



## Energy conservation and circular economy in China's process industries

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### ARTICLE INFO

#### Article history:

Received 24 June 2007

Received in revised form

8 June 2008

Accepted 4 April 2009

Available online 17 May 2009

#### Keywords:

Energy conservation

Circular economy

Process industry

Cleaner production

Ecological industrial park

### ABSTRACT

Since energy consumption in process industries accounts for a great proportion of China's total energy consumption, energy conservation becomes the practical choice to reduce the conflict between energy demand and energy supply in China, and therefore, promoting energy conservation is the long-term solution to China's energy and environment problems from the source. In this paper, based on the introduction of the concept of energy consumption status in China's key energy-consuming process industries, the main technical bottlenecks and resource-environment problems were analyzed with special emphasis on energy utilization efficiency, energy consumption mode, and waste emission. As for the measures to resolve these problems, at the policy level, policies and programs of Chinese government related to energy conservation were introduced in combination with China's circular economy structure. At the technical level, the key technologies and research progress to improve energy utilization efficiency, reducing energy consumption, as well as utilizing the resource of discharged wastes were reviewed. Finally, three typical cases of the development of circular economy at three levels, namely the chemical industry, metallurgical industry, and electric power industry, were studied for the enforcement of circular economy and energy conservation in China's process industries.

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### 1. Energy consumption in China's process industries

In recent years, the energy consumption in China has been keeping up a rapid rate of increase (see Fig. 1) and is expected to rise to an annual growth of about 5% by the year 2020 [1]. Now, China is not only the second-largest energy producer in the world, but also the second largest energy consumer [2].

However, the total efficiency of energy utilization in China is only about 33% that is 10% lower than that of the developed countries [3]. Energy consumption per unit GDP is two times greater than the world average. The process industry is one of the pillars of the national economy, and accounts for approximately 70% of the total annual energy consumption [4]. These important energy-intensive industries such as the steel industry, the non-ferrous metallurgical industry, the chemical industry and building materials have low energy utilization efficiency with the average unit product energy consumption exceeding international advanced levels by 25–50% (see Fig. 2) [5]. Industrialization is still

underway in China, and the proportion of high-energy-consuming industries in this country is higher than those in others.

The high-energy consumption in process industries gives rise to a series of severe environmental problems. Equipment deficiency and lag in technology have lead to significant excess in the total pollution emitted. The amount of total annual industrial pollutants emitted presents an increasing trend (shown in Table 1) [6,7]. Air, water, and solid waste pollution pose a great threat to human health and security of ecology. The technical bottlenecks and environmental problems of the process industries have badly hampered China's sustainable development.

China is a developing country in its industrialization phase. With economic development, population growth, and living standards improving, the amount of energy consumed will undoubtedly increase in the future. Therefore, improving energy utilization efficiency it is of vital importance for the energy conservation efforts of China's process industries. The substantial gap in energy utilization levels between China and the developed countries shows that China is at the low end of the value chain of the worldwide industrial order. So there is vast potential for energy conservation in China's process industries. Energy saving technologies involve technical renovation, elimination of outdated equipment, new energy production capacity using advanced technology,

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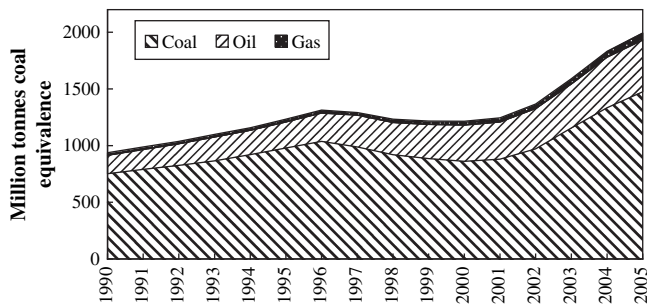


Fig. 1. Energy consumption in China (1990–2005).

implementation of the industry technological standards, and industry energy-saving targets. Policies such as fiscal, tax and finance, and other economic incentives also can be adopted to promote energy conservation.

## 2. Progress of circular economy and energy conservation in China

Working hard to build a resource-saving and environment-friendly society, China must properly handle its energy problem to balance the relation of the economy to society and the environment. The Chinese government considers energy saving as one of its basic state policies. Centering on energy conservation and raising the efficiency of energy utilization, China is making enormous efforts to develop circular economy.

The concept [8] of circular economy broadly accepts that an economic growth and development system to integrate economy with resources and environmental factors is based on the material metabolism mode of “resource-product-regenerated resource”, which incorporates a mechanism of efficient resource use and waste stream feedback, while its metabolism is compatible with the whole ecosystem. For the system, the reduction of resources, energy, and waste stream through the lifecycle of products and the increase in economic output and effectiveness can be achieved simultaneously by improving resource productivity (or eco-efficiency). There are three principles of circular economy, namely to reduce, to reuse and to recycle. And it is generally achieved at three levels [9]. At the level of enterprises, circular economy mainly

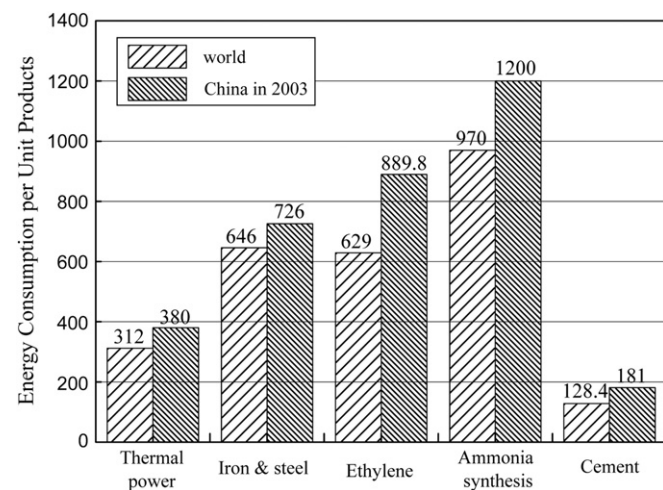


Fig. 2. The comparison of energy consumption per unit product between China (2003) and the advanced world.

focuses on cleaner production. At the regional level, circular economy emphasizes structuring a substance recycling eco-industrial park. At the national level, circular economy represents a new pattern of economic operation and aims to create a recycling oriented society.

After the concept of circular economy was introduced into China, it started to flourish. The Chinese government has instituted many measures and enacted relative policies and programs (shown in Table 2). Cleaner production is the first and most vital step toward the ultimate goal of circular economy, especially for the industrial sector. In June 2002, China's National People's Congress approved legislation mandated new and comprehensive cleaner production processes, the Cleaner Production Promotion Law [8]. Cleaner production has been in practice in over 5000 enterprises nationwide. A new law named circular economy law is to be legislated and may be effective January 2008 [10].

Many circular economy tasks have been developed in recent years [11]. Forty-two pilot manufacturers in seven sectors of enterprise such as the iron and steel industry, non-ferrous metallurgical industry, and chemical industry circular economy have been demonstrated to explore the circular economy development mode of high energy-intensive industries. Four typical fields comprising 17 pilot enterprises for wastes recycling and remanufacturing demonstrated the formation of the renewable resources recycle and utilization systems and construct the mechanism of resource recycle and utilization; 13 national pilot eco-industrial parks such as the national and provincial development areas, heavy chemical centralized area and agriculture demonstration area are demonstrated to build “medium-sized circulation”. Ten national pilot regions, including two provinces and eight cities which are resource-abundant or energy scarce were created to build “big/regional-sized circulation”. Economic policies are constituted with the aim of progress of circular economy.

In order to measure and evaluate the process of circular economy development, the criteria for evaluation of circular economy should be laid down. There are four generally acknowledged integrated sustainability frameworks including Global Reporting Initiative (GRI) [12], United Nations Commission on Sustainable Development Framework [13], Sustainability Metrics of the Institution of Chemical Engineers [14], and Wuppertal Sustainability Indicators [15]. Based on these frameworks and actual conditions in China, several research institutions proposed index systems for assessment of circular economy. The Development Research Center of the State Council constructed an indicator framework for the evaluation of circular economy development in cities. The system was established from resource efficiency indicators, environmental impact indicators, and social progress achieved (shown in Table 3) [16]. The State Environmental Protection Administration initially proposed the indicator frameworks of circular economy that are based on the indicator of eco-efficiency. The method used is to completely measure regional economy benefit levels, resource and energy utilization efficiency, ecological environment benefit and cycle characteristics (see Fig. 3) [17].

Table 1  
Status of industrial pollutants discharged in China.

| Indicators                                | 2005    | 2004    | Annual increase (%) |
|---|---------|---------|---------------------|
| Wastewater discharge (100 million tons)   | 243.1   | 221.1   | 10.0                |
| COD discharge (10,000 ton)                | 554.8   | 509.7   | 8.8                 |
| NH <sub>3</sub> -N discharge (10,000 ton) | 52.5    | 42.2    | 23.7                |
| SO <sub>2</sub> emission (10,000 ton)     | 2168.4  | 1891.4  | 14.6                |
| Dust emission (10,000 ton)                | 948.9   | 886.5   | 7.0                 |
| Solid waste output (10,000 ton)           | 134,448 | 120,030 | 12.0                |
| Solid waste discharge (10,000 ton)        | 1654.7  | 1762.0  | -6.1                |

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