

**News and Highlights****Coal-to-Oil: China has Successfully Realized Large-Scale Industrial Production**HAO Ziguo<sup>1,2,\*</sup>, FEI Hongcai<sup>1,2</sup>, HAO Qingqing<sup>3</sup> and LIU Lian<sup>1,2</sup><sup>1</sup> Chinese Academy of Geological Sciences, Beijing 100037, China<sup>2</sup> Editorial Office of Acta Geologica Sinica (English Edition), Geological Society of China, Beijing 100037, China<sup>3</sup> Editorial Office of Geology and Exploration, Institute of Mineral Resources Research, China Metallurgical Geology Bureau, Beijing 101300, China

Statistics have shown that the world's proven recoverable coal reserves are 984.211 billion tons, including 246.643 billion tons in the USA, 157.01 billion tons in Russia, 114.5 billion tons in China, 90.4 billion tons in Australia, 74.733 billion tons in India, 67 billion tons in Germany, 55.333 billion tons in South Africa, 34.356 billion tons in Ukraine, 34 billion tons in Kazakhstan, 14.309 billion tons in Poland and 11.950 billion tons in Brazil. Coal resources account for 25% of the world's energy consumption structure, and play a critical role in global economic development.

In 2015, China consumed 3.95 billion tons of coal (including 3.75 billion tons of self-production and 0.2 billion tons of imports), 0.543 billion tons of oil (0.215 billion tons of self-production; 0.328 billion tons imports) and 196.4 billion m<sup>3</sup> of natural gas (135 billion m<sup>3</sup> of self-production; 61.4 billion m<sup>3</sup> imports). Among the proven recoverable reserves, coal occupies 72.7%, oil 5.9% and natural gas 1.4%. The coal consumption, which accounts for 70% of China's primary energy consumption, has remained essentially unchanged in recent decades.

According to the data from the U.S. Energy Department, the USA produced 0.567 billion tons of oil and consumed 0.852 billion tons of oil in 2015. In same year, the USA produced 767.3 billion m<sup>3</sup> of natural gas and consumed 778 billion m<sup>3</sup>; it produced 0.89 billion tons of coal and consumed 0.636 billion tons. Coal resources accounted for 16% of the USA energy consumption structure in 2015.

In 2012, the Chinese Ministry of Land and Resources announced that China had 3.24 billion tons of remaining recoverable oil reserves and 114.5 billion tons of coal. Based on these predictions and China's annual consumption, it is inferred that China's oil will last for another six years and coal mined for 29 years.

The above data are indicative of China's energy resource reality of much coal and little oil, which urges

Chinese scientists to concentrate on the deep development and utilization of coal, and, as a result, the conversion of coal to oil has long been pursued.

As early as in 2008, China announced a draft of "The Long-Term Development Plan of Coal Chemical Industry", and proposed that China would produce 30 million tons of coal-to-oil, 660 million tons of coal-to-methanol, 20 million tons of coal-to-dimethyl ether and 8 million tons of coal-to-olefine, with an accumulative coal demand of 0.252 billion tons for the coal chemical industry.

On December 21<sup>st</sup>, 2016, the 400 t/a coal-to-oil production equipment from the Shenhua Group of the Ningdong coal chemical industry base in Ningxia was put into production, which marks the beginning of large-scale coal-to-oil production in China.

Statistics show that a total of five coal-to-oil projects had been put into operation in China until 2016, i.e., the Ningxia project just noted with production of 4 million t/a, the Ordos project of the Shenhua Group with production of 180000 t/a, the Yitai project with production of 0.16 million t/a, the Lu'an project with production of 0.16 million t/a, and the Xianfeng coal-to-oil project in Yunnan with production of 0.20 million t/a. At present, there are ten projects under construction, with a total capacity of 14.25 million t/a (Table 1).

China has three more coal-to-gas projects put into production, i.e., the Hexigten Banner project of the Datang Corporation with production of 1.33 billion m<sup>3</sup>/a, the Ordos project of Huineng Group in Inner Mongolia with production of 0.4 billion m<sup>3</sup>/a, and the Yili project of Kingho in Xinjiang with production of 1.375 billion m<sup>3</sup>/a. Another six projects are under construction, with a total capacity of 18.4 billion m<sup>3</sup>/a. The total coal-to-gas capacity is expected to reach up to 126.8 billion m<sup>3</sup> by 2020.

Till now, there are nine coal-to-olefin projects in operation. Among these, the Shenhua Group Baotou coal-to-olefin project is the most successful, with annual production of 0.6 million tons. In addition, there are 29 projects under construction in China, with a total capacity

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**Table 1 List of China's proposed coal-to-oil projects and those under construction**

| Location                                        | Company name                                           | Capacity (t/a)                                                                                                                     | Progress                                                 | Coal-to-oil technology                                          |
|-------------------------------------------------|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|-----------------------------------------------------------------|
| Ordos in Inner Mongolia                         | Yitai Group                                            | Demonstration device with production of 0.16 million tons of coal-to-oil                                                           | In operation                                             | Indirect liquefaction technology of Synfuels China              |
| Ordos in Inner Mongolia                         | Yitai Group                                            | Annual production of 5.40 million tons of coal-to-oil, with 3.60 million tons of production during the first phase of construction | Preliminary work                                         | Indirect liquefaction technology of Synfuels China              |
| Ordos in Inner Mongolia                         | Yanzhou Coal Mining Company                            | Annual production of 1.10 million tons of coal-to-oil                                                                              | Preliminary work                                         | Indirect liquefaction technology of Yanzhou Coal Mining Company |
| Ordos in Inner Mongolia                         | Shenhua Group                                          | Demonstration device with production of one million tons of coal-to-oil                                                            | In operation                                             | Direct liquefaction technology of Shenhua Group                 |
| Ordos in Inner Mongolia                         | Shenhua Group                                          | Demonstration device with production of 0.18 million tons of coal-to-oil                                                           | In operation                                             | Indirect liquefaction technology of Synfuels China              |
| Yulin in Shaanxi                                | Yanzhou Coal Mining Company / Yanchang Petroleum Group | Annual production of one million tons of coal-to-oil (the first phase)                                                             | In operation                                             | Indirect liquefaction technology of Yanzhou Coal Mining Company |
| Changzhi in Shanxi                              | Lu'an Group                                            | Demonstration device with production of 0.16 million tons of coal-to-oil                                                           | In operation                                             | Indirect liquefaction technology of Synfuels China              |
| Changzhi in Shanxi                              | Lu'an Group                                            | Annual production of 5.40 million tons of coal-to-oil                                                                              | Trial production of 1.80 million tons                    | Indirect liquefaction technology of Synfuels China              |
| Jincheng in Shanxi                              | Jincheng Anthracite Mining Group                       | Demonstration device with production of 0.10 million tons of methanol-to-gasoline                                                  | In operation                                             | MTG technology of Exxon Mobil                                   |
| Jincheng in Shanxi                              | Jincheng Anthracite Mining Group                       | Annual production of one million tons of methanol-to-gasoline                                                                      | Under construction                                       |                                                                 |
| Urumqi in Xinjiang                              | Shenhua Group                                          | Annual production of three million tons of coal-to-oil                                                                             | 0.68 million tons in the first phase, under construction | Indirect liquefaction technology of Synfuels China              |
| Heishan in Xinjiang                             | Shenhua Group                                          | Annual production of 3.20 million tons of coal-to-oil                                                                              | Preliminary work                                         |                                                                 |
| Yili in Xinjiang                                | Yitai Group                                            | Annual production of 5.40 million tons of coal-to-oil                                                                              | Being planned                                            | Indirect liquefaction technology of Synfuels China              |
| Altay in Xinjiang                               | Guanghui Group in Xinjiang                             | Annual production of 3.60 million t/a, with 1.80 million tons of production in the first phase                                     | Preliminary work                                         |                                                                 |
| Ningdong coal chemical industry base in Ningxia | Ningxia Coal Group, Sasol Company                      | Annual production of 400 tons of coal-to-oil                                                                                       | In production                                            | Indirect liquefaction technology of SASL                        |

of 22.89 million t/a. There are also nine coal-to-glycol projects in operation and 11 other facilities under construction, with a total capacity of 2.87 million tons. For converting coal to aromatic hydrocarbons, the Yuheng Company in Shaanxi of the Huadian Corporation is now in a 10000-ton class industrial test stage, with two sets of 0.1 million ton instruments under construction.

However, there is still controversy and misunderstanding of China's coal-to-oil projects.

(1) Immaturity of technology. Converting coal to oil is mainly direct liquefaction and indirect liquefaction, both of which have good transformation effects, with comprehensive energy efficiency of up to 45.9%. In addition, China has formed its own set of technical systems and an equipment manufacturing capacity greater than 85%.

(2) Uneconomic cost. In theory, the production of one ton of coal-to-oil requires about five tons of coal, and the production of 1000 m<sup>3</sup> of coal-to-gas requires about three tons of coal. In contrast, the one million t/a coal-to-oil project in Yulin, Shaanxi, which was built jointly by the Yanzhou Coal Mining Company and Yanchang Petroleum Group, can produce one ton of oil by consuming 3.441 tons of coal, with notable economic efficiency. Statistics show that the coal-to-oil cost of the whole industry is

about \$40 per barrel oil, such as the Yulin project at coal-to-oil cost of about \$37 per barrel oil in May of 2016, which is roughly the same as the current world oil prices.

(3) Serious waste of water resources. In theory, the production of one ton of coal-to-oil needs to consume 10–15 tons of water, and the production of 1000 m<sup>3</sup> of coal-to-gas requires 6 tons of water. Water resources are a bottleneck which restricts the realization of converting coal to oil. At present, the one million t/a coal-to-oil project in Yulin, noted above, needs 2.68 tons of water to produce one ton of oil; the water reuse rate reaches up to 98.26%, which has generally solved the problem of water waste.

(4) CO<sub>2</sub> emission. The CO<sub>2</sub> emission of one ton of coal-to-oil is 4.5–5.0 tons. If the coal-to-oil production reaches 100 billion m<sup>3</sup> in the future, the annual increase of CO<sub>2</sub> will be about 0.5 billion tons. At present, China has mature technology to use CO<sub>2</sub> to produce industrial dry ice and to enter CO<sub>2</sub> into the underground through the chemical reaction to form calcium carbonate.

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