

# Strategy and technology development of coal usage in mainland China

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2007. 1

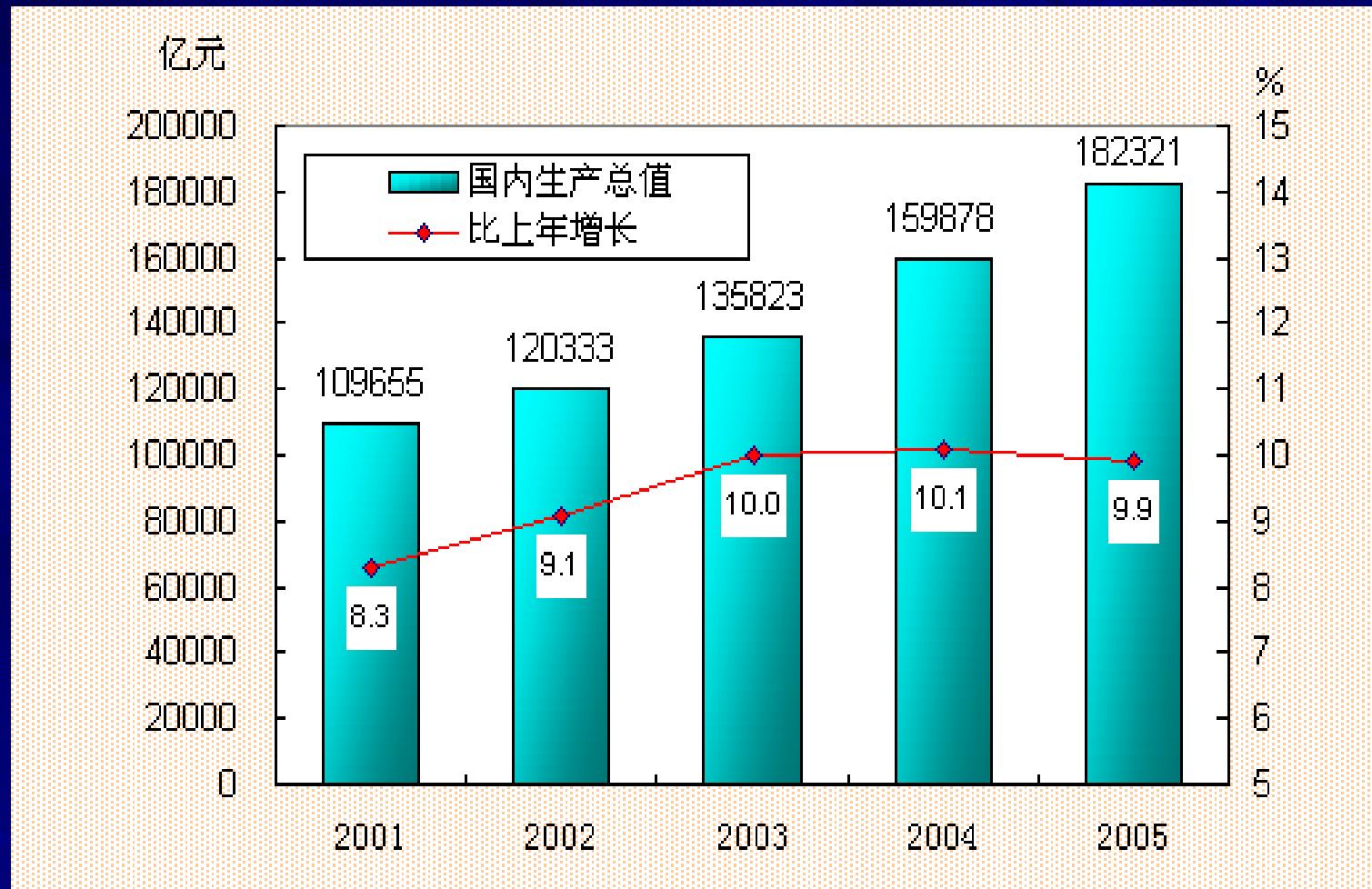
# Strategy and technology development of coal usage in mainland China

- Background of China energy development
- Policy of China energy development
- Pretreatment technologies of coal
- Efficient combustion of coal
- Saving energy
- Coal Gasification
- Coal conversion
- Control and improvement technology of pollutants from coal
- Remarks

# Background of energy development in China (mainland)

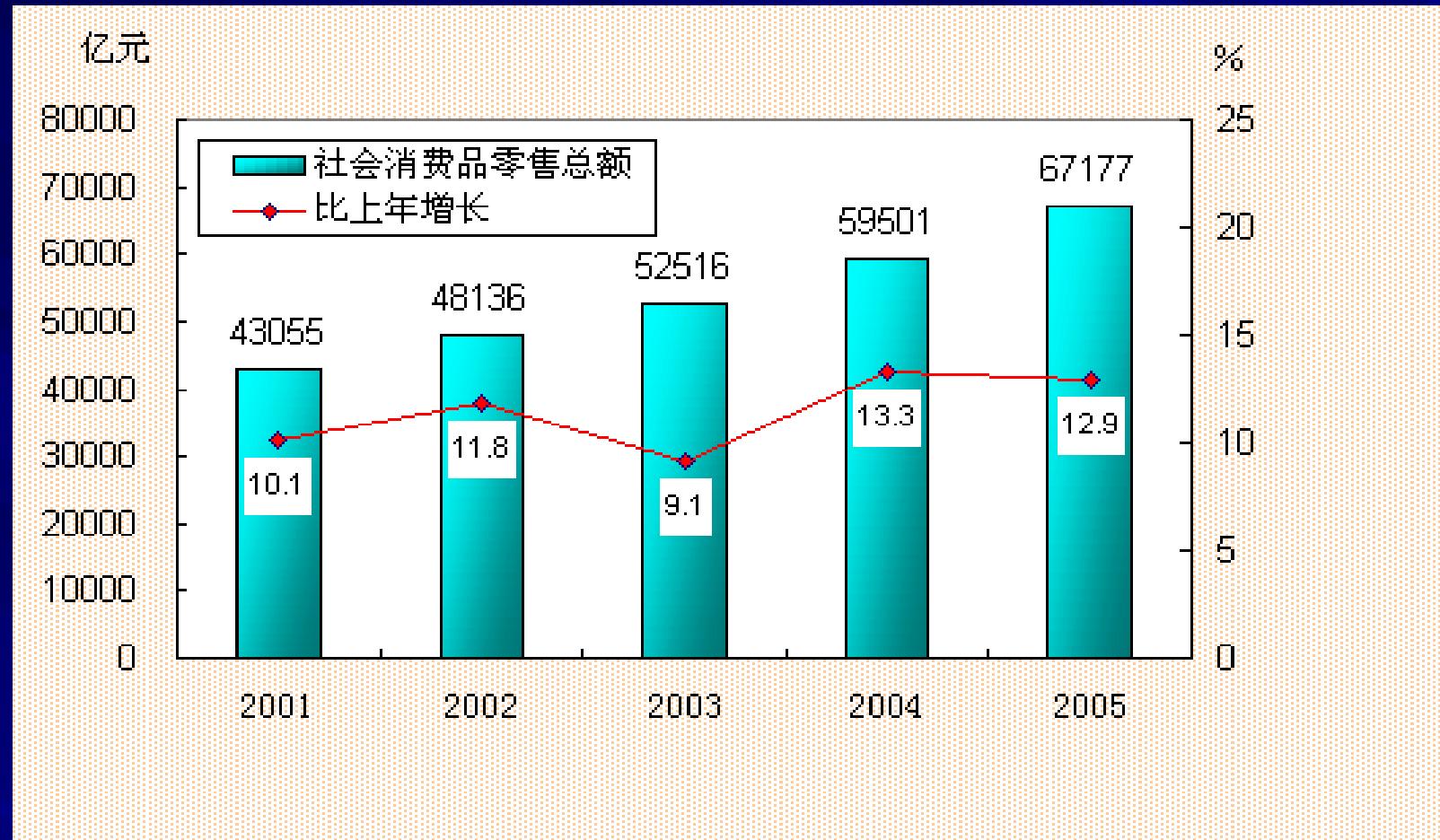
- Rapid expand of economy
- Energy consumption
- Energy production
- Pollutant emission and environment
- Sources of China

# Rapid development of national economy



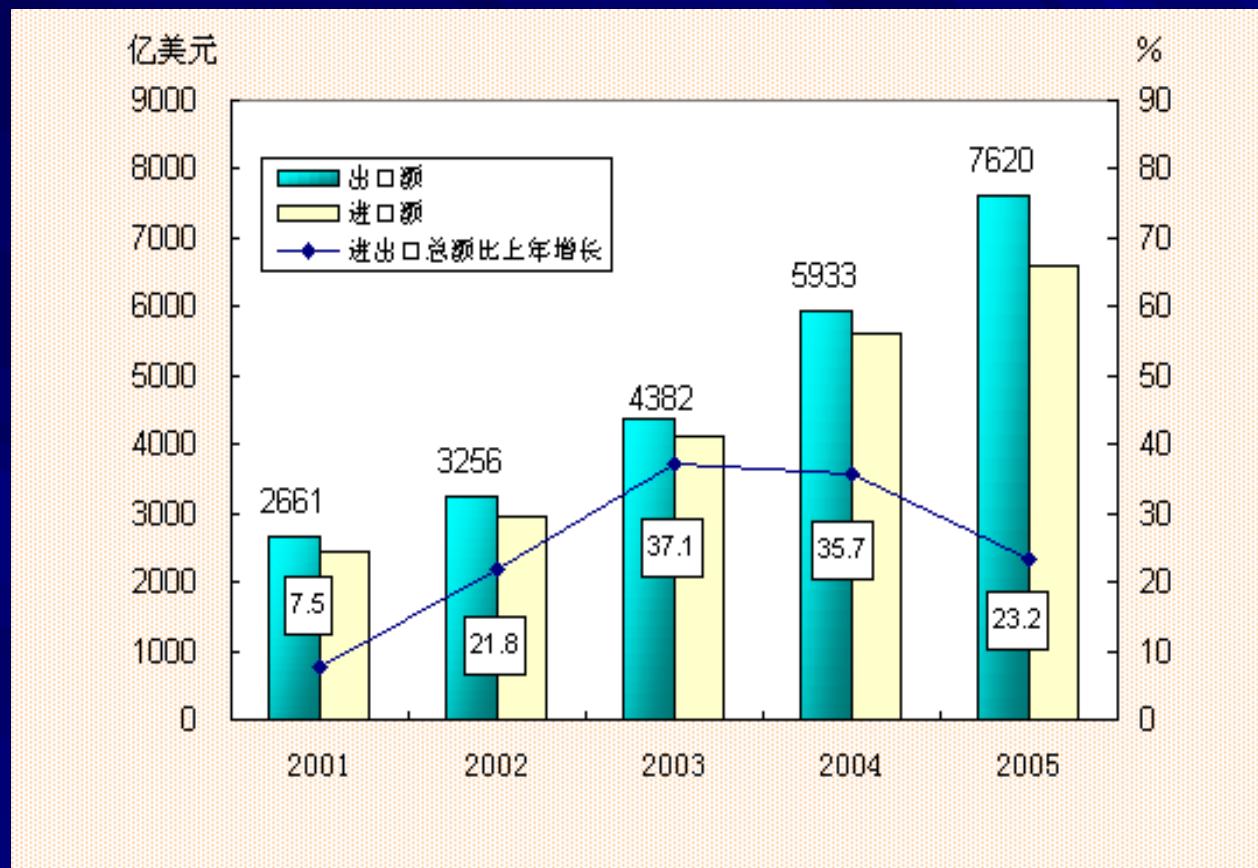
The increase of GDP is above 10% , about 20 trillion,  
about 2.6 trillion US\$ at current rate ( 7.86 RMBY/US\$)  
or about 10 trillion at purchasing power ( 2 RMBY/US\$)

# Huge consumption market



2006 ,increase about 14%, Total of consumption is 7.8-8.0 trillion

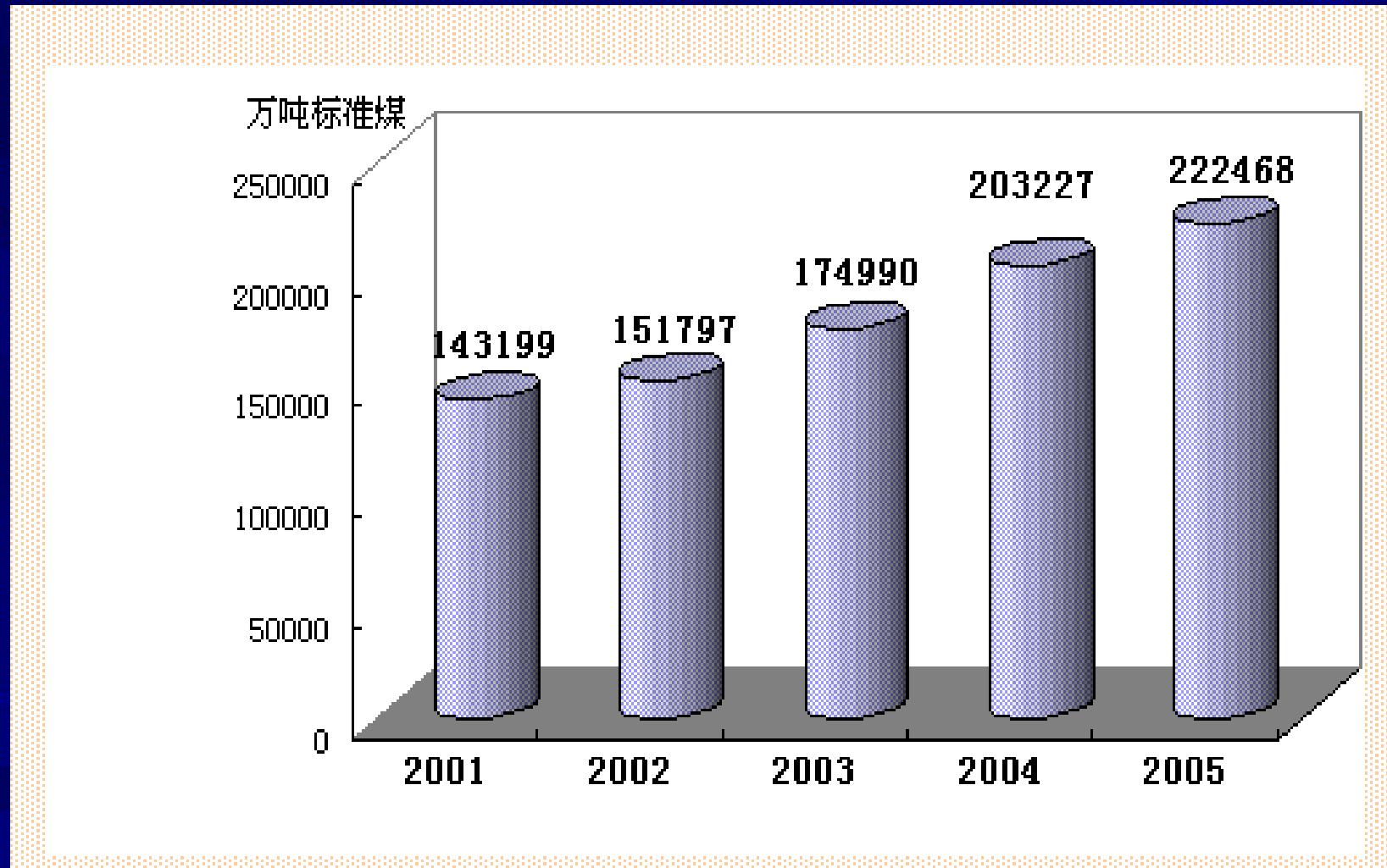
# export and import



年份	总值	出口值	增 %	进口值	增 %
2003	8512	4384	34.6	4128	39.9
2004	11548	5934	35.4	5614	36.0
2005	14221	7620	28.4	6601	17.6
2006*	17000	9200		7800	*估计数据

# Large energy consumption

( 10 thousand ton standard coal)



# Production of primary energy in 1-9 months of 2006

- Coal, 1.478 billion tons, +11.7%, export 47.22 million tons
- Generated power 2.0111 trillion KWh, +12.9%, coal-fired power plants 75%, +14.5% ,
- Crude oil 137.93 million tons, +1.7%; import 104.89 million tons , +10.4%; processing oil 2.2415 million tons , +5.2%
- Natural gas 43.1 billion M3

# The trend of energy consumption in the world

Prediction: 2050 approach maximum for crude oil and natural gas consumption, coal consumption increase sustained in future 200 years

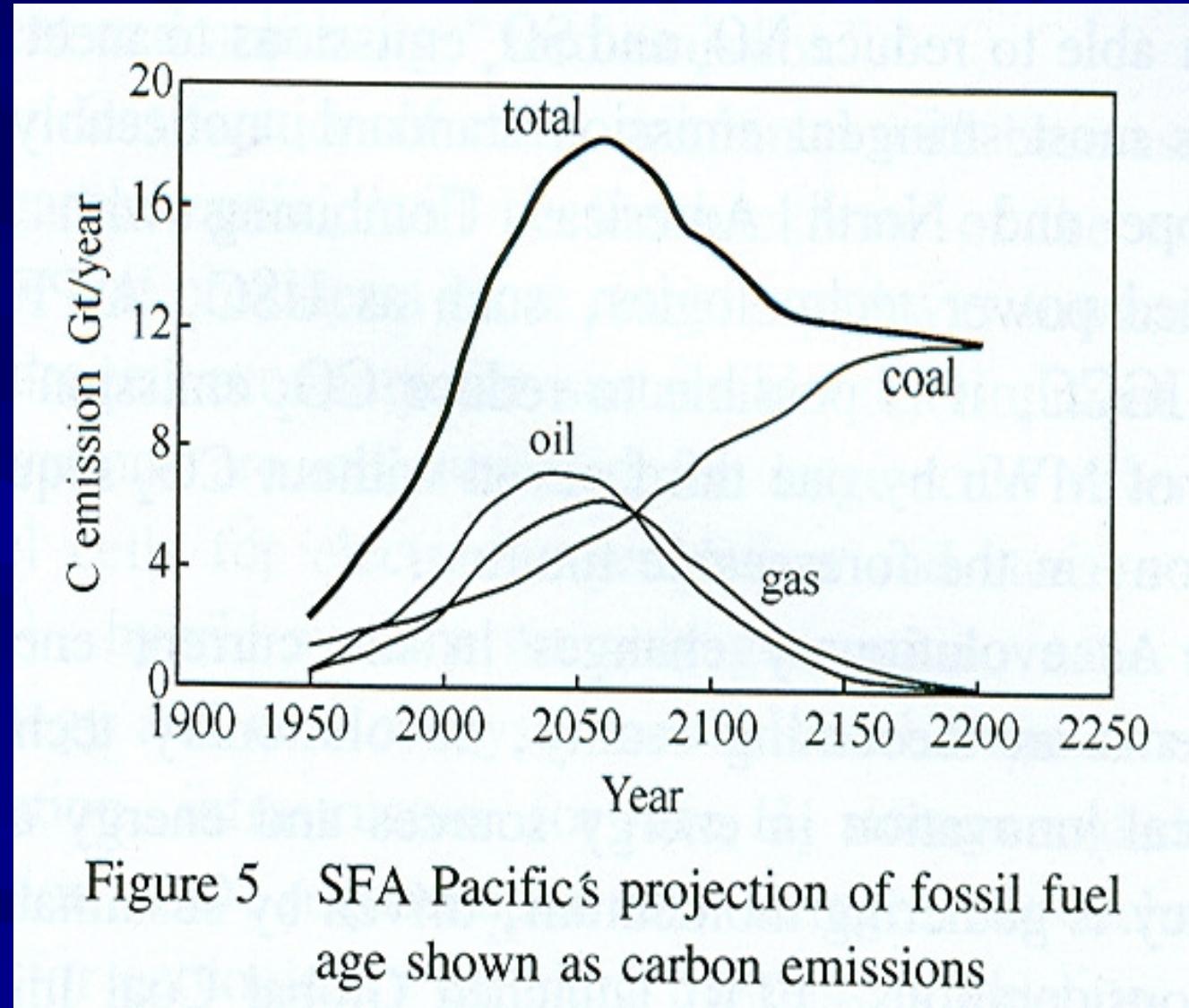


Figure 5 SFA Pacific's projection of fossil fuel age shown as carbon emissions

# Serious environment problem

- For 1kWh from coal-fired power, SO<sub>2</sub>, NO<sub>x</sub> and CO<sub>2</sub> emission is higher 6.678, 3.82 and 0.93g respectively for us than Japan
- In 2005 SO<sub>2</sub>, 25.493, chimney, 11.825, Powder and dust from industries , 9.112 billion tons , higher 13.1%, 8.0% and 0.7% than in 2004
- 90% of SO<sub>2</sub>, 60% of NO<sub>x</sub> and Powder and dust discharged come from coal combustion
- area covered by acid rain more than 30 % of total national area
- Solid wastes produced 1.34 billion tons, rise 12.0% , discharged 16.547 million tons, decrease 6.1%
- Total Waste water discharged 52.45billion tons, rise 8.7% . Waste water from industries 24.31, rise 10.0% . Waste water from life 28.14billion tons, rise 7.7%
- In 509 Chinese cities, only 44.9% their quality of air is good, poor there are 43, 16 in Shanxi

# Fossil fuel in Mainland China: coal

- amount of theoretical source, more than 5.5 trillion tons; ascertain reserves 1 trillion tons; recoverable reserves, more than 190 billion tons
- Area having coal deposit more than 0.6 million km<sup>2</sup>
- Rich type of coal , good quality
- Coal bed methane (shallow layer, less than 2000 m): more than 37 trillion m<sup>3</sup>

# Petroleum and Natural gas

- Petroleum: Ascertain reserves, 21.2 billion tons; surplus recoverable reserves, 2.5 billion tons, ascertain rate 33%
- Only 5.6% of ascertain fossil energy
- Natural gas: amount of recoverable sources, 22 trillion m<sup>3</sup>; ascertain recoverable reserves, 3.5 trillion m<sup>3</sup> ascertain rate 15.9%
- Only 2% of ascertain fossil energy

# Regenerable energy sources

- Hydropower: 400 million kW, exploited only  $\frac{1}{4}$
- Wind energy: 1 billion kW, exploited only 0.13%
- Solar energy have very great potentialities,  
more than 2/3 of national area of time of sunshine  
more than 2200 hours/y
- Biomass resources: crops straws 700 million tons  
(150 million tons standard coal)
- amount of forest surplus sources, 200 million tons  
standard coal
- oil crops and energy plants, 50 million tons/y b i o -  
liquid fuel

# Important notes of China energy

- Increase rate is **5.16%** for energy consumption , **9.6%** for GDP from 1978 to 2005 in China
- China is one of big-nation in energy consumption and also in energy produce, rank 2nd in energy production in the world
- Chinese energy sources and consumption per capita are far below the world average: primary energy consumption per capita 1.18 ton oil equivalent for China, 1.65 for world average , 4.13 for Japan, 7.97 for USA. Only their  $\frac{3}{4}$ , $\frac{1}{4}$  and  $\frac{1}{7}$
- Chinese petroleum consumption per capita is **0.242 tons**, only  $\frac{1}{2}$  of world average,  $\frac{1}{13}$  of USA,  $\frac{1}{8}$  of Japan;
- Chinese natural gas consumption per capita is only **8.5%** of world average, **1.6%** of USA, **5.6%** of Japan
- Import petroleum **136 million tons** in 2005, only **0.1tons** per capita,  $\frac{1}{4}$  of world average ; **613 million tons** and **2.09 tons** per capita for USA
- Pollutants discharged per capita is lower for China than the world average level.

# Important notes of China energy

- Usage efficiency of energy is not high, 1.22 tons standard coal/ 10000 RMBY in 2005, 2010 down 20% to 0.98
- Comparison with advanced countries, energy consumption ,high 1/5 for cement industry, 1/6 for iron and steel industry, 1/5 for coal –fired power plants

# Mainland China must rely on coal energy

- Based upon its unique circumstance
- Its energy resources and production limitations
- consideration of the energy development, supply, and consumption in mainland's future
- Technology development of clean-coal and high efficient coal usage has become a national policy

# The national Energy policy of China

- Insist on conserve energy as the first priority, dependent on our own country , based on coal, explore alternative sources
- Optimize the energy production and consumption structure
- Establish a stable, effective, clean, and safe energy supply system
- Requirements of rapid development of national economy, country sources and its region distribution
- Requirements of environment protection
- Requirements of sustainable development strategy
- Determined by the history and status quo of energy production and consumption

# Base on coal and explore alternative energy resources

- To ensure domestic supply of energy
- To developing clean and efficient technologies of coal usage;
- Improving the petroleum and natural gas exploitation
- Exploring clean energy resources including solar, nuclear, wind, and biomass energy

# Coal : main primary energy

- More than 65-70% come from coal, one of few countries that main energy is coal
- Reality of energy sources: coal rich, oil poor and gas lack
- 2005, coal 76.3% and 68.7% in production and consumption of primary energy
- This situation is still kept in predictable future

# sustainable development strategy

- Make rapid development of economy, at same time keep clean environment
- Devote main effort to develop technologies of coal usage (clean and high efficiency)
- Central government focus on these issues in national plans and huge projects
- Recent years devote many effort to usage technology of regeneration energy sources

# The projects about clean coal and efficient usage technologies

- 10 sub-fields and 83 projects related to energy
- 15 related to clean coal and efficient utilization; 18 to second energy (power, hydrogen, fuel cell)
- The most important: coal-fired power plants in supercritical condition; multi-products technology based on coal gasification; direct and indirect liquefaction of coal; wetness DeS technology of flue gas ; coal gasification technology in air flow bed ; combustion technology in heavy gas turbine et al

# Research and development of clean coal and efficient usage technologies

- In future 15 year more than 1 trillion RMBY will invest into coal chemical field: 50% for equipment 10% for software.
- 2000 tons /d gasification reactor; large-scale air compression engine; large-scale synthesis reactor et al.
- Priority topics in “863 plan”; : clean and efficient usage ,liquefaction and multi-products production of coal; IGCC generation technology and equip; conversion technology of coal; construct a demonstrate engineering for technology of multi-products system based on coal gasification

# Technologies of clean and efficient usage of coal

- Clean exploiting technology
- Pretreatment technology
- Advanced fired generation technology\*
- Saving energy technology
- Conversion technology\*
- Pollutant control and treatment technology\*
- Utilization and treatment technology of wastes
- Exploiting and usage technology of marsh gas
- Utilization and fixing technology of CO<sub>2</sub>

# Pretreatment technology of coal

- Washing and selecting of coal, shaping coal and coal water slurry.
- Improving quantity of coal,
- Reducing emission of pollutants
- Raising combustion efficiency,
- Saving amount and cost of transport
- Stead of a port of liquid fuel
- Pretreatment above 50% of coal output in 2010
- Some new technologies developed and used

# advanced technologies of coal combustion

- More than 85% of coal could be combusted
- Improving burner/furnace
- Developing mainly cyclic fluidization bed: AFBC、PFBC、A-PFBC
- Developing clean and efficient technologies of combustion used and developed: supplying oxygen at different port of burner, rich oxygen combustion, re-combustion, burn with high temperature air, burner of low NOx formation, SCR technology , spouting of adsorbent, wet scrubber for de-SO<sub>2</sub> et al
- Large power set (0.6-1m kW) , IGCC, IGFC, super critical power set(38-40%, 600°C), super-super critical power set(40-50%, 700°C, Shandong and Zhejiang )
- 120MWe and 200MWe IGCC (gasification-deS and de-ash at high temperature- gas turbine- exhaust-heat boiler- stream turbine) to be developed: electric efficiency 50-52%, DeS 99%, very low NOx emission (with FC, electric efficiency > 60%)

# Potentiality and goal of saving energy

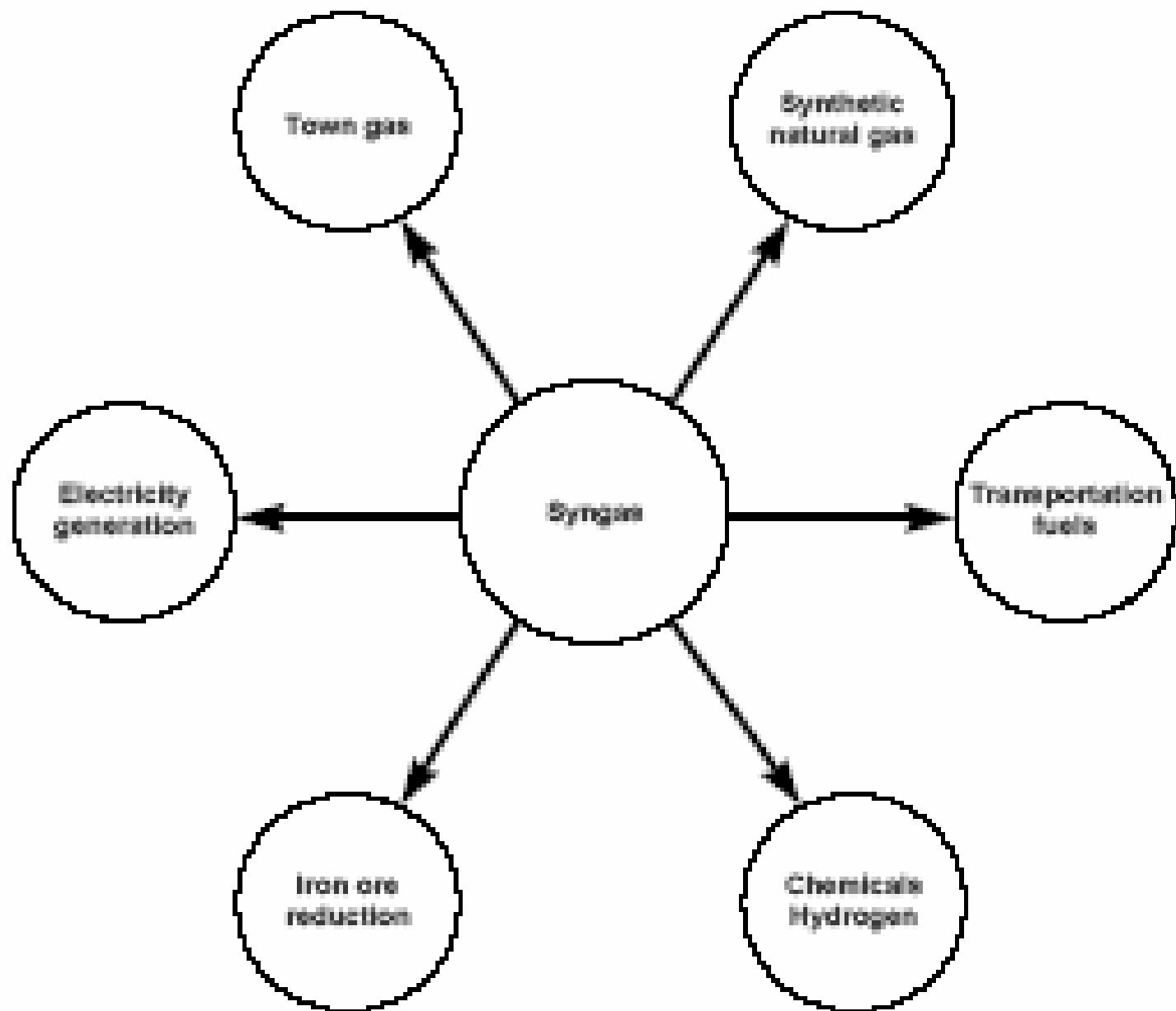
- Saving energy 20%, Saving 240 m S-coal during “eleven five”, drop from 1.22 in 2005 to 0.98 tons/10000RMBY GDP in 2010
- Saving energy projects in “eleven five” save, 5 big projects related to coal burning.
- Burner/furnace improvement, local heat and electricity co-production, residual-heat and –pressure utilization to replace petroleum, optimization of energy system, systematic energy conversion and environmental friendly lighting
- Multi-product technology: electrify, heat, liquid fuel, chemicals, coke, hydrogen et al

# Multi-products co-production technology

- Multi-products could include electricity, gas, tar, oil and chemicals
- Improves the efficiency of energy sources
- Increases their relative values
- Several multi-products co-production systems, such as synthesis oil, large syn-gas turbine as well as oil-electricity co-production unit, are currently under demonstration

# Gasification of coal

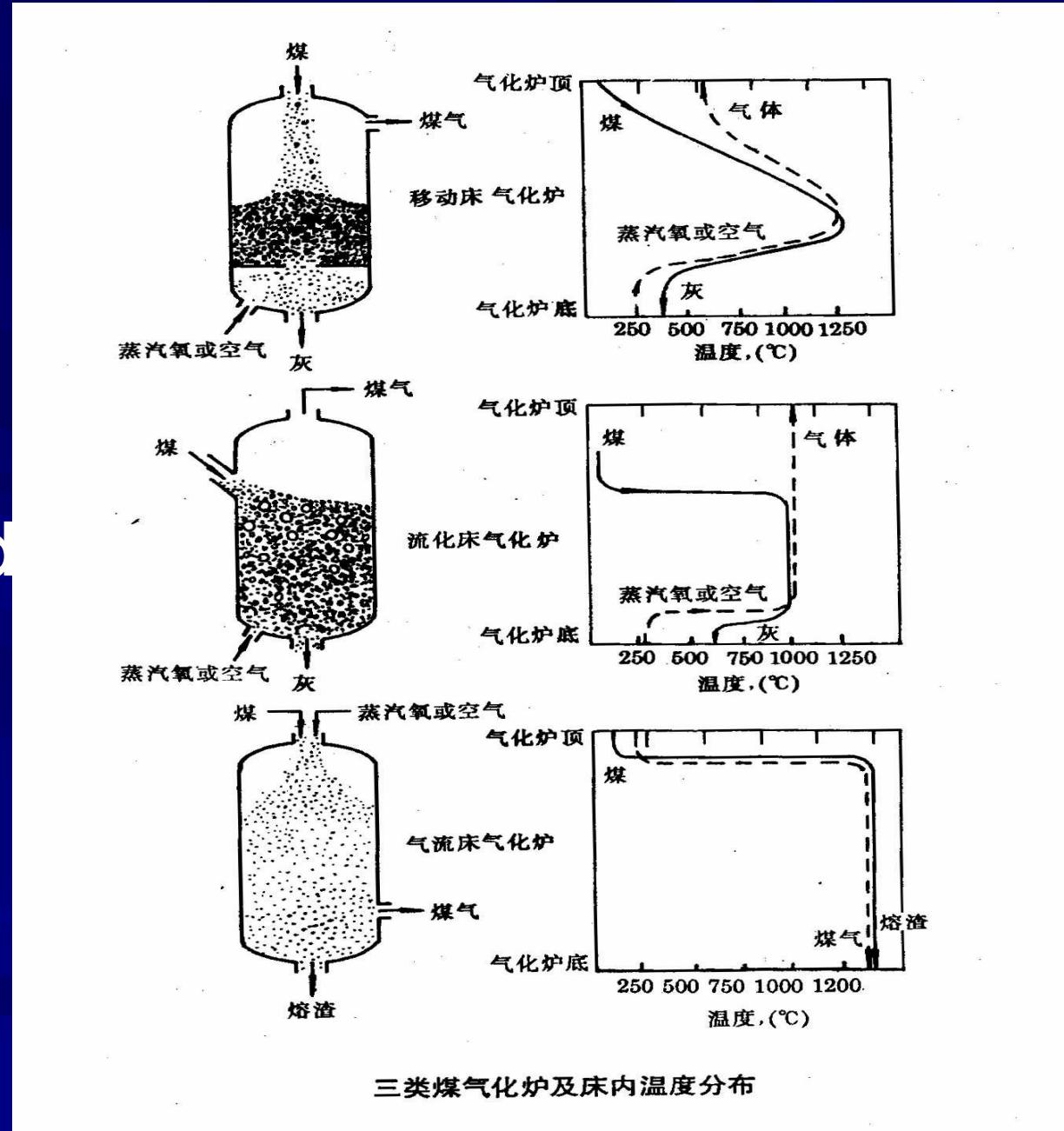
- Coal gasification is key technology for the processes of liquid fuel, chemicals, IGCC et al
- 60-75% of process investment
- Gasification furnaces: moving bed (small capacity 4-15MW heat) ; fluidized bed (middle scale 15-200MW heat) ; air steam bed ( large scale >200MW heat, key technology)
- in the world 117 of Integrated coal chemical-energy factory based on coal gasification, 385 Gasification furnaces, total capacity 45 m kW
- 49% of raw material is coal, 36% petroleum coke。 37%for chemical products, , 36% for liquid fuel



# Fluidized bed

## air steam bed

# moving bed



Lurgi

HTW  
KRW  
ICC

Texaco  
Destec  
Shell  
Prenflo

# Typical coal gasification conditions

	Moving bed	Fluidized bed	Entrained flow
Coal type	non-caking	non-caking	all
Feed system	dry	dry	dry or wet
Particle size	5-80 mm	1-5 mm	<0.1 mm
Residence time	15-30 min	5-50 sec	1-10 sec
Oxidant	air or oxygen	air or oxygen	oxygen
Minerals removal	slag or ash	ash	slag
Syngas temperature	800-1100 °C	800-1000 °C	1200-1700 °C
Syngas pressure	1-30 bar	10-25 bar	20-80 bar

# Coal gasification in domestic

- Very old fixed bed gasification furnaces is the most, more than 4000 sets, use lump coal, low efficiency
- Almost all gasification furnaces (Lurgi, U-gas (6 sets), Texaco (> 20 sets), Shell(15 sets) and USP was introduced.
- Through digestion, assimilation and master, ash melt agglomeration gasification process is in the stage of commercial application
- A demonstration factory (1150 tons per day) of pressured gasification of powder coal is operating success.

# Coal gasification in domestic

- It is going on that industrial factory design, test and operation and demonstration
  - # coal slurry gasification (2000 tons/d)
  - # pressured gasification of dry power coal (2000tons/d)
  - # pressured gasification of dens-phase air-flow of powder coal (600 tons/d) for engineering application of IGCC.
- It is also going on to research and develop
  - # the gasification technology of underground coal
  - # spouted bed technology for utilization of low heat value coal and industrial wastes.

# Air steam bed

- Coal powder or slurry carried by steam and oxygen pour into furnace and fire, temperature can up to 2000 °C and coal gasification and ash melt
- Features: any kind of coal, contacting time only 1-3 second, high carbon conversion, very low content in slag, slag discharge simple, no waste water involving phenol ; oxygen consumption high, heat loss large, low heat value because low methane
- As head in multi-products co-production systems

# Texaco and Dow ( Destec ) process

- Coal-water slurry and oxygen gasification, liquid slag discharge
- About 80% of CO+H<sub>2</sub> in coal gas, carbon conversion 96-99%
- Tampa, power capacity 250MW, 2000 ton coal/d
- Introduced more than 20 sets
- In domestic, after some improvement , performance ( oxygen and coal consumption and coal gas composition) better than Texaco furnace

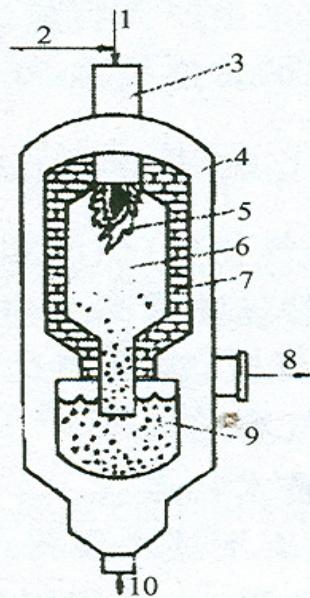


图 1 德士古气化炉中气化部分的结构示意图

Fig. 1 Structure scheme of gasifying parts  
in Texaco gasifier

1—Coal water slurry inlet; 2—O<sub>2</sub> inlet; 3—Burner  
4—Pressured shell; 5—Burning flame; 6—  
High temperature reaction zone; 7—Firebrick  
lining; 8—Gas outlet; 9—Slag basin;  
10—Water slurry slag outlet

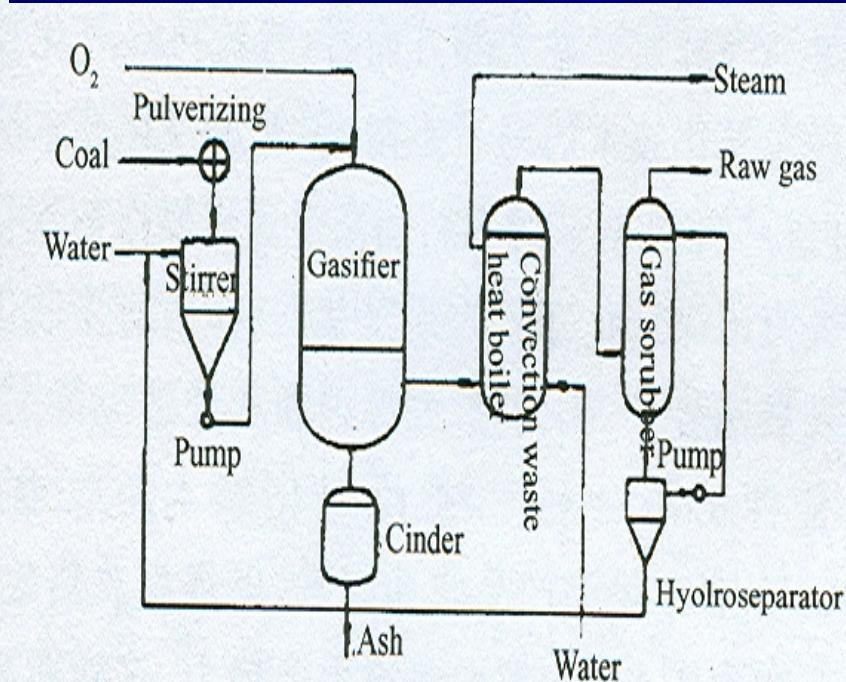
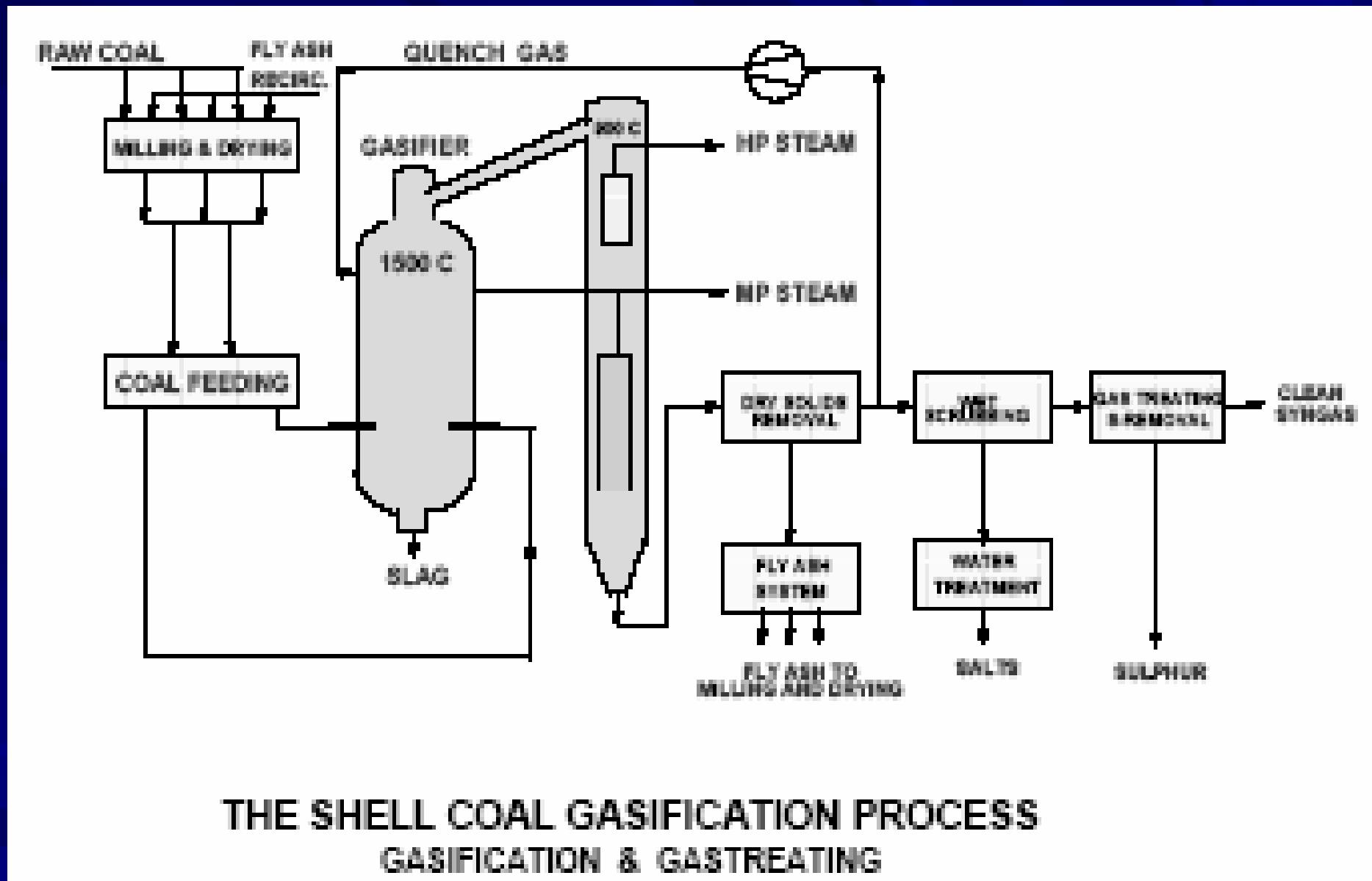


图 2 德士古气化法的典型流程图

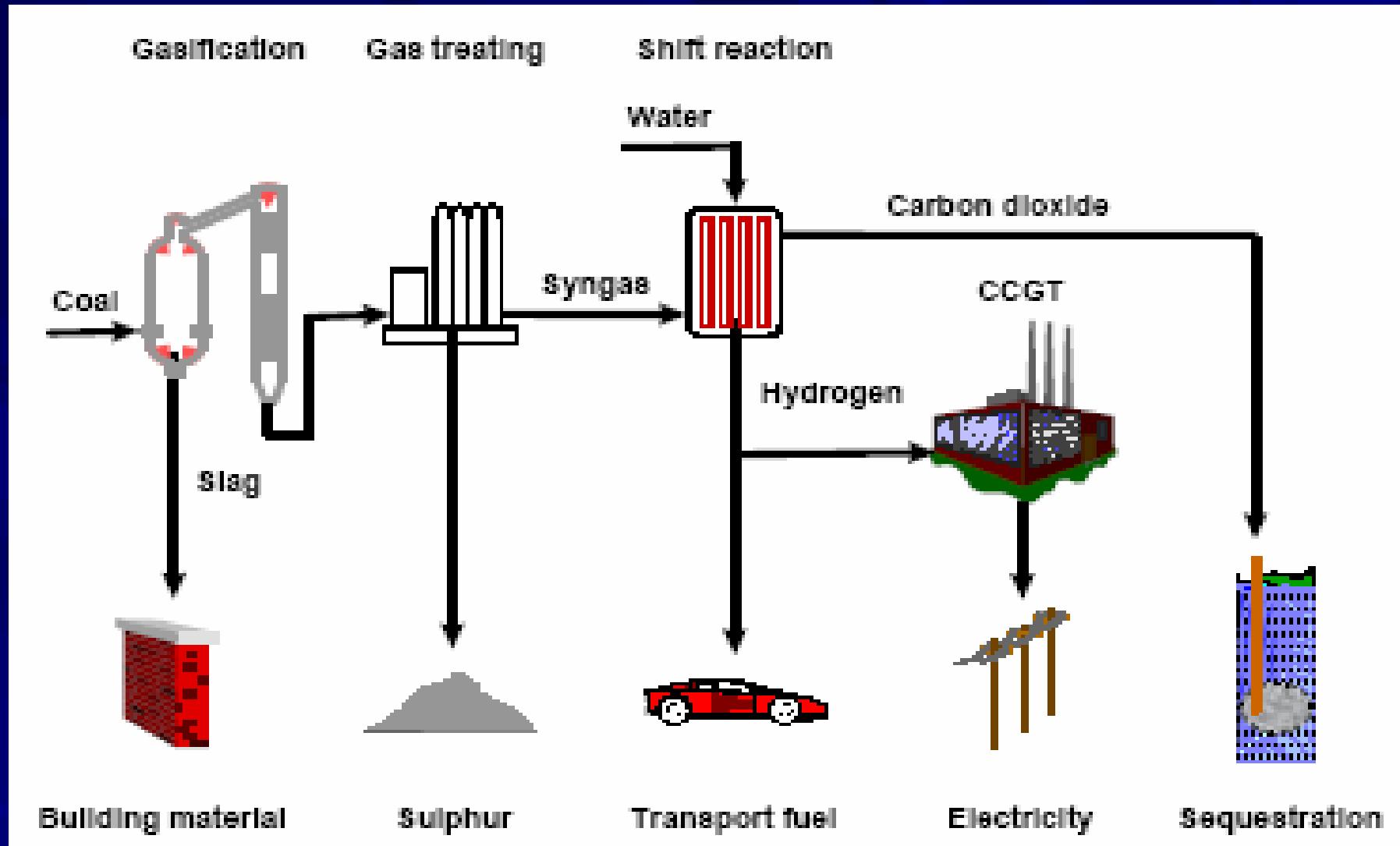
Flow sheet of Texaco gasification process

# Shell, Kropp and Prenflo gasification furnace

- Kropp: only in Buggenum for IGCC, capacity 250MW , 2000 tons coal/d
- Prenflo: capacity 300MW , 2600 tons coal and oil/d
- Introducing 15 set, Hubei 2006/5/17 operating, 900 tons coal/d, for ammonia synthesis
- Anhui, to introduce GSP furnace for coal with high ash melt point



**THE SHELL COAL GASIFICATION PROCESS**  
**GASIFICATION & GASTREATING**



Sustainable coal utilization

# Spouted Bed

- Used for combustion and gasification of low heat vale coal and industrial wastes
- Research and develop in some groups in USA, UK, Canada and some universities and institutes in domestic

# Analysis and selection of coal gasification processes

The comparison of cold coal efficiency and the process efficiency

	Lurgi <sup>a</sup>	HTW	KR W	AFB	Shell	Texaco <sup>b</sup>
cold coal efficiency	79.9	82.4	80.7	73.9 (78) *	80.7	76.8 (70)
process efficiency	–	76.7	73.8	68 (72) *	71.0	67.2 (68)

a: Large particle coal, complex clean system of coal gas

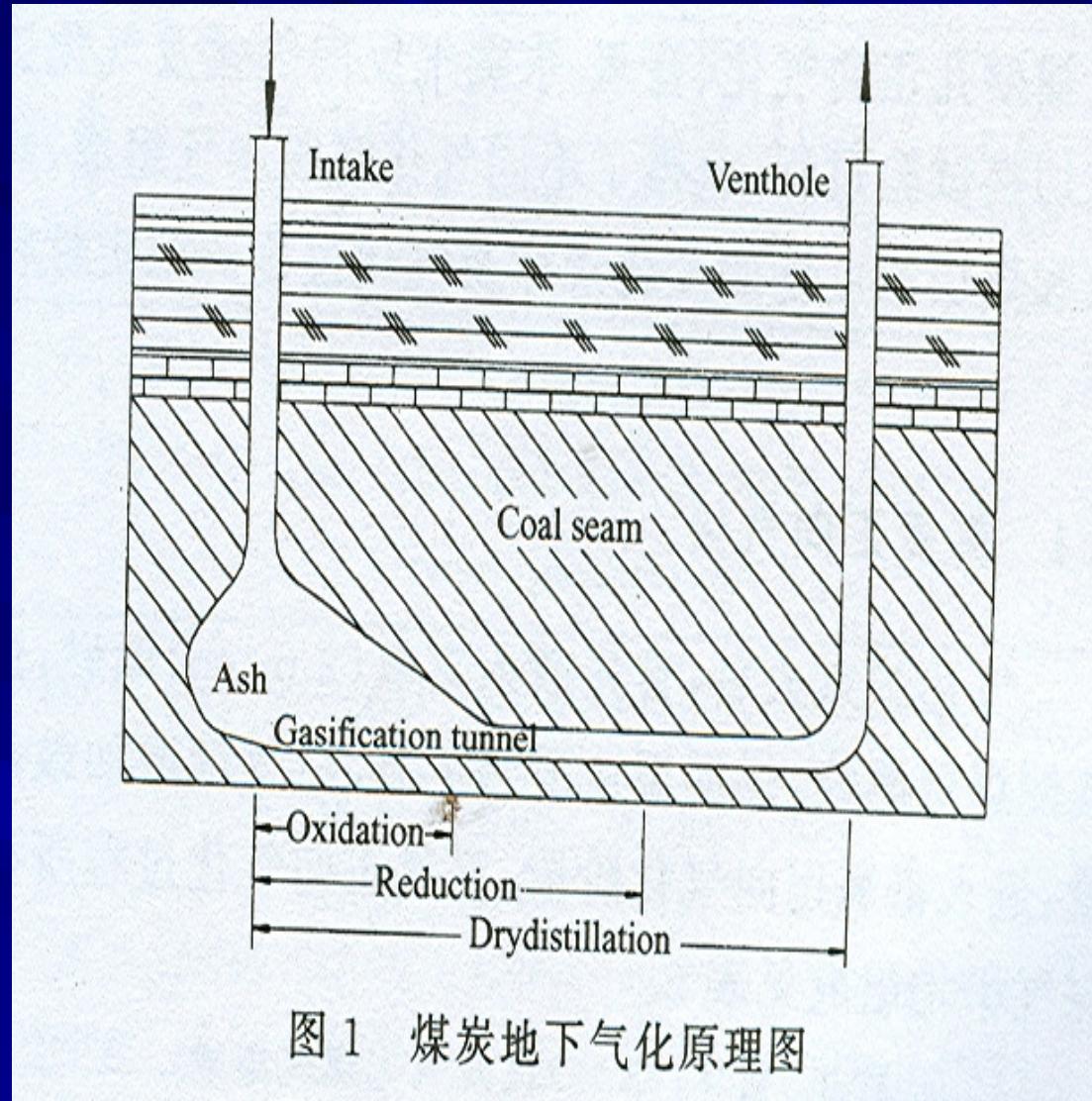
b: Concentration of Coal slurry: 66.5% (62%)

\* recover 10% residual carbon

# gasification underground coal

@developed in Russian and USA, cost down 30% for syn-gas, 27% for power, 50%for space, 37% for metal consumption

@ domestic, developing new process and industrial test success in Xuzhou and Tangshan as well we Taiyuan



The principle of gasification underground coal

# coal direct liquefaction

- NEDOL from Japan, PSU test with Yilan coal in Heilongjiang , success;
- Coal-oil co-refine of UOP, fundamental researches
- The prior work, Pingdingshan coal in Henan, Zalannuoer in Inner-Mongolia , entered in the stage of project proof
- Also going on for coal from Guizhou, Shandong, Shanxi and Ningxia.

# coal direct liquefaction

- A hot point in Mainland
- Shenhua' process

# A factory is constructing in Inner-Mongolia, 1million finishing-oil /y in first term , finished in 2007 in schedule

# Total invest 25 billion RMBY , 5 million finishing-oil /y , consume 15 million ton coal/y

- New IGOR process from Germany

# Construct a factory, Xianfeng coal , Yunnan,

# Total invest 10.425 billion RMBY , produce 0.8828 million tons gasoline and diesel oil and 67.5thousand tons LPG/y, consume coal 5.1million ton/y

# coal indirect liquefaction

- hydrocarbon fuel : 1.5, 10(4%), 30(10%) million tons in 2010, 2015, 2020
- alcohol- ether fuel : DME (dimethyl ether) 5 ,12, 20 million tons
- Methanol 11.7(16), 33(38), 54(66) million tons in 2010, 2015, 2020

# fixed and slurry bed F-T technology ( Institute of Coal Chemistry, Chinese Academy of Science )

- # industrial slurry reactor , total operation time more than 6000 hours
- # high quality paraffin , diesel oil ( 70-78 of cetane value )
- # more than 10000 km road driving test , oil consumption down 8-12% pollutant emission better Euro 4 standard
- # New higher temperature process , new generation F-T process
- # Three demonstration projects started in 2005 , 160-200 thousand tons diesel oil/y
- # the first demonstration factory will begin to operate in Inner-Mongolia or Shanxi province in 2008.

**First vessel drive with 100%  
synthesized diesel oil, >10000km  
cetane value > 70  
EU III 2.0 engine,  
4.5 liter/100 km  
No smoke, no sulfur, no smale**



# Commercial of syn-oil technology

- 3 demonstration projects was started in 2005, 160-200 thousand tons diesel oil/y
- The first demonstration factory, to operate in Inner-Mongolia or Shanxi province in 2008
- **2008-2012: 2-3 industrial plants, 2 million tons/y**
- **2013-2016: capacity 10 million tons/y**
- **2007: catalyst production 1.500 southand tons/y**



# coal indirect liquefaction

- Yanzhou Group, F-T technology is also developed with an institute in Shanghai.
  - # in April of 2006 in Yulin of Shan'xi , construct prior demonstration engineering, 1 mt gasoline and diesel oil/ y
  - # total invest 2 billion RMBY
- Shenhua Group,
  - # to introduce the F-T technology of South Africa
  - # government will invest a lot of money to construct two large “coal change oil engineering in Shan'xi and Ningxia to relieve shortage of petroleum supply
- central government issued a public notice, it was told that project of coal chemical engineering less than 3 million ton/y can not be approved no longer. For alcohol- ether fuel,

# coal indirect liquefaction—alcohol-ether fuel

- Methanol, dimethyl ether (DME)
- 2010, 2015, 2020: 1.5, 10(4%), 30(10%) Mt oil from coal
- 2010, 2015, 2020: DME 5,12,20 Mt
- 2010, 2015, 2020: Methanol 16,38,66 (94%) Mt
- Three tubes for transport of alcohol-ether fuel

# Engineering projects for coal to oil

- Shenhua Group: invest in Shan'xi, Inner-Mongolia, Ningxia and Xinjiang.
- Yanzhou Group: invest in Shan'xi and Guizhou
- Lu'an Group: Shanxi
- Yitai Group: Inner-Mongolia
- Center government will used the technology from South Africa : Ningxia and Inner-Mongolia

# Engineering projects for coal to oil

- Ningxia coal group
- Datong coal group
- Heilongjiang: Yilan and Shuangyashan
- Yunnan: Xianfeng
- Guizhou: Liubanshui
- Inner-Mongolia: Xilingule
- Henan : chemicals
- Shanxi: chemicals
- USA and UK invest in Shan'xi
- Now the project less than 3mt cannot approved by goverment

# control of pollutant emission and the treatment of wastes

- Total goal is to reduce or to eliminate emission of pollutants such as chimney, SO<sub>2</sub> and NO<sub>x</sub> et al
- There are technologies before, in and after
- Before burner: washing/selecting coal, shaping coal and coal-water slurry, bio-deS and supercritical deS
- In burner, clean combustion: pouring into desulfurating reagent, injecting oxygen at different ports of burn/furnaces, mixing gas and oil burning, reducing emission of NO<sub>x</sub>, chemical loop burning et al
- After burner: deS and deNO<sub>x</sub>, SCR-deS, deS of coal-gas at high temperature and electrostatic precipitation et al.

# control of pollutant emission and the treatment of wastes

- end of 2005, the generator capacity with deS equipment (is in operation) 53 million kW, 10 factor to 2000
- another 100 million kW constructing. The technology used is more than 10
- more than 90% use lime-gypsum wet technology.
- The cost of deS engineering has been decreased to 200RMB Y/kW from more than 1000RMB Y

# R e m a r k s

- Clean coal and efficient usage technologies is essential and very important for Mainland China, because not only in order to keep rapid development of national economy and environment protection as well as to carry out sustainable development strategy , but also to be determined by mainland situation of vast territory and condition complicated and varied as well as of coal as main primary source.
- The government and enterprises have invested and will invest huge manpower, materials and financial resources to research and develop clean coal and efficient usage technologies from the pretreatment and efficient combustion of coal, saving energy to the gasification and liquefaction of coal and the control and treatment of pollutants.
- It is my attempt to introduce briefly the utilization, research and development, progress as well as problems and resolution way et al.

Thank You  
for your attention !