

Research on the competitiveness and development strategy of china's modern coal chemical industry

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Abstract. China's modern coal chemical industry has grown into a certain scale after over a decade of development, and remarkable progress has been made in key technologies. But as oil price collapsed since 2015, the economic benefit of the industry also slumped, with loud controversies in China over the necessity of modern coal chemical industry. The research believes that the modern coal chemical industry plays a positive role in the clean and sustainable exploitation of coal in China. It makes profit when oil price is no lower than \$60/bbl, and outperforms petrochemical in terms of cost effectiveness when the price is between \$60/bbl and 80\$/bbl. Given the low oil price and challenges posed by environmental protection and water restraints, we suggest that the state announce a guideline quickly, with adjusted tax policies and an encouragement to technological innovation, so that the modern coal chemical industry in China can grow sound and stable.

1. Introduction

A rich deposit of coal and a relatively small deposit of oil and gas are the characteristics of China's resource endowment. During the 11th Fifth-Year Plan and the 12th Fifth-Year Plan (2006-2015), as the global oil price remained high, the Chinese government started a series of modern coal chemical demonstration projects focusing on chemical products from energy commodities, with a view to ensure national energy security, accelerating the process of raw material diversification and fostering new growth areas. Currently a series of demonstration projects are already up and running, including coal to oil, coal to gas, coal to olefins and coal to ethylene glycol. Some of them are already in commercial operation, leading the global industry in terms of technological innovation and industrial production. The growth of the industry has become a major highlight of China's energy and chemical sector during the 12th Five-Year Plan (2010-2015).

Since 2015, global oil price collapsed while China's economic growth slowed down to a medium-to-high speed with less demand for energy and chemical products. This led to massive profit losses in China's modern coal chemical projects, as the heated industry cools down and pessimism rises up. Hence, it is crucial to understand the significance of the coal chemical industry, to realize its problem and analyze its economic benefits when determining the positioning and development path of the industry.

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2. Progressing China's modern coal chemical industry

2.1. The Industry has formed scale

Modern coal chemical projects such as coal to oil, coal to olefins and coal to gas now have completed industrial procedure, with their scale continuing to grow and the industrial layout starting to form. The demonstration projects of coal to oil and coal to olefins are able to operate stably over a long term, manifesting superior technology and economic benefits to traditional coal chemical industries.

Table 1. Scale of China's modern coal chemical industry in 2015

Category	Coal Chemical Productivity	Coal Chemical Output	Petrochemical Output	Import	Apparent Consumption	Proportion of Coal Chemical Productivity
Refined Oil (1,000 t)	2630	1193	297141	4675	301816	0.54%
Natural Gas (10 million m3)	310	85	12077	5981	18059	1.72%
Olefins (1,000 t)	4680	1470	35790	27740	65000 equivalent	7.26%
Ethylene Glycol (1,000 t)	1500	580	3900	7870	12350	12.15%

(Investigated and calculated by Shenhua Science and Technology Research Institute)

2.2. Products not Easily Produced in the Petrochemical Industry are Obtained

Oil products of direct coal liquefaction has low condensation point, large specific gravity and high calorific value. It is suitable for military or aerospace use and is a special oil product with promising military prospects. In 2014, simulation testing and the first testing flight were held for coal-based jet fuel. In 2015, hot commissioning of missile diesel engine burning coal-based fuel was conducted, and diesel with a super-low condensation point was sent to cold areas like the South Pole and Mohe for trial use. Oil products of indirect coal liquefaction have a high cetane number (above 70) and could serve as a clean additive to oil. Once mixed with normal diesel, the additive could raise the grade of the oil (Guo V or Guo VI) and significantly cut pollutants in car exhausts, and it has already been used during the APEC summit in Beijing with good results. In addition, direct coal liquefaction and indirect coal liquefaction have a strong complementarity, forming a special category of coal-based oil products.

2.3. Constantly improving the level of clean and efficient utilization

Due to the characteristics of its raw materials, modern coal chemical projects consume relatively more resources and energy than the petrol approach. During the 12th Five-Year Plan", on the basis of complete procedures, the consumption of energy and water had been constantly reduced through technical and managerial improvement. (Figure 1, 2).

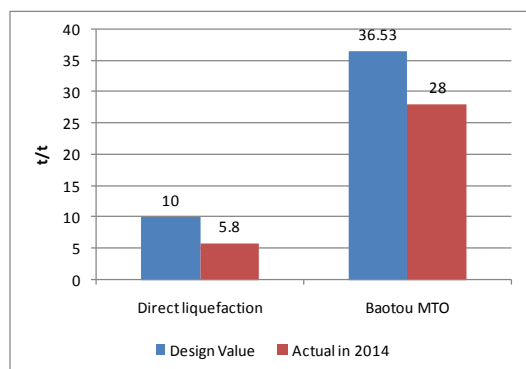


Figure 1. Consumption of water in coal chemical projects. (Provided by Shenhua Erdos and Shenhua Baotou CO. LTD.)

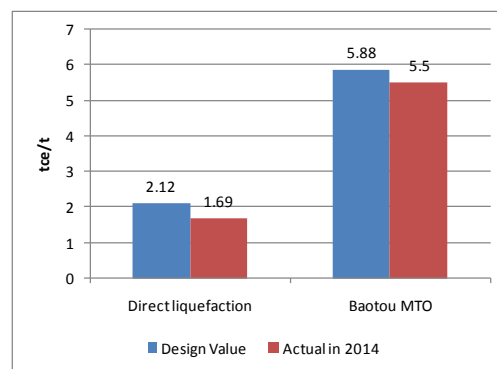


Figure 2. Consumption of energy in coal chemical projects. (Provided by Shenhua Erdos and Shenhua Baotou CO. LTD.)

3. Ten years of demonstration as a testimony to the necessity of developing modern coal chemical industry in china

3.1. Developing modern coal chemical industry to compensate for the lack of basic resources

China's rich-coal and poor-oil endowment results in a weak guarantee of oil and gas, unable to ensure sustainable supply, with obvious resource restraints (Table 2).

Table 2. Known reserves of major traditional primary energies (2014) [1]

Energy	Deposit	Global Share	Deposit-Production Ratio
Oil	18.5 billion bbl	1.1%	11.9
Gas	3.5 trillion m3	1.8%	25.7
Coal	114.5 billion t	12.8%	30

China's dependence on external oil and gas has increased over the years (Figure 3). 50% of imported oil is from the politically unstable Middle East, and 70% has to go through the Malacca Straights. Gas is principally imported from Asian countries with a high premium. Hence there is risk in the importation of oil and gas[2].

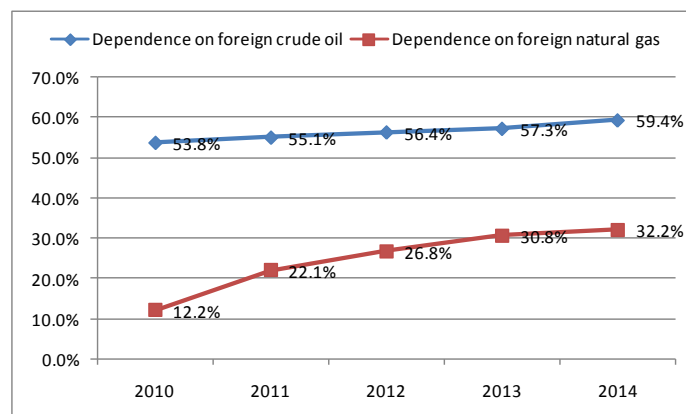


Figure 3. China's external dependence in oil and gas ^[2]

Modern Coal Chemical Industry led by chemical products from energy commodities aims at replacing oil and gas, directly or indirectly by coal, relatively rich in deposit in China. It is a practical and feasible energy development path that is in line with China's fundamentals.

3.2. Developing modern coal chemical industry for clean use of coal

Coal burning has a relatively low efficiency and creates high pollution. The real thermal efficiency of coal burning furnaces in China is 15% to 20% lower than that in advanced countries[3]. China's total emission of pollutants like SO₂ and NO_x, as well as CO₂ all rank the first in the world[4][5]. PM10 density is four to five times the WHO normal[6]. Among all the causes the burning of coal is certainly a principal one.

Modern Coal Chemistry turns complex and “dirty” raw material into high-quality and clean oil products and chemicals, and is an important approach to use coal both as energy and as resources. Based on the gasification of coal, modern coal chemical projects turn coal into gas by adding pure oxygen in a reducing environment, while the nitrogen largely becomes nitrogen gas and ammonia with virtually zero nitrogen oxides. Sulfur in coal is reduced to hydrogen sulfide, which then turns into sulfur or sulfuric acid through multiple-stage Claus reactions, recovering more than 99.9% of sulfur. Only some furnaces emit a small amount of sulfur dioxide, while the emission of air pollutants (SO₂, NO_x) in coal to oil plants is about one fifth to one tenth of that of traditional thermal plants. The process emits almost no dust or smoke with most of the dust captured in a liquid phase. During the process some carbon is fixed in the products while some turns into carbon dioxide. The waste air is dense with CO₂ (87%-99%) which is easy to capture and store. Most of the mercury in coal enters coal ash water, and the emission of mercury into the air is extremely low.

3.3. Developing modern coal chemical industry for the transformation of the coal industry

According to BP energy analysis, the share of China's coal consumption will decline from 68% in 2012 to 52% in 2035, with the actual consumption being largely equal to the present and coal remaining the dominant form of energy[7]. But due to the impact of shrinking downstream demand, China's coal industry has been declining for more than three years. By the end of 2015, coal production registered negative growth for the second year (Figure 4).

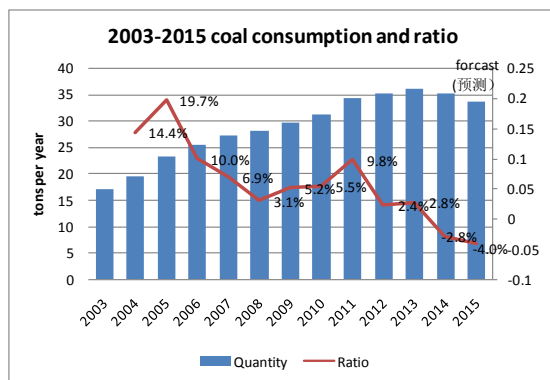


Figure 4. Dynamics of China's coal production (National Bureau of Statistics Department)

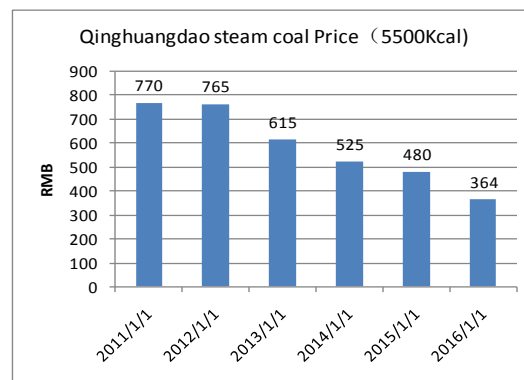


Figure 5. Dynamics of Qinghuangdao steam coal price (China Coal Resource Network)

Coal price has dropped significantly (Figure 5). 80% of the industry was in losses in the first ten months of 2015. The market condition has been so severe that it forces the industry to reform. Modern coal chemical projects are an effective way to extend the traditional industrial chain, with large investment, high value-added and high tax per ton of products. Developing modern coal chemical industry can effectively boost regional economic growth and help big producing provinces and coal companies improve and upgrade their structure. It has good economic benefits when oil price is moderate, and is a way of transformation and upgrading of coal companies.

3.4. Developing modern coal chemical to fill the structural shortage of the petrochemical industry

China has an oil refinery capacity of over 750 million tons with 200 million tons' glut, while ethylene, propylene, paraxylene and other chemical commodities are in short supply. In 2014, China relies on import for 51% of ethylene, 33% of propylene and 52% of paraxylene[8]. China became a net importer of naphtha[9] in 2009 with an increasingly sharp shortage, which amplified the lack of supply of commodities such as ethylene and propylene. By diversifying raw materials and approaches through modern coal-based chemical industry is an effective way of breaking the resources bottleneck and enhance the global competitiveness of primary products.

In addition, the improvement of oil quality also calls for diversified raw materials and approaches. With a higher content of alkenes and arenes, the current oil products in China do not compare well with Europe or the US. The upgrading of existing refineries is circumscribed by many factors[10][11][12], unable to fully realize oil upgrading to meet Euro VI standards.

Coal-based oil has a low content of sulfur, nitrogen, arenes and a low condensation point. It is a very clean fuel which can meaningfully reduce emissions of particle matters and promote high oil quality at a lower cost.

4. Economic competitiveness analysis of china's modern coal chemical industry

4.1. Breakeven analysis of modern coal chemical industry

The result of demonstration project operation suggests that when oil price is no lower than 60 dollars, modern coal chemical projects could generally stave off losses; when oil price is no less than 80 dollars, they could generally reach the benchmark earnings rate of the industry (11% pre-tax); if calculated using the lower limit for activating oil price adjustment set by the NDRC (40 dollars per barrel), the projects will suffer some losses. Below are the calculations.

Table 3. Economic competitiveness analysis of modern coal chemical projects

Item		Breakeven Point (\$, Brent)	Benchmark Earnings Rate (\$, Brent)	Losses Incurred at \$40/bbl (Yuan)
Coal to Oil	DCL	55-60	75-80	500-700
	ICL	60-65	80-85	600-800
	Coal Tar	60-65	75-80	600-800
	Hydrogenation	45-50	70-75	0-200
Coal to Chemicals	Olefin	50-55	75-80	300-500
	Glycol	55-60	80-85	500-700
	Arènes			

Note: On Jan 13, 2016, the NDRC of China finalized the bottom line of 40 dollars per barrel of oil, below which no further adjustment will be made to the price of oil products. (Calculated by Shenhua Science and Technology Research Institute CO. LTD.)

4.2. Competitiveness of modern coal chemical industry relative to petrochemical

In the area of 80 dollars per barrel, overall cost of coal oil would be lower than that of petroleum oil by 1300-1800 Yuan per tonne of products; profit margin would be higher by 1000-1300 Yuan per tonne under China's existing taxation system; and net profit would still be higher than that of petroleum oil by 400-700 Yuan per tonne. (Figure 6).

In the area of 60 dollars per barrel, overall cost of coal oil would be lower than that of petroleum oil by 200-600 Yuan per tonne of products; profit margin would be higher by 230-300 Yuan per tonne. Because coal oil pays more tax than petroleum oil, net profit of coal oil would be lower than that of petroleum oil by 130-310 Yuan per tonne. (Figure 7)

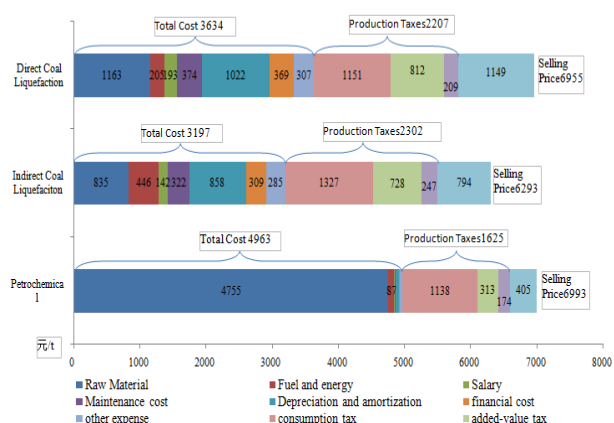


Figure 6. Coal to Oil vs. Petroleum Refinery in Economic Terms (at around \$80/bbl)

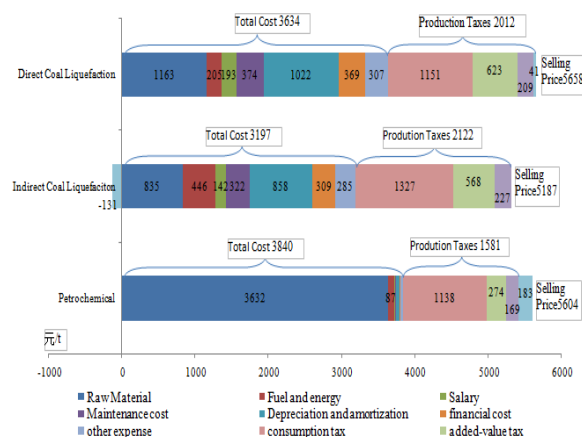


Figure 7. Coal to Oil vs. Petroleum Refinery in Economic Terms (at around \$60/bbl)

In the area of 80 dollars per barrel, overall cost of olefin production from coal would be lower than that from petroleum by 2,160 Yuan per tonne; profit margin higher by 2,000 Yuan per tonne; and net profit higher by 860 Yuan per tonne. (Figure 8)

In the area of 60 dollars per barrel, overall cost of olefin production from coal would be lower than that from petroleum by 260 Yuan per tonne. Because coal-derived olefins pay an extra 570 yuan per tonne in tax, net profit of olefin production form coal is lower than that from petroleum by 300 Yuan per tonne. (Figure 9)

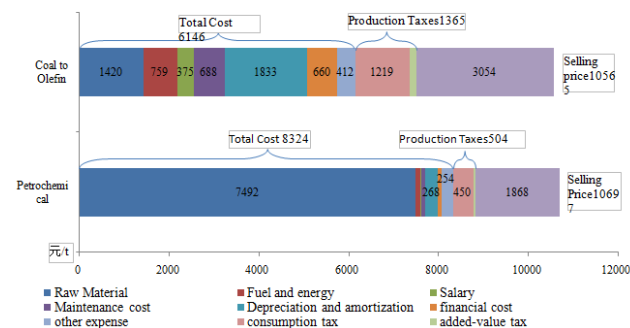


Figure 8. Coal vs. petroleum in production of olefins in economic terms (at around \$80/bbl)

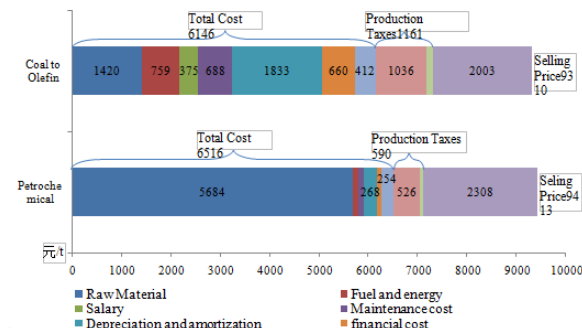


Figure 9. Coal vs. petroleum in production of olefins in economic terms (at around \$60/bbl)

4.3. Prediction of global oil price

Many factors influence global oil price, including global economic growth, balance of supply and demand of oil, oil reserves, exploitation of non-traditional oil and gas, development of new energy, balance of payments of oil producers and geopolitics. So far, many institutions have predicted the oil price during the 13th Five-Year Plan (2015-2020), as shown in Table 4.

Table 4. Estimates by different institutions of global oil price during the 13th five-year plan (\$/bbl)

Institution	Time of Announcement	2016-2017	2017-2020
IEA	December 2015	60-70	70-80
EIA	October 2015	53-62	80
BP	November 2015	<60	<60
Morgan Stanley	September 2015	45-65	75-85

In conclusion, oil price is likely to fluctuate at a low level during the 13th Five-Year Plan, which will probably move around 60 dollars per barrel in 2016-2017 and rise moderately to 70-80 dollars per barrel in 2017-2020.

5. China's modern coal chemical industry faces many challenges in development

5.1. Industrial competitiveness is affected by low oil prices and high taxes

The world economy is still in deep transition with deep uncertainty in growth. In 2015 Brent Oil fell to 57 dollars per barrel and below 40 dollars in the second half of the year. Coal to olefins fell below its breakeven point, and coal to oil and coal to ethylene glycol operate at losses. With basic energy price falling, the Middle-East and North American countries will move faster from oil and gas production to chemical export, adding to the risk of fluctuation in the energy and chemical markets and a fiercer competition. In addition, the overweight tax burden seriously impacts on production and operation of the enterprises (as shown in Table 5). At present, the consumption tax on diesel oil is up to ¥1411.20 / ton (\$214.31), the consumption tax on naphtha is up to ¥2105.20 / ton (\$319.70), the comprehensive tax burden is close to 50%.

Table 5. Effect of consumption tax on the economic benefit of coal to oil

Item	IRR (before tax)				
	40 \$/bbl	50 \$/bbl	60 \$/bbl	70 \$/bbl	80 \$/bbl
Full amount	-4.0%	-0.5%	3.1%	9.5%	13.3%
Free of consumption tax	0.3%	4.2%	6.1%	12.4%	16.3%

Note: The benchmark IRR (before tax) of the project is calculated by 11%.

5.2. Controversies exist around environmental protection

China's Modern Coal Chemical Industry is largely located in the western regions, where ecology is fragile with prominent conflict between industrial development and environmental protection. Treatment of waste water is the key issue facing the industry. Many pilot projects are working hard on key technologies in waste water treatment and improving environmental facilities, but so far the treatment of waste water with a high concentration of salt still remains a problem, and the treatment cost of high-concentration organic waste is too high to make companies profitable.

5.3. Restraints of Water Resources Become Prominent

At present, China's modern coal chemical industry uses a huge amount of water, with 6 million tons of water use for million-tonne class oil projects, 20 million tons for 600 thousand-tonne olefin projects, and 10 million tons for 1.3 billion cubic-meter gas projects. The projects largely being located in Mid-West China where water resource is scarce and the ecology is weak further intensifies the restraints on the development of the industry.

6. Suggestions on the Development of China's Modern Coal Chemical Industry

6.1. Modern Coal Chemical Industry Urgently Needs a National Guideline

Over a decade, China's policy on modern chemical industry, while regulating the growth of the industry, had problems such as unclear planning, inconsistency, and multi-head administration. The underlying reason of the problems is that there has neither been a national guideline nor a strategic positioning for the industry.

I participated in the initial research of the *Plan on Deep Processing of Coal during the 13th Five Year for NEA* and I believe that the formulation and release of a plan on the development of modern coal chemical industry, which sheds light on the strategic positioning and development path for coal to oil, coal to gas and coal to chemical, will be conducive to gradually constructing a healthy, scientific

and orderly environment in which the market takes the lead in allocating the resources, and will provide the necessary basis to competent authorities for drawing up specific industrial policy.

6.2. By exploring a reasonable tax system and reducing the cost to deal with low oil prices

First, The Coal-to-Oil Industry Needs an Appropriate Taxation Regime. Consumption tax levied with a reference to the petrochemical industry is not in accordance with the features of coal to oil, preventing the industry to grow in a sound and scientific way. The taxation structure at present aggravates the burden of companies and retards the growth and technological progress of the industry. Coal to oil industry should be allowed to enjoy differential low tax policies, namely reduced or exempted consumption tax for oil products and differential VAT and income tax support policies, so as to cushion the blow by oil price slump to the coal-to-oil industry and ensure sound growth. Subsequently, by optimizing the process design and utilities system, to further reduce the production cost. During the 13th Five Year period, the project breakeven point reduced 10 \$/bbl compared to the current.

6.3. Industrial upgrading and demonstration are needed during the 13th five-year plan

The 13th Five-Year Plan (2016-2020) is a good window for solving the problems of competitiveness, environmental protection and water resource restraints in modern coal chemical industry through industrial upgrading and demonstration projects.

Processes need to be improved to integrate more technology. Ways to reduce cost and increase efficiency need to be explored. We should further lower project cost and increase competitiveness through systemic integration, process optimization and managerial improvement.

Water conservation should be strengthened in processes and systems. Water pinch technology and refined management of water systems are introduced to improve water balance in the whole system. We use coal mine drainage and recycled water first, separate different waste water in procedures, separate clean water from dirty water, and treat wastes separately and differently so as to maximize the use of water resources.

We should actively research and apply advanced processes and technology with a high energy transformation rate and low pollutant emission, ensuring that appropriate coal is used with specific technology and equipment, to improve response to irregular conditions and reduce pollutant emission at the source. Treatment of high-concentration organic waste water and recycling of different salts should be applied in demonstration projects to address the problems in waste water discharge.

Given the high concentration of carbon dioxide in gas emission from modern coal chemical industry, we should explore embracing IGFC advanced generation system, CCS and EOR, and engage in developing forest carbon sinks.

6.4 Appropriate demonstration projects can be started in eastern china

In China, energy chemical industry represented by petrochemicals is largely located in Eastern China (Figure 10), with a clear coastal layout[13].



Figure 10. Seven petrochemical bases in China petro-chemical industry layout scheme



Figure 11. China's Modern Coal Chemical Bases China Coal Chemical Industry 13th Five-Year Plan

China's modern coal chemical industry is mainly concentrated in the mid-west (Figure 11), similar to the pattern of its coal resource distribution. During the 13th Five-Year Plan, we suggest that coal chemical demonstration projects could be tentatively started in eastern regions rich in oil and gas, water and chemical resources so as to circumvent the environmental and water restraints the industry facing in western regions.

Many problems facing the modern coal chemical industry are transitional, which could be gradually solved during the 13th Five-Year Plan through upgrading and demonstration.

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