBON MITIGATION IN CHINA

-------- IV --------
Government Action: Energy Revolution

Chinese government is taking actions

- Energy Production and Processing
- Energy Conversion and Utilization
- Energy Storage and Transportation
- Energy consumption

Lead energy revolution: improve the energy structure, enhance energy efficiency and lower the total energy consumption

Clean, efficient and sustainable development and utilization of fossil energy, especially coal

Enable economical and scalable development of non-fossil energy. Particularly promote the safe and efficient development of nuclear power.
Government Action: Strategies

- **2007.6.3** 
  - National climate change program in China

- **2007.7.19** 
  - White paper on Chinese policies and actions response to climate change

- **2007.10.29** 
  - Notice on carrying out the pilot work of low carbon provinces and low carbon cities

- **2011.3.14** 
  - Work schemes on the control of greenhouse gas emission in the 12th five years

- **2011.10.29** 
  - Notice on printing and distributing national response to climate change plan (2014-2020)

- **2011.12.1** 

- **2014.11.12** 
  - US-China Joint Presidential Announcement on Climate Change

- **2014.9.19** 
  - Outline of the economic and social development plan in the 12th five year of the people’s Republic of China

- **2015.9.25** 
  - US-China Joint Announcement on Climate Change

- **2014.5.15** 
  - Notice on printing and distributing national response to climate change plan (2014-2020)

- **2016.3.17** 
  - Outline of the economic and social development plan in the 13th five year of the people’s Republic of China
Government Action: Carbon Mitigation Policies

2011.10.29
《Interim Measures for the administration of voluntary emission reduction transactions for greenhouse gases》
The aim is to ensure the orderly development of voluntary emission reduction trading activities and mobilize the whole society to participate in carbon emission reduction activities. Accumulate experiences on the gradual establishment of the total control of carbon emission trading market.

2012.6.13
《Notice on carrying out the pilot work of carbon emission right trading》
Formal approval of seven provinces (Beijing, Shanghai, Tianjin, Chongqing, Hubei, Guangdong and Shenzhen) to carry out pilot programs on carbon trade.

2012.10.9
《Interim Measures for the administration of voluntary emission reduction transactions for greenhouse gases》
The aim is to ensure the orderly development of voluntary emission reduction trading activities and mobilize the whole society to participate in carbon emission reduction activities. Accumulate experiences on the gradual establishment of the total control of carbon emission trading market.

2013.10.15
《Guide for validation and certification of greenhouse gas voluntary emission reduction projects》
To further clarify filing requirements for the audited and certified institutions of voluntary greenhouse gas emission reduction projects, work report format, promote the audited and certified results to be objective and fair, to ensure voluntary greenhouse gas emission reduction transactions carried out smoothly.

2014.1.13
《Notice on the work of the organization to carry out the work of greenhouse gas emission in the enterprises (matter) sector》
The objective is to control the key units of greenhouse gas emissions, accelerate the establishment of key units of greenhouse gas emissions reporting system, improve greenhouse gas emissions statistics and accounting system at the national, local, enterprise levels.

2014.12.10
《Notice on the effective implementation of the key work of the national carbon emissions trading market》
This is to ensure that national carbon emission trading system is launched in 2017, implement the carbon emission trading rules, and effectively advance the preparing work.

2016.1.11
《Notice on printing and distributing the accounting methods and reporting guidelines for greenhouse gas emissions for the first batch of 10》
Industry include power generation, power grids, iron and steel, chemical, electrolytic aluminum, magnesium smelting, flat glass, cement, ceramics, civil aviation, etc.. The purpose of this notice is to establish and to improve the statistical accounting system of greenhouse gas, and gradually establish the carbon emission trading market.

2016.1.11
《Interim Measures for the administration of carbon emissions trading》
To promote the construction of ecology, accelerate transformation of the economic development and promote the system innovation and mechanism innovation. Respect the deciding role of the market in the allocation of greenhouse gas emissions, regulating the construction and operation of carbon trading market.
Enterprise Action: CCS Demo Plant

CO₂ Capture → Transportation → Storage → Monitoring
Monitoring Diagram Comparison at 2350m Depth
Enterprise Action : Wind Power

- To reduce carbon emissions, Shenhua is vigorously developing the renewable power, and the installed capacity of wind power has exceeded 6200 MW now, accounted for about 5% of the total installed capacity of wind power in China.

Shenhua wind farm in the coast of Jiangsu province

Shenhua wind farm in Inner Mongolia province
The purpose for CO₂-EOR Supply Chain Study

- China’s oil demand grows steadily
  
  ≥50% dependence on the import since 2011

- CO₂-EOR utilization
  
  Oil output in U.S. increased by ≥10 MT/a
  
  Oil output in China may increase ≥350 MT
  
  (potentially)
With an increase of CO₂ injection from 0.1MT/a to 1MT/a, the total CCS cost reduces from 250RMB/t to 150RMB/t.

# CO₂ transport distance: 10 km; Transportation Method: Truck (0.1 MT/a), Pipeline (1 MT/a);
CO₂ source: highly concentrated CO₂ from a coal chemical company.
NICE Action : Solar Cell
NICE Action: Distributed Energy System

Energy Storage → Power Electronics → Energy Management

System Design

Carbon Emission

De-centralization for less Carbon

Centralized Energy → Distributed Energy

Being able to integrate more renewable

Energy Efficiency

Maximum Cost-Effective → Design to Requirements → Design to Cost → Low Cost

High Performance

Low Cost

Cost

Performance

National Institute of Clean & low-carbon Energy (NICE)
From Vision to Design

Multi-Energy based Carbon Negative Solution
China: Abide by its commitment and strong in execution.

- At the Copenhagen climate summit in December 2009, Chinese government promised to reduce carbon emissions by 40~45% per unit of GDP in 2020, compared to those in 2005.

- In November 2014, China and the United States released “U.S.-China Joint Presidential Announcement on Climate Change”, Chinese government first proposed to reach carbon emission’s peak in 2030 or early, and plan to increase the proportion of non-fossil energy to 20% in the primary energy consumption.

- At the Paris climate summit in December 2015, China proposed to reduce carbon emissions by 60~65% per unit of GDP in 2030, compared to those in 2005.
Looking Forward:

**Carbon Emission Reduction in 2014**

- Reduced CO₂ and energy consumption per unit GDP by 33.8% and 29.6%, respectively (compared with 2005).
- The non-fossil energy was 11.2% of total primary energy consumption (increased by 64.7% than that in 2005).
- The CO₂ emission per unit industrial added value was expected to reduce by 21% in 2015 compared to the 2010 level.

**Carbon Emission Reduction in 2020**

- The CO₂ emissions and energy consumption per unit GDP will decline by 44.7% and 46.1%, respectively (compared with 2005).
- The non-fossil energy will account for 15% of the total primary energy consumption (2.2 times that of 2005);
- Chinese government’s carbon reduction commitment will be achieved!

**Carbon Emission Reduction in 2030**

- The CO₂ emissions and energy consumption per unit GDP will decline by at least 65.4% and 64.3%, respectively (compared with 2005).
- The non-fossil energy will account for up to 20% of total primary energy consumption (2.9 times that of 2005);
- Chinese government’s carbon reduction commitment will be achieved!
Acknowledgements:

- Colleagues at NICE
- Chinese Academy of Engineering
Thank you for Your attentions!

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