strategy&

2017

Natural Gas Application Opportunities in China

pwc

Disclosure: Content based on the Strategy& independent research project sponsored by Shell

Foreword

China’s energy market is becoming more diversified towards clean energy with increasing digitalization and marketization supported by technological innovation and policy reform. Meanwhile natural gas consumption continues to rise in China. In June 2017, the National Development and Reform Commission and 12 other commissions drafted a memo to set natural gas as one of China’s main energy source. The memo reinforces the importance of natural gas and boosts the confidence of the industry. Nevertheless, natural gas still faces a series of challenges such as high retail price, low marketization level, lack of awareness among end-users and slow policy development etc. To sustain the development of natural gas, PwC Strategy& published the “Natural Gas Application Opportunities in China” report sponsored by Shell. Through 6 months of market research, expert interview, data analysis and modeling etc, the report analyzed the full value of natural gas and evaluated strategies for natural gas to expand in different regions and sectors. We welcome different industries to understand natural gas and collaborate with us to further promote natural gas as well as other green energy in China.

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Gas As Strategic Enabler For China's Transformation

Promoting Gas Usage in High Value Sectors

- ***Industrial Heating***
- ***Residential/Commercial***
- ***Co-generation - Centralized Heating***
- ***Co-generation - Distributed Energy***
- ***Power Generation***

Policy Action to Realize Gas Potential

Sustainable development has become one of the most important elements of China's national strategy

National strategy planning

Greening is the premise to sustainable development of China and the ask of Chinese people for a better life

Building a conservation-minded society and protecting environment must be the basic state policy

In the 13th five year period, emission control of SO_2, NO_X and PM will be enhanced with stricter standards

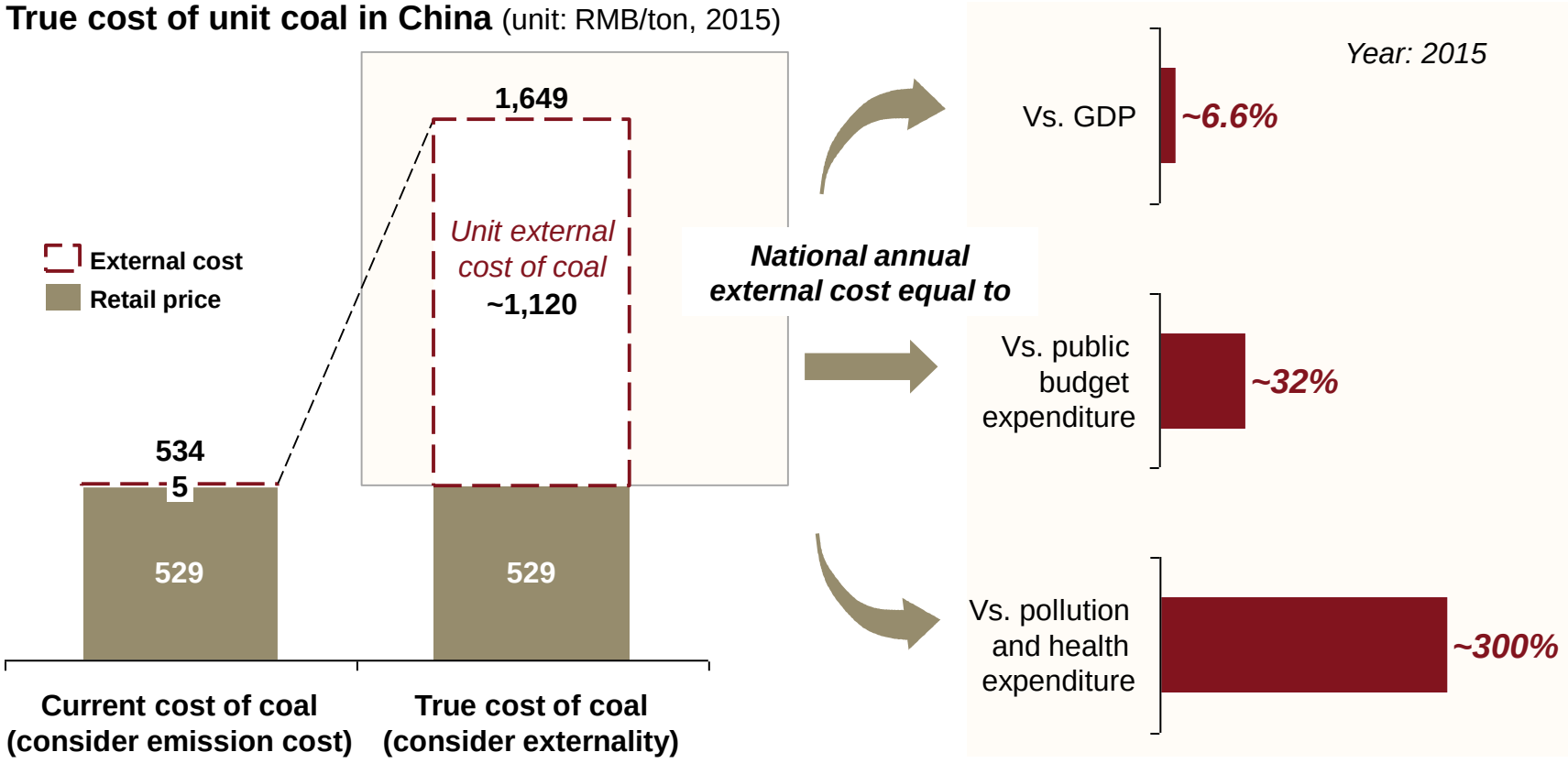
In the 13th five year period, target to reduce accumulative emission of SO_2 and NO_X by 15% respectively

Source: NDRC, MEP, Strategy& analysis

However, a predominantly coal-based energy system has a significant cost on the society because of air pollution

Externality cost (air pollution related) per unit coal consumption in China (2015)

True cost of unit coal in China (unit: RMB/ton, 2015)



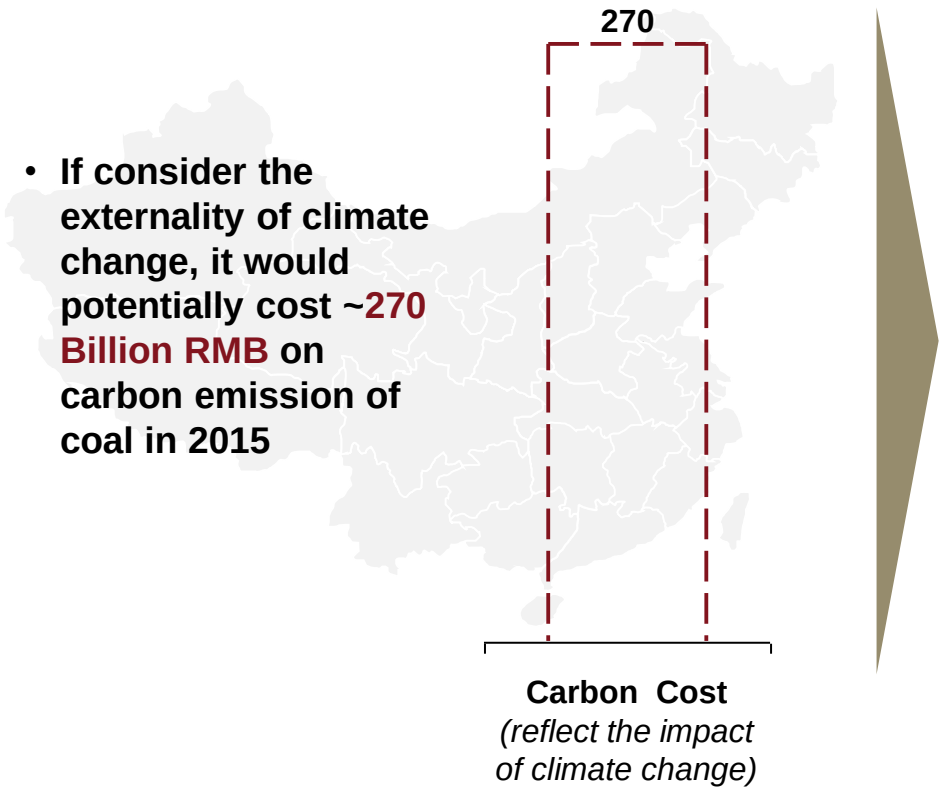
Note 1: The new environmental tax will replace the emission fee and raise the cost of coal in 2018
Note 2: Externality cost refers to the environmental and health cost associated with producing and consuming coal
Source: IMF "Getting energy price right" , "Externalities of coal 2012"State Statistics Bureau, Xinhua News, Strategy& analysis

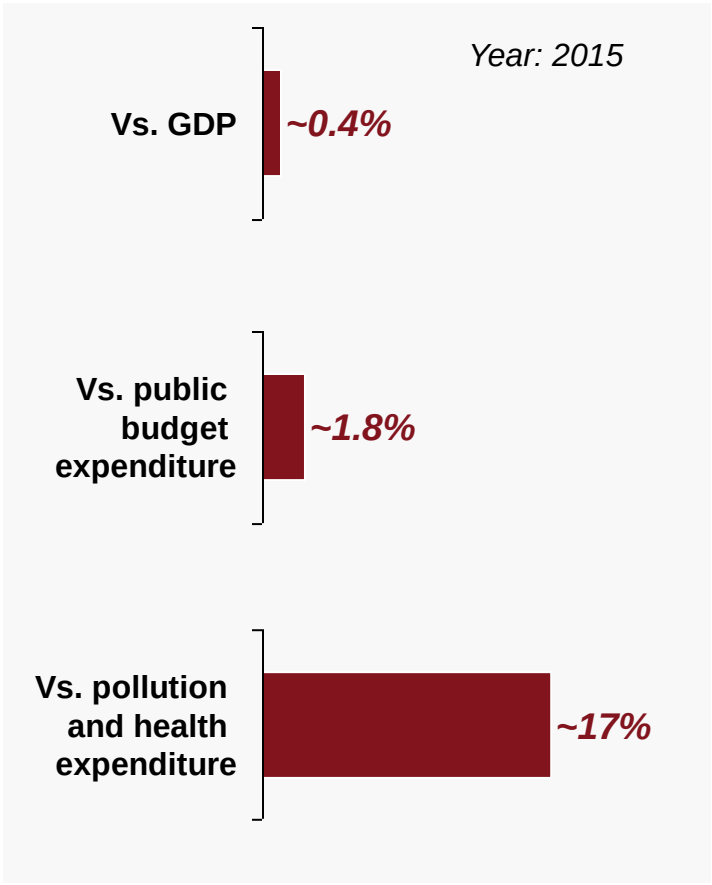
In addition to air pollution related cost, coal consumption may result in 270 billion RMB climate related cost

Carbon cost of coal, @ 30 RMB/t carbon price

Carbon cost of coal in China (unit: billion RMB)

- **If consider the externality of climate change, it would potentially cost ~270 Billion RMB on carbon emission of coal in 2015**



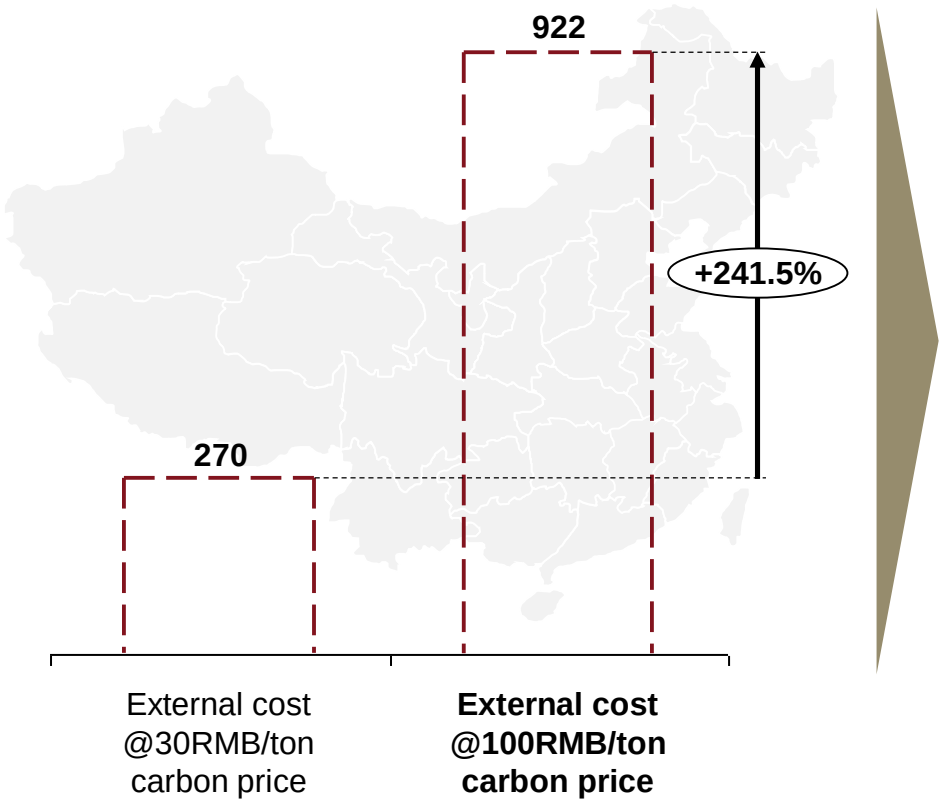


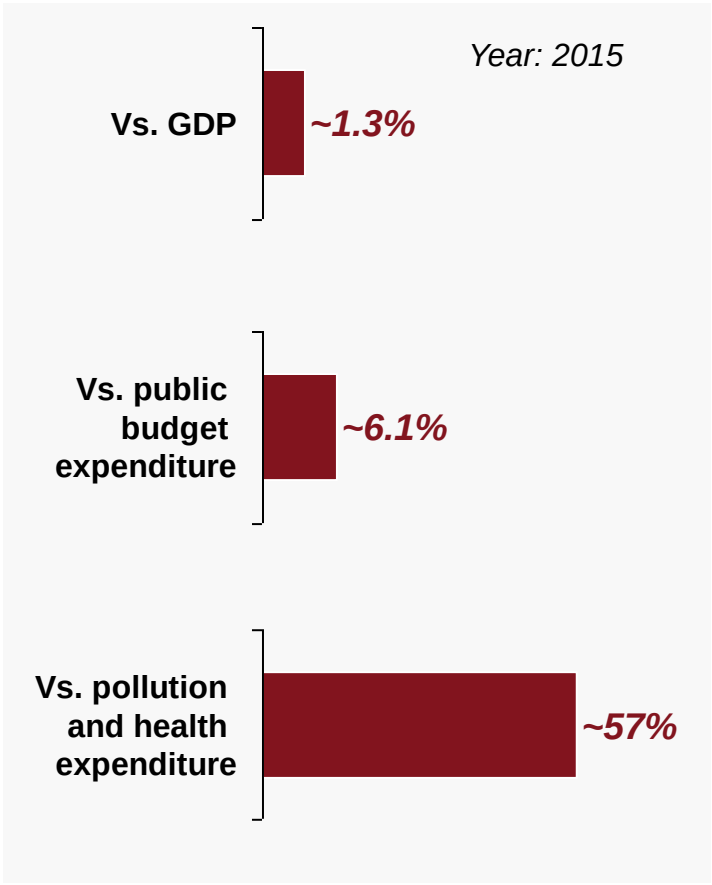
Source: IMF "Getting energy price right" , State Statistics Bureau, Strategy& analysis

Given the higher carbon cost at 100 RMB/t, carbon cost will increase from 270 billion to ~920 billion RMB

Climate change external cost of coal, @ 100 RMB/t carbon price

Carbon cost of coal in China (unit: billion RMB)

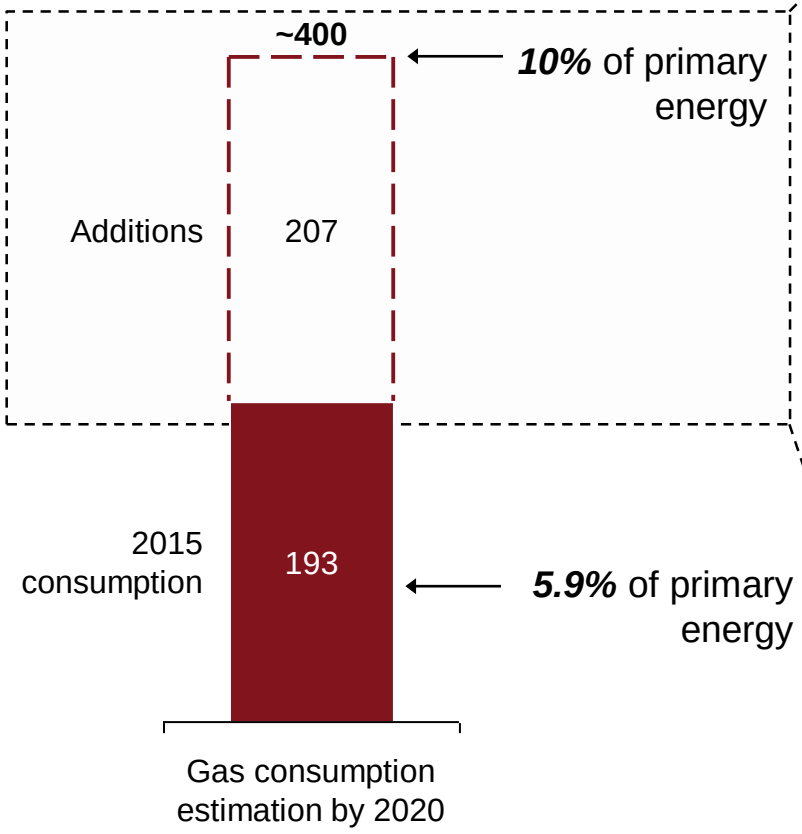




Source: IMF "Getting energy price right" , State Statistics Bureau, Strategy& analysis

Meeting the target of 10% gas in energy mix by 2020 can result in net system cost savings of ~85 billion

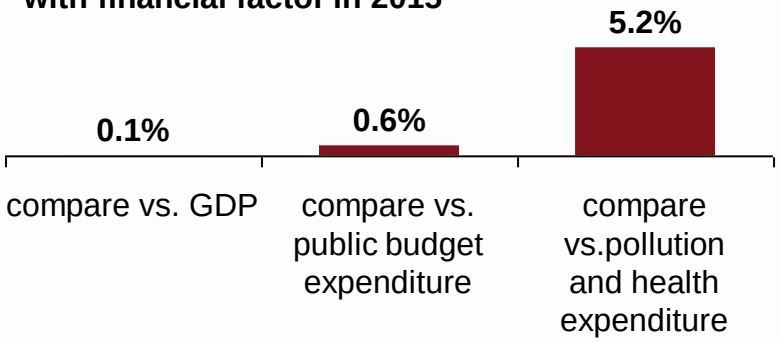
Gas consumption estimation by 2020
(unit: billion m^3)



Cost saving of "coal to gas" by 2020

- **Assume the additional gas consumption will all come from "coal to gas" switch**
- **~85 Billion RMB** total cost saving (differential between decreased external cost of air pollution and increased fuel cost) for 4% additional gas consumption*

Total cost saving estimation by 2020 compare with financial factor in 2015



Note: Not considering negative GDP impact due to lower coal output at major coal production provinces*
Source: China Energy Development 13th Five Year Plan, IMF "Getting energy price right" , State Statistics Bureau, Strategy& analysis

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Policy Action to Realize Gas Potential

Promoting coal to gas switch in various sectors will help China to meet its 10% gas in energy mix target by 2020

Industrial heating

- Overall, gas is a better alternative for coal boiler retrofitting
- Efforts should be concentrated into high value industries and key regions such as Textile, Food, Paper, Ceramic etc. & Shandong, Hebei, Jiangsu, etc.
- LNG-based supply can play a role to drive down the gas retail price by promoting market competition.

Residential sector

- Gas as cleaner and more convenient fuel source have better usage in residential activities like cooking and water heating
- Large-scale centralized gas CHP is more applicable for the environment sensitive regions and non-coal zones

Distributed energy

- Distributed gas CHP with 70+% efficiency and less emissions can be positioned as core component of China power reform and micro-grid development
- Users with large and stable energy demand, and higher utilization are identified as better near-term consumers: data center, industrial park, etc.

Power generation

- Gas peak plant is an important source for power flexibility along with increasing amount of renewable energy that requires higher flexible grid system to integrate
- Pricing on the flexibility would be important to encourage investment in peak-shaving plant

- ***Promoting coal to gas switch in those sectors will help China to meet its 10% gas in energy mix target by 2020, in addition to gas application in transportation, chemical and other sectors.***

Source: Expert interview, Strategy& analysis

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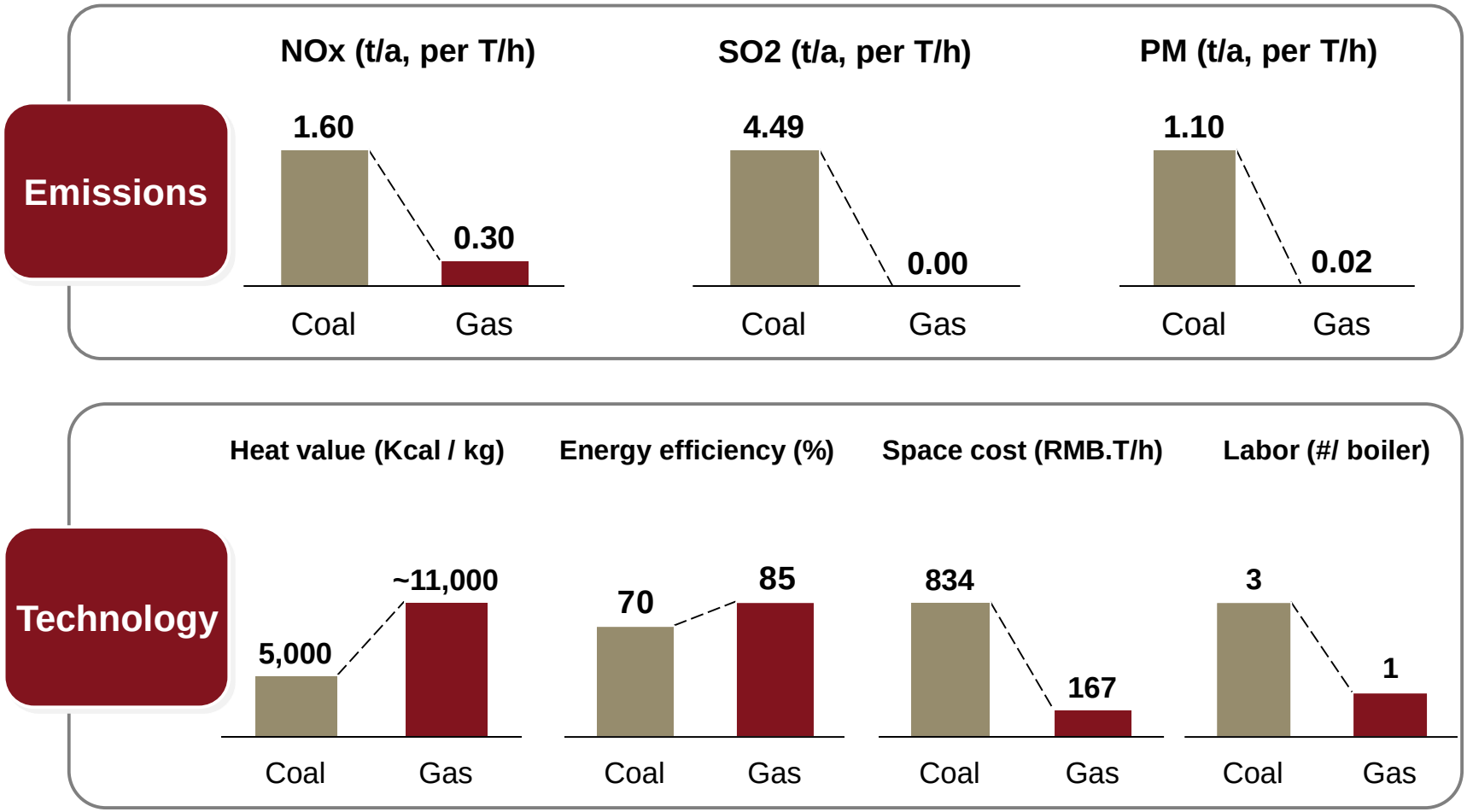
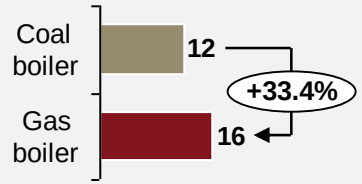
Policy Action to Realize Gas Potential

As an industrial fuel, the value gas provides is beyond emissions reduction



Source: Expert interview, The environment impact assessment report of Beijing Yanjing beer company C2G program, Strategy& analysis

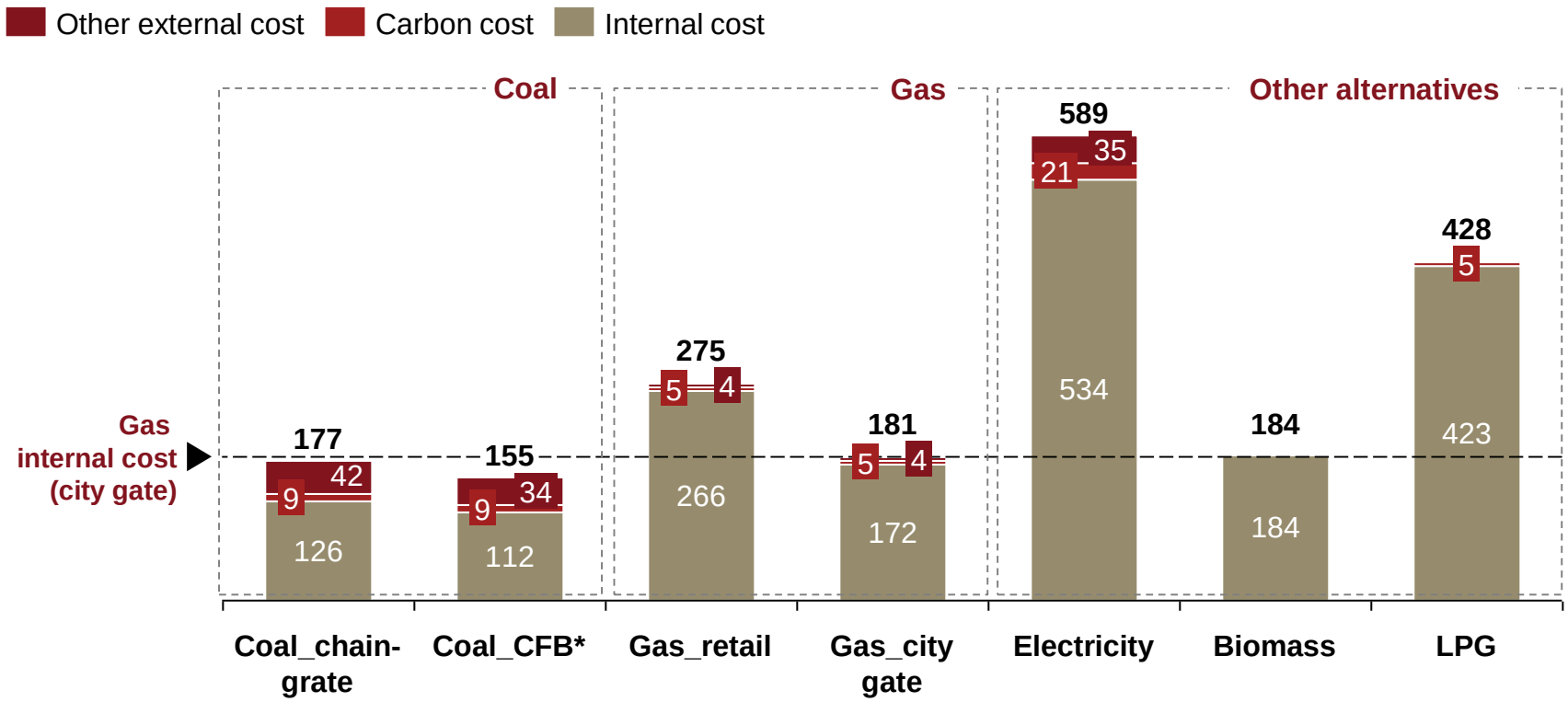
For investors, coal to gas switch helps to mitigate policy risk, lower land cost, improve productivity and reduce failures

	Description	Case
Mitigate policy risk mitigation	• Coal boilers are in policy risk of being shut down, resulting in sunk cost and impeding plant operation	• **A textile company in Changshu, Jiangsu** : A 2-year coal boil which worth **4 million RMB** was forced to shut down. • The increased cost is pushing us to upgrade the technology and product. ----- Operation director
Lower land cost	• Gas boiler does not require coal storage and waste disposal; it saves land space and related cost	• **A cigarette factory in Yunnan**: The construction area of gas boiler room is only **1 /4** of coal • **A textile company in Jiangsu** : over hundreds m2 have been saved and converted as warehouse
Improve productivity	• Gas boiler will increase the yield and quality in specific industries, with the higher heat values and stable supply	• **A chemical company in Xinjiang**: The product revenue (unit: thousand ￥) has been increased by 33.4% 
Reduce equipment failures	• Gas boiler is more stable , with less failure rate and longer working hours	• **A chemical company in Xinjiang**: The coal boiler had shut down **30 times per year** because of high equipment failures rate, lead to halted service of **47 working days**

Source: Expert interview, Literature review, Strategy& analysis

Gas boilers at city gate price are cost competitive against alternatives such as electricity, biomass and LPG boilers

Annualized unit cost of different boilers (RMB / t.h)



Note: 1. CFB= Cycle Fluidized Bed; 2. 30 RMB/ton for carbon cost; 3. Gas Retail price: 2.9 RMB/m^3, City gas at 1.8 RMB/m^3; 4. Lack of valid data in Biomass and LPG's external costs*

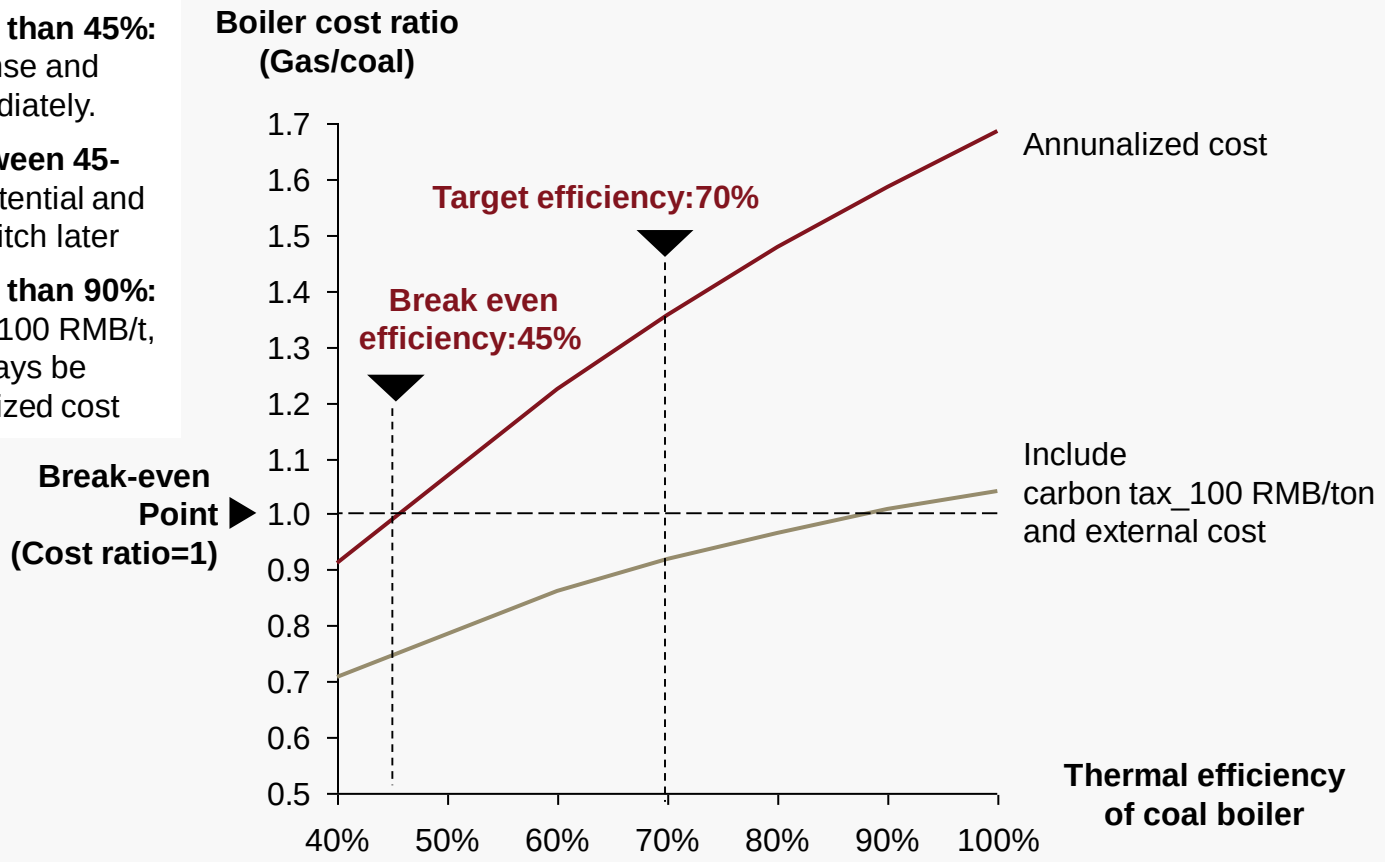
Source: IMF "Getting energy price right", Wind, 315i, Strategy& analysis

Gas boiler switch can first target coal boiler with efficiency less than 70% as low-hanging fruit

How thermal efficiency impact energy production cost ratio?

City gate gas price @ 1.8 RMB/m^3

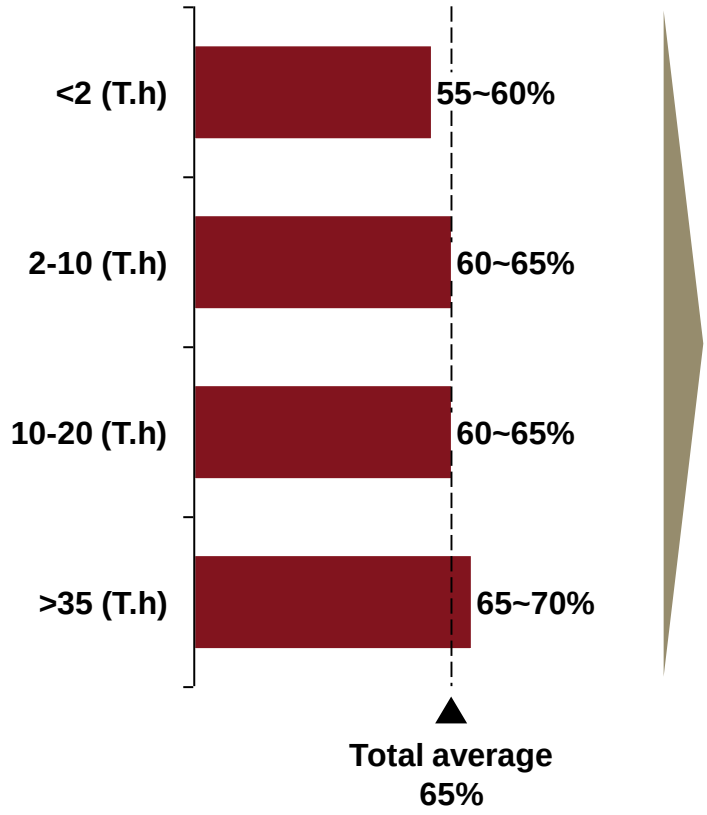
- **For efficiency less than 45%:** make economic sense and should switch immediately.
- **For efficiency between 45-70%:** have great potential and should target for switch later
- **For efficiency less than 90%:** if carbon price is at 100 RMB/t, C2G switch will always be economic in annualized cost



Source: Strategy& analysis

In many cases, the thermal efficiency of coal boilers are still less than 70%, especially for small boilers

Actual thermal efficiency of boilers
(national average, 2016)



Case: Some measured data of coal boilers in Hebei

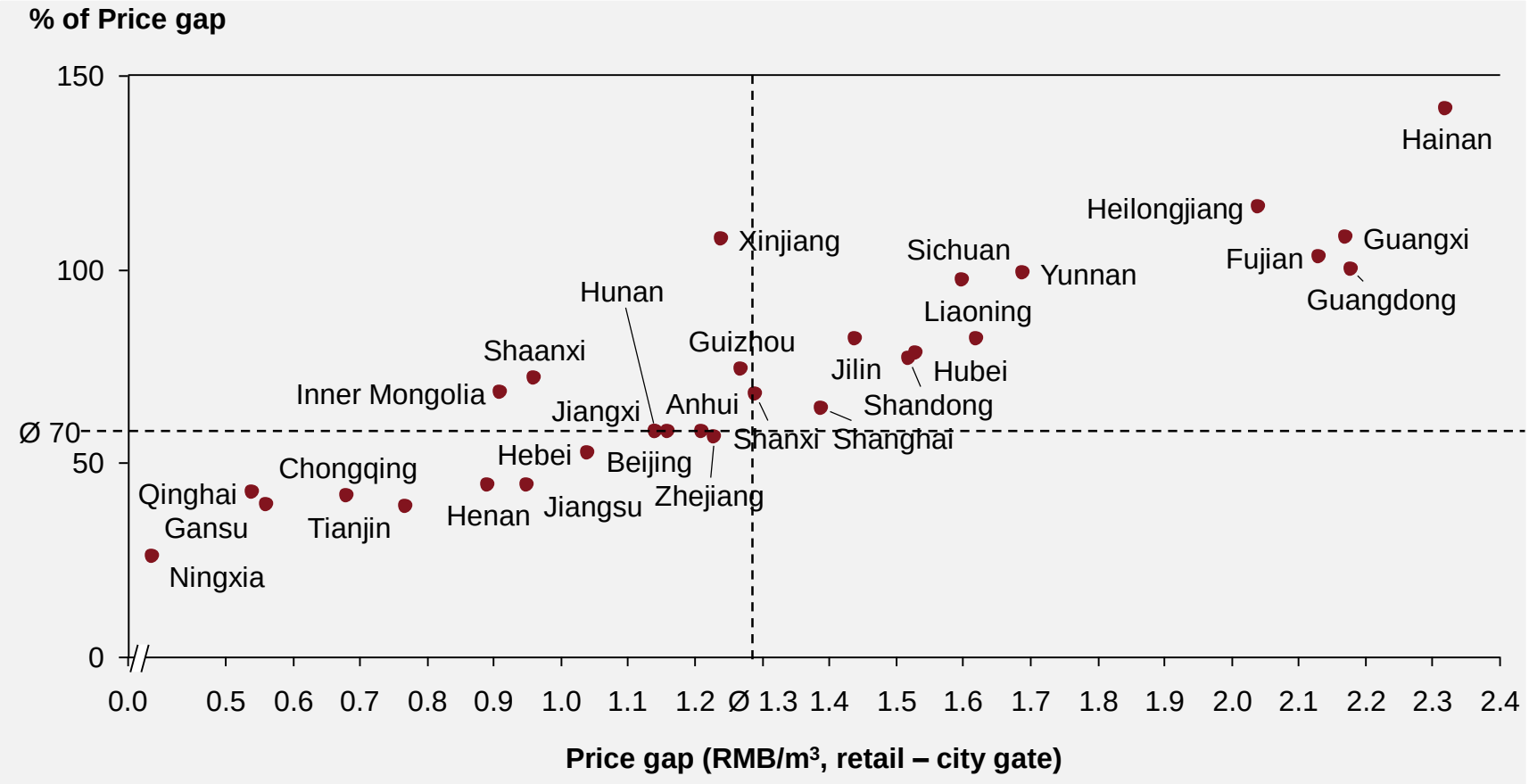
Indicator \ Boiler capacity	2 T/h	4 T/h	6 T/h	10 T/h	20 T/h	Total
• Number #	6	138	47	57	8	256
• Average ash carbon content (%)	19.2	18.6	18.1	18.2	18.3	18.5
• Average excessive air coefficient (a)	5.54	5.54	3.79	5.28	3.15	4.66
• Average flue gas temperature (°C)	160	139	136	148	204	157
• **Average operation thermal efficiency**	**41%**	**57%**	**64%**	**58%**	**53%**	**57%**

The average thermal efficiency is only 57%

Source: China boiler market report 2016, 315i, Literature review, Strategy& analysis

However, industrial gas retail price is on average 70% (or 1.3 RMB/m³) higher than the city gate prices

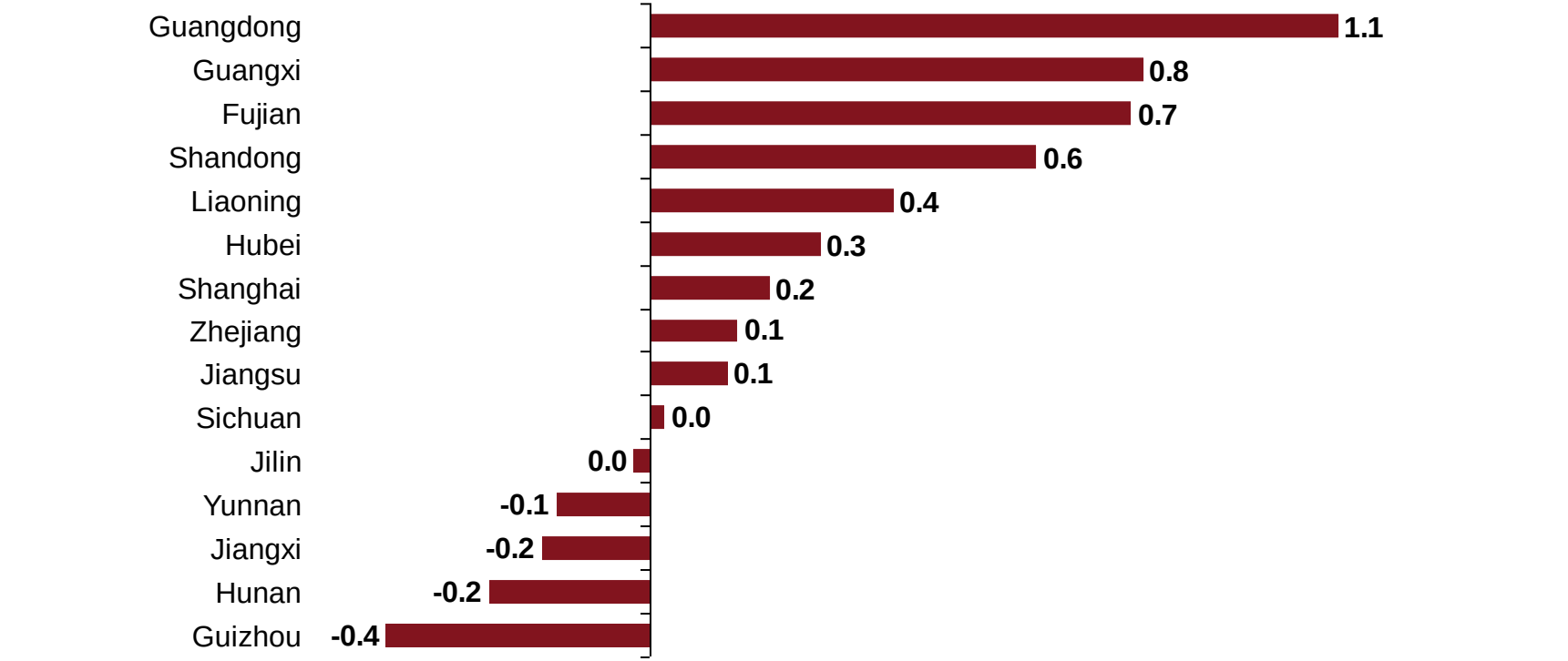
Price gap between provincial retail price and reference city gate* price, as of Feb, 2017



Note: Reference City Gate price (基准门站价格) here is based on the guideline announced by NDRC in 2015, actual price may be different
Source: NDRC, Wind, Strategy& analysis

LNG price in most regions is attractive vs pipeline gas and offers an alternative option for industrial gas users

Price differential* in selected provinces (pipeline industrial - LNG, RMB/m3, June/2017)

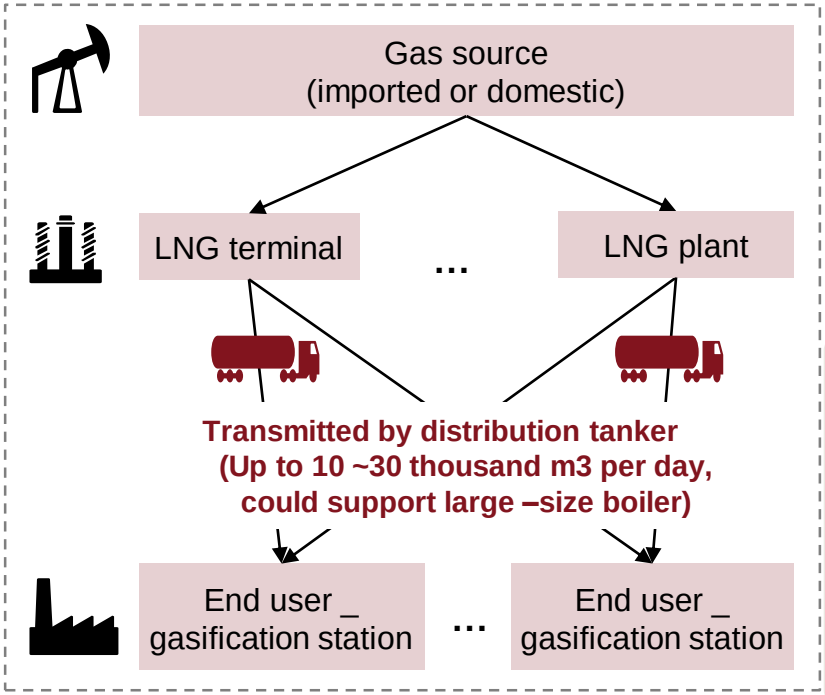


- With lower oil price and surplus supply, LNG price is reducing and becoming competitive vs pipeline gas.
- Investors using LNG are mostly from areas with well-developed industries or weaker pipeline network

*Note: *Price gap = pipeline gas price (industrial) - LNG price, which already consider the gasification cost, traffic cost, VAT (11%) and margin of supplier (~10%)*
Source: China boiler market report 2016, Gas online, Strategy& analysis

LNG-based supply offers better flexibility and choices, and can become a complementary supply for end-users

LNG- based supply for industrial user



LNG distributed supply market cases:

- **Taizhou, Zhejiang:** Over 50 companies
- **Chaozhou, Guangdong:** ~40% of ceramic producers
- **Shandong:** Encourages LNG to compete with gas

Comparison with pipeline gas

	LNG	Pipeline gas
• **Price**	• Unregulated • Connected to global market	• Semi-regulated
• **O&M cost**		• Lower
• **Initial investment**	• Provide more options, including free or paid leasing	• ~1.5 million RMB (equipment, con-struction, deposit)
• **Supplier**	• Competitive market, with wide range of choices,	• Franchise mode, usually dominated by 1~2 suppliers per city

Source: Customer survey, Literature review, Strategy& analysis

The 'catfish effects' brought by LNG will help to promote gas market development

C2G initiative will create more distributed industrial customer demands in China

- Since there are numerous small and medium - sized industrial users in China, more distributed markets will emerge along with the development of C2G policy. These distributed markets requires a more flexible business model of gas supply.

Stricter supervision of government

- As a clean fuel, LNG will eventually be encouraged by local governments but with stricter supervision.

Values of the LNG-based supply

- **Drive competition:** LNG will be a catalyst in gas market, which will help to bolster the competition of both price and service,.
- **Accelerate business model innovation in gas market:** LNG providers are developing innovative business models such as leasing
- **Become an effective alternative of pipeline gas:** LNG can efficiently meet the surging and distributed demand, especially in remote areas where pipeline network may not make economic sense.

Note: The catfish effect is the effect that a strong competitor has in causing the weak to better themselves.*
Source: Literature review, Expert interview, Strategy& analysis

However, regulation and pressure from existing pipeline gas suppliers hinder LNG growth and need to be addressed

Key LNG market barrier

1 Inappropriate regulatory codes

- Current regulatory codes for LNG is decade-old and tailored for big regas facilities (eg safety distances)
- End users cannot meet these outdated standards and are concerned with compliance risk
- Several small regas projects have been declared as illegal with unqualified safety condition

2 Ambiguous regulations

- Most provinces in China do not have clear approval process for use of LNG
- The boundary of “franchise right” of pipeline gas company is not clearly explained
- There are some areas excluded from regulations e.g. stealing or replacing gas with hydrogen

Conflict with pipeline gas companies

Pipeline gas companies may view LNG suppliers as market disruptor and push the local governments conduct compliance investigation on LNG supplier

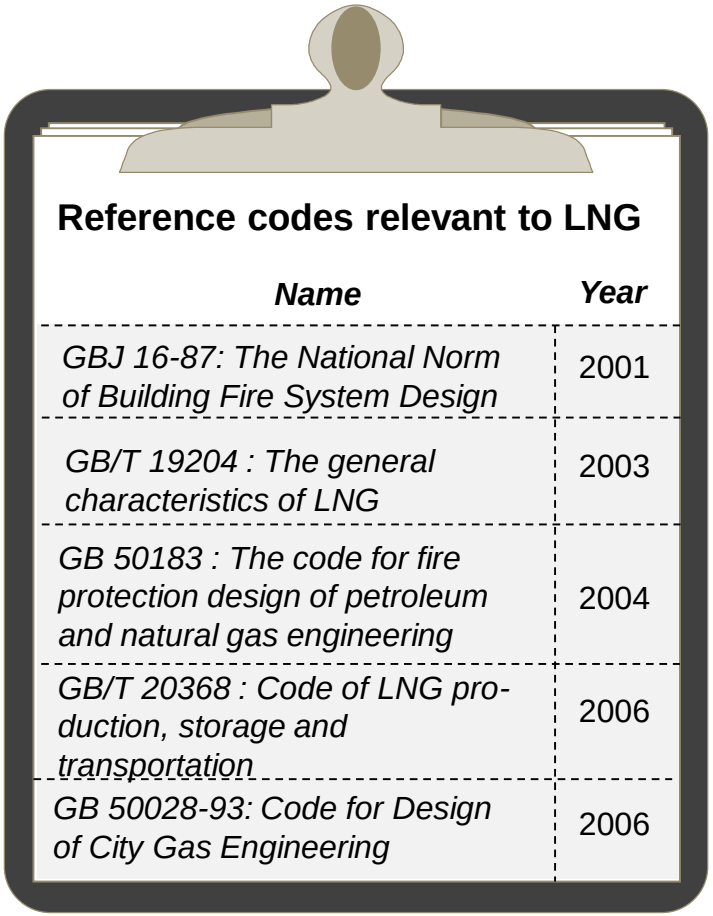
LNG project construction should be tightly regulated and self--built LNG gasification station must be under resolute control

—— the Ministry of Construction in Hubei

《关于加强城镇燃气规划管控，严格LNG工程建设管理的通知》

Source: Public reports, Hubei Provincial Housing Department, Expert interview, Strategy& analysis

Inappropriate regulatory codes: Current regulatory codes for LNG use are decade-old and not applicable to small scale LNG used by industrial users



Reference codes relevant to LNG

Name	*Year*
GBJ 16-87: The National Norm of Building Fire System Design	2001
GB/T 19204 : The general characteristics of LNG	2003
GB 50183 : The code for fire protection design of petroleum and natural gas engineering	2004
GB/T 20368 : Code of LNG production, storage and transportation	2006
GB 50028-93: Code for Design of City Gas Engineering	2006

Analysis

- **LNG suppliers and industrial users face complaints about not meeting safety standards,** which is difficult to evaluate due to the lack of suitable standards.
- Eg. According to "*Code for Design of City Gas Engineering*", a gas tank with less than 10 m3 must be located at least 15m away from buildings, 20m away from gas tanks. Most mid- small industrial users can't meet the requirements due to limited space

Market quote

- "Even though we've selected the LNG supplier who were recommended by local Environmental Protection Agency, and we were promoted as C2G best practice, **our company was still forced to shut down and take corrective actions due to the unqualified safety distance.**

—— A coating producer in Zhejiang

Source: China Gas Association Professional Committee of LNG, Customer survey, Literature review, Strategy& analysis

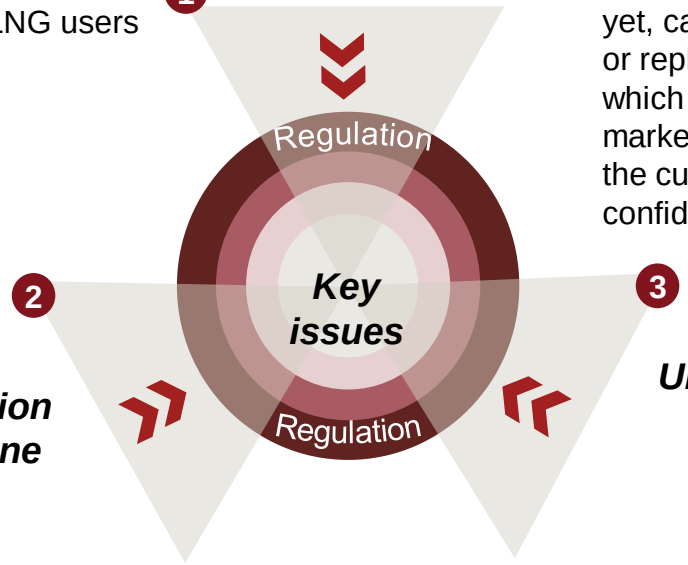
Ambiguous regulation: LNG use is also hindered by unclear approval process and regulatory gaps

Key issues of LNG regulation

- Most provinces in China do not have uniform and clear approval process for industrial LNG users

1 *Unclear approval process*

- Across LNG supply chain some areas are not supervised by local governments yet, causing stealing or replacing gas, which will distort the market and impact the customer confidence



2 *Unclear differentiation with pipeline gas*

3 *Unsupervised areas*

- Some pipeline gas companies believe LNG supply is creating an unfair competition, and the boundary of "franchise right" is not clearly explained by government

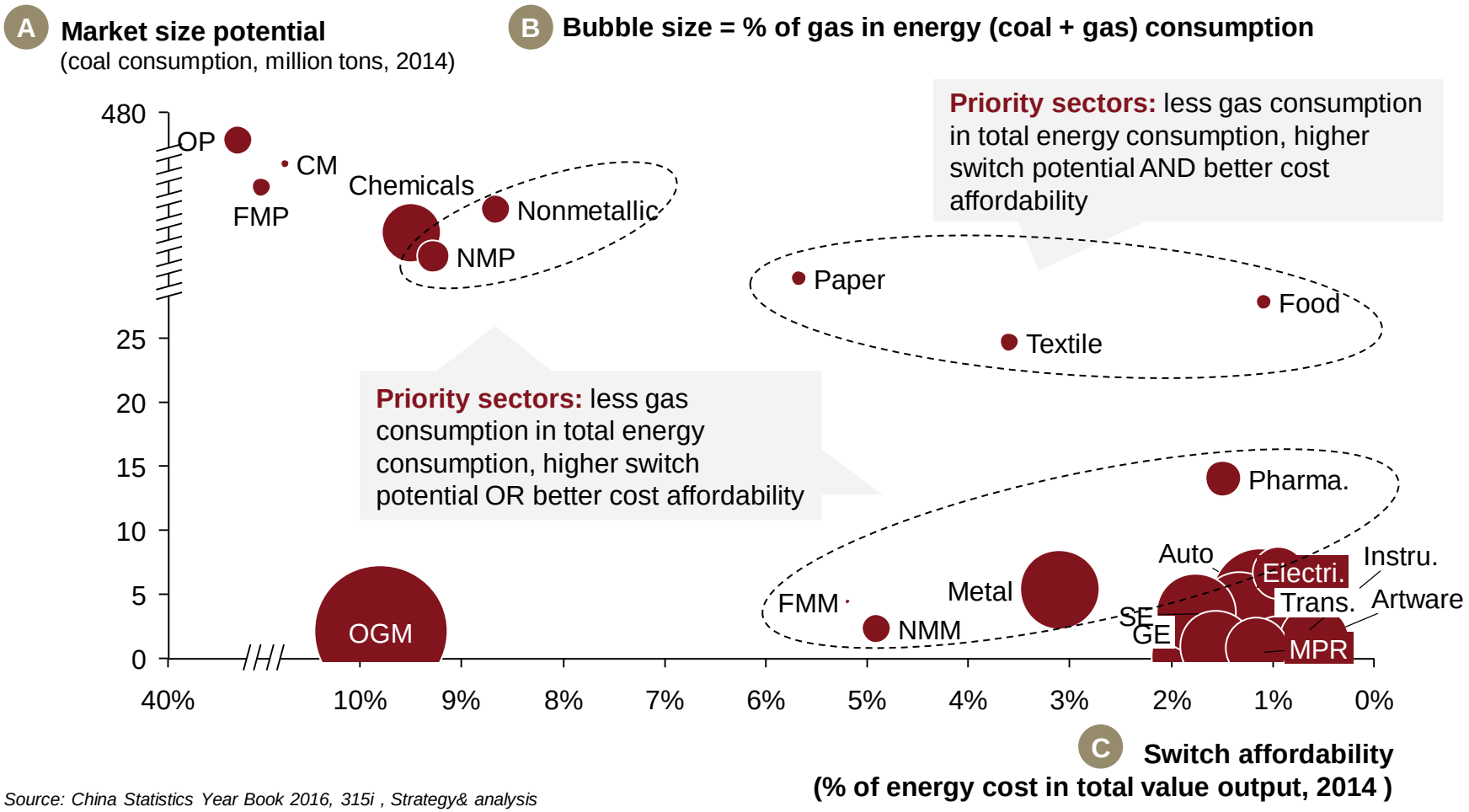
Market quote

- Many small-size users like us are under great cost pressure due to C2G policy. We can only use the cheaper LNG (2.5 RMB compares to 3.1 RMB of pipeline gas) , **fear to be shut down at any time.**
- We hope the government could acknowledge the value of LNG and **give us more options on gas supply.**

—— A textile producer in Guangdong

Source: Customer survey, Literature review, Strategy& analysis

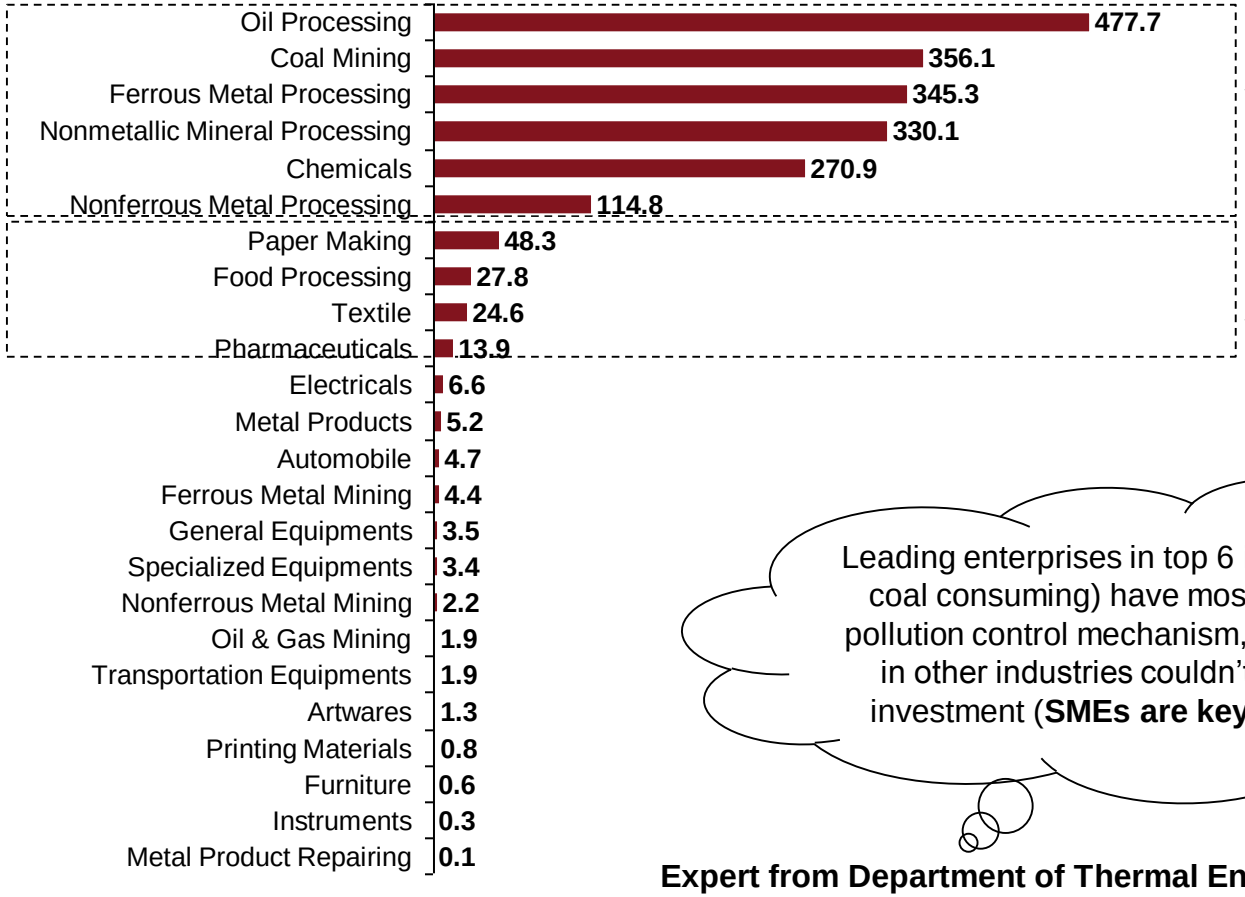
Overall, industries with higher coal consumption, lower gas penetration rate and better switch affordability can be targeted as priority for coal to gas switch



Source: China Statistics Year Book 2016, 315i , Strategy& analysis

Industry with higher coal consumption represents bigger overall switch potential

Coal consumption ranking by industry (million tons, 2014)



Largest coal consumer, major players are SOEs and listed private giants, more concentrated industry clustering

Key polluters, consist of large number of SMEs (Paper, Food, Textile), with less capital to invest in pollution control

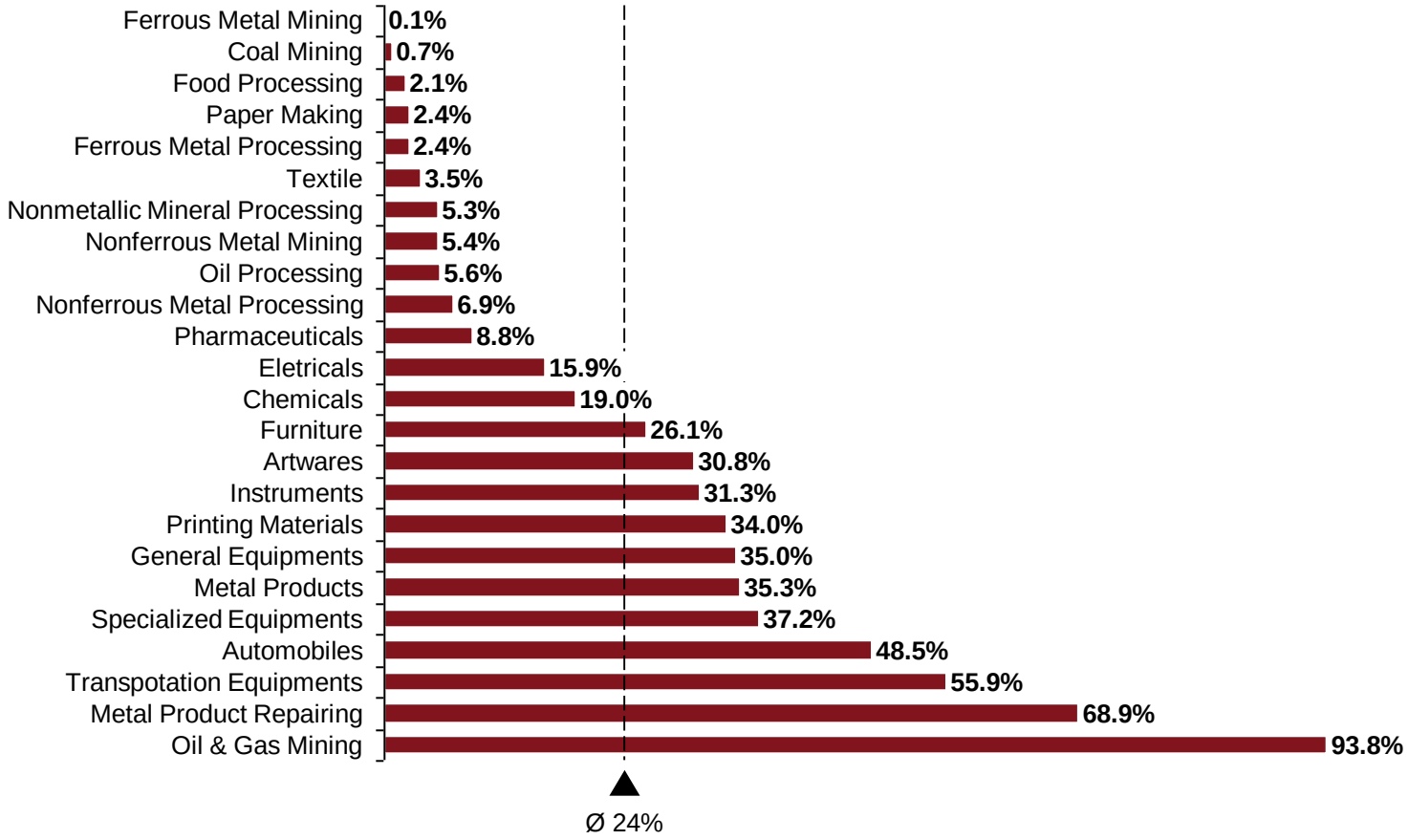
Leading enterprises in top 6 industries (by coal consuming) have mostly adopted pollution control mechanism, whilst SMEs in other industries couldn't afford the investment (**SMEs are key polluters**)

Expert from Department of Thermal Engineering, Tsinghua University

Source: China Statistics Year Book 2016, 315i , Strategy& analysis

Overall gas penetration is still lower than 24% in industry, while industry like FMM, food processing and paper making has good potential

Gas consumption ranking by industries in 2014 % of gas in energy (coal + gas) consumption



Source: China Statistics Year Book 2016, 315i , Strategy& analysis

Industries with lower energy cost as part of their output value can likely afford the switch

Industry	Output Value, Billion RMB	Energy Cost, Billion RMB	Coal	Gas	Others	% of total value
Artwares	1476.2	8.5	0.7	1.0	6.9	**0.6%**
Instruments	828.6	7.6	0.2	0.2	7.2	**0.9%**
Electrical	6692.2	62.1	3.5	2.1	56.5	**0.9%**
Transportation Equipment	1865.4	21.1	1.0	4.1	16.0	**1.1%**
Automobiles	6634.2	73.8	2.5	7.4	64.0	**1.1%**
Food Processing	6359.6	68.3	14.7	1.0	52.7	**1.1%**
Furniture	734.8	8.4	0.3	0.4	7.7	**1.1%**
Specialized Equipment	3503.9	45.8	1.8	3.3	40.6	**1.3%**
Pharmaceuticals	2320.0	34.3	7.4	2.2	24.7	**1.5%**
Metal Products repairing	85.9	1.4	0.0	0.2	1.2	**1.6%**
Printing Materials	689.4	10.7	0.4	0.7	9.5	**1.6%**
General Equipment	4715.1	82.3	1.8	3.1	77.3	**1.8%**
Metal Products	3661.2	113.0	2.8	4.7	105.5	**3.1%**
Textile	3770.4	135.1	13.0	1.5	120.6	**3.6%**
Nonferrous Metal Mining	634.8	31.1	1.2	0.2	29.8	**4.9%**
Ferrous Metal Mining	933.1	48.4	2.3	0.0	46.1	**5.2%**
Paper Making	1377.5	78.1	25.5	2.0	50.6	**5.7%**
Oil & Gas Mining	1166.4	114.2	1.0	48.6	64.6	**9.8%**
Nonmetallic Mineral Processing	5824.0	503.9	174.6	30.7	298.6	**8.7%**
Chemicals	8235.3	781.5	143.3	105.7	532.5	**9.5%**
Nonferrous Metal Processing	4615.5	427.7	60.7	14.1	352.8	**9.3%**
Coal Mining	2602.5	279.5	188.4	4.2	87.0	**10.7%**
Ferrous Metal Processing	7102.7	1312.4	182.6	14.4	1115.4	**18.5%**
Oil Processing	4080.3	1603.4	252.7	46.9	1303.8	**39.3%**

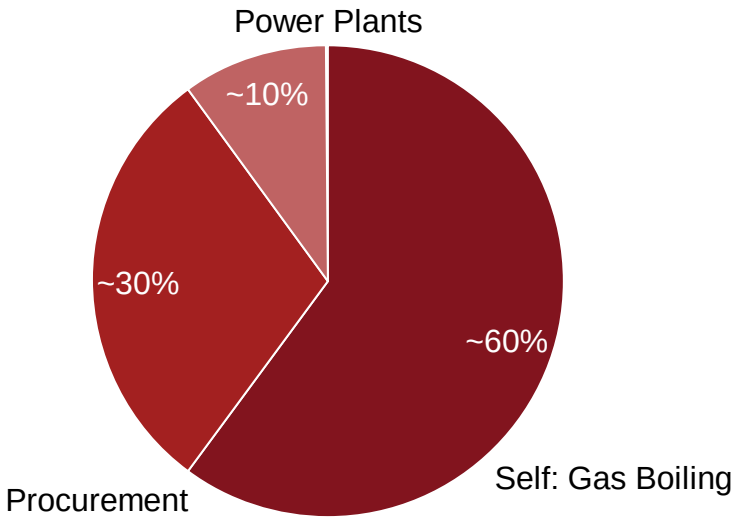
Least sensitive to energy cost rising

Very sensitive to energy cost rising

Source: China Statistics Year Book 2016, strategy& analysis

Food Industry: A leading food manufacturer has been using gas since 2007 in order to build CSR image and meet the government's environmental protection requirements

The company's sources of steam



Steam from gas boiling

- 16 factories, located in different regions, are using gas boilers
- The first gas boiler dated back to 2007, driven by **CSR** and **long-term strategic assessment**

Steam from procurement

- 30% of the company's steam demand comes from external procurement
- A majority of the steam is procured from **gas and other clean energy boilers**

Steam from power plants

- 2 of the company's factories are using steam produced by power plants along with power generation

CSR consideration and meeting central and local government's environmental protection target are the main drivers for this industry leader to switch to gas boilers

Source: Expert Interview, Strategy& analysis

Food Industry: Coal to gas switch has provided environmental、operational and branding values for this leading food manufacturer

Benefit fields	Gas boiler
Environment	• Cleaner ambient environment and workspace
Security	• Automatic and immediate shut-down during emergency
Stability	• Able to keep the temperature stable
Headcount cut	• No fuel loading worker needed
Incentive gain	• Stronger bargaining power against local regulators
CSR image	• Better CSR image especially as industry leaders

"Our products require stable processing temperature. The gas boiler enables our production to be more efficient and our products to be higher quality"

"As a pioneer that could be set as a successful case to promote the C2G switch, we negotiated with local governments to get favorable supports"

"Before we chose to use gas, we did experiments and calculation, which many users haven't, and found out that overall in long term gas is beneficial"

— Equipment Director of the Company

Source: Expert Interview, Strategy& analysis

Food Industry: A leading beer manufacturer in Beijing has switched all its coal boilers to gas, leading to many benefits for the environment and the factory

Project background

- Yanjing, one of the biggest beer manufacturing factories in the region
  - Area: 14,8817.3 m^2
  - Asset: 448.54 million RMB
  - Production Capacity: > 250 tons beer
  - Headcount: > 2,000 personnel
- The company had 10 coal boilers with 6 t/h capacity each before the C2G switch
- In 2015, the company switched all its boilers into one 4 t/h, one 6 t/h and five 10 t/h gas boilers
- As a result, the company **meets government's emission requirements**

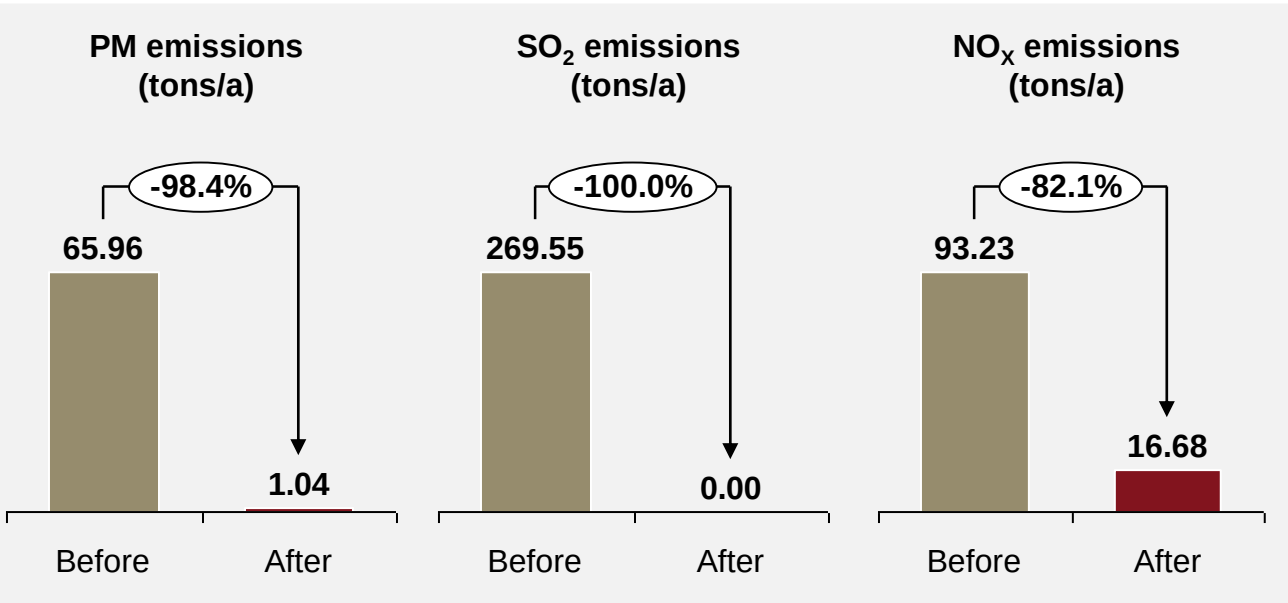
Key benefits of the C2G switch

1 **Atmosphere**	• Gas boilers emit less air pollutions in terms of density and volume
2 **Water**	• Gas boilers don't produce waste water from desulfurization and denitration process
3 **Solid waste**	• Gas boilers don't produce coal cinders
4 **Noise**	• Gas boilers' noise is lower than coal's
5 **Land**	• Gas boilers occupy smaller space as gas is supplied via pipeline without storage

Source: Expert Interview, Yanjing Beer C2G environment impact report, Strategy& analysis

Food Industry: The switch resulted in 98%, 100%, 82% reduction for PM、SO2 and NOx, helping to address the air pollution challenge

1. Atmosphere
2. Water
3. Solid waste
4. Noise
5. Land



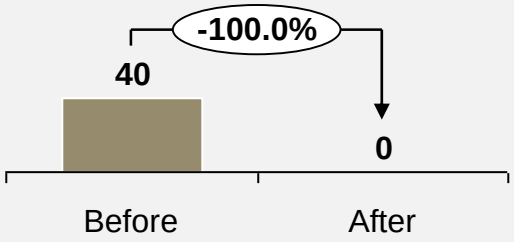
	PM	SO_2	NO_X
Gas boiler (mg/m^3)	5	0	80
Beijing standard (mg/m^3)[1]	5	10	80

1) applied DB11 139-2015 Standard for new industrial boilers constructed before March 31, 2017
Source: Expert Interview, Yanjing Beer C2G environment impact report, Strategy& analysis

Food Industry: The switch reduced the water consumption and solid waste by 100%

1. Atmosphere
2. **Water**
3. **Solid waste**
4. Noise
5. Land

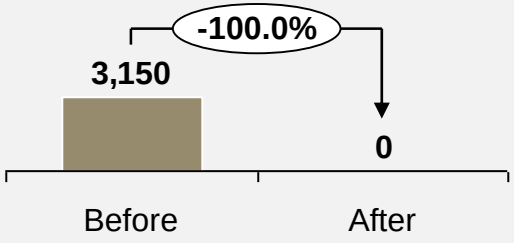
Use of Water (excluding Steam) (tons/day)



Before
- 12, 000 tons water is used for desulfurization and denitration per year

After
- No need for desulfurization and denitration
- Little impact on ambient water environment

Emission of Coal Cinders (tons/a)



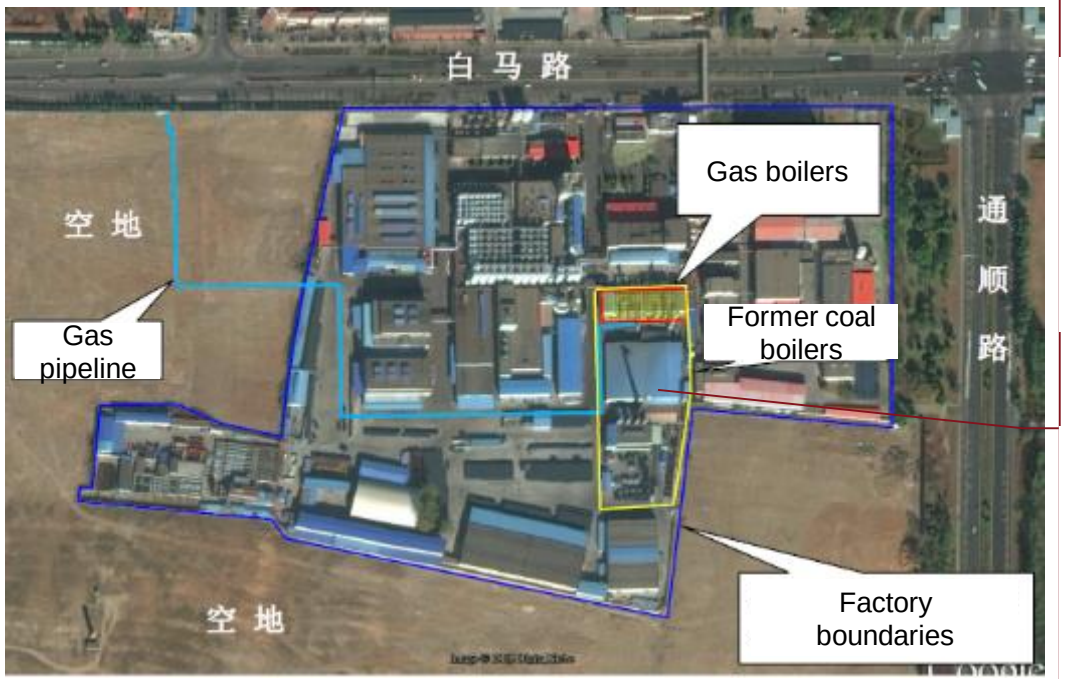
Before
- 3150 tons coal cinders are produced along with steam generation per year

After
- No cinder emission from boiling process

Source: Expert Interview, Yanjing Beer C2G environment impact report, Strategy& analysis

Food Industry: The switch reduced the boiler land occupation by 80% and increased real estate utilization

Overview of the beer factory

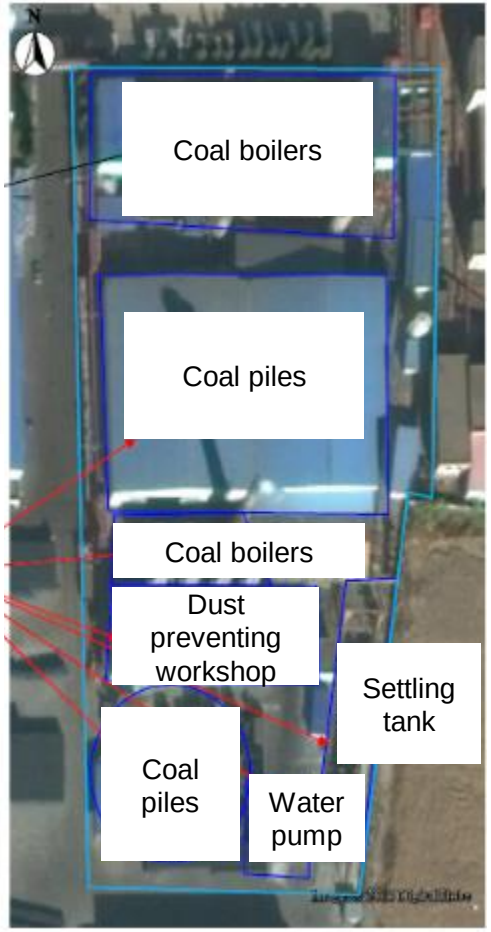


After the C2G switch, only ~20% of former boiling area (2,500 m² total) is used for generating steam, the other 80% area is saved for alternative usage e.g. storage

Boiling zone before switch

Become location for gas boilers

Become beer bottle storage area

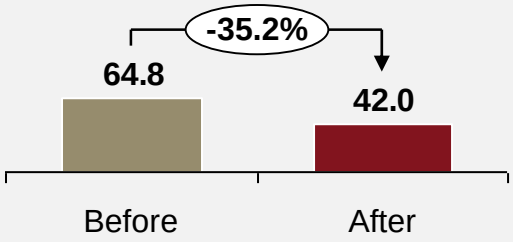


Source: Expert Interview, Photo and data from Yanjing Beer C2G environment impact report, Strategy& analysis

Food Industry: Noise is lower and land occupation is smaller

1. Atmosphere
2. Water
3. Solid waste
4. **Noise**
5. **Land**

Noise of daytime to north boundary (dB)



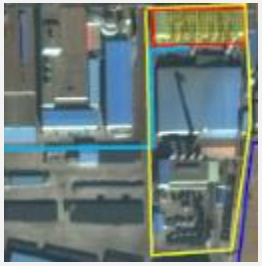
Before

- To the north boundary (nearest), average noise is 64.8 dB for day and 53.6 dB for night

After

- To the same point, average noise is less than 42 dB

Use of land for the boilers And related activities



before

after

Before

- Coal boilers require additional space for coal piles, dust inhibition, etc.

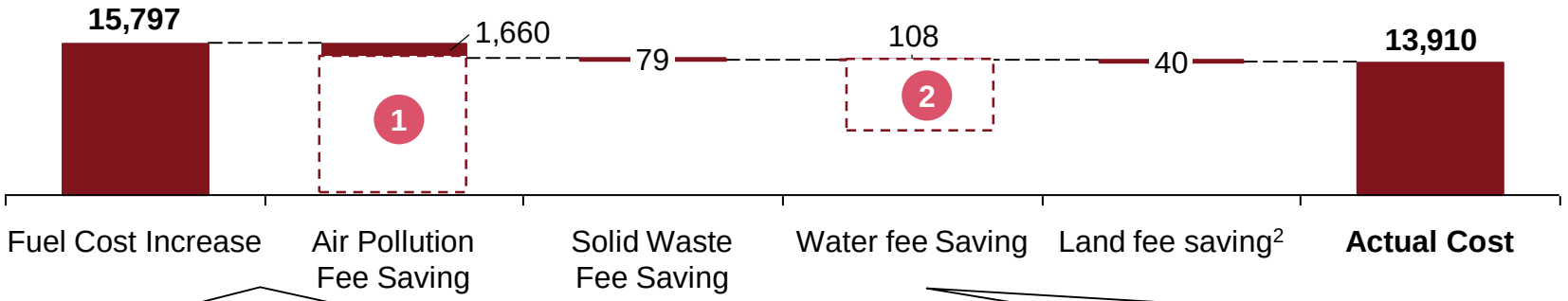
After

- No need for above mentioned space
- Used save space for beer bottle storage

Source: Expert Interview, Photo and data from Yanjing Beer C2G environment impact report, Strategy& analysis

Food Industry: Coal to gas switch can also reduce plant's emission cost and the need to lease land

Annual fuel cost increase vs. Operational cost reduction at current fee and tariff (thousand RMB)



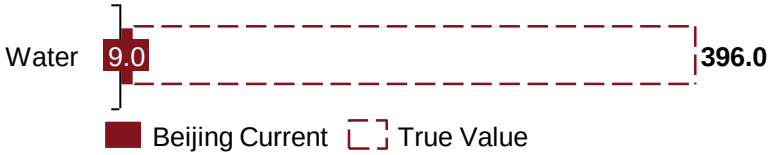
1 **S1:** If air pollution fee increase 9.5 times

2 If water tariff increase 44 times

Air pollution penalty rates (RMB/kg)

If air pollution penalty rates increase **9.5 times** in average, the air pollution penalty fee saving would be **15 million RMB**

Water tariff (RMB/t)

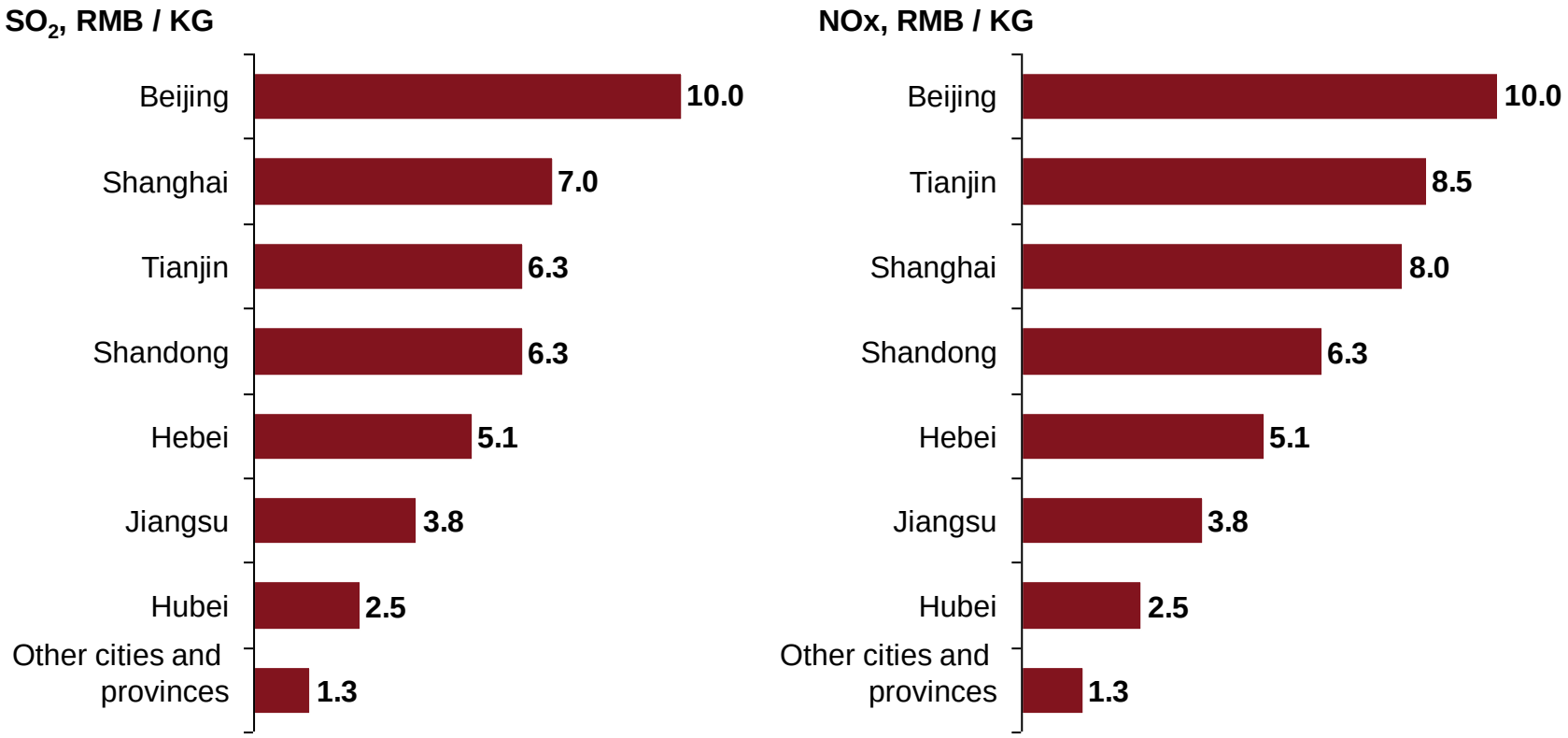


Dean of School of Environment of RUC suggests that "**the true value of water isn't realized via water fees**" – By end of 2015,total water use fees charged was 100 billion RMB (2.27% of true value)

Pollution fees and water tariff need to be raised to close the gap.

1) indicates annual cost after depreciation (30 years); 2) coal: 487RMB/t, gas: 2RMB/m³, land: 200RMB/m² per year, exchange rate: 1USD = 6.217RMB
Source: Expert Interview, Yanjing Beer C2G environment impact report, Strategy& analysis

Emission cost remains low in most provinces in China compared to Beijing and Shanghai



The new environmental tax will replace the emission fee in 2018 and increase the emission cost for *NOx and SO_2*

Source: Literature Review, Xinhua News, 163 News, Strategy& analysis

Gas As Strategic Enabler For China's Transformation

Promoting Gas Usage in High Value Sectors

- *Industrial Heating*
- ***Residential/Commercial***
- *Co-generation - Centralized Heating*
- *Co-generation - Distributed Energy*
- *Power Generation*

Policy Action to Realize Gas Potential

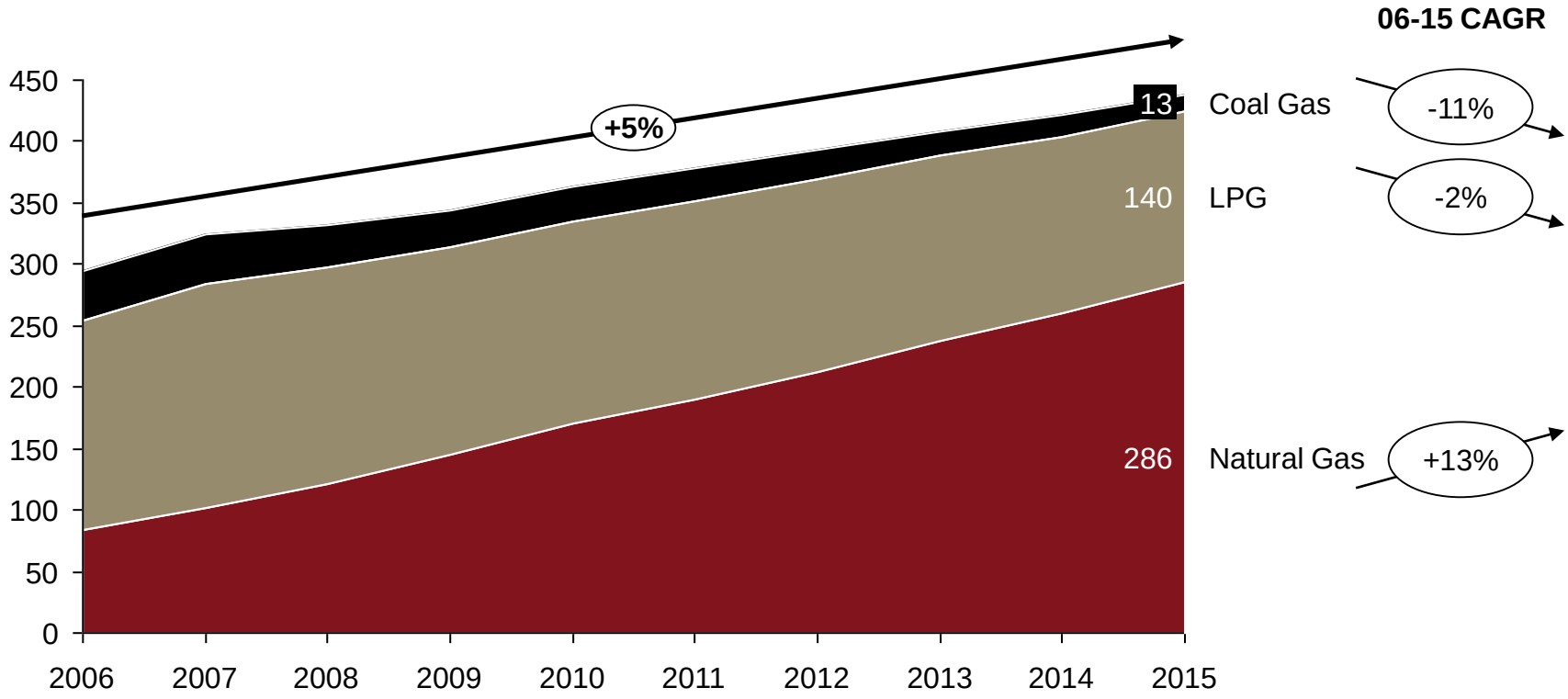
Compared to coal, gas is a cleaner, safer, more convenient and more efficient fuel source for residential users

	Gas	Coal
Cleanness	✓ • Emit less air and solid waste pollutions when generating heat	✗ • High carbon, SO_2, NO_X and coal cinder emissions
Safety	✓ • Gas boiler, stove and heater can be shut down immediately whenever needed	✗ • Coal boiler, stove and heater cannot be shut down quickly as it needs time to cool down
Convenience	✓ • Pipeline gas supply provides convenience to end users	✗ • Coal requires storage space and labor for fuel loading
Efficiency	✓ • Thermal efficiency can be over 85% with 11000 kcal/m^3 average heat value	✗ • Average thermal efficiency is around 70% with 5000 kcal/kg average heat value

Source: Strategy& analysis

And natural gas as a cleaner and safer fuel is gradually replacing coal gas and LPG as the primary residential fuel supply

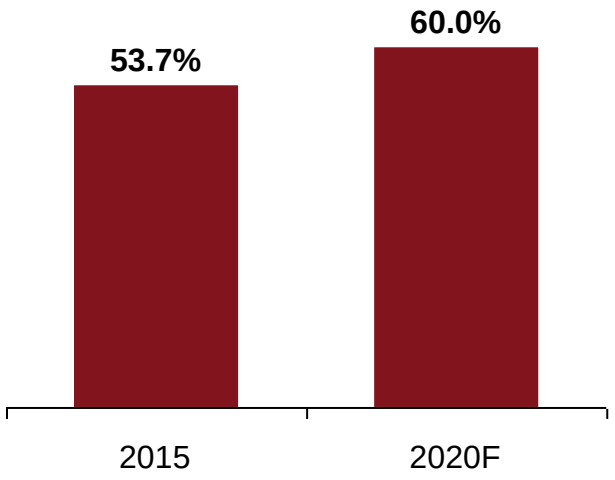
Gas and other alternative fuel supply for residential usage (mainly cooking and showering)
(million persons)



Source: Wind, Strategy& analysis

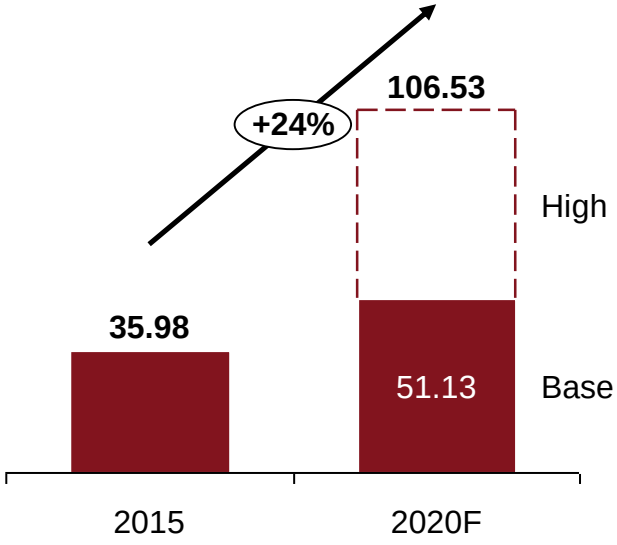
Urbanization is expected to drive residential gas demand to at least 51 billion m³ by 2020

China urbanization rate
(urban habitants % in total population)



- Official urbanization target stated in 《国家新型城镇化规划（2014-2020）》（National Plan for New Urbanization）is **60% of total population** by 2020
- The annual growth rate of Chinese population is assumed to be **0.5%** by World Bank, projecting **1.41 billion** by 2020

China residential gas need
(billion m^3)

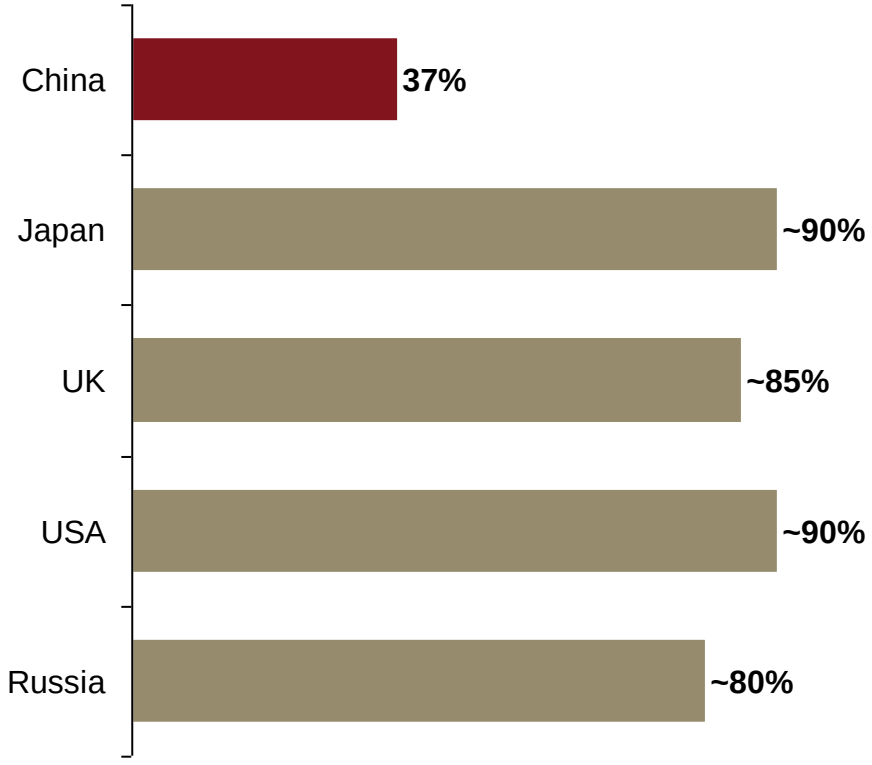


- Assumptions for 2020 Projection:
  - **Base scenario:** residential gas coverage rate grows steadily as the past five years, increasing **11 percentage points to 48%**
  - **Upper case:** all citizens staying in urban areas use gas

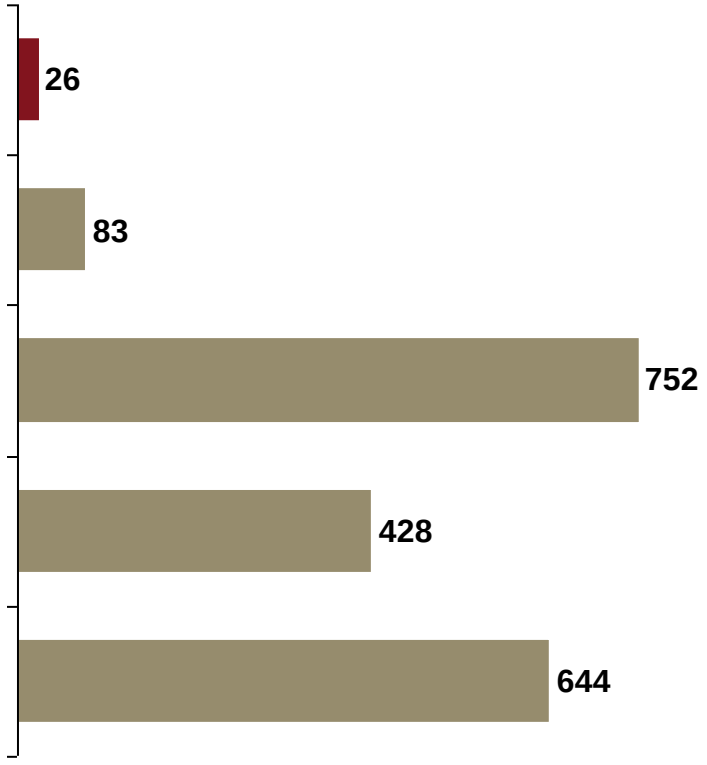
Source: Xinhua News Agency, World Bank, Wind, Strategy& analysis

However, both residential gas penetration and consumption per capita are still lower than developed markets, suggesting growth potential

Urban gas penetration (%, 2015)



Residential gas consumption per capita
(m^3/a, 2015)



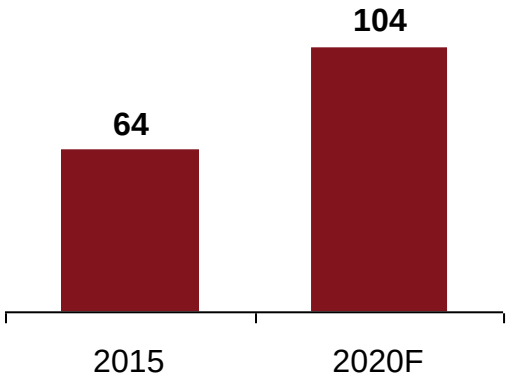
Source: International Petroleum Economics, Strategy& analysis

This is partially due to lack of gas infrastructure

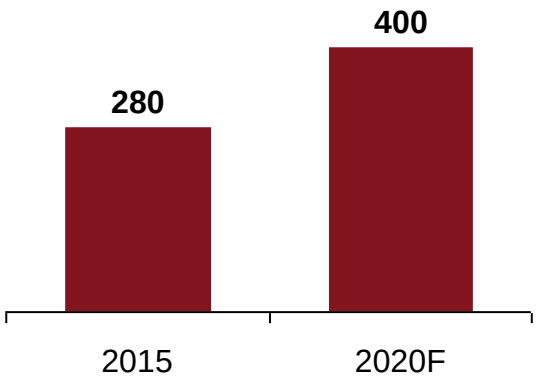
National

National gas pipeline plan

Long-distance pipeline
(thousand km)



Transportation capacity
(billion m^3)



Local

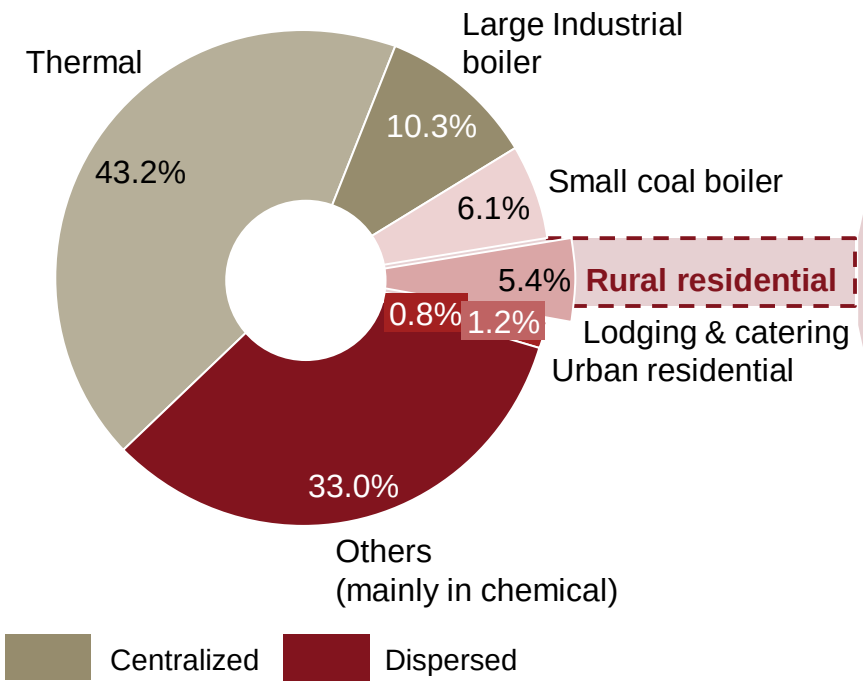
Total length of local gas branch pipeline
(thousand km)

- China and USA comparison
  - USA's local gas branch pipeline is **5.4 times longer** than China
  - China's current total length is equal to USA **in 1950s**

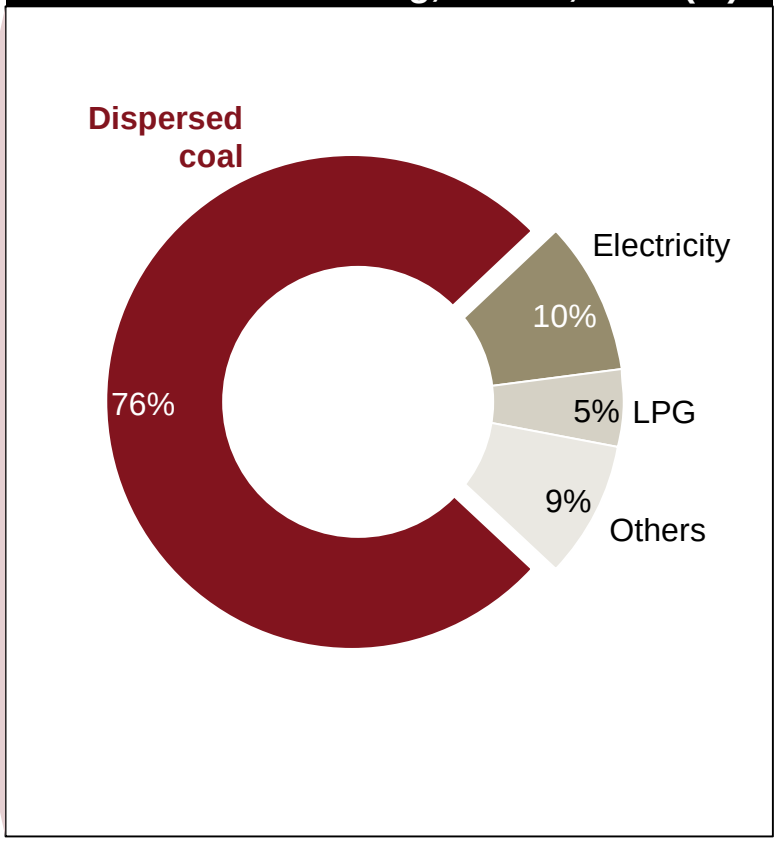
Source: Natural Gas 13th Five Year Plan, National Energy Bureau, Literature Review, Strategy& analysis

Meanwhile, dispersed coal accounts for less than 14% in the total coal consumption but has been used as major energy in rural areas

Coal consumption structure in China, 2014 (%)



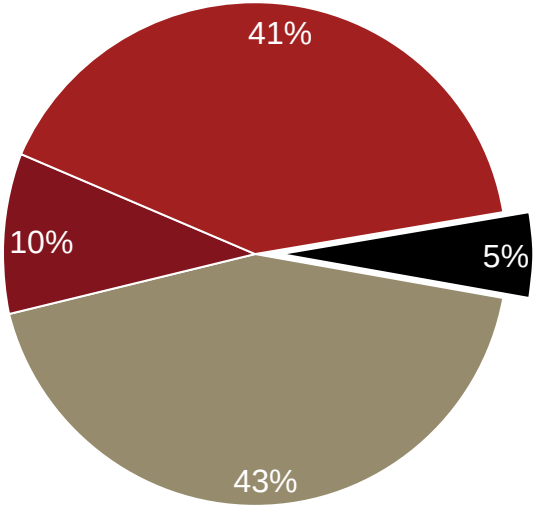
Energy consumption structure of rural households in Baoding, Hebei*, 2014 (%)



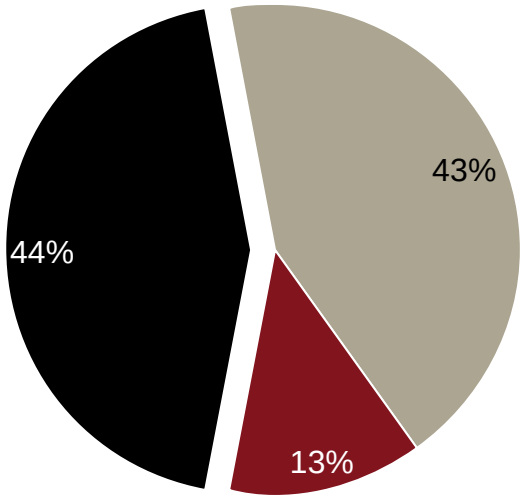
Note:Sample size = 534 households in Baoding, Hebei*
Source: Energy research institute of the State Grid, CRAES, Strategy& analysis

Dispersed coal in rural residential use has contributed to high emission, despite its smaller share in the total coal consumption…

Coal consumption share
（%）



Annual PM2.5 emission comparison
(2014, 10 thousand tons)

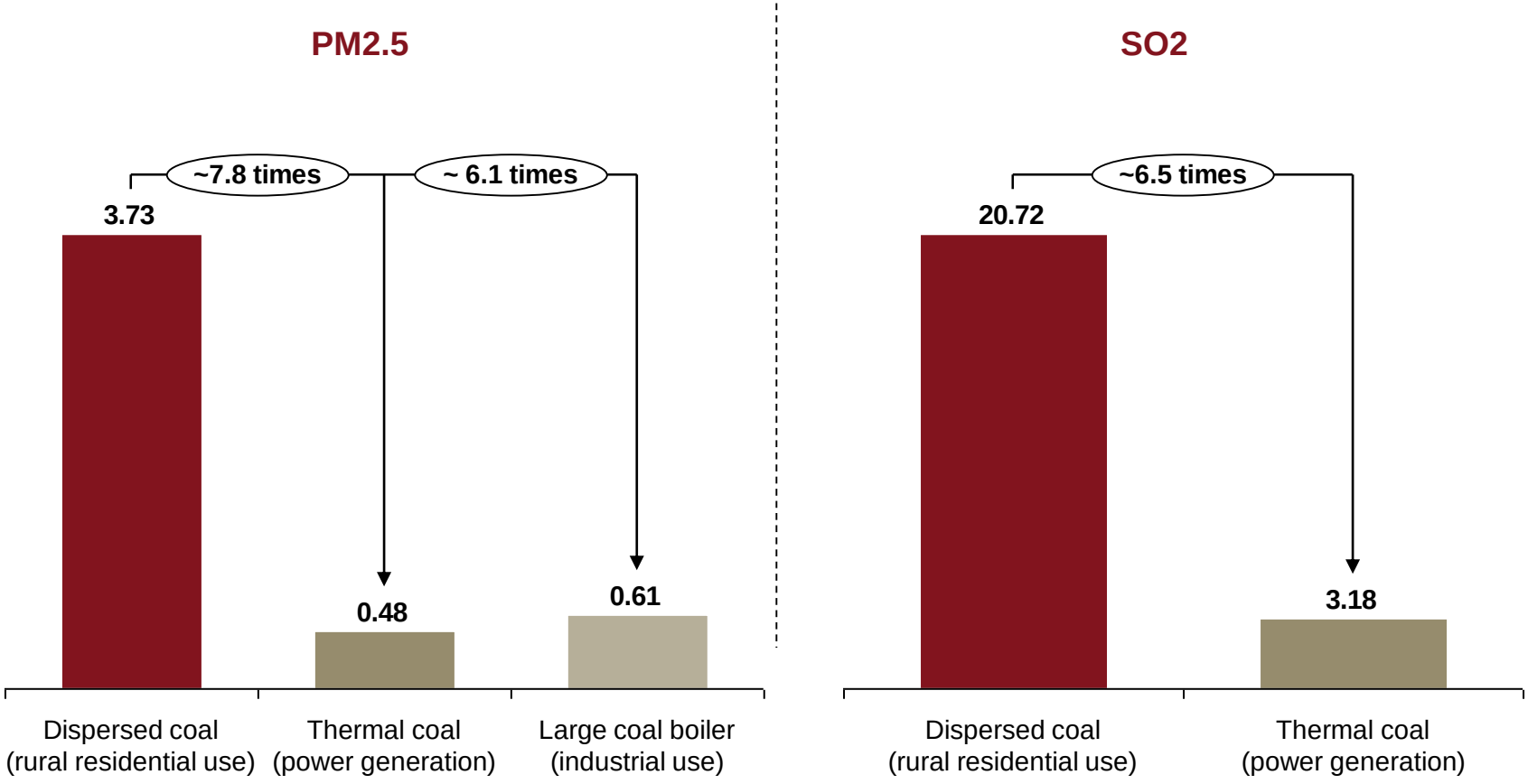


Dispersed coal (rural residential use)
Thermal coal (power generation)
Large coal boiler (industrial use)
Others

Source: Energy research institute of the State Grid, Strategy& analysis

...because the unit emission of dispersed coal is much higher than the processed coal used by power plants or boiler

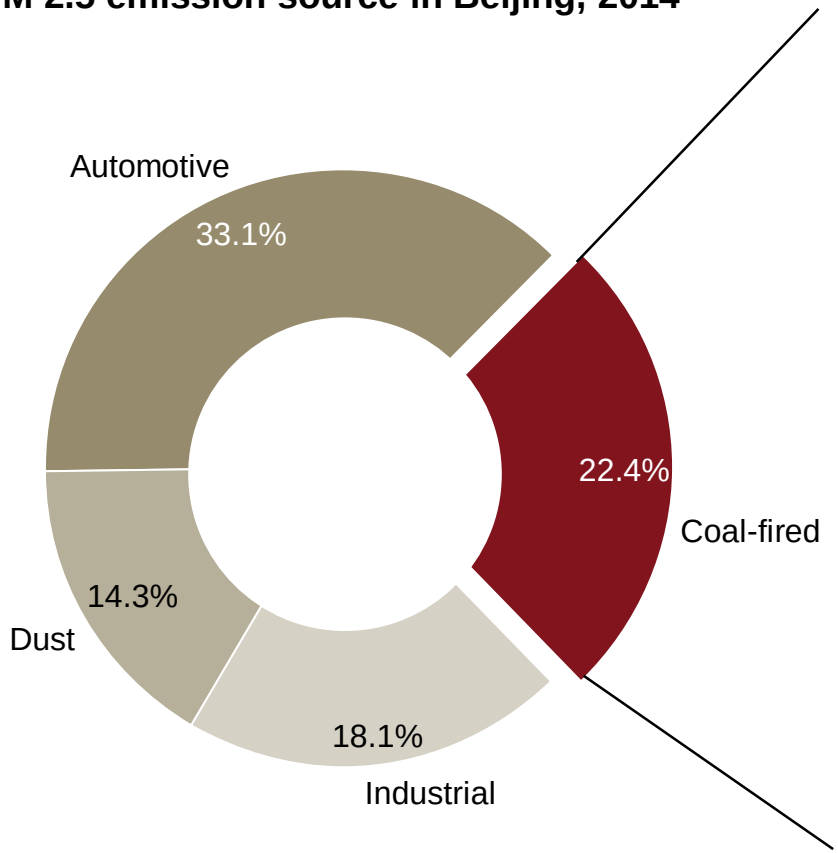
Unit emission of comparison (kg/ton)



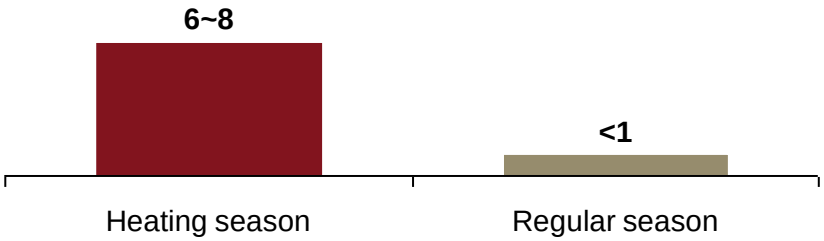
Source: Energy research institute of the State Grid, Strategy& analysis

Moreover, the pollution has expanded to the urban areas, especially during heating season (1/2)

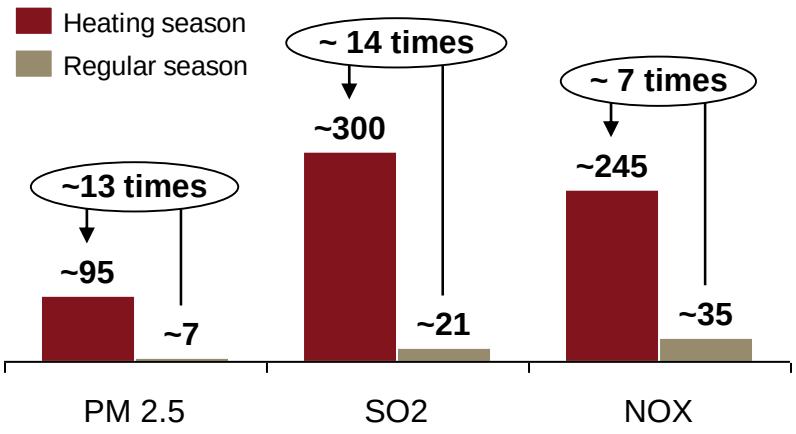
PM 2.5 emission source in Beijing, 2014



Average coal-use comparison in Beijing, 2015
(tons/per day)



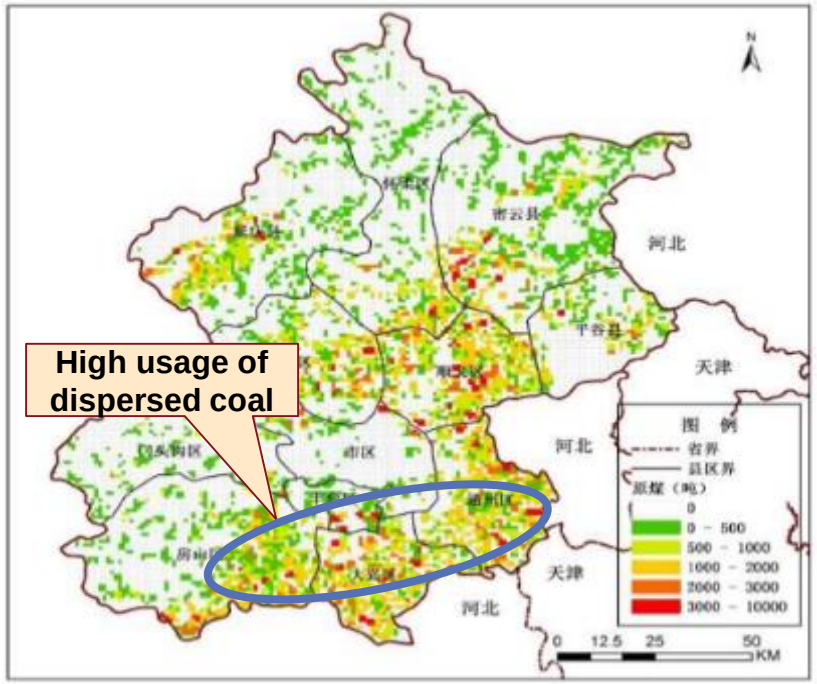
Air pollutant emission comparison in Beijing, 2015
(tons/per day)



Notes: automotive is mainly caused by trucks; industrial mainly refer to coal-boiler use; coal-fired mainly refer to for heating and power
Source: Beijing Environmental Protection Bureau, Strategy& analysis

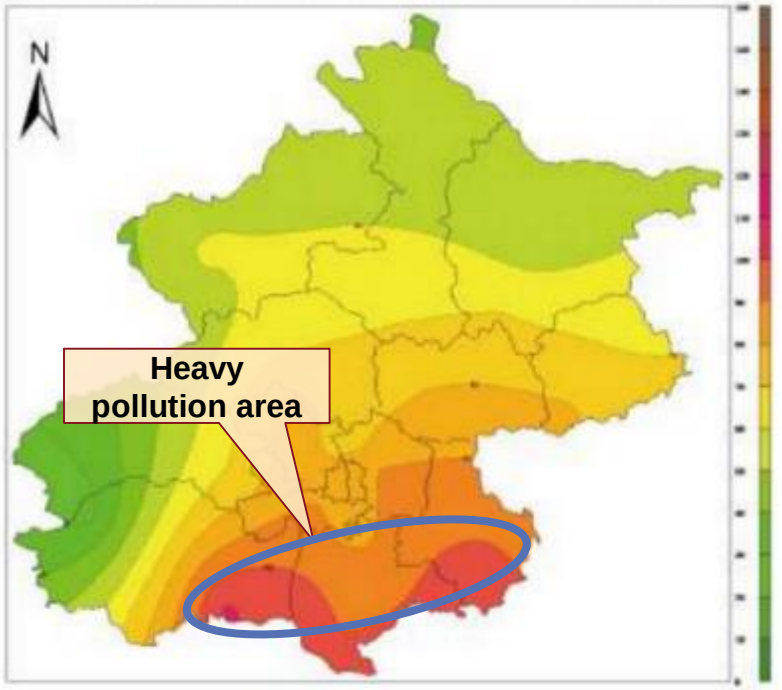
Moreover, the pollution has expanded to the urban areas, especially during heating season (2/2)

The dispersed coal spatial distribution in Beijing



PM 2.5 concentrations in Beijing

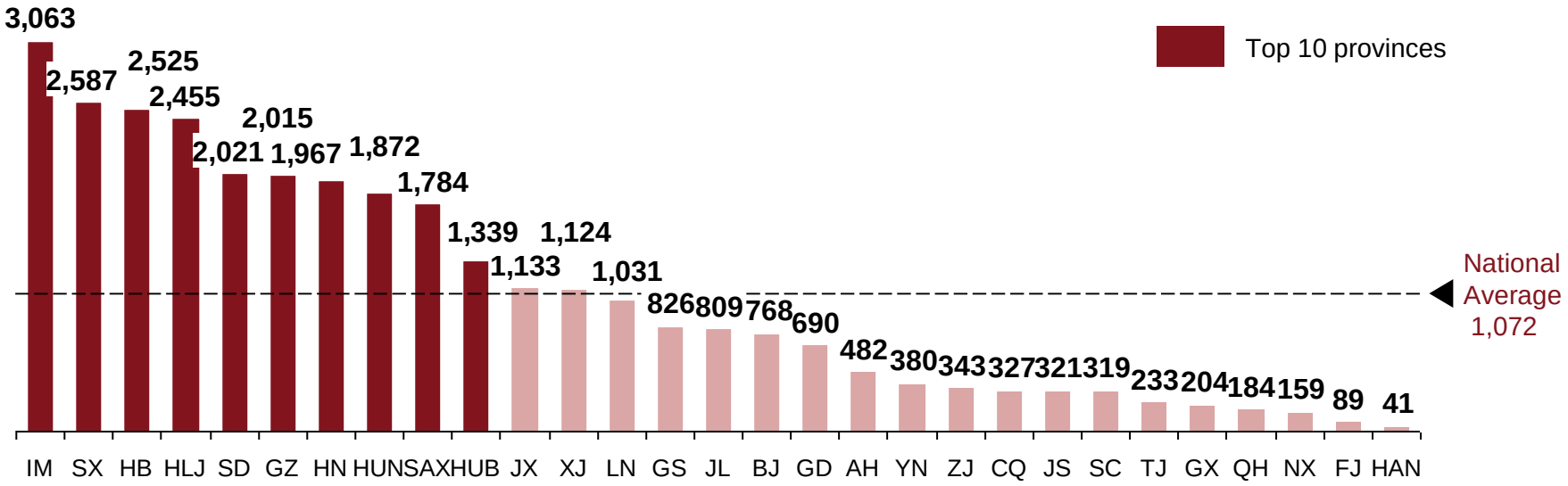
National standard average concentration: 35μg/m3



Source: Beijing Environmental Protection Bureau, CRAES , Strategy& analysis

Given the high impact on air quality from dispersed coal, it needs to be reduced by targeting provinces with high consumption

Dispersed coal consumption in China, 2014, 10,000 tons

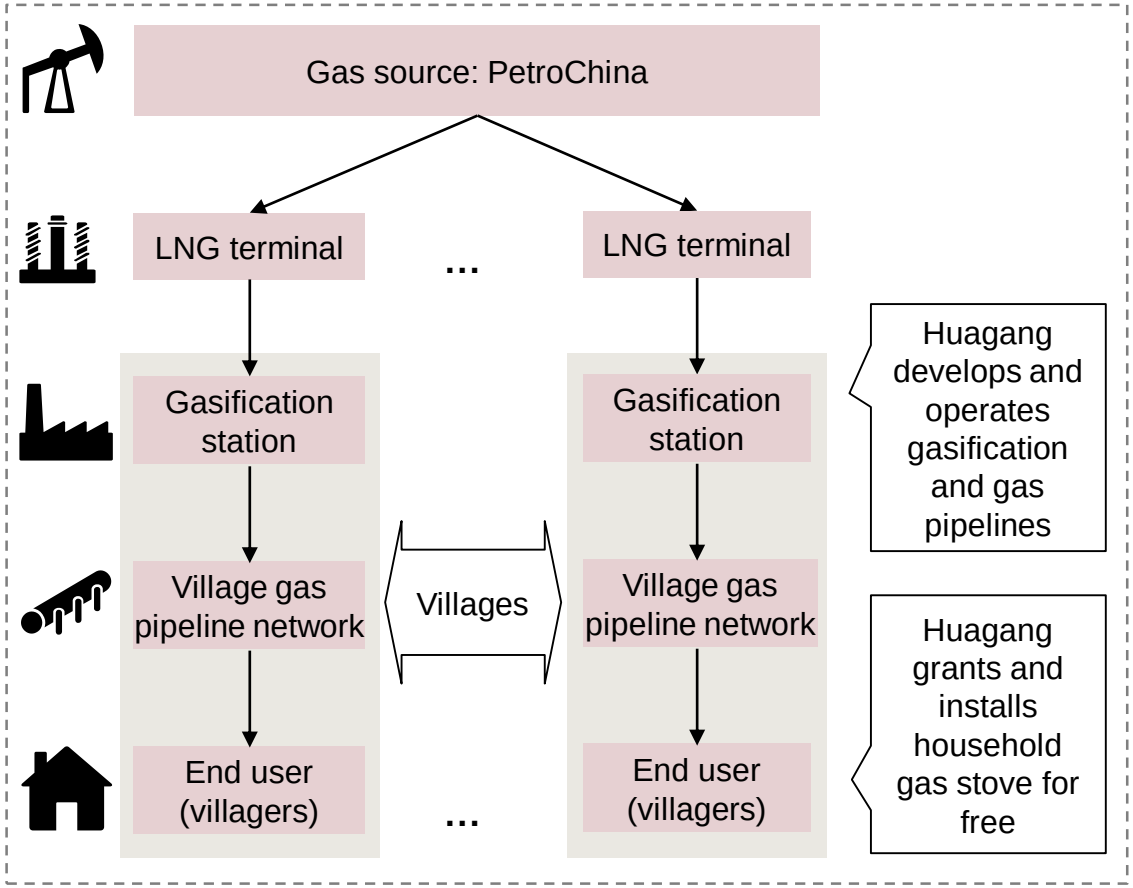


- **Heating demand is the main driver for dispersed coal consumption**
- **Unbalance distribution:** The top10 provinces had consumed 220 million tons dispersed coal in 2014, which contributed ~70% of the total
- **Concentrate in coal-producing province and nearby regions:** the dispersed coal consumption are usually around coal-producing provinces, such as Inner Mongolia, Shanxi and Guizhou

Source: Energy research institute of the State Grid, State Statistics Bureau, Strategy& analysis

Case: There are pioneers to promote residential gas usage to replace dispersed coal in rural area

Huagang: LNG- based supply for rural area



LNG and village gas pipeline address the difficulties of gas pipeline connection between urban and rural areas

Household gas stove installation and maintenance subsidy ensure successful promotion among villagers

Source: Oil Business Daily, Strategy& analysis

Case: Huagang's rural gas promotion helps Renqiu reduce CO_2, SO_2 and NO_X emissions significantly

Renqiu "gasifying villages" air emission reduction (totaling 364 villages)

- **Coal consumption reduction** — *1m tons*
- **CO_2 emission reduction** — *2.6m tons*
- **SO_2 emission reduction** — *8.5k tons*
- **NO_X emission reduction** — *7.4k tons*

Comparison with LPG

	Pipeline gas	LPG
Price	• 0.28RMB/Mcal • ~45% of LPG price	• 0.63RMB/Mcal
Safety	• Safer • Supplier better regulated	• Riskier • Supplier poorly regulated
Convenience	• Very convenient for use	• Less convenient due to fuel loading
Supply	• Less impacted by external incidents	• More impacted by extreme weather, etc.

1) heat value of pipeline gas = 8500kcal/m^3 with 90% thermal efficiency; heat value of LPG = 11000kcal/kg with 92% thermal efficiency
Source: Oil Business Daily, Strategy& analysis

Case: Hebei Government also provided subsidies to support Renqiu's C2G switch in rural areas

Fiscal subsidy of Renqiu C2G switch in rural areas, 2017

Equipment procurement

- **Subsidize 3700 RMB CAPEX** to each household including 1000 RMB for installation charge and 2700 RMB for wall-hung gas boiler
- Provincial government and municipal government will both undertake the subsidy, and the cost savings of Huagang Group will also contribute

Gas pipeline construction

- **Subsidize 4000 RMB / m3 / household** to the gas pipeline construction
- Provincial government will undertake the subsidy of 1000 RMB, while the rest will be covered by municipal government

Gas price

- **Guarantee to remain the residential gas price of 2.4 RMB / m3** for at least 3 years with no price rising
- **Subsidize 0.6 RMB / m3** to the gas exceeding 200 m3, and the subsidized volume should be no more than 1200 m3 / household per year
- **Provide tiered bonus gas** based on time of payment, ranging from 100 m3 to 200 m3

Source: Literature Review, Expert Interview, Strategy& analysis

Gas As Strategic Enabler For China's Transformation

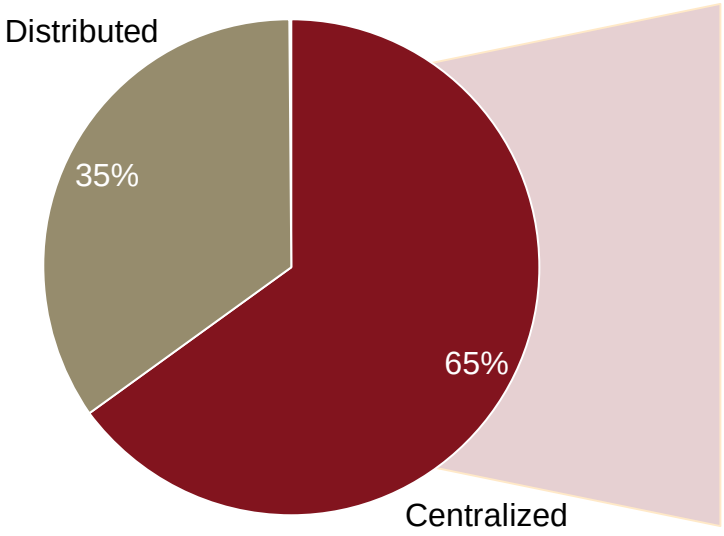
Promoting Gas Usage in High Value Sectors

- *Industrial Heating*
- *Residential/Commercial*
- ***Co-generation - Centralized Heating***
- *Co-generation - Distributed Energy*
- *Power Generation*

Policy Action to Realize Gas Potential

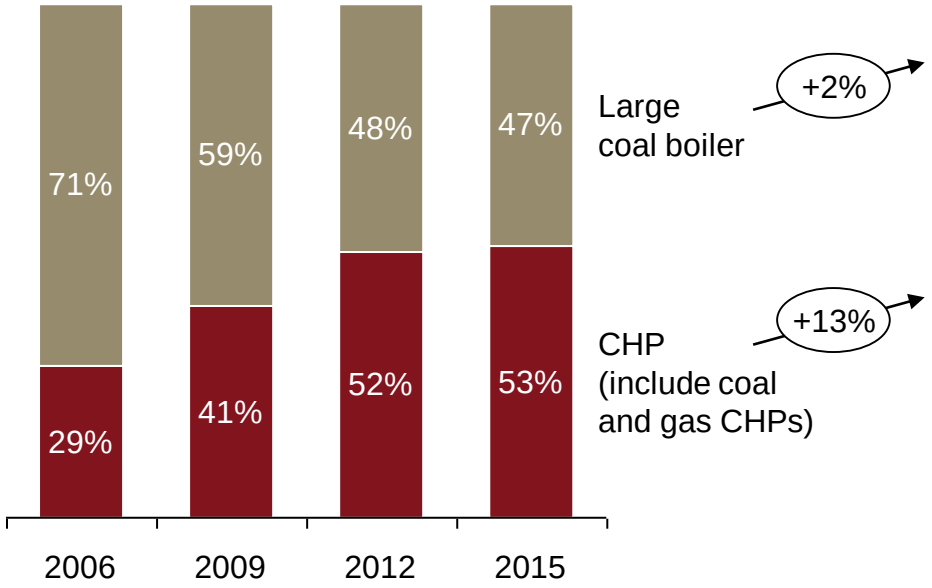
Centralized heating accounts for ~65% of total city heating demand in 2015, supported by fast growth of CHP

City heating demand breakdown (%, 2015)



- In 2015, coverage of city centralized heating is estimated to be ~65%, indicating ~35% of heat is provided by scattered boilers, out of which the majority use coal
- **City heating centralization is the trend**

City centralized heating capacity (MW, 2015)

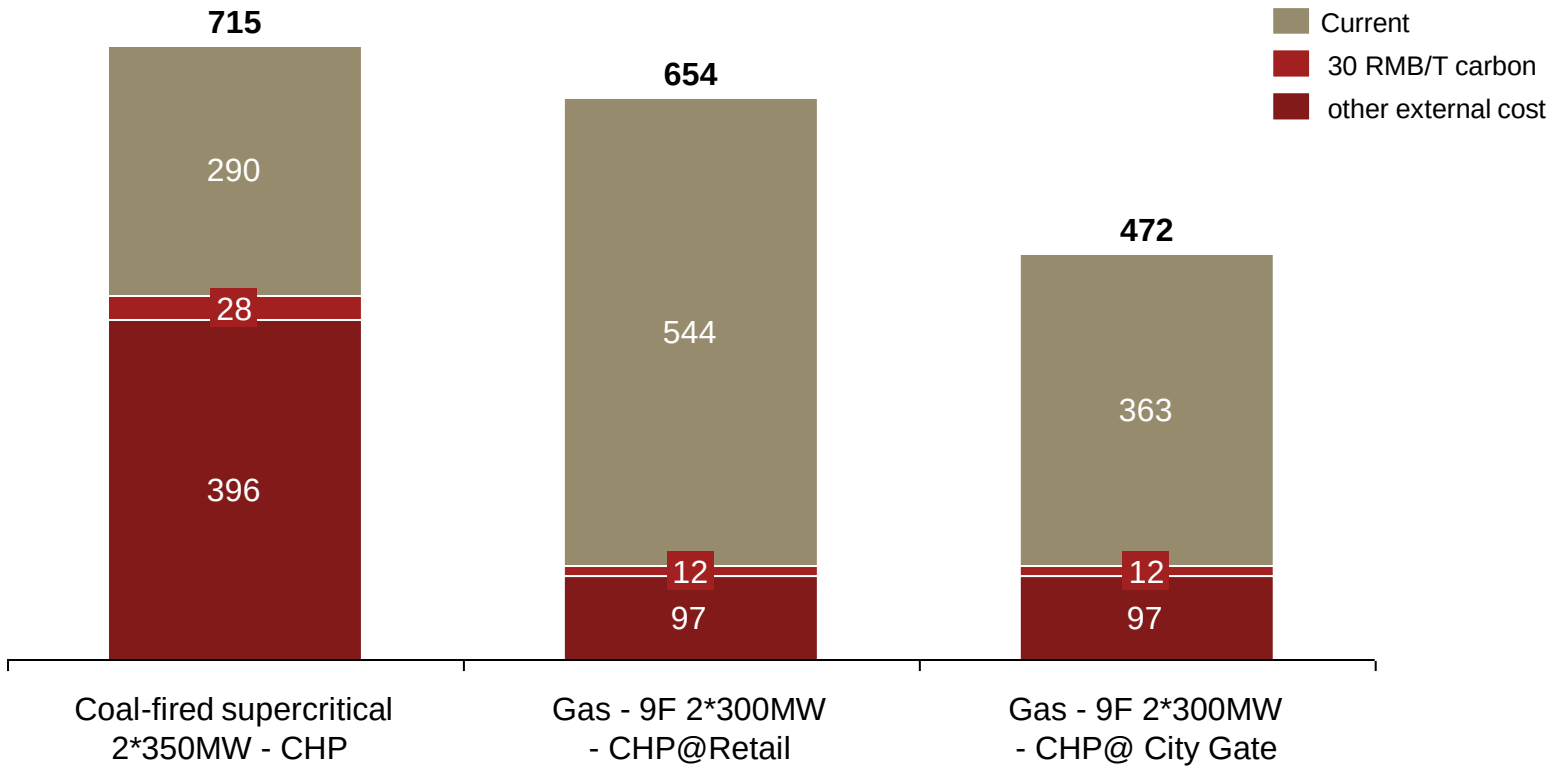


- According to 《电力行业十三五规划》（The 13th Five-Year Plan for the Power Generation and Utility Industry）, CHP is to be the prior type of centralized heating for the 13th 5-year period, suggesting that **gas CHP has potential to replace current city heating coal boilers**

Source: Wind, Literature Review, Strategy& analysis

At current gas price, large scale gas CHP is competitive vs coal-fired CHP if externalities are considered

LCOE, RMB/MWh



Note: Coal: 529 RMB/ton, Retail Gas: 3RMB/m3, City gate gas 1.8 RMB/m3; operate at same capacity factor (based load)
Source: Literature Review, Strategy& analysis

Case: Shanxi Jiajie is the 1st large scale gas CHP project in Central China

Shanxi Jiajie Heat and Power Plant

Case profile

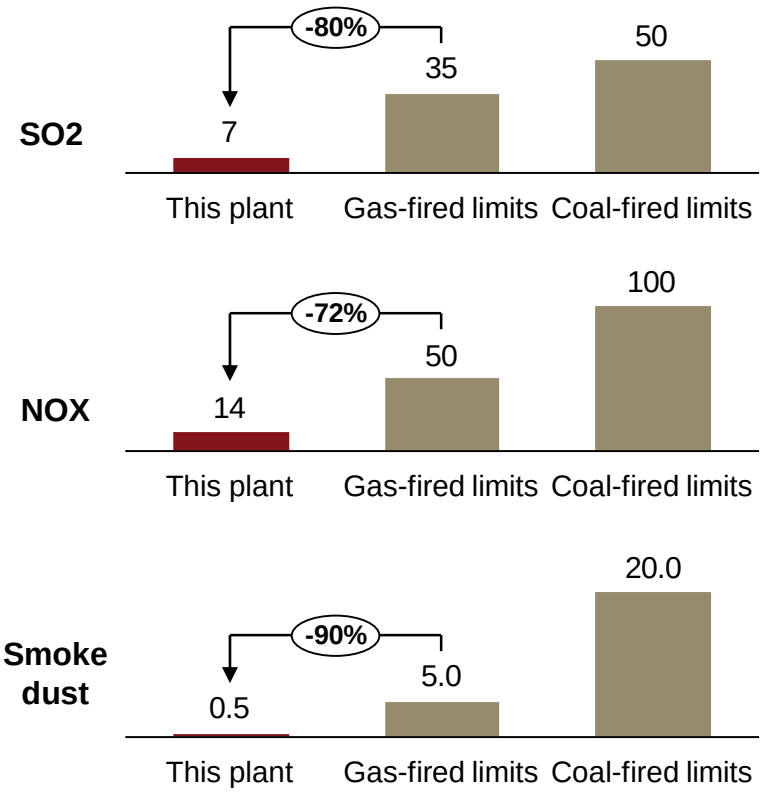
- **Located:** Taiyuan south urban area, Shanxi
- **Scale:** 860 MW in total, 2 * 298 MW gas turbine generator units + 1* 264 MW steam turbine generators units
- **Total investment:** 2.76 billion RMB
- **Annual energy efficiency:** 61%
- **Heating area:** Over 12 million m2
- **Gas supply:** Pipeline gas or coal-bed gas
- **Supplier:** Shanxi Provincial Guoxin Energy Development Group Co., Ltd.
- **Highlight:** Shanxi Jiajie heat and power plant is not only the ***1st*** *large* scale CHP project in Shanxi, but also the **most efficient** gas-steam combined cycle CHP project in China

Source: Expert interview, Literature review, Strategy& analysis

Case: The plant has a much stricter emission standard than government requirements and significantly reduce air emission

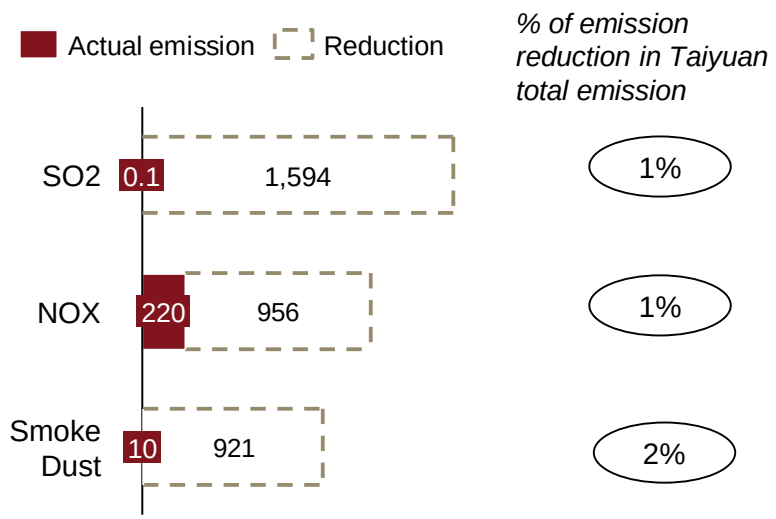
Strict emission

Measured data by local government (unit: mg/m3)



Pollutants reduction

Contribution of annual emission reduction (t/a)



Coal to Gas

- More than ***62*** coal-fired boilers in urban area, and over ***3800*** small coal-fired boilers in suburbs be replaced

Source: Expert interview, EIA report, Literature review, Strategy& analysis

Gas As Strategic Enabler For China's Transformation

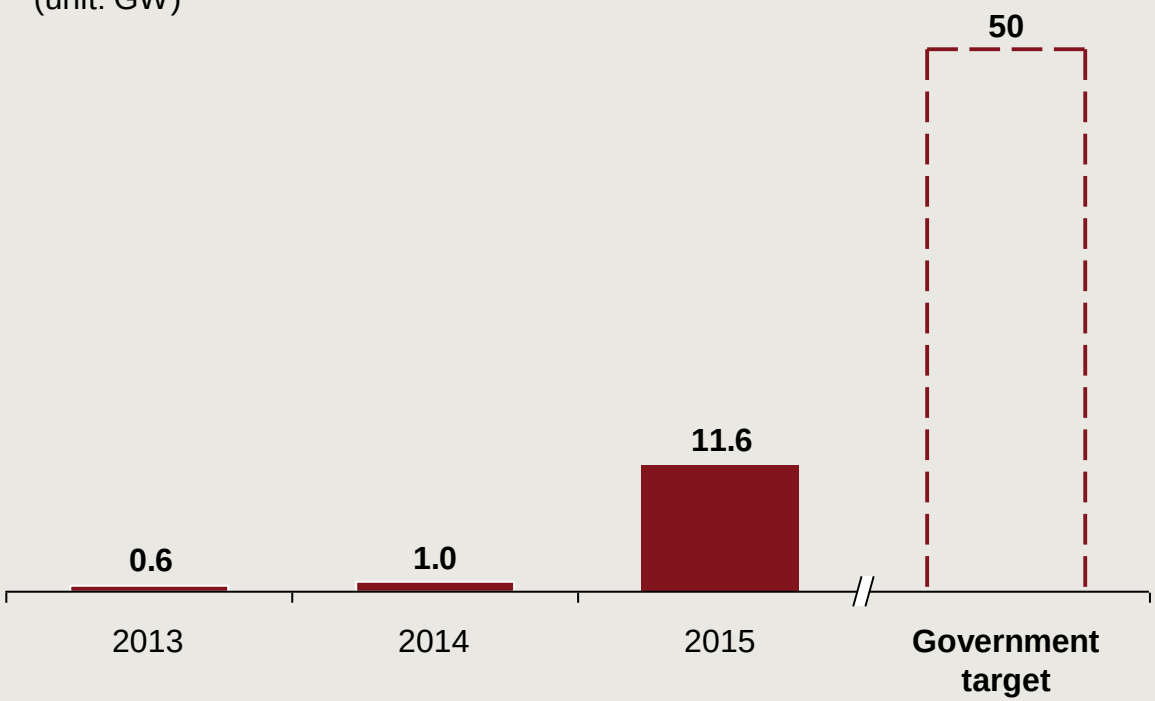
Promoting Gas Usage in High Value Sectors

- *Industrial Heating*
- *Residential/Commercial*
- *Co-generation - Centralized Heating*
- ***Co-generation - Distributed Energy***
- *Power Generation*

Policy Action to Realize Gas Potential

Distributed gas energy system is expected to grow rapidly by 2020

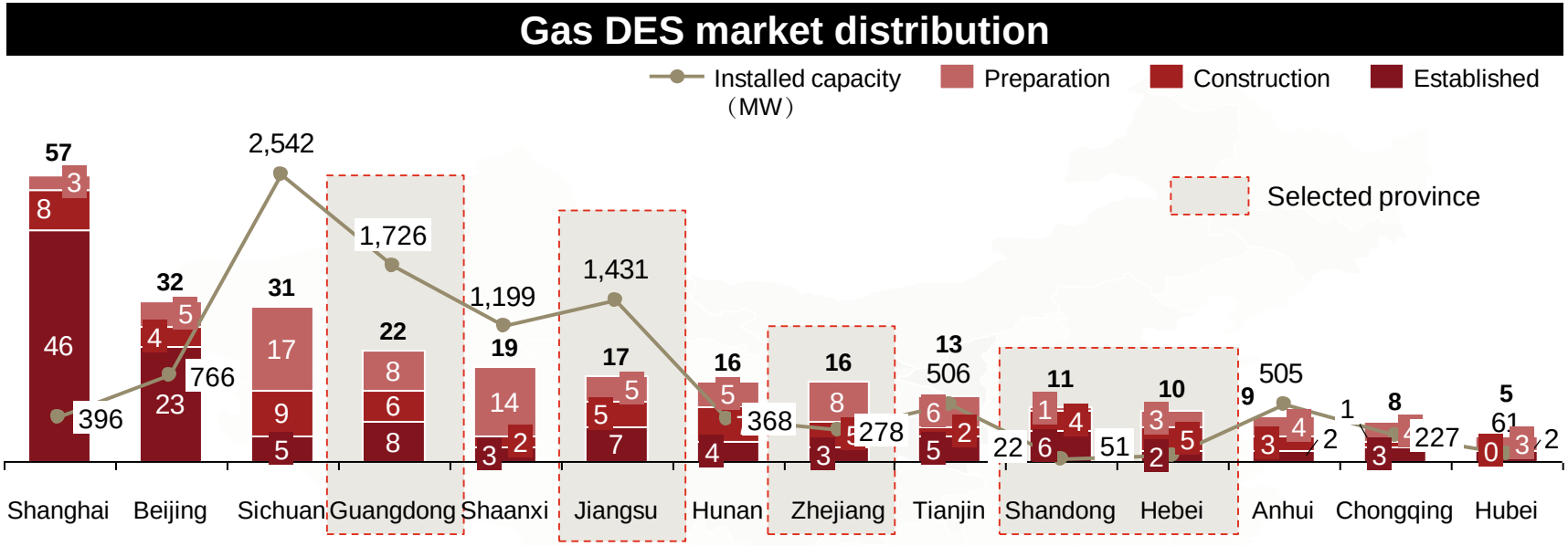
Installed capacity of Gas Distributed Energy System (DES)
(unit: GW)



- By 2015, there are total **288** Gas DES projects in China, far behind the **1000** Gas DES projects target set by *"The guideline of developing Gas distributed energy "* in 2011
- Boosted by C2G and other supporting policies, Gas DES will likely grow faster during the next five years

Note: 2015 data including existing, under construction and planning
Source: Gas DES market report 2016, Strategy& analysis

Over 50% of Gas DES projects are located in Yangtze river delta and North China



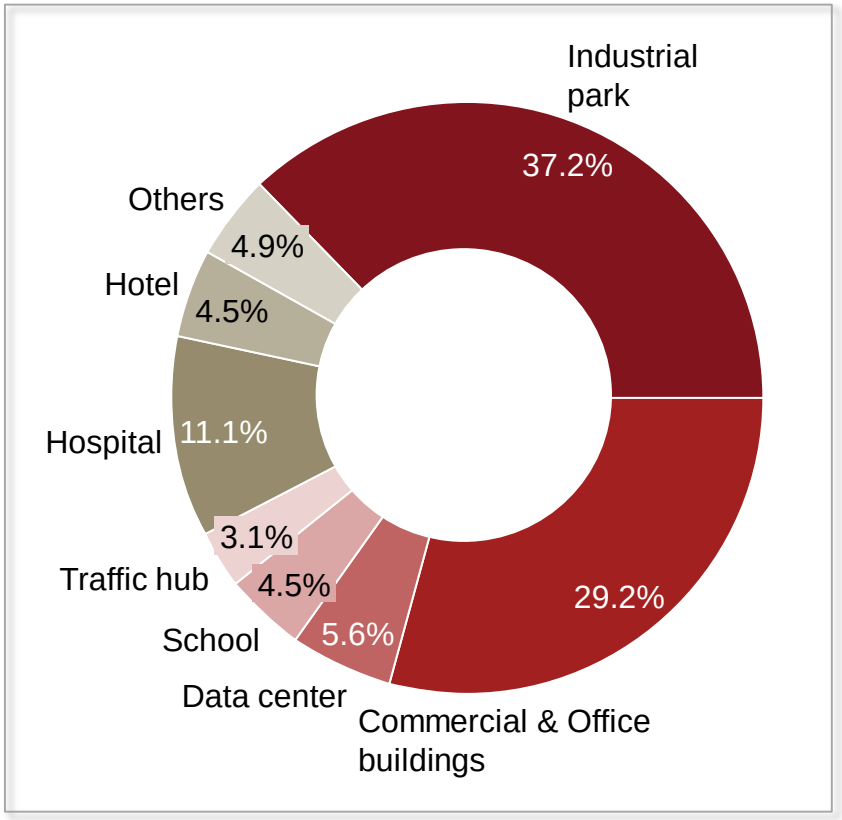
	Yangtze River Delta	North China	Sichuan & Chongqing	Pearl River delta	Other areas
• **Project #**	99	70	39	22	58
• **Share**	**34.38%**	**24.31%**	**13.54%**	**7.64%**	**20.14%**
• **Installed capacity**	2609 MW	1346 MW	2768 MW	1725 MW	2673 MW
• **Share**	**23.46%**	**12.10%**	**24.89%**	**15.51%**	**24.03%**

Source: Gas DES market report 2016, Strategy& analysis

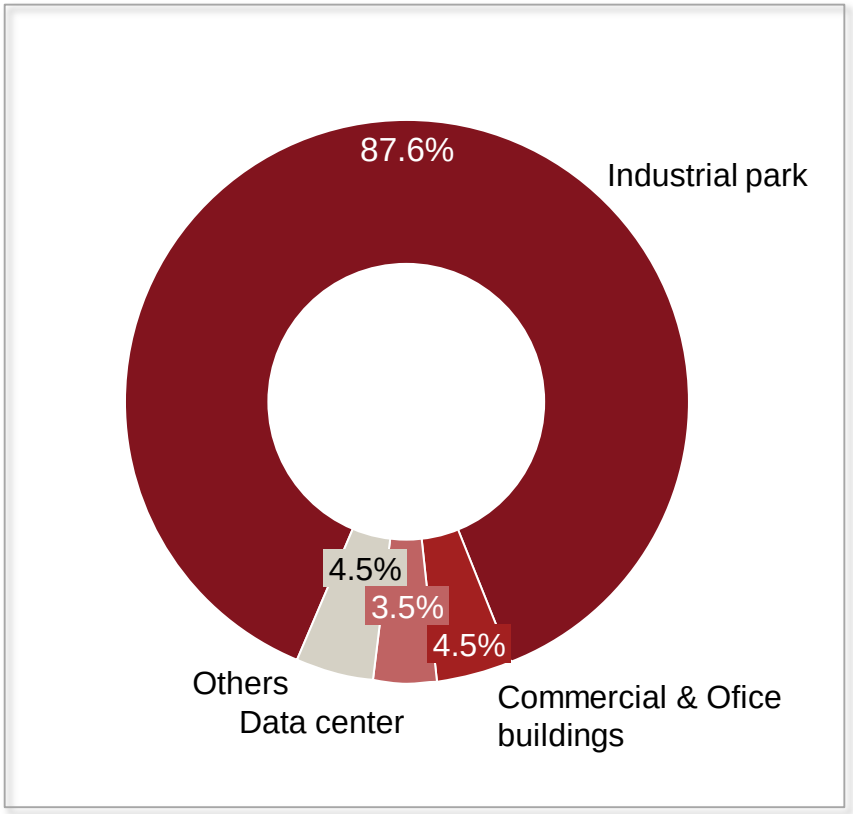
Industrial parks, commercial buildings, along with other stable energy demand are main Gas DES projects type in China

Gas DES market distribution (Including existing, under construction and planning)

By projects, Total 288

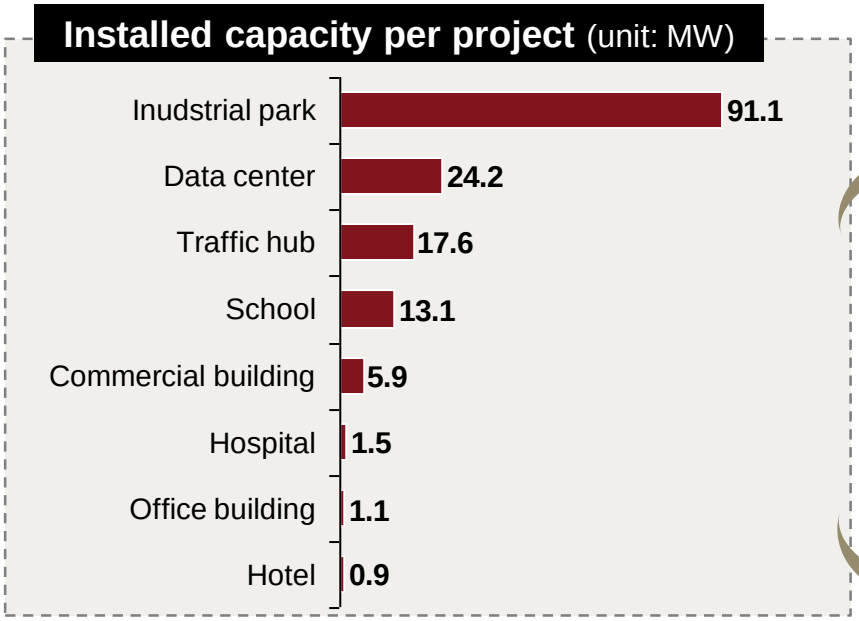


By installed capacity, total 11 GW

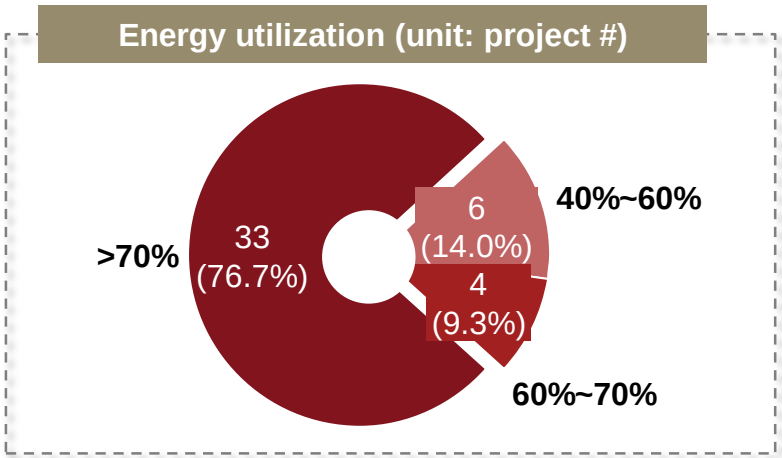


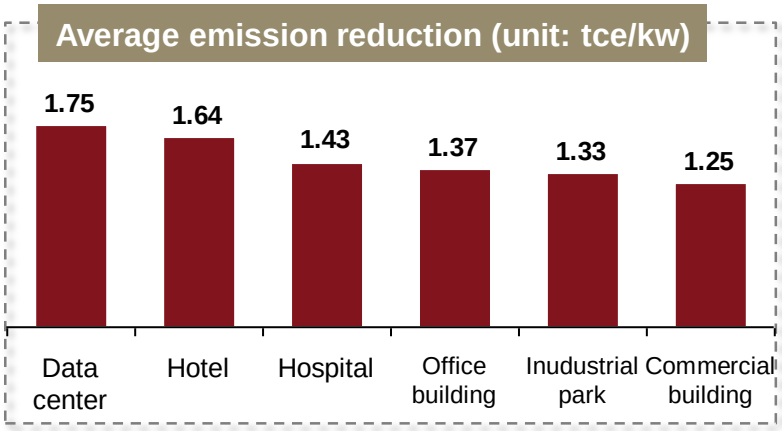
Source: Gas DES market report 2016, Strategy& analysis

Most projects operate at +70% efficiency and help to reduce emissions



Energy saving and emission reduction analysis
(based on 46 selected case)



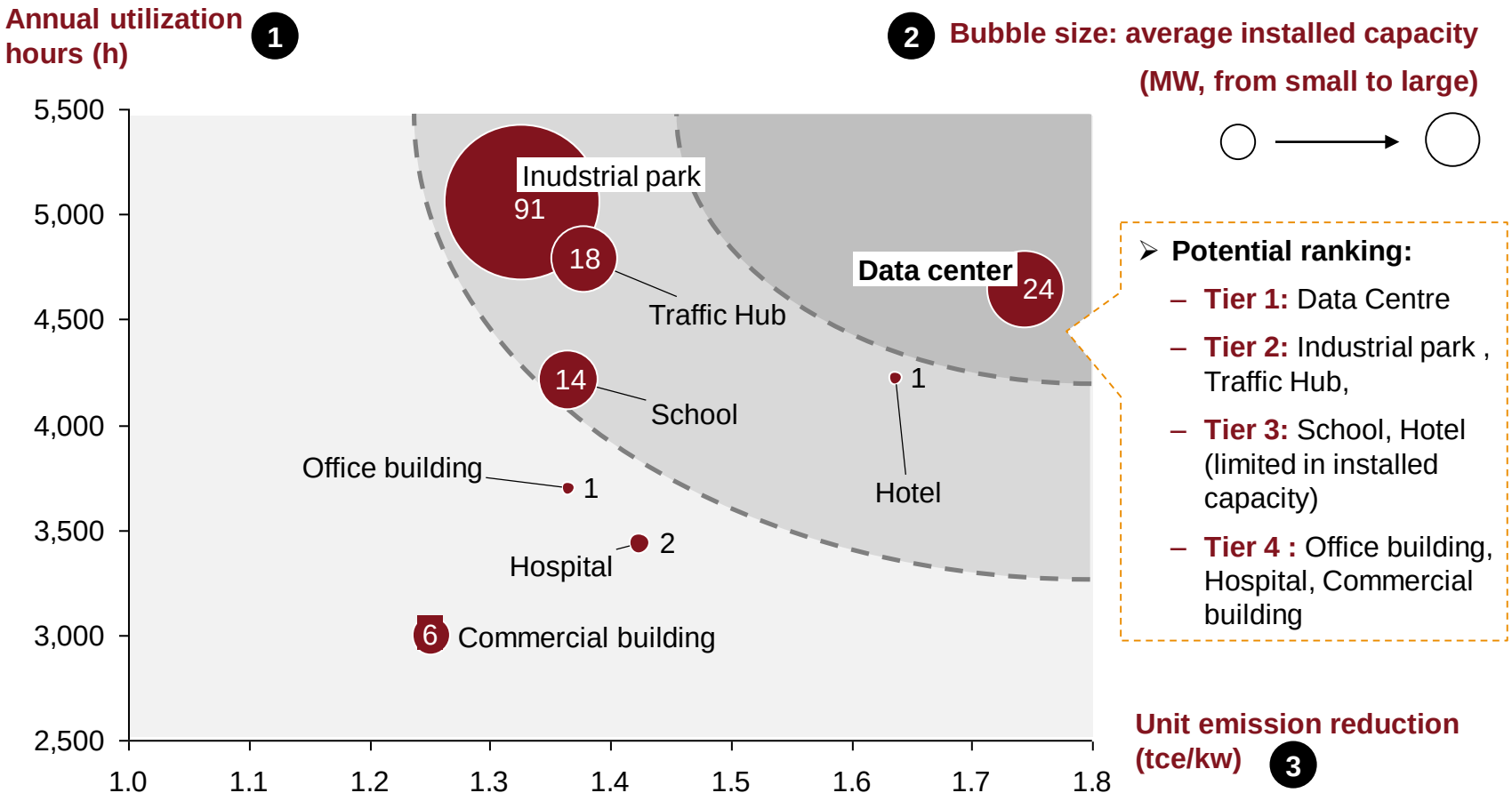


Financial efficiency (based on 46 selected case)

	Total investment (RMB /kw)	Incremental investment (RMB /kw)
• **Gas engine**	1900 ~2000	7000~8000
• **GTCC**	9000 ~10000	6000~7500
• **micro turbine**	20000~22000	16000~19000

Source: Gas DES market report 2016, Strategy& analysis

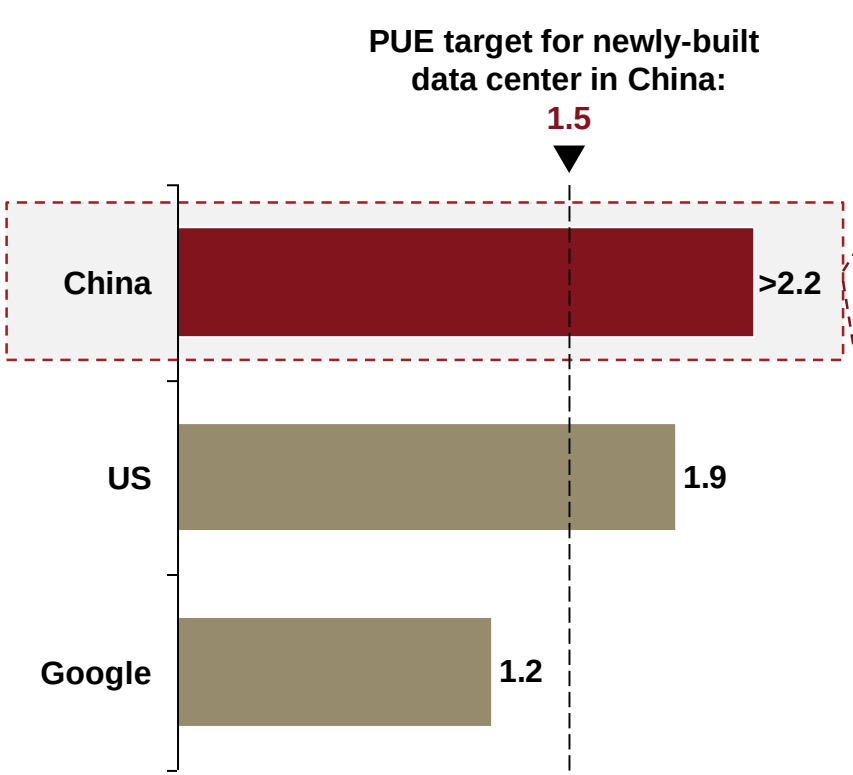
Some sectors such as data center, industrial park, traffic hub are good fit for Gas DES in China



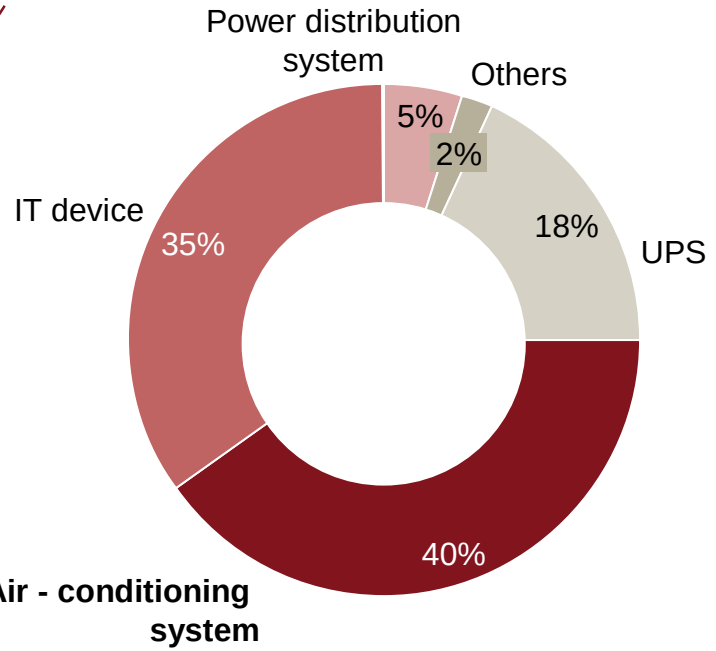
Source: Gas DES market report 2016, Strategy& analysis

However, most data centers in China are not energy efficient, compared to US and best practice

PUE comparison between China and USA



Power consumption break-down

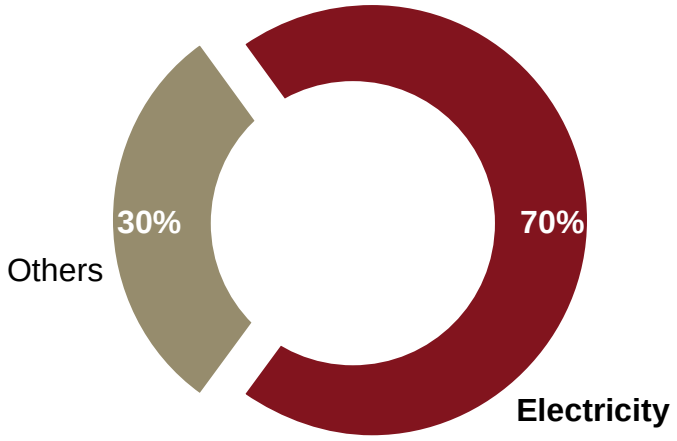


- 75% of the electricity are consumed by air - conditioner and IT device

Notes: Power Usage effectiveness = Total power consumption of data center / The power consumption of its IT device*
Source: Ministry of Industry and Information Technology of China, The Green Grid, Strategy& analysis

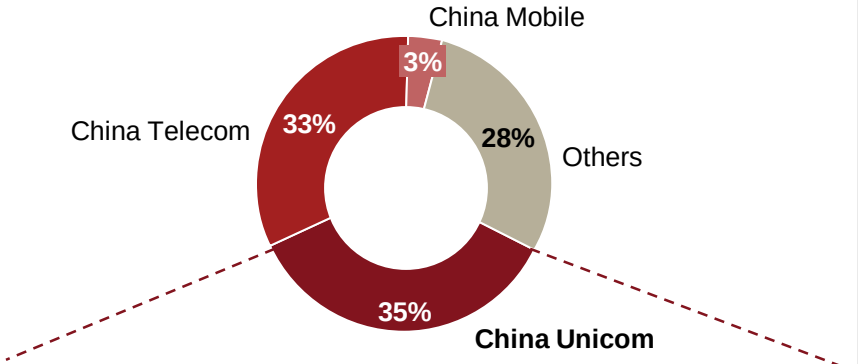
Electricity accounts for 70% of data centre O&M cost, hence, energy efficiency is critical

O&M cost breakout of data center in China
(national average)

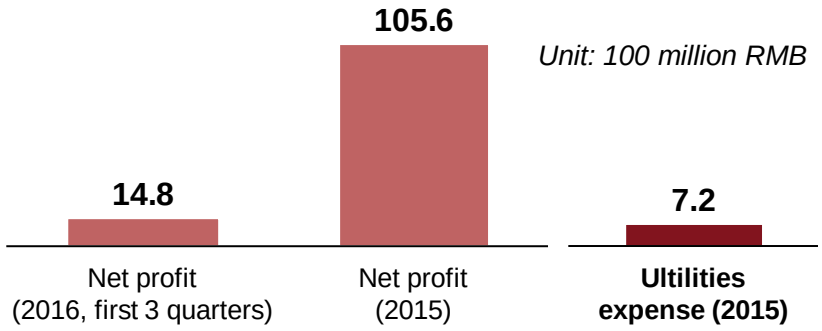


- According to the survey of the Ministry of Industry and Information Technology in 2013
  - The average electricity price of 255 data centers in China was **0.87 RMB/ kwh**.
  - For large and hyper scale, the average price were **0.66/kwh and 0.78/kwh,** the latter could be as low as **0.3 RMB/kwh**

Case: China Unicom has the most data centers by 2015



Case: China Unicom spent 720 million RMB on utilities (electricity & water & heating)



Source: Annual report of China Unicom, GDCT, Literature review, Strategy& analysis

Adopting Gas DES will be able to improve energy efficiency, reduce emission and increase reliability

Energy consumption features of Data Center

High energy density

- Large-size data center is equipped with ~2000 cabinets or above, its energy density could be 30 times higher than that of regular commercial building.

Huge demand of cooling

- 95% of the electric energy are converted as heat energy, and create large demand on cooling, to maintain the performance.

High reliability & safety requirement

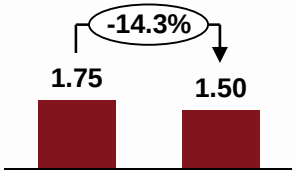
- Since the data is running uninterrupted for 24 hours / 7 days, it has an extremely high requirement on the security and reliability

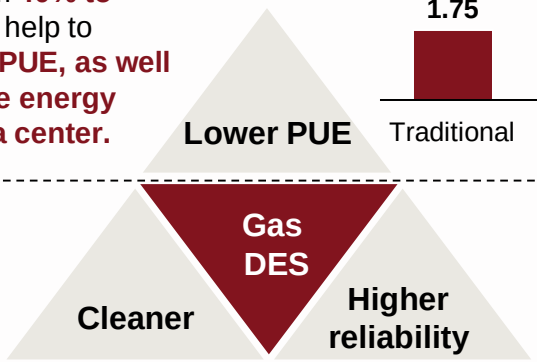
Stable, predictable power load

The benefits of using Gas DES in the Data Center

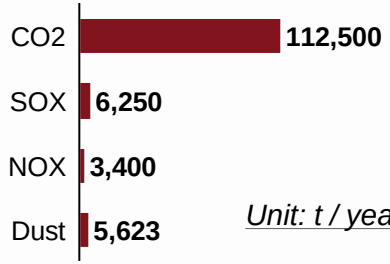
- As the Gas DES system could improve the efficiency of energy using (usually from **40% to 80%**), it can help to **reduce the PUE, as well as lower the energy cost of data center.**

PUE comparision of newly-built data center





Emission reduction of Gas DES (sample: a 40MW data center)



- **Reliability and continuous uptime are also enhanced** by adding an on-site power generation resource next to standby systems

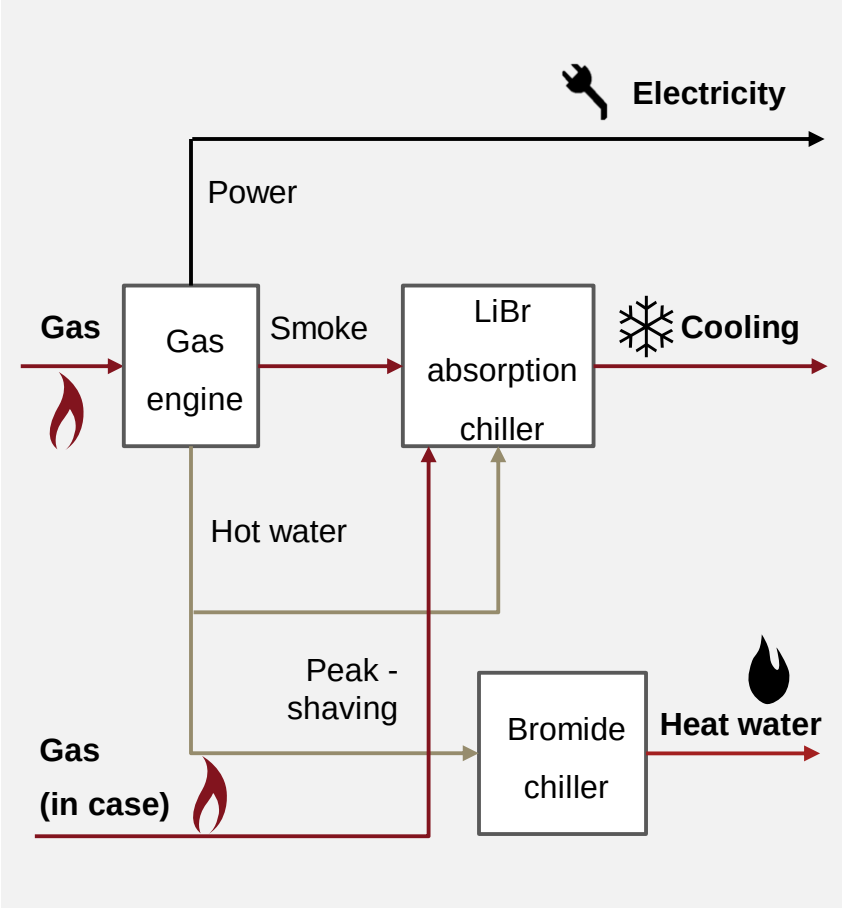
Source: GDCT, Literature review, Strategy& analysis

Case: Tencent data center in Shanghai has adopted gas DES system

Case profile

- **Built and operated by:** ENN Energy Hoilding Limited
- **Serve for:** Tencent
- **Business model:** BOT
- **Online operation:** Aug, 2016
- **Installed Capacity:** 2540*4 KW, power for over 100 thousand server
- **Annual utilization hours:** 5840 h
- **Annual gas consumption:** 12,746,000 m3,
- **Annual energy efficiency:** 75.89%
- **Annual power generation:** 54 million KWH, 89% for self –use
- **Annual cooling energy generation:** 162 million MJ

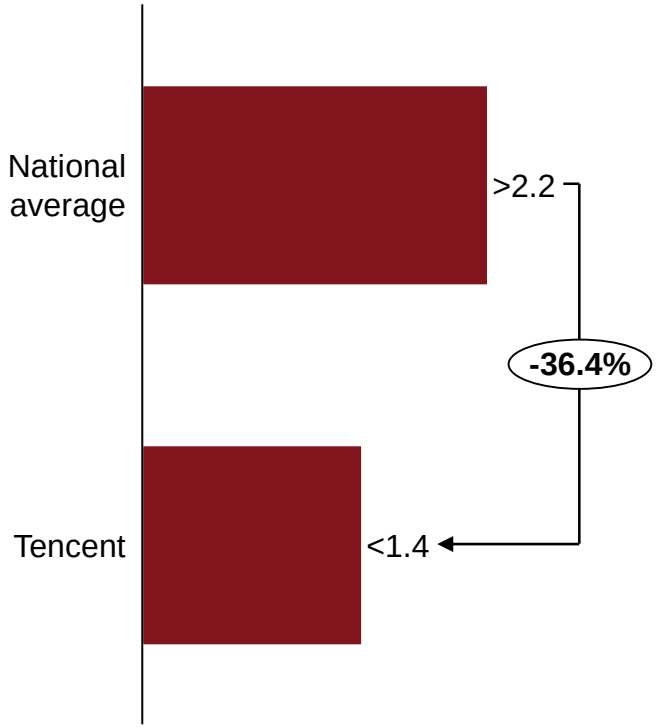
DES system



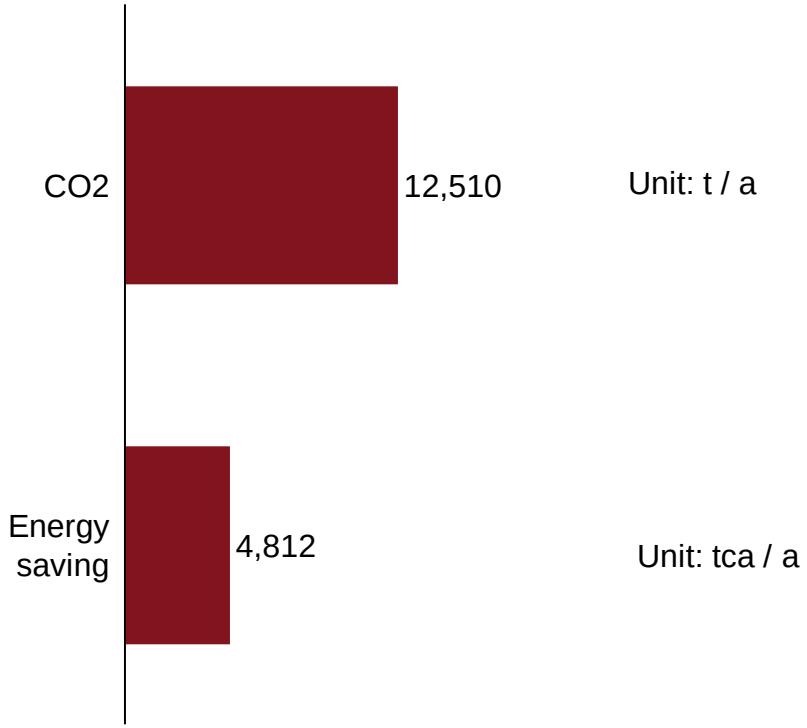
Source: Gas DES market report 2016, Strategy& analysis

Case: The project demonstrated both environmental and energy efficiency benefit

Operation PUE



Annual emssion reduction and enegy saving

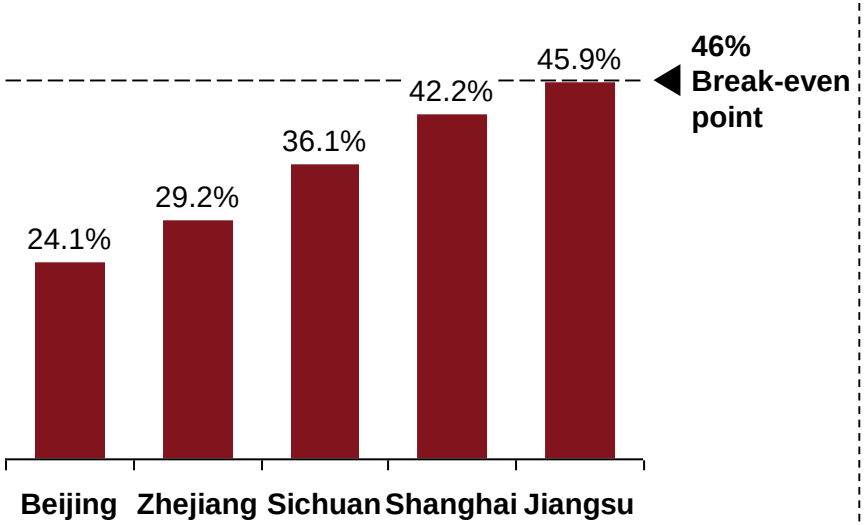


Source: Gas DES market report 2016, Literature review, Strategy& analysis

However, in many cases, most DES projects are operating at loss, as the capacity factor can't reach the designed level

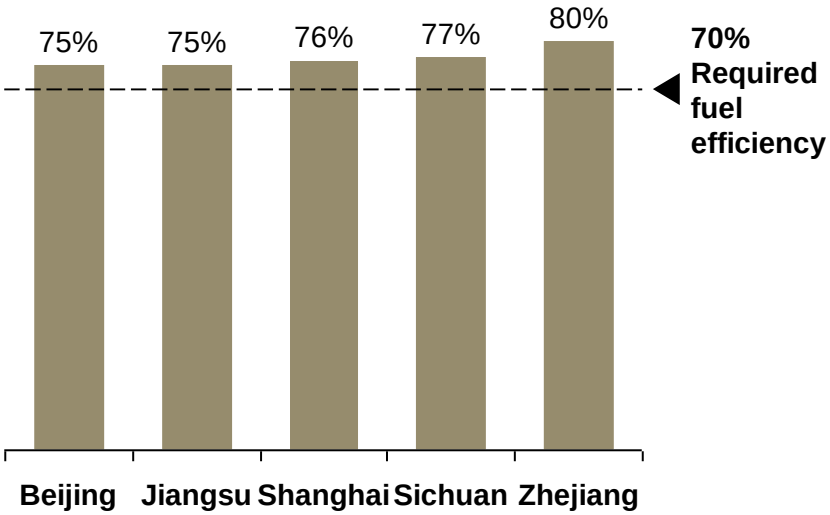
Technical indicators* of key areas

Capacity factor (%, 2016)



- For most DES projects, low utilization is the major reason for loss, as most of them are less than 3000 hours (capacity factor < 34%)

Fuel efficiency (%, 2016)

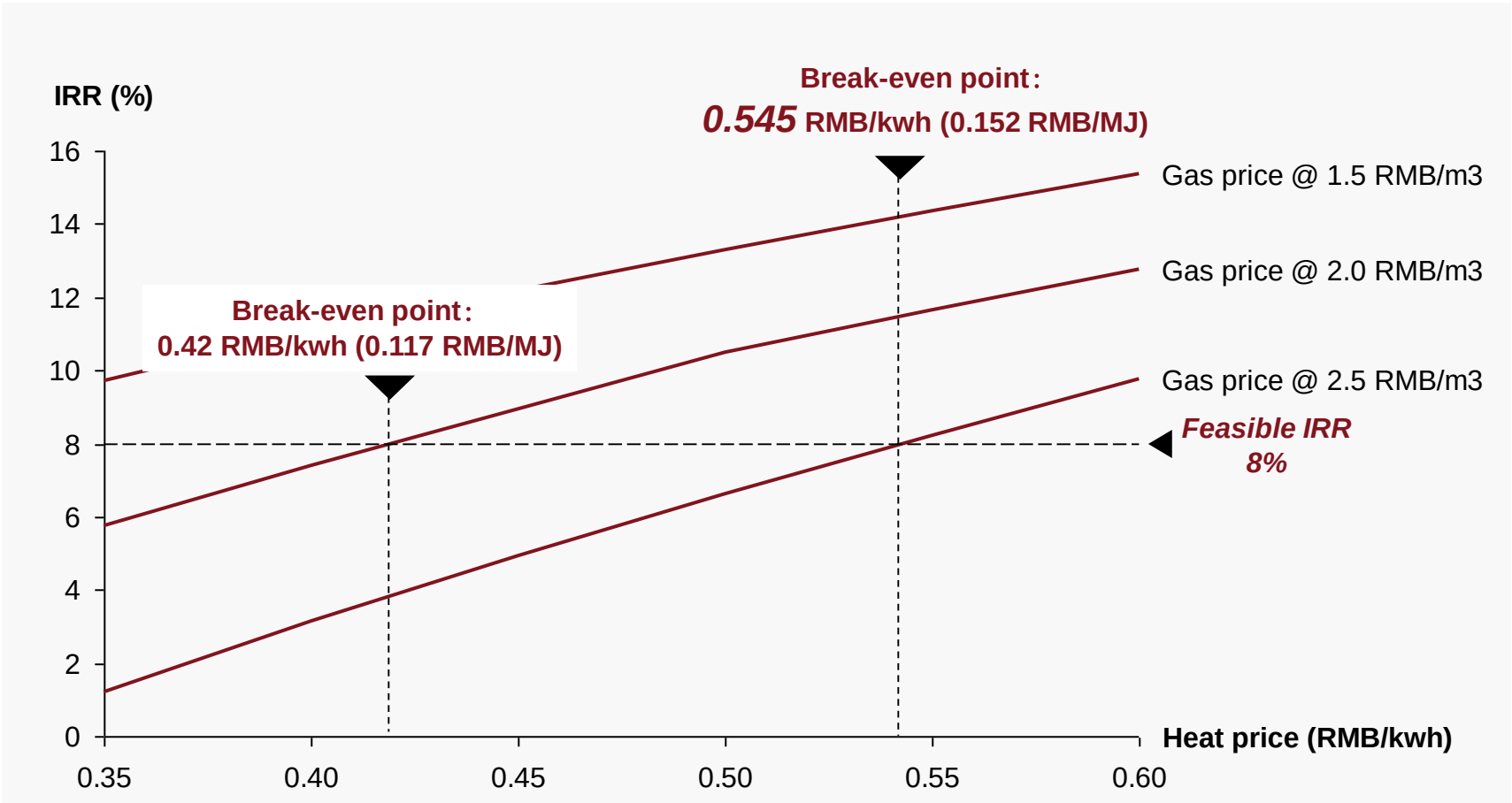


- All the DES projects are required to reach 70% fuel efficiency

Note: 1) Calculation of 46 selected Gas DES cases; 2) According to the sensitive analysis, 46% is the minimum break-even point*
Source: China Gas Des Annual Report 2016, Strategy& analysis

Gas price and heat price are the cost and revenue indicators to impact the project return

How heat price affect the project IRR

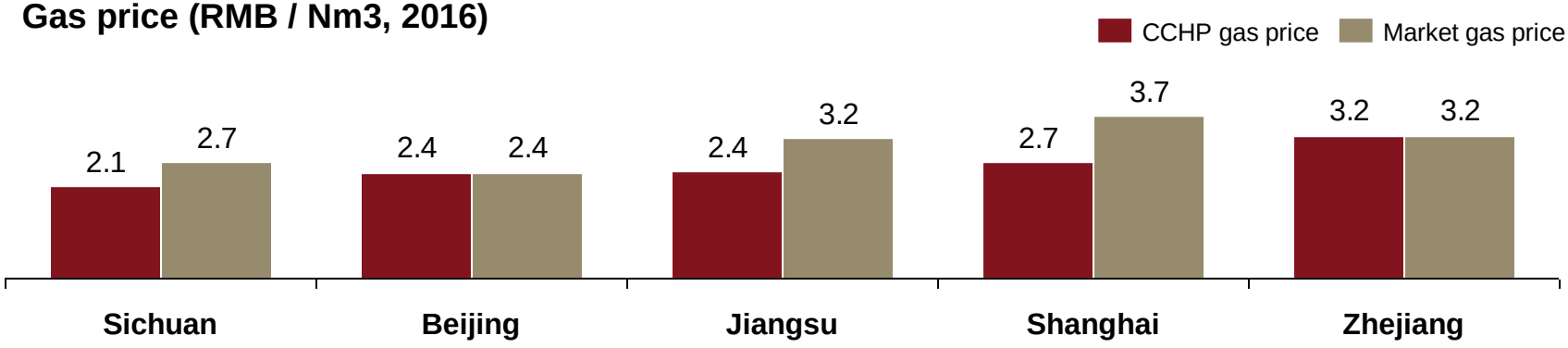


Source: Strategy& analysis

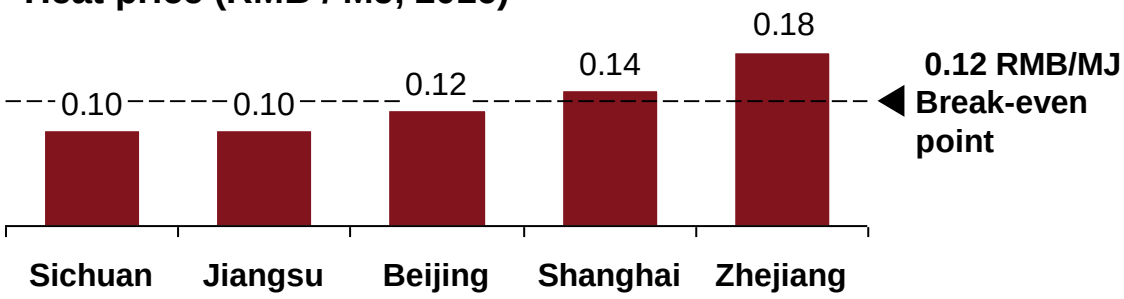
Even though most projects have received subsidized gas price, low heat price reduces the economic benefit

Economics indicators* of key areas

Gas price (RMB / Nm3, 2016)



Heat price (RMB / MJ, 2016)



- For most provinces, current heat price are lower than the expectation, results in poor revenue of the DES project.
- Shanghai and Zhejiang offer higher heat price for the projects, which help to improve the economic benefit

Note: 1) Calculation of 46 selected Gas DES cases; 2) According to the sensitive analysis, 0.12 RMB/MJ is the minimum break-even point of heat price for a DES project*
Source: China Gas Des Annual Report 2016, Strategy& analysis

Gas DES can help to develop a more integrated and competitive energy system

Gas DES

Double peak shaving

- Since the inverse distribution of the consumption between power and gas, developing gas DES can help both on the seasonal peak and the day-night peak shaving

Promote the integration with smart energy system

- With more customized and smart infrastructure, Gas CHP system can help promote the integration of different energy supply via a micro grid

Become the driver for the transformation of China power market

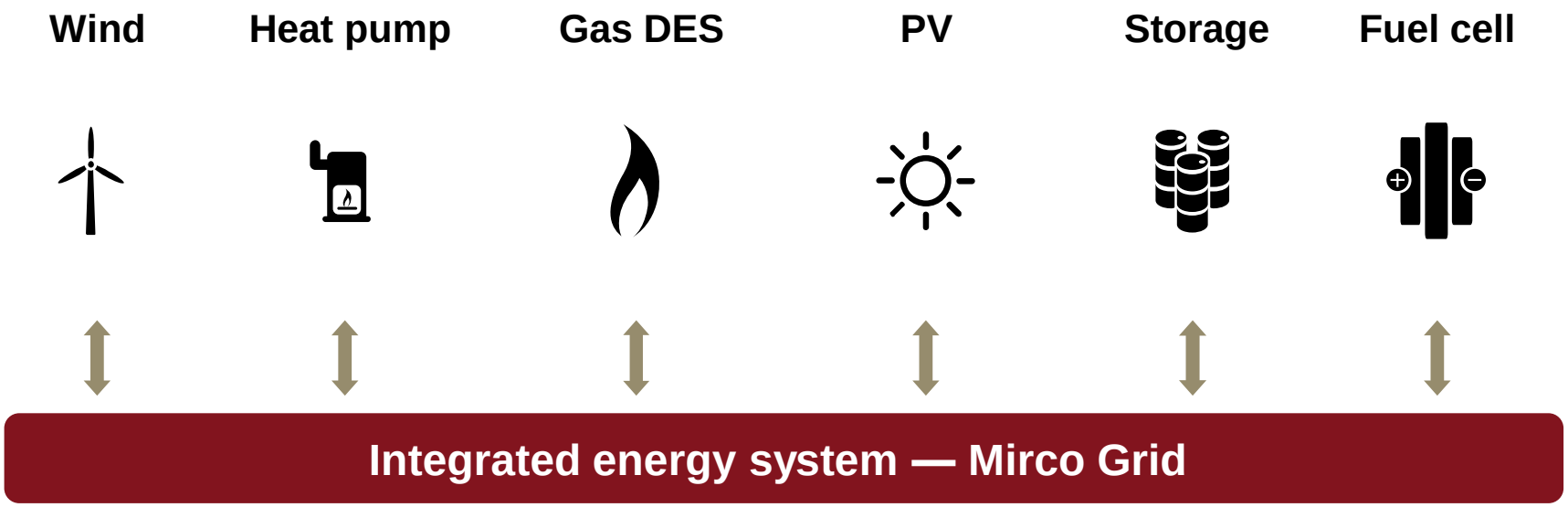
- The Gas DES market is developing with flexible price mechanism and innovative business model, supporting power market development
- The development of the power spot market will help to further promote gas power development

Become the new driver for economic growth

- The development of Gas DES will drive the growth of other industries across the value chain, especially for the high-tech device and energy saving service

Source: Literature review, Gas DES market report 2016, Strategy& analysis

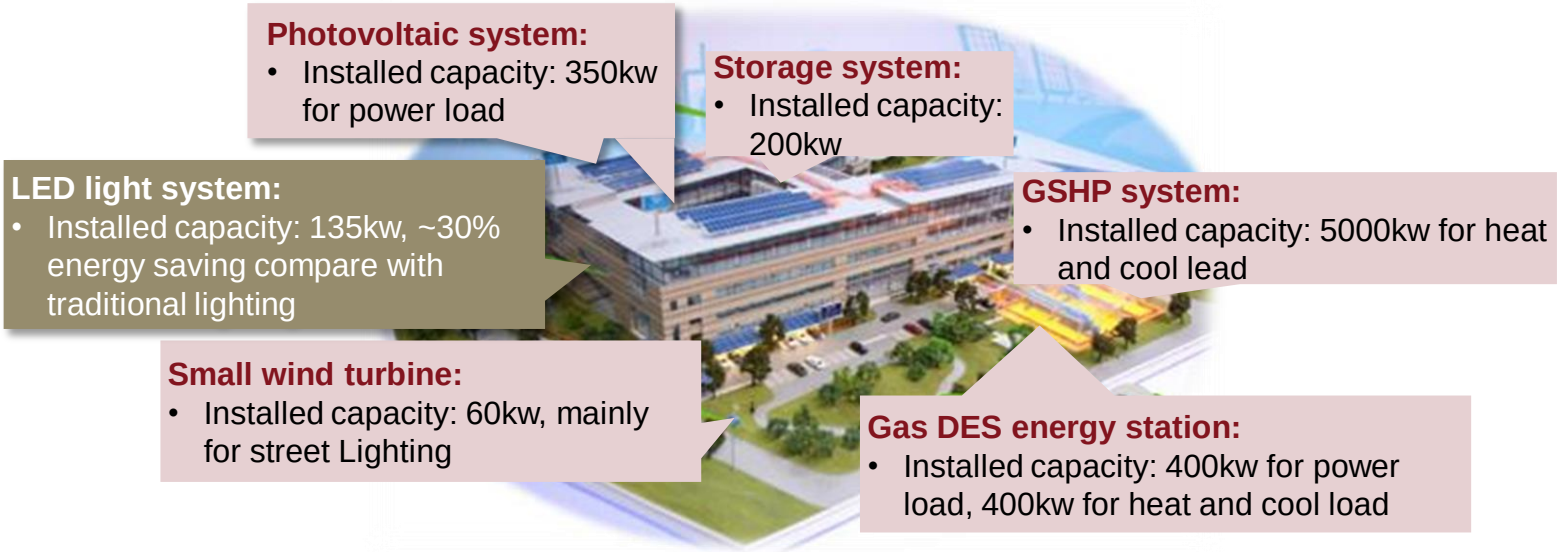
Gas DES can be integrated with other energy technology to promote integrated energy system in China



Source: Literature review, Gas DES market report 2016, Strategy& analysis

Case: Suzhou GCL R&D park multiple and micro energy system is the 1st "Six in One" energy service project in China

Integrated energy system structure of Suzhou GCL R&D park



Case profile

- **Location:** Suzhou, Jiangsu, total construction area is 20724 m2
- **Built and operated by:** Gloden Concord Power Group Limited
- **Online operation:** Mar, 2015
- **Total investment:** ~49 million RMB
- **Designed energy demand:** ~3000 KW, ~ 30% lower than the traditional plan
- **Energy supply rate of micro-grid system:** **over 50%**
- **Building energy saving efficiency:** **over 30%**

Source: Literature review, Strategy& analysis

However, the development of Gas DES in China is still hindered by policy and market challenges

Policy related

Power trading market

- Implementation measures (market access & retreat, power measuring…) for gas DES's participation in power trading market is unclear
- Peak-shaving value can not be realized without an ancillary market

Relationship with grid

- Development of DES may impact local power grid revenue and face grid connection challenge

National policy

- Gas DES is treated as normal power source during administrative application, resulting in high project feasibility study and application cost
- Currently no national subsidy

Market related

Financing

- Poor bankability due to project uncertainty and lack of proven successful experience/cases

Product price

- End products' (power, heat, cool) price are regulated but does not take into account the risk of rising labor and fuel cost

Environmental value

- DES environmental value (NOx/SOx, PM, solid waste reduction) are not fully recognized in money value

Source: Gas DES market report 2016, Literature review, Strategy& analysis

Gas As Strategic Enabler For China's Transformation

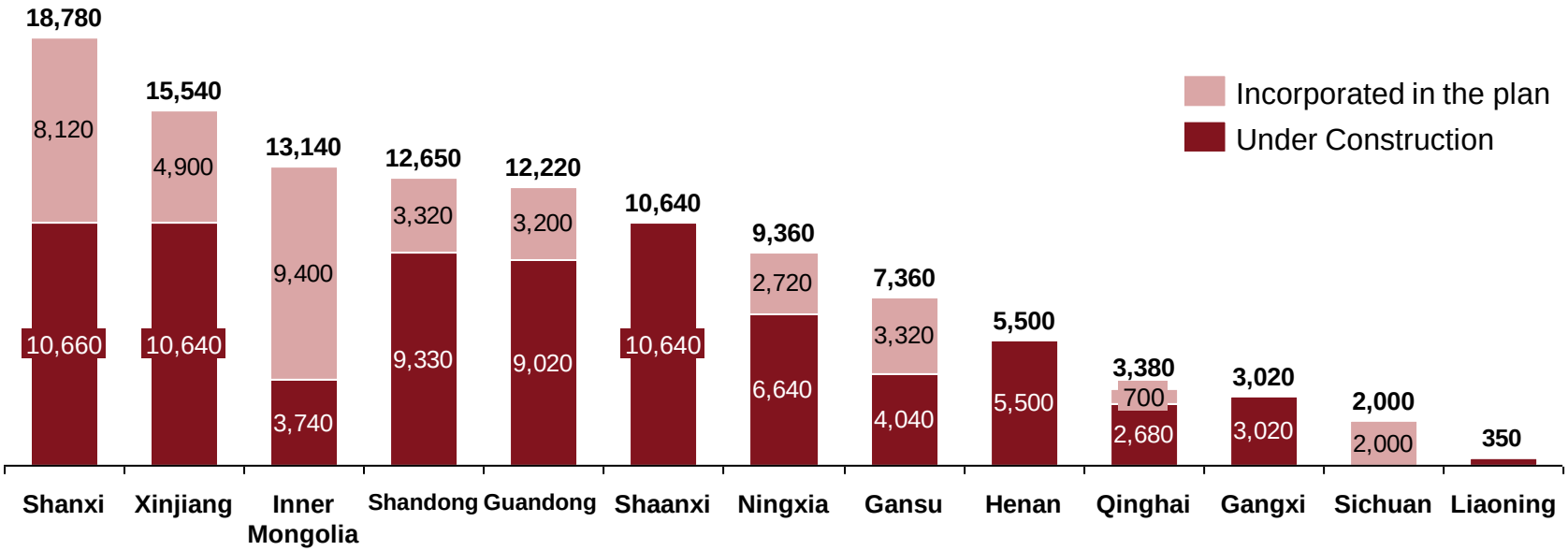
Promoting Gas Usage in High Value Sectors

- *Industrial Heating*
- *Residential/Commercial*
- *Co-generation - Centralized Heating*
- *Co-generation - Distributed Energy*
- ***Power Generation***

Policy Action to Realize Gas Potential

Many planned coal-fired projects in China are suspended due to environmental and overcapacity concern

Suspended projects by National Energy Administration of China (unit: MW)



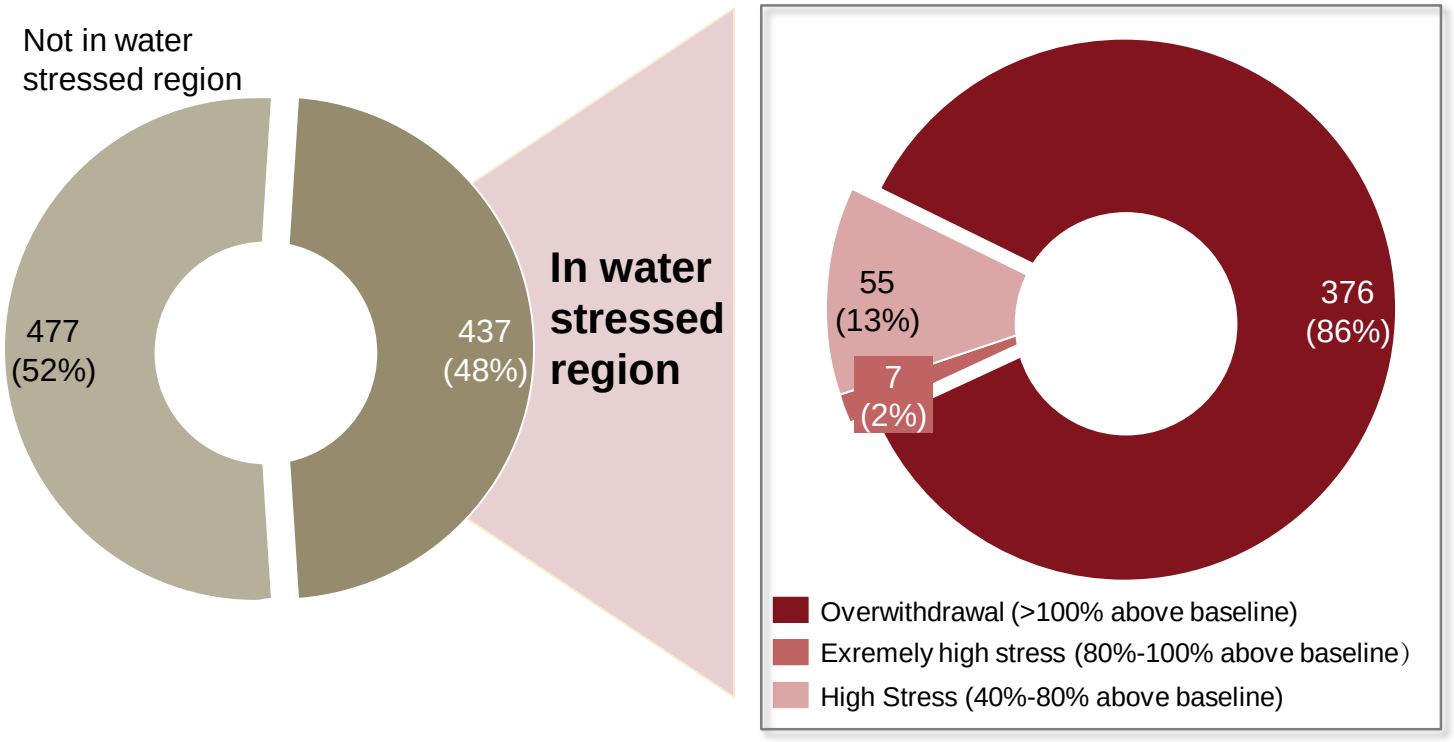
Project #	19	18	10	10	9	6	6	6	5	4	3	1	1

- **98 coal-fired projects with total capacity of 114 GW, including under construction and planning, have been suspend to 14th five-year or later** (one has been directly cancelled) by National Energy Administration of China
- According to "China power industry 13th Five Year Plan", **total capacity of coal-fired power generator should be kept in 1.1billion KW by 2020**

Source: National Energy Administration, China power industry 13th Five Year Plan, Strategy& analysis

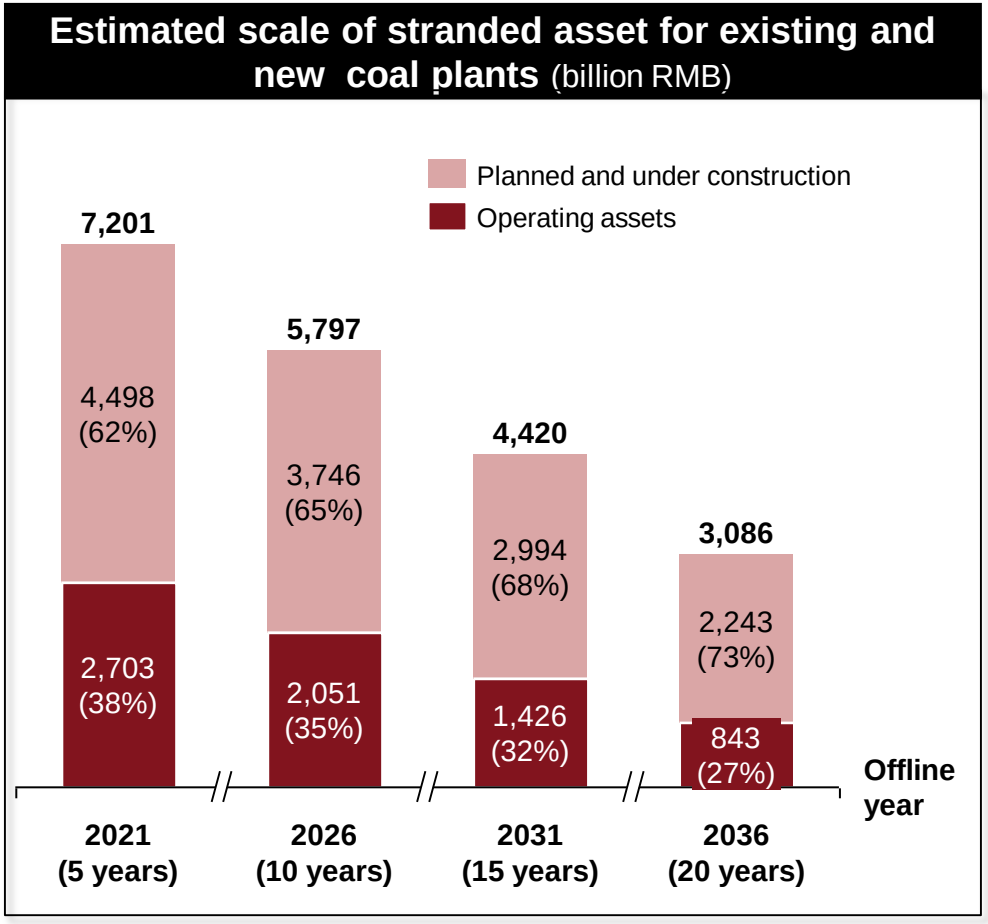
Moreover, Over 40% of China's existing coal-fired capacities are already in regions with extremely high water stress level

Coal-fired power plants installed capacity (GW) distribution by water stress level



Note: regions with water stress level at least 40% above baseline are considered stressed
Source: "OVERCAPACITY, OVER-WITHDRAWAL: HOW TACKLING COAL POWER OVERCAPACITY CAN EASE WATER STRESS", GREEN PEACE

Coal power plant investors face trillions of asset stranding risk

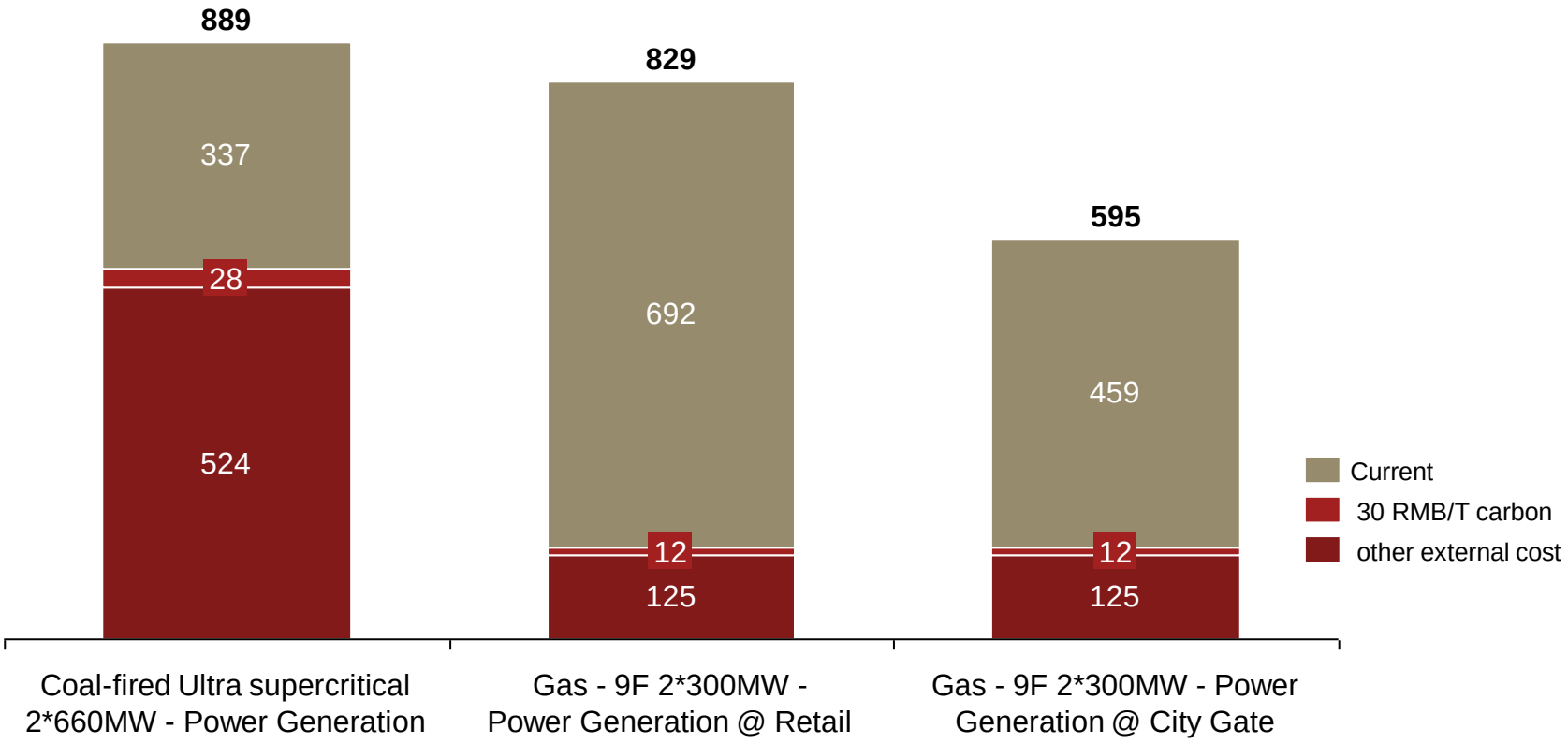


- Assume all the coal-fired power plants will be offline in 2036, ***over 3 trillion RMB will be stranded,*** 27% are operating assets.
- If offline years will be brought forward from 2036 to 2026, ***over 5 trillion RMB will be stranded,*** 35% are operating assets.
- Investment of coal-fired projects will bear risk of capital misallocation

Source: "Stranded coal-fired power assets in China", Oxford university, Literature review Strategy& analysis

At current price, gas – fired generation can be competitive even at base load if cost of externalities are considered

LCOE, RMB/MWh



Note: Coal: 529 RMB/ton, Retail Gas: 3RMB/m3, City gate gas 1.8 RMB/m3; operate at same 57% capacity factor (based load)
Source: Strategy& analysis

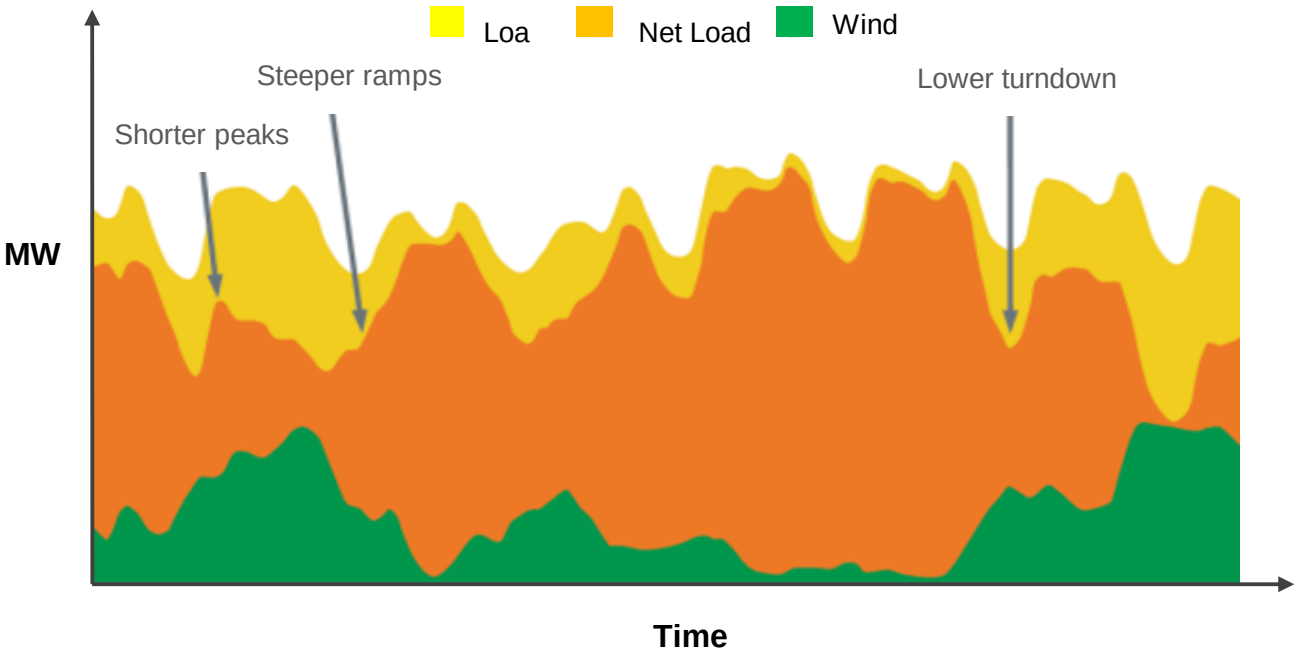
In China, most provinces have set ambitious RPS targets to encourage the development of renewable energy

Region	2020 RPS targets	2015 Renewable power consumption ratio	2020 – 15 difference	Region	2020 RPS targets	2015 Renewable power consumption ratio	2020 – 15 difference
Beijing	10.0%	7.6%	2.4%	**Jiangsu**	7.0%	3.3%	3.7%
Tianjin	10.0%	7.6%	2.4%	**Chongqing**	5.0%	1.4%	3.6%
Shannxi	10.0%	2.7%	7.3%	**Tibet**	13.0%	8.2%	4.8%
Hainan	10.0%	2.8%	7.2%	**Xinjiang**	13.0%	10.5%	2.5%
Liaoning	13.0%	4.0%	9.0%	**Hebei**	10.0%	7.6%	2.4%
Shandong	10.0%	7.7%	2.3%	**Jiangxi**	5.0%	2.2%	2.8%
Henan	7.0%	2.3%	4.7%	**Heilongjiang**	13.0%	11.1%	1.9%
Shanxi	10.0%	7.0%	3.0%	**Guizhou**	5.0%	2.0%	3.0%
Guangdong	7.0%	1.8%	5.2%	**Guangxi**	5.0%	1.0%	4.0%
Zhejiang	7.0%	2.4%	4.6%	**Fujian**	7.0%	3.4%	3.6%
Yunnan	10.0%	5.1%	4.9%	**Jilin**	13.0%	12.2%	0.8%
Hunan	7.0%	2.8%	4.2%	**Qinghai**	10.0%	13.5%	-3.5%
Hubei	7.0%	3.7%	3.3%	**Ningxia**	13.0%	13.4%	-0.4%
Anhui	7.0%	3.9%	3.1%	**Gansu**	13.0%	11.4%	1.6%
Shanghai	5.0%	1.6%	3.4%	**Inner Mongolia**	13.0%	12.0%	1.0%
Sichuan	5.0%	1.4%	3.6%				

Note: RPS is Renewable Portfolio Standard
Source: National Statistics Bureau, Strategy& analysis

Renewable generation will lead to greater demand for flexibility…

How wind generation can impact power system operations

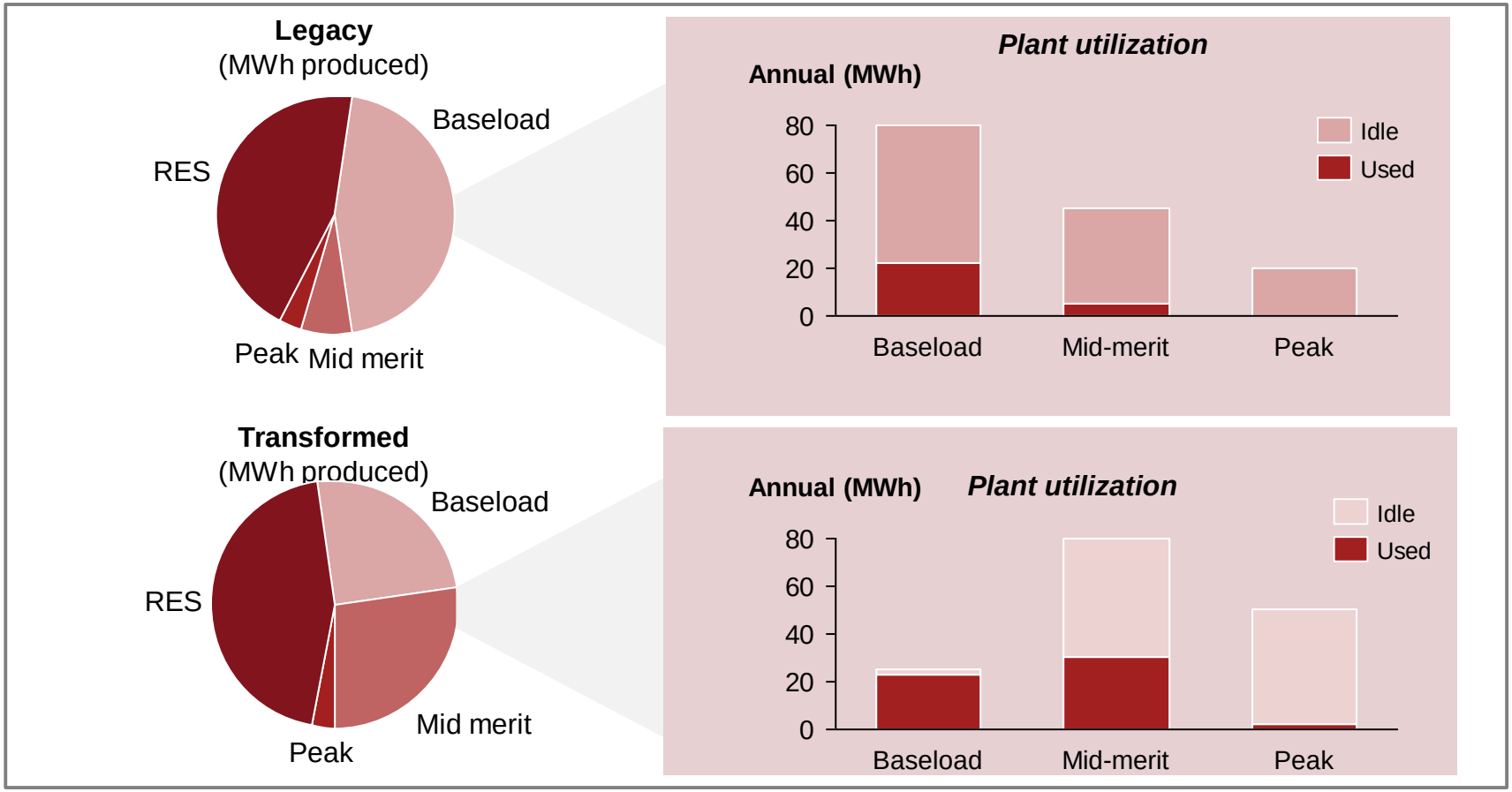


- RAP study indicated that services that will be in greater demand in a high RES system will be those that can respond within minutes to tens of minutes to hours and offering the following capabilities:
  - Flexible, fast start-stop cycling capability
  - Regular, dispatchable ramping capability
  - Ramping capability reserved now to be used in the future

Note: the RAP study is on Capacity Mechanisms For Power System Reliability
Source: "NREL, Advancing System Flexibility for high penetration of renewable energy", Strategy& analysis

… and larger share of peaker/mid-merit will help to increase overall efficiency in a renewable energy world

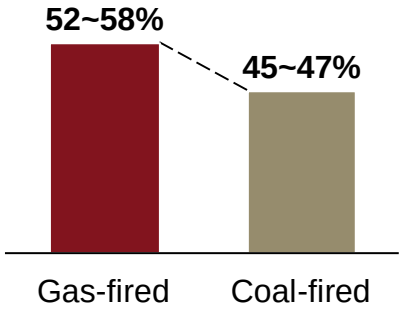
Impact of thermal plant mix on investment and plant utilization rates



Base load: power plants that are designed to operate around the clock and that cannot change their output dynamically
Source: "IEA, The Power of Transformation: Wind, Sun and the Economics of Flexible Power Systems", Strategy& analysis

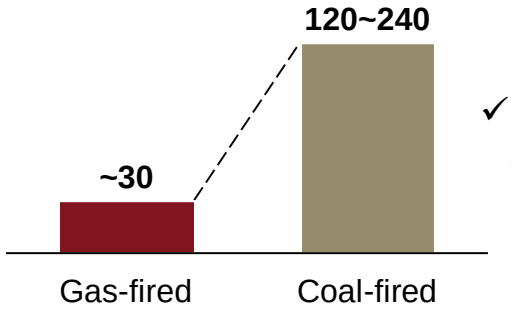
Compared to coal, gas can better meet the peak demand

Operation efficiency （%）



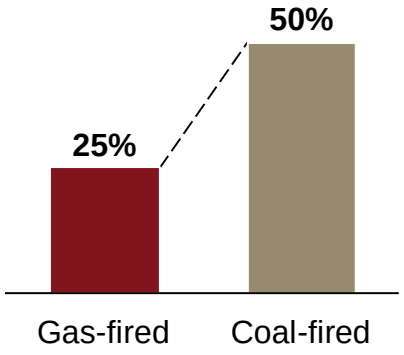
✓ **More efficient**

Start – grid connection duration (min）



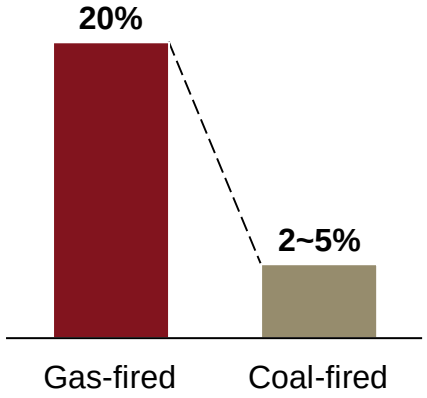
✓ **Faster start – stop**

Lowest load（%）



✓ **Wider load range**

Ramp speed（%/min）

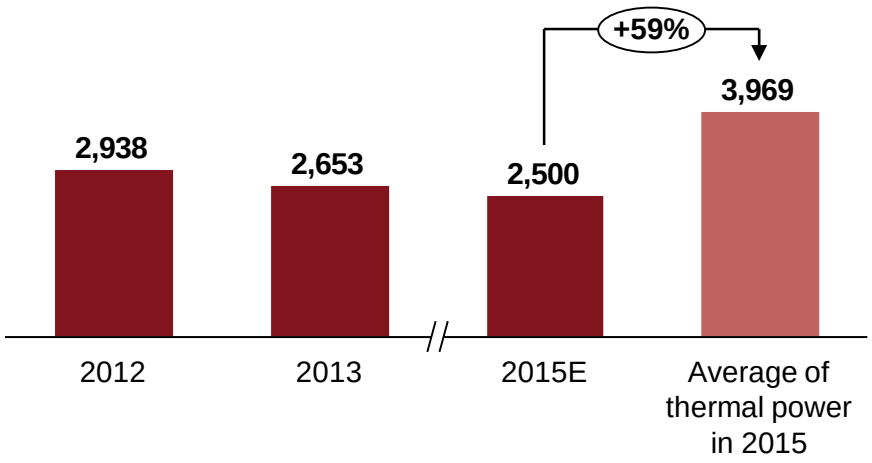


✓ **Faster ramping**

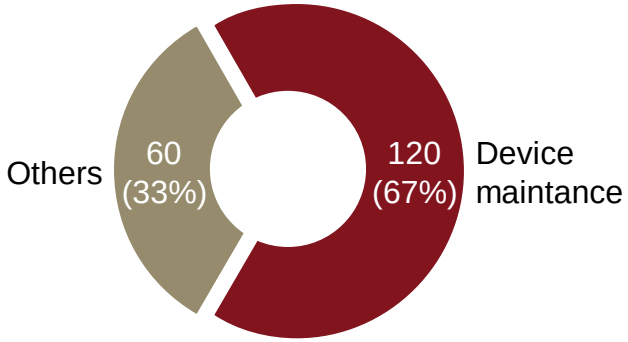
Source: SGERI research, Literature review, Strategy& analysis

However, current pricing mechanism has limited the peak shaving potential

Annual utilization hours of gas power generator (h)



Maintenance cost of a sample generator (100m RMB)



- **Low utilization hours:** 70% of gas power generator in China is used for peak shaving, the average utilized hours is only ~2500 hours
- **High operation cost:** Due to frequently start-stop, over 100 million RMB is required by maintenance.

- **Current pricing mechanism has greatly limited the peak shaving potential:**
  - Current pricing mechanism is opaque, varied greatly among generators.
  - Most gas generators receive single pricing, which only consider the power generation.
  - Current pricing mechanism can't reflect the value of peak-shaving and environment protection

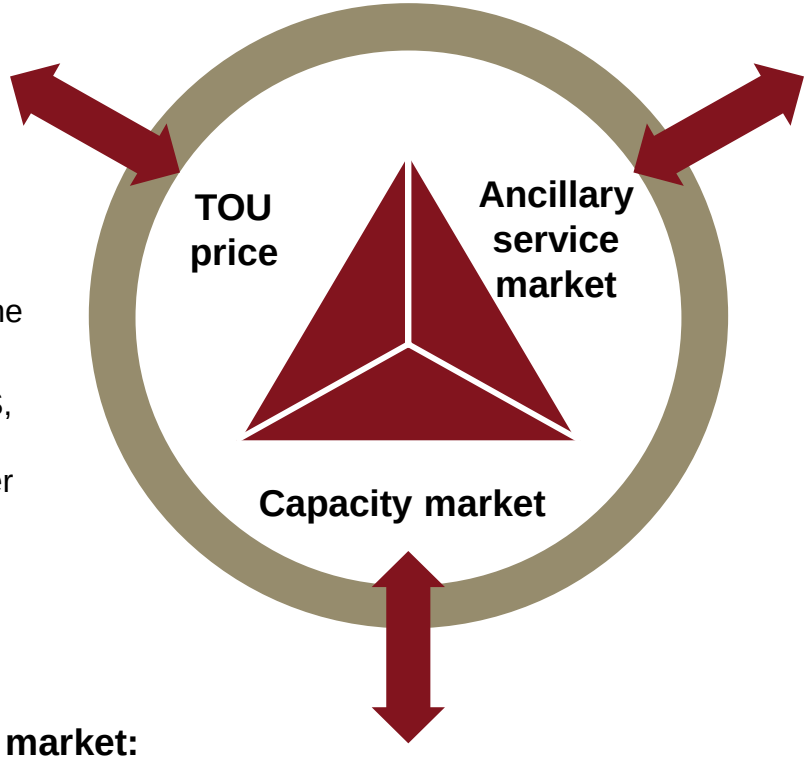
Main bottleneck

Source: National Energy Bureau, Literature review, Strategy& analysis

There are mainly 3 ways to price the flexibility value of a power peaker

TOU price:

- The TOU price should reflect different power generation cost and market value based on the load demand
- In other countries like US, the power price of peak time is 1.8~2 times higher than the average feed-in tariff, 5~8 times higher than the off-peak



Ancillary service market:

- Through establishing ancillary service market, power generator can gain extra income by providing ancillary service such as regulation and peak shaving.
- Some generator in UK have gained half of their revenue from ancillary service

Capacity market:

- Through bidding and transaction mechanism, power generator with low utilizations can benefit from capacity market by selling the extras

Source: Literature review, Strategy& analysis

Gas As Strategic Enabler For China's Transformation

Promoting Gas Usage in High Value Sectors

- *Industrial Heating*
- *Residential/Commercial*
- *Co-generation - Centralized Heating*
- *Co-generation - Distributed Energy*
- *Power Generation*

Policy Action to Realize Gas Potential

Policy action to realize gas potential

1	***Market education***	• Promote successful coal to gas switch cases to raise market awareness and provides capacity building support to enable better end-user decision
2	***Transparent pricing***	• Transparent pricing on the transmission and distribution gas pipeline cost and cut “middleman” cost
3	***Standards development***	• Develop standards and procedures for LNG-based supply to encourage supply competition
4	***Increase pollutants fees & penalty rates***	• Increase emission fees, penalty (NOx/ SOx/PM) and water resource fee to reflect true externality
5	***Industrial user subsidy***	• Provide tax, equipment and gas price subsidy to encourage coal-to-gas switch in high potential industry and region
6	***Support gas CHP***	• Capacity factor guarantee, tax favor (VAT wave for example, green finance (lower interest rate) and price subsidy for large-scale gas CHP at environmental sensitive regions
7	***Support DES***	• Equipment subsidy, energy saving subsidy, reserve capacity fee exemption for distributed gas and promotion through wholesale power market
8	***Peak plant pricing***	• Promote spot and ancillary market to capture gas power's value of flexibility

Source: Expert interview, Strategy& analysis

Glossary

Abbreviation	Definition
C2G	Coal to Gas
CCHP	Combined Cooling, Heating and Power
CHP	Combined Heat and Power
CM	Coal Mining
CSR	Corporate Social Responsibility
FMM	Ferrous Metal Mining
FMP	Ferrous Metal Processing
GE	General Equipment
GSHP	Ground Source Heat Pumps
GTCC	Gas Turbine Combined Cycle
LCOE	Levelized Cost Of Electricity
MPR	Metal Product Repairing
NMM	Nonferrous Metal Mining
NMP	Nonmetallic Mineral Processing
OP	Oil Processing
PUE	Power Usage Effectiveness
RAP	Regulatory Assistance Project
RES	Renewable Energy Source
RPS	Renewable Portfolio Standard
SE	Specialized Equipment
TOU	Time of Use