Research on Energy Conservation for Industry in China

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Abstract. The period of "the 13th Five-Year Plan" will be a decisive stage to build the moderately prosperous society and achieve the first “Centenary Goal”, and a critical period to promote overall economic transformation and upgrading and embark on the new industrialization road. New development stage and idea will have a profound influence on Chinese economy, society and culture, from which a comprehensive and profound transform is being fostered. Building the modern, high-end and low-carbon industrial development pattern in line with Chinese benefits should be necessary to create the economically-upgrading and industrially-transformed development in China. Industry, as the most important department for energy consumption in China, has been the priority for promoting energy consumption reform and energy conservation and emission reduction in China. How to make further progress by virtue of transformation development of the industry is also an important proposition to be faced.

1. Introduction

As the important mainstay industry of Chinese economy and the most important field of energy consumption, industry has been the essence of energy conservation and emission reduction[1]. The energy consumption characteristics of the industry sector in China, energy conservation and emission reduction progress and main policies will be reviewed in this section to provide the research basis for energy consumption reform and energy conservation and emission reduction in China.

1.1. Industry is the most important energy consumption sector in China

Industry is the most important energy consumption sector in China, and the industrial energy consumption always keeps at about 2/3 of the national total energy consumption. Since 2000, the industrial urban progress has been sped up with the constant high-speed economic development, and GDP is grown up by almost 10% averagely[2]. Correspondingly, the total energy consumption was steadily increased to 4.17 billion tce in 2013 from 1.47 billion tce in 2000, with the annual average growth rate as 8.4%. During the same period, the annual industrial added value growth and the industrial energy consumption growth were 10.5% and 8.6% respectively, and the industrial energy consumption is grown up at 8.6% averagely (see Figure 1). In 2013, the energy consumption of the industrial sector was 2.79 billion tce in 2013, accounting for 66.8% of the national total energy consumption, with an increase of 0.4% compared with 2001.
From the perspective of energy consumption elasticity coefficient, not only GDP and the industrial added value but also total energy consumption and industrial energy consumption were increased at high speed during "the 11th Five-Year Plan", while the energy consumption growth was lower than the economic growth. This changes the situation in which the energy consumption elasticity coefficient is greater than 1 during "the 10th Five-Year Plan", with the average energy elasticity coefficient as 0.58 and the industrial energy elasticity coefficient as 0.5. [3,4] Since "the 12th Five-Year Plan", with the fall of economic growth and energy consumption growth, the annual growths of national total energy consumption and industrial energy consumption had dropped to about 5% between 2011 and 2013, and the energy elasticity coefficient and the industrial energy elasticity coefficient were 0.58 and 0.56 respectively (see Table 1).

Table 1. Energy Consumption Elasticity Coefficients between 2000 and 2013.

| Year | Total energy consumption growth rate | Growth rate of GDP | Energy elasticity coefficient of GDP | Industrial energy consumption growth rate | Industrial added value growth rate | Industrial energy consumption elasticity coefficient |
|------|------------------------------------|-------------------|--------------------------------------|------------------------------------------|-------------------------------|--------------------------------------------------|
| 2001 | 5.8%                               | 8.3%              | 0.70                                 | 6.6%                                     | 8.7%                          | 0.76                                             |
| 2002 | 9.0%                               | 9.1%              | 0.99                                 | 9.2%                                     | 10.0%                         | 0.92                                             |
| 2003 | 16.2%                              | 10.0%             | 1.62                                 | 16.7%                                    | 12.8%                         | 1.31                                             |
| 2004 | 16.8%                              | 10.1%             | 1.67                                 | 17.7%                                    | 11.5%                         | 1.53                                             |
| 2005 | 13.5%                              | 11.3%             | 1.19                                 | 14.8%                                    | 11.6%                         | 1.28                                             |
| 2006 | 9.6%                               | 12.7%             | 0.76                                 | 10.0%                                    | 12.9%                         | 0.78                                             |
| 2007 | 8.7%                               | 14.2%             | 0.61                                 | 9.7%                                     | 14.9%                         | 0.65                                             |
| 2008 | 2.9%                               | 9.6%              | 0.31                                 | 2.4%                                     | 9.9%                          | 0.24                                             |
| 2009 | 4.8%                               | 9.2%              | 0.52                                 | 4.8%                                     | 8.8%                          | 0.54                                             |
| 2010 | 7.3%                               | 10.6%             | 0.69                                 | 3.7%                                     | 12.6%                         | 0.30                                             |
| 2011 | 7.3%                               | 9.5%              | 0.77                                 | 10.9%                                    | 10.8%                         | 1.01                                             |
| 2012 | 3.9%                               | 7.7%              | 0.50                                 | 2.0%                                     | 7.9%                          | 0.25                                             |
| 2013 | 3.7%                               | 7.7%              | 0.48                                 | 3.2%                                     | 7.6%                          | 0.42                                             |

Source: (1) National Bureau of Statistics (NBS); China Statistical Yearbook (2015); (2) NBS; National Energy Administration; China Statistical Yearbook (2014);
1.2. Energy-exhaustive industries belong to the focus industrial energy consumption field in recent years.

As the industrial energy consuming subjects, the average energy consumption growth of six energy-exhaustive industries in China has been 10%, higher than 1.4% compared with the average industrial energy consumption growth of 8.6% since 2000, even higher than 20% in 2003 and 2004 since 2008. Affected by the global financial crisis in 2008, the energy consumption growth of the energy-exhaustive industries dropped to 1.8% from 11.1% in 2007. Between 2008 and 2013[5], the energy consumption growth of energy-exhaustive industries was 3%, even lower in addition to 2009 and 2011. The energy-exhaustive industries have always kept at over 70% of the total industrial energy consumption since 2003 (as shown in Figure 2). They kept a steady rising trend essentially between 2003 and 2013, and were 76.3% in 2013.

From the energy consumption variation trends of all main energy-exhaustive industries, energy consumption of steel, nonferrous metal, chemical and building materials increased maximally between 2000 and 2013. In 2013, their energy consumption was 4.0, 3.8, 3.3 and 3.3 times higher than those in 2000; the energy consumption of petrochemistry and paper-making grew slowly, with the increase of only 2 times[6]. On the other hand, the energy consumption of steel, nonferrous metal, chemical and petrochemistry steadily rose between 2000 and 2013, while the consumption of building materials and paper-making reached the peak respectively in 2011 and 2009, and then gradually dropped. In the industrial energy consumption structure of different industries (see Figure 3) between 2000 and 2013, the energy consumption proportion of steel increased to 32.5% in 2013 from 23.9% in 2000, with a rise of almost 9%; the energy consumption of the chemical industry increased to 16.7% from 14.8%, with a rise of almost 2%;[7,8,9] and moreover, the energy consumption proportion growth of building materials and non-ferrous metal was not obvious, while there was a negative growth in energy consumption of petrochemistry and paper-making[10,11].
1.3. The industrial end-use energy consumption structure still focuses on coal.

In the industrial end-use energy consumption structure in China, coal and coke consumption proportions are high, while natural gas consumption is low. In 2013, the total consumption of coal and coke was 52.7% of the industrial end-use energy consumption, while natural gas consumption was only 5.1%. By comparison, the industrial end-use energy consumption structure in China is in contrast to those in the developed countries. The energy consumption of coal and coke generally accounts for no more than 10% of the industrial end-use energy consumption in the developed countries, for instance, only 4% in the USA, and less than 10% in Britain, Japan and Germany, while it is over 50% in China. Instead, the natural consumption is over 50% in most developed countries, but just over 5% in China. By contrast, the industrial end-use energy consumption structure in China features “depending on coal” and high carbonization degree obviously.

Based on the consumption proportion variation trends of different kinds of energy, the consumption of raw coal and coke has been half of the industrial end-use energy consumption, for instance, 51.8% in 2001 and 52.7% in 2013. In the past ten years, this proportion has kept on increasing. Due to natural gas supply capacity and price, natural gas consumption in industrial sector has been low, even it was about 3% without change between 2001 and 2010. Since "the 12th Five-Year Plan", large number of industrial enterprises have carried out “coal to gas” to solve the regional environmental pollution problems. In the meantime, the natural gas consumption rose to 5.1% of energy consumption proportion of the industrial sector in 2013 from 3.3% in 2010, but was still different from over 50% in the developed countries. For the power consumption, the electrification was in progress obviously between 2001 and 2013, and the power consumption increased to 21.1% in 2013 from 15.9% in 2001 (see Figure 4).
2. Energy conservation of the industrial sector

China has been the mid-late development stage of the industrialization process. According to the historical experience of the development countries, the proportion of industry to GDP will be stable with a slight decline to make space for development of the third industrial development. Hence, the proportion of Chinese industry will decline gently during the 13th Five-Year Plan and in the future. Considering fusion of industrialization and informatization as well as manufacturing industry and service industry, and the great development opportunity for financial and technical research and development for the Internet economy provided by the Internet, the research group makes the judgment for the industrial added values as shown in Figure 3-10. The proportion of secondary industry to GDP will decline to 42% in 2020 from 47.1% in 2014, in which the industry proportion will decline to 35% in 2020 from 38.3% in 2014.

Within the industrial sector, the traditional and emerging industries will develop differently. Such resource intensive industries as mining, steel and cement will shrink under the dual-directional extrusion of cost and market, and the proportions of their added values will decline apparently. But such labor-intensive industries as food manufacturing, dyeing and textile may step into the intensive and high-end development path, their industrial added values will be elevated, but limited to the market capacity, the proportions of their added values will still fall back slightly. Such manufacturing industries as machinery, transportation and electric equipment, and chemical products with high added values will account for half of the added value of the entire industrial sector based on the data of Japan, Germany, South Korea and the USA. From this, the proportions of these industries will be greatly improved in the future.

Since entering the 21st century, the energy-exhaustive industries have expanded faster in China, and the yields of various energy-exhaustive products have kept going up. As shown in Fig. 3-12, the yields of steel, cement, coal and ethylene in 2014 is 4-6 times higher than those in 2000 in China, and the yield of electrolytic aluminum is even 9 times higher than that in 2000. From 2005 to 2010, the crude steel production in China rose to 637 million tons from 353 million tons, with an annual average growth of 12.5%, and even it is higher than the sum of the first steel yield and the tenth steel yield in the world at the same year. The cement yield rose to 1.88 billion tons from 1.07 billion tons, with an annual average growth of 12.0%, and it is even 60% of the global proportion. Besides, the yields of electrolytic aluminum, sheet glass, ethylene and caustic soda rose by over 10% annually. With the
highest industrial productivity in the world, China has a half, even higher yields of such energy-
exhaustive products as steel, cement, electrolytic aluminum, even such light industry products as TV,
air conditioner and mobile phone.

3. Energy Consumption and Conservation Prospects for China’s Industrial

3.1. Industrial End-Use Energy Consumption Structure during “the 13th Five-Year Plan” Period
In terms of the terminal energy consumption structure in industrial subsectors, the energy consumption
of traditional energy-exhaustive industries like steel and building materials is limited in the growth
space in future. Their proportion in the energy consumption for industrial production will also
continue to drop. The end-use energy consumption proportion of steel and building materials declines
from 54% in 2010 to 48% in 2020. The energy consumption in the petrochemical industry rises,
accounting for 24% in the energy consumption for industrial production from 21% in 2010. However,
in terms of internal chemical industry, the energy consumption of traditional industries like synthetic
ammonia and calcium carbide has been reduced from 39% in 2010 to 17% in 2020. They are replaced
by more high value-added chemical products. Therefore, the overall development quality and energy
efficiency have been enhanced significantly.

3.2. End-use energy consumption structure by variety of industrial sectors
The energy consumption structure of industrial sector has been improved to a certain degree. During
the 13th Five-Year Plan period, with the restriction of production process and energy costs, there was
no essential change in the energy structure of industrial activities, and a situation of tripartite
confrontation of “coal, electricity and oil gas” was still maintained. However, the use of such clean
energy as electricity and natural gas was increased slightly, and the ratio of electricity consumption
was raised from 21% in 2010 to 23% in 2020, while that of coal consumption was reduced from 56%
in 2010 to 51% in 2020. Energy-exhaustive industries, especially the steel and cement industries with
high coal consumption, should slow their development, which will be conducive to optimizing the
energy structure of industrial activities.

3.3. Primary energy consumption of secondary industry
Basically like the trend of final energy consumption change in industrial (in a narrow sense) sector, the
primary energy consumption of full-caliber secondary industry will also present a trend of “slow
increase - plateau - peak - slow decrease”. According to the primary estimation, the primary energy
consumption of secondary industry in China will reach 3.18 billion tce in 2020. It shall be noted that
the research group’s forecast of future energy consumption of industrial (processing and conversion)
sector is linked to the industrial (in a narrow sense) sector and adjusted with consideration of power
structure optimization and technical progress, which may underestimate the industrial (process and
conversion) sector to a certain degree, as the growth of future energy consumption of industrial (in a
narrow sense) sector will be lower than that of the whole society. The research group will revise and
improve the method for forecasting the primary energy consumption of secondary industry in the next
stage, so as to obtain more reliable and accurate results.

4. Main Approaches and suggestion
According to the changes in internal structure of industry, output and energy effectiveness of major
high energy-consuming products and forecast data of energy economic efficiency of non-energy-
exhaustive industry during the 13th Five-Year Plan period, the research group calculated the possible
energy conservation potential of each measure for energy conservation and emission reduction, which
is shown in Table 2.
Table 2 Major Measures and Effect Estimations of Energy Conservation and Emission Reduction in Industrial Sector during the 13th Five-Year Plan Period

| Approach                                      | Scope                                                                 | Energy conservation potential (effect) |
|-----------------------------------------------|-----------------------------------------------------------------------|----------------------------------------|
| **Structural adjustment inside the industry** | Industries                                                           | 246.84 million tce                      |
| Replace traditional materials, improve technology, and recycle and reuse products | Industries as steel, paper-making, electrolytic aluminum and synthetic ammonia | 8.71 million tce                        |
| Popularize advanced energy-saving technologies | Such energy-exhaustive industries as steel, building materials, non-ferrous metal, petrochemical engineering and paper-making | 78.42 million tce                        |
| **Energy-exhaustive industry**                | Capacities have been eliminated during the 13th Five-Year Plan period: 55 million tons of steel, 165 million tons of cement, 2.2 million tons of electrolytic aluminum, 60 million weight cases of plate glass... | By 2020, the proportion of newly built capacities after 2000 of energy-exhaustive industry will exceed 90% generally; that of newly built capacities after the 11th Five-Year Plan period will exceed 70% basically. |
| Elimination of backward production capacity   | Such industries as steel, building materials, non-ferrous metal, petrochemical engineering and paper-making | 41.73 million tce                        |
| Prolong the industry chain and produce high-value-added product | Such industries as pharmaceuticals, mechanical engineering and transport and communication facilities | 17.89 million tce                        |
| Apply advanced technology                     | All non-energy-exhaustive industry                                    | 17.89 million tce                        |

To be more specific, from 2010 to 2020, in terms of replacement of traditional materials, improvement of production process and recycling and reusing of products, the ratio of short process technology (electric furnace steel) will be increased from 12.4% to 18%, and the output of direct reduced iron process will be increased to 2% in the steel industry; in non-ferrous industry, the output of recycled aluminum will be increased from 3.95 million tons to 8 million tons, and that of reclaimed copper will be increased from 38.5% to 45%; in paper-making industry, the output of recycled paper will be increased from 61.7% to 64%, and the ratio of imported paperboard will be raised from 11.3% to 14%; in the production of synthetic ammonia, the ratio of “gas feeding” will be increased from 22% to 25%; in the production of caustic soda, the ratio of ion-exchange membrane will be increased from 71.3% to 80%; in the production of ethylene, the ratio of feed naphtha will be decreased from 68% to 40%.

It is suggested that the central government should emphasize importance of the ecological civilization construction, promote energy conservation and emission reduction unsgrily, strive to find out a new way to lower energy emission and improve economic development, and make unremitting efforts to promote energy consumption revolution firmly. The decline rate of energy consumption per unit GDP of “the 13th Five-Year Plan” will be determined to be about 15%, and the
total energy consumption control target is set as 4.8 billion tce. The above two indexes will be incorporated into the national economy and social development planning outline of "the 13th Five-Year Plan". The total energy consumption targets of industry, building and transportation sectors are respectively 3,100 million, 800 million and 600 million tce as the anticipatory indexes. The targets of unit activity level (product, unit area or unit turnover) of the industry, building and transportation are incorporated into the relating national energy conservation planning as the anticipatory indexes. And further, we should focus on "boosting growth" during "the 13th Five-Year Plan", optimize and adjust the economy based on its development rule by virtue of properly lowering the economic growth speed, and exert the market force more greatly with the aid of deepening the form, so as to reduce the excessive intervention to the economic growth from the governmental “visible hand”. We strive to improve the proportion of the third industry by 5% during "the 13th Five-Year Plan" based on the strategic adjustment for the economic structure.

As for the improvement of quality and efficiency, It is necessary to speed up development of such advanced technologies as informatization, network technology and cloud computing, actively cultivate such strategic emerging industry as energy conservation and environmental protection, and promote the internal structure adjustment of the industry. Haphazard development of steel, cement and building materials shall be strictly limited. The central government shall strengthen early warning and monitoring for new energy-exhaustive and high-pollution projects, set more severe energy conservation and environmental protection access threshold, and take the approval policy of “decremental substitution”. There is a necessarily to control the industrial sector development speed, striving for the product yield peaks of steel, cement and other basic raw material industries prior to 2020. The energy efficiency levels of main energy-exhaustive products will reach the leading level of the world in 2020 by virtue of transforming the industrial energy conservation technology, eliminating the out-dated energy production line and energy-exhaustive equipment, and boosting transform of such universal equipment as industrial boiler and electric motor driving system.

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