Trend of Energy Use and Nitrogen Oxides Emissions in China

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Dec. 17, 2008, Tokyo

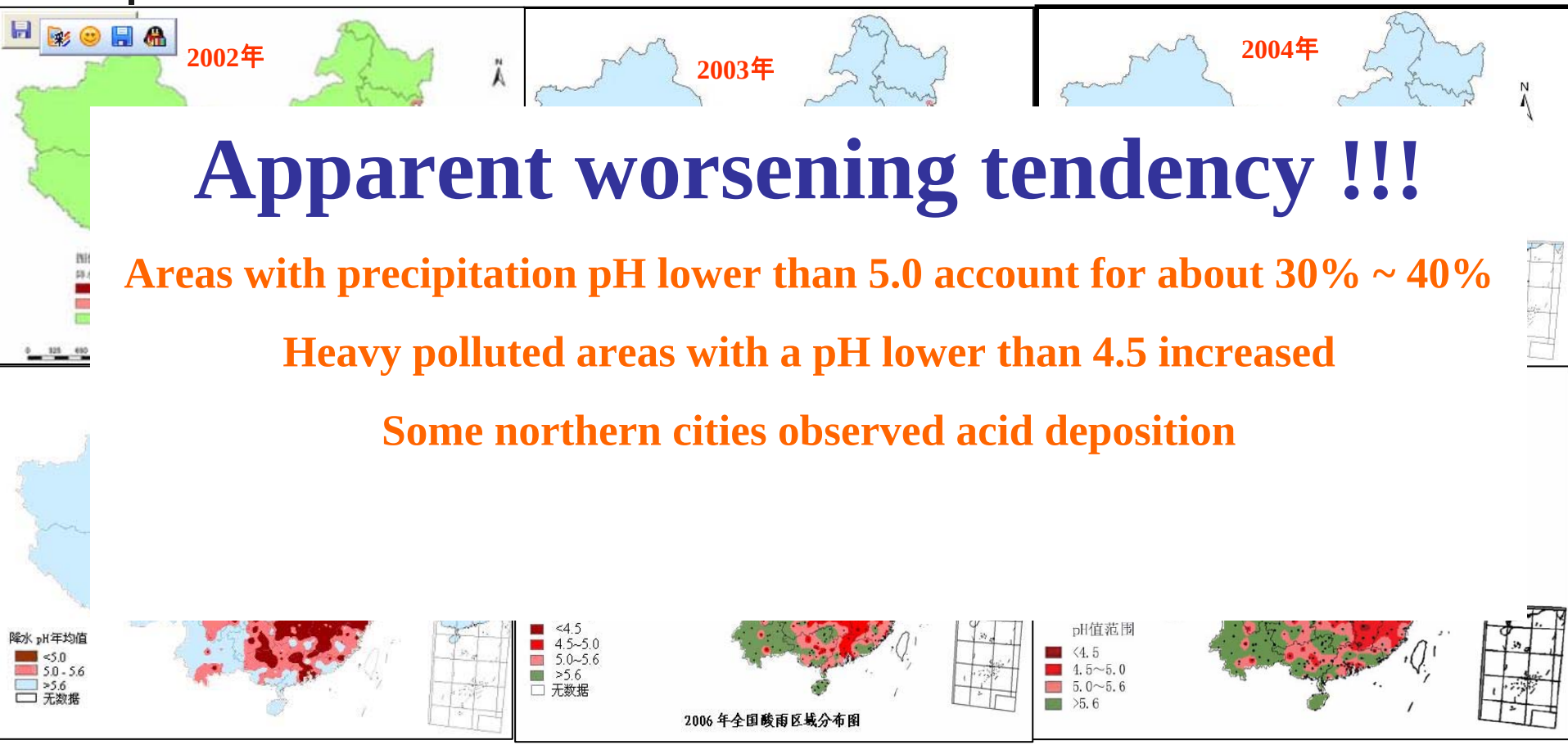
OUTLINE

- ***Background***
- **Trend of National Economy in China**
- **Trend of Energy Output and Consumption**
- **Effects on Atmospheric Environment**
- **Trend of NO_X emissions and Its Distribution**
- **Concluding Remarks**

Background

- **Owing to the continuous economic growth, China is one of the largest energy producers and consumers in the world.**
- **China is also one of a few countries whose energy mix is dominated by the high polluted fuel---coal.**
- **Large amount of coal-dominated fossil fuel burning has lead to very complex atmospheric environmental problems, such as PM_{10}/PM2.5/SO_2/NO_X/Hg/As/Se/BC/O_3/Haze, etc.**
- **China has become one of the three large areas suffering from severe acid deposition, mainly owing to huge emissions of SO_2 and NO_X.**

Averaged annual pH value in precipitation, 2002-2007



Apparent worsening tendency !!!

Areas with precipitation pH lower than 5.0 account for about 30% ~ 40%

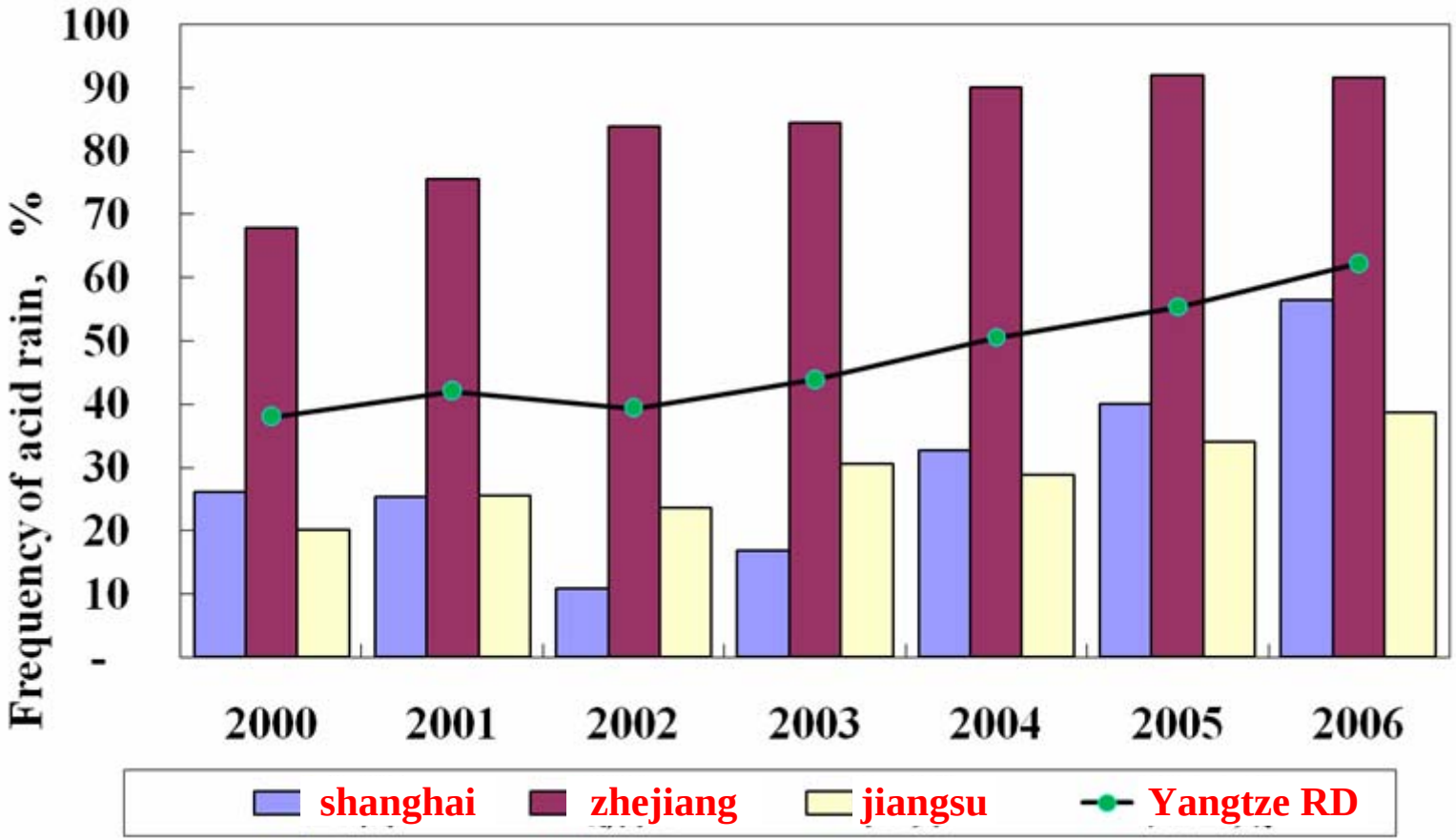
Heavy polluted areas with a pH lower than 4.5 increased

Some northern cities observed acid deposition

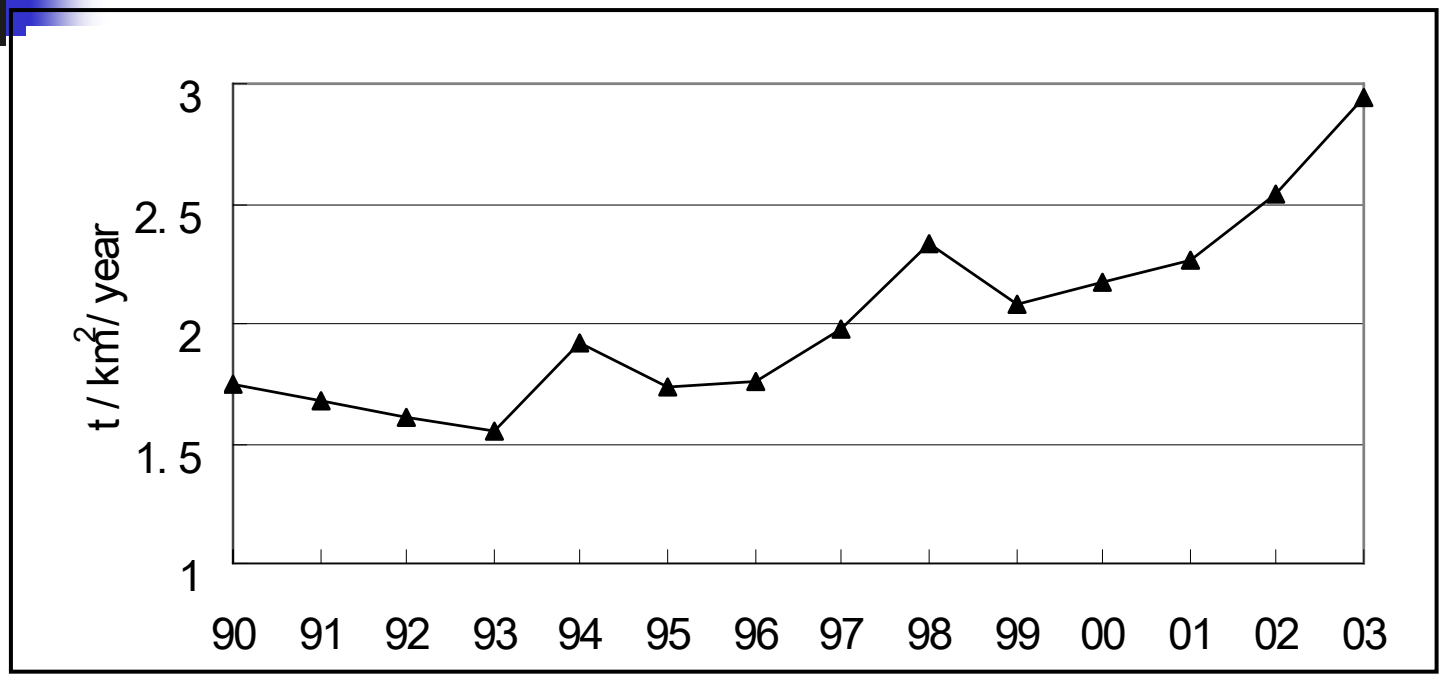
Source: SEPA

Acid Deposition

Frequency of acid deposition in Yangtze River Delta



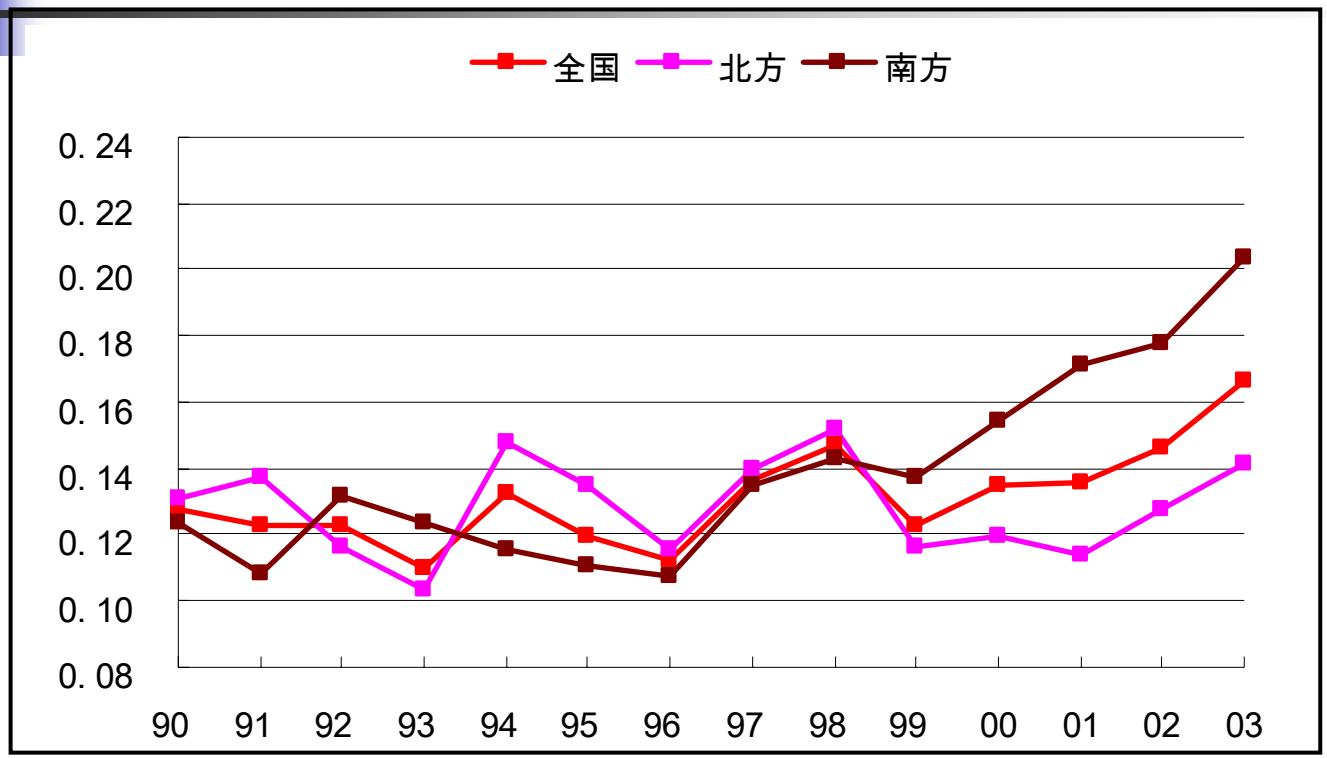
Change of NO_3^- deposition in precipitation, 1990-2003



- The averaged annual NO_3^- deposition from 2000 to 2003 is at about 2.5t/km^2;
- Increased 39% compared with that in 1990s。

Source: SEPA

Ratio of NO_3^-/SO_4^{2-} Concentration in Precipitation, 1990-2003



- Ratio of NO_3^-/SO_4^{2-} Concentration in Precipitation in the Southern areas kept rising since 1996,
- It reached about 2.0 by 2003.

Source: SEPA

Background

- **Multi-pollutants and Multi-scale pollution Co-exist:**
  - **Inferior local air quality: primary pollutant: PM_{10}/$PM_{2.5}$;**
  - **Regional acid rain: SO_2, NO_X, etc;**
  - **Regional O3 and haze pollution: Beijing, Guangzhou, etc;**
  - **Emerging heavy metals: Hg, Pb, As, Se, etc;**
  - **Global warming: CO_2 emissions, CH_4, etc**

- **It is an ever tough challenge to tackle with such a complex air pollution situation in China.**

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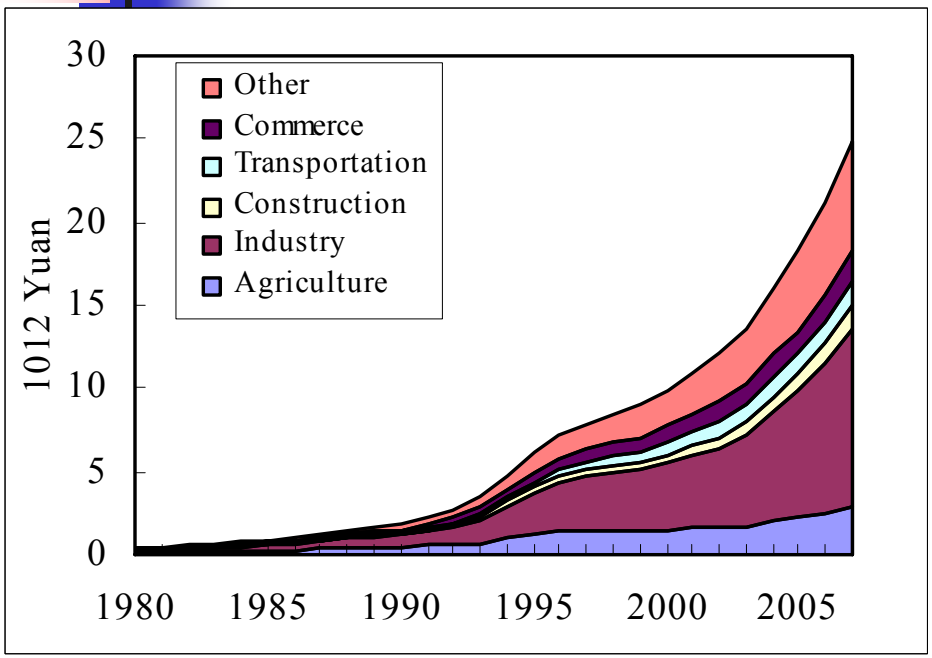
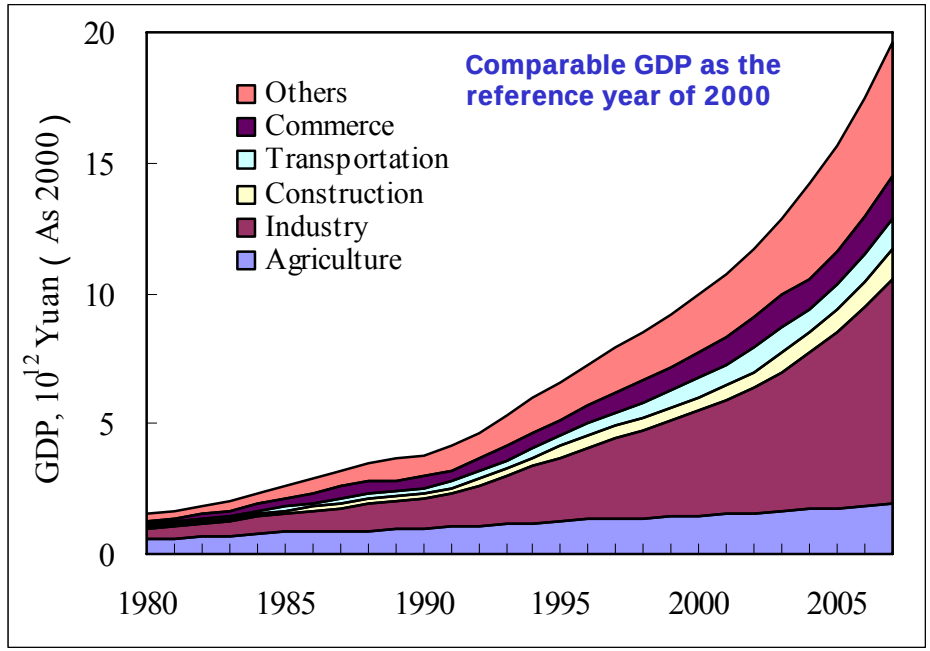
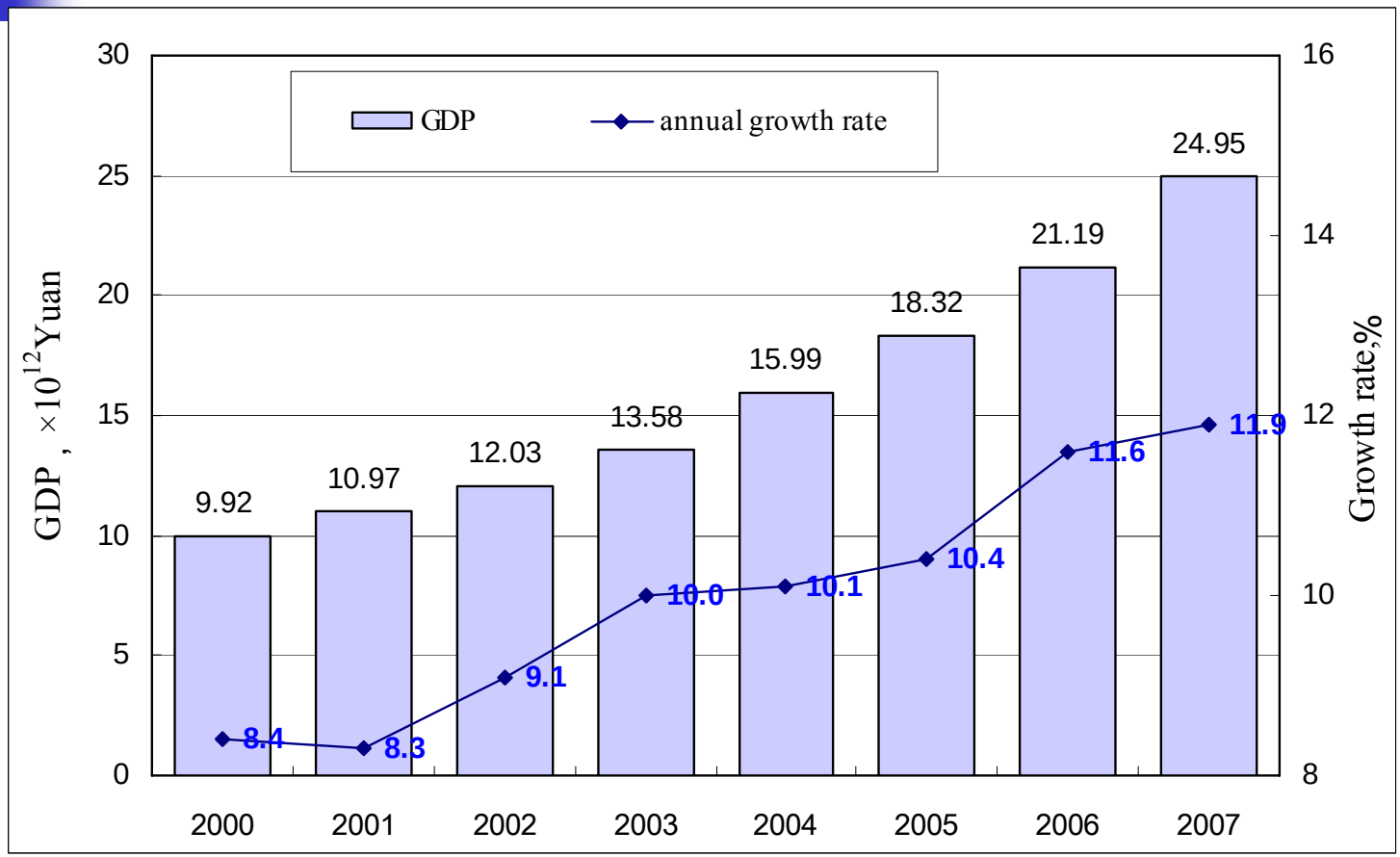
Trend of National Economy of China, 1990-2007



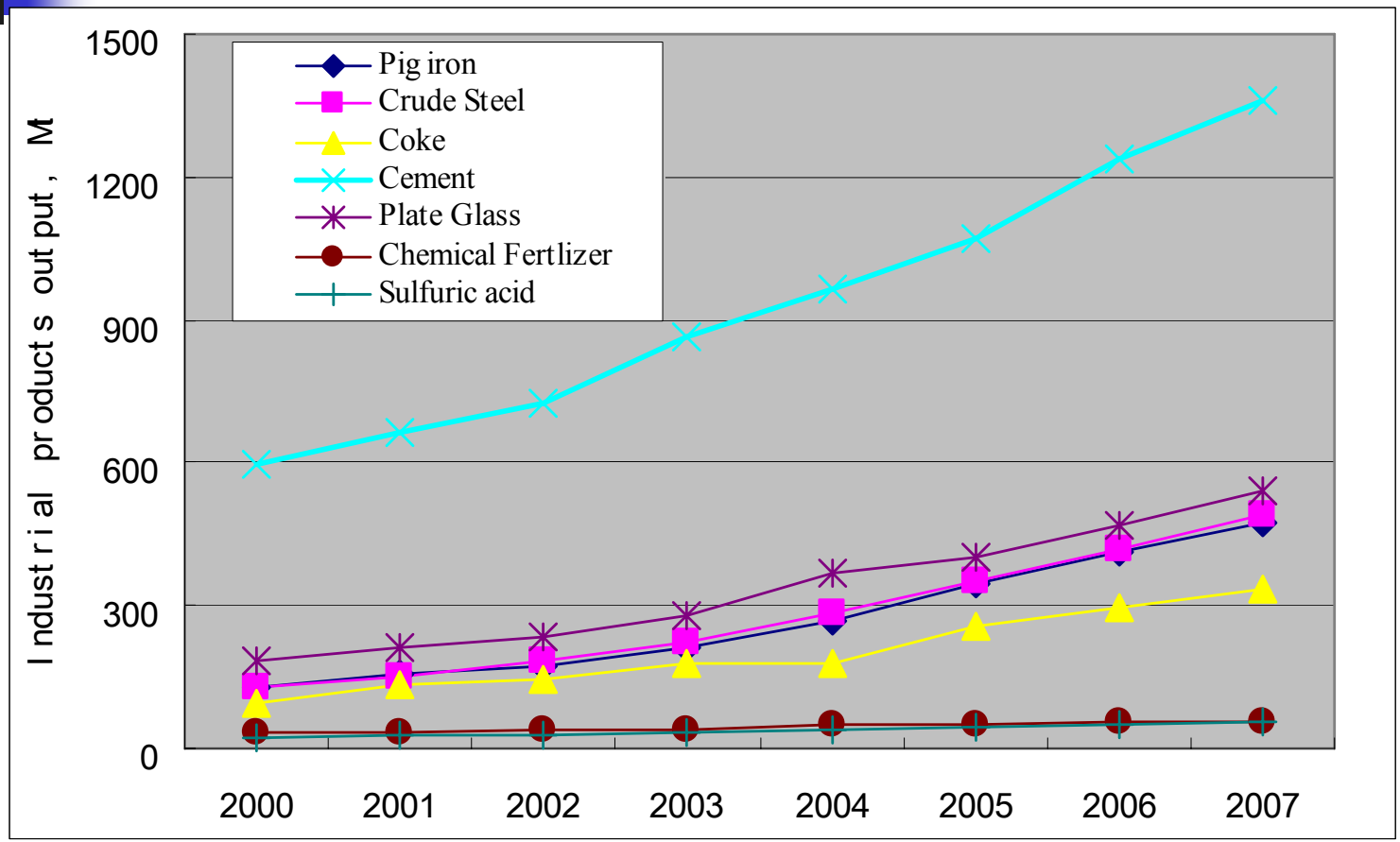


- **By 2007, China's total GDP has reached up 24953 Billion CHY, and GDP per capita has exceeded 18,934 CHY;**
- **The average growth rate from 1990-2006 reached as high as 10.35%.**

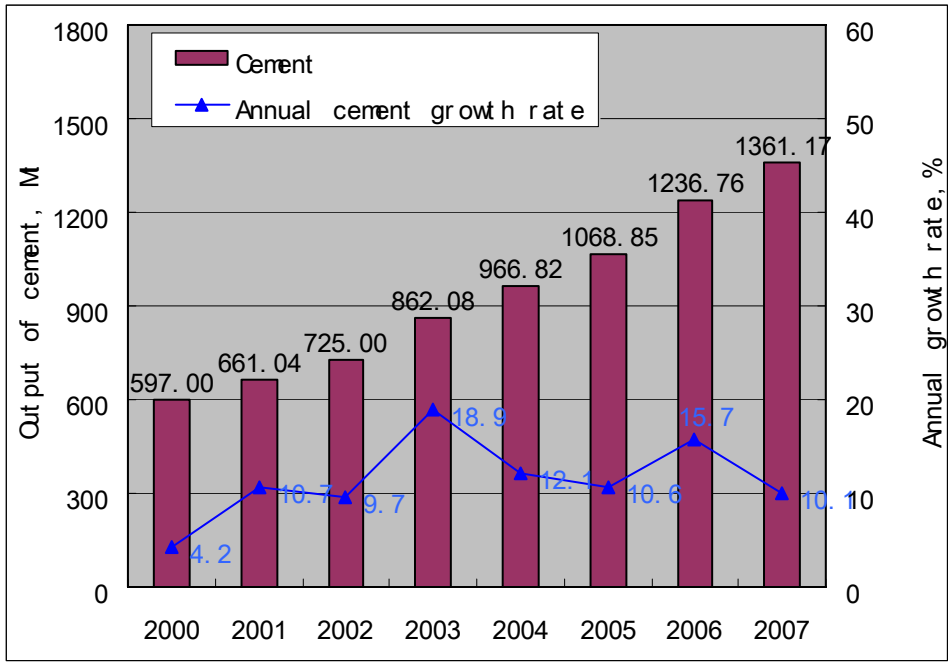
GDP growth, 2000-2007

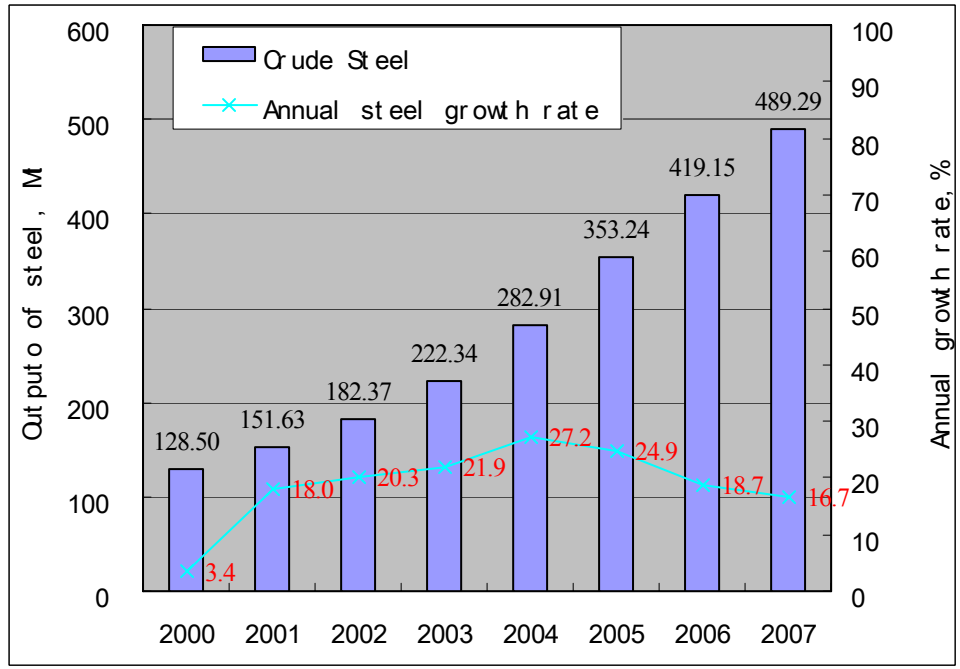


Trend of industrial products output, 2000-2007



Trend of cement and steel output, 2000-2007





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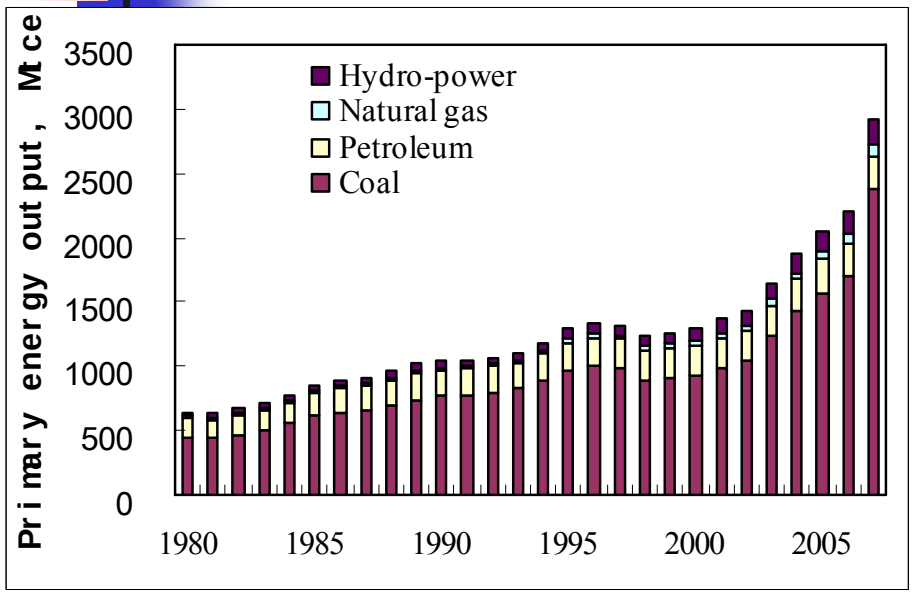
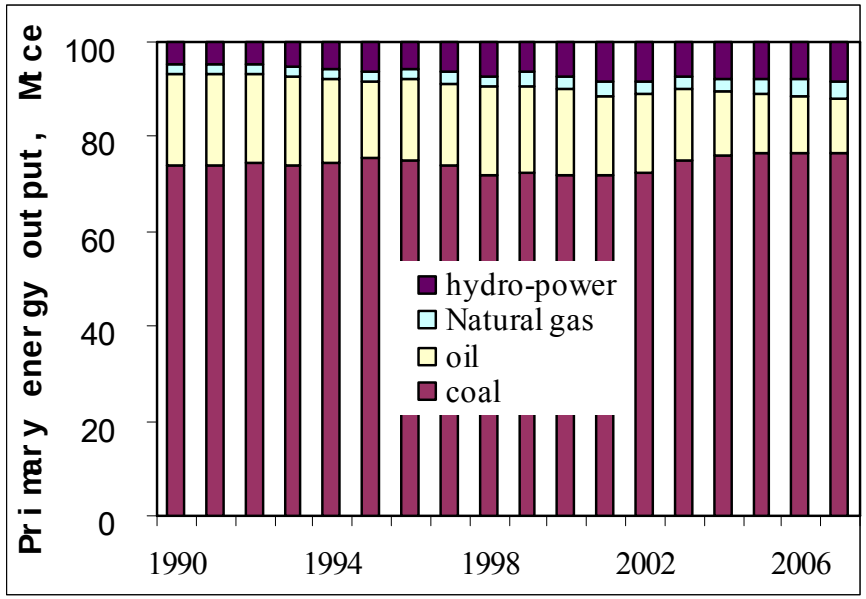
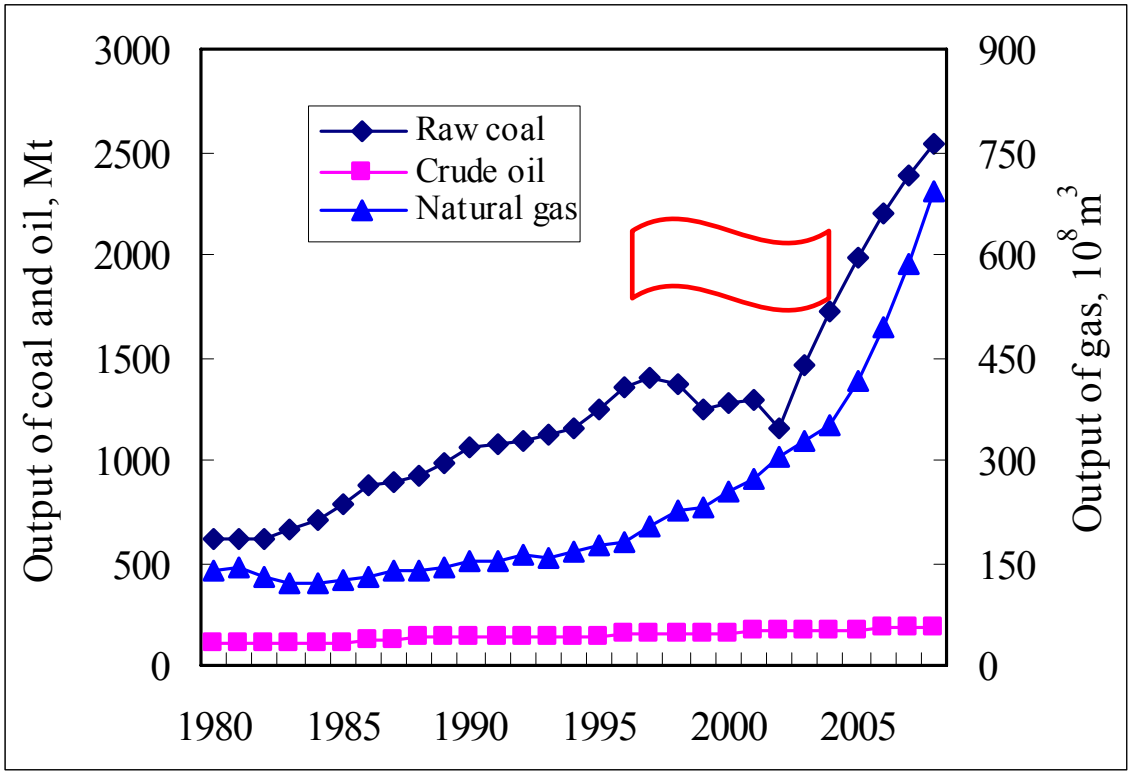
Trend of Primary Energy Output, 1980-2007





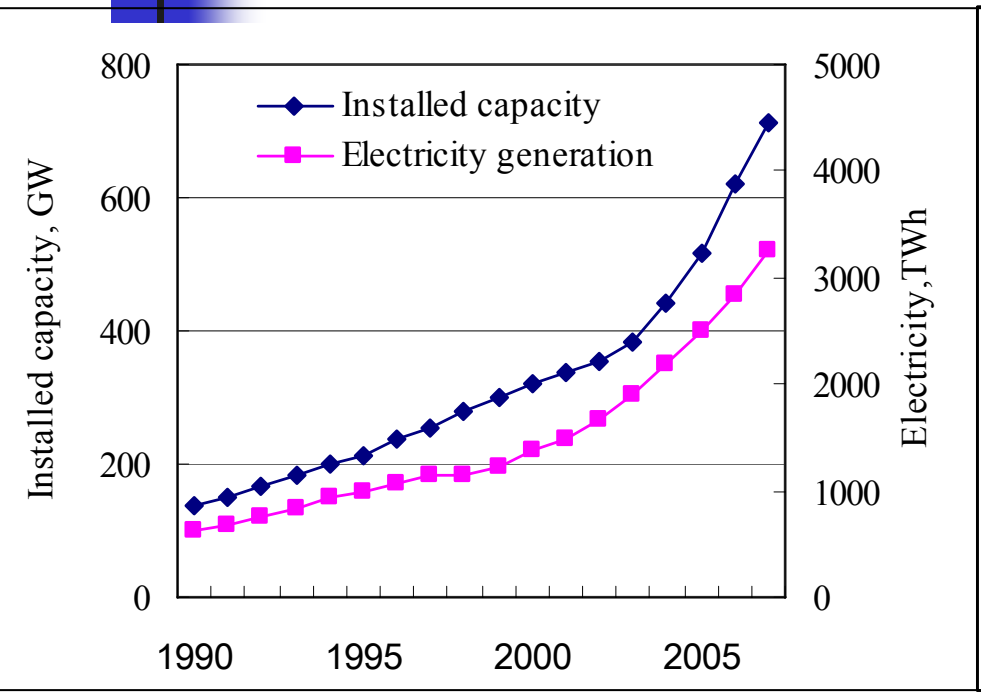
- By 2007, the total primary energy output has grown up to 2354.5Mtce;
- Coal output was 2526Mt, accounting for 76.7% of totals in 2007;
- Share of oil dropped gradually, though output of crude oil has been growing slowly, from 160Mt in 2000 to 186Mt in 2007

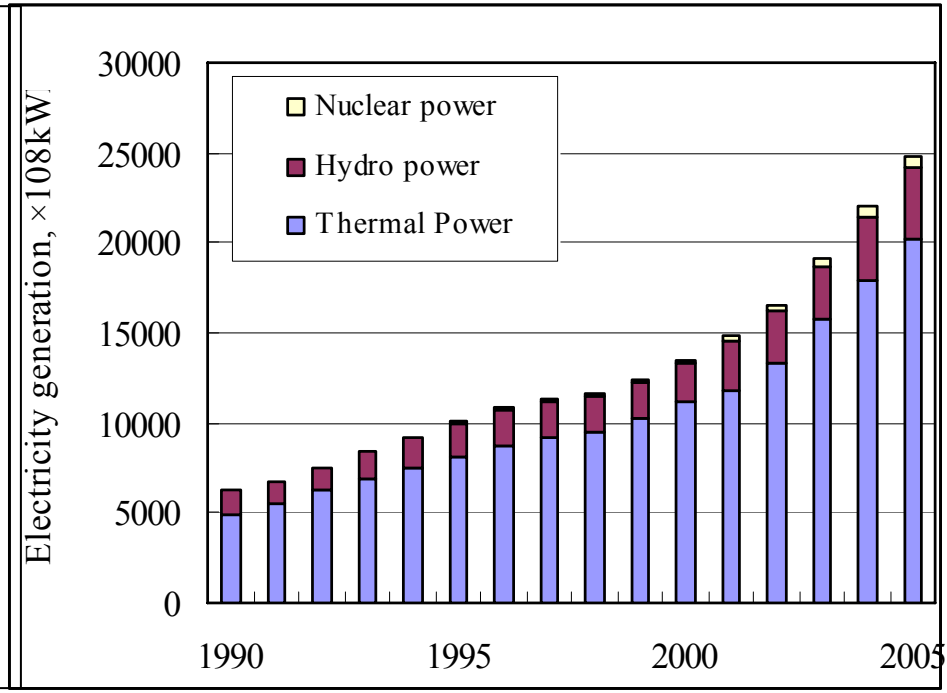
Output of coal, oil and natural gas, 1980-2007



- **Sharp change in coal production in the late 1990s;**
- **Natural gas output has been increasing in the over past 2 decades.**

Installed capacity and electricity generation, 1980-2007

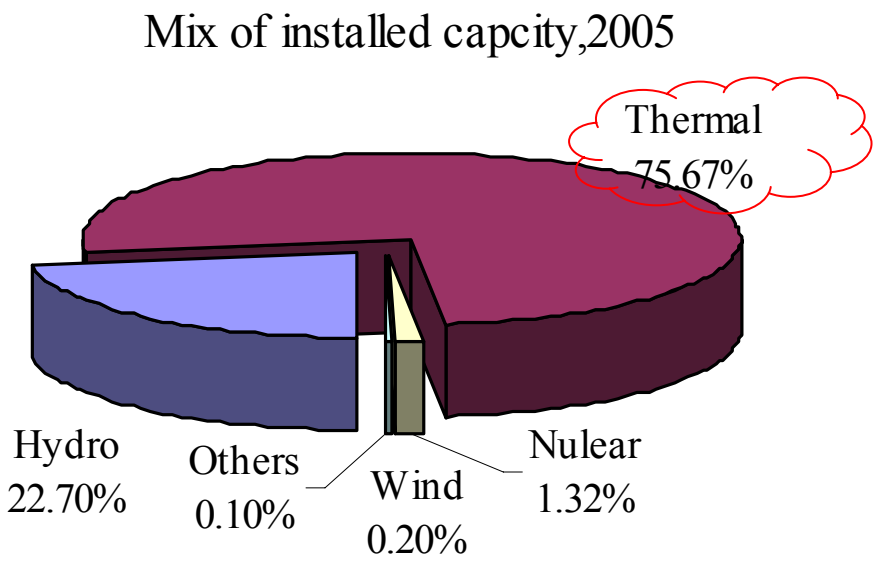


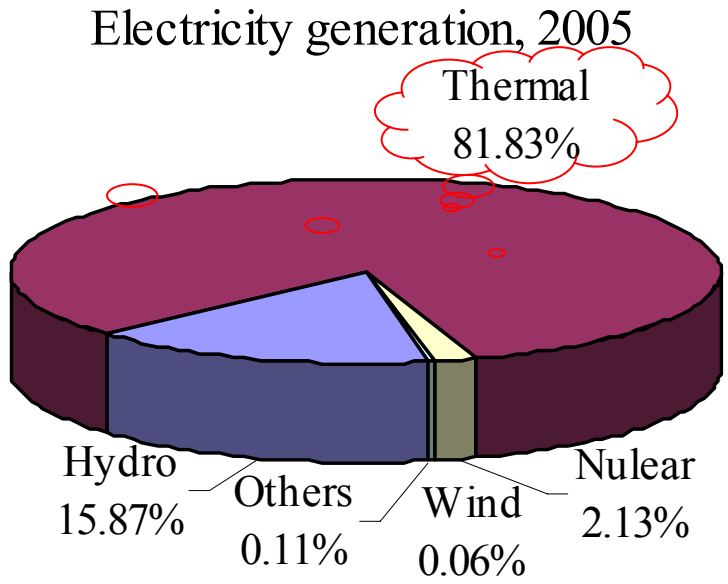


➢**By 2007, the total installed electricity capacity and generation reached at 713.3GW and 3255.9TWh, respectively.**

➢**Over 80% of total electricity generation was produced by coal-fired power plants, though electricity by hydro and nuclear power has been increasing.**

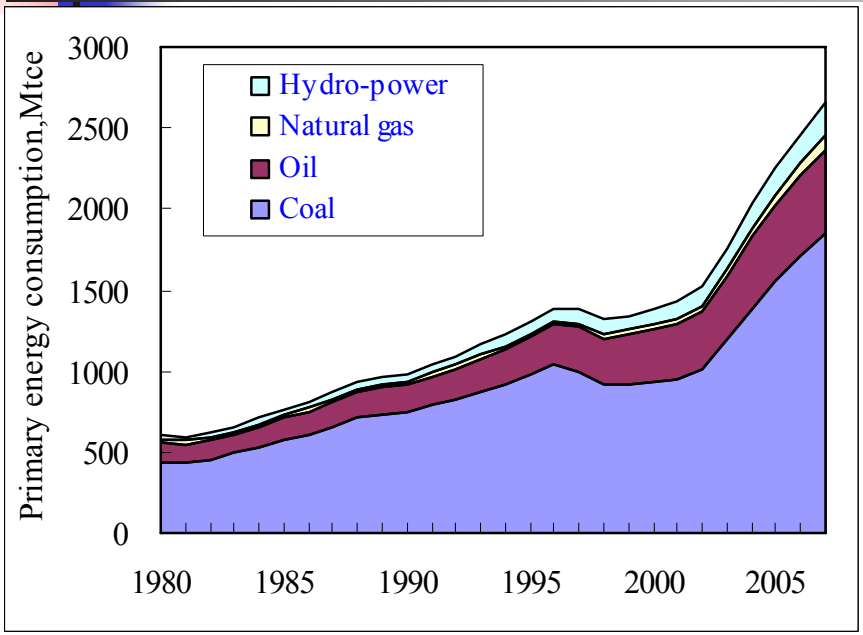
Mix of installed capacity and electricity generation, 2005

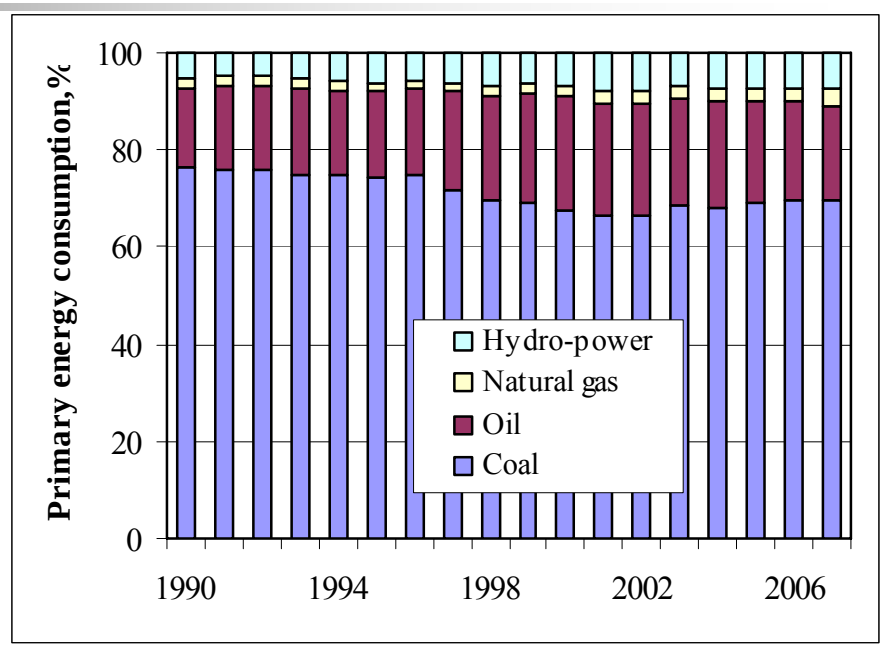




- Electricity generation were dominated by coal-fired power plants

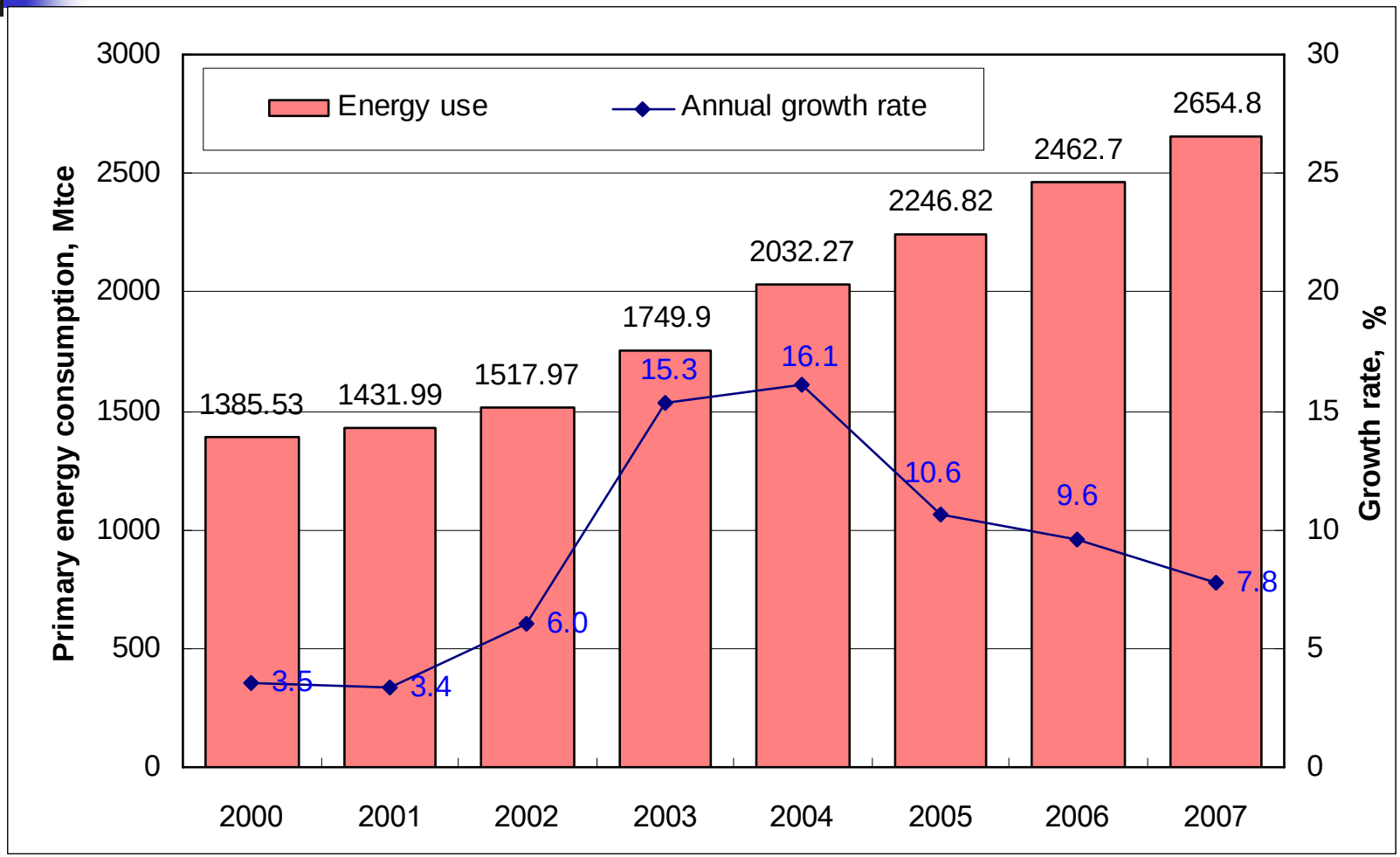
Trend of Primary Energy Consumption, 1980-2006



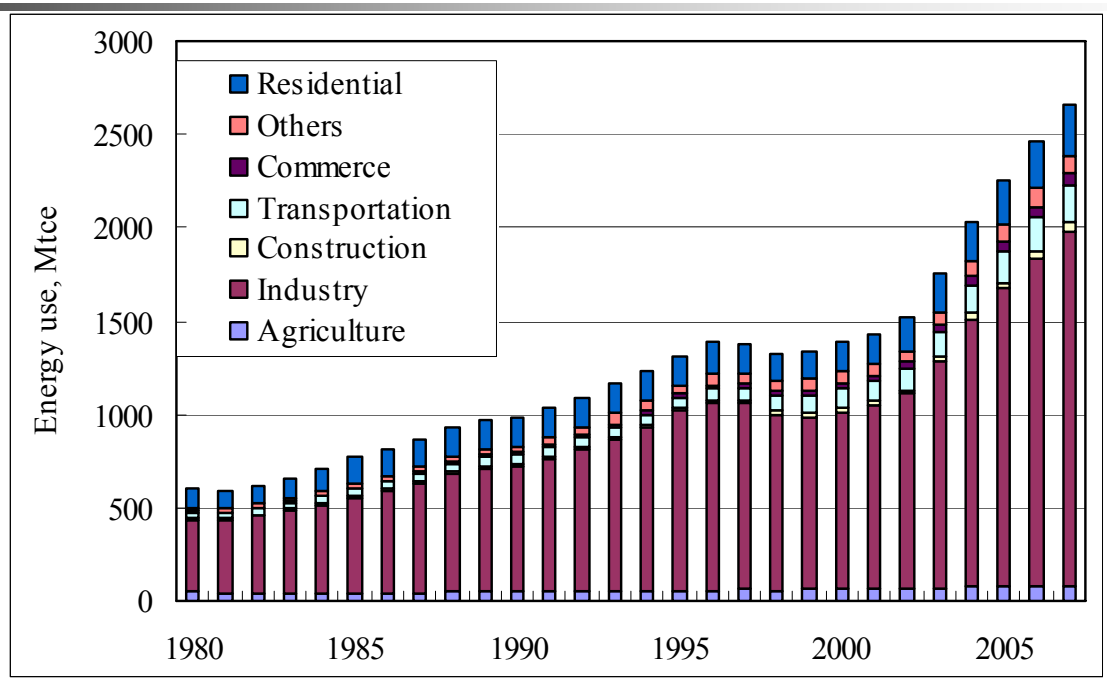


- **By the end of 2007, the total primary energy consumption has increased up to 2655.83Mtce, an average growth rate of 5.86% compared with 1990;**
- **Coal-dominated energy consumption mix, accounting for about 70% , though dropped from 76.2% in 1990 to 69.4% in 2007.**

Trend of Primary Energy Use and Growth Rate, 2000-2007

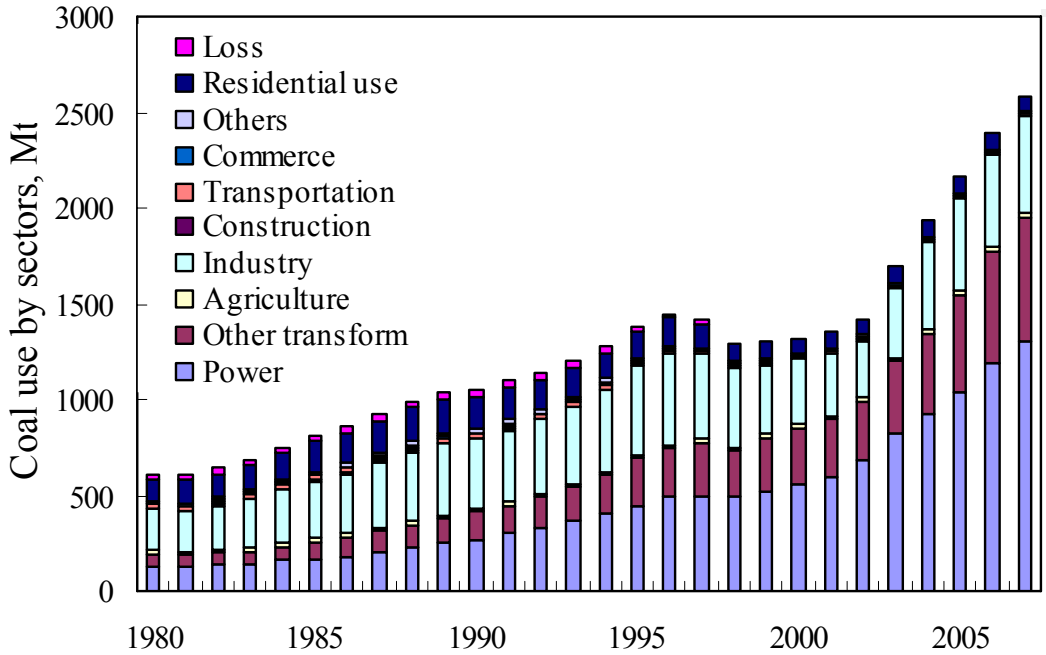


Primary Energy Consumption by Sectors, 1990-2006



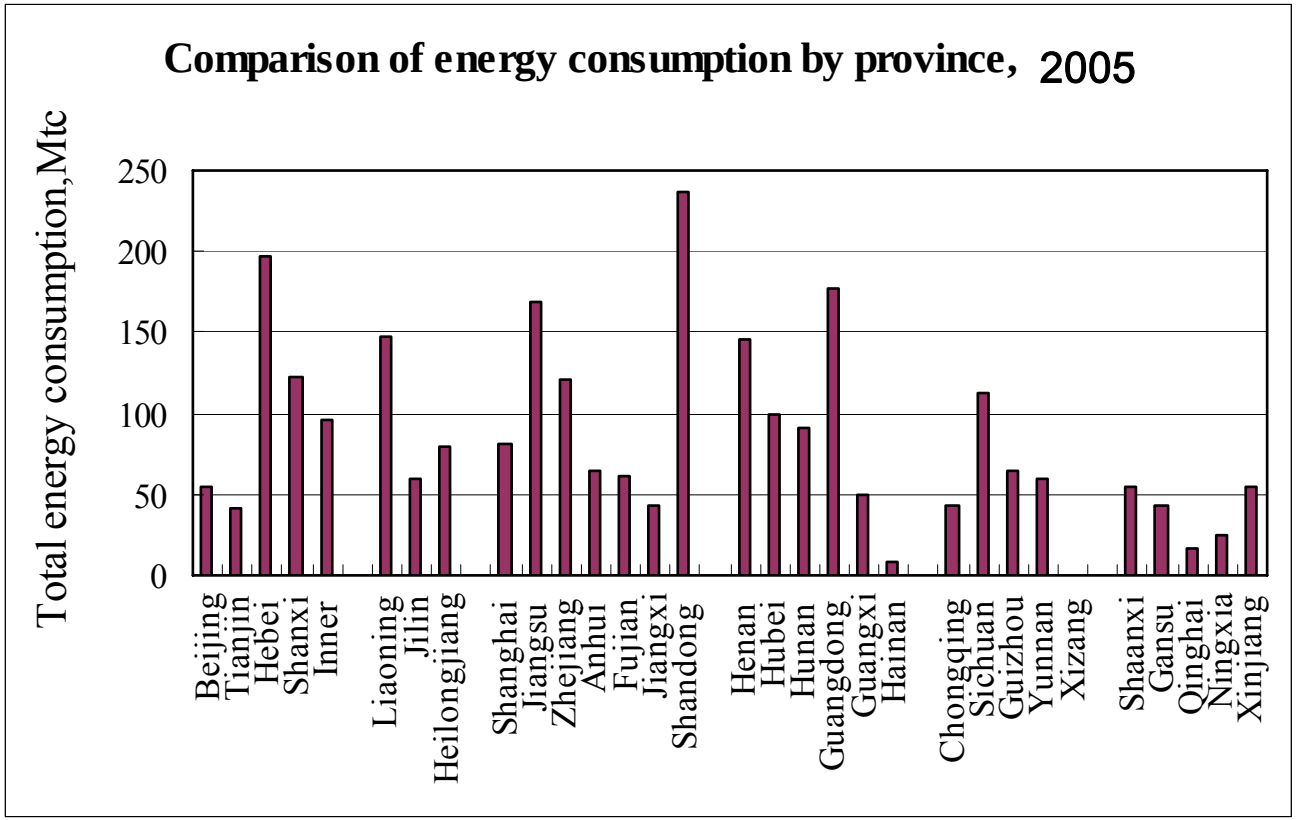
- Mainly consumed by industry sector, 71.6% of the totals in 2007;
- Followed by residential use, accounting for about 10.2%.
- Share of transportation has been increasing quickly, mainly owing to rapid growth of private owned vehicles.

Coal consumption by economic sectors, 1980-2007



- By 2007, the total coal consumption is about 2586.4Mt ; 1305.5 Mt coal used for power generation, accounting for 50.5%.
- The newly added coal output has been mainly used for electricity generation by coal-fired power plants.
- Coal was Mainly consumed by power, other transform (Heat, coking, coal gas), and industry sector, 49.2%, 24.3% and 18.9% of the totals in 2007, respectively;

Primary energy consumption by province, 2005



- **Shandong province ranked the largest consumer,**
- **Next by Hebei, Guandong, Jiangsu, henan, Shanxi, etc.**

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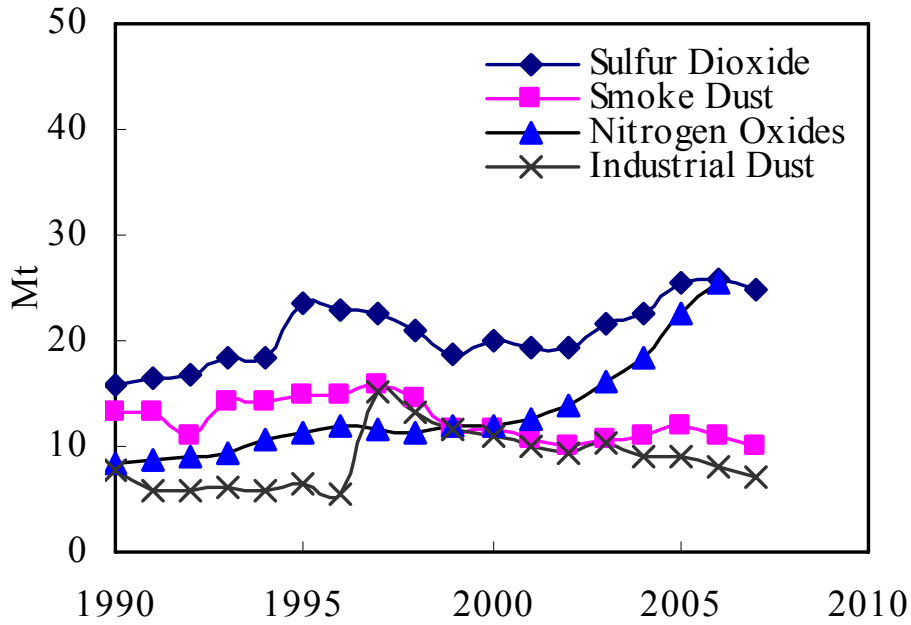
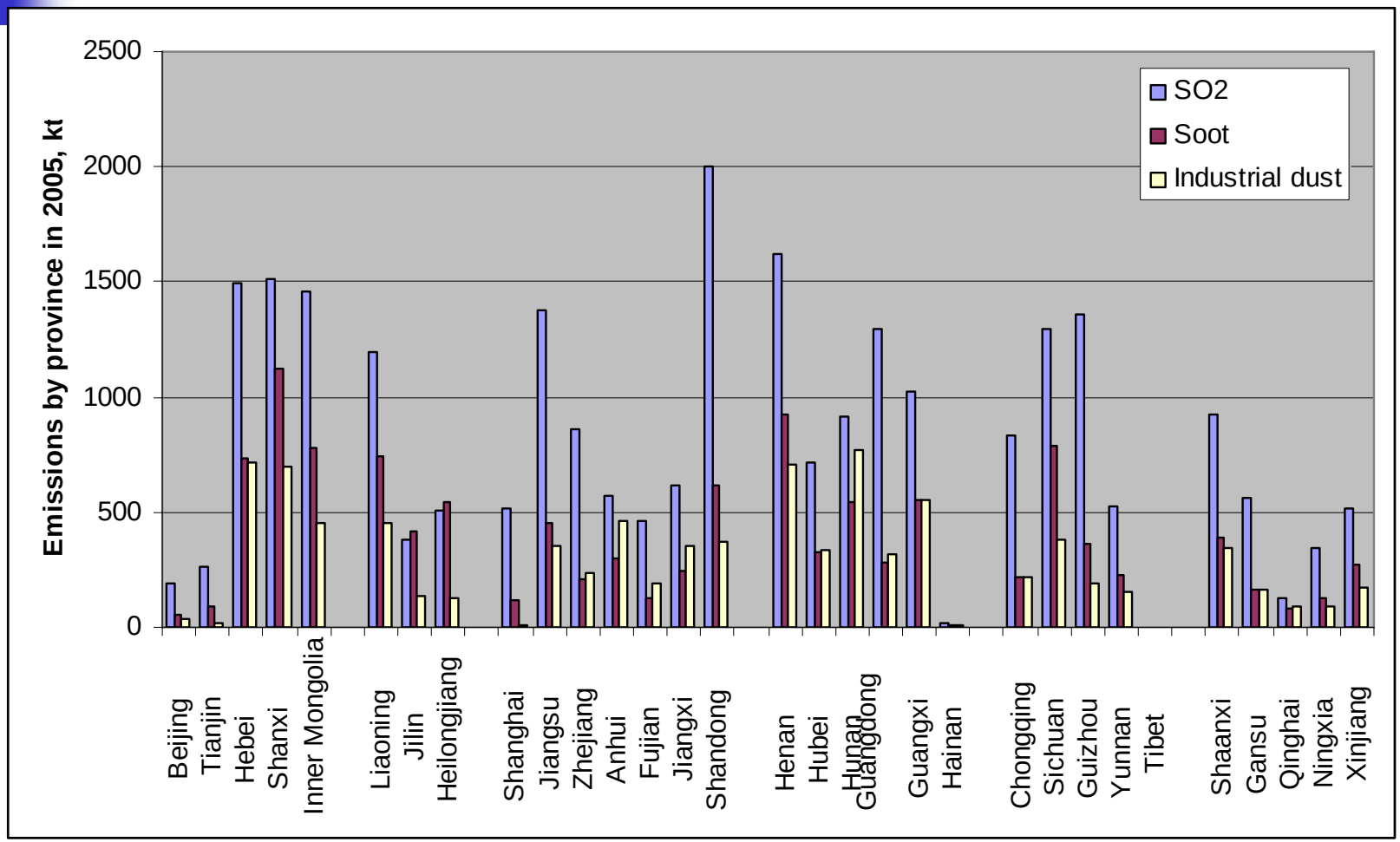
Trends of air pollutants emissions in China, 2000-2007

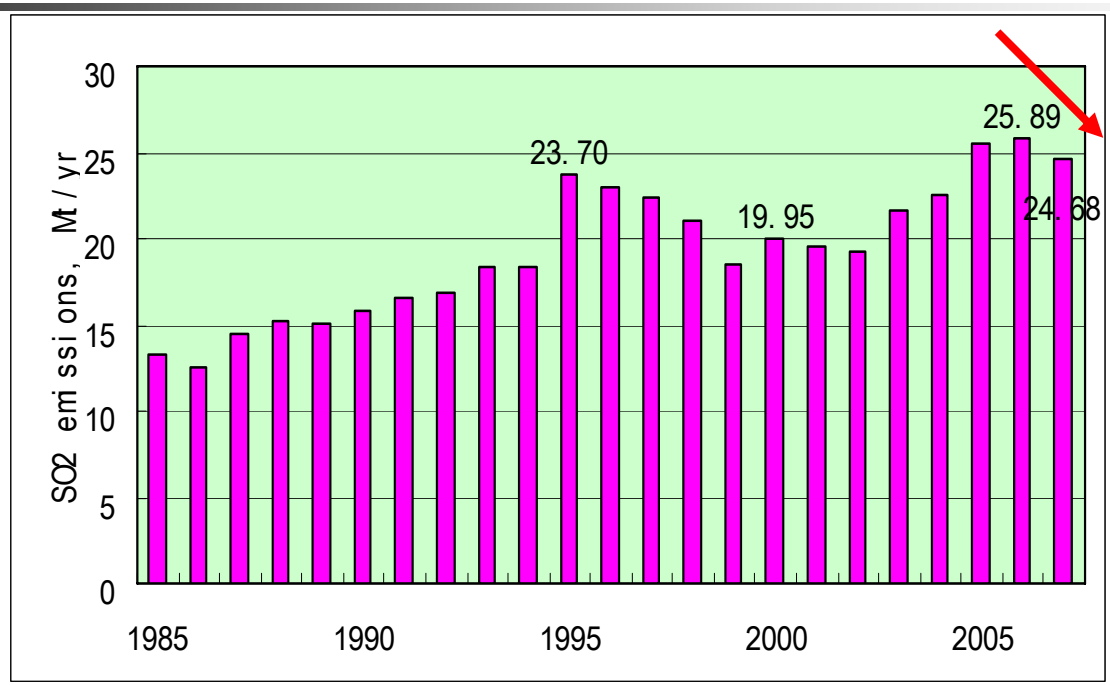


- **By 2007, the total emissions of SO_2, Soot, and industrial dust is reported by SEPA at 24.68Mt, 10.86Mt, and 6.99Mt, respectively**
- **On June 4, 2008, SEPA reported the total SO2 emissions dropped to about 24.68Mt in 2007, decrease by 4.66% compare with 2006**

Emissions of primary air pollutants by province, 2005

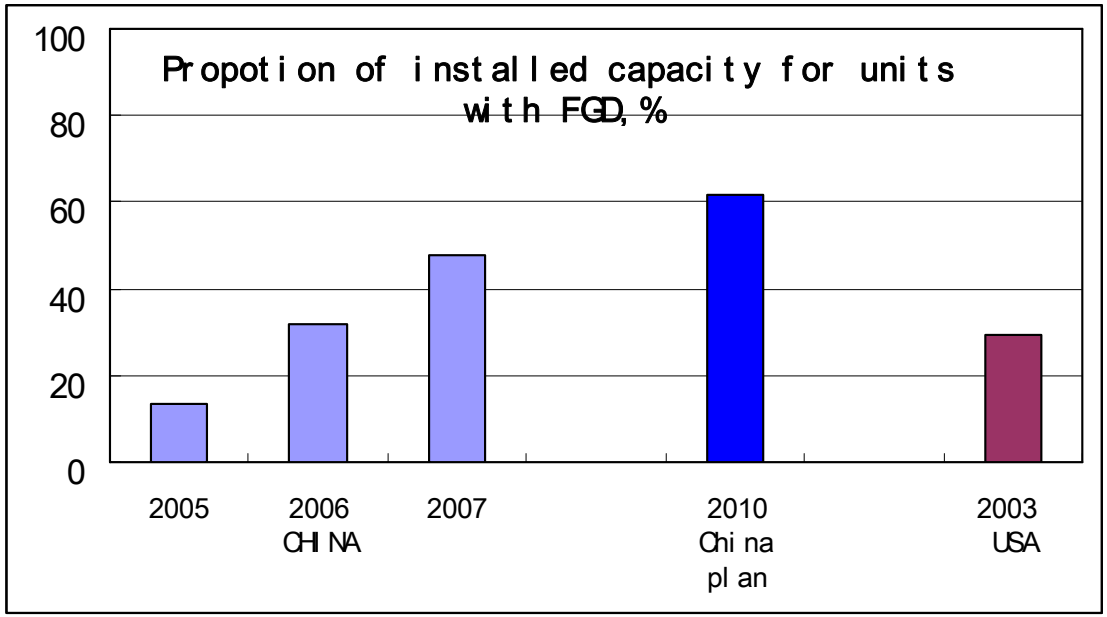


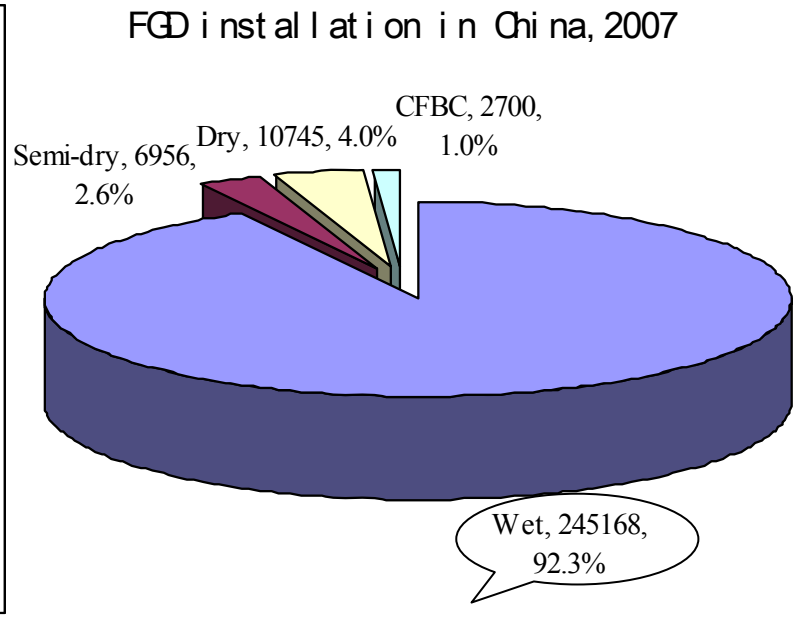
Trend of national SO_2 emissions, 1986-2007



- In 2006, Coal-fired power plants emitted about 11.12Mt, accounting for about half of the total SO2 emissions in China.
- The decrease of SO2 emissions in 2007 are mainly owing to the installation and operation of FGD in coal-fired power plants.

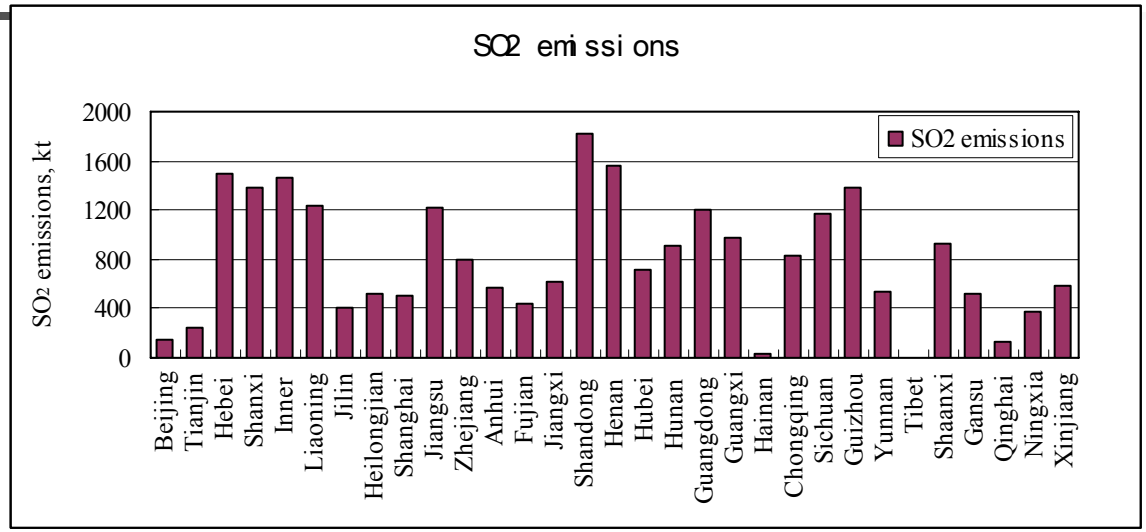
FGD installation, 1986-2007

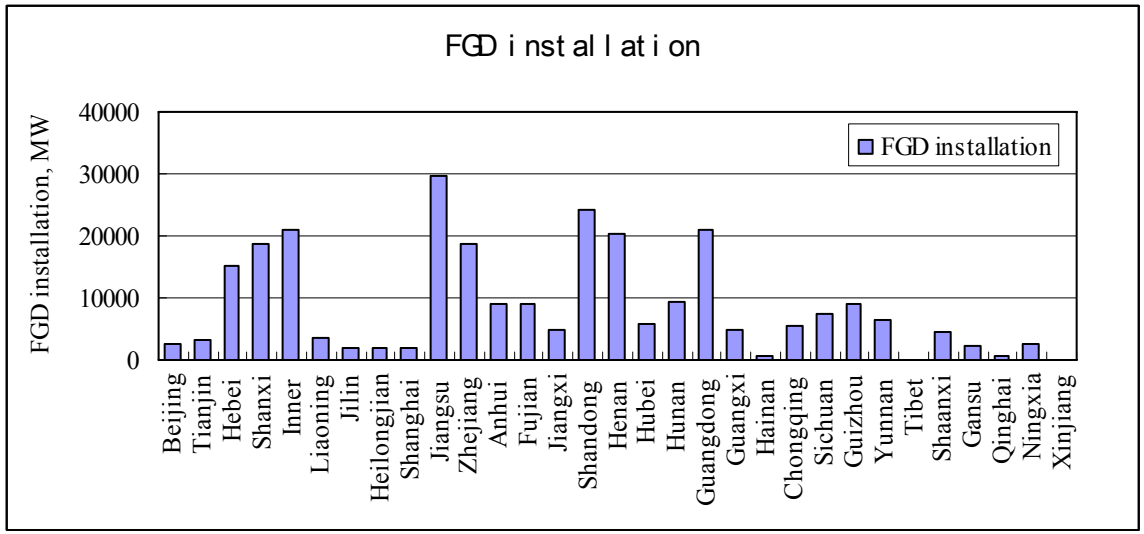




- By 2007, the installed capacity of FGD reached 270GW, accounting for 48% of the total thermal power capacity.
- Limestone-Gym process accounted for 87.4% of total FGD capacity

SO_2 emissions and FGD installation by province





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Methodology for NO_X emission estimation

- - Emission Factor by fuel use

$$Q_T^N(t) = \sum_i Q_i^N(t)$$ ← Country level

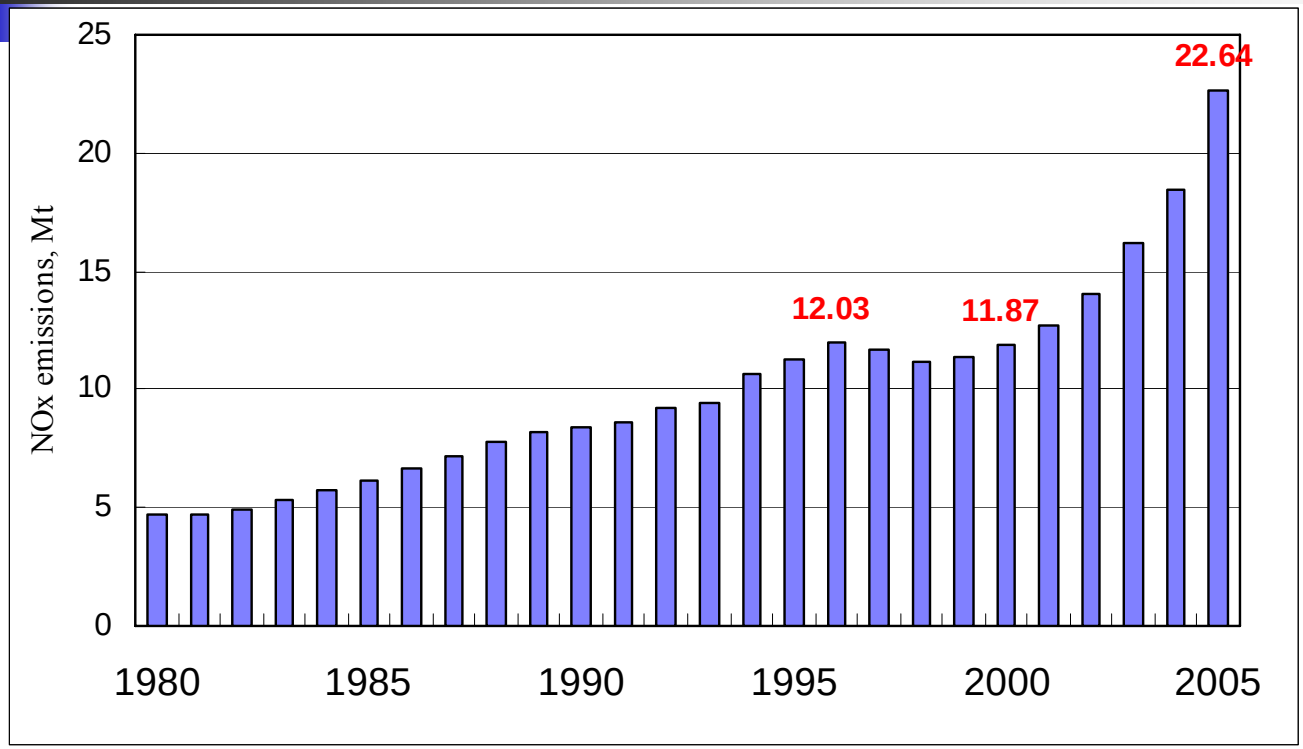
$$Q_i^N(t) = \sum_j Q_{i,j}^N(t)$$ ← Province level

$$Q_{i,j}^N(t) = \sum_f \sum_k Q_{i,j(k),f}^N(t)$$ ← Sector level in province

$$Q_{i,j(k),f}^N(t) = (1 - P_{i,j(k),f}^N(t)) K_{i,j(k).f}^N(t) F_{i,j(k),f}(t)$$

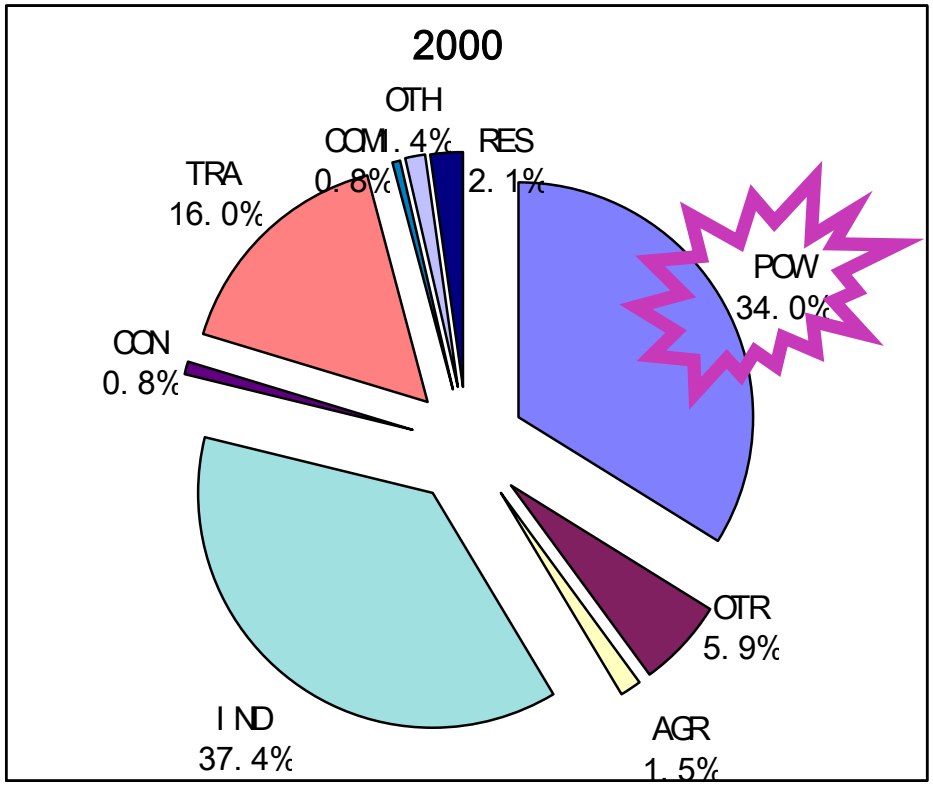
- Fuel level in a sector
- NO_X removal efficiency
- NO_X emission factor
- Fuel use

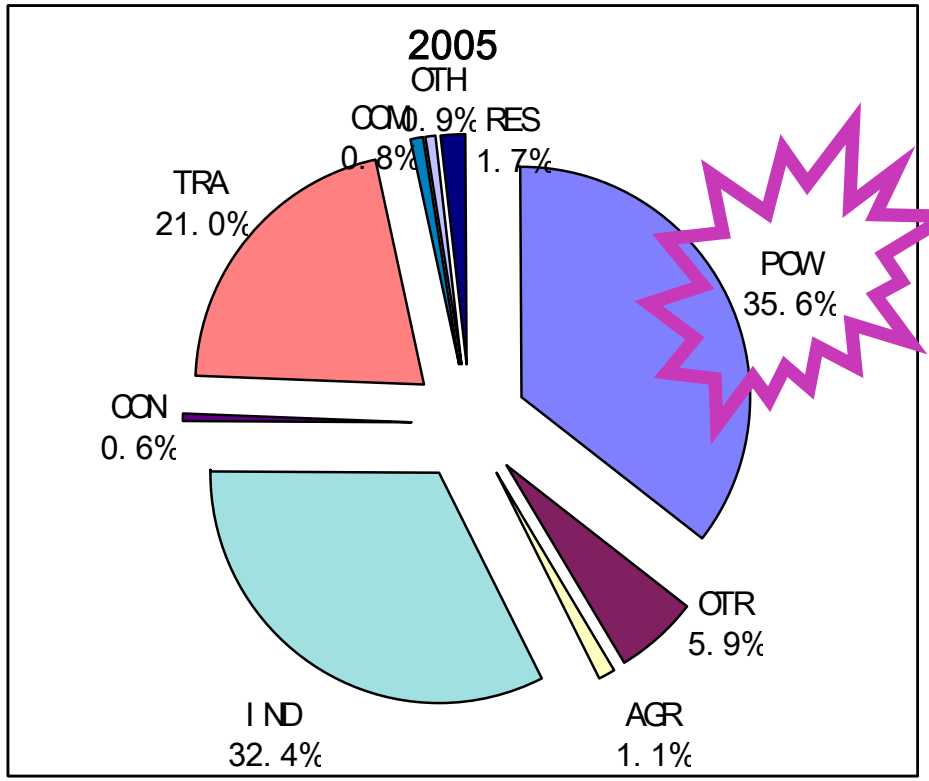
Trend of NO_X emissions estimation in China, 1980-2005



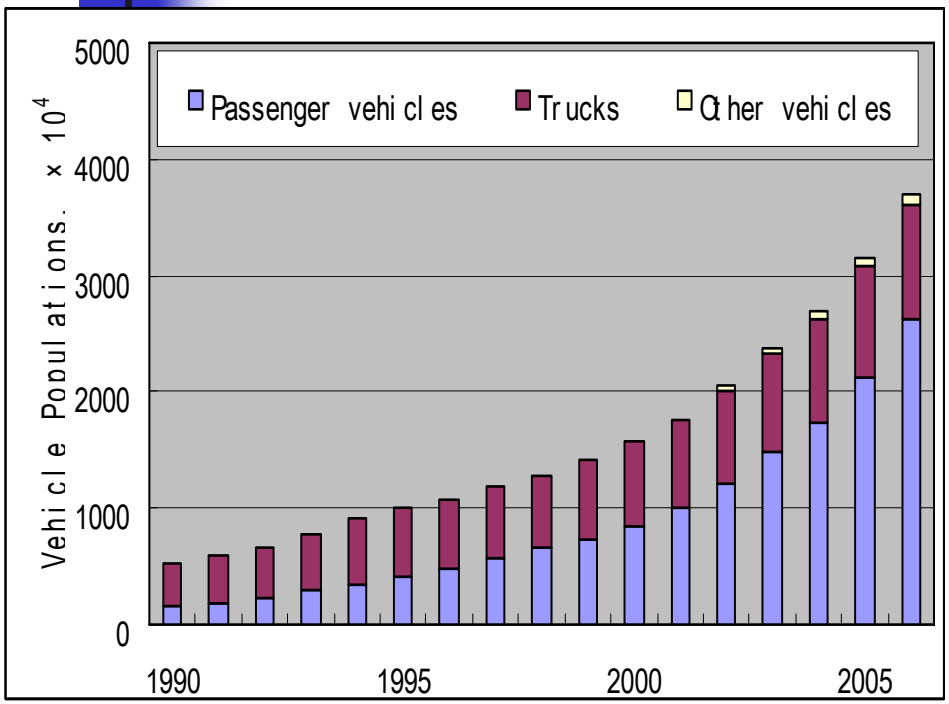
- The total NO_X emissions has kept increasing rapidly since 1998, reaching up to 22.64Mt by 2005;
- An average growth rate of 10.2% from the valley level of 1998 to 2005.

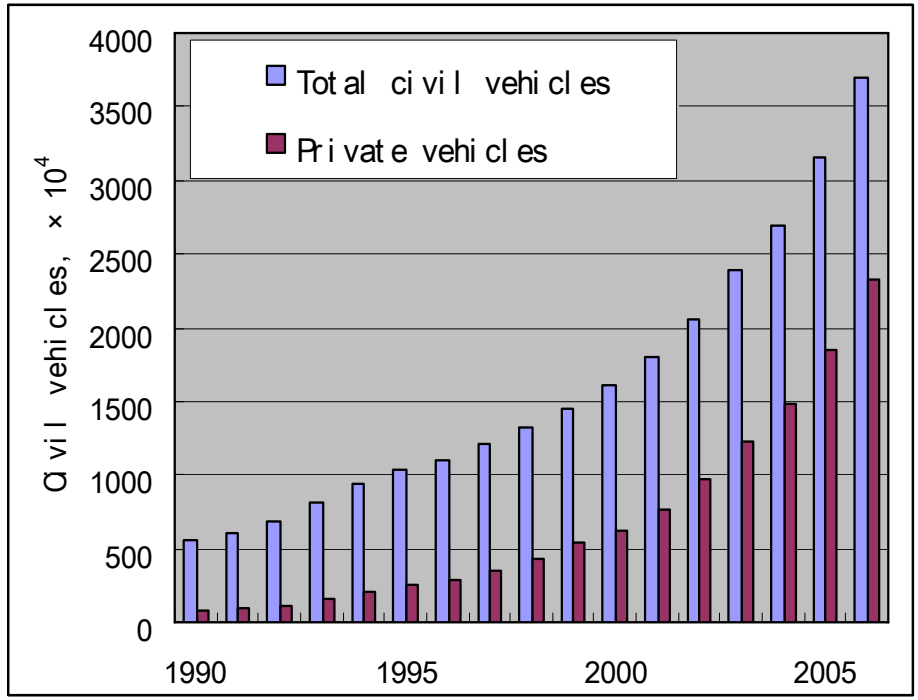
NO_X emission inventories by sectors, 2000 & 2005





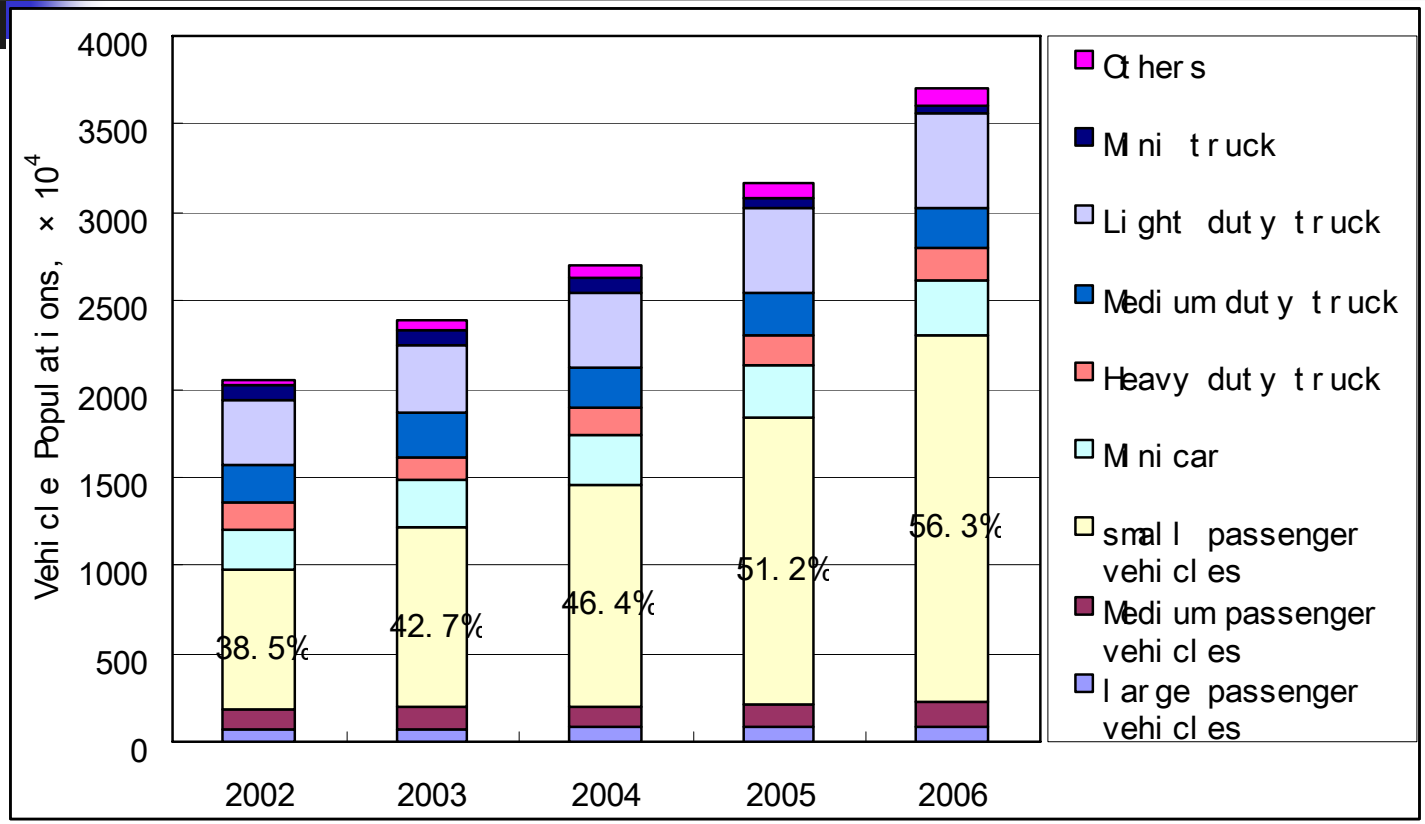
Population of civil vehicles in China, 1990-2006





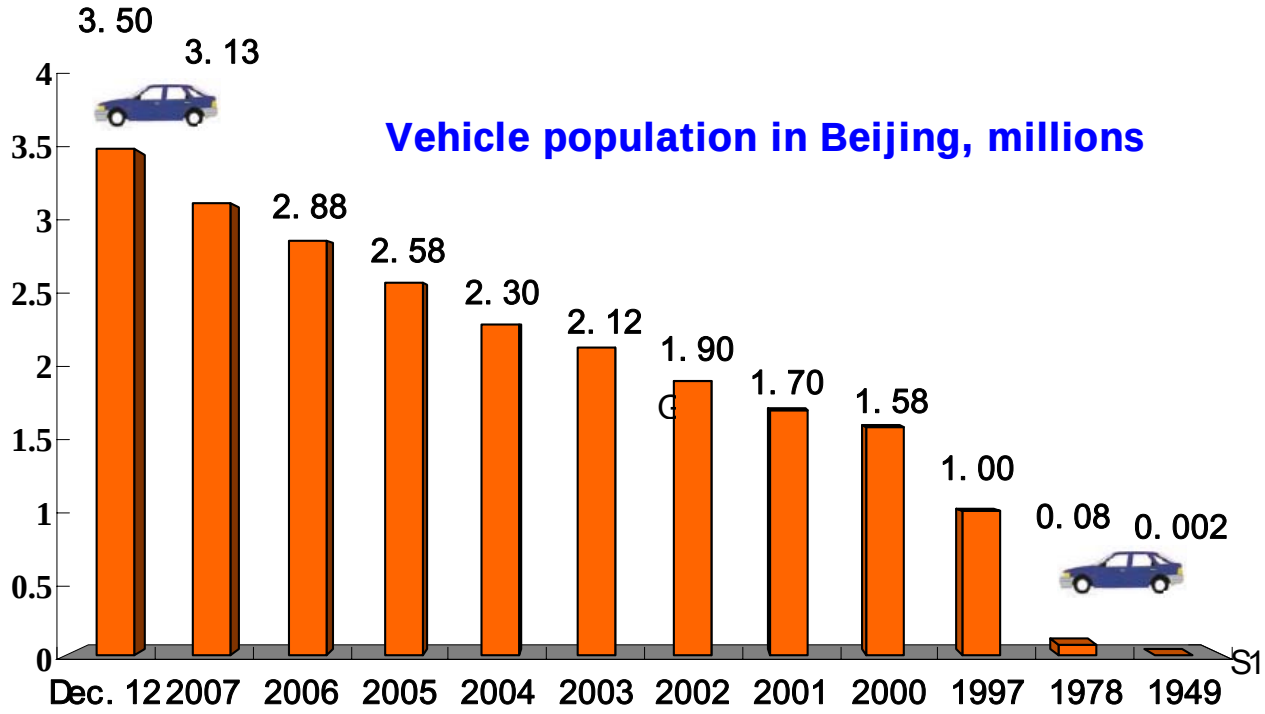
- By 2006, the total civil motor vehicles has grown to **36.97 millions**;
- Populations of private vehicles has increased to **23.33 millions**.

Composition of vehicles in China, 2002-2006



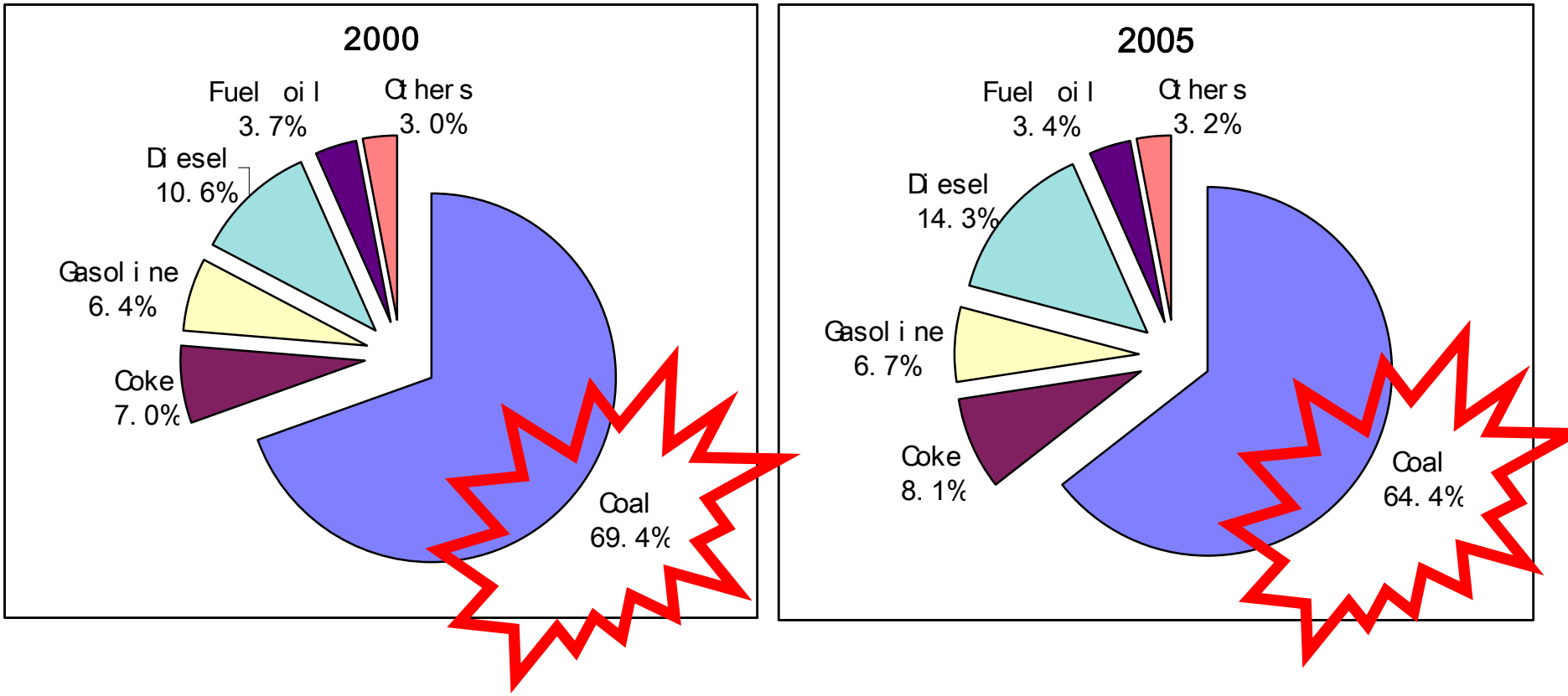
➢**Passenger Car, especially the private car is the main power for rapid increase of vehicle populations**

2008年12月12日，北京机动车突破350万辆
Total vehicle population in Beijing exceeded 3.50 millions by the end of 2008

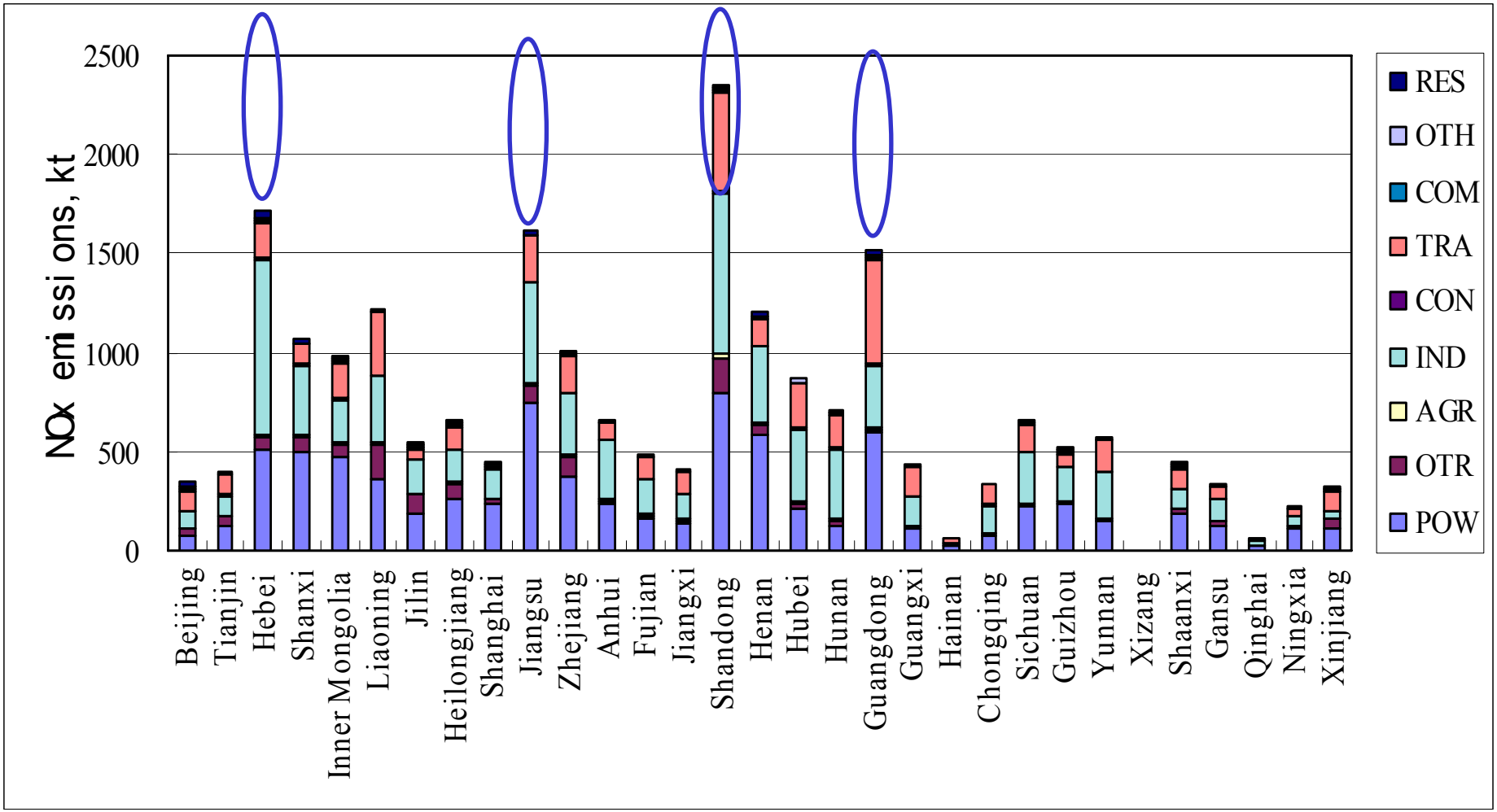


- The newly registered vehicles is over 1000 per day in Beijing .
- Since Oct.11,2008, over 20% of the vehicles were restricted to use on each weekday, for improvement of traffic jam and air quality

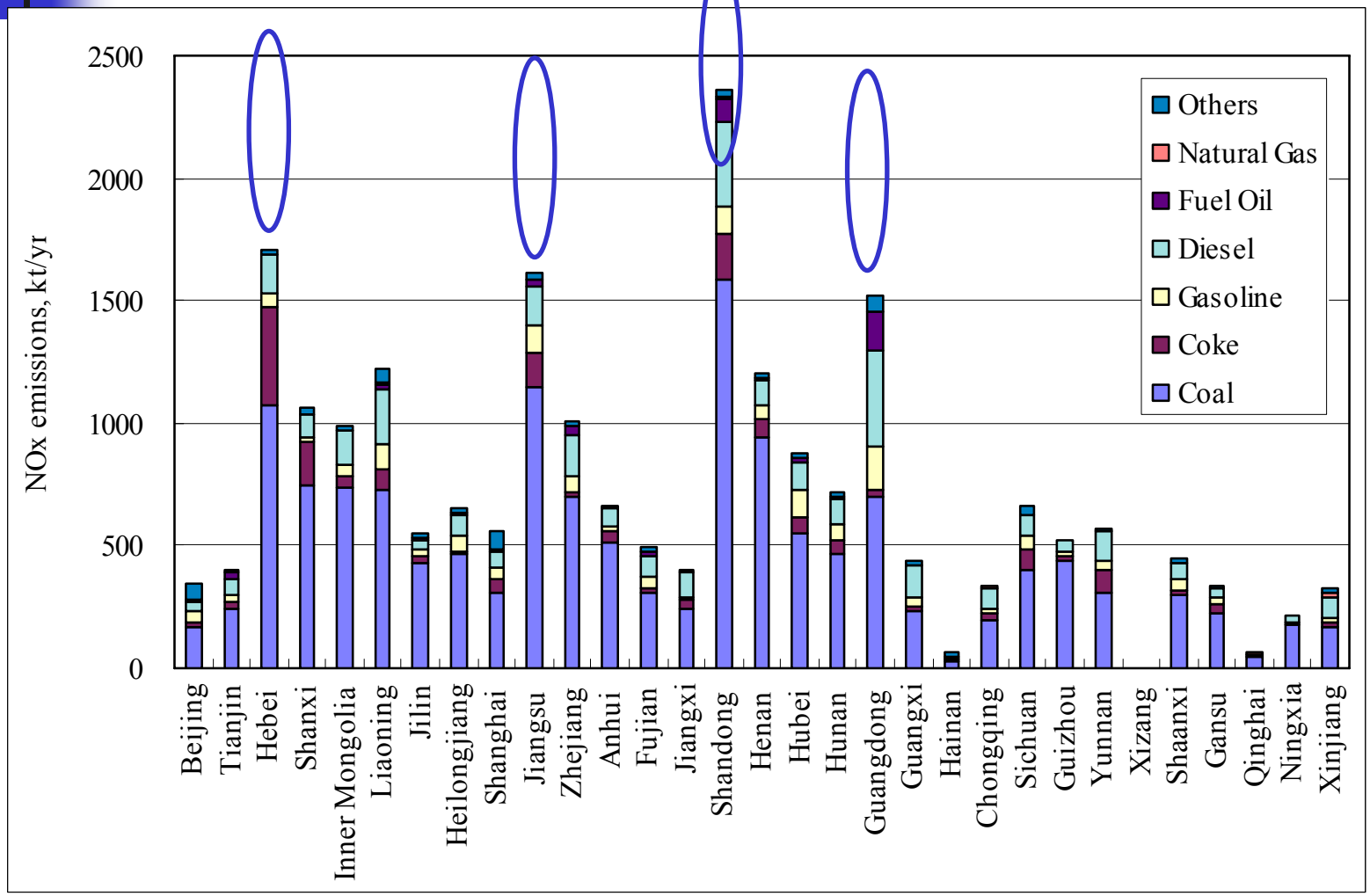
NO_X emission inventories by fuels, 2000 & 2005



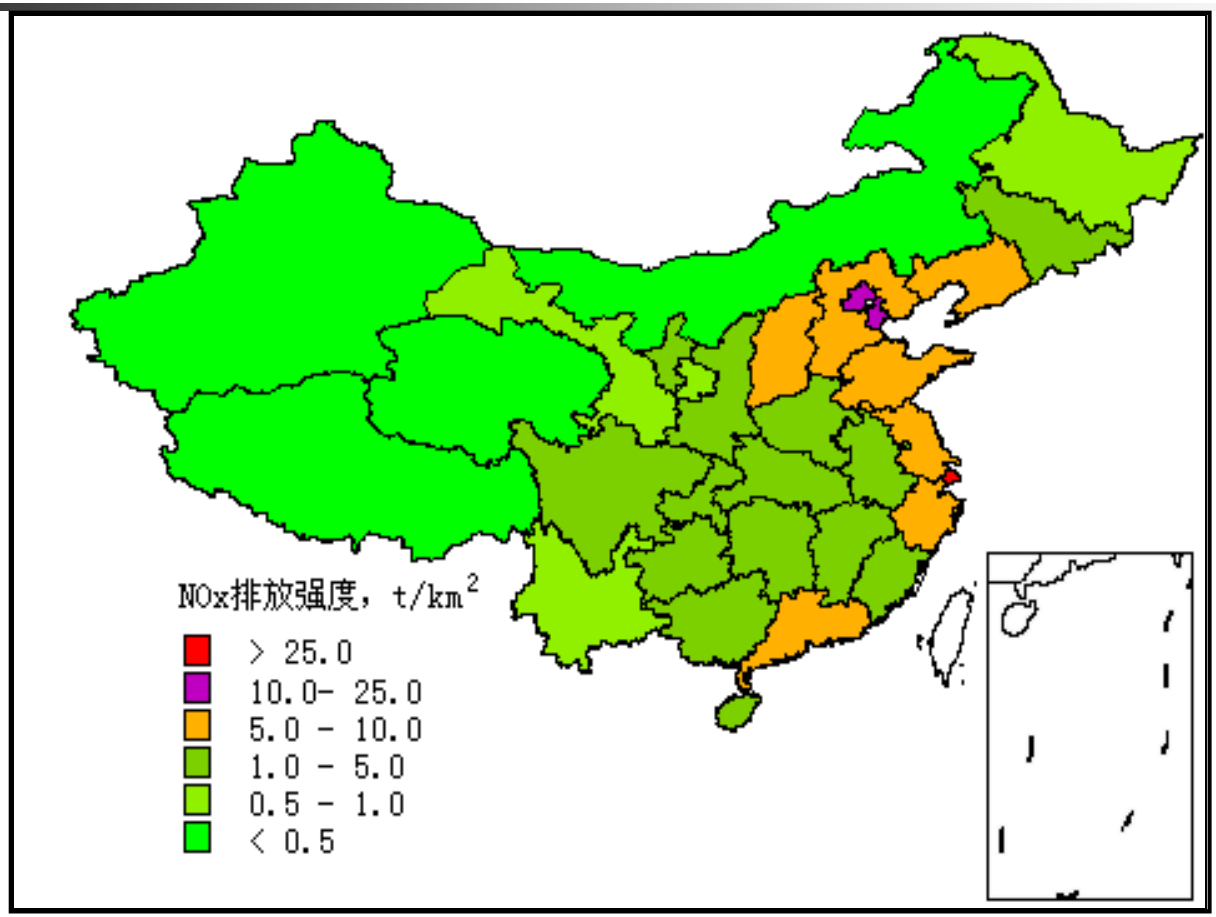
Provincial NO_x emissions by sectors in China, 2005



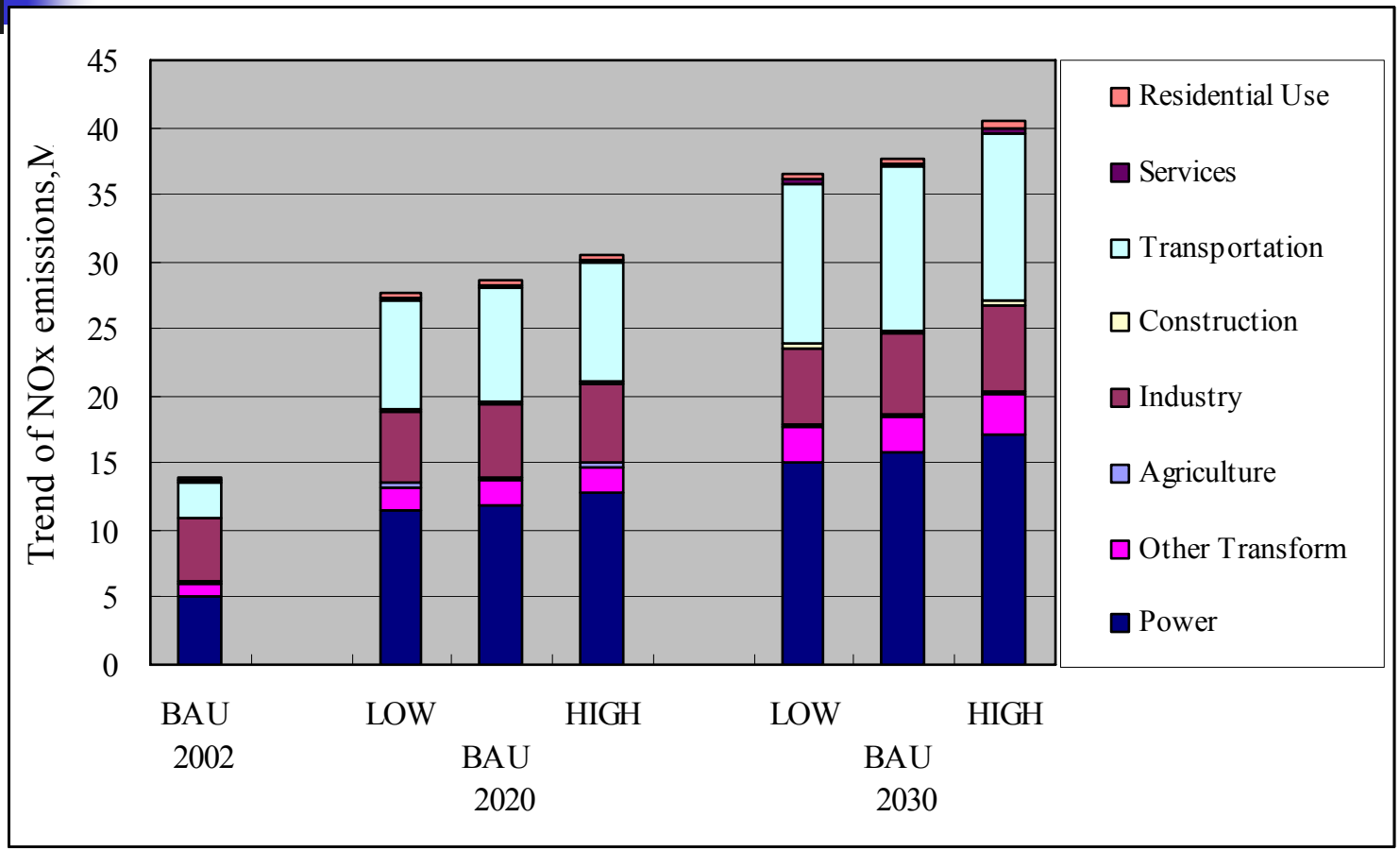
Provincial NO_x emissions by fuels of China, 2005



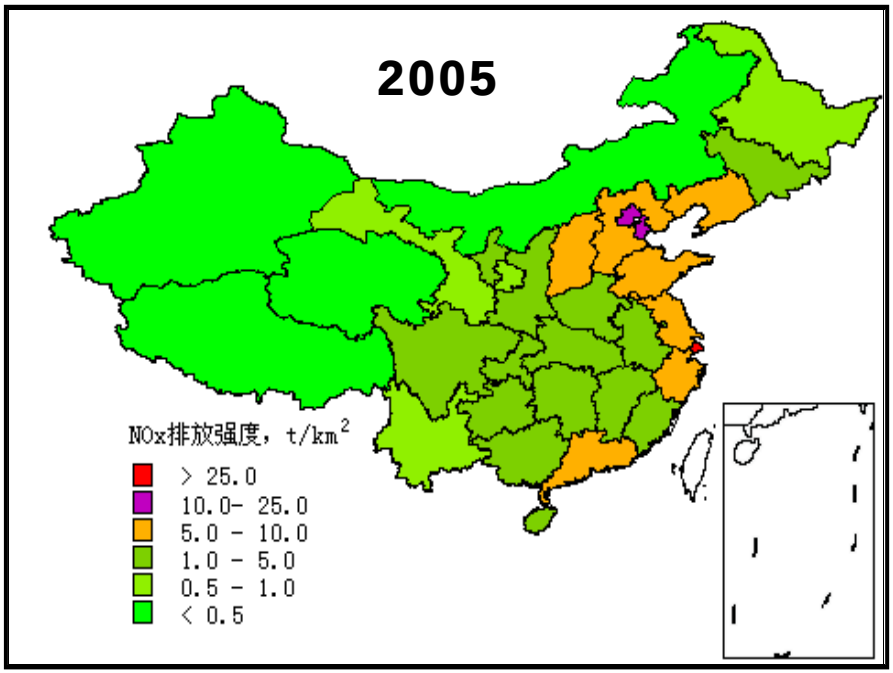
Distribution of NO_X emission intensity by province, 2005

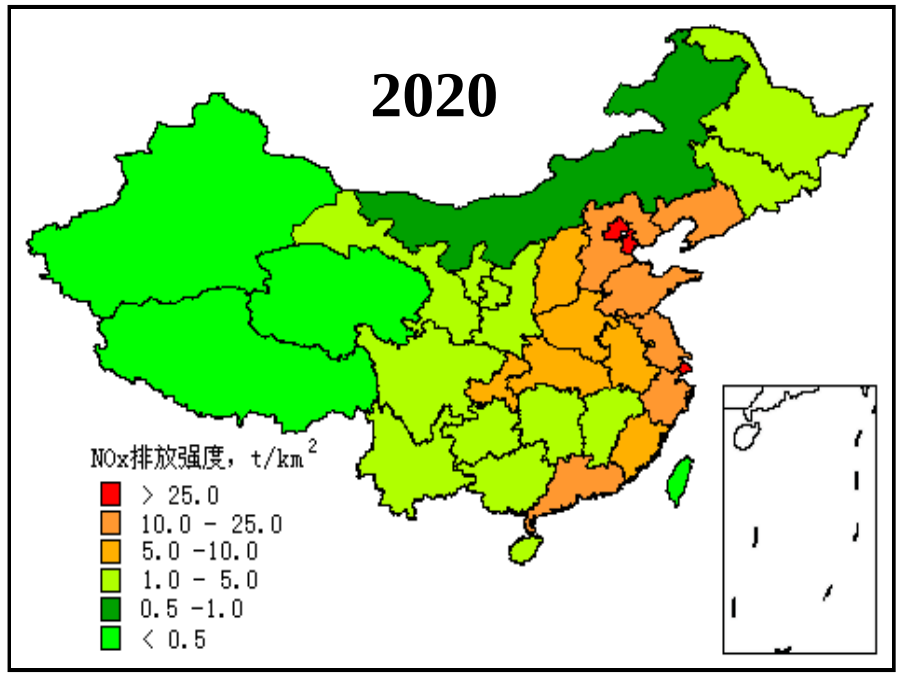


Projection of NOx emissions, 2020 & 2030

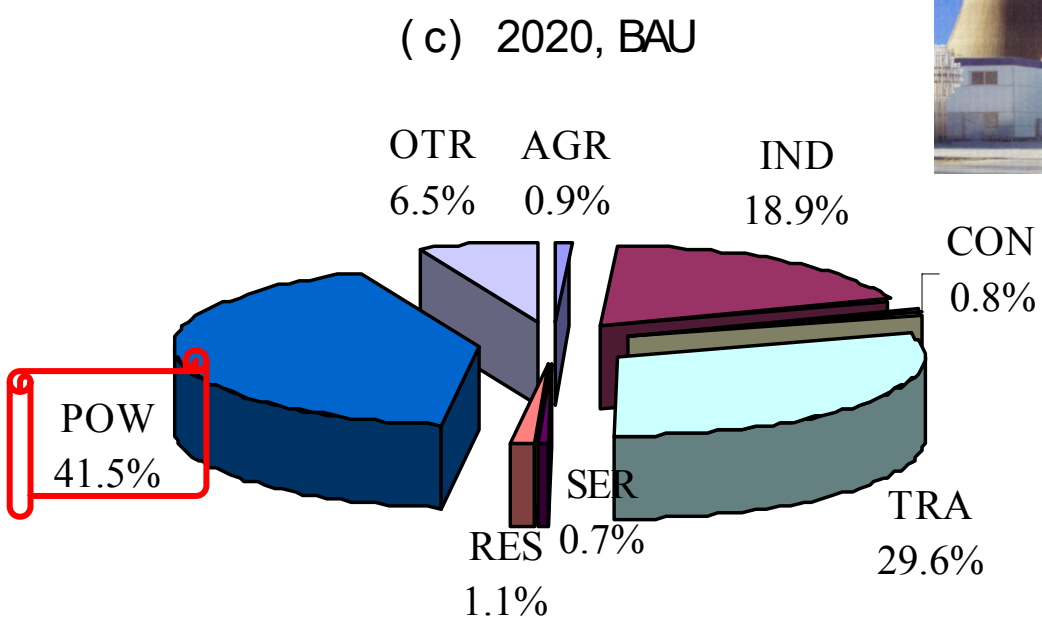


Trend of NOx emission intensity in the future, 2005 & 2020





Scenario of NO_X emissions by sectors, 2020



- **Power plants is the largest sources**
- **So, it is very necessary to control NO_X emissions from coal-fired power plants in China**
- **Implement total NO_X emission control on typical regions and important sectors such as power plants**

Controlling NO_X emissions from coal-fired power plants in China

- More **stringent emission standards** and relevant policies should be enforced to control NO_X emissions from coal-fired power plants in China
- **SCR** demonstration projects for coal-fired power plants should be initiated for future wide-spread applications
- Ever **Stricter emission standards** for vehicles is very crucial for air quality improvement in large cities in China.
- Appropriate economic environmental policies such as **Emission Trading System** will be a cost-effective way for NO_X control in China

Emission Inventory of Hg, As,Se from Coal Combustion in China

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2. Methodology for emission estimation

- Applying emission factor based on fuel consumption to evaluate the emissions of trace element of Hg, As,Se:

$$Q_{i,j}=C_{i,j}M_{i,j}R_{i,j}(1-P_{i,j})$$

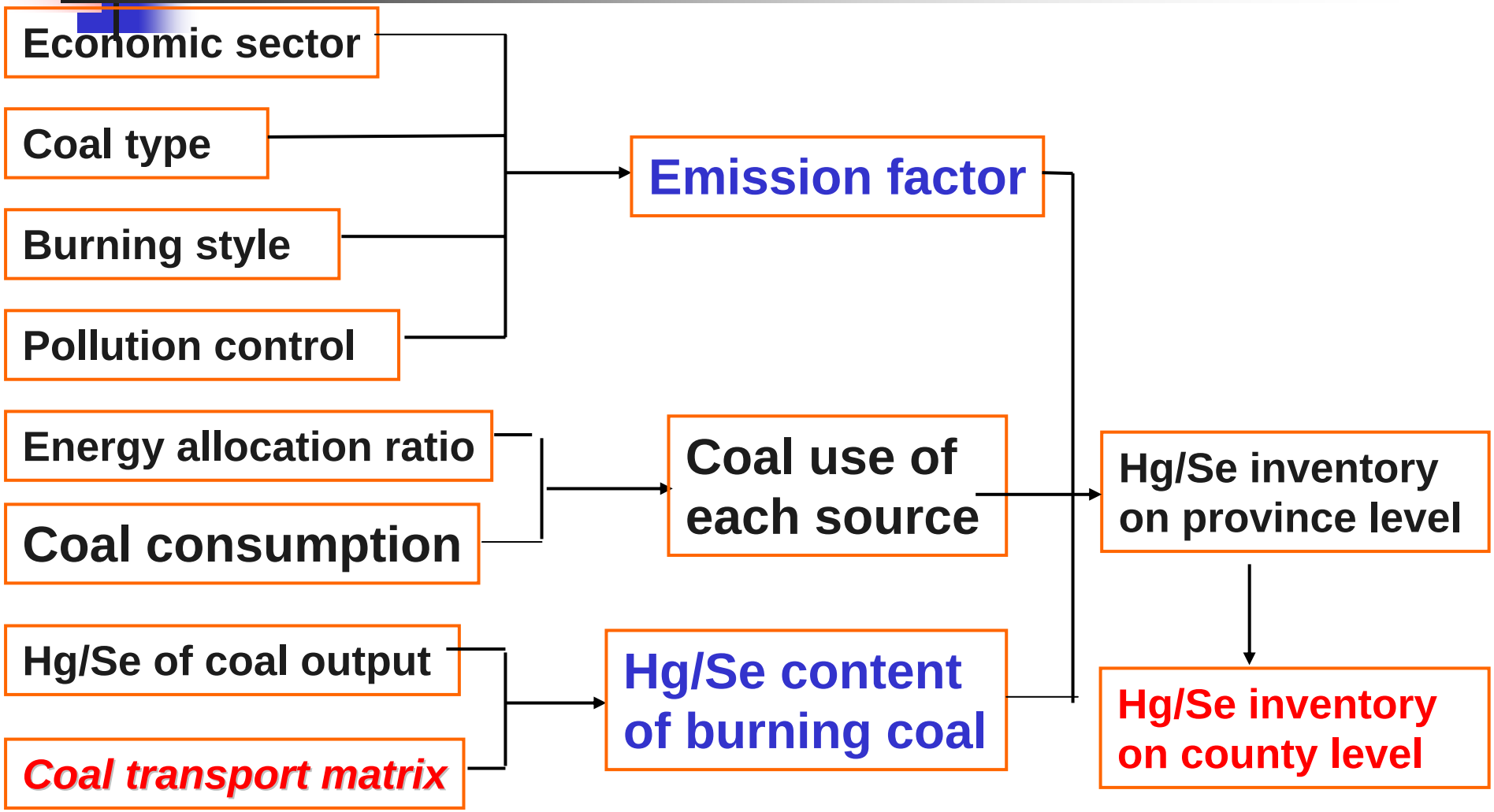
$$Q_i=\sum Q_{i,j}$$

$$Q_T=\sum Q_i$$

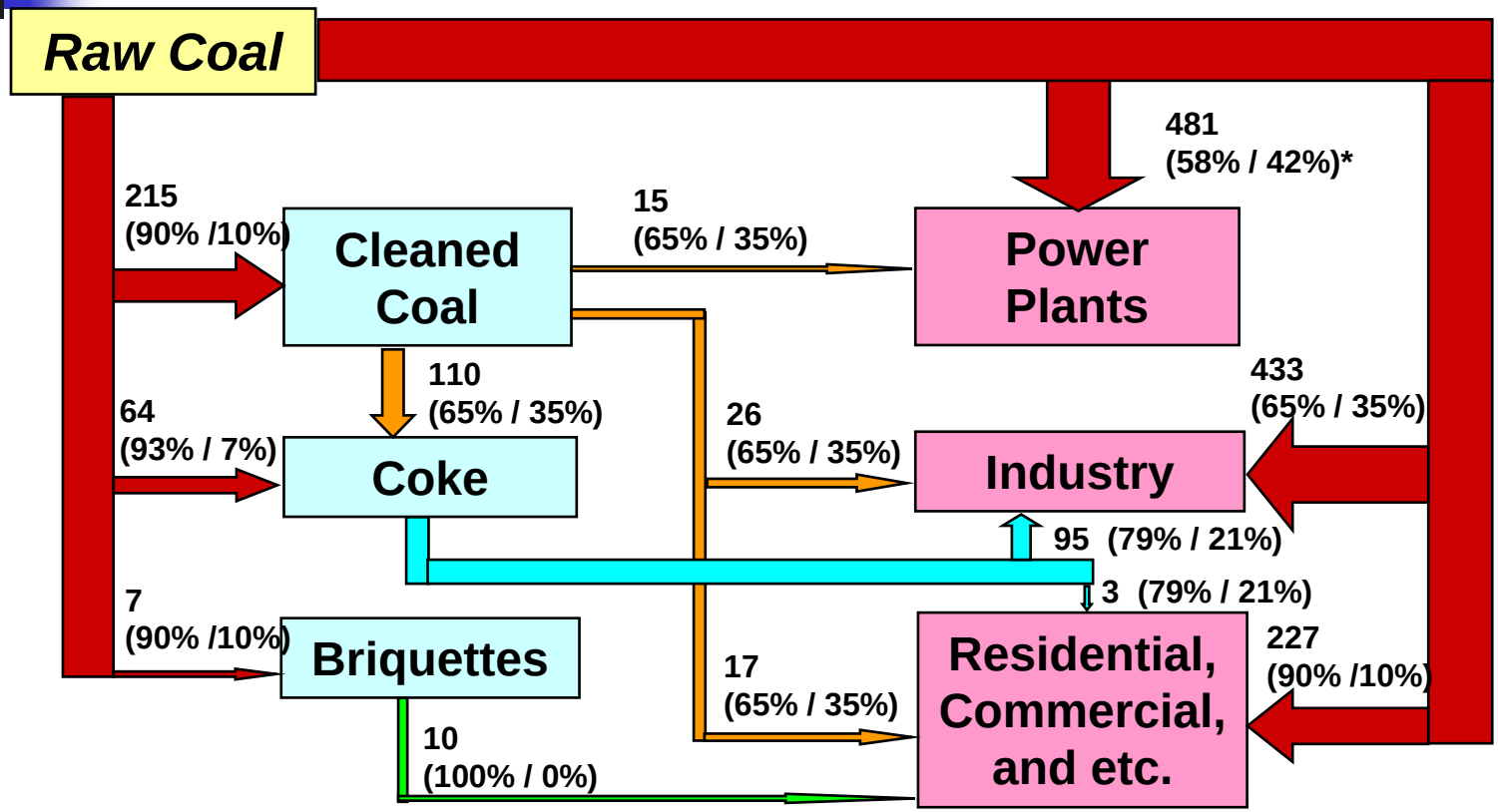
Where:

***Q*—atmospheric As/Se/Hg emissions, t;**
***C*—Trace element content in burning coal,%;**
***M*—Quantity of coal combustion, t;**
***R*—release portion of combustion facility, %;**
***P*—removal efficiency of air pollution control facilities, %;**
***T*—whole China;**
***i*—Province;**
***j*—source category;**

Path of Hg/Se/As emission inventory estimation

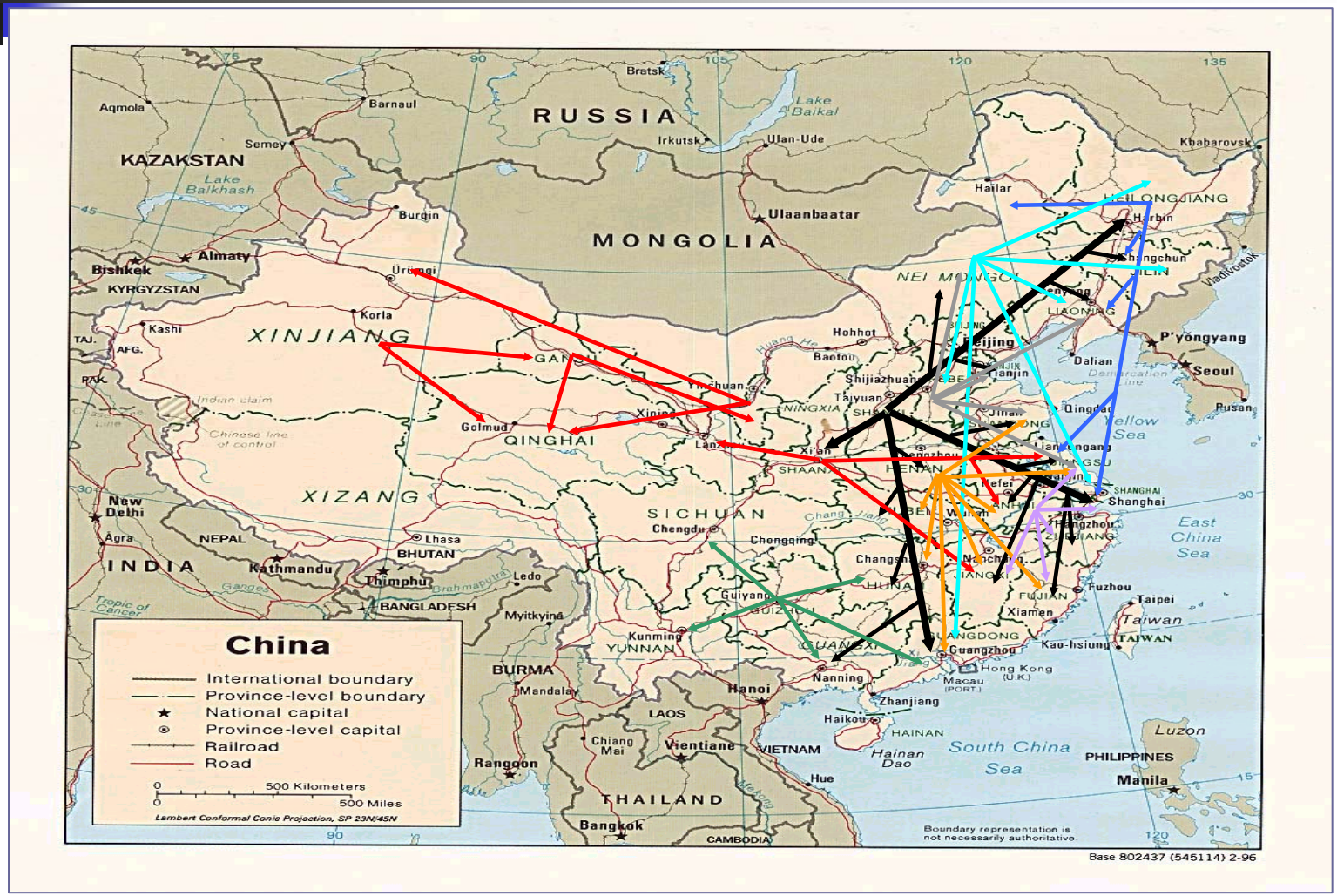


Coal transportation flows by usage, 1999

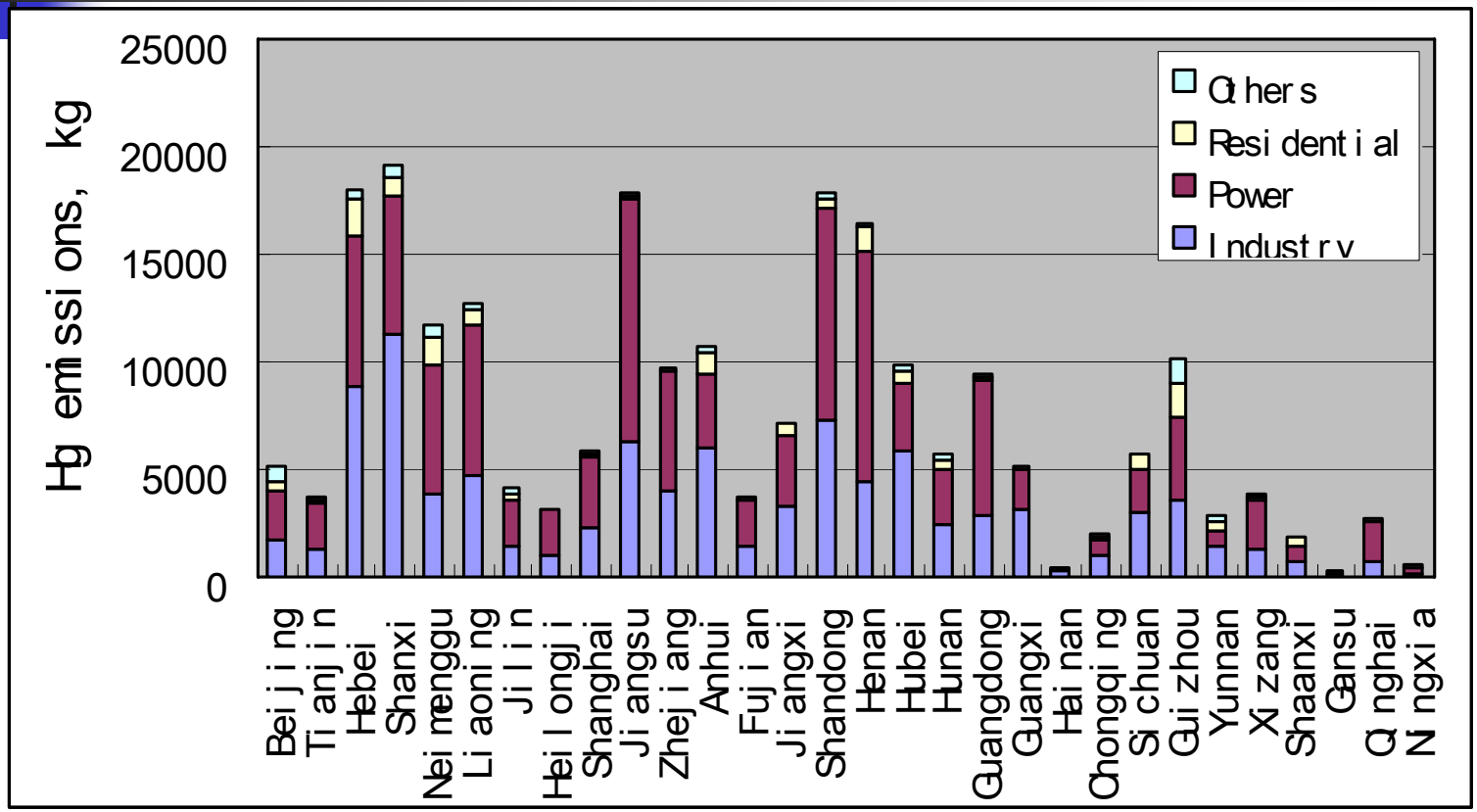


*** 481 (58% / 42%): million tons of coal used (the ratio of in-province supply / the ratio of out-province supply)**

Inter-province model of coal transportation flows



Hg emissions from coal in China, 2004



The total Hg emissions from coal burning in 2004 is estimated at about 227.7 tons.

Mercury (Hg) emission inventory of China, 2004

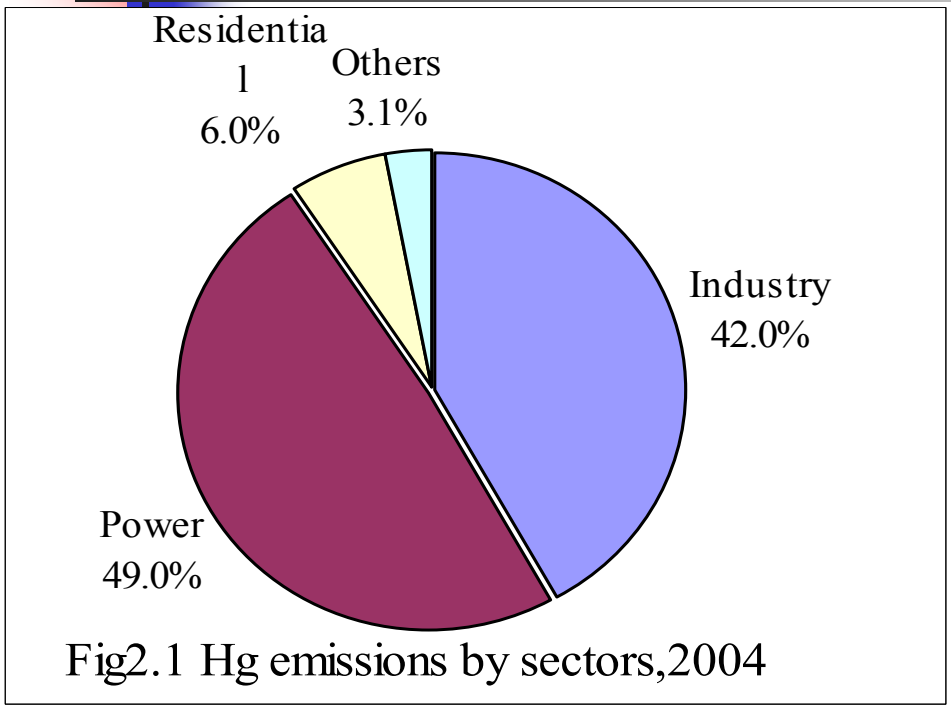


Fig2.1 Hg emissions by sectors,2004

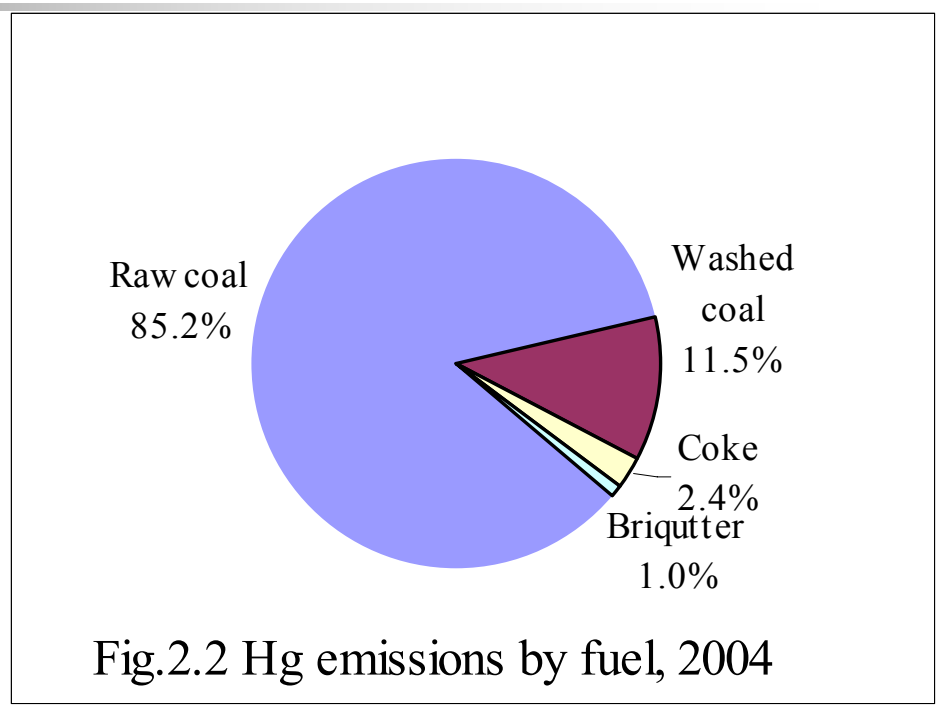
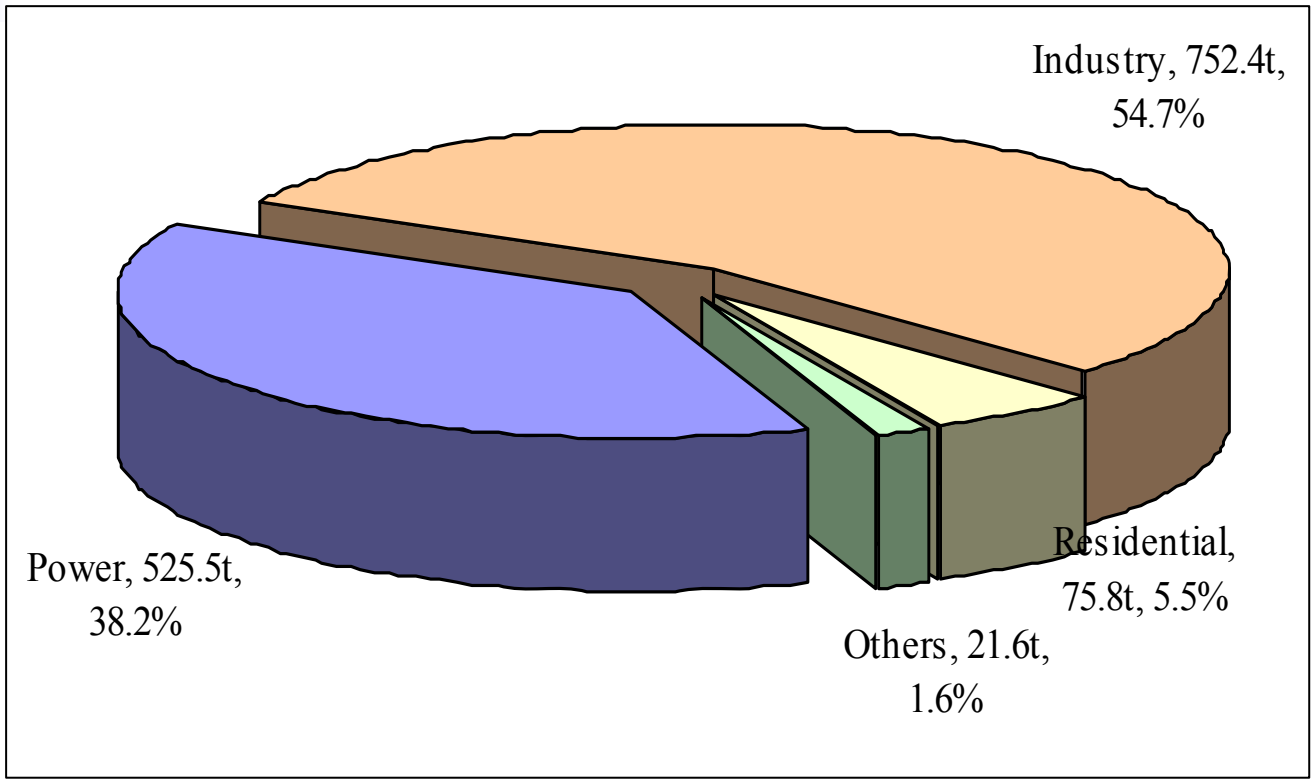


Fig.2.2 Hg emissions by fuel, 2004

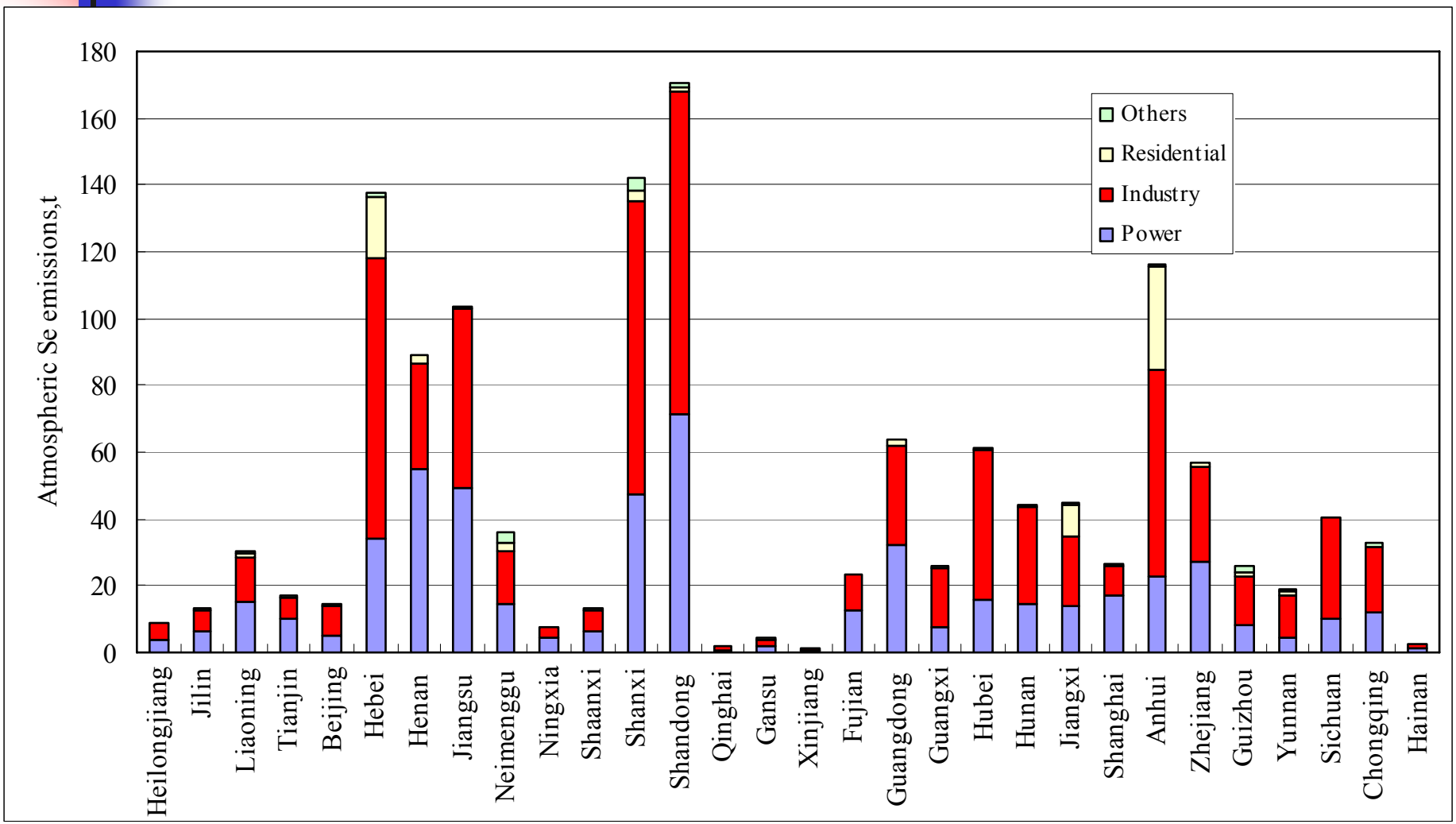
- **The total Hg emissions in China is estimated at about 227.7t in 2004.**
- **The majority of Hg emissions are from raw coal burning by utility and industrial boilers.**

Atmospheric Se emissions from coal burning by sectors, 2004

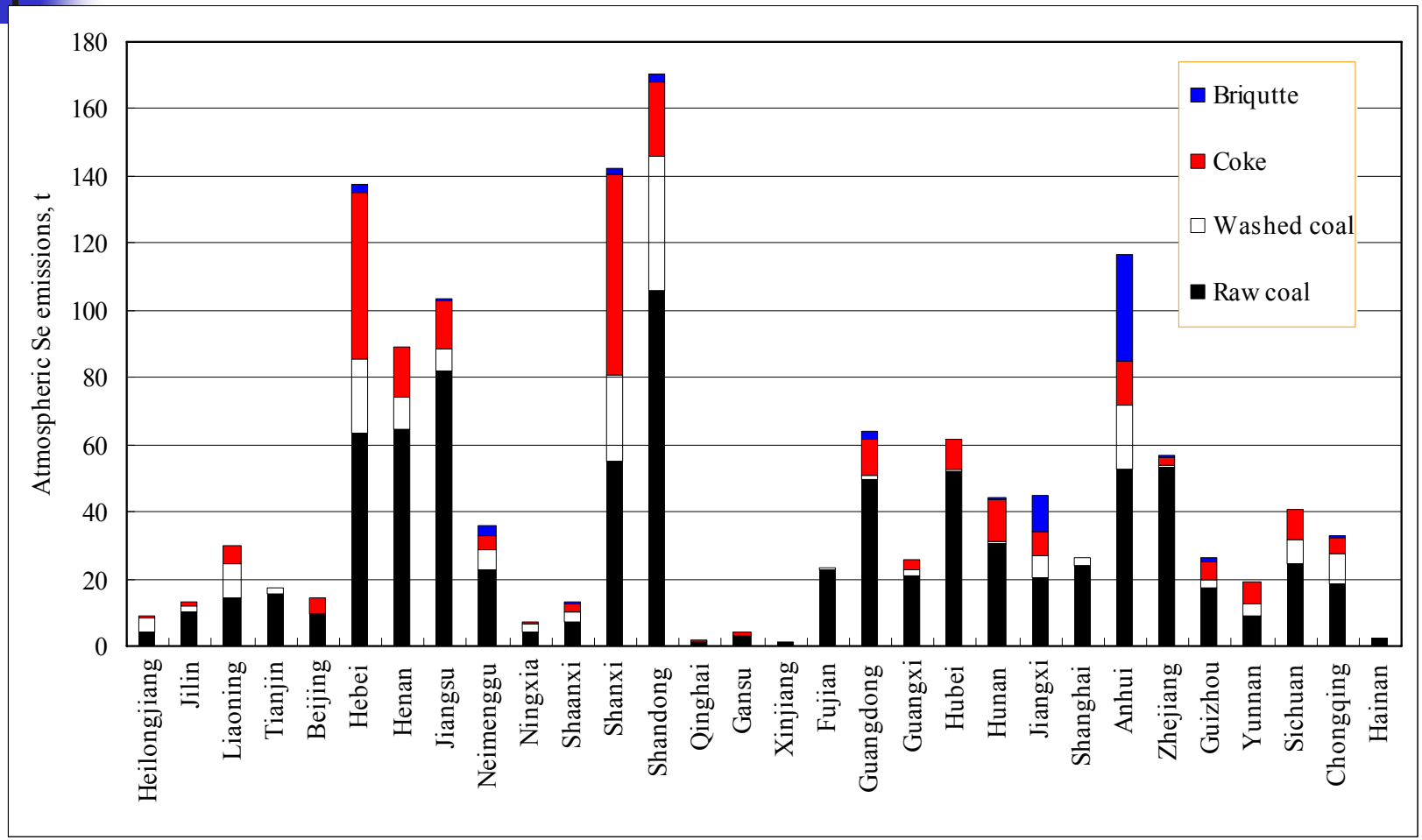


The total atmospheric Se emissions from coal burning in China is estimated at about **1375 tons** in 2004

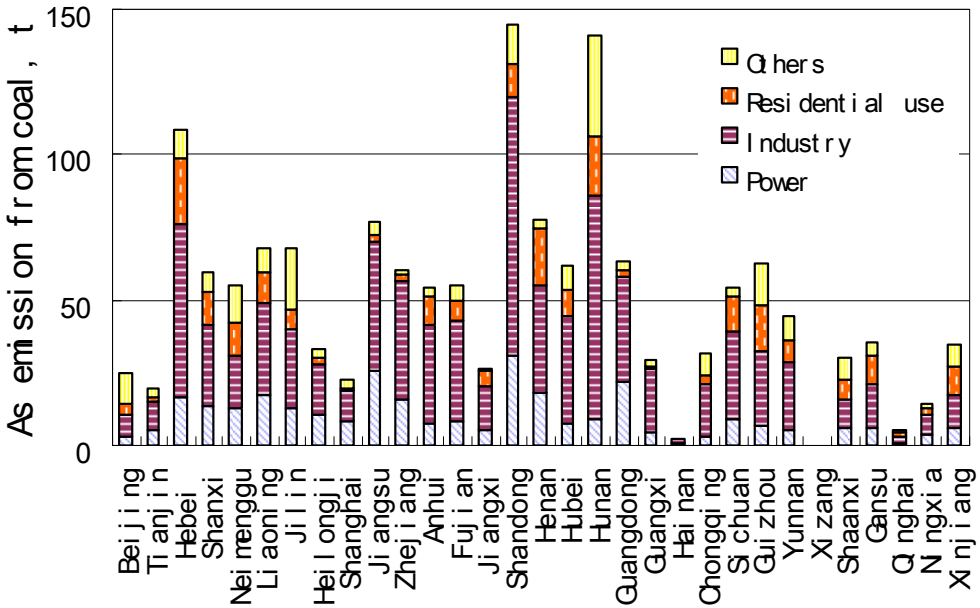
Atmospheric Se emissions from coal burning by province and sectors, 2004

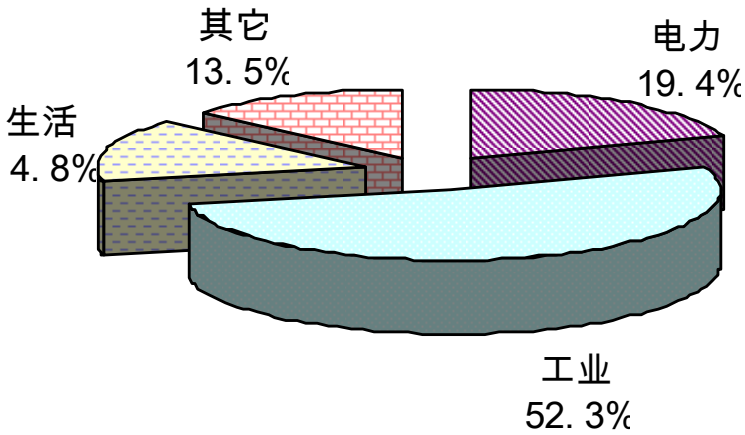


Provincial Se emission inventories from coal burning, 2004



Arsenic emission from coal burning in China, 2005





The total arsenic emissions from coal combustion is estimated at about 1564.9 tons in 2005.

Conclusions

- **NO_X emission control is becoming a new challenge on local air quality, regional acid deposition, ground-level O_3, and Haze pollution in China**
- **Advanced De-NO_X installations (SCR) should be equipped to reduce NO_X emission in newly coal-fired power plants.**
- **Trace elements emission from coal burning and its effects such as Hg, Se, As, should also be paid much attention.**
- **Thus, Advanced multi-pollutants combined control technologies as well as effective environmental management experiences are expected to simultaneously control SO_2/NO_X/PM/trace elements and its environmental effects from coal burning in China.**

Thanks for your attention !!!