

The Chinese Electric System's Quarter-Century

Presented at
*Third Annual Carnegie-Mellon Conference
on the Electricity Industry*

Pittsburgh

by

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March 14, 2007

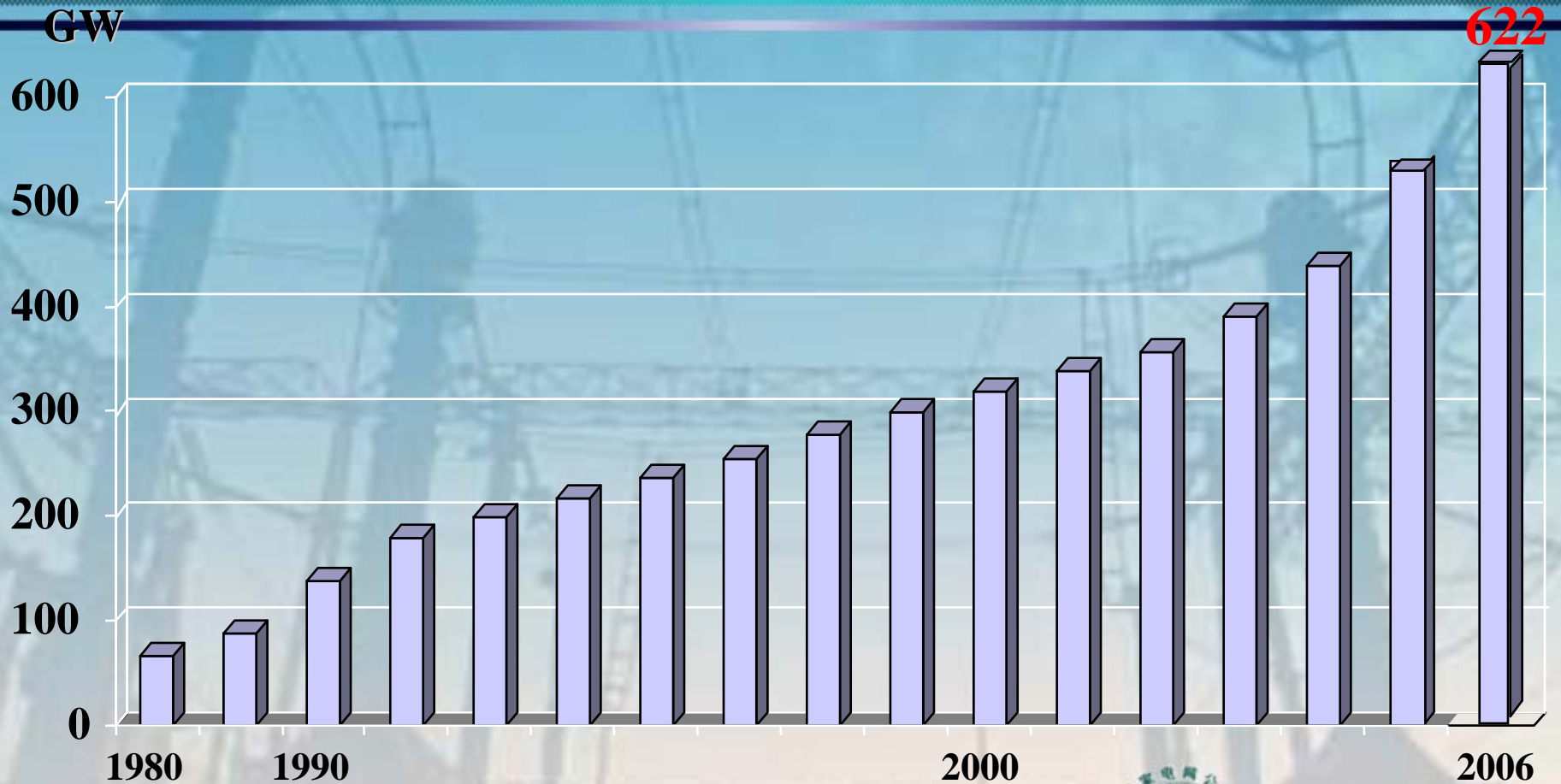


Organizations in China's Electric Power Industry

- State-owned Assets Supervision and Administration Commission of the State Council (SASAC)
- State Electricity Regulatory Commission
- China Electric Council (the reliability and industry council)
 - **The China Electric Reliability Management Center (CER), within the China Electricity Council**
- The China Electric Power Research Institute
- China IEEE
- China National Association of Engineering Consultants
- China Academy of Engineering
- State Grid Corporation of China (China Northern, Central, East, Northwest, & Northeast grid companies)
- China Southern Power Grid Company Limited (+ 5 interconnected grids)
- 5 corporatized generating entities

中国电网装机容量

The installed Capacity of China

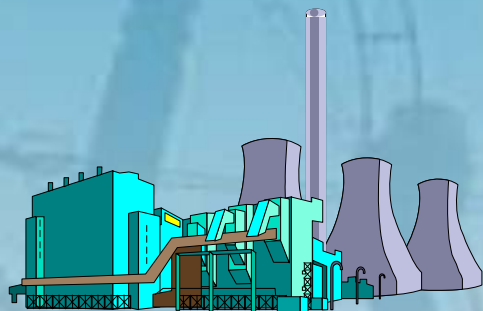


The installed capacity grows rapidly. From 1980 to 2006, the average annual growth rate of installed capacity is over 10%.



国家电网公司
STATE GRID
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全国装机容量 The installed capacity of China



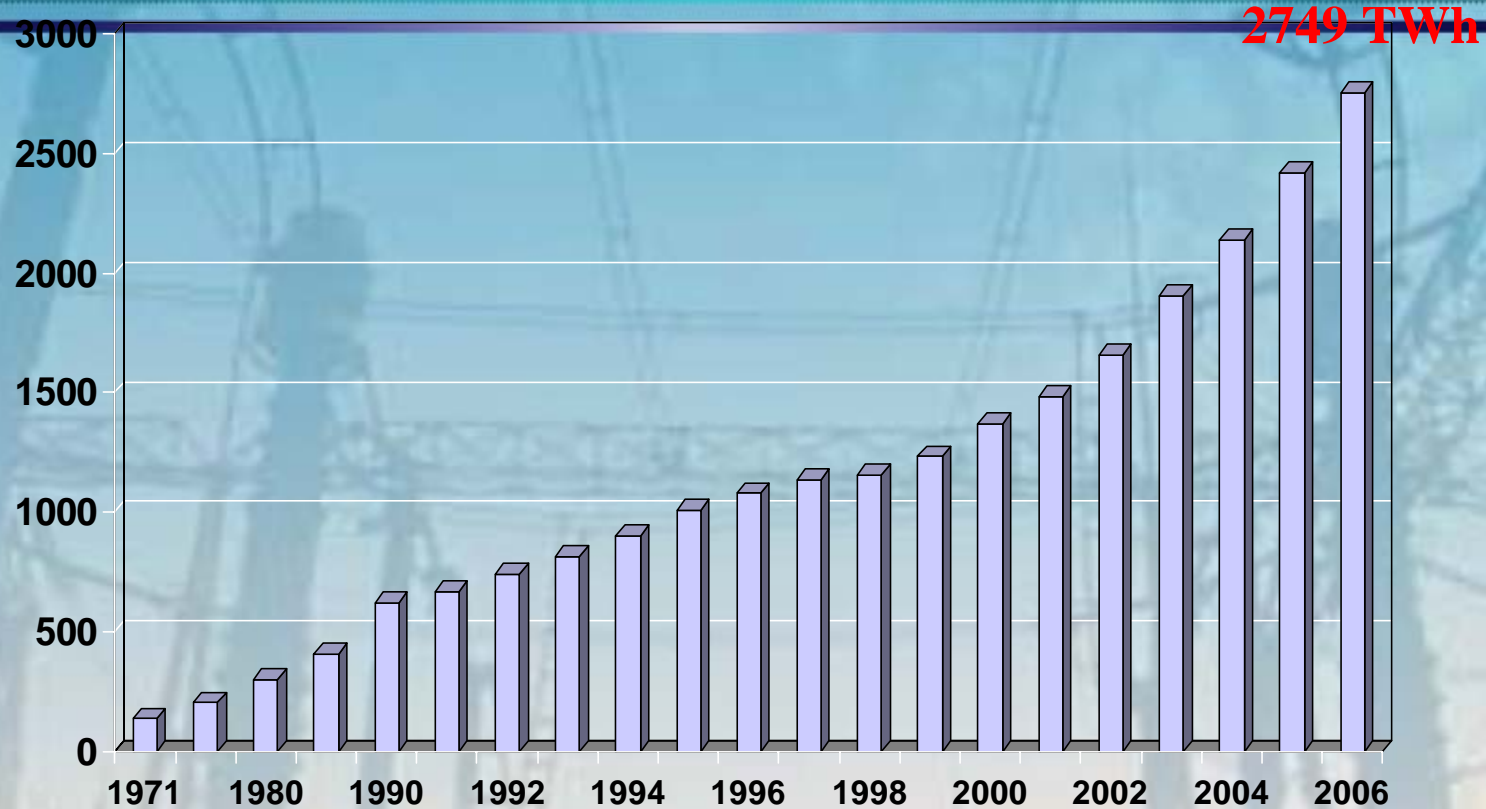
总装机 Total	622GW
火电 Thermal	484GW
水电 Hydro	129GW
核电 Nuclear	6.86GW
其它 Others	2.53GW



国家电网公司
STATE GRID
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全国年用电量增长情况

China Electricity Generation



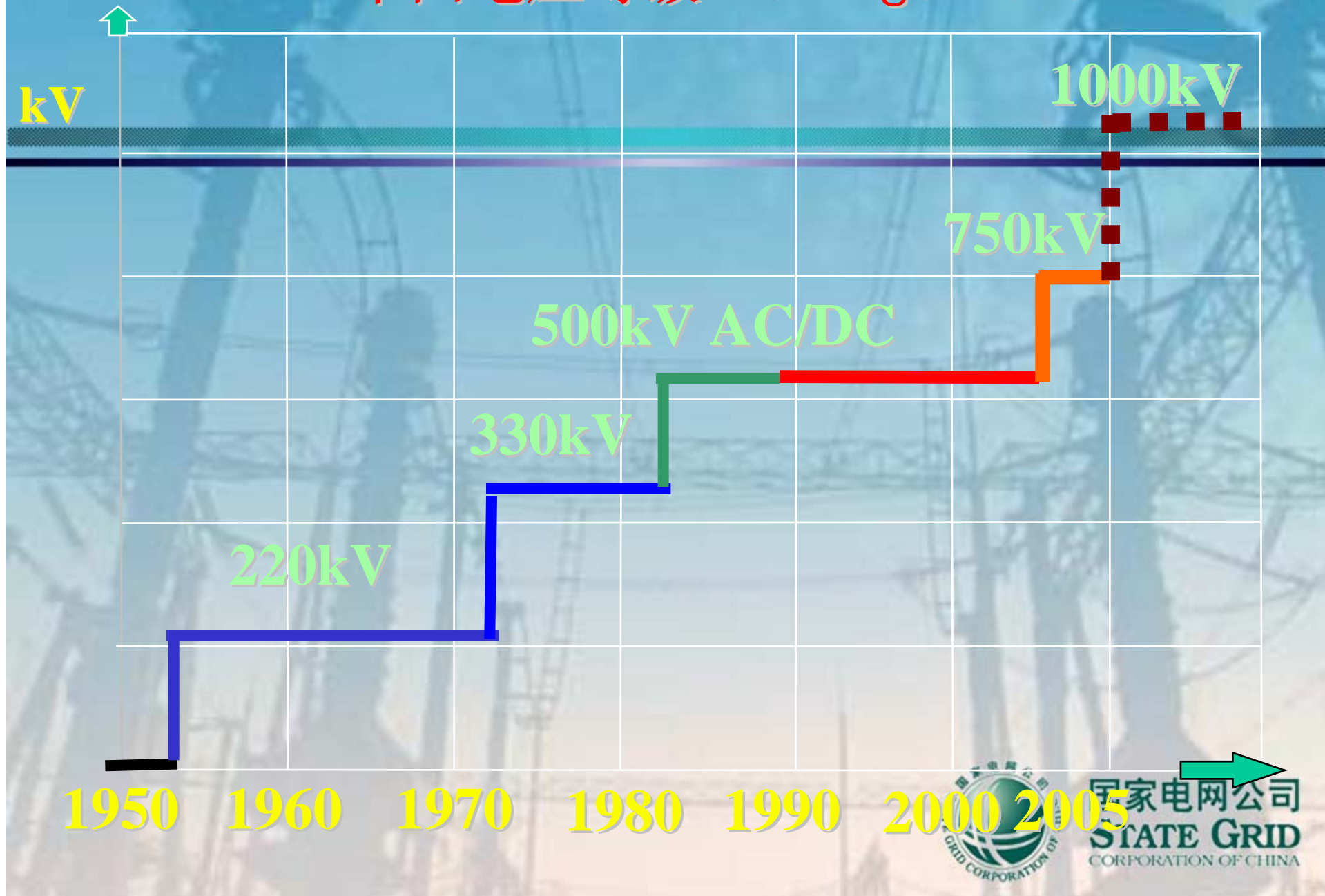
Electricity generation grows rapidly. From 1998 to 2006, the average annual growth rate of electricity generation is over 10%.

全国年用电量增长迅速，1998至2005年间，平均年增长率超过10%。



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中国电压等级 Voltage Level



国家电网输电线路长度

Transmission Lines Over 220kV in SG

- 截至2006年底，220kV电压等级线路总长达19.3997万公里。
- By the end of 2006, the total length of 220kV transmission lines in SG is about 193,997km.
- 500kV及330kV电压等级线路8.7369万公里。
- There are 87,369km 500kV and 330kV transmission lines.
- 2005年9月26日，中国第一条750千伏交流线路（140.7km）开始运行。
- On September 26th 2005, the first 750kV transmission line which is 140.7km was put into operation.

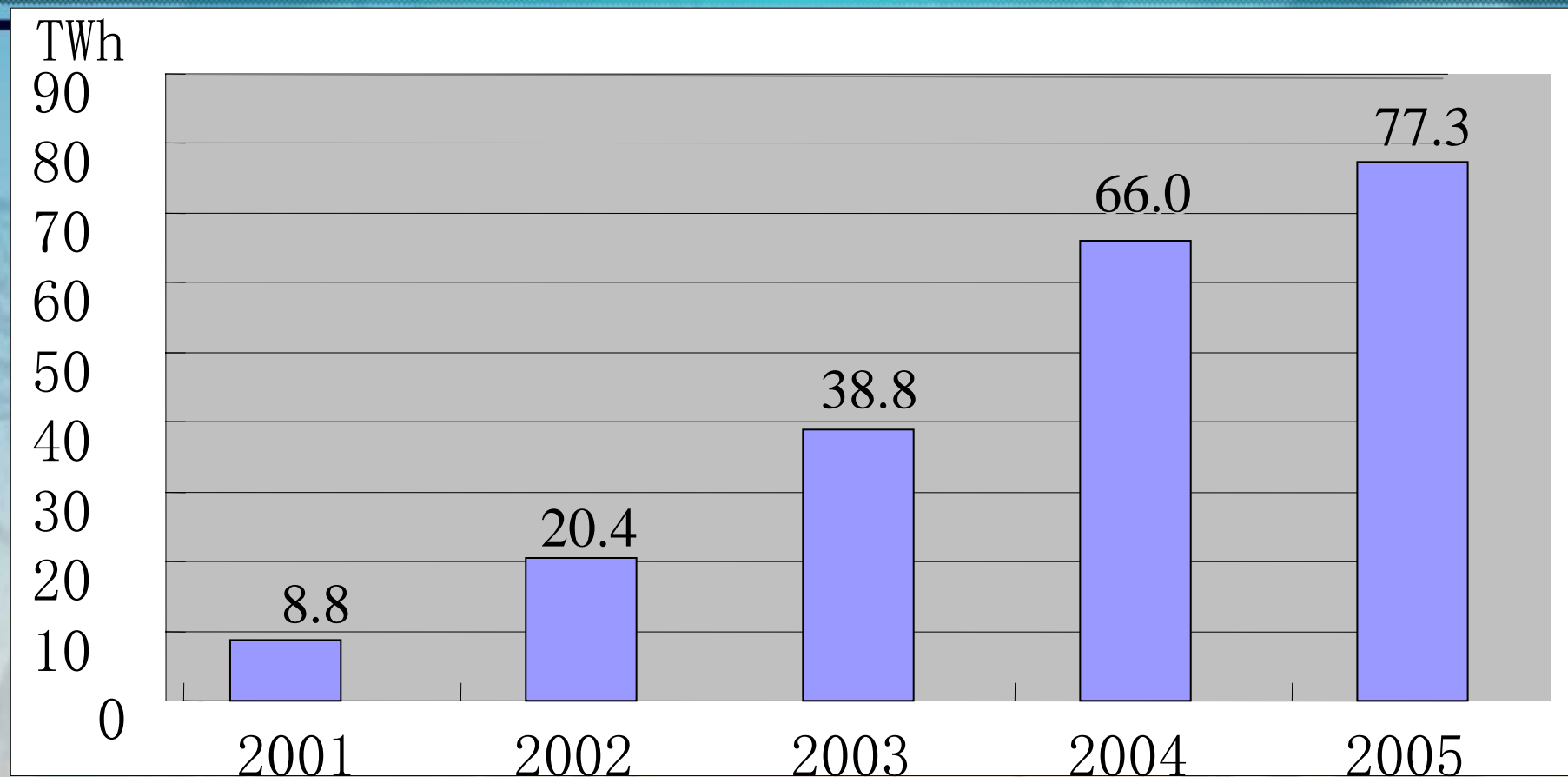
全国联网示意图

Inter-connected Grid in China



2001-2005年跨区送电情况

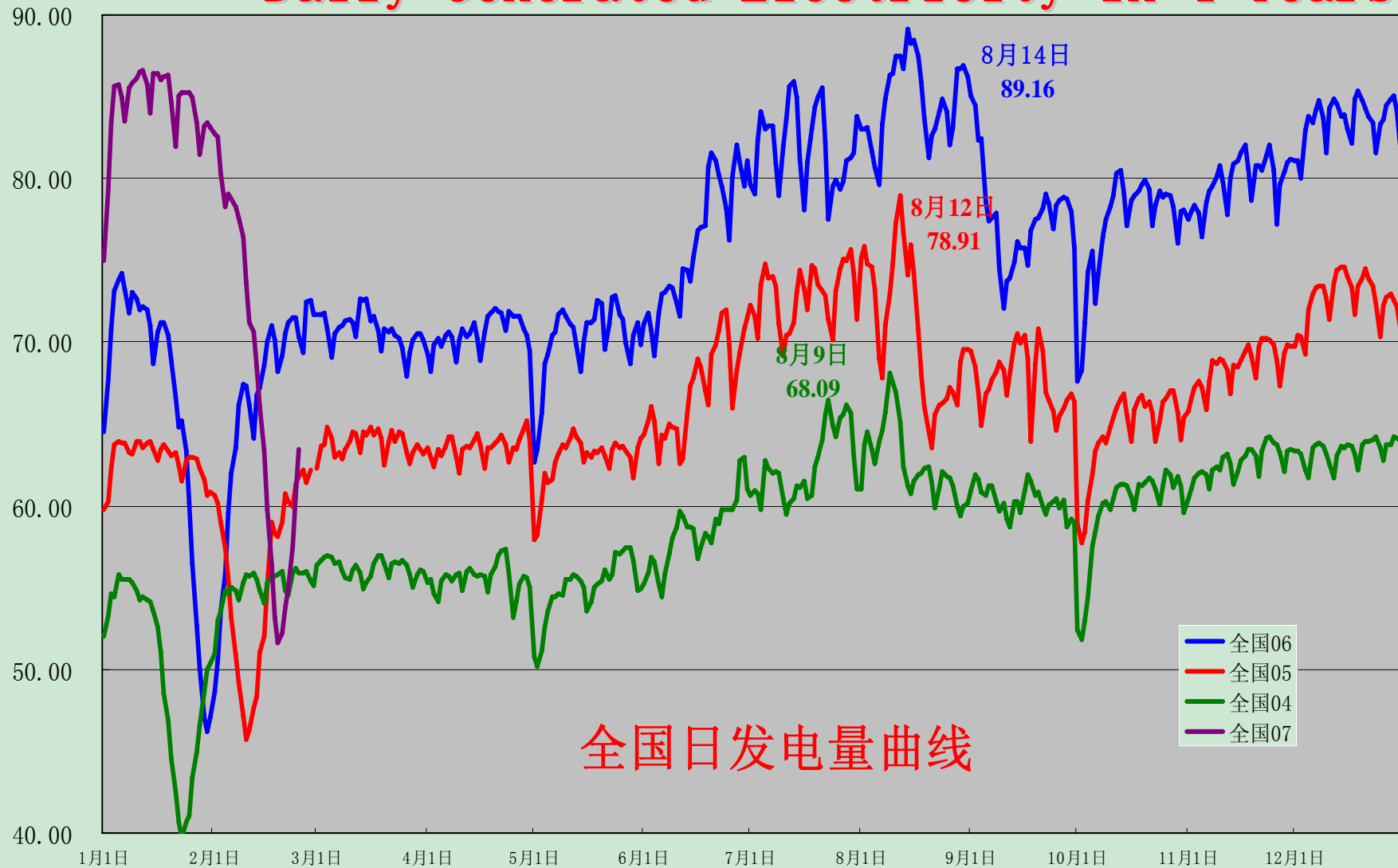
Inter-regional Power Transmission



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全国日发电量曲线

Daily Generated Electricity in 4 Years



全国日发电量曲线

全国电网概况 2006.12

installed Capacity and peak load



中国电网稳定性

China Power System Stability

1970—1980 19 stability fault per year

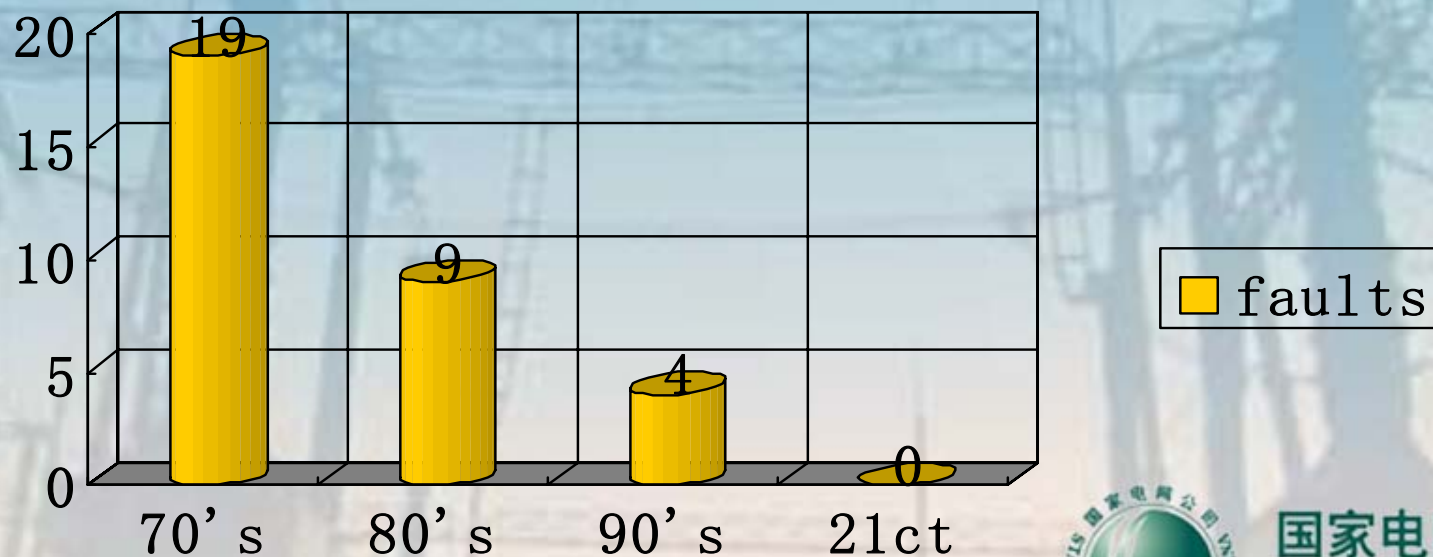
1981—1988 9 stability fault per year

1989—1996 4 stability fault per year

1997--Now no stability disruption fault

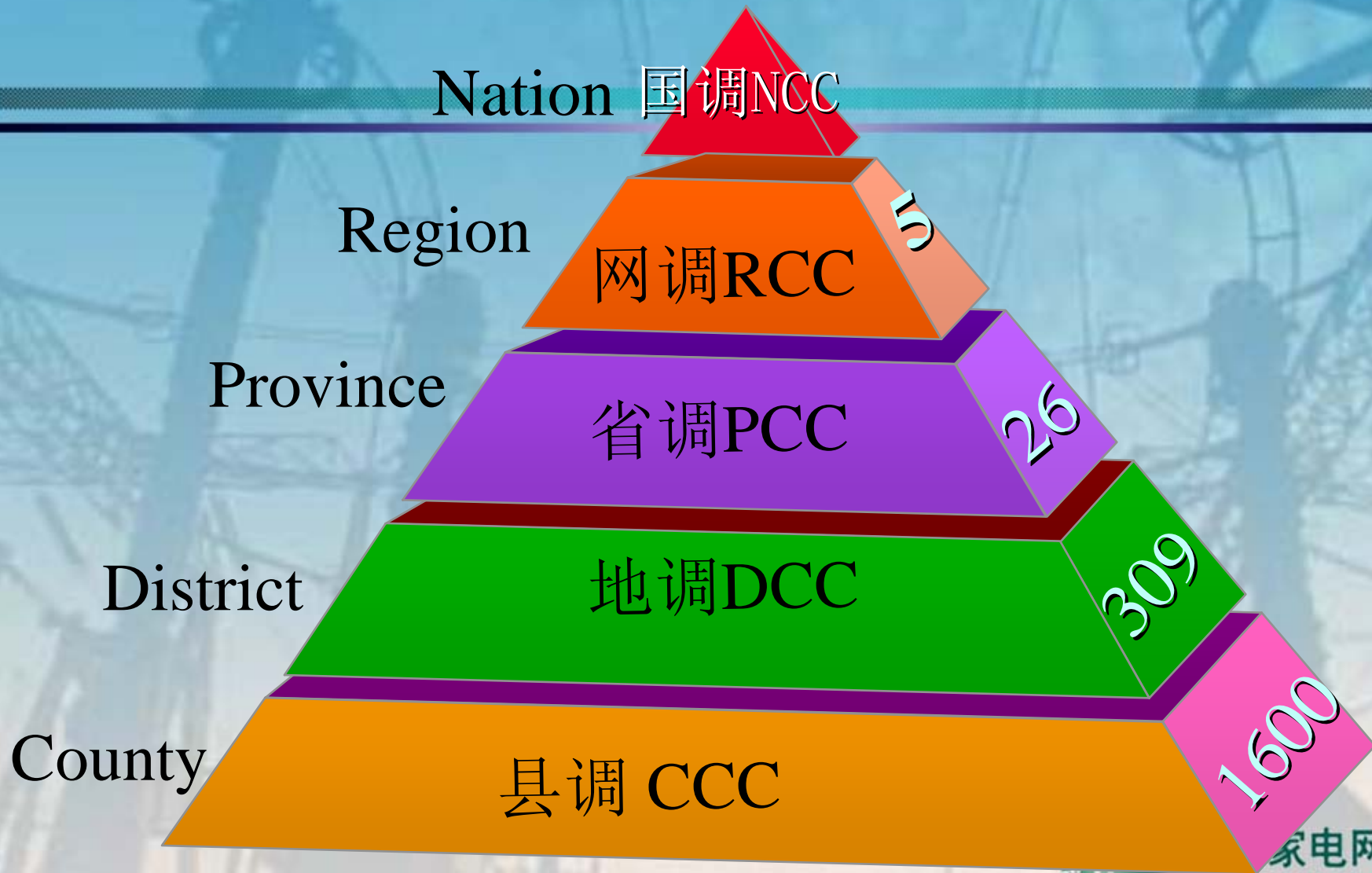
RS1: 99.747,

RS3: 99.893



国家电网公司的调度组织体系

Dispatching Organization of SGCC



国调中心技术支持系统

Technical Supporting Systems in NCC

国调目前采集全国各网省330kV以上线路及百万以上电厂的实时数据。监视280个厂站的实时运行工况，采集遥测量9144个，遥信量17227个，并可对电厂进行AGC控制。

NCC now collects the real-time data of power lines above 330kV and plants each of whose capacity is more than 1000MW. NCC supervises status of 280 stations and acquires 9144 measurements as well as 17227 indications. NCC also can implement AGC on plants.



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国调中心的现代化装备

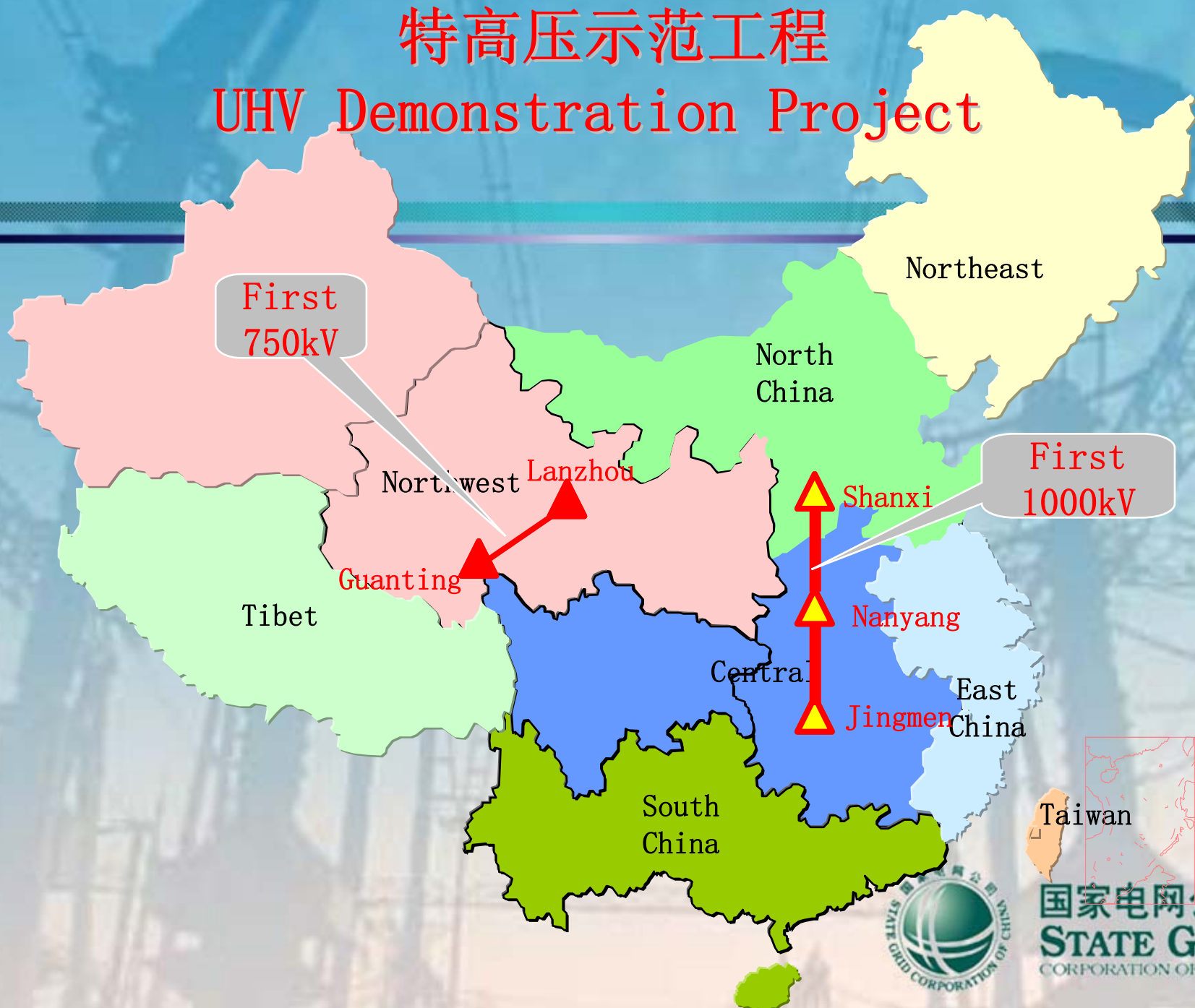
Monitoring and Control Facilities in NCC

1. 能量管理系统Energy management system (EMS)
2. 调度员仿真培训系统Dispatching Training System (DTS)
3. 水调自动化系统Hydro-power Management System (HMS)
4. 市场管理系统Market Management System (MMS)
5. 电量计量系统Tele-Meter Reading System (TMR)
6. 调度数据网State Grid Dispatching Data Network (SGDnet)
7. 广域测量系统Wide Area Measuring System (WAMS)
8. 保护信息管理系统Relay and Fault Information Management System(RMS)
9. 调度信息管理系统Dispatching Management Information System (DMIS)
10. 雷电监测系统 Lighting Monitoring System (LMS)



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特高压示范工程 UHV Demonstration Project



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China's Natural Gas Pipelines and Major LNG Terminals Under Construction, Approved, or Proposed



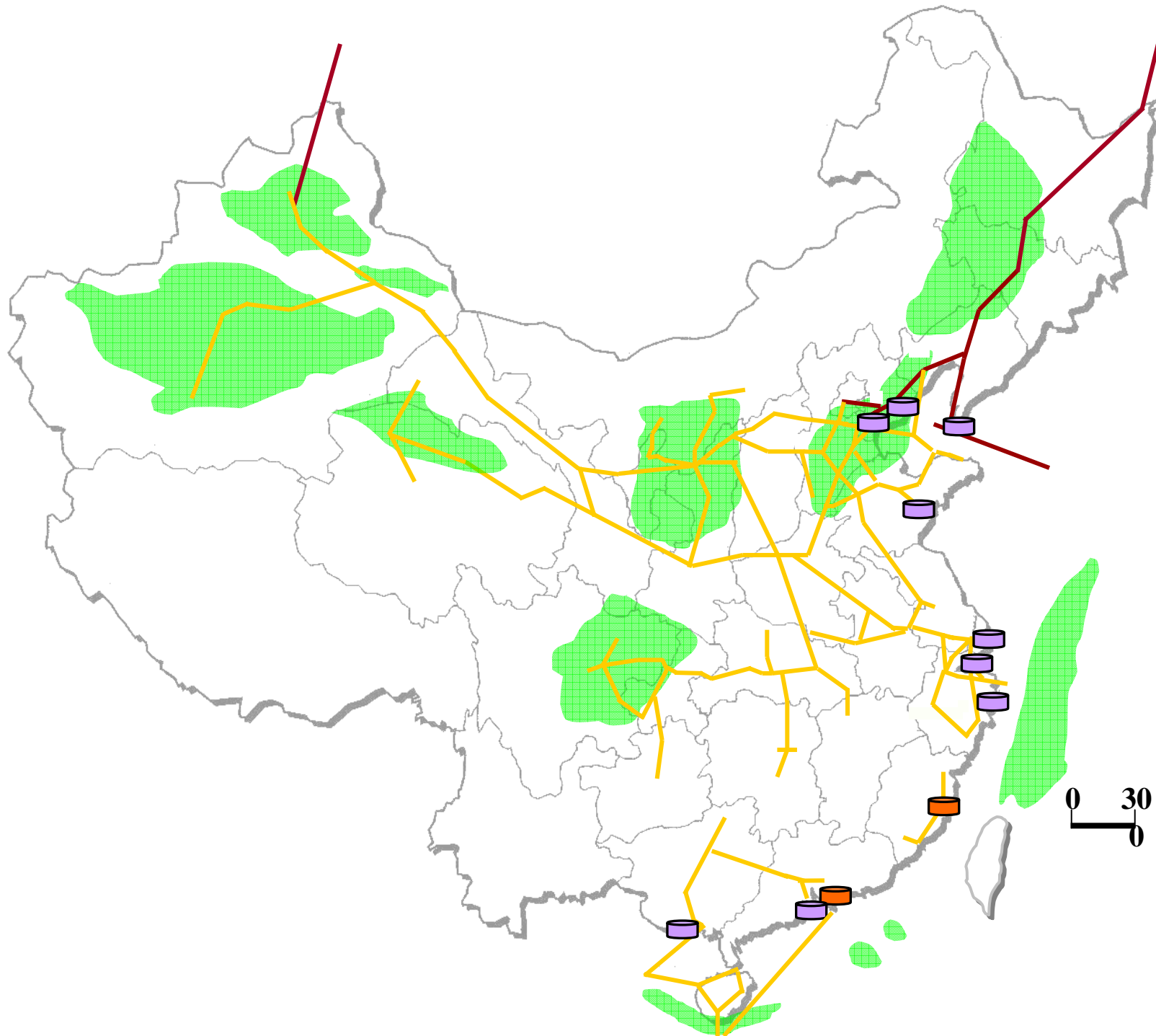
SOURCE http://www.eia.doe.gov/oiaf/ieo/nat_gasboxfigure.html

Sources: Coal: Barlow Jonker Pty. Ltd., *Major Coalfields of China* (Sydney, Australia, 2001). Natural Gas: Jeffrey Logan, Senior Energy Analyst and China Program Manager, International Energy Agency, "China Oil and Gas Outlook and Implications for Energy Markets," Testimony Before the U.S. Senate, Committee on Energy and Natural Resources, Hearing on EIA's Annual Energy Outlook for 2005 (Washington, DC, February 3, 2005), web site <http://energy.senate.gov/public/>.

SOURCE: PetroChina Planning & Engineering Institute 中国石油规划总院

发展多气源

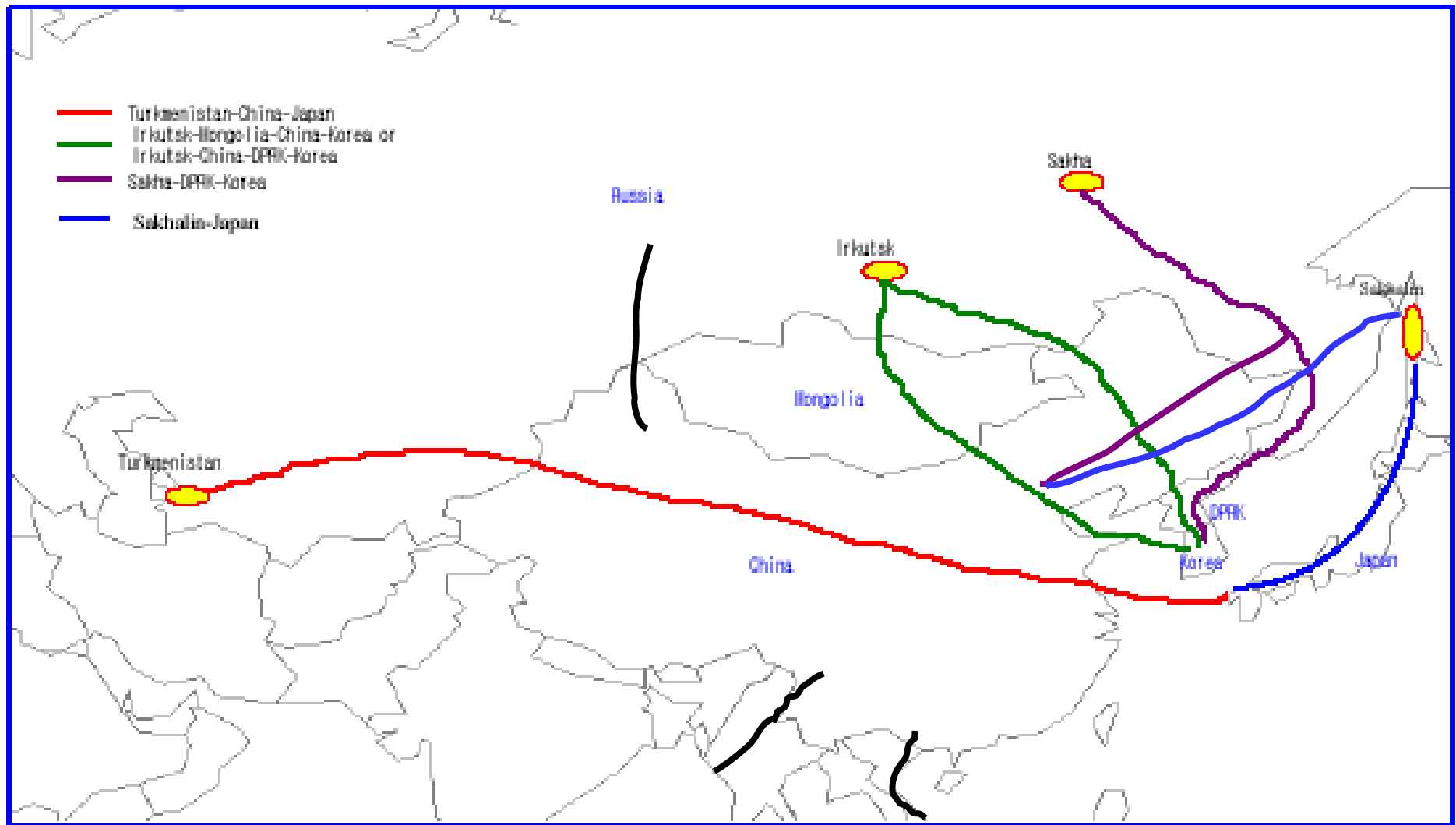




0 30 公里
0 Km

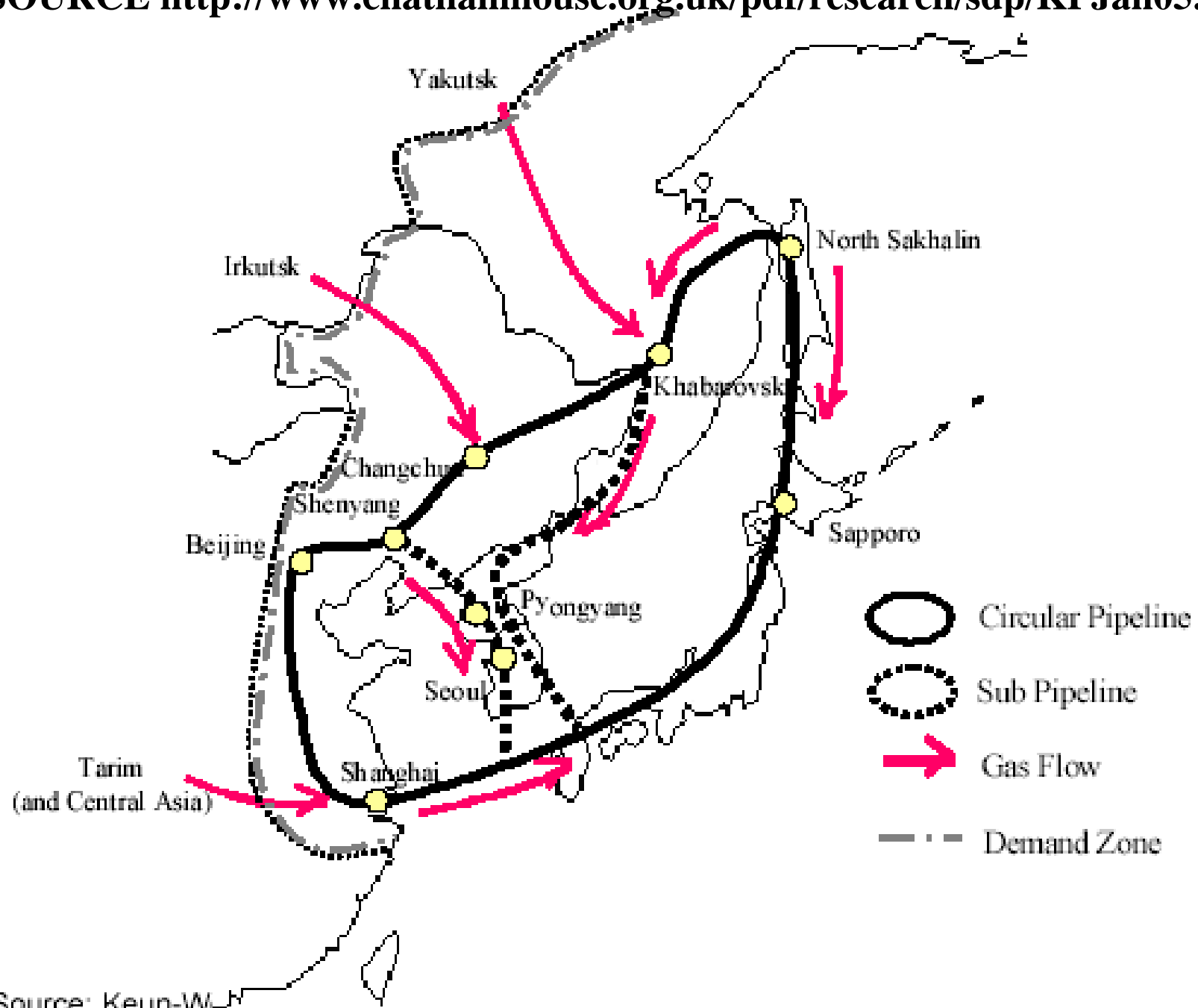


Figure 25 Various regional pipeline projects under consideration



Source: <http://www.ieej.or.jp/aperc/final/ne.pdf>

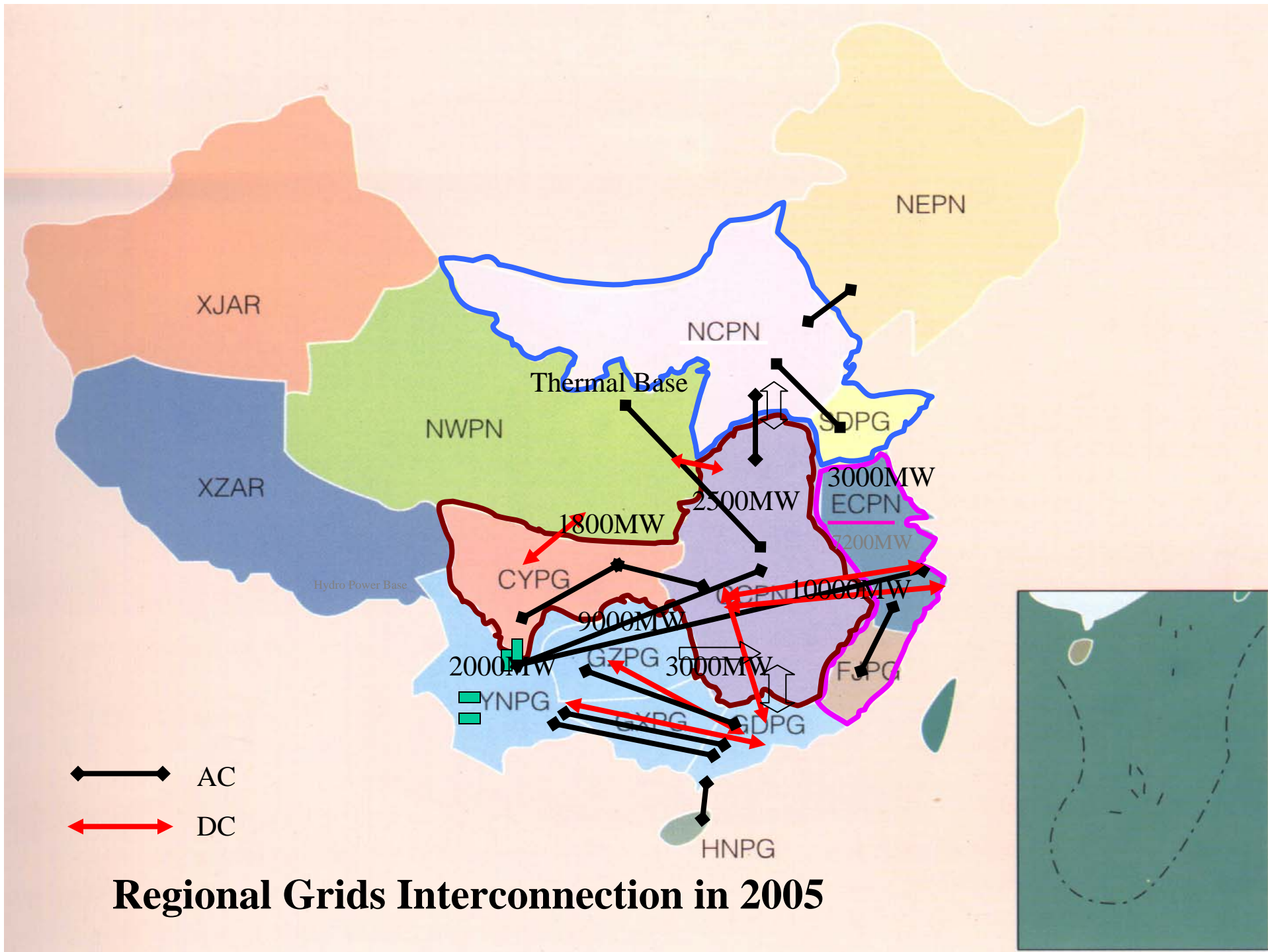
SOURCE <http://www.chathamhouse.org.uk/pdf/research/sdp/KPJan05.pdf>

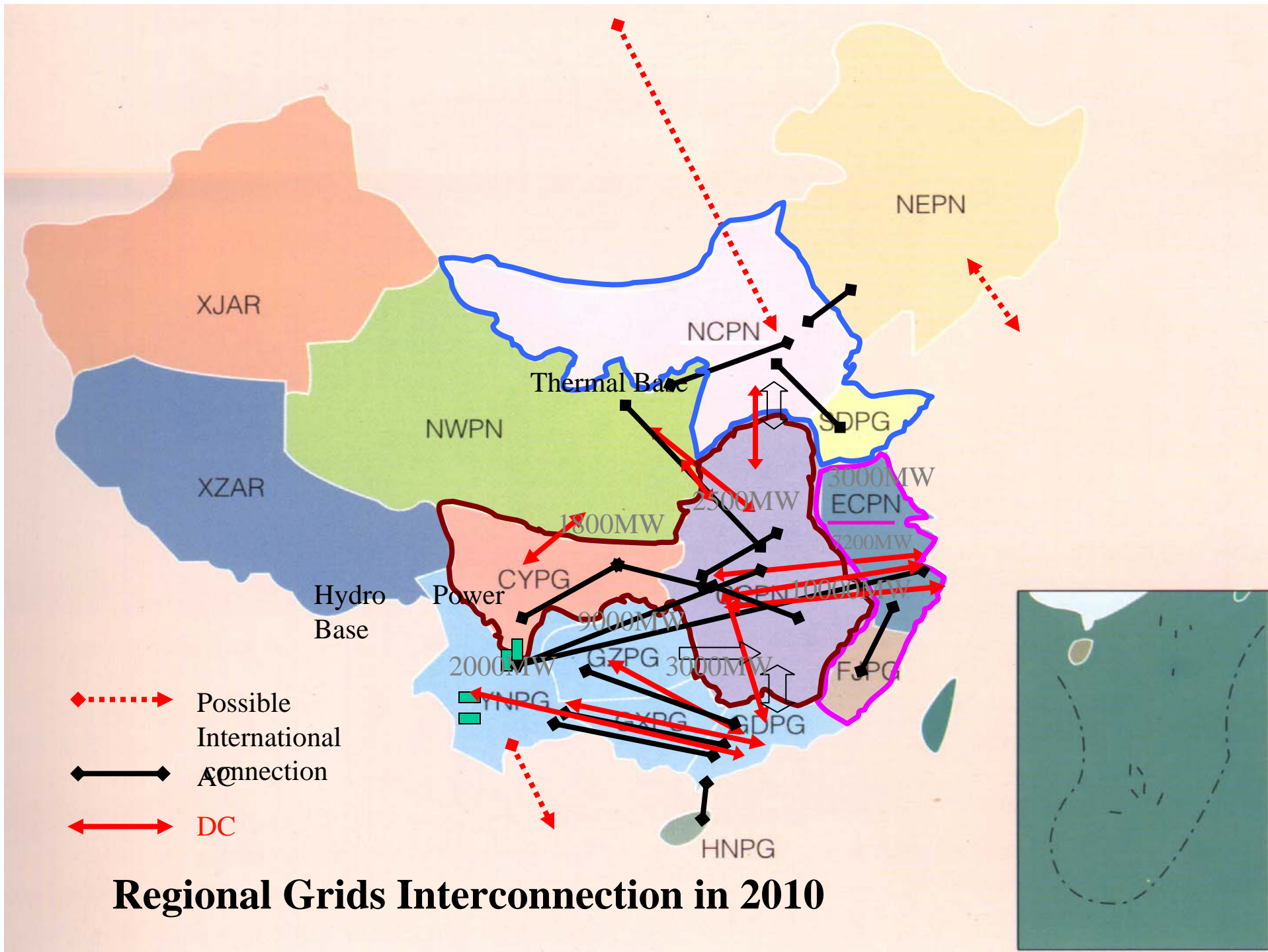


Source: Keun-W

China's Electric Grid Should be Planned so that Electric Transmission Does not Substitute too much for Natural Gas Pipeline.

- **Example: Sichuan to Guangzhou, Sichuan to Shanghai**
- **Plan to use Ultra-High Voltage to move remote coal and hydro power.**
- **Maintain the dominant roles of hydro and coal in China's energy mix, and China's status as world's biggest hydro producer and 2nd biggest coal producer?**





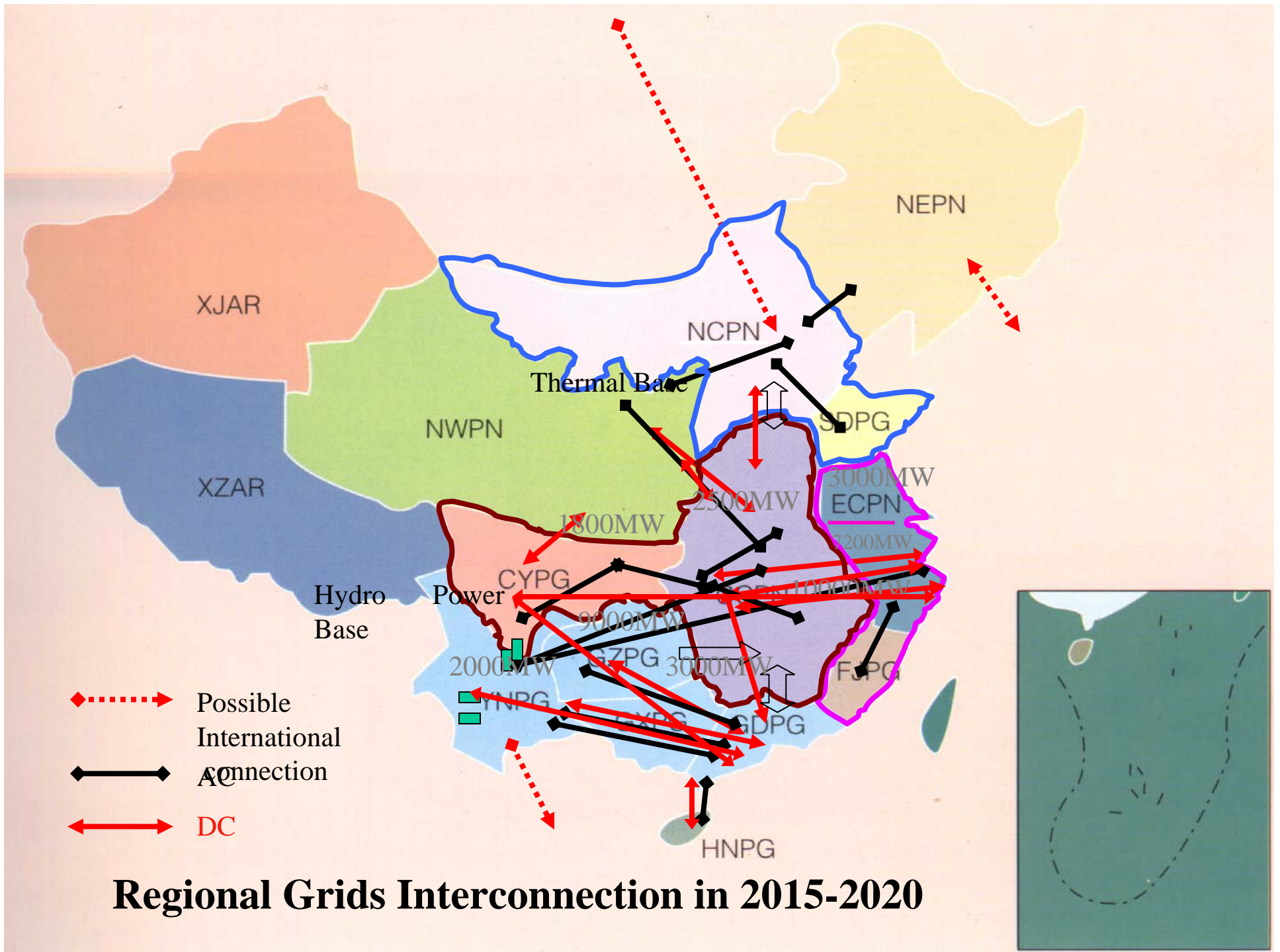
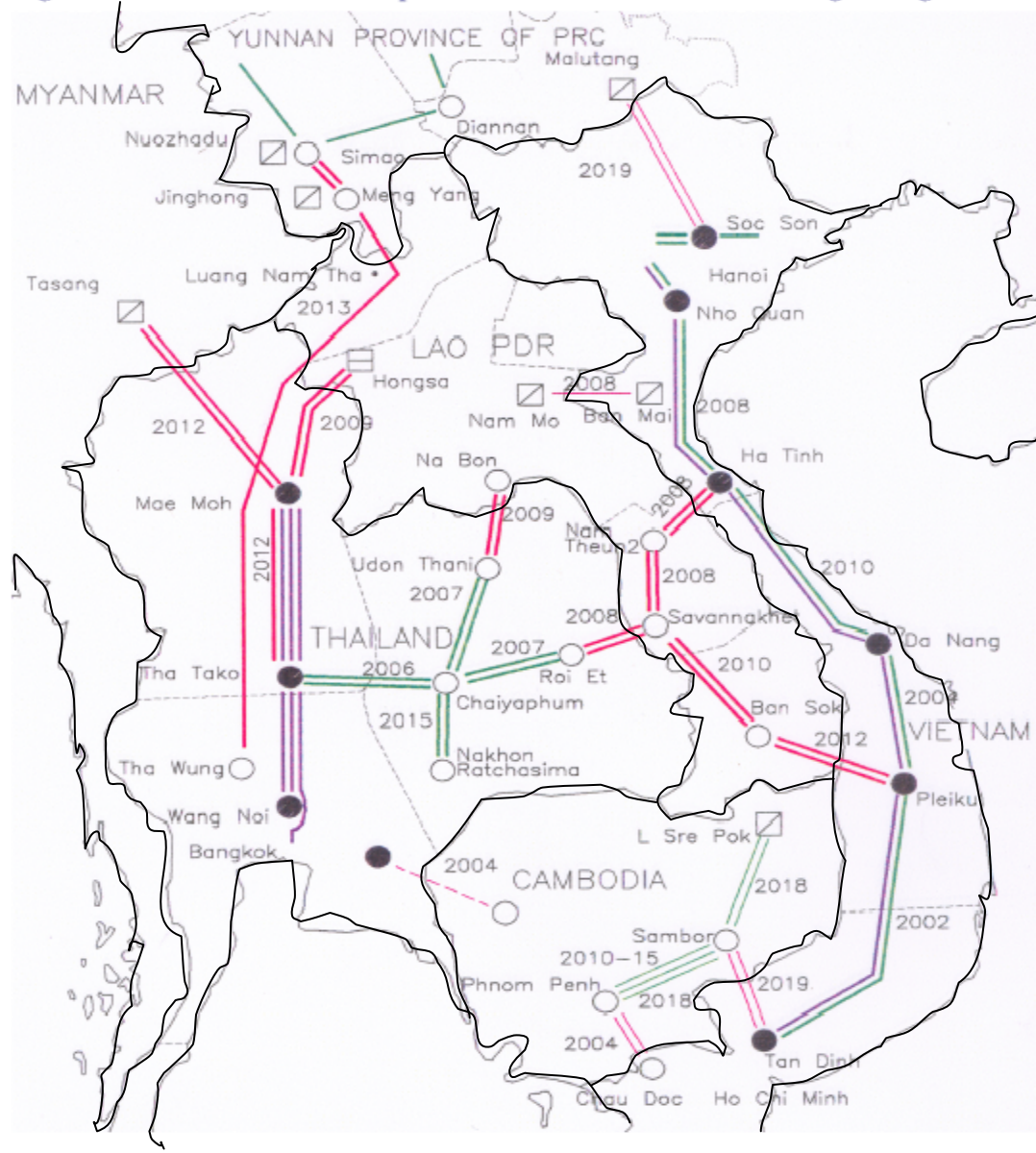


Figure 9 Extended Power Cooperation Scenario for Greater Mekong Subregion



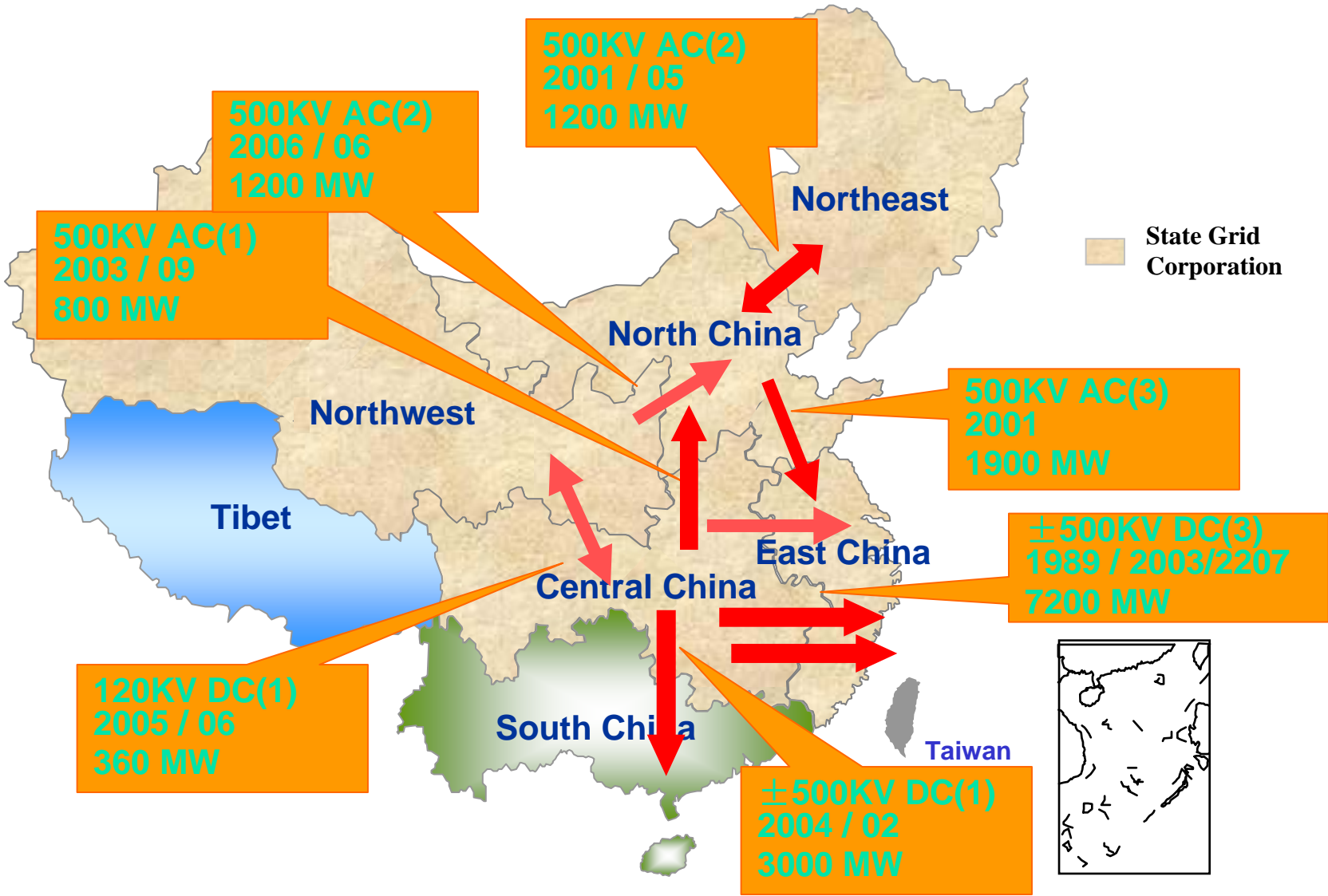
Source: Dooman and others (2004). Note: Existing substations are shown as filled circles, planned substations as empty circles. Hydro plants are shown as squares with a diagonal slash, fossil-fuelled plants as squares with a horizontal slash.

SOURCE: http://www.iej.or.jp/aperc/pdf/GRID_COMBINED_DRAFT.pdf

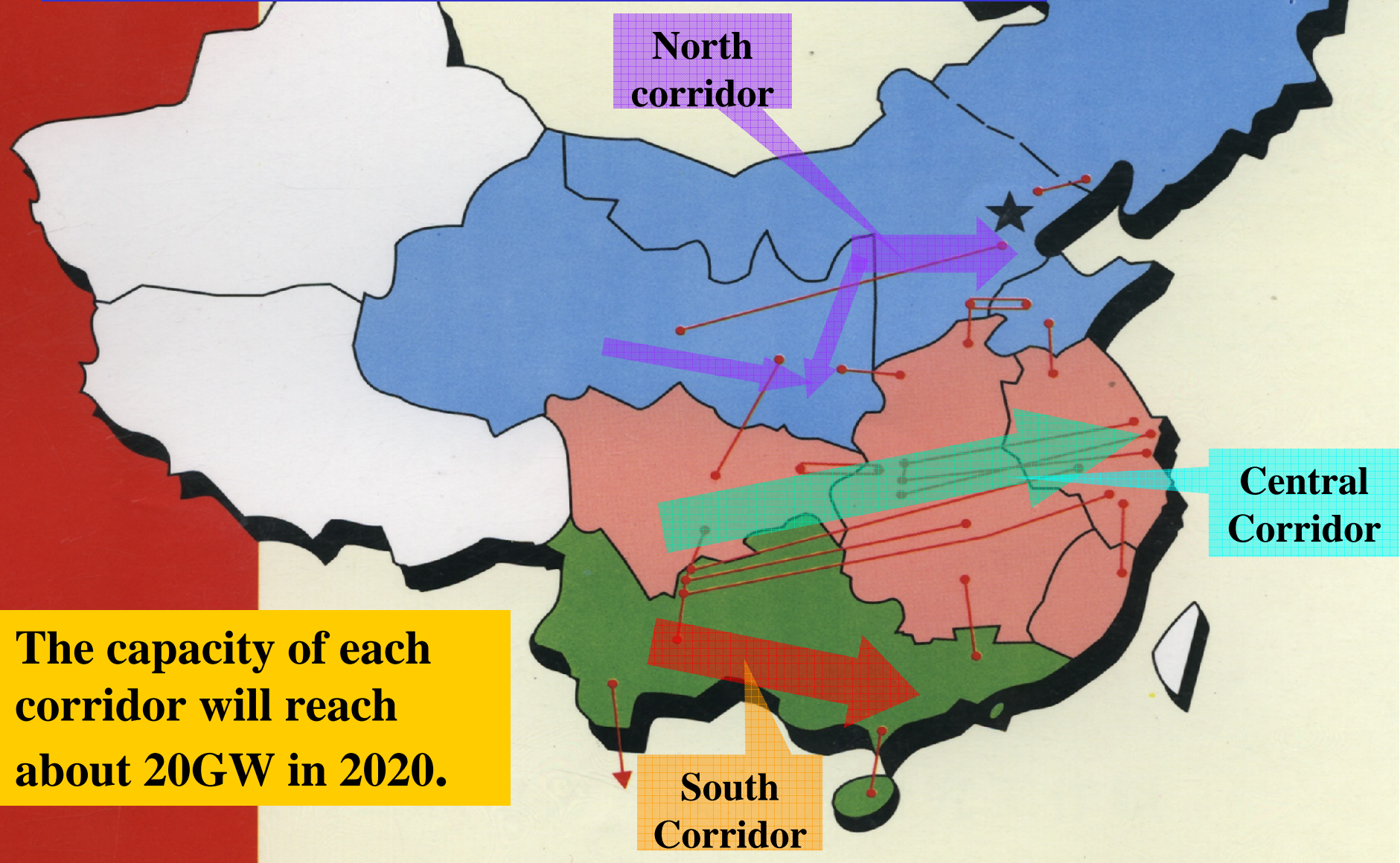
Power network in China



Grid interconnection



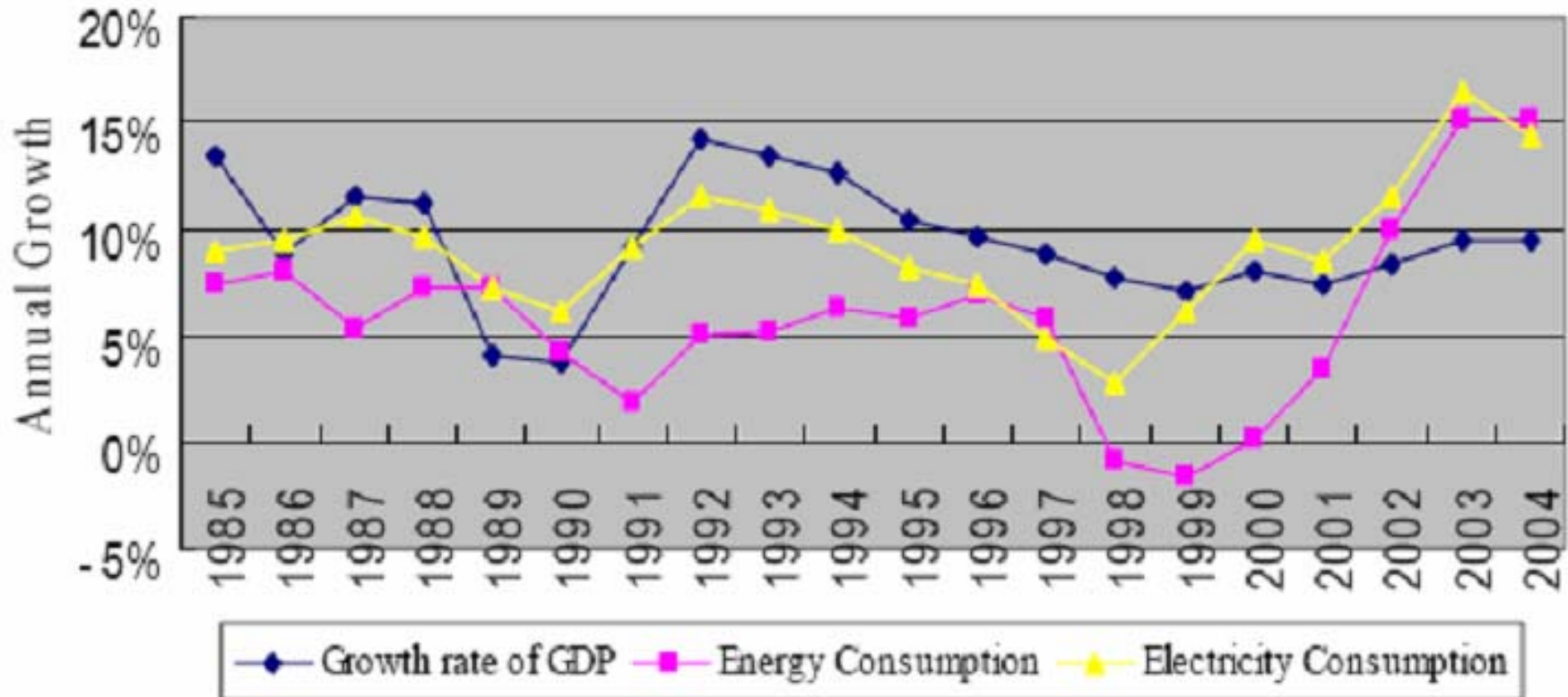
Power transmission from The West to the East: Three transmission corridors



The capacity of each corridor will reach about 20GW in 2020.

Power supply and demand

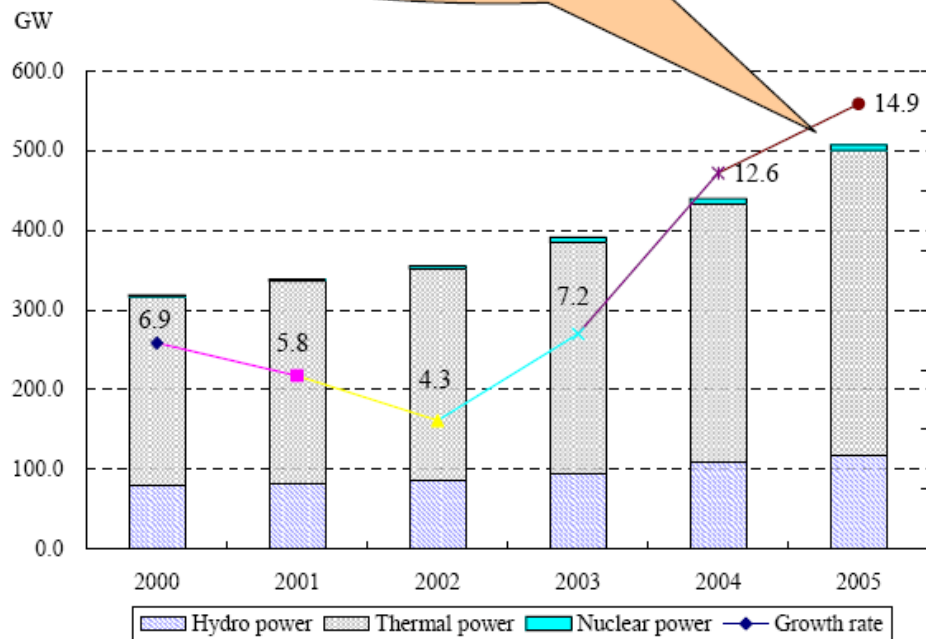
Growth of GDP, energy and electricity use



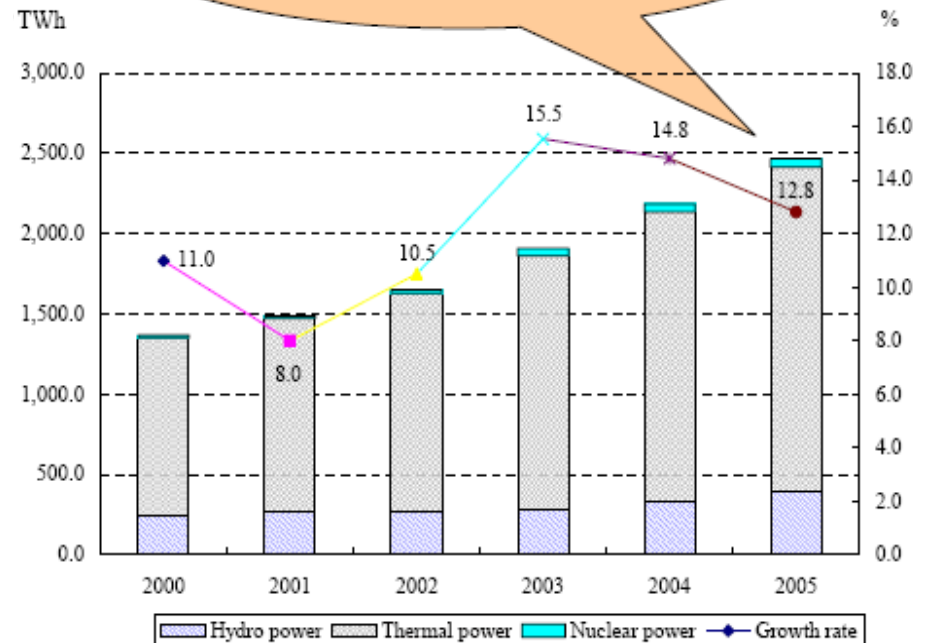
Power supply and demand

- China's installed capacity and power generation output are second largest in the world's electricity industry following the United States

By 2005, installed capacity reached 508 GW



By 2005, power generation reached 2,475 TWh



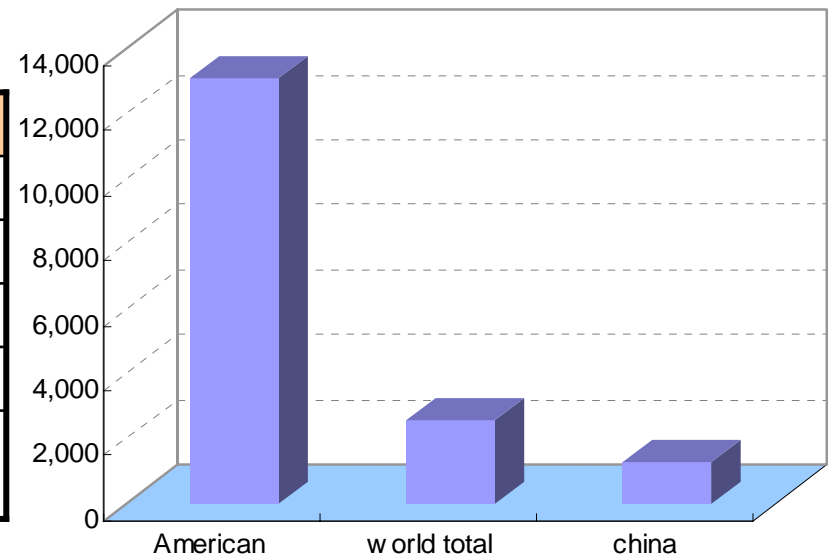
Source: China Electricity Council (<http://www.cec.org.cn/cec-en/index.htm>)

Power supply and demand

- Electricity intensity per capita is 1/10 that of U.S. and less than half of the world's average.

	China	U.S.	World total
Installed capacity (GW)	356.6	979.6	3,372.8
(% of world total)	(9.6%)	(26.4%)	(100%)
Power generation (TWh)	1,654.2	3,858.5	15,614.1
(% of world total)	(10.6%)	(24.7%)	(100%)
Power generation per capita (KWh/person)	1,288	13,120	2,578

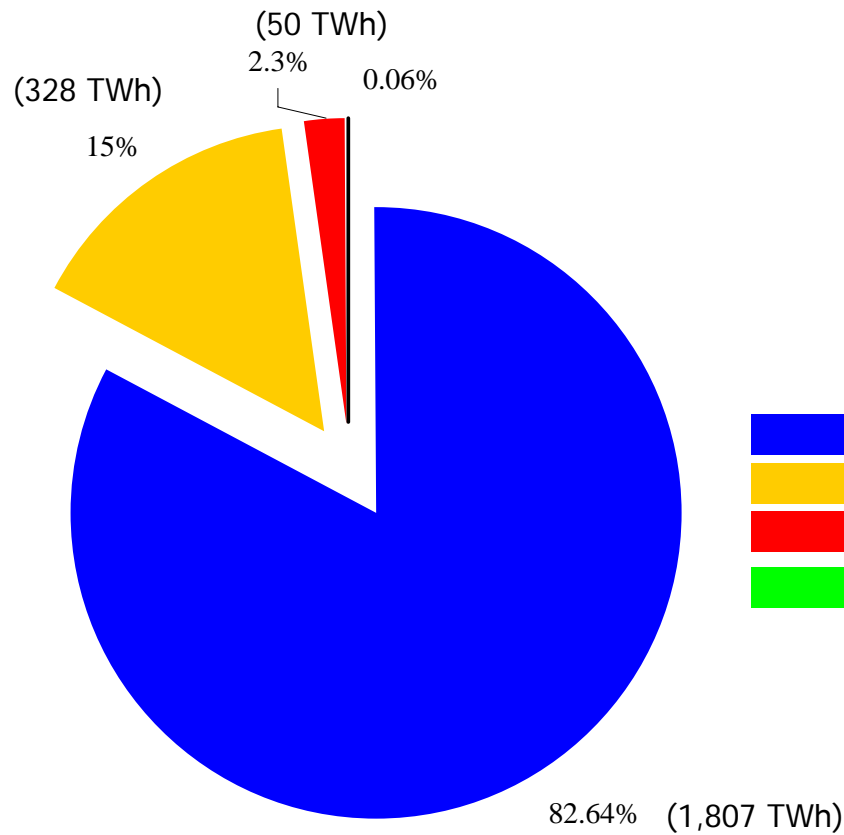
2002 Data



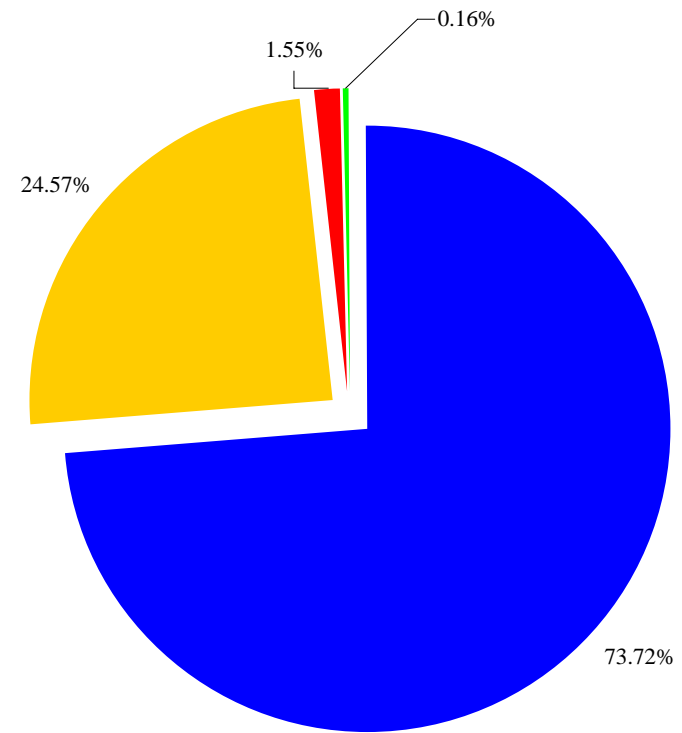
2002 Per Capita Generation in KWh per person

Power supply and demand

- Coal is the major generation supply fuel.

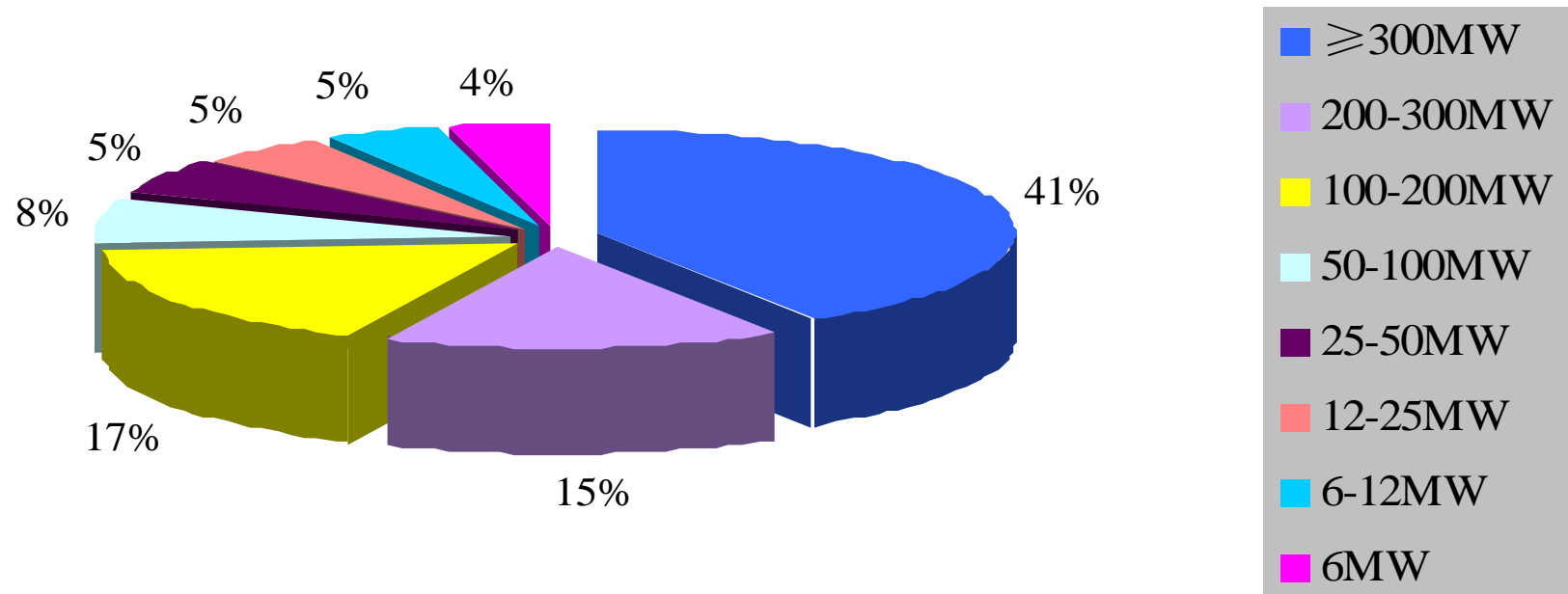


Power generation in 2004



Installed capacity in 2004

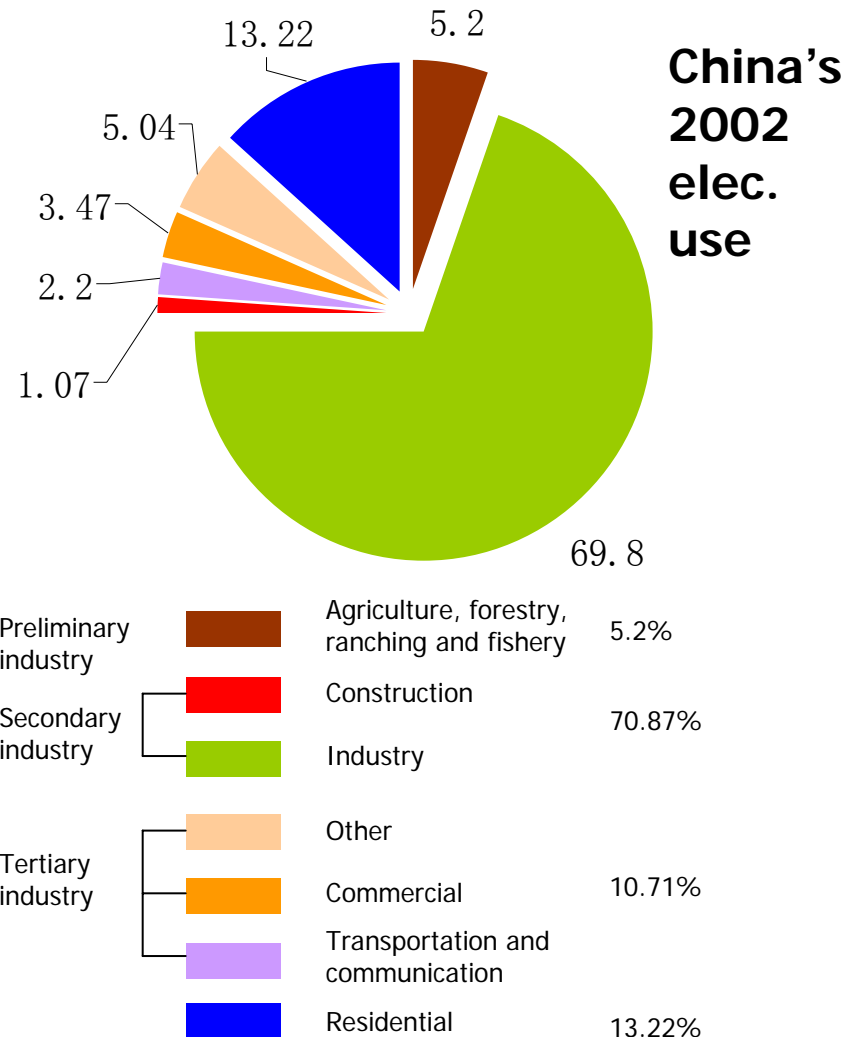
Power supply and demand



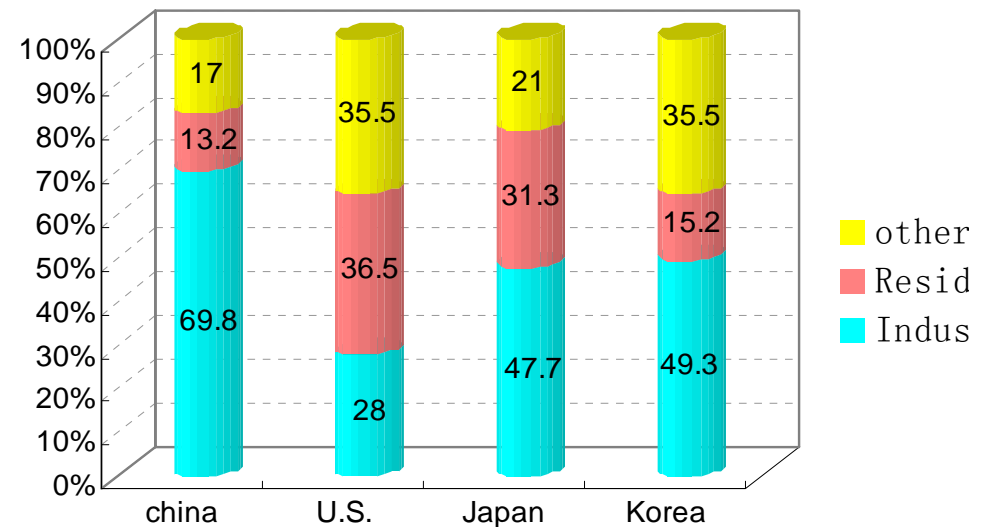
Coal-fueled installed capacity mix in 2003 by unit size. The total installed capacity is 289,770MW

Power supply and demand

■ Industry electricity use dominates other sectors



Share of total 2002 electricity use by sector in 4 countries



Source: China Statistical Annual and China Energy Resource Statistical Annual, and China Electric Power Information Center. 2002 data.

Power supply and demand

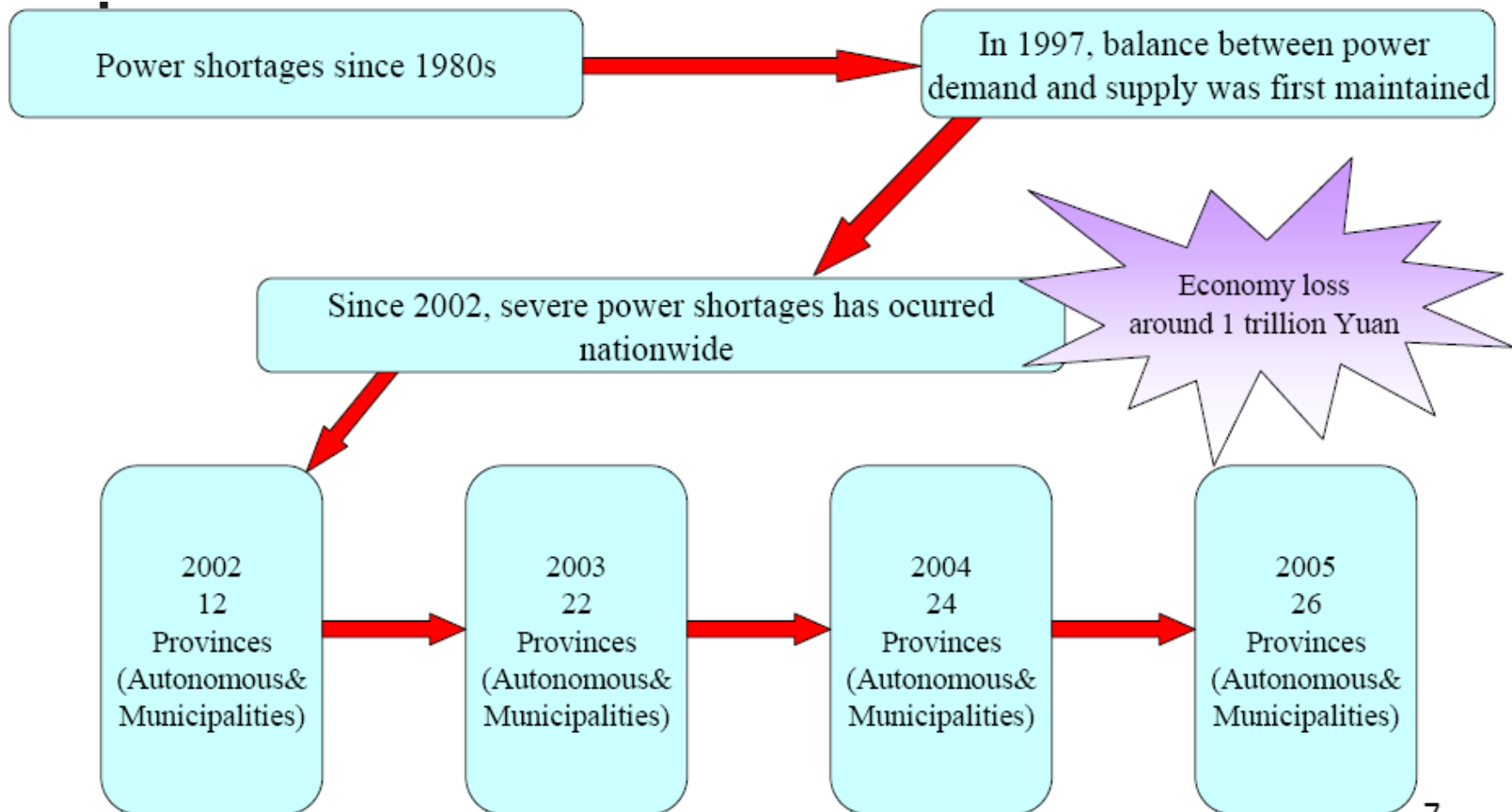
Business consumption growth dominates total growth

Year	Total	Agriculture, forestry, ranching and fishery	Industry and construction	Transportation, communication, commercial and others	Residential	Rate of increase relative to the previous year
2002	14,979	780	10,619	1,600	1,980	10.4%
		5.2%	70.87%	10.71%	13.22%	
2003	18,633	559	13751.2	2,422.2	1,900.8	24.4%
		3%	73.8%	13%	10.2%	
2004	21,762	687.5	16,301	2,329.5	2,444	16.3%
		3.16%	74.9%	10.7%	11.24%	
2005	24,690	740	18,480	2,630	2,840	13.5%
		3%	74.85%	10.65%	11.5%	
'02-'05 annual growth	18%	-2%	20%	18%	13%	

Electricity consumption (2002-2005)

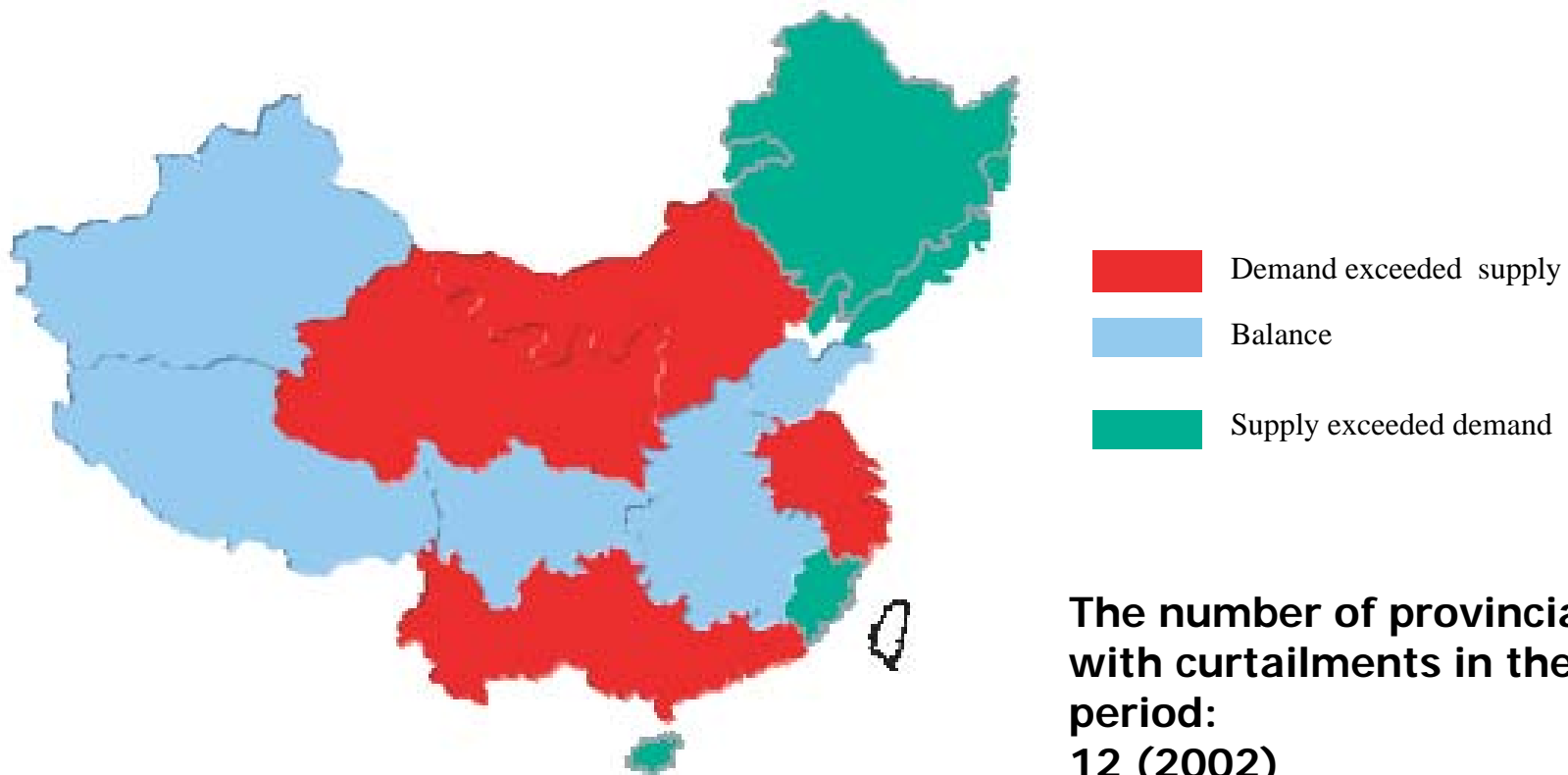
Power supply and demand

- Power shortages were being caused by need for more generation capacity (Trillion Yuan = \$130B)



Power supply and demand

- Power shortages occurred in three major regions.



Demand and supply condition by region (2005)

The number of provincial grids with curtailments in the peak period:

12 (2002)

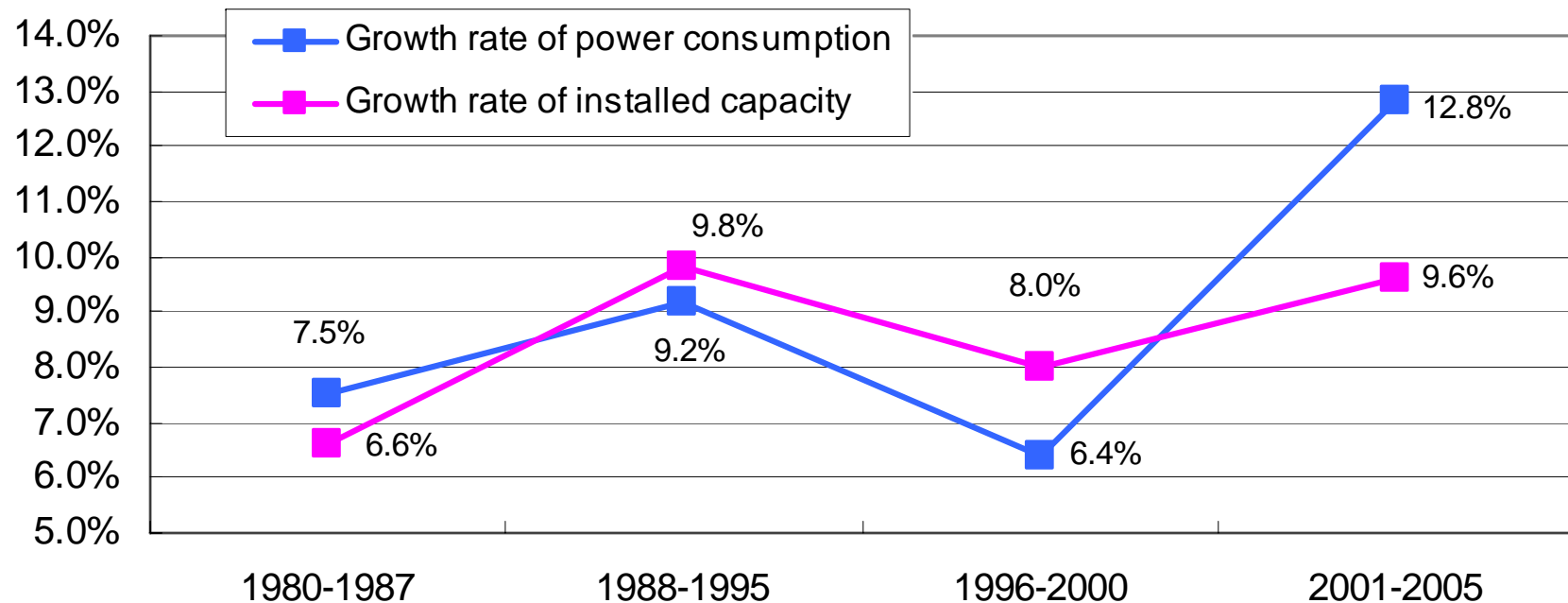
22 (2003)

24 (2004)

26 (2005)

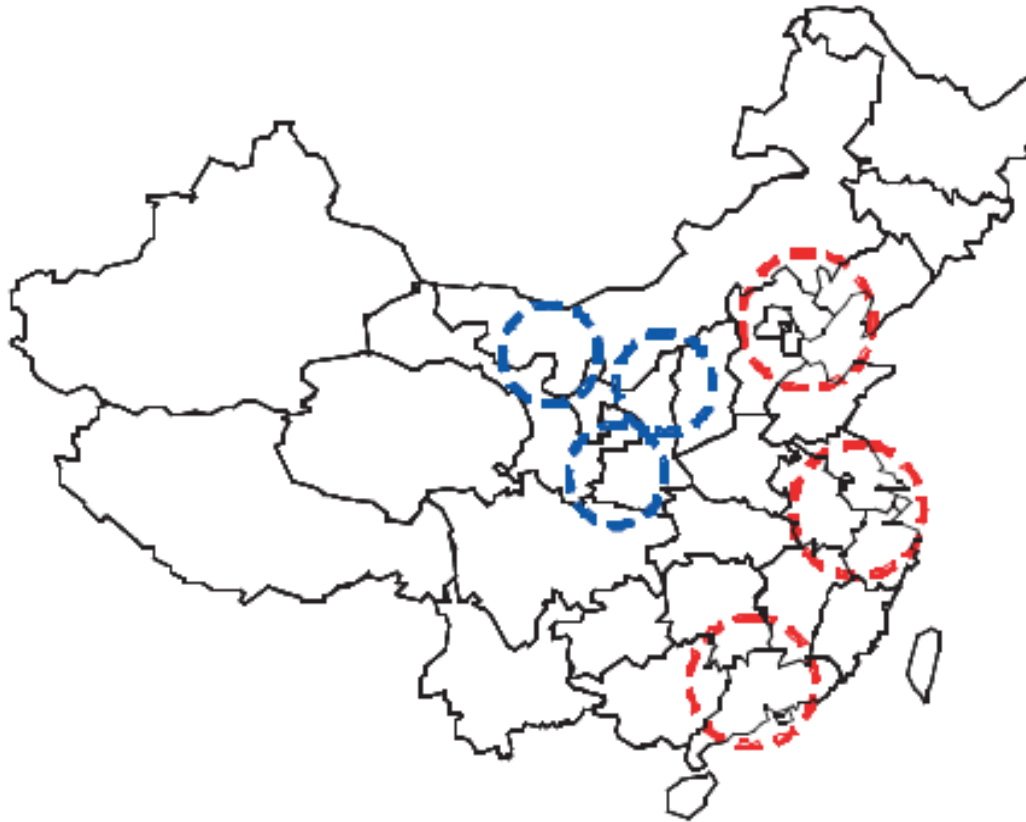
Causes of power shortages

- Climatic variability (droughts and heat waves)
- Economy, and therefore energy use, is growing faster than electric generation capacity can be built.



Causes of power shortages

- Coal supply shortages and transport bottle-necks
- Escalating coal prices and decreased energy content of coal. Differences in price trends of “regulated power prices” and “unregulated coal prices”.



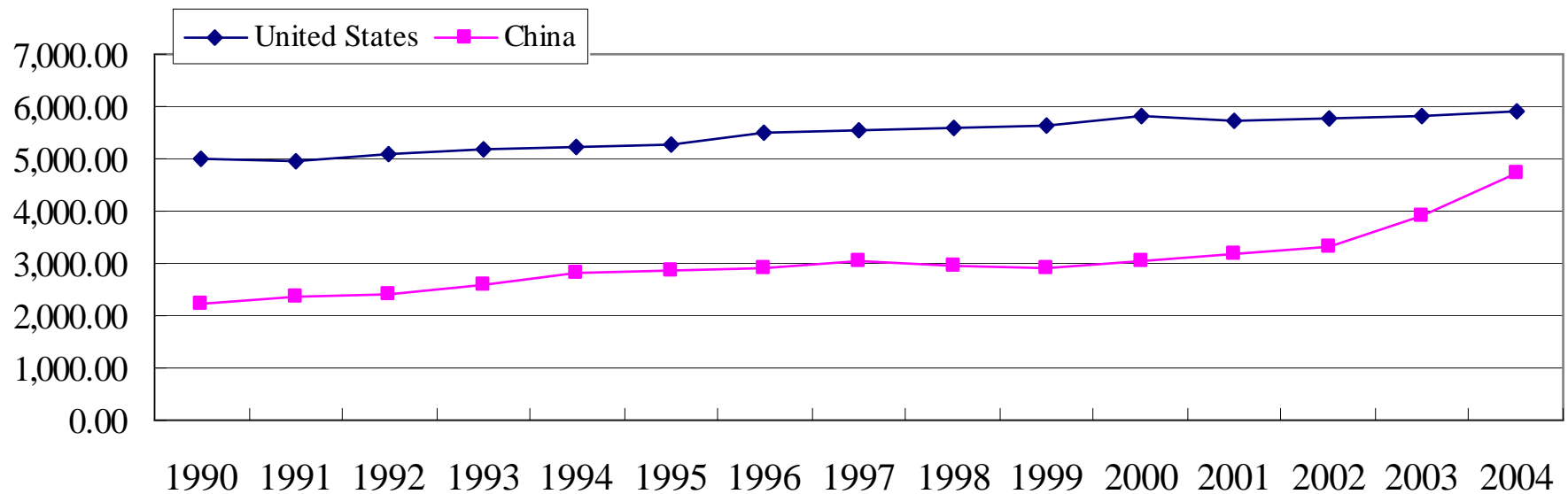
Blue indicates supply sources and red indicates major load centers

Addressing power supply shortages

- Generation sector
 - Developing coal-fired generation – high boiler pressure, high capacity, and environmentally friendly – is the direction.
 - Accelerating development of hydropower, nuclear power, and gas-fired power generation.
 - Introducing renewable energy (solar, wind,...)
- Network sector
 - Strengthening the grid.
- Intensifying energy conservation efforts and improving energy efficiency.

Environmental challenges

- China's carbon dioxide emissions from consumption of fossil fuels are expected to increase from 3,000 million tons in 2000 to 5,700 million tons in 2020.



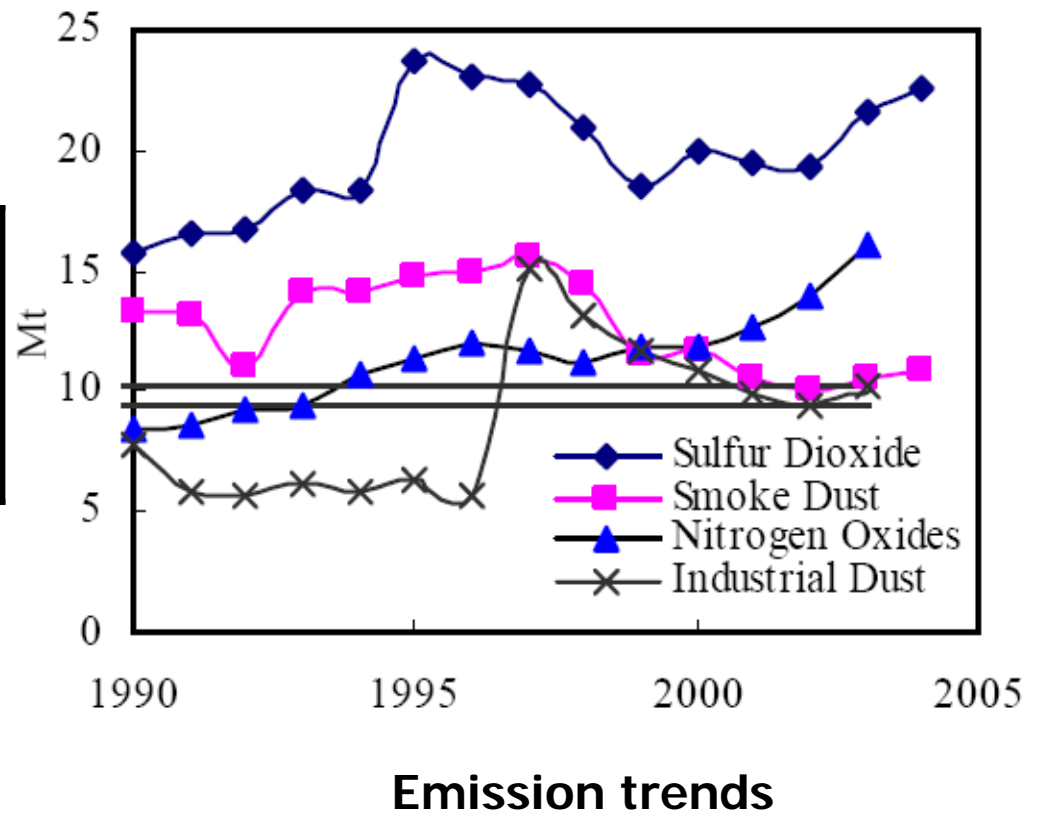
Source: International Energy Association 2004

Environmental challenges

- China is experiencing rising SO₂ and NO_x.

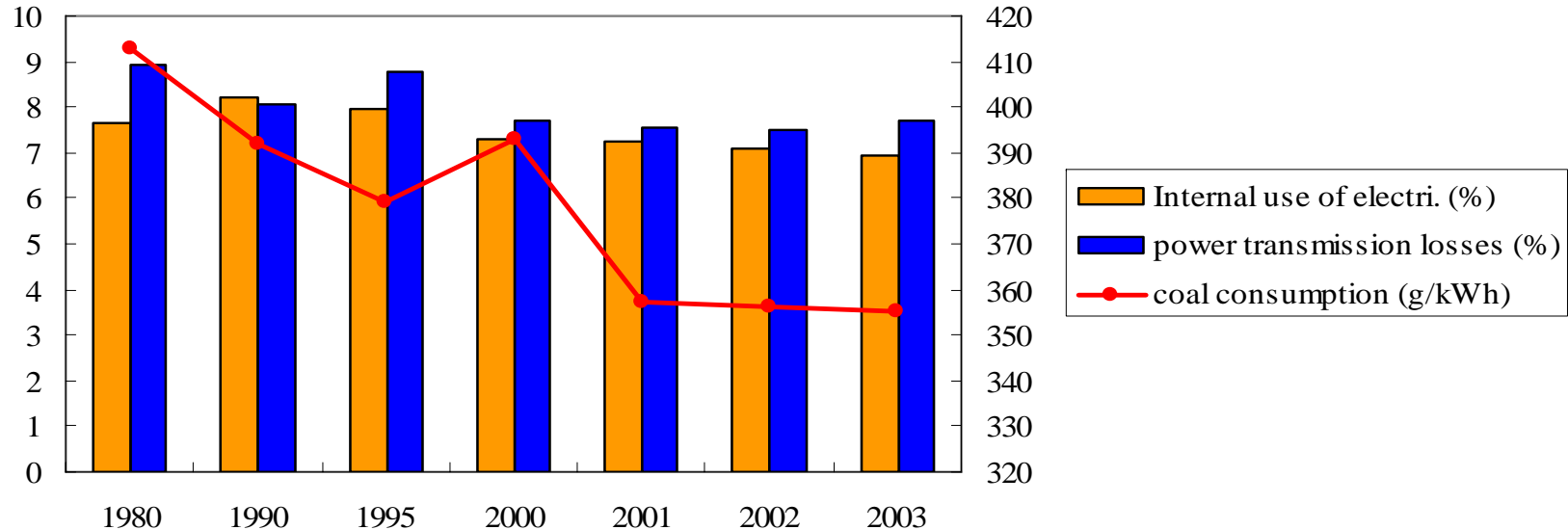
	emission	removal	efficiency
SO ₂	8.01Mt	0.97Mt	10.8%
Smoke dust	3.13Mt	120.8Mt	97.5%

Efficiency of SO₂ and smoke dust emission reduction systems(2003)



Improving generation and delivery efficiency

- Greater generation and delivery efficiency is reducing rates of internal use of electricity, transmission losses, and coal consumption.



	Internal use of electricity %	Power transmission losses %	Coal consumption (g/kWh)
2005	5.82	7.18	374
2020	5.1	6.2	320

Strategies for overcoming coal supply and delivery challenges

- *Alliances between coal mining companies and power generation companies*
- *Mine-mouth power plants substituting electric transmission for coal transportation*



Shenhua model: simultaneous stock holding and building of power stations

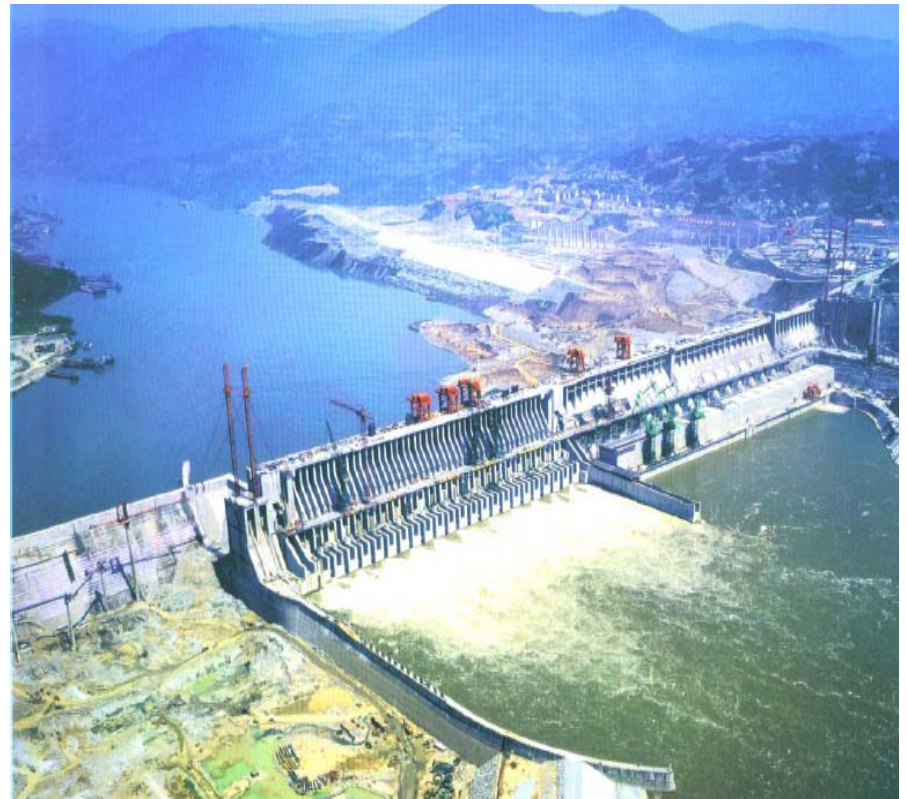
Shanxi coking coal co. model: building of power station by coal mines

Luneng model: building of coal mines by power enterprises

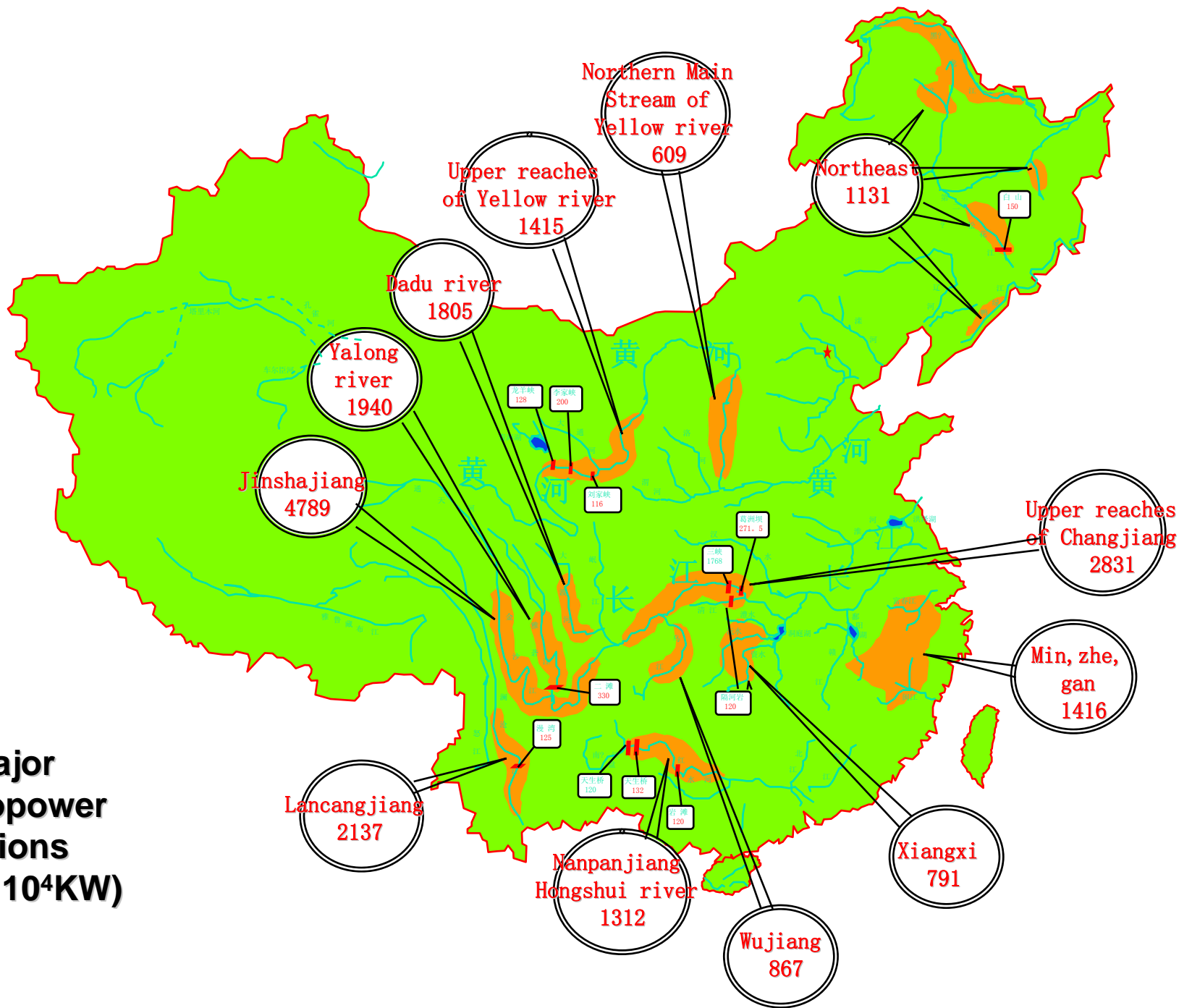
Huainan model: joint venture to establish the new coal mines and power stations

Hydro-power development

- Hydro
 - Resources: 500GW
 - By the year 2005:
 - Installed capacity 120GW (including 34.1GW from small hydro plants).
 - 395TWH, 15% of the total annual generation.



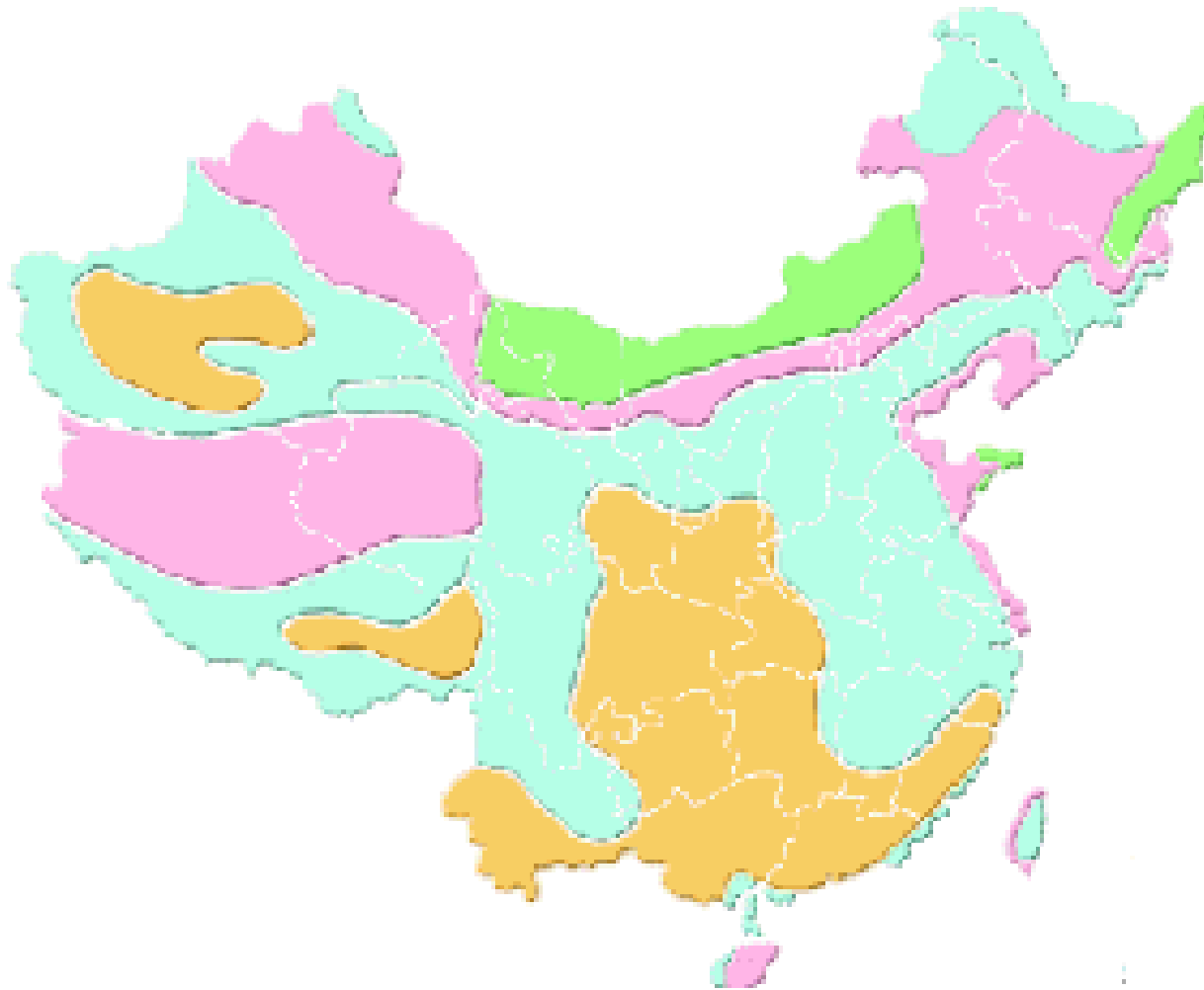
**12 Major
Hydropower
Locations
(unit: 10⁴KW)**



Nuclear power



Potential wind power resource > 3000 GW



green=great, pink=good, blue=ok, yellow=poor
(offshore & coastal potential not shown)

Wind power

- By the year 2005:
 - 59 wind power plants, with total installed capacity of 1266MW.
 - 200,000 small wind units, located in rural areas, with total installed capacity of 30MW.
 - Mass production of 750KW (and below) units; units at MW level is still in the trial phase.
 - Key technology dependent on imports. However, design expertise growing in China.
- By the year 2020 – 40GW

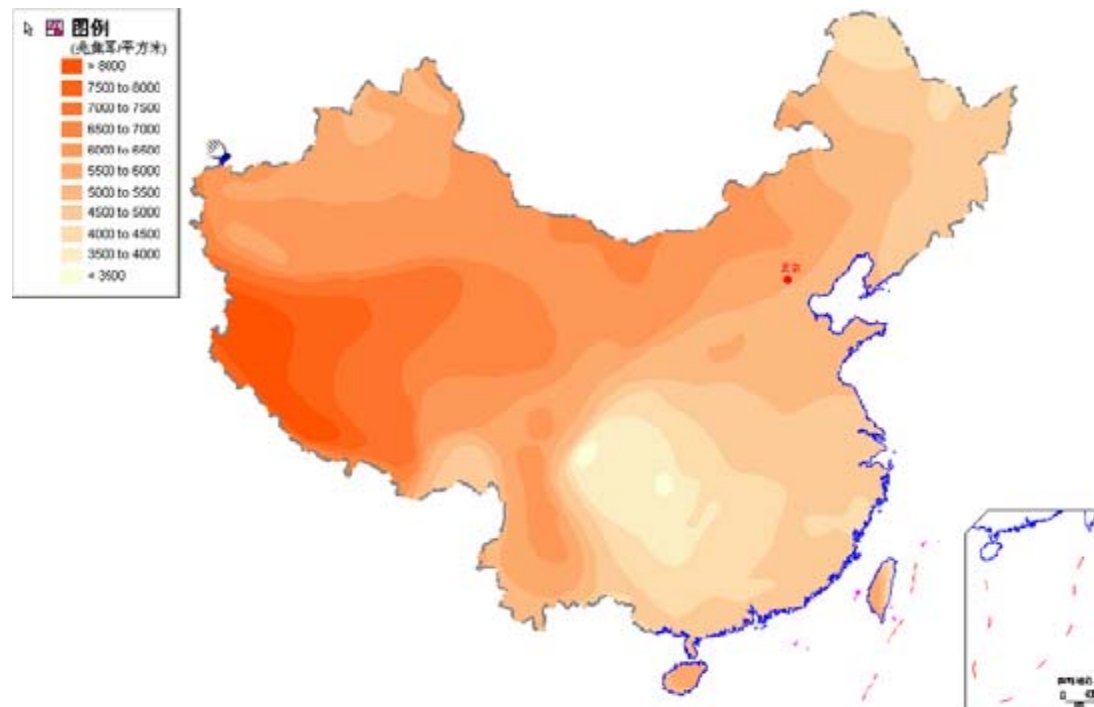
Wind farm under-construction



Dan Nan wind farm in Nan'ao

Solar power resource

- Theoretically 1.7 trillion ton coal equivalent/year
- 2/3 of the land with daylight hours surpassing 2,200 hours/year, equaling 5,000mega joule/m²
- Most abundant in western regions



Solar power

■ PV

- Installed capacity: 70 MW, mainly in the rural areas. (including “sending electricity to townships” project: 17MW).

- On-grid ceiling PV: Shenzhen 1MW project.

- Industrial capacity: 300MW units/year, but silicon materials depend on import.

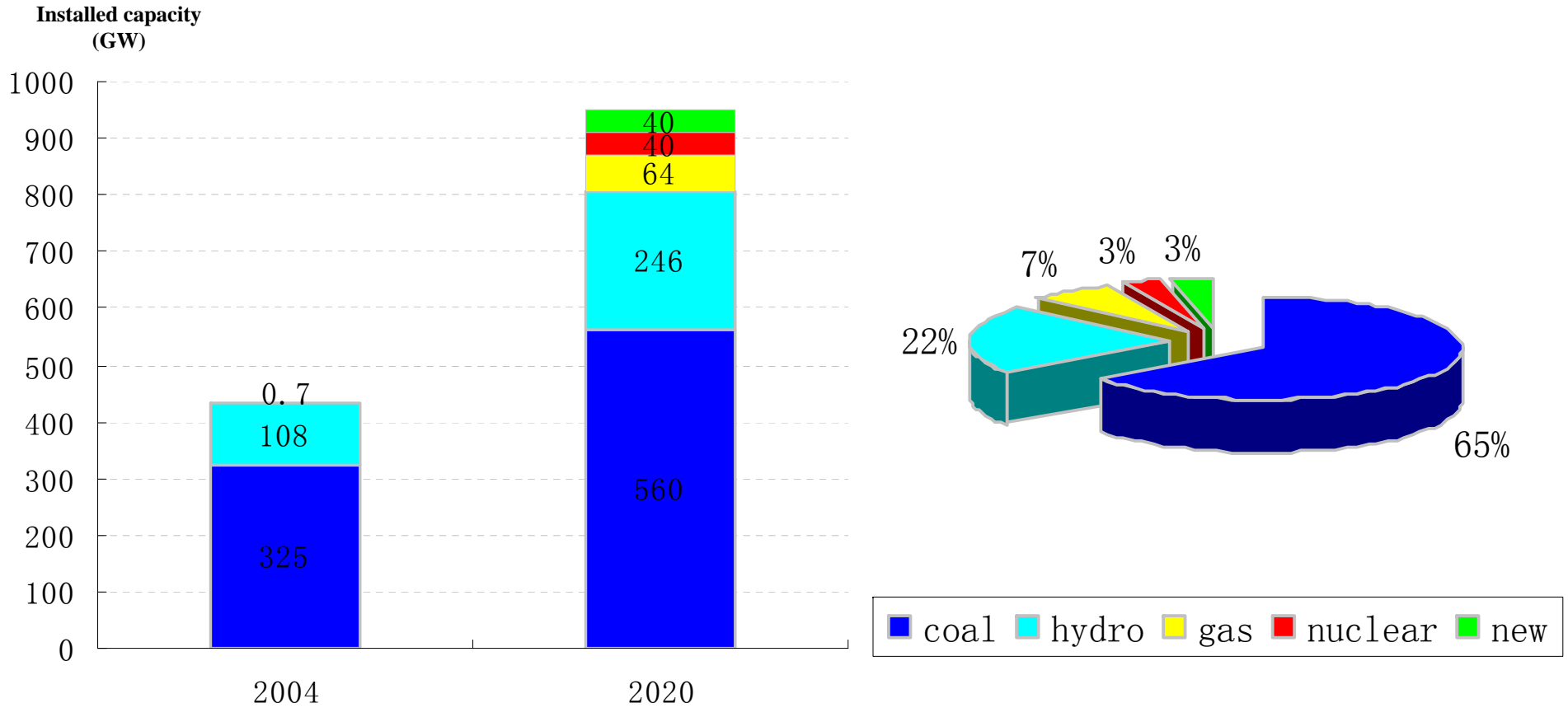
■ Solar water heaters



Renewable energy policy

- *Renewable Energy Law of China* -- effective from January 2006.
 - Establishing national targets
 - Grid connection priorities
 - Classifying tariffs for RE electricity
 - Sharing cost at national level
 - Special fund for renewable energy
 - Favorable credit and favorable tax treatment

Long-term target generation mix



Target generation mix in 2020

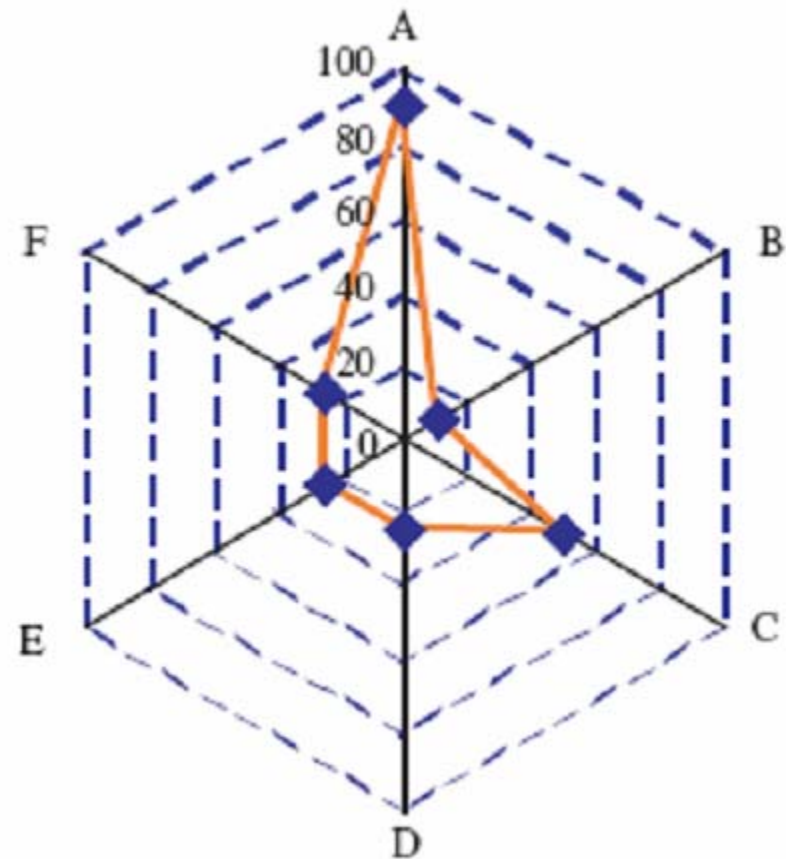
Power industry reform objectives

- To establish a power market system that will introduce competitive incentives, improve efficiency, lower cost, improve power pricing, optimize resource allocation, promote electric power development, and advance nationwide grid construction.
- This market system should encompass fair competition, orderly transition, and efficient development using separation of government functions from enterprise functions.

Reform goals

Goals of “Article Five” during the “10th Five-year Plan”

- A: Separation of generation from grid (completed)
- B: Corporate separation of non-core functions (such as planning, designing, construction, etc.)
- C: Direct access to market by large users
- D: Formulation of competitive regional power market
- E: Bidding for access to grids
- F: Make retail tariffs more market-driven



Power industry reform history

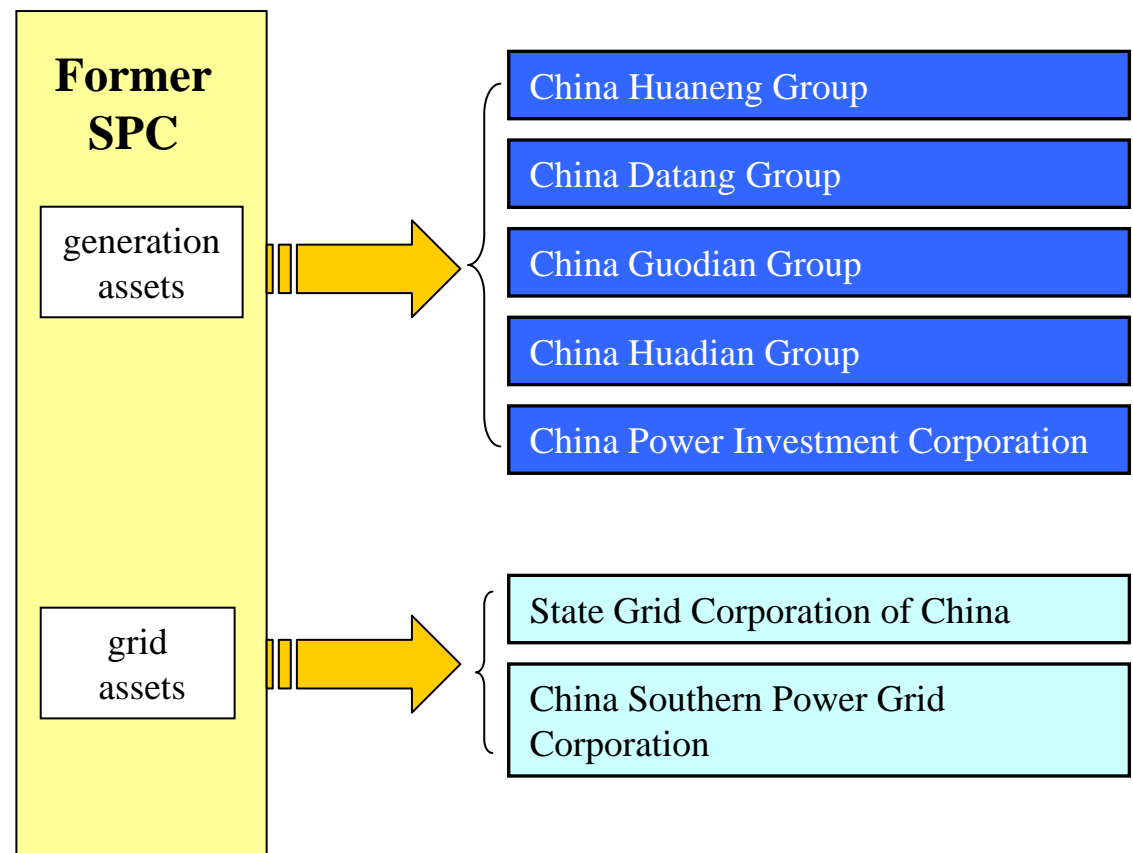
1997	1998	2002	2002	2002	2004	2004	
State Power Corp. (SPC) established	Dissolved Ministry of Electricity	Power Regime Reform formally approved by the State Council	State Elec. Regul. Commission (SERC) created (October 2002)	SPC restructured	Separation of gen. assets from transmission assets	East China starts pilot regional power market operation.	

Power industry reform

- To “ *introduce competition and break the market monopoly* ” generation and grid sectors were separated.

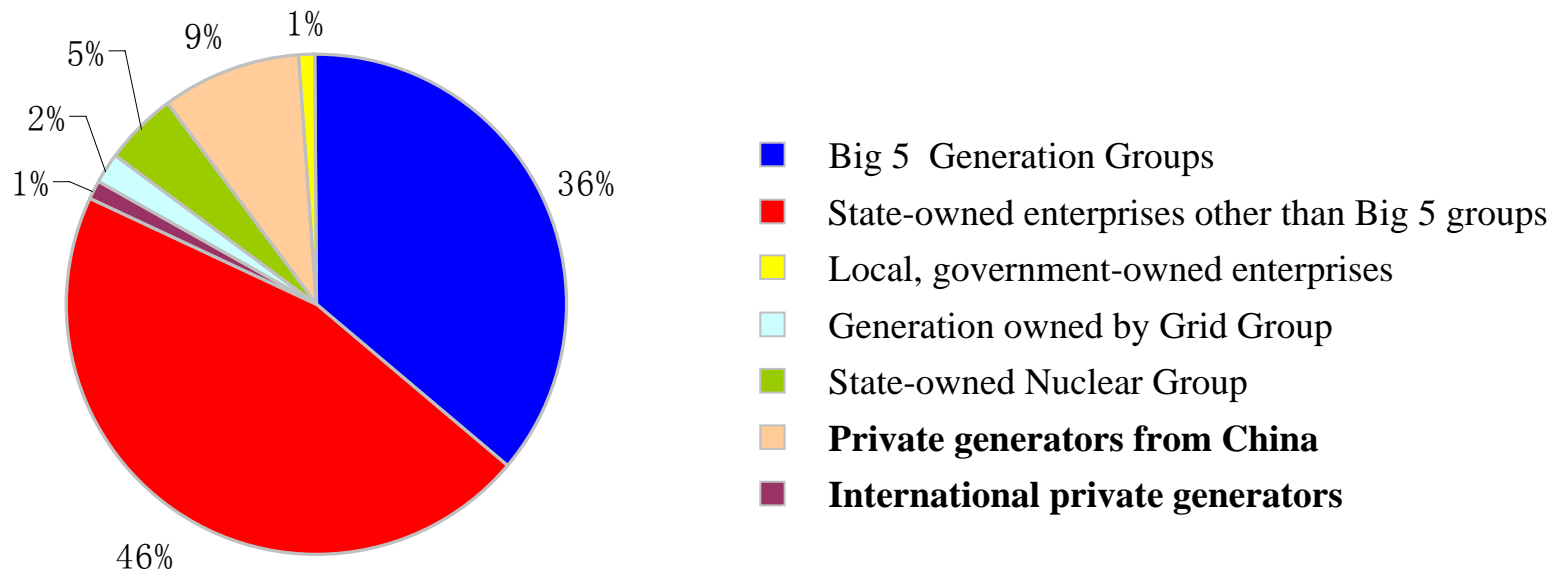
Restructuring of the State Power Corporation of China

December 2002

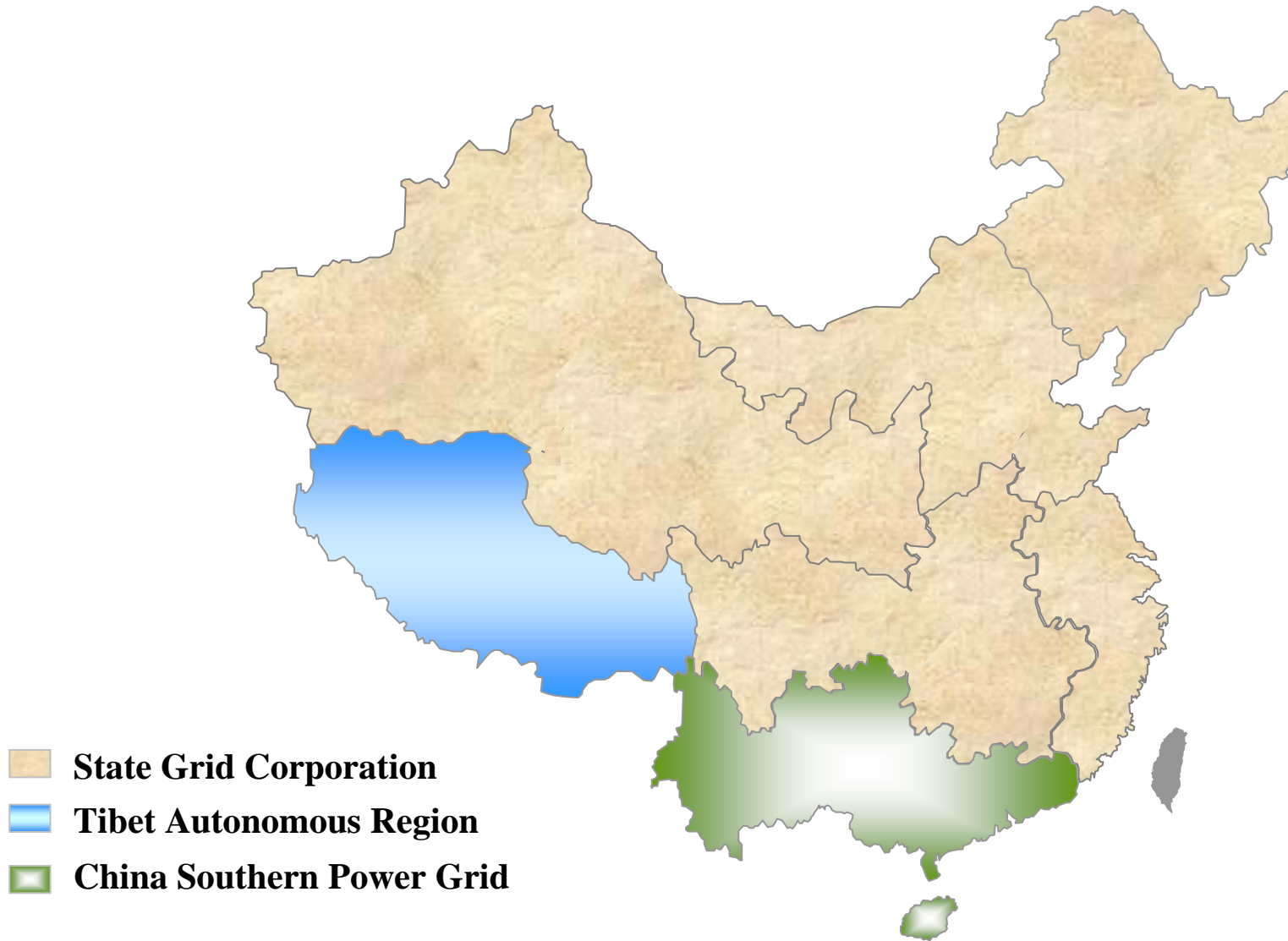


Power industry reform

Comparison of the installed capacity of different types of players (2004)

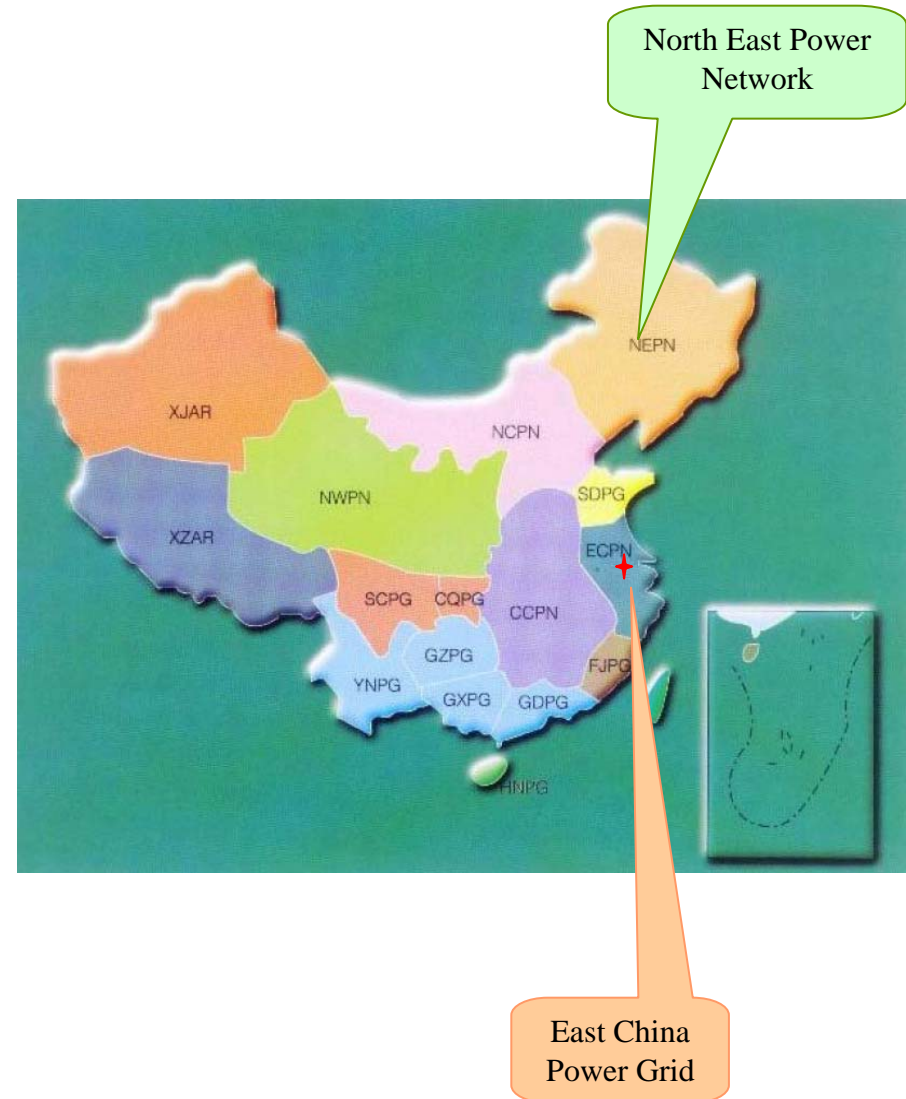


Power industry reform – grid sector

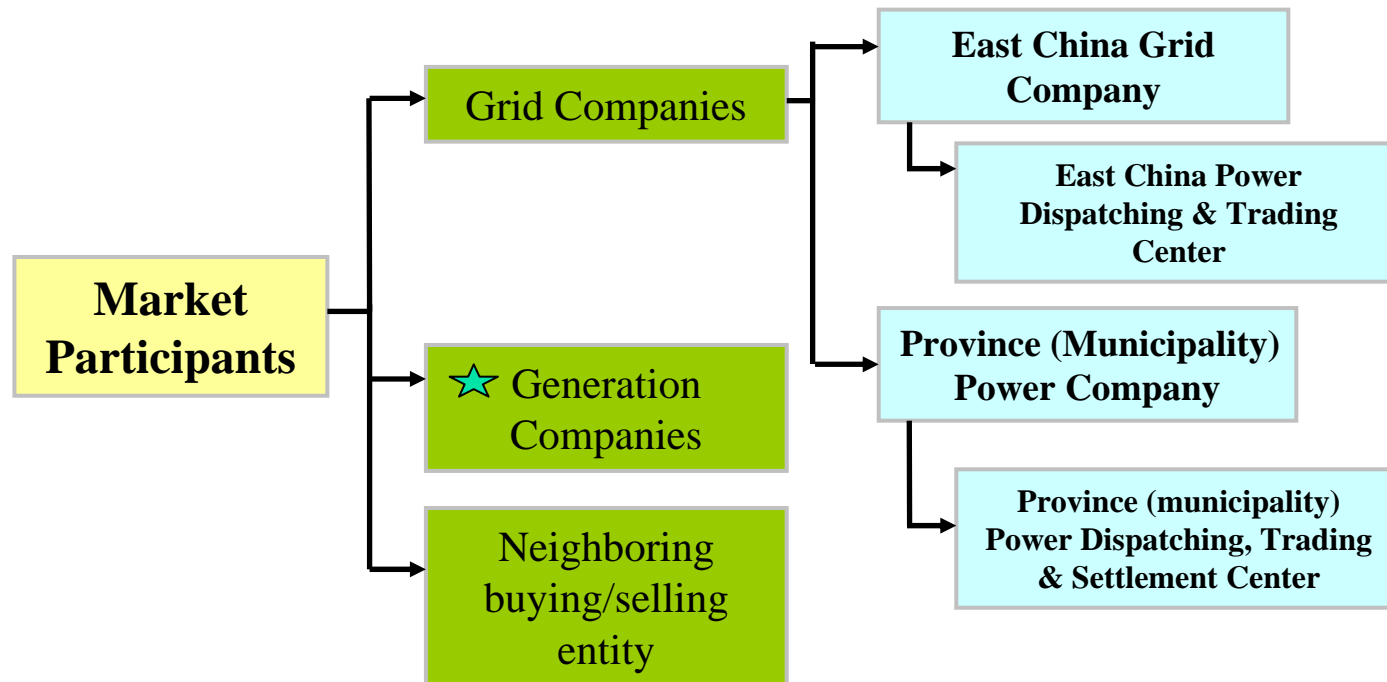


Restructuring pilot program

- East China: the most developed area; electricity consumption ranks first; installed capacity \geq 100,000MW in 2005.
- One of two pilot regional power markets in China.
- May 18, 2004: East China's first simulated bidding process for the next month.
- October 2005: simulated operation of China's first day-ahead power market.
- April 2006: trial operation of day-ahead power market.



Restructuring pilot program



Generation units in East China: ★

Category A: coal-fired units with capacity over 100MW (216 units registered by the end of 2005, generation capacity $\geq 58,818\text{MW}$ = 56.7% of total generation capacity in East China area). Participation Required.

Category B: gas-fuel units, oil-fuel units, hydro units, nuclear power units, etc. Participation Not Required

Trading modes:

Bilateral Transactions (between neighboring provinces and municipality)

Yearly Generation Contract
Monthly Contract Bidding
Day-ahead Market
Real-time Balance Market