The 9th IEEJ-CNPC Oil Market Workshop

CNPC

Prospects on the Substitution of Natural Gas for Coal in China

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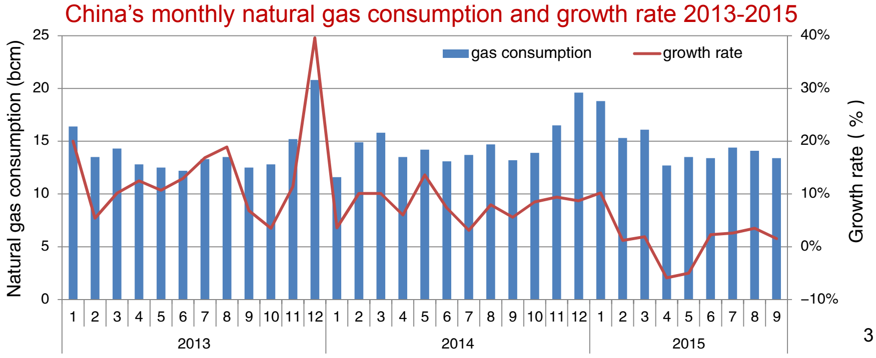
1.1 Natural gas demand growth slowed down

- From 2000 to 2013, China's natural gas market has been rapidly growing, with natural gas consumption increasing by 16.1%/year, from 24.5 bcm to 170.5 bcm.
- Driven by economic slowdown, price reform, mild weather and the penetration of alternative energy sources, demand growth rate declined to 8.6% year on year in 2014 and further declined to 2.5% for the first 9 months in 2015.

China's monthly natural gas consumption and growth rate 2013-2015



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1.2 Surplus of gas supply

- China's gas demand in 2015 is expected to be 192 bcm, 10 bcm lower than supply, and nearly 40 bcm lower than the goal of 12th Five-Year-Plan.
- With many long term contracts coming online in the next few years, at least 15 bcm annual incremental demand is needed to absorb the excess resource.

Long term contracts coming online in the next few years

Buyer	Resource	Volume（mtpa）	Period（yr）	Contract year	Delivery start year
CNOOC	TOTAL Portfolio	1	11	2014	2014
	BG QCLNG	3.6	20	2010	2014
	BG combined resources	5	20	2012	2015
CNPC	Shell Gorgon	2	20	2008	2016
	ExxonMobil Gorgon	2.25	20	2009	2016
Sinopec	PNG LNG	2	20	2009	2014
	APLNG	4.3	20	2011	2015
	APLNG	3.3	20	2011	2016

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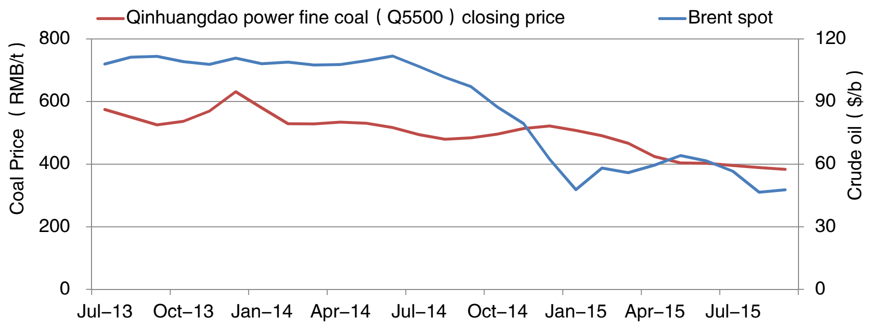
1.3 Natural gas price remains high

- From July 2014 to September 2015, city gate price of existing gas in Shanghai increased by 18%, from 2.44 RMB/m^3 to 2.88 RMB/m^3, while the prices of coal and oil dropped sharply.
- The domestic natural gas price comes close to LPG and fuel oil, and is three times higher than coal.

Price of China's coal, gas and oil 7/2013 -9/2015



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1.4 Infrastructure is falling behind

- By the end of 2014, China's total natural gas pipeline length amounted to 435, 000 km, including 65, 000 km of transmission pipelines.
- With a similar geographical size, the transmission and distribution natural gas pipeline lengths in the United States are 7.7 and 5.4 times of in China.
- By 2014, there are 11 gas storage facilities in China, with total capacity 4.3 bcm, only around 2.4 % of total gas consumption, far below world's average.

The pipeline networks of China, United States and France

	Population (100 millions)	Area（10, 000 km2）	Transmission pipeline (10, 000 km)	Distribution pipeline (10, 000 km)	Transmission pipeline intensity（km/10, 000 km2）	Distribution pipeline intensity（km/10, 000 km2）
China	13.7	963	6.5	37	67.5	415
US	3.1	960	50	200	521	2083
France	0.66	55	3.8	20	691	3636

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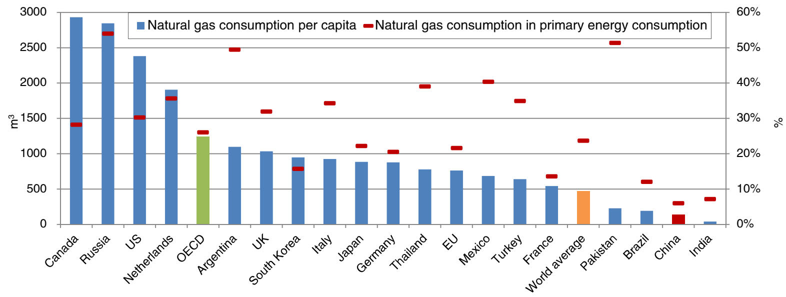
1.5 Huge market potential

- China's per capita natural gas consumption was 135 m^3 in 2014 and natural gas penetration in total primary energy consumption is only 6%, while the world averages were 467 m^3 and 23.7%.
- China's natural gas market development is still in relative early stage. 1.4 billion population would mean 650 bcm natural gas demand, if calculated with world average consumption level.

Natural gas consumption per capita and share in primary energy consumption



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1.6 Opportunities from environmental protection

- China's energy mix has caused serious air pollution. As the major carbon emitter in the world, China has also promised to limit its carbon emissions.
- Before the technical breakthrough of new and renewable energy, natural gas will be the most viable bridging fuel.

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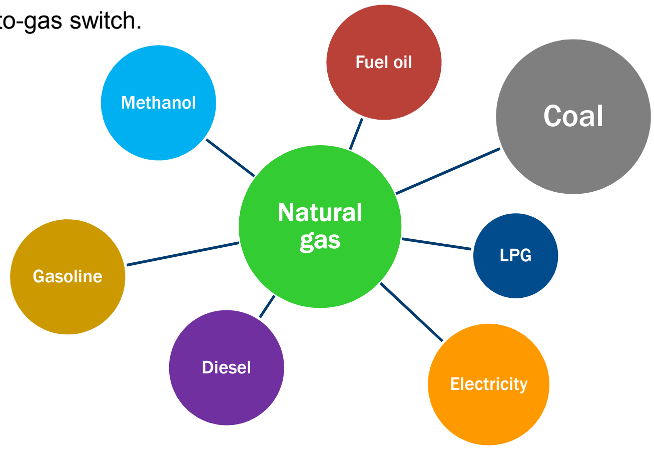
1.7 Coal-to-gas switch is the main direction

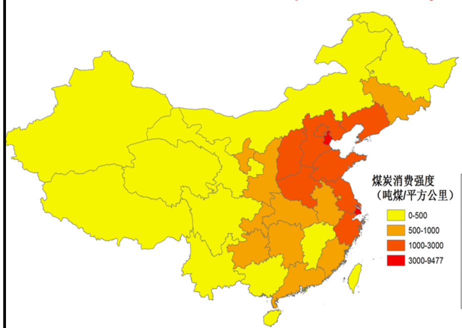
- Natural gas has been growing as an alternative fuel in China.
- While the demand of natural gas in traditional industries and transportation sector is expected to be weak, the market takes a positive view on the demand in coal-to-gas switch.



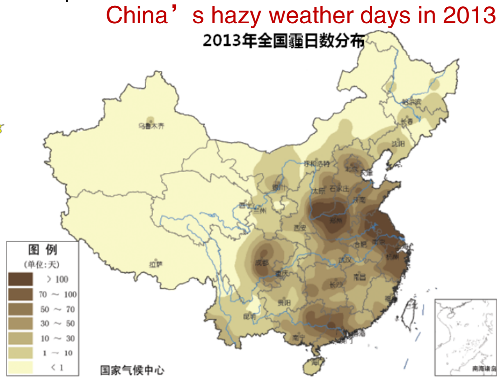
1.8 Coastal China will be the target region

- Beijing-Tianjin-Hebei-Shandong Region, Yangtze River Delta and Peral River Delta are coal demand centers with extreme environmental protection pressure.
- The emission level in where coal power plants concentrated is 5 times of national average, leaving potentials for gas power development.

China’s coal consumption intensity



China’s hazy weather days in 2013



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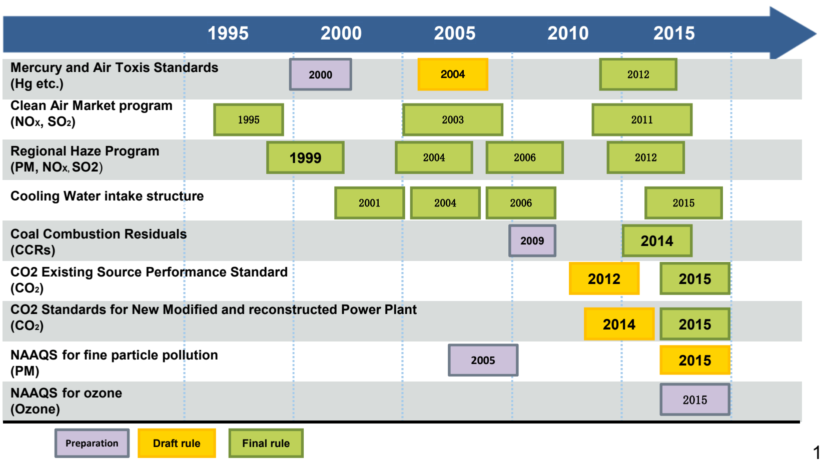
2.1 Environmental regulation is the key

- US EPA carries out several policies to control the pollutions in industrial sector in the past two decades.



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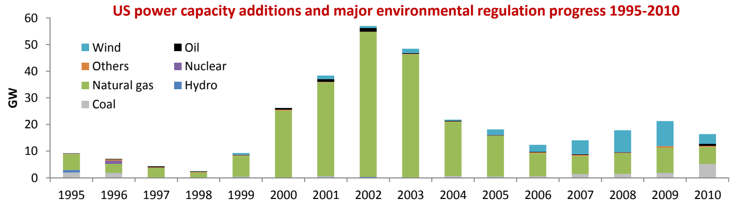
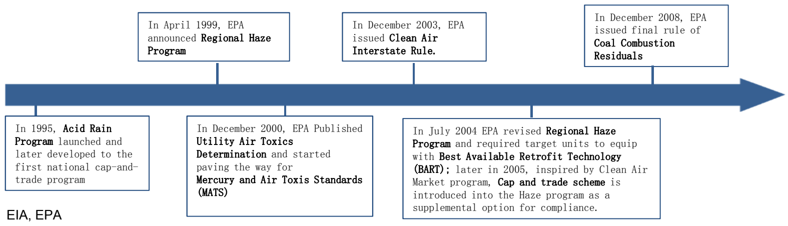
Source：EPA

2.1 Environmental regulation is the key

- In the single year 2002, 54 GW capacity was added into gas power generation fleet. Gas power capacity reached to 425 GW in 2013, representing 42% in US total power capacity.

US power capacity additions and major environmental regulation progress 1995-2010





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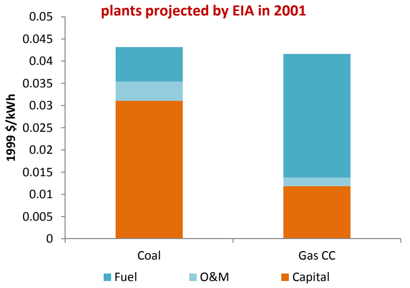
Source：EIA, EPA

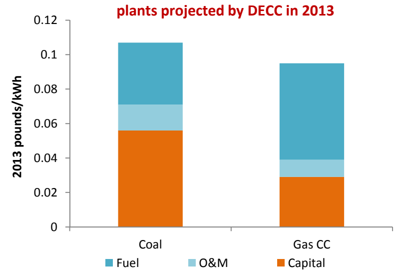
2.2 Gas power is cost competitive

- US：According to 2001 data, driven by lower capital cost and operation and maintenance (O&M) cost, gas power generation was more competitive than coal, amid bearing higher fuel cost.
- UK：Similar to US, gas power is more competitive than coal in UK owning to combined cycle power generation technology advancement and more favorable lead time.

2005 LCOE of new build coal and gas power plants projected by EIA in 2001



2019 LCOE of new build coal and gas power plants projected by DECC in 2013



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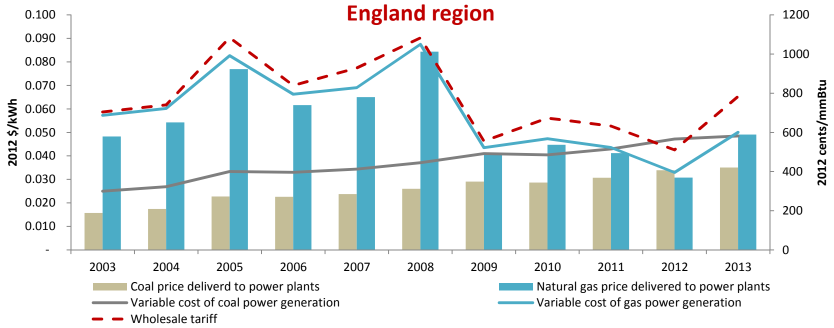
Source：EIA, DECC

2.3 Wholesale power price reflects the cost of gas power

- US：As an example of New England, the average variable cost of gas power generation has been slightly lower than the wholesale price in the last decade, and became even lower than coal after the shale gale.

Variable costs of power generation and wholesale tariff--US New England region



Source：EIA, CNPC ETRI

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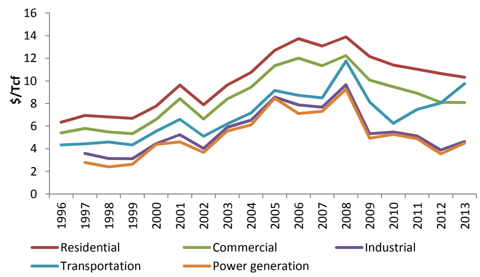
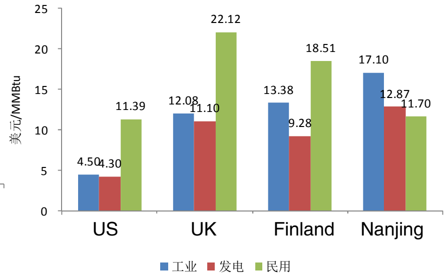
2.4 The price of natural gas for power generation is lower than for other sectors

- US：Residential customers bear the highest cost, with natural gas price two times higher than power generation and industrialcustomers.
- Europe：UK and Finland share the same situation with US.
- China：Residential customers enjoy the lowest natural gas price.



US natural gas prices by sector 1997-2014

Source：EIA



Natural gas prices of US, UK, Finland and China(Jiangsu Nanjing) in 2013

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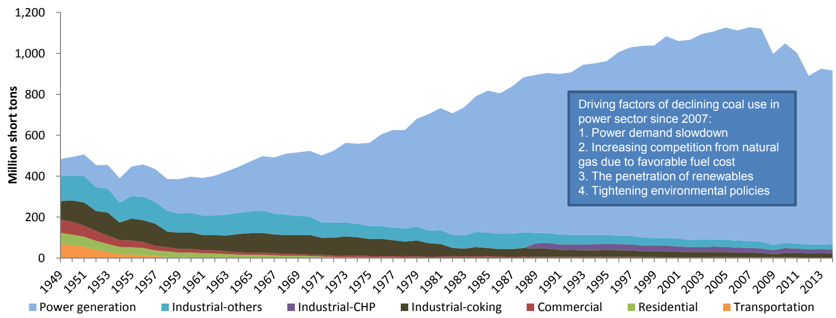
2.5 Coal demand concentrates on power generation

- Coal consumption was evenly distributed among sectors in 1950s, before coal was gradually replaced by gas in residential, commercial, industrial sectors.
- Coal consumption in power sector has steadily increased, currently accounting for 90% in total coal consumption.

US coal consumption by sector 1949-2014



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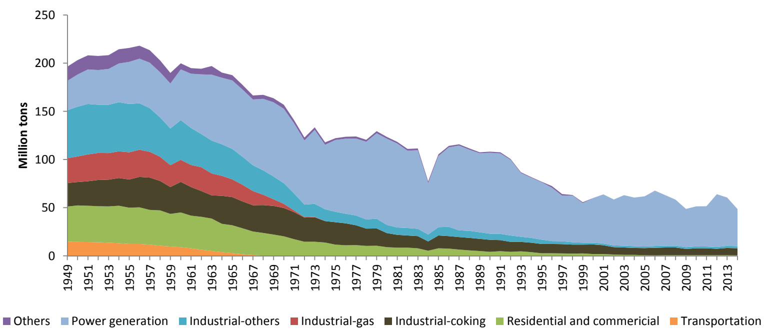
Source: EIA

2.5 Coal demand concentrates on power generation

- Similar to the US, the share of coal consumption of power sector in UK's coal consumption increased to 80% by 2014 from 20% in early 1950s, while coking use accounts for 13% and others account for the rest.

UK coal consumption by sectors 1949-2014



Source: DECC

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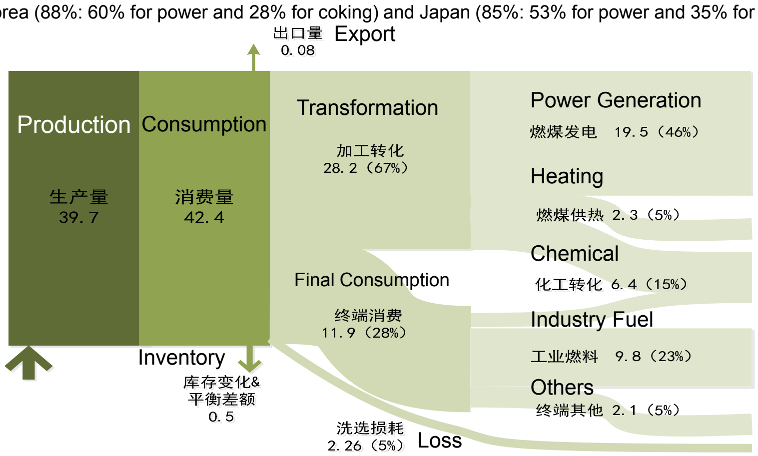
3.1 China's coal consumption structure

- Coal consumption for generating power only accounts for 46% in total China's coal consumption, far below US (90%), Germany (80%)
- The combined share of coal consumption in power generation and coking is about 61%, far below Korea (88%: 60% for power and 28% for coking) and Japan (85%: 53% for power and 35% for coking).



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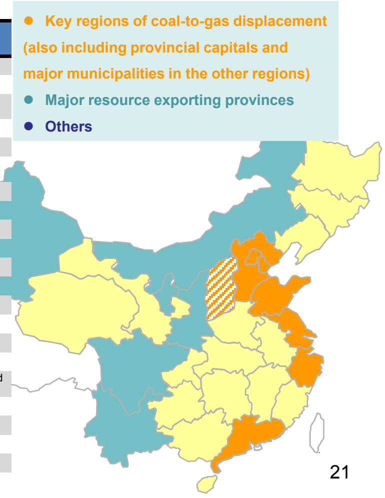
3.2 Defining key regions of coal-to-gas switch

- We classified 30s provinces into three groups based on the initiatives of controlling air pollution and future coal capacity expansion plan.

Region	Issue date	Program name
National	2013-Sep	National Action Plan for the Control of Air Pollution
BJ-TJ-HB	2013-Sep	Implementing Rule for the Control of Air Pollution
	2014-Jul	Treatment Scheme for the Control of Air Pollution of Key Industry
Beijing	2013-Sep	Clean Air Action Plan for 2013-2017
	2013-Aug	Limit Coal Use and Promote Clean Energy Working Plan for 2013-2017
	2015-May	Special Working Plan on Displacing Distributive Coal Use, Transforming Coal Boilers and Emission Control for Vehicles
	2015-Jan	Rule for Prevention and Control of Air Pollution
Tianjin	2013-Sep	Action Plan for Prevention and Control of Air Pollution
	2015	Working Plan for Cleaner Distributive Coal Use
	2015	Working Plan for Transforming Coal Boilers
Hebei	2013-Sep	Proposed Implement Plan for the Control of Air Pollution
	2015-Mar	Implementing Scheme for the Control of Coal Boilers
Shandong	2013-Sep	Plan for the Prevention and Control of Air Pollution 2013-2020
Shanxi	2013-Feb	Measure for the Control of Air Pollution 2013-2020
Shanghai	2013-Oct	Clean Air Action Plan for 2013-2017
Jiangsu	2014-Jun	Implementing Scheme for the Control of Air Pollution
	2014-Sep	Implementing Scheme for Improving Efficiency, Controlling Emissions and Limiting Coal Use for 2014—2015
Zhejiang	2013-Dec	Action Plan for the Control of Air Pollution for 2013-2017
Guangdong	2014-Feb	Action Scheme for the Control of Air Pollution for 2014-2017
Chongqing	2014-Jan	Proposed Action Plan for the Prevention and Control of Air Pollution
Anhui	2014-Mar	Implementing Scheme for the Control of Air Pollution
Inner Mongolia	2014-May	Proposed Action Plan for the Prevention and Control of Air Pollution
Fujian	2014-Jan	Implementing Rule for the Control of Air Pollution



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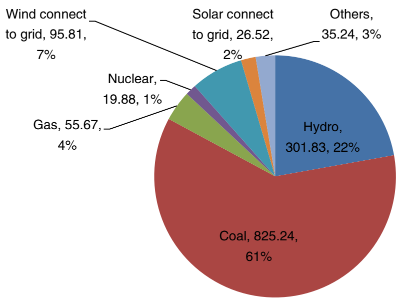
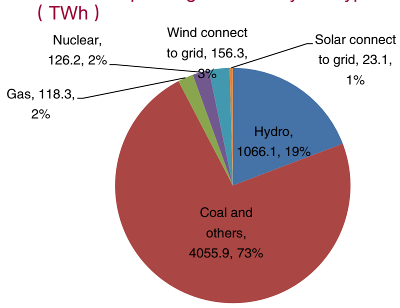
3.3 Coal-to-gas switch in power sector—natural gas's low penetration in power sector

- By 2014, China's gas-fired power capacity amounted to 55.7 GW, accounting for 4.1% in overall power capacity; in the same year, gas-fired penetration in overall power generation was 2.1% (118 TWh), much lower than the global average of 20%.
- In 2014, Gas used for power generation only accounted for 15% in total China's gas consumption, much lower than US (30.4%), UK (23.8%), Germany (36%), Korea (44%).

2014 China power capacity by fuel type (GW)



2014 China power generation by fuel type (TWh)



Source：China Electricity Council, *2014 Power Industry Operation Brief*, Wu, Jingru *Power Industry Outlook 2015–2030*

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3.3 Coal-to-gas switch in power sector—the versatility of gas-fired power

- High efficiency：gas unit heat rate is generally 10% higher than coal units, while the efficiency of gas-fired distributed energy system could reach 70%.
- Meet peaking load：Gas units are most favorable for meeting peaking load due to the flexibility and ability to run infrequently for short periods.
- Less pollution：Compared with regular coal units, the emissions of soot, SO2, NOx, CO2 is much lower for gas units.

Comparison between gas and coal on air pollutants emission

	Unit	Key region emission standards for coal unit (Special)	Regular coal unit	"Ultra low emission" Coal unit	Emission standards for gas units	Gas unit
Soot	mg/NM3	20	14.9	3.6	5	3.1
SO2	mg/NM3	50	84.7	16.8	35	0
NOx	mg/NM3	100	80.6	31.8	50	32.2
CO2	g/KWh	–	750–1090	750–1090	–	416

Note：Data of regular coal unit is from Zhejiang Lanxi plant, "Ultra low emission" coal unit is from Zhejiang Jiaxing plant, gas unit is from Guangdong Zhujiang plant.

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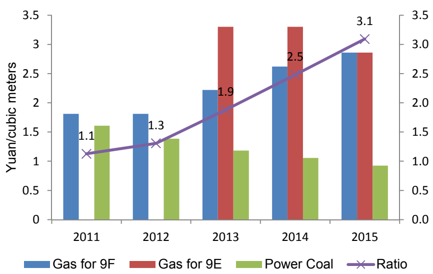
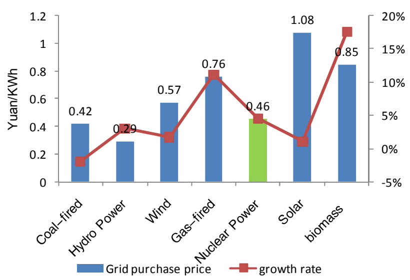
3.3 Coal-to-gas switch in power sector—gas-fired power is not cost competitive

- Wholesale tariff for gas-fired generating units is higher than coal, hydro and wind (with feed-in-tariff).
- Grid companies feel reluctant to purchase gas-fired power under the current pricing mechanism.



Price Ratio between Gas and Coal 2011-2015



Grid Purchase Electricity Price by Fuel 2014

Note: price information is derived from a Zhejiang gas power plant with direct sale and circum–Bohai–Sea steam coal price

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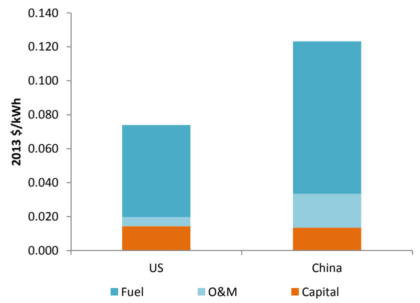
3.3 Coal-to-gas switch in power sector—gas-fired power is not cost competitive

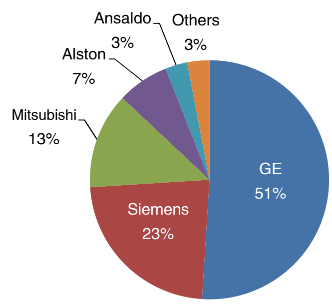
- As lacking of core technology, China's gas power plants still have to heavily rely foreign gas turbine producers on meeting maintenance and upgrade need.
- The fixed maintenance cost of gas unit is around 0.03 RMB/kWh, accounting for around 4% in overall generation cost.

The LCOE costs of conventional combined cycle unit between US and China



Source: EIA, CNPC ETRI

2014 market shares of gas turbine business-by capacity



Source: Caixin Media

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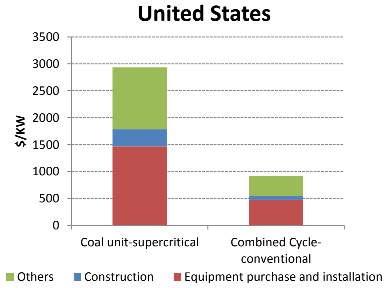
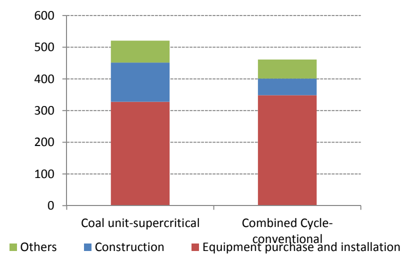
3.3 Coal-to-gas switch in power sector—gas-fired power is not cost competitive

- The capital cost per power generation for gas unit is around 90% of coal unit in China, compared with 30% in US.
- For the equipment purchase and installation portion of total capital cost, China's gas unit is slightly higher than coal unit, while US's gas unit is only 1/3 of coal unit.





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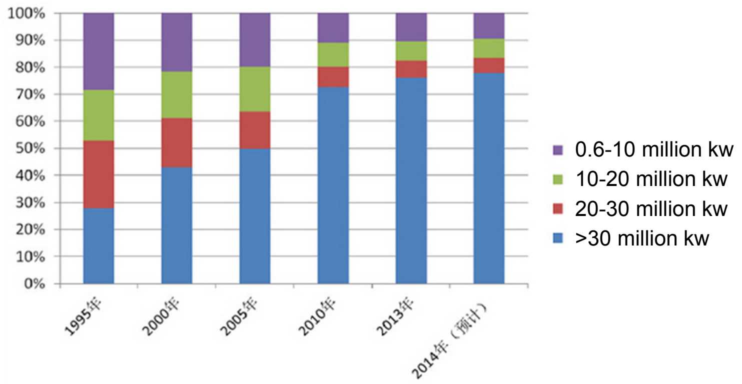
Note："Others" includes ex-construction preparation, management fees, emergency plan fees etc.
Source：EIA, CNPC ETRI

3.3 Coal-to-gas switch in power sector—small coal units are the targets for displacement

- In 2014, NDRC, MEP and NEA jointly issued "the Action Plan for Upgrades and Retrofits of Coal-fired Power Plants", aiming to control air pollutant emissions and improve efficiency of coal power fleet. The target units are coal-fired generating units with capacity under 300 MW.

China's thermal power capacity



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3.4 Coal-to-gas switch in power sector—gas is cleaner

- Compared with coal, using gas as energy fuel generally provides 10% more efficiency for industrial boilers, furnaces or CHP units and in turn provides better performance in emission control.

Indicators on heat efficiency between gas and coal boilers

Fuel type	Fuel received based on low heat content	Boiler rated evaporating capacity (D, t/h) or rated thermal power (Q, MW)			
	(kJ/kg)	6≤D≤20 or 4.2≤Q≤14		D>20 or Q>14	
		Boiler heat efficiency (%)			
		Target value	Limited value	Target value	Limited value
Bituminite coal	14400<Qnet.v.ar<17700	82	76	83	78
Bituminite coal	17700<Qnet.v.ar<21000	85	79	86	81
Bituminite coal	Qnet.v.ar>21000	87	81	87	82
Lean coal	Qnet.v.ar>17700	84	78	85	80
Lignitous coal	Qnet.v.ar>11500	85	79	86	81
Fuel type	Fuel received based on low heat content	Boiler rated evaporating capacity (D, t/h) or rated thermal power (Q, MW)			
	(kJ/kg)	D≤2 or Q≤1.4		D>2 or Q>1.4	
		Boiler heat efficiency (%)			
		Target	Limited	Target	Limited
Gas	Depends on actual test value	92	88	94	90

Source: Supervision and Management Regulations of Boiler Technology (TSG G0002–2010)

The standards for air pollutants emission between gas and coal boilers （Mg/m^3)

Pollutant	Existing boilers		New build boilers		Special	
	Coal	Gas	Coal	Gas	Coal	Gas
PM	80	30	50	20	30	20
SO2	400	100	300	50	200	50
NOx	400	400	300	200	200	150
Hg	0.05		0.05		0.05	
Blackness of exhaustion Ringelman emittance	≤1		≤1		≤1	
Note	Start from 10/1/2015		Start from 7/1/2014		For regions only	

Source: The Standards for Air Pollutants Emission of Boilers (GB 13271-2014)

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3.4 Coal-to-gas switch for distributive coal consumption—supportive policies

- According to the National Action Plan for the Control of Air Pollution: small coal boilers will be eliminated gradually; all the coal-to-gas switch plans for boilers, industrial furnace and self-contained power plants will be completed by 2017.
- Followings are a few action plans issued by provincial governments

Hebei	Zhejiang（2013—2017）	Jiangsu	Guangdong（2014—2017）
•By 2017, shut down 4, 125 coal boilers amid 3, 111 of them (11, 024t) will switch to other fuels and at the same time promote centralized heating. •For coal units beyond heating supply network, natural gas , electricity and renewables will be forced to use. •The coal boilers serving for government bodies will be "vanguards".	•By 2015, coal boilers with capacity under 10t/hr will be either replaced or shut down in prefecture-level city, while the benchmark for other cities is 6t/hr. •By 2017, all industrial parks will be equipped with centralized heating amid getting rid of all distributive coal boilers. The distributive coal boilers beyond heat supply network will be forced to use electricity or renewables.	•By 2017, the following actions on distributive coal units will be completed: •Within heating supply network—shut down; •beyond heating supply network but within gas supply network--coal-to-gas displacement •beyond gas supply network—units with capacity under 10t/hr will be forced to use electricity or renewables •CHP is the only allowed type of coal units to be built in urban area.	•By 2015, the centralized heating will amount to 30% in total heating . •By 2017, all the industrial parks and the Pearl River Delta industrial cluster district will realize centralized heating, total to 80% in overall province heating supply

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3.4 Coal-to-gas switch for distributive coal consumption—using gas also saves money

- The cost of natural gas and coal is almost same if considering the costly parts of utilizing coal, including transportation, processing, man power, occupied area and pollutant control practices.
- Take a factory in Zhejiang for example, the price ratio of gas over coal is 3:1 if only considering the heat contribution per unit energy consumed while the compound cost ratio declines to 1.2:1.

Economic indicators ex/post-displacement

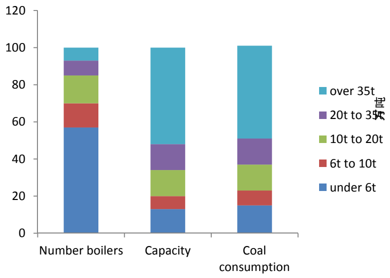
Index	Unit	Coal boiler	Gas boiler
Capital cost	10, 000 RMB	60	52
Coal consumption		2, 280 t (Bituminite coal)	780 mcf (Natural gas)
Fuel cost	10, 000RMB/yr	200	293
Electricity expense	10, 000RMB/yr	39	7.2
Water expense	10, 000RMB/yr	-	-
Manpower	10, 000RMB/yr	18	8.4
Pollutant control	10, 000RMB/yr	3.9	0.1
Operation cost	10, 000RMB/yr	260.9	308.7

Production index ex/post-displacement

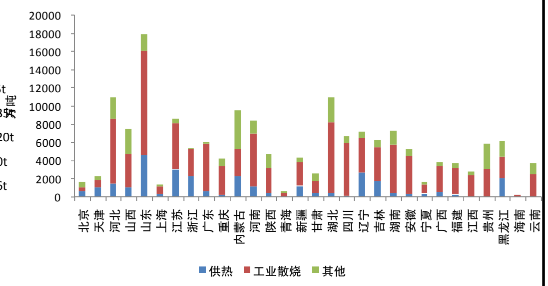
Index	Coal boiler	Gas boiler
Electricity consumption	540 MWh	100 Mwh
Occupied area	400 m²	50 m²
Work force	5	2
Ambient environment	DIRTY	TIDY
Pollutants	CO2, SO2, Nox, soot	CO2
Steam parameter	Fairly stable	Very stable
O&M work	Huge	Limited

3.4 Coal-to-gas switch for distributed coal consumption——focus on coal boilers displacement

- The number of China's industrial coal boilers totaled at around 540, 000 amid more than 70% with capacity over 10t/h and 53% locating at Eastern China.
- Required by the National Action Plan for the Control of Air Pollution, unless otherwise noted, all the coal boilers of prefecture-level cities with capacity under 10t/h will be displaced and new build coal boilers with capacity under 20t/h are prohibited by 2017. The coal boilers with capacity under 10t/h are restricted in the rest urban and rural areas.



China's industrial coal boilers by capacity



China's regional distributive coal use by application (10,000t)

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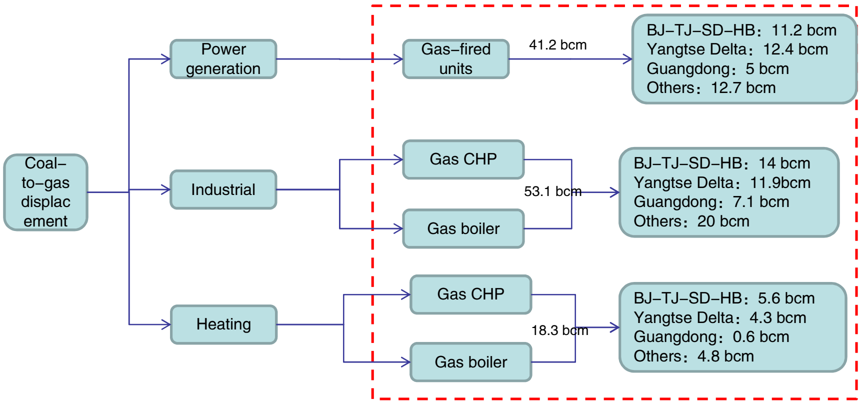
3.5 The market potential of coal-to-gas switch

- 112.6 bcm gas will be needed for coal–to–gas switch during the 13th Five–Year Plan. Most of the displacement will happen in industrial sector (47%), followed by power sector (37%) and then heating (16%)
- Another 160 bcm gas will be needed in 2020–2025 for coal–to–gas switch, mainly led by the displacement in CHP units, with minor portion for boilers and furnaces.



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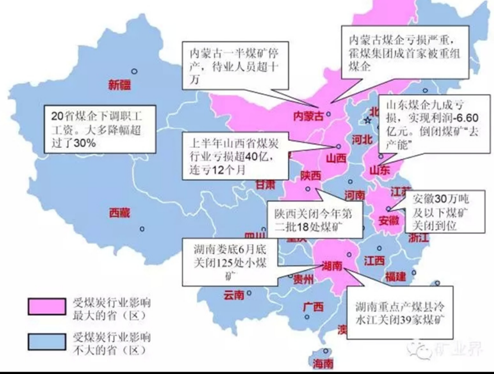
3.6 Coal-to-gas switch in power sector——
overcapacity of coal industry

- China's coal consumption and production decreased by 4.6% and 4.3% in Q1-3/2015, over 80% of the total coal companies are not profitable.
- The profits of 90 top coal companies shrinked to 0.97 billion RMB from 42.7 billion RMB of last year's same period.
- 4,947 coal mines are closed currently in China, representing 48% in total, including 3,346 of them have been closed for more than one year.

Situation of Closed Coal Mine in China



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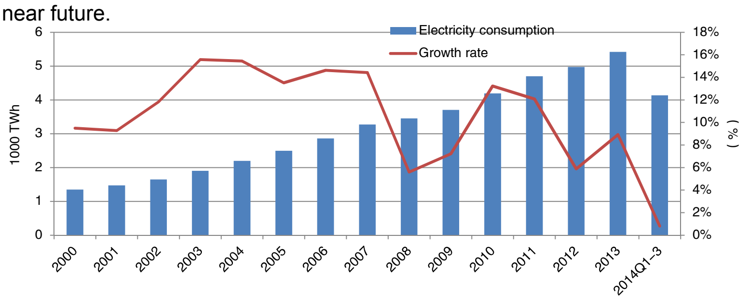
3.6 Coal-to-gas switch in power sector——
overcapacity in power market

- 5, 520 TWh electricity was consumed by China in 2014, while the average utilization hours of power plants dropped to the lowest level since 1978.
- By the end of 2014, China's total power capacity reached 1.36 TW (For all generating units above 6 MW). With another 173 GW capacity under construction and around 100 GW capacity in schedule, the market may see more surplus power capacity in the near future.



China electricity consumption and y–o–y growth rate 2000–2014

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Content

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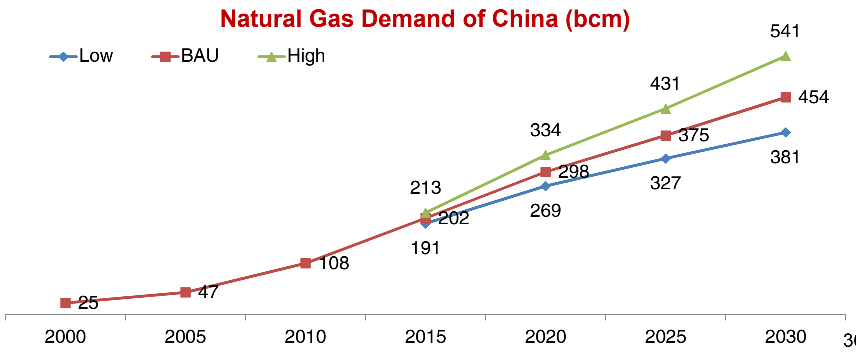
4.1 Opportunities and challenges coexist

- China's natural gas market is facing challenges from economic slowdown, imperfect pricing mechanism and insufficient infrastructures.
- However, there are still huge market potentials for China's natural gas, while substituting coal is the major direction.



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4.2 Suggestions

Market Reform

- Pricing mechanism: cross-subsidization and price inversion; price adjustment period; gas trading hub.
- Electric power market: gas linked pricing mechanism, peak load price mechanism.
- Pipeline system: supervision; reduce intermediate links; direct sale model; measured and trade by heat value.

Environmental Protection

- Make stricter emission standards and environmental policies.
- Encourage replacing coal by natural gas, set up ‘coal free area' in the cities.
- Impose carbon tax or environmental tax on energy utilization.

Industrial Policy

- Cooperation between gas and electric power enterprises.
- R&D, grasp the key technology of Gas turbine.
- Fiscal and taxation policy to support infrastructure investment.
- Guidance for coal industry upgrade, especially for resource-based cities.

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