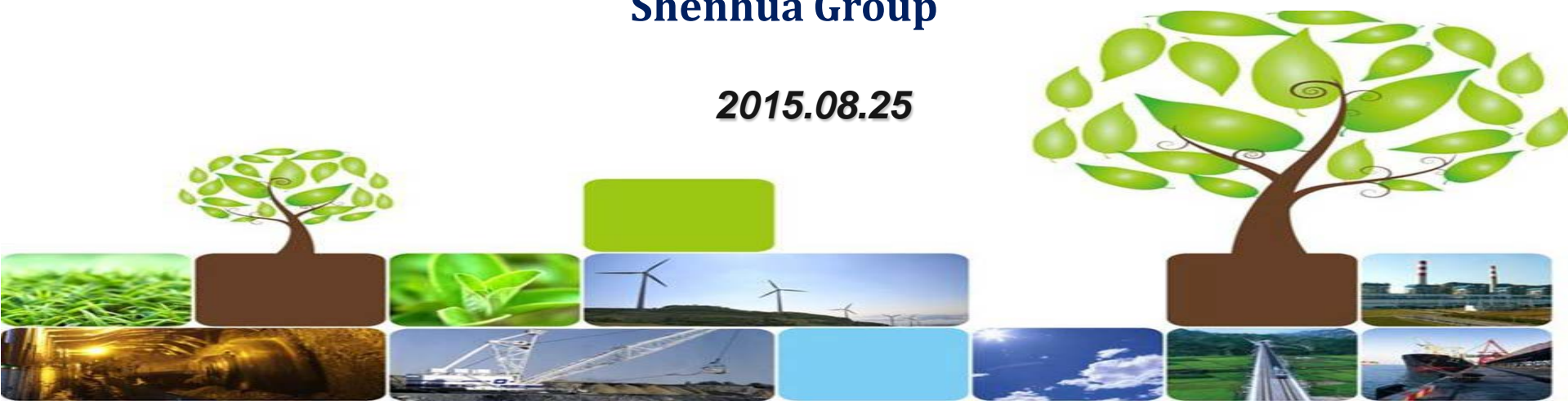


Clean and Highly Efficient Conversion Is the Only Way Forward for Coal Use

Wang Pingang

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Shenhua Group

2015.08.25



Outline

1) Coal use must be clean and highly efficient

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2) Shenhua's credo in clean and highly efficient coal utilization

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3) Shenhua's practices in clean and highly efficient coal utilization

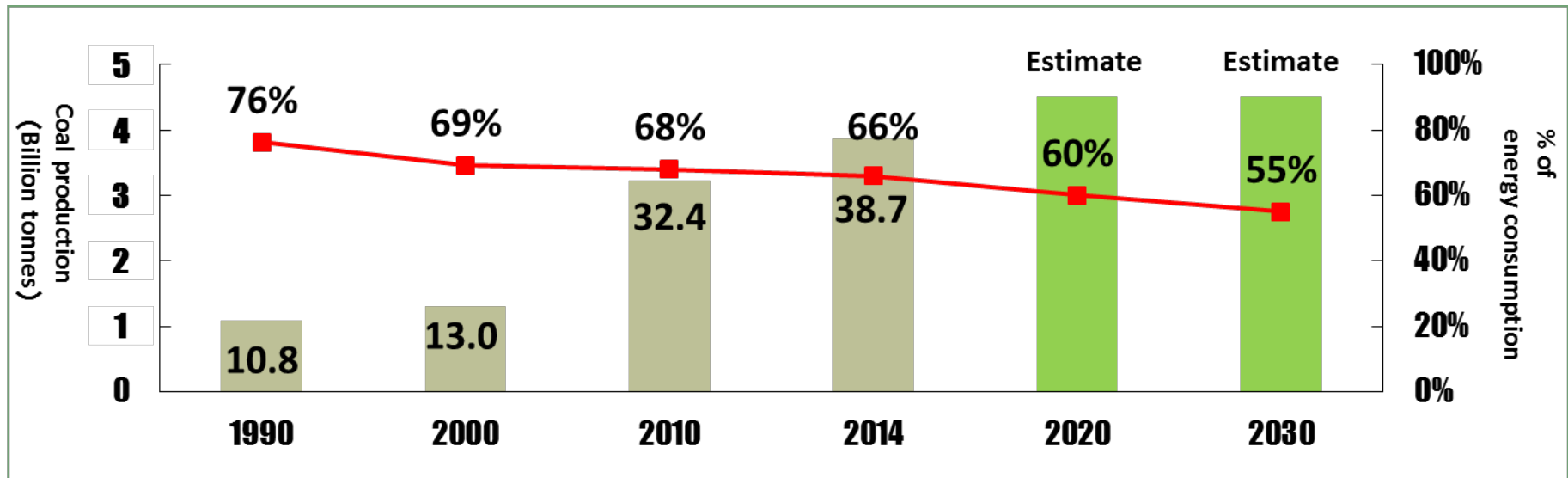
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4) Conclusion

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1) Coal use must be clean and highly efficient

- Coal will continue to dominate the energy mix well into the foreseeable future.
- Coal: The most abundant fossil energy of China (96%)
- Coal has made up approx. 70% of total primary energy consumption for a long time (2014, 66%)
- Coal is projected to make up approx. 55% of primary energy consumption in 2030



1) Coal use must be clean and highly efficient

Negative environmental impacts of conventional coal exploitation and utilization are coming to the fore.

- **Extensive coal development damaged underground water and ground ecology**
 - Surface subsidence: 0.2-0.3 hectare/10k tonne produced, restoration rate less than 30%
 - Underground water damage: 8 billion m³/year of water depleted, less than 30% utilized
- **Raw coal use results in harmful emissions into the air**
 - Coal for power generation only accounts for 53% , significantly lower than US (90%) , and also lower than global average (65%)
 - Coal burned in small kilns or by households takes up a very large proportion and is the main contributor to air pollution



1) Coal use must be clean and highly efficient

Multiple imperatives like environmental protection, combating climate change and sustainable development of coal industry entail fast-tracking clean and highly efficient coal utilization.

- **Chinese government's commitment: by 2020, carbon emissions per unit of GDP 40%-45% lower than that of 2005**
- **Low-carbon development of a carbon-intensive industry**
- **A transition from extensive development to sustainable and smart development**
- **From high-level pollution to clean and efficient utilization**

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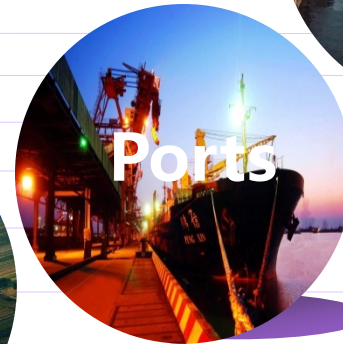
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2) Shenhua's credo in clean and highly efficient coal utilization

- Incorporated in 1995
- Integrated operation of coal production, electricity generation, railway transportation, ports management, seaborne shipping, coal-to-liquids/chemicals
- 2014 Figures (RMB): Asset: 928.6 bn, Revenue: 324.9 bn, Profit: 64bn. No. 196 in Fortune Global 500.



2) Shenhua's credo in clean and highly efficient coal utilization

Shenhua is the largest coal-based, diversified energy corporation in the world. In 2014 it sold 588million tonnes of coal, approx. **14%** of total domestic consumption. Under the new normal of the economy Shenhua is faced with multiple challenges :

- Depressed coal market leading to serious erosion of profitability
- Growth that relies heavily on capital investment has hit a bottleneck
- Increasing risks in environmental control and management.
- Lack of sci-tech innovation capability to go with the tide of energy technology revolution

2) Shenhua's credo in clean and highly efficient coal utilization

- **Strategy: to transform itself into a world-class clean energy provider via technical innovation**
- **Clean energy supplier with three pillars**
 - **Coal based energy:** integration of production, transportation and sales value chain
 - **Clean energy industry:** based on application of sophisticated new technologies
 - **Clean energy technology:** driven by innovation and technology transfer & promotion



2) Shenhua's credo in clean and highly efficient coal utilization

- The ultimate goal of clean and highly efficient coal conversion is to produce electricity, fuel and chemicals, among other things. During the process, we should
 - minimize emissions of various pollutants and greenhouse gases, realizing **ultra-low emissions**.
 - press ahead **highly-efficient & comprehensive utilization** of associated resources, wastes or pollutants
 - mitigate CO2 emissions with **CCUS**



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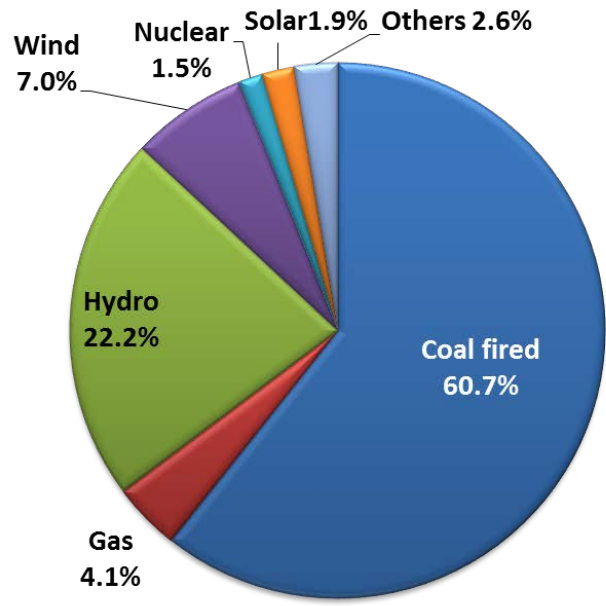
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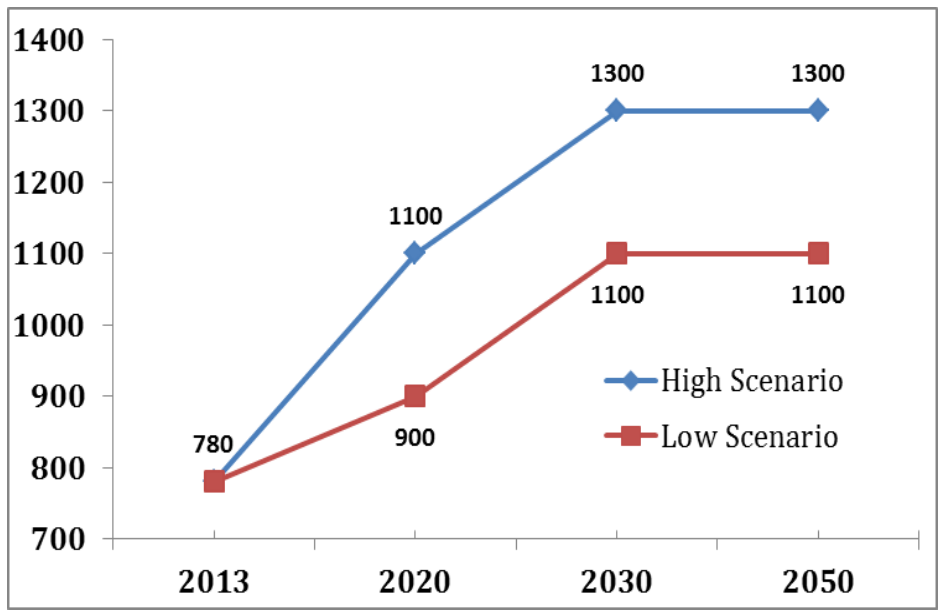
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① Coal-fired generation with ultra-low emission

- Coal-fired power generation is a main source of energy for China, accounting for **60.7%** of total installed capacity and approx. **75%** of total generation
- Coal will still dominate the power generation structure into the foreseeable future (est. coal fired generation capacity **1100-1300GW** in 2030)



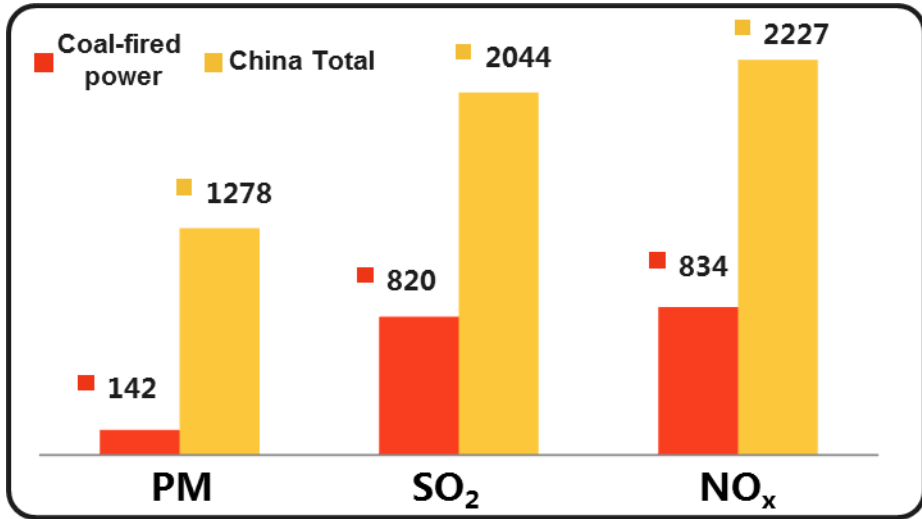
China power generation compositions (capacity 1360GW)



Coal fired estimate (source China electric power planning institute)

① Coal-fired generation with ultra-low emission

- Coal-fired power generation by itself isn't significantly more polluting than other industries but because of absolute volume of coal used for generating electricity, it nevertheless is one of the leading contributor of harmful pollutants
- 2013, thermal power (mostly coal-fired) generated 1.42million tonnes (12%) of airborne PM, 7.8million tonnes SO₂ (38%) ; 8.34 million tonnes NO_x(37%)



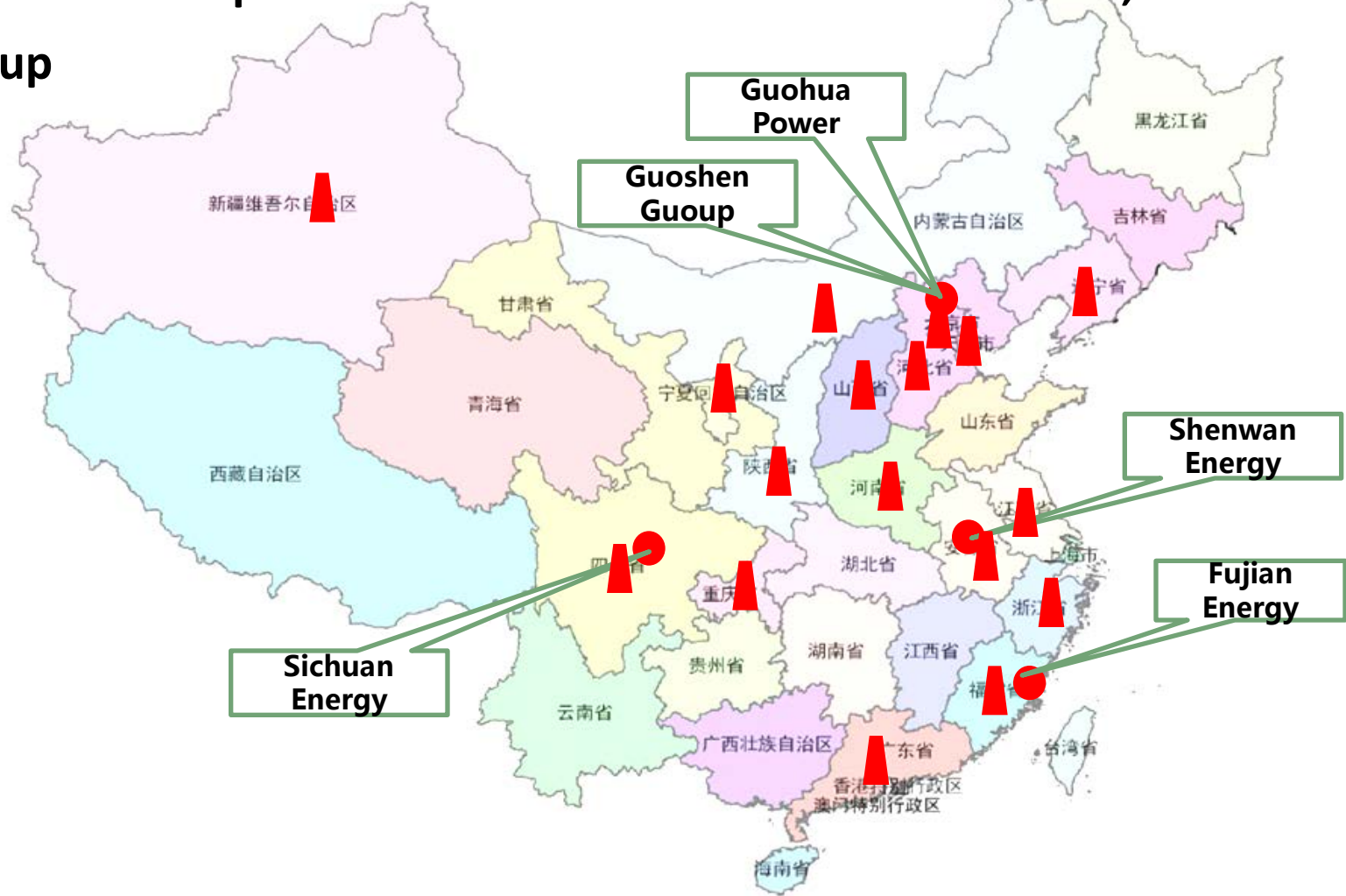
2013 Thermo Power Pollutant Table



① Coal-fired generation with ultra-low emission

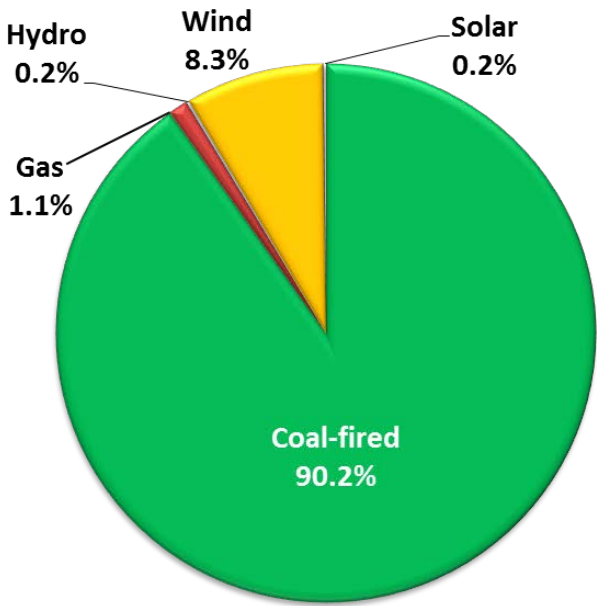
■ 2014: Shenhua **68.8GW** capacity, 325.8Billion KWH generated

■ Five coal-fired power subsidiaries such as Guohua Power, Guoshen Group

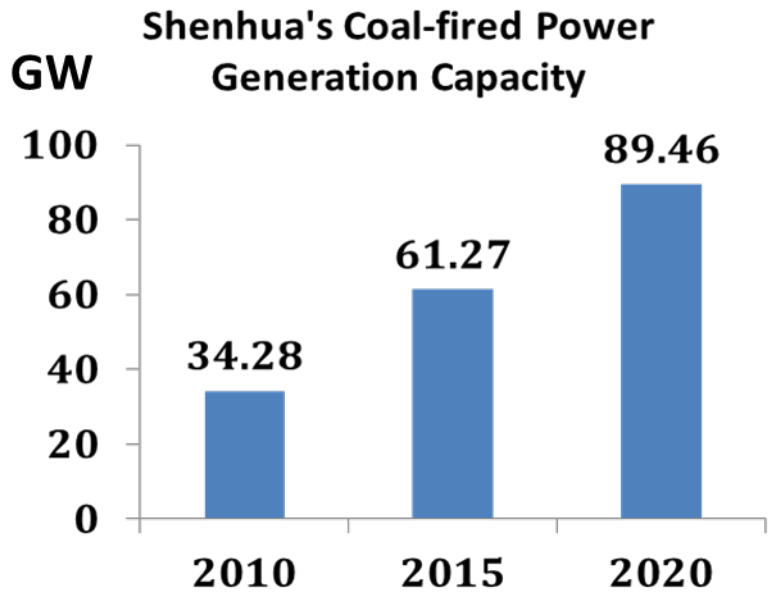


① Coal-fired generation with ultra-low emission

- Coal fleet capacity **61.27GW**, **>90%** of total
- By 2020 coal-fired generation capacity will approach **90GW**, if all goes according to plan



Shenhua Power Generation Mix (2015)



① Coal-fired generation with ultra-low emission

■ Proposal of the concept of ultra low emissions from coal-fired power generation

Sino/US fossil thermo power pollutant guidelines (new installations)

Pollutants (mg/Nm ³)	PM	SO ₂	NO _x
Coal-fired (China-common regions)	30	100	100
Coal-fired (China-important regions)	20	50	100
Coal-fired (US)	20	184	135
Natural Gas (China)	5	35	50

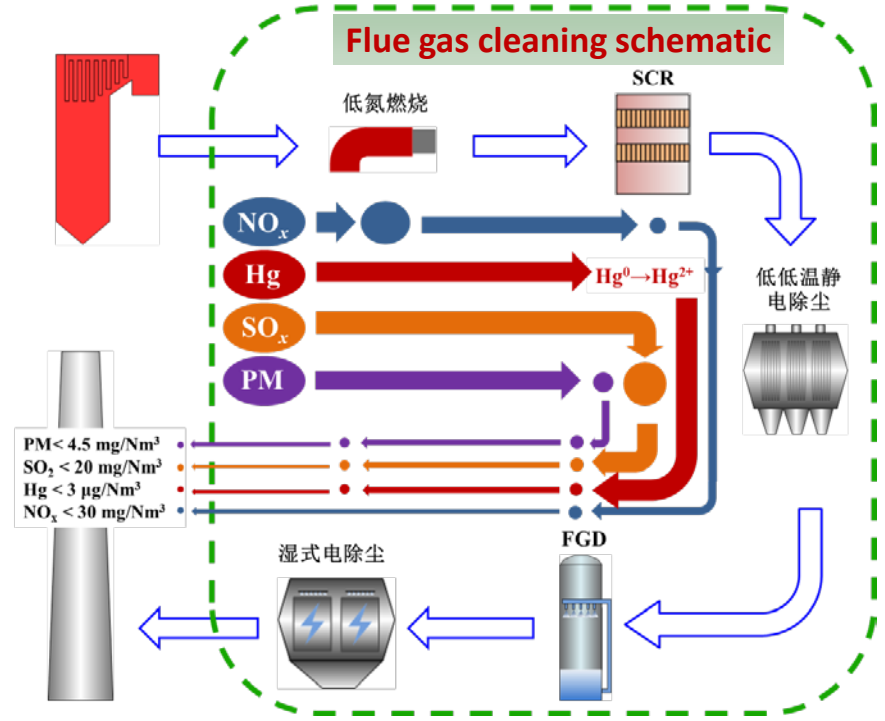
- ultra low emission for coal means emission of coal fleet is at the same level as or even lower than that of gas fleet

① Coal-fired generation with ultra-low emission

- Path to achieving ultra low emission for coal-fired power plant
- Integrate advanced pollutant scrubbing technology, achieve efficient and integrated removal of pollutants
- Upgrade existing capacity to achieve ultra low emission, apply most advanced technologies in new installation to build clean and efficient benchmark coal-fired power plants

Integrated Pollutant Removal

- PM scrubber ●
- Wet SO_x scrubber ●
- Full load NO_x Scrubber ●
- Demercuration via sorbent injection ●
- Operational Optimization ●
- Integrated technology, pilot trials



① Coal-fired generation with ultra-low emission

■ Demo project data

		Pollutant	PM (mg/Nm ³)	SO ₂ (mg/Nm ³)	NO _x (mg/Nm ³)
		Emission	Emission	Emission	
Plant Location					
1	Natural Gas Emission Standard		5	35	50
2	GH Zhoushan No. 4 (new 350MW)		2.46	2.76	19.8
3	GH Sanhe No. 1 (conversion 350MW)		5.00	9.00	35.00
4	GH Dingzhou No. 3 (conversion 660MW)		2.00	6.00	17.00
5	GH Huizhou No. 1 (conversion 330MW)		1.40	8.00	18.00
6	GS Wanzhou No . 1 (new 1000MW)		3.50	9.00	23.00
7	GS Dagang No. 3 (conversion 300MW)		2.96	17.88	30.45
8	GN Yuanyang Lake No.1(conversion 600MW)		4.27	22.57	29.28

■ The long-term monitoring data from environment authorities shows that ultra low emission plants outperform natural gas plants in criteria emissions

① Coal-fired generation with ultra-low emission

■ The economics of ultra low emission plant

Using Zhoushan No. 4, Sanhe No. 1 and Dingzhou No. 4 as examples to analyze the construction and retrofitting costs and their impact on feed-in tariff.

Increase in tariff is less than RMB 1 cent per KWhr

Project Item	Zhousha No. 4	Sanhe No. 1	Dingzhou No. 3
Capital Investment (million yuan)	40.93	48	75
Incremental increase(yuan/KW)	117	137	114
Impact on price (cents/KWhr)	0.66	0.98	0.52

Note: Tariff includes tax, based on 5500hr of generation per annum

① Coal-fired generation with ultra-low emission

■ Economic analysis of ultra low emission upgrade

RMB one cent increase in tariff for the retrofitting (construction) cost will achieve better emission level than that of gas-fired units. Feed-in tariff for coal-fired units is **¥0.4/KW hr** (while the price of gas-fired electricity is **¥0.8/KW hr**). The economic and social benefits of ultra low emission coal plants are obvious.



GH Cangdong Coal-fired power plant



GH Yuyao gas-fired power plant

① Coal-fired generation with ultra-low emission

■ Contribution to the industry

- Shenhua already retrofitted **22 units** to ultra low emissions, accounting for **1/3** of national total. (Shenhua coal-fired capacity accounts for 7.5% of national total)
- Encouraging ultra low emission upgrade of coal-fired plants has been included in **Premier's government report** this year. The government required that emission from all new installations along the Eastern Coast must be similar to that of natural gas plants
- If ultra low emission technology is promoted across China, coal-fired pollutants will be **90%** lower than the 2013 level.

Environmental impact of Ultra Low Emission Conversion

Pollutant	2013 Thermo Power Emission (Million Tonnes)	Total conversion to ultra low emission (Million Tonnes)
SO ₂	8.2	0.53
NOx	8.34	0.76
PM	1.42	0.08



① Coal-fired generation with ultra-low emission

■ Next steps

- All new installation to be of Ultra Low Emission
- By **2017**, complete retrofiting **50+** generators in three key regions:
Beijing/Tianjin/Hebei, Yangtze River Delta and Pearl River Delta
- Continue to invest in R&D of ultra low emission technology integration and online real-time monitoring technologies, among others



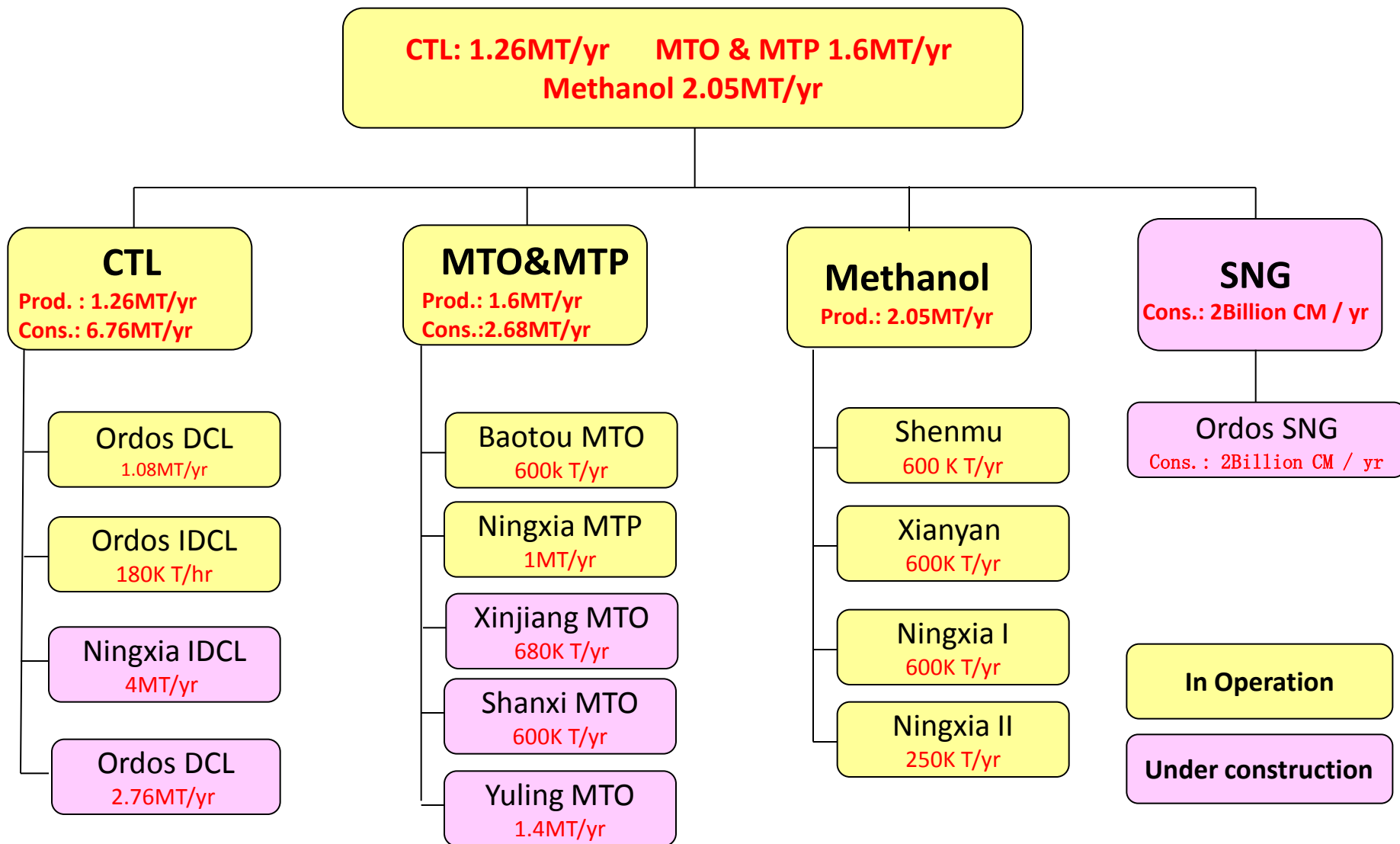
② Modern coal chemical industry based on clean conversion

■ Key technology development status (as of end of 2014)

- CTL: **1.63Mt** capacity installed. **6.8Mt** under construction. China still imports 60% of its crude oil consumption. Oil demand will continue to rise. The outlook for DCL is bright.
- MTO: **4.72Mt** capacity installed , or **20%** of China's total olefin production capacity. **8 Mt** capacity on the stocks, with an additional **13MT** capacity in the pipeline. The market is heading towards saturation and competition is expected to intensify.
- SNG: **2.7 Bn m3** capacity installed, **16.4Bn m3** under construction, SNG is of wide prospectivity but need to improve its profitability.
- Coal to Alcohol, Ether & Aromatics: Commercial scale plants for coal to alcohol and ether already in place, 10K tonne scale aromatics pilot test completed. There is a supply gap in the domestic market for those chemicals but projects are yet to prove their profitability.

② Modern coal chemical industry based on clean conversion

Shenhua Coal Chemical Operation



② Modern coal chemical industry based on clean conversion

World's first million-tonne-scale DCL facility

- From 2011 to 2014, Shenhua has produced **3.42 million tonnes of liquid oil products**, generating revenue of **¥22.8B**, gross profit **¥5.8B**, and net profit **¥1.2B**
- Diesel oil from DCL process contains much lower sulfur & nitrogen as compared to diesel from crude oil; therefore, a much cleaner alternative.
- DCL products have high density, low melting point, high heat tolerance and high stability among other features. They can replace oil-based fuels and significantly improve aircraft performance, lending themselves to aviation fuel.

World's first million tonne scale DCL facility



② Modern coal chemical industry based on clean conversion

World's first 600K T/yr MTO demo plant

- From 2011 to 2014, Baotou MTO facility has produced **2.12 Million tonnes** of polyolefin product, generating revenue of **¥23.5B** and net profit of **¥4.2B**
- As a result of this project, Shenhua has advanced the MTO technology and is one step closer to replacing crude oil as the feed stock for polyolefin production, thus reducing the reliance on oil imports.

World's first 600K T/yr MTO demo plant



② Modern coal chemical industry based on clean conversion

World's largest single investment in coal chemical project— 4 million tonnes Ningxia IDCL project

- Total Investment **¥55B**, 4million tonnes annual capacity, estimated annual revenue of **¥26.6B** and profit of **¥15.3B**
- The project has catalyzed new domestic equipment capabilities for large scale slurry bed reactor, 100K m³ air separator and 2K tonne/day scale dry feed gasifier

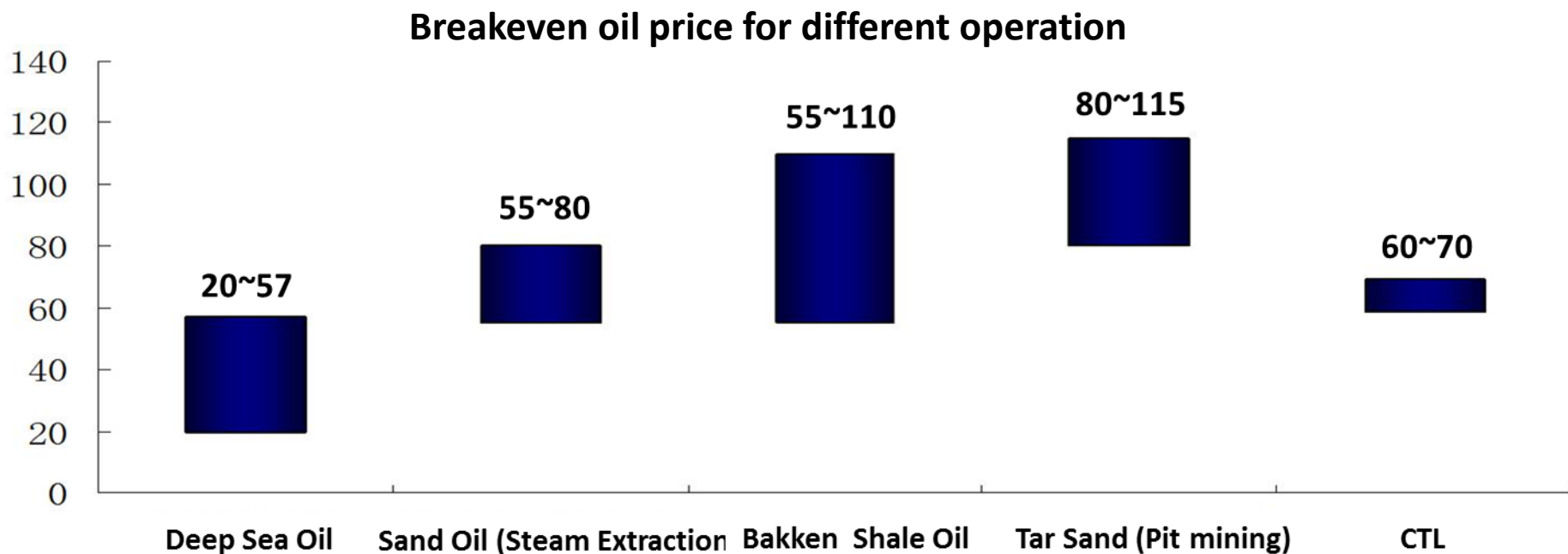
Under Construction: 4million tonne IDCL facility



② Modern coal chemical industry based on clean conversion

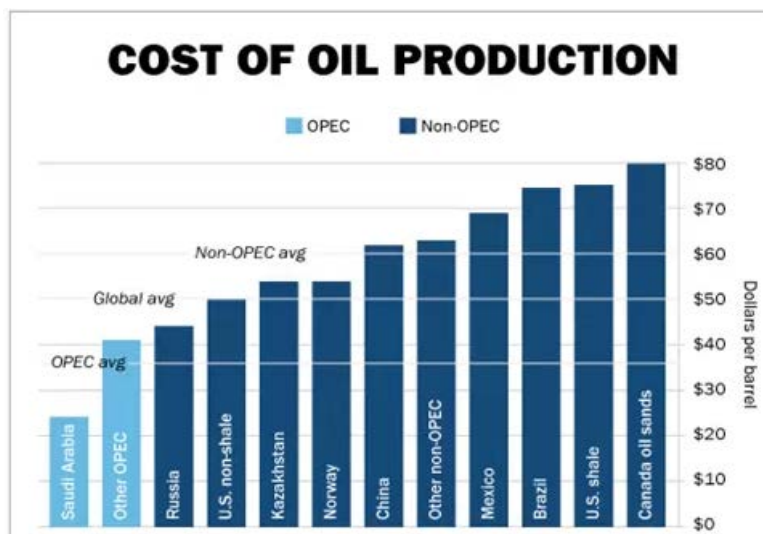
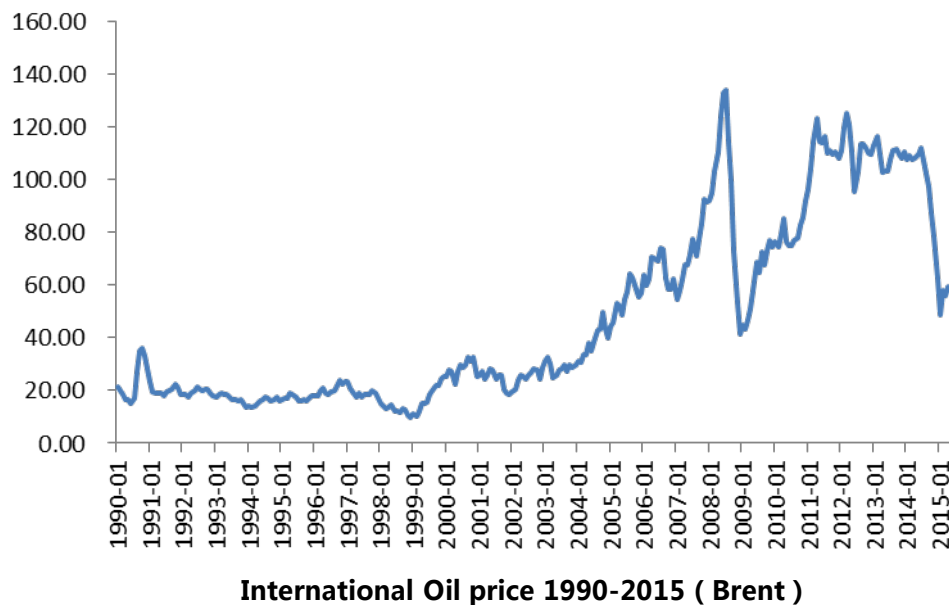
Key Point 1: Coal Chemical profitability is subject to crude oil price fluctuations

- CTL breakeven point **60~70USD**, MTO breakeven point is lower than that of CTL
- Coal accounts for 30% of the total CTL cost, as the price of coal drops so will the CTL product cost
- Fixed asset depreciation accounts for 30% of the total cost, as the economy of scale increases and technology advances the cost will decrease



② Modern coal chemical industry based on clean conversion

- Over the past 20 years, fluctuating as it is, oil price has been generally trending upwards. Most oil producing nations' cost of production is higher than current market values. Many OPEC nations need oil price to stand at **90USD** to balance their fiscal budgets.
- Therefore, oil price will not remain at the current low level in the long run, thus making for a positive market conditions for CTL operations



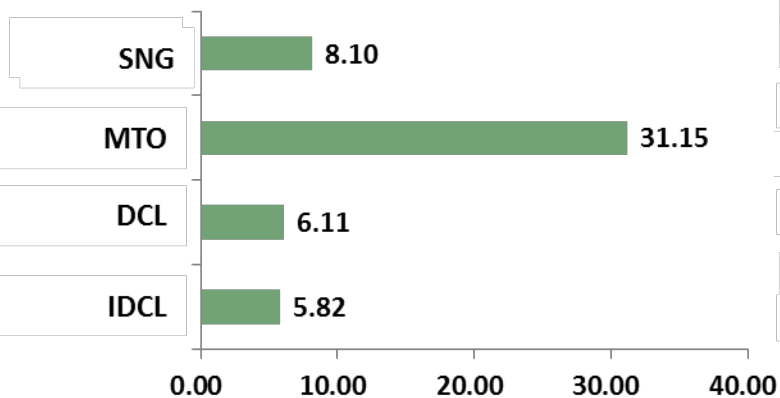
Source: Financial Times

② Modern coal chemical industry based on clean conversion

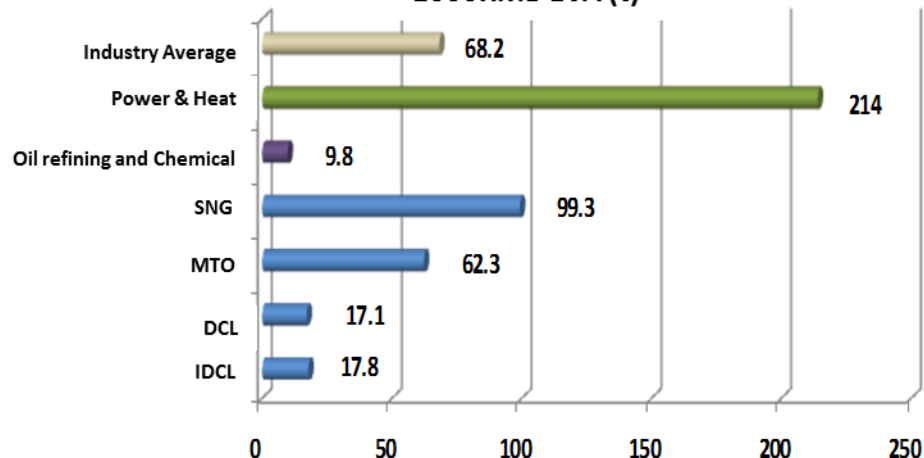
Key Point 2: Coal chemical industry is hobbled by water shortage

- Using water consumption per 10K RMB of EVA as base, DCL water consumption is $\frac{1}{4}$ of industry average. MTO is slightly lower than industry average, while SNG is 1.5X of industry average
- Water shortage is exacerbated by the fact that most coal chemical projects are situated in arid western mining areas.
- As per our calculation, if coal were transported to water-rich eastern regions to get converted there, the production costs would increase **15~20%**, significantly impacting economic value proposition

Water Consumption (tce/t,tce/kNm³)



Water Consumption per 1000RMB EVA (t)



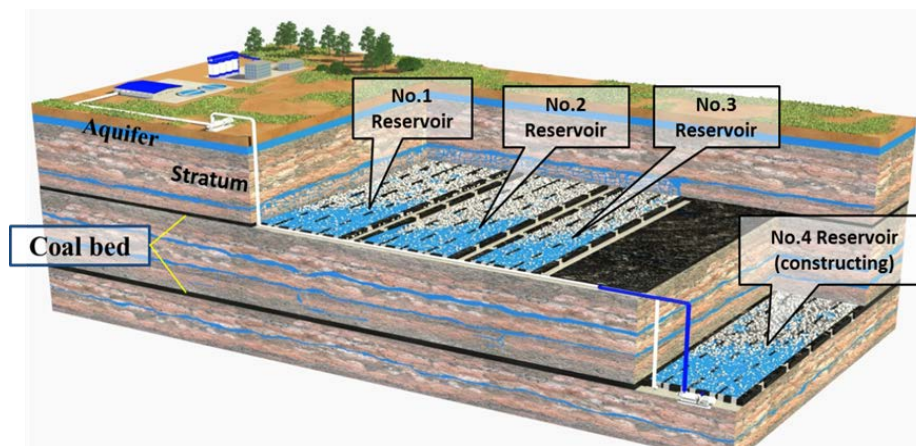
② Modern coal chemical industry based on clean conversion

Overcoming water shortage for Coal Chemical operation

- Improve and innovate processes: enhance reuse, recycle and reduce water demand
- Use mine water and reclaimed water to reduce use of fresh water



Integrated water treatment technologies resulting in water use falling from 10 to 5.3 tons, and zero waste water release

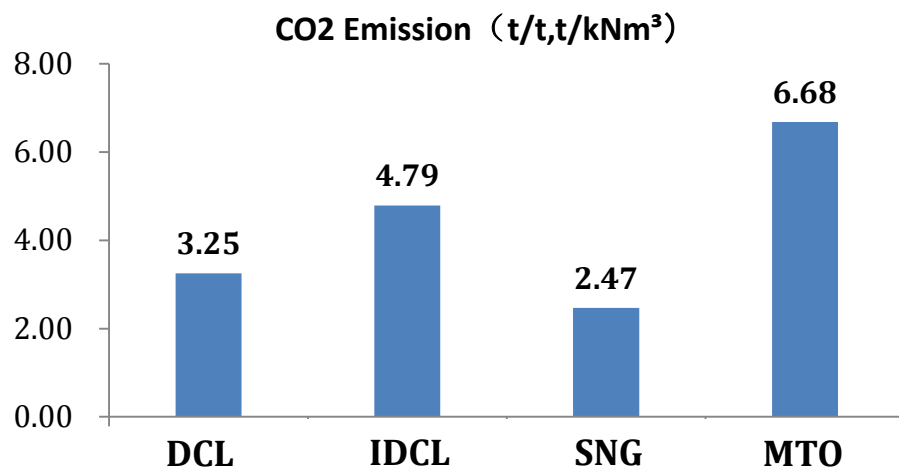


Use coal mine underground reservoir as water supply (35000m³/day)

② Modern coal chemical industry based on clean conversion

Key Point 3: CO₂ emission from coal chemical plants

- Emission from coal chemical plants comes primarily from coal conversion ; therefore, carbon emission intensity is higher than average industrial operations
- Over 50% of carbon emissions are of high concentration, hence cheaper to capture (1/3~1/4 of the capture cost for power plant)
- Shenhua has completed a 100K t/yr CCS demonstration project, fully grasping the technique of CO₂ sequestration in saline aquifer. 300K tonnes CO₂ have been stored.



Shenhua's CCS project

② Modern coal chemical industry based on clean conversion

■ Conclusion and Future Plans

- Clean coal conversion is part and parcel of China's energy mix, serving as a major supplement to petrochemical industry.
- Demonstration projects have proven that modern coal chemical industry can make both **end products** and **processes** pollution-free .
- By 2017 Shenhua will have reached **8million tonnes** of CTL capacity and **3million tonnes** of olefin capacity. By 2020, Shenhua's coal chemical capacity is planned to be able to replace **35million tonnes** of crude oil



Ordos DCL demo project

③ The technique of aluminum and gallium extraction from fly ash

- Aluminum and Gallium extraction from fly ash
- Coal field in Zhungeer Inner Mongolia has more than **4Billion** ton of Al and **860K** tons of Ga: 7X more than the current Al reserve estimate and 80% of global Ga reserve estimate
- Shenhua developed the one-step acid dissolution process which is advantageous for its short process, low emission and low cost. A 4K ton/yr pilot plant constructed.
- Successfully extracted: metal grade Aluminum oxide (**99.35%** pure) , Ga (**99.99%** pure), planning to construct 1M ton/yr Al facility and 100 ton/yr Ga facility



Fly Ash



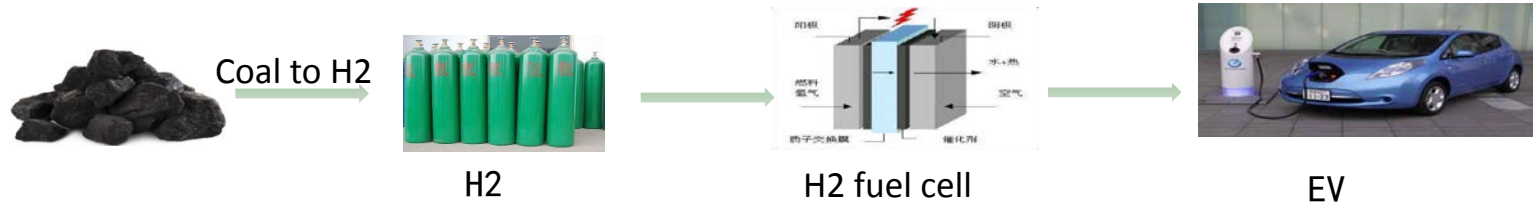
Al and Ga extracted from Fly Ash

④ Hydrogen Technology

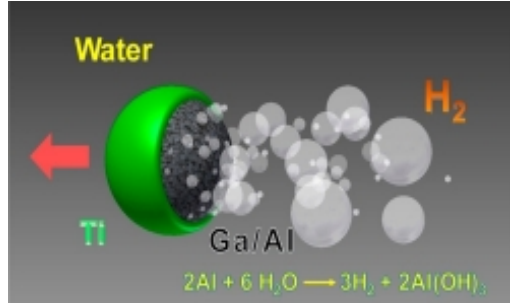
- Coal to Hydrogen is the cheapest way to produce H₂. Shenhua has already started fundamental research in H₂ utilization, particularly hydrogen fuel cell vehicles.

Cost comparison of producing H₂ from different base material

Fuel	Coal	Natural Gas	Dry Air	Heavy Crude
Cost of H ₂ production (¥/m ³)	0.6~0.7	1.21	1.33	1.66



- Ga/Al alloy can produce H₂ directly from H₂O. Combining this chemical reaction with Shenhua's abundant Ga reserve may result in the fuel of the future



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4) Conclusion

Goal: Transition to a world leading clean energy supplier

- Transform coal industry through ultra low emission coal-fired power generation, coal-based chemical upgrades, realizing high-value low-pollution use of coal
- Comprehensive approach to investing in new energy, novel materials: a foundation for future growth for Shenhua
- Scale up R&D efforts and work cooperatively with other solution providers in clean energy



4) Conclusion

Rely on Innovation to support Shenhua's transformation

- Leverage four critical elements: strategy, investment, integration and commercialization
- Leverage internally developed core technologies to provide clean energy solutions





Thank You