Shenhua CTL (Clean Coal) Projects and CO_2 Sequestration

Ren Xiangkun
China Shenhua Coal Liquefaction Co., Ltd

May 29th, 2008

Table of Contents

- Overview of Sino-US joint research program
- Coal-to-liquids (CTL) development in China
- Shenhua direct coal liquefaction (DCL) plant
- CO_2 sequestration potential of Shenhua DCL plant
- Conclusions: CO_2 vs. Prospect of CTL

US-China Clean Energy Protocol

- First meeting between Shenhua and WVU in 2002
- MOU signed by WVU and CSCLC in 2004
- WVU participation funded by DOE since 2003 with Shenhua cost sharing support in China
  - Environmental and economic impacts of Shenhua DCL plant in the long run
  - Pre-feasibility study of CO_2 sequestration for Shenhua DCL plant
- WVU-Shenhua cooperative research takes place under Annex II of the US-China Clean Energy Protocol between USDOE and China NDRC
- US-China Clean Energy Protocol—Chinese side Led by PRC Ministry of Science & Technology

CTL in China

- China launched DCL and ICL technology R&D effort in 1980
  - (Oil price increased from $14/b in 1978 to $34/b in 1980)
- In 1981, China's National Council set up a special "Coal-Replacing-Oil" (CRO) fund
  - Initially to promote power plant development
  - Supported CTL development since 1990s
    - (Oil price fluctuated between $15/b and $20/b)

Shenhua CTL Development

- 1997 – Shenhua initiated planning for CTL development
- January 1998 – State Council earmarked 11 billion RMB from the CRO fund to Shenhua for CTL development
  - (Crude oil price then: $12/bbl)
- 2002 – Feasibility study for the Shenhua DCL plant completed
  - (Crude oil price then: $23/bbl)

Shenhua CTL Development

- June 2003 – Shenhua set up CSCLC to develop and build DCL plant
- 2004 – Official groundbreaking for Shenhua DCL plant
  - (Crude oil price then: $37/bbl)
- 2008 – Shenhua DCL plant start-up
  - (Crude oil price: $128+/bbl)
- Three ICL and two CTC plants are being planned by Shenhua

CTL Development in China

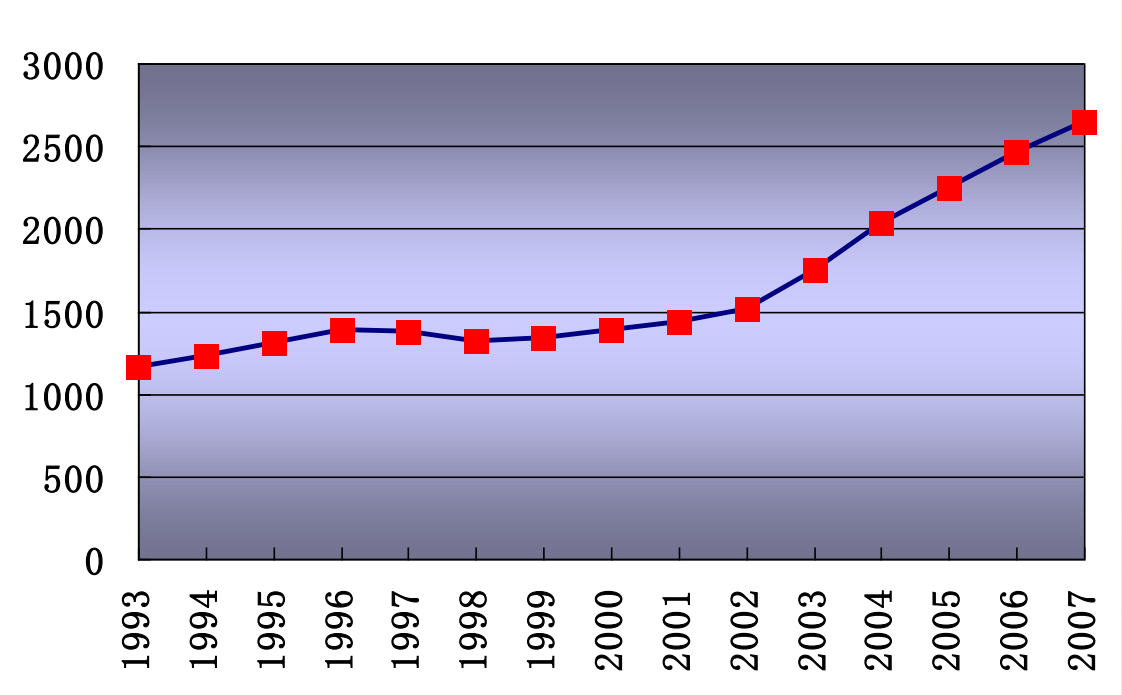
- Seven CTL demonstration plants are being developed in western China
  - One DCL and three ICL plants by Shenhua
  - Yankuang ICL plant
  - Luan ICL project
  - Yitai ICL plant
- Approval of additional CTL plants by Chinese central government is expected
- Multiple CTC, coal-to-methanol, DME, and GreenGen projects are under way

CTL Development in China

Why CTL in China?

- National strategy for energy security
- Environmental requirements for clean coal

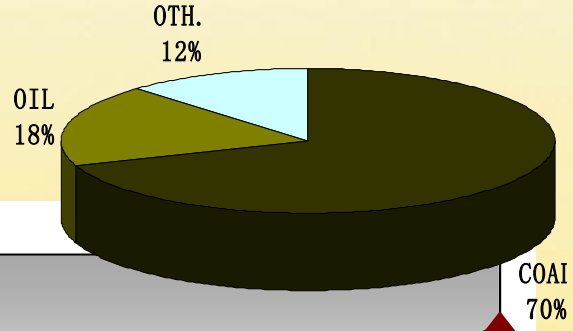
Fossil Energy in China: Resource, Production & Consumption

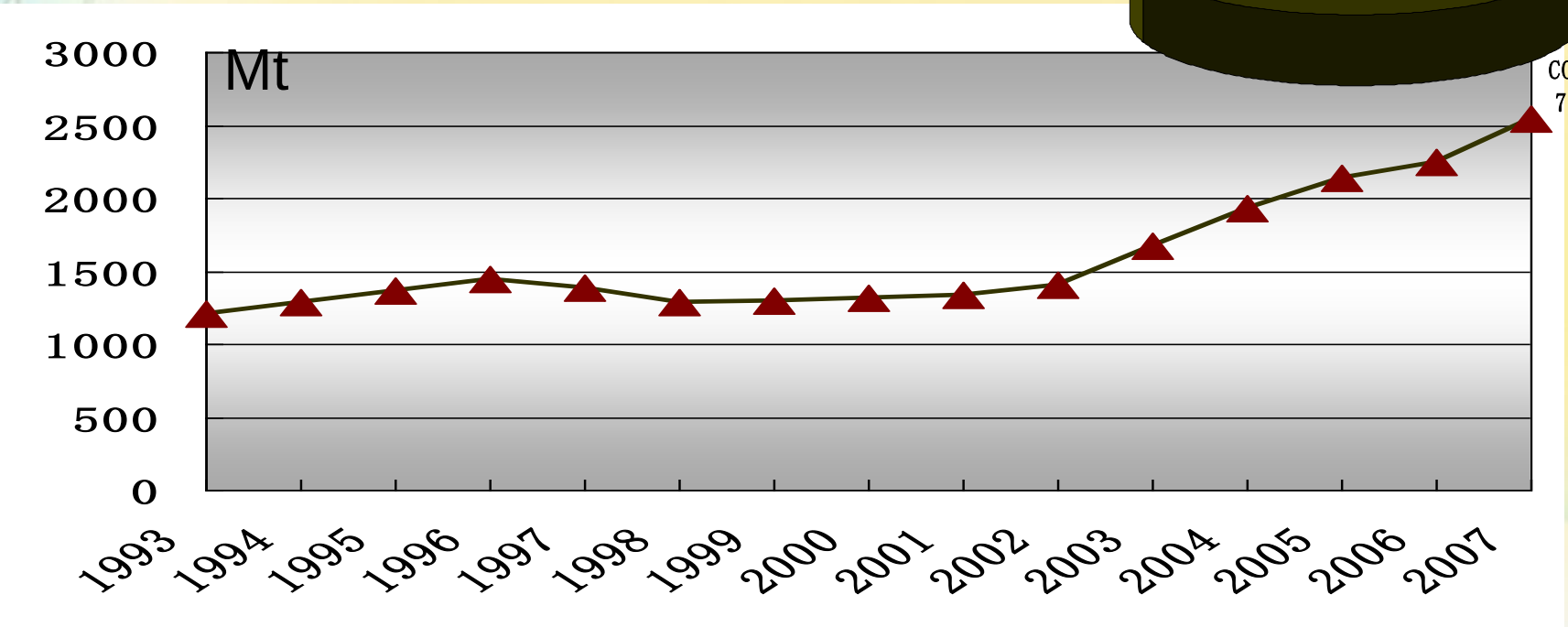


- **Chinese energy consumption grows very fast since 2002**
- **Primary energy consumption totaled 2650Mtce in 2007, representing an increase of 75% compared with 2002.**

Fossil Energy in China: Resource, Production & Consumption

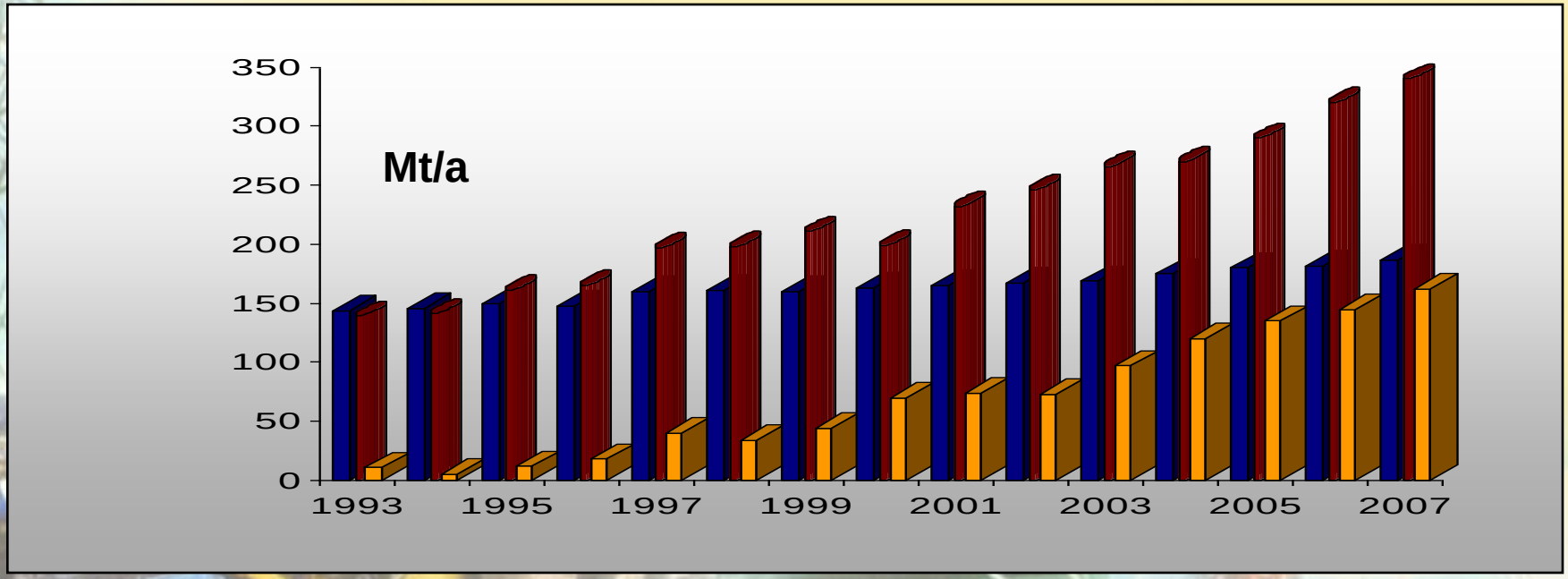
- In 2007, Chinese petroleum output amounted to 187Mt, representing an increase of 12% compared with 2002.
- It is expected that petroleum consumption will amount to over 450Mt/a by 2020.
- Coal provides 75% of energy output.



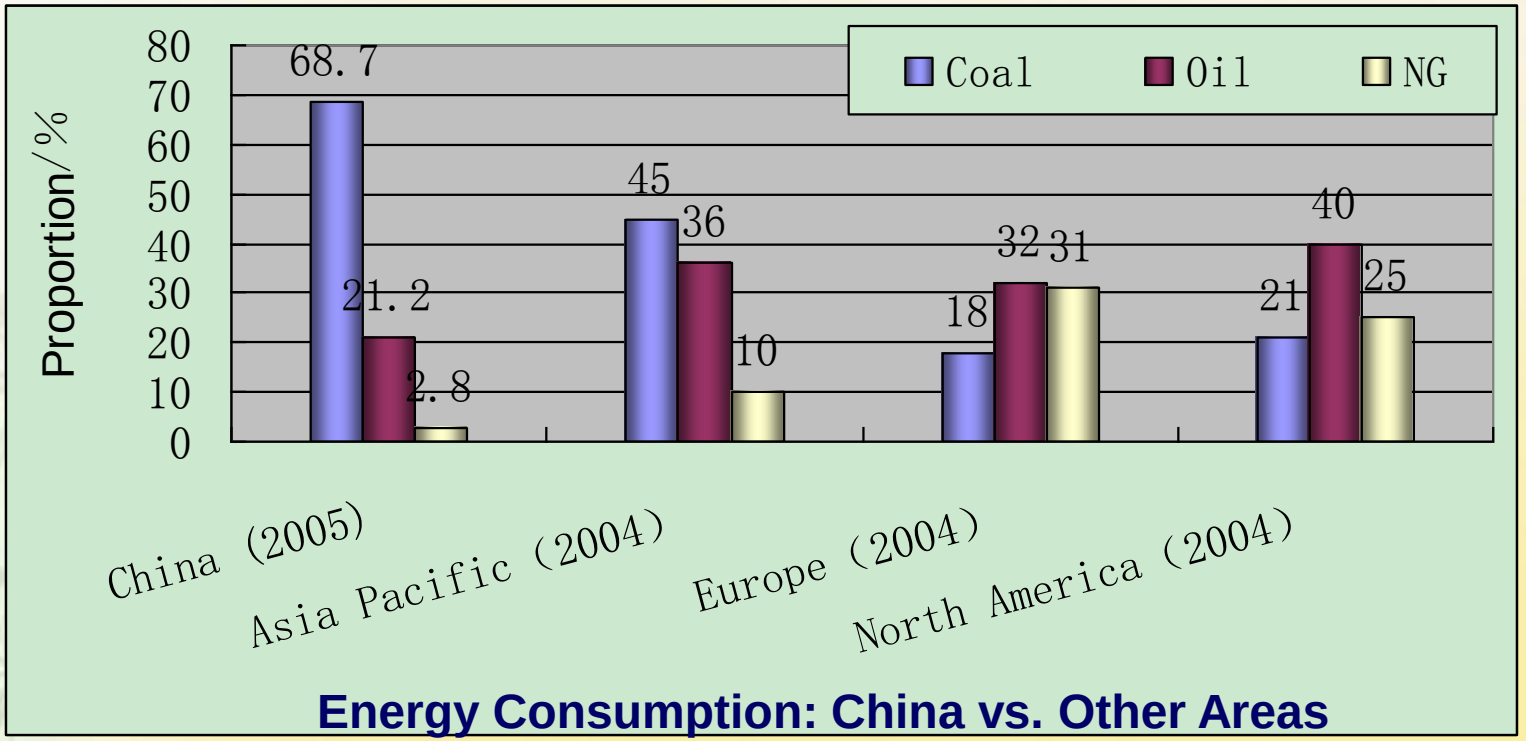


Fossil Energy in China: Resource, Production & Consumption

- In 2007, Chinese petroleum output amounted to 187Mt, representing an increase of 12% compared with 2002.
- In 2007, the petroleum consumption was 340Mt, representing an increase of 38% compared with 2002.
- In the same period of time, the net import increase of petroleum is 110% , accounting for 48% of the total petroleum consumption.
- It is expected that petroleum consumption will amount to over 450Mt/a by 2020.



Fossil Energy in China: Resource, Production & Consumption



Energy Consumption: China vs. Other Areas

- **Coal-dominance in Chinese energy production and consumption will not change much in a long period of time.**
- **It is anticipated that coal will account for 60% and 50% in Chinese energy consumption by 2010 and 2050 respectively.**

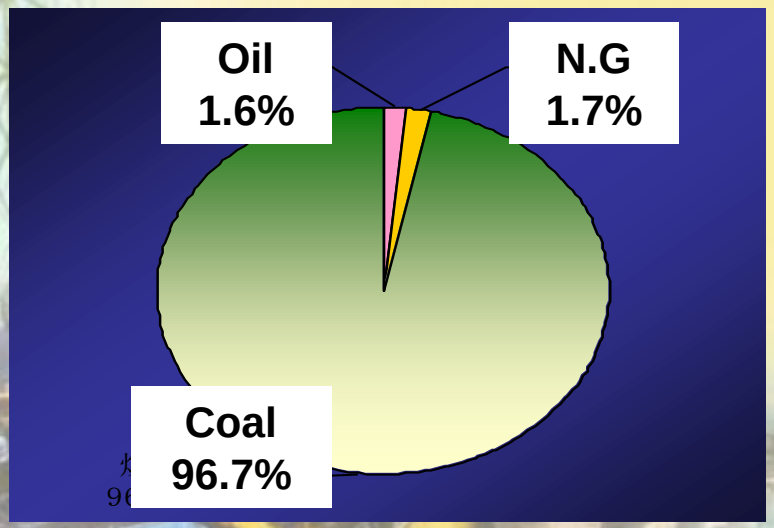
Renewable Energy in China —Development & Use

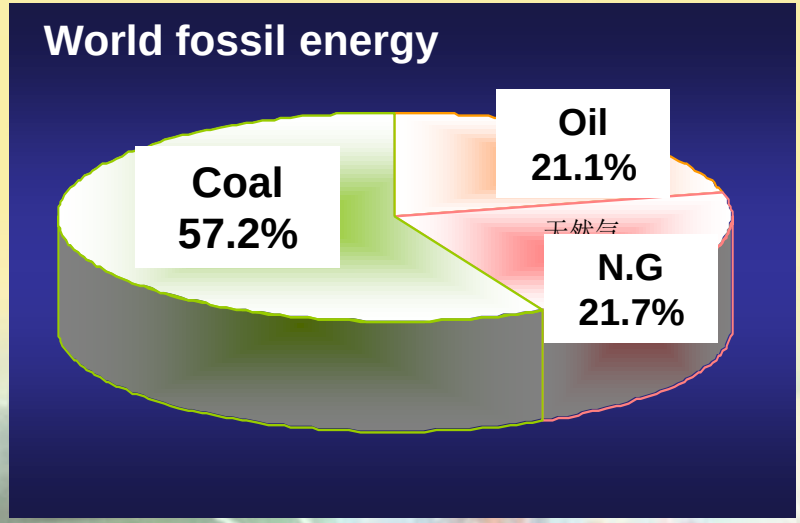
Ratio of renewable energy consumption to primary energy consumption: 2.83:100

Category	Capacity	Standard coal equivalent/Mtce
Large- and medium-sized hydropower plant	78.86GW,208.1TW•h	96.07
Conventional ways of biomass use	295.6Mtce	295.6
Renewable energy		62.80
Micro and small hydropower plant	38.74GW,121.28TW•h	41.60
Biomass		9.32
Household, large- and medium sized biogas system	Household biogas output: 7.06billion m^3	6.70
	Biogas output: 0.2billion m^3	0.03
Centralized gas supply system for straw gasification	2GW,4800GW•h	1.67
Biomass power plant	1Mt	0.92
Biomass ethanol	Photovoltaic cell: 70MW,78GW•h	10.69
Solar energy	Power generation: 28MW,140GW•h	0.65
Geothermal	Incorporated wind power generator: 1266MW	0.54
Wind power		
Total		454.47

Chinese Fossil Energy: Basic Reserves

Chinese fossil energy: basic reserve & per capital reserve		
Designation	**Reserve**	**Per capita reserve**
Petroleum (Mt)	2758.6	2.1 (t/person)
Natural gas (Gm^3)	3000.9	2283 (m^3/person)
Coal (Mt)	333480	254 (t/person)





Coal Use Poses Severe Environmental Challenge

- Fossil energy use will definitely bring about environmental pollution.
- Negative environmental impact of non-clean coal use becomes more evident.
- Economic loss caused by air pollution in China exceeds US$100 billion every year.

CO2 Emission from Coal Burning

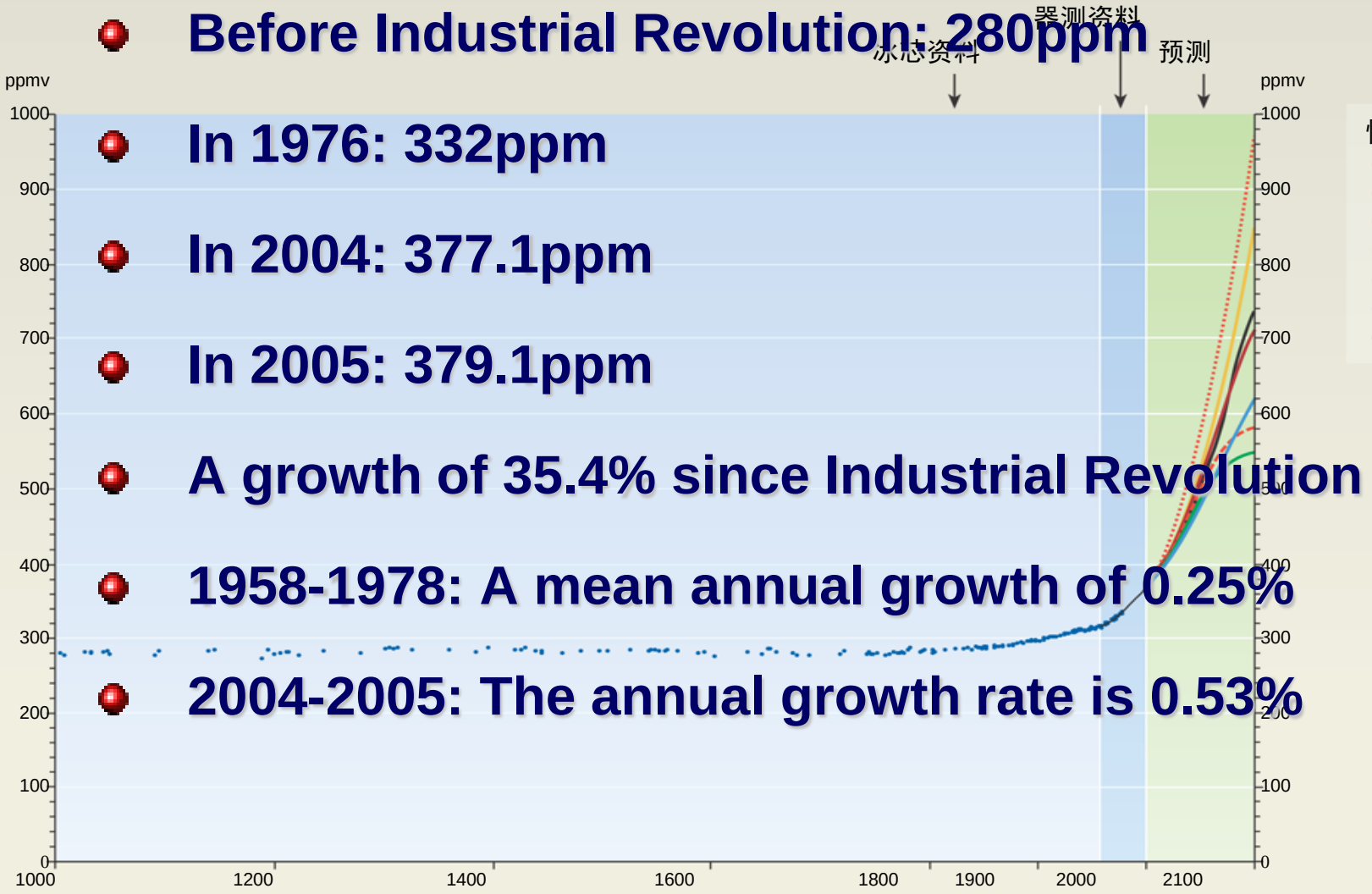
Country	CO_2 emission/Mt-C(2003)	Emission from coal-burning/%
PRC	1127	80.5
US	1565	36.6
Japan	336	34.7
India	298	61.7
Korea	124	41.0
World's Total	6869	40.6

Main Pollutants Emission in 2005

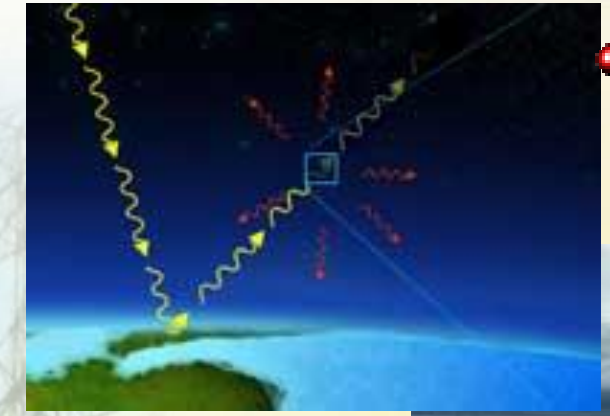
SO_2/Mt	Smoke & dust/Mt	Industrial dust/Mt
25.49	11.82	9.09

Fast Growth of CO2 Content in the Atmosphere

- Before Industrial Revolution: 280ppm
- In 1976: 332ppm
- In 2004: 377.1ppm
- In 2005: 379.1ppm
- A growth of 35.4% since Industrial Revolution
- 1958-1978: A mean annual growth of 0.25%
- 2004-2005: The annual growth rate is 0.53%



Aftereffects of Growing CO2 Content in the Atmosphere



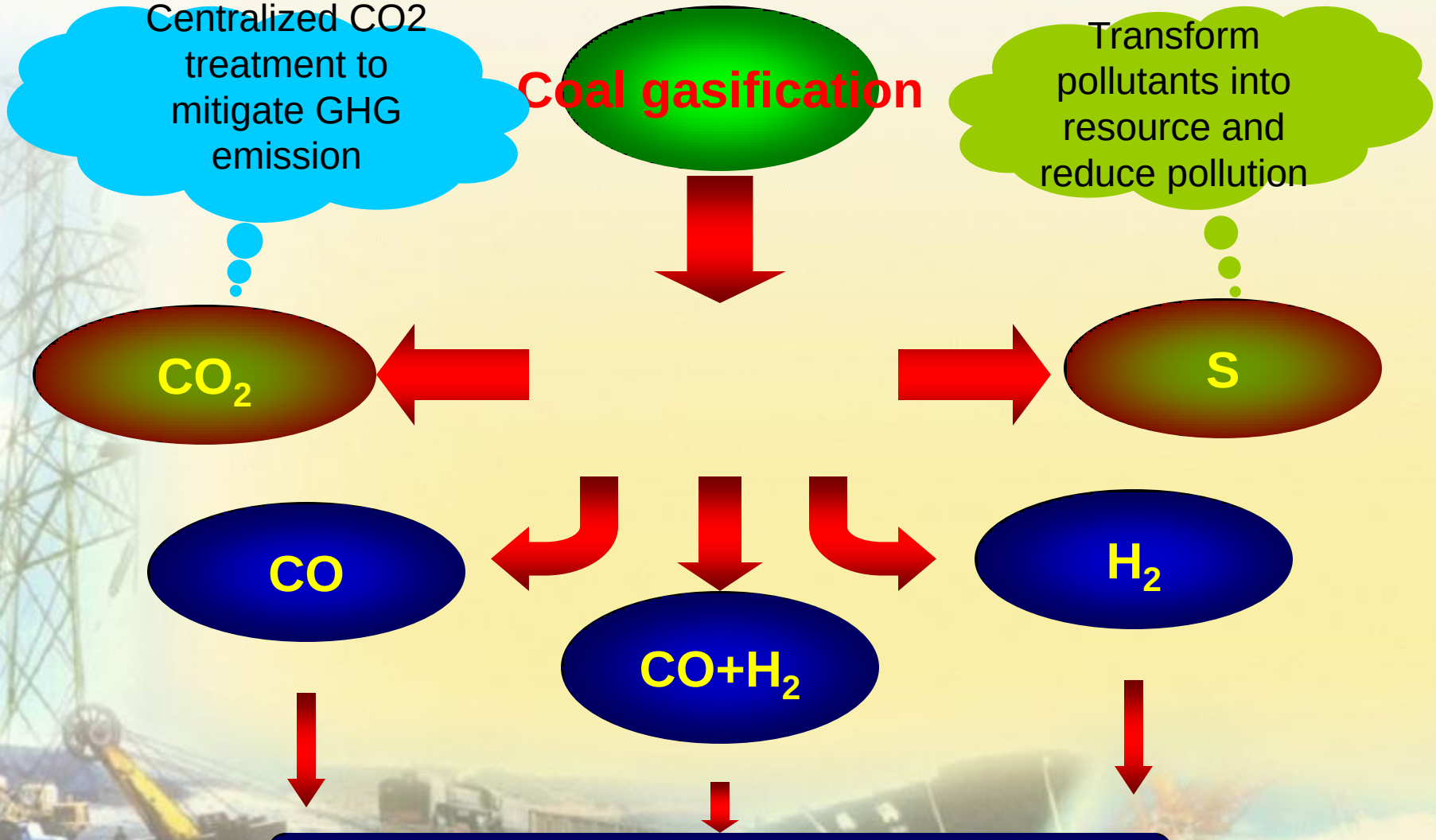
- Greenhouse Effect

- Melting glacier

- Rising sea level

- Frequent hit of natural disaster

Clean Coal Conversion Enabled by Abundant Coal Reserve



Oil Substitution Enabled by Clean Coal Conversion

Gasification

Coal-based polygen

Thermal Chemical products

IGCC power generation

Electricity

Liquefaction

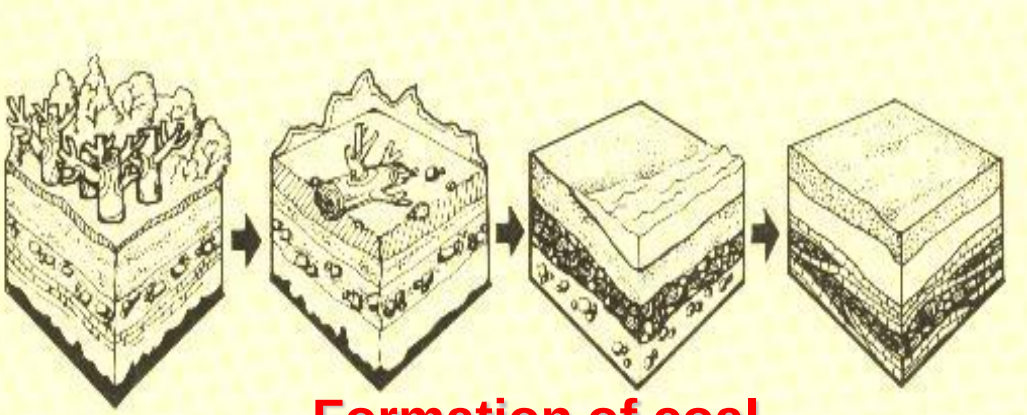
Hydrogen power

Chemical products

Power fuel

Substituting petroleum

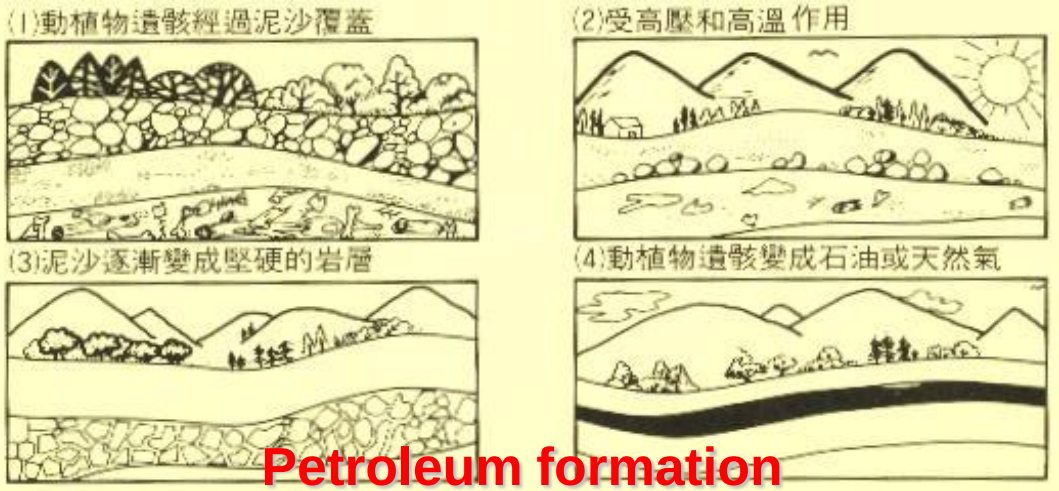
Feasible Option– Oil Substitution with Coal



Formation of coal

- Abundant coal resource

Coal and petroleum have similar properties:



Petroleum formation

	石油Oil	煤炭Coal
C碳%	87-88	75-80
H氢%	13-14	5.0-6.0
O氧%		10.0-20.0
N氮%		1
S硫%		0.5-2.0
H/C ratio	1.8	0.8

CTL—A Trend of Chinese Energy Consumption

Fast growing energy demand

Energy mix featuring coal-dominance & petroleum insufficiency

State: Policy support & guidance

Develop Coal-to-Oil Technology

Enterprise: Adjust product mix; strive for the balanced development of economy and environment

Sustainable economic & environmental development

128US$/bbl

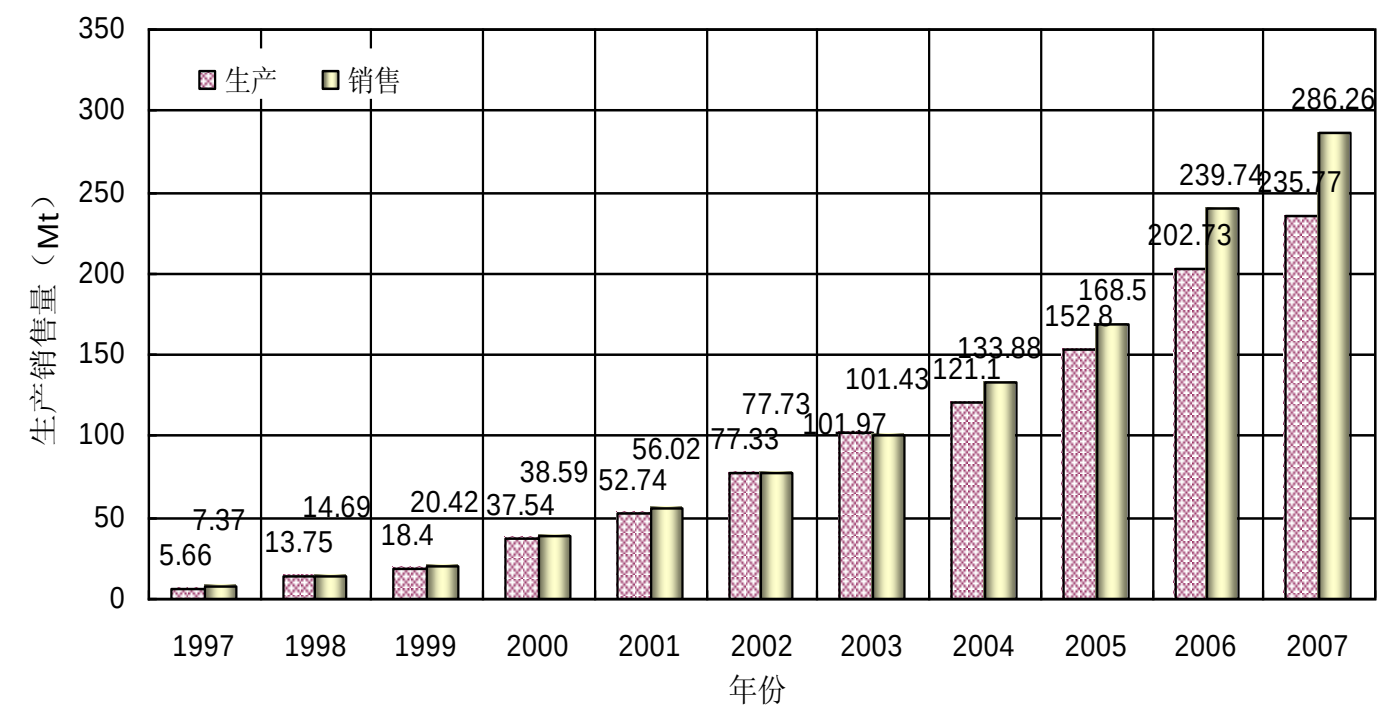
Why CTL for Shenhua?

- Shenhua's business development plan
  - Overcome shipping bottlenecks to increase output
  - Support economic development in mining areas
  - Anticipate future profitability
- Shenhua capabilities for CTL development
  - Governmental support
  - Abundant coal reserves
  - Capital
  - Technical support
  - Human resource

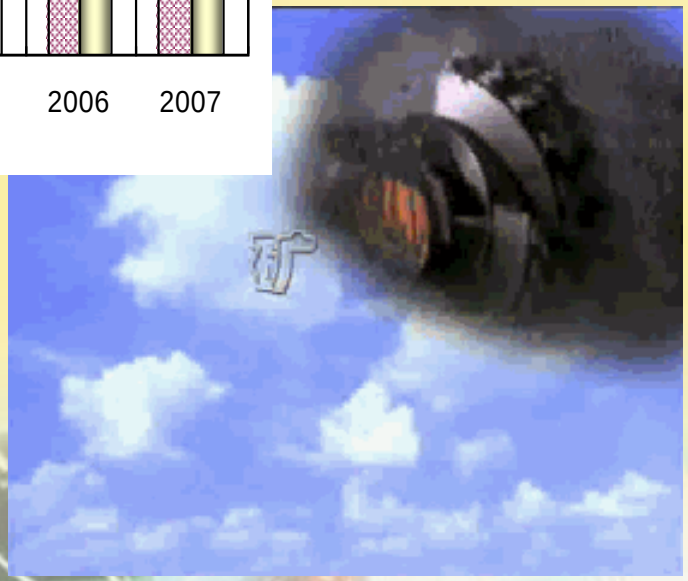
Our Main Businesses

- Shenhua Group is the No.1 coal producer in China (and world as well) under the leadership of SASAC (State-Owned Assets Supervision and Administration Commission);
- Our coal mines and power plants have achieved scale of economy by forming a value chain;
- Our railroad, ports and shipping facility support our development;
- New CTL and coal chemical programs are underway.

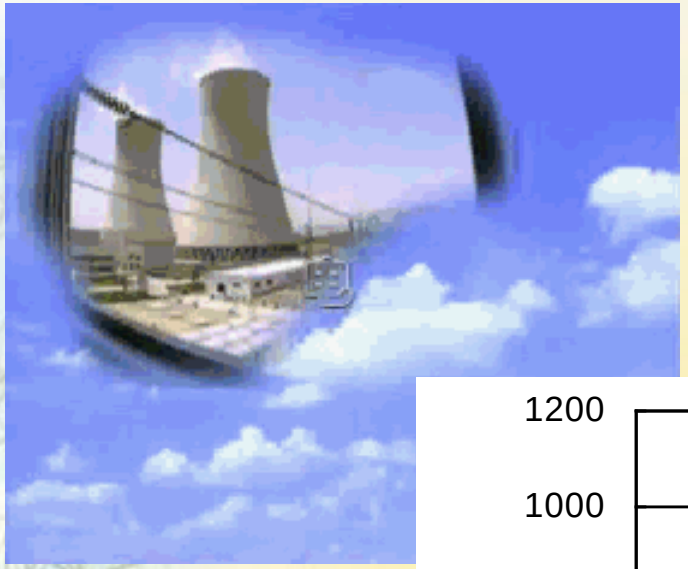
World No.1 Coal Producer & Supplier 2007



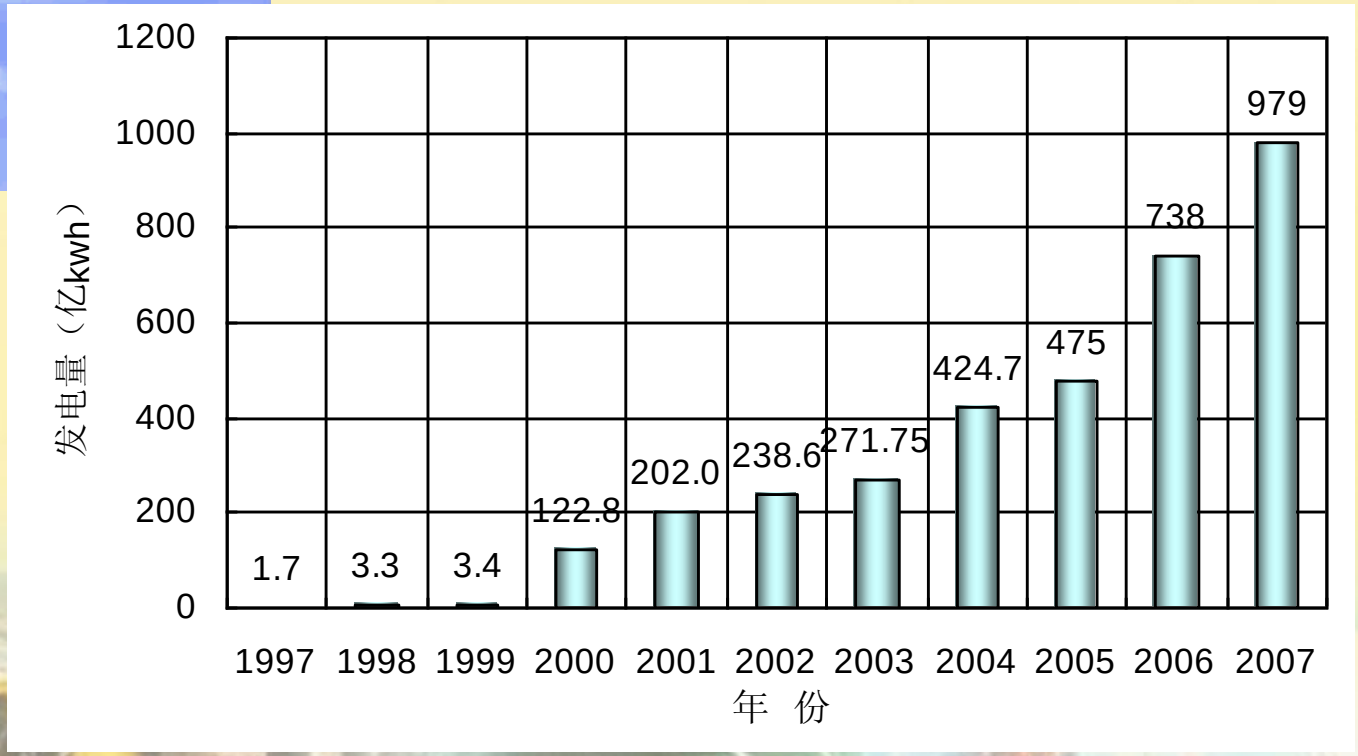
Our Coal Production & Sales 1997-2007



Emerging Scale Advantage of Our Coal-Fired Power Plant



Our Power Generation 1997-2007



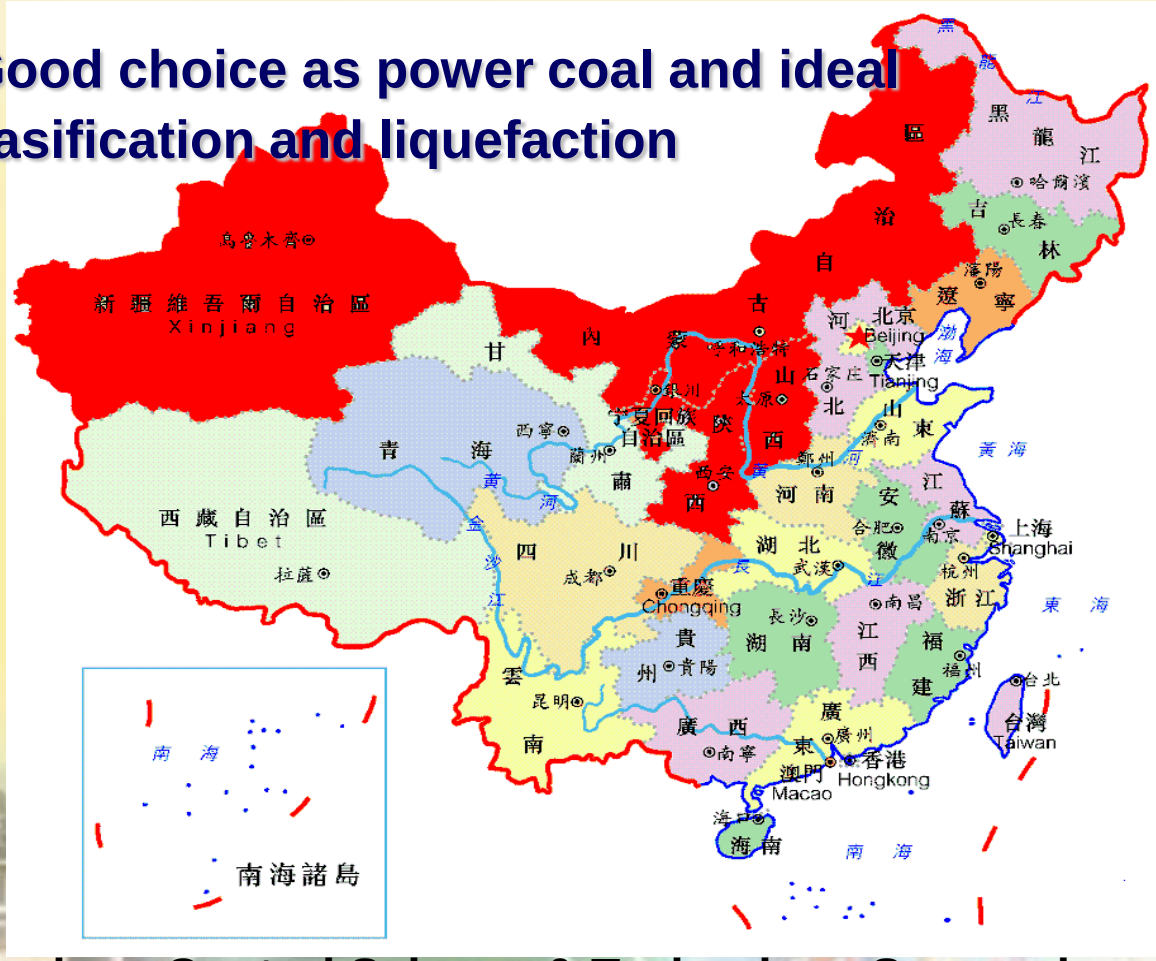
Emerging Edge in Railway Transportation and Portal Service

Railway length: 1,500km

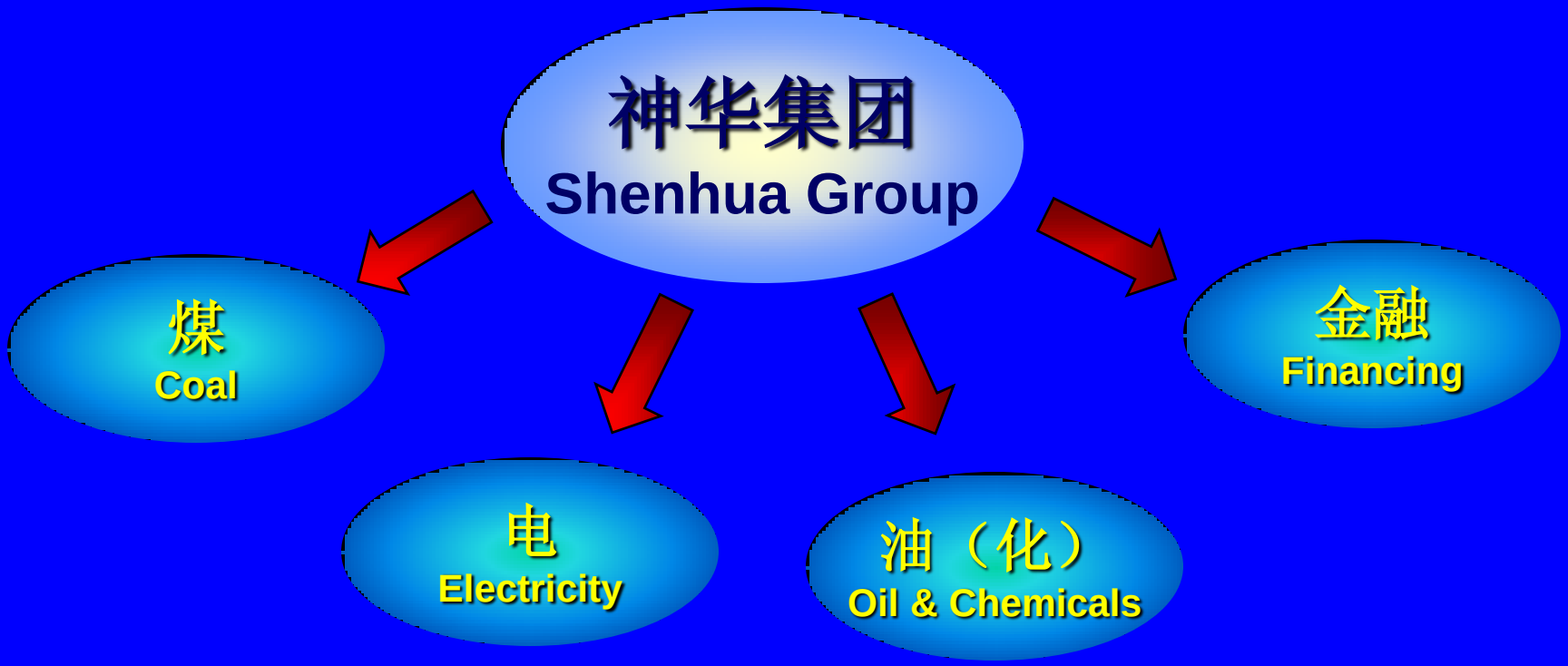
Harbor capacity: 80 million tons per year

Outstanding Resource Secures Our Coal Conversion Program

- Shenhua is possession of the coal resource concentrating in North China and the northwestern part of China.
- Quality coal—Good choice as power coal and ideal feedstock for gasification and liquefaction

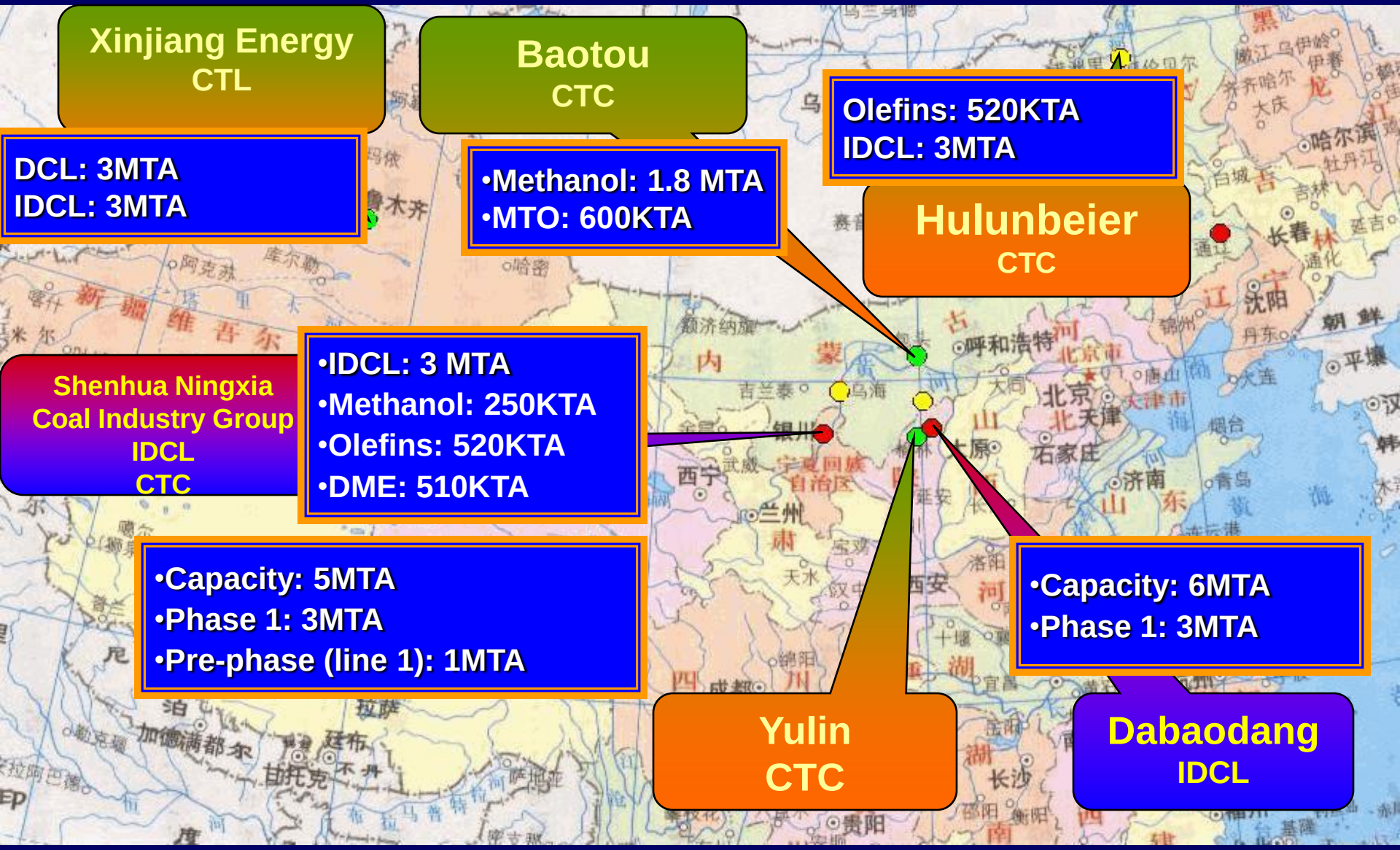


Shenhua Clean Coal Development Plan

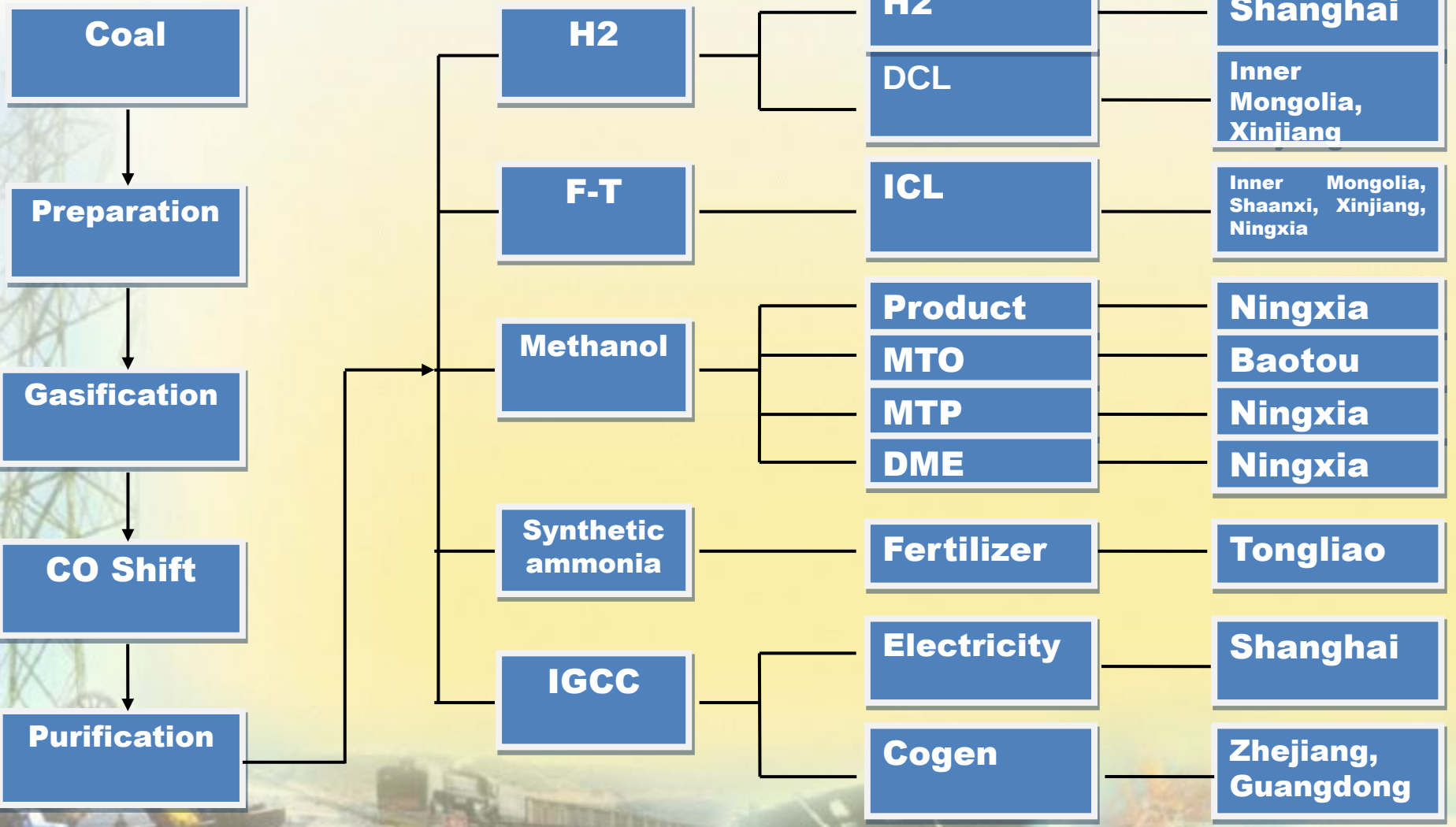


Coal output	Power generation	CTL/CTC	
400 million tons	30,000 MW	4 million tons	2010
800 million tons	48,000 MW	31.50 million tons	2020

Our Coal Conversion Program



Clean Coal Business Chain Based on Coal Gasification

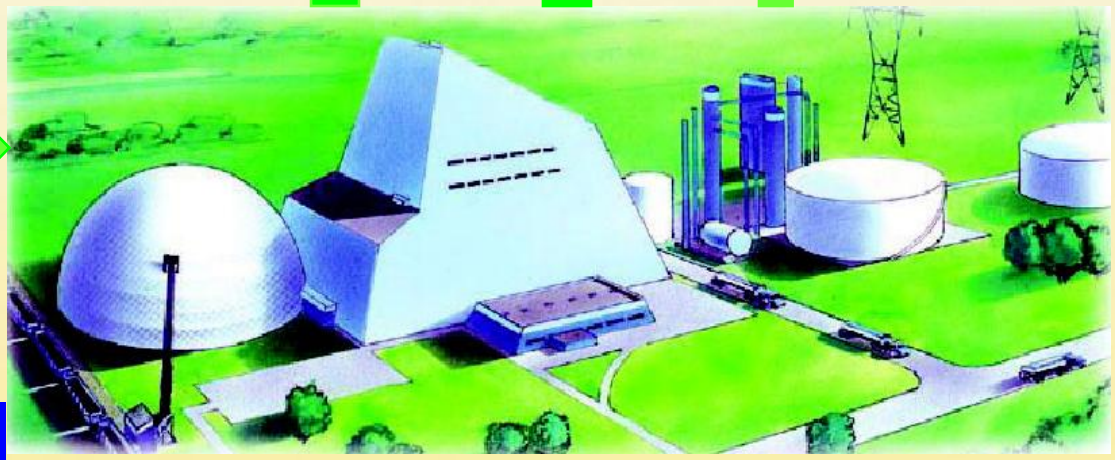


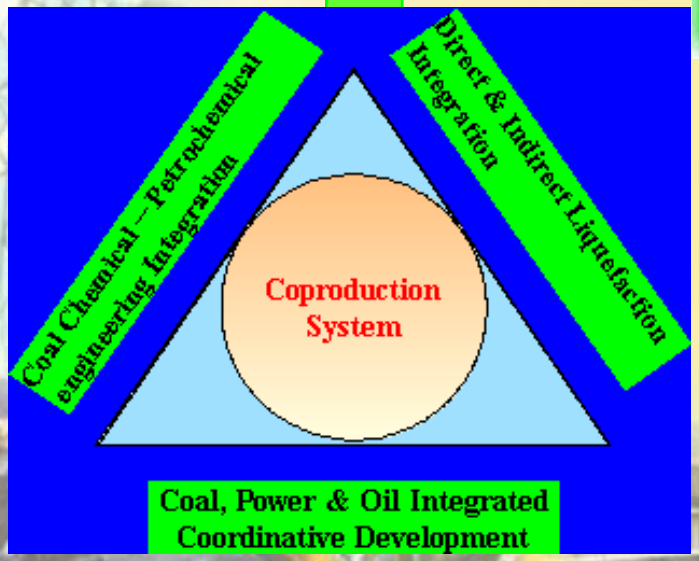
Shenhua Coal-based Ecological Industrial Park

High Quality Fuel

Electric Power

Chemicals





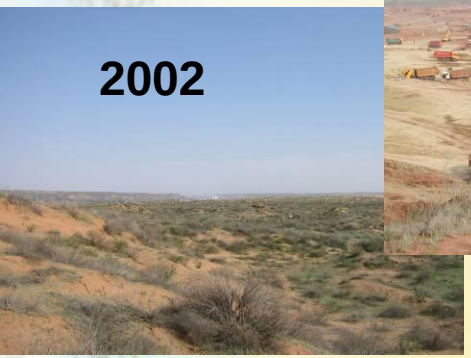
Coal -based Ecological Industrial Park

—In line with the long-term sustainable development goal which is based on the promoted use of hydrogen energy and reduction of CO_2 emission

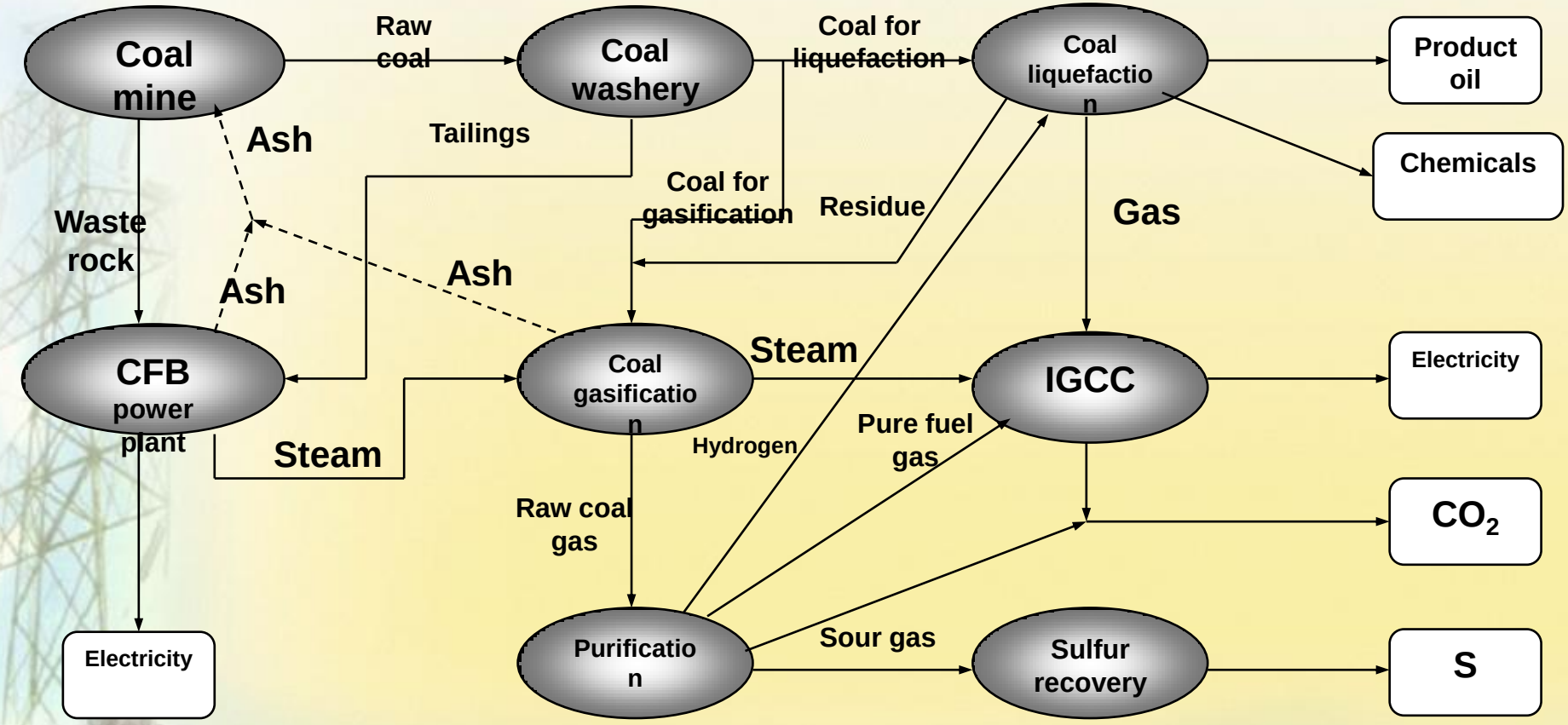
Shenhua DCL Plant in Inner Mongolia

- **First DCL commercial plant in the world combining technology from the US, Japan, and Germany with Chinese innovations**
  - **24,000 BPD (diesel mainly)**
  - **US$1.5 billion**

Shenhua DCL Plant



CCSM Demonstration Project—NDRC/DOE/WVU



DCL Plant CO_2 Production

- Direct liquefaction process produces little CO_2
  - Coal + H_2 + Catalyst ➔ Oils
- CO_2 is produced as follows (about 3.6 MMt/y):
  - Hydrogen production (about 2.9 MMt/y)

$$C + 2H_2O \rightarrow CO_2 + 2H_2$$

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

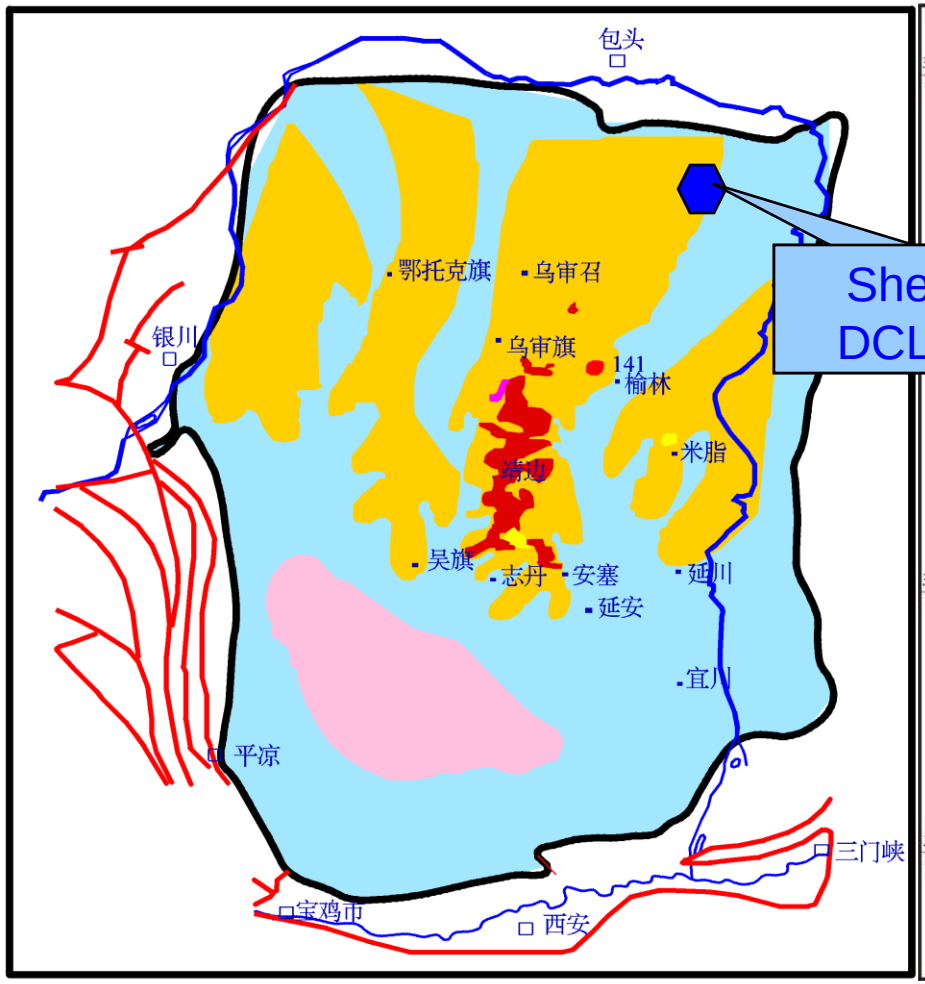
$$CH_4 + 2H_2O \rightleftharpoons CO_2 + 4H_2$$

  - Combustion for power and steam and other low quality emissions (about 0.7 MMt/y)

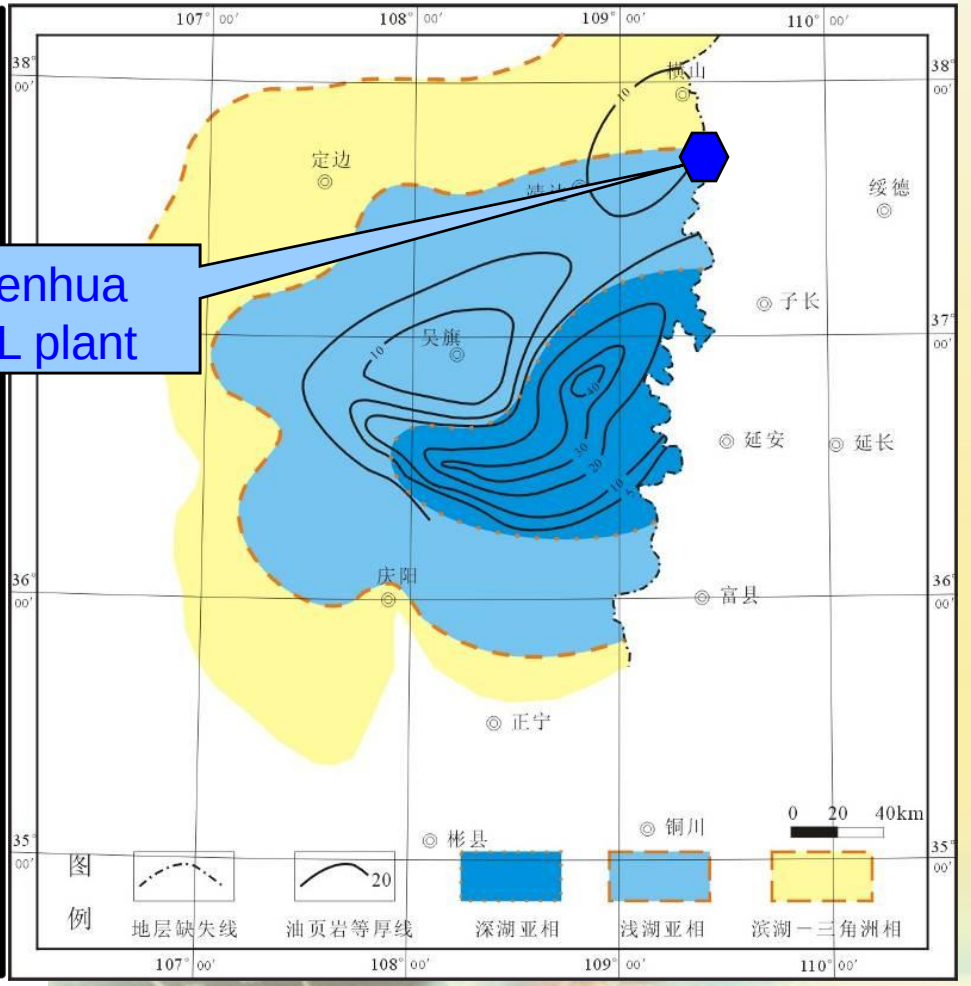
CO_2 Sequestration Project

- World's largest CO_2 sequestration project
- Primary costs are transportation and storage
- Pre-feasibility study stage
- Major carbon sequestration alternatives:
  - Enhanced oil recovery (200km)
  - Deep saline aquifers (+2000m)
  - Deep coal seams

Enhanced Oil and Gas Recovery



Shenhua DCL plant



Gas and Oil Reserves in Ordos Basin

Oil Shale Deposits in Ordos Basin

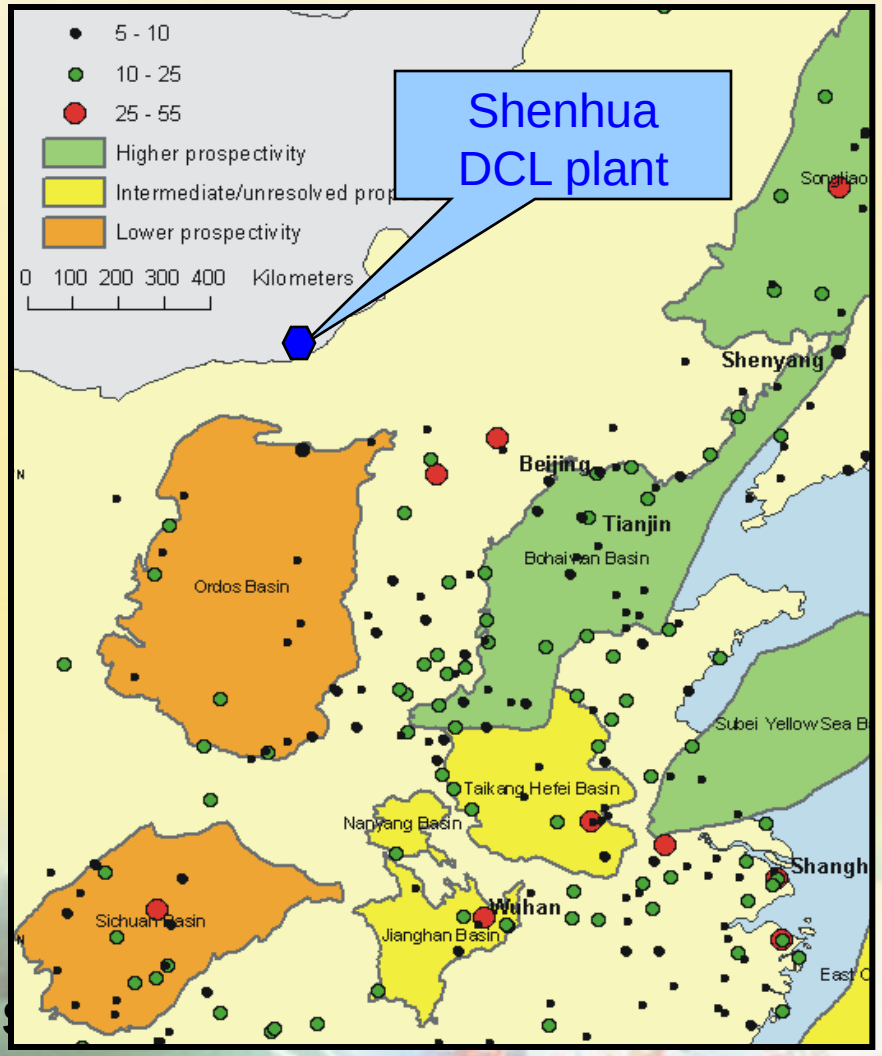
CO_2 Storage in the Ordos Basin: Unique Opportunities and Challenges

Many target reservoirs

- Majiagou Fm. (Ord. carbonates)
- Taiyuan Fm. (Carb. sandstones)
- Xiashihenzi Fm. (Perm. sandstones)
- Yanchange Fm (Jurassic sandstones)

Low permeability in general

- Must characterize injectivity carefully
- Can be augmented (deviated wells)
- Improved residual phase trapping
- Many stacked potential targets



CO_2 Storage in the Ordos Basin: Unique Opportunities and Challenges

Structural complexity modest

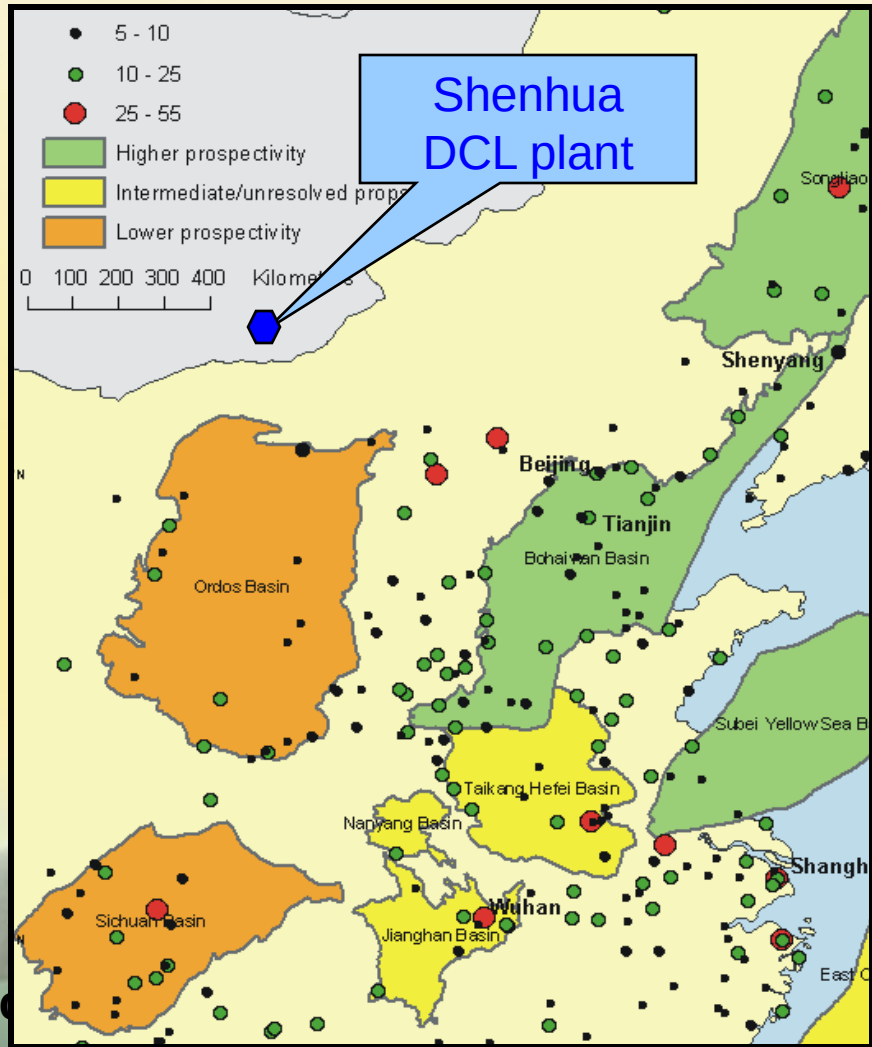
- Compression and extension
- Not isotropic in-situ stress

Demonstrated effectiveness

- Substantial oil & gas seals (>5MPa capillary entry pressures)

Some monitoring challenges

- Fast velocity – seismic limitations
- InSAR, tilt, microseismic strong



Facts

- Direct liquefaction process does not generate CO_2
- 70-80% of CO_2 from Shenhua DCL plant comes from hydrogen production – most of the rest from power plant and heating
- CO_2 emissions can be nearly eliminated if there is an external hydrogen source and power/heat supply
- CO_2 from an ICL plant primarily gasification process
  - Highly concentrated, capture ready
  - Can be sequestrated at low cost

Summary

- CTL is a technically feasible and economically viable source of alternative fuels given current oil prices
- CO_2 management is the key constraint to future CTL development in the US (all OECD countries)
- Integrated CTL, CTC, and IGCC plants combined with carbon sequestration will be the trend

Thanks!