

THE EXPERIENCE OF CHINA'S LED LIGHTING INDUSTRY'S DEVELOPMENT

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ABSTRACT

As a big country with the production and sale of lighting products in the world, LED lighting products are widely used in China, and the LED lighting industry is playing an important role in the whole national economy. To analyze the characteristics and experience of the development of China's LED lighting industry, the development history of China's LED lighting industry was reviewed, the characteristics of the development of China's LED lighting industry were summarized, and the development prospect of China's LED lighting industry was forecasted. Results show that the development of LED lighting industry in China is divided into three stages, which show the characteristics of industrial policy support, core technology leap breakthrough and industrial agglomeration effect. The conclusion has guidance and reference for the development of LED lighting industry in developing countries.

Keywords: LED lighting, industrial development, China

1. INTRODUCTION

With the increasing global greenhouse gas emissions and the deterioration of the ecosystem environment, there is a worldwide consensus on the development of a low-carbon economy. Countries around the world have introduced energy saving and emission reduction policies, actively develop

new sustainable energy, and seek a more green energy saving and environmental protection lifestyle. As the new generation of light source in the world, LED is known as the most promising green lighting source in the twenty-first Century because of its advantages of energy saving, environmental protection, good colour display and long life. LED green lighting technology has gradually aroused the attention of all countries [1]. Under the same illumination brightness, the average power savings of LED lamp are more than 40 %-50 % than that of the ordinary lamp, and there is almost no maintenance cost in 3–5 years after installation. The LED lamp does not contain harmful substances such as mercury, lead, and harmful gases, such as the ordinary energy saving lamp, and the average service life of the LED lamp can reach 50 thousand –10 million h, which is 3–5 times that of the ordinary lamp [2]. At present, lighting consumption accounts for about 20 % of the total electricity consumption, and greatly reducing the use of general lighting is an important way to save energy. Therefore, the major developed countries such as the United States, Germany, Japan and other countries have also introduced relevant support policies to accelerate the development of LED industry. China, as a major energy consuming country, has no time to delay in strengthening green lighting technology.

At the same time, as a big country in the production and sale of world lighting products, lighting industrial economy is also playing a pivotal role in China's national economy. China's LED industry

has made great progress under the guidance of national support policies and industrial base construction, and has been listed as a new strategic development industry. According to the export amount of LED lighting, the related data showed that in 2014, it was \$14 billion 200 million, an annual increase of 59%. In 2015, it reached 16 billion 400 million US dollars, the annual increase was 15%, and the export volume in 2016 was 16 billion 960 million US dollars, a small increase of 3% compared with 2015. The export volume of 1–7 months in 2017 was \$8 billion 220 million [3]. It can be seen that, after the rapid growth of the previous years, China's LED lighting industry has entered a mature period, and the advantages and competitiveness of the enterprise also change the scale of enterprise and the cost of product from the product and technical ability. Therefore, the analysis of the characteristics and experiences of the development of LED lighting industry in China and the characteristics of the economic development of the LED lighting industry are instructive and useful for the development of the LED lighting industry in developing countries.

2. DEVELOPMENT PROCESS OF LED LIGHTING INDUSTRY IN CHINA

The development of China's LED lighting industry began in the late 1960s. Because of the limited application field of LED lighting research and development, the development of industry is slow, which is dominated by the enterprises of scientific research institutes or with the background of scientific research institutes, and the ability of industrialization is relatively weak. In twenty-first century, because of the continuous growth of China's macro economy, the support of the national industrial policy, and the continuous breakthrough in the related technical fields, the LED lighting industry has ushered in a breakthrough period of development. From the perspective of its development process, the development of China's LED lighting industry is closely related to the development of LED lighting technology. According to the different development stages of LED lighting technology, the development process of the LED lighting industry in China can be roughly divided into the following stages.

1st stage: 1969–2002 years, LED lighting products had shown the initial symptoms

In 1965, the first commercial light-emitting diode was born in the world. In 1968, nitrogen doping technology enabled the *GaAsP* device to reach 1 lm/W efficiency, and it could emit red light, orange light and yellow light [4]. In the early 1980s, the *AlGaAs* LED lighting technology developed was able to glow with a luminous efficiency of 10 lm/W. In 1990, the industry improved *AllnGaP* technology which is 10 times higher than that of *GaAsP* devices. In 1994, development of blue light diodes has accelerated the application of large screen display, and many media, large sports venues and entertainment places began to use LED large screen display. After that, scientists generated white light by using blue light to generate white light on a single LED. The LED production enterprise, which was primarily used for instrument display and automobile instrument lamp, appeared gradually.

Following the development of LED lighting technology in the world, China's R & D in LED lighting has been another major breakthrough. In 1999, the Semiconductor Research Institute of the Chinese Academy of Sciences and Peking University jointly carried out research on nitride materials, and achieved some results. But until 2003, blue light LED chips have been produced independently, China's blue light LED chips are all dependent on import, and the number of Chinese LED lighting enterprises is few, the main application products are mainly production indicator light, automobile instrument lamp and signal display, technology research and development ability and enterprise independent development ability are weak.

2nd stage: 2003–2008 years, China gradually had formed the LED lighting industry and the scale of the industrial economy

In June 17, 2003, the Ministry of science and technology of China announced the creation of a national semiconductor lighting project coordination leading group to start the "national semiconductor lighting project" to open a new era of China's LED lighting. LED lighting products through independent innovation, breakthrough white light lighting part of the core patents, to solve the urgent industrialization of LED lighting market key technologies, establish a perfect system of technological innovation and industrial clusters, improve the LED lighting industry chain, to form a new industry with international competitiveness of the LED lighting.

The Ministry of science and technology has carried out the entire industry chain deployment on the breakthrough of LED lighting core technology and key technologies for industrialization. The efficiency of white light LED lighting has jumped from only 20–30 lm/W in 2003 to more, than 60 lm/W efficacy in 2008.

At this stage, China started the application of LED functional lighting, and LED lighting industry has made certain achievements. By the end of 2008, with the large number of traditional lighting enterprises involved in the production of LED lighting products, the total number of enterprises has exceeded 3000, and the Yangtze River Delta and the Pearl River Delta have developed into a certain industrial base. The relevant data show that the total output value of LED lighting industry in China in 2008 is nearly 70 billion yuan, but the scale of LED lighting enterprises is generally small, of which 70 % are concentrated in the downstream industry, and the technical level and product quality are uneven. Upstream chip enterprises have no independent intellectual property rights and the industrial concentration is not high, and the overall coordination between the regions is lacking. With the interaction and cooperation, there are still blind investment, low level duplication, product homogenization, and inferior products disrupting the market. Although there are a lot of enterprises in the application, they lack leading enterprises.

3rd stage: 2009–2017 years, the industrial scale is improving and the industrial economic benefits are gradually emerging

In 2009, in order to further promote the development of China's LED lighting industry, expand the market scale, stimulate consumption demand, reduce energy consumption, promote the development and innovation of industrial core technology and improve the overall competitiveness of China's LED lighting industry, the Ministry of science and technology introduced the "LED lighting should be covered in 21 developed cities" in China. Utilizing the project demonstration city plan, we carried out the LED lighting application demonstration [5]. In October of the same year, the 6 departments of the national development and Reform Commission, such as the national development and Reform Commission, introduced the "opinion on the development of energy saving industry for semiconductor lighting", pointed out the problems existing in the development of China's LED lighting industry, and

put forward the guiding principles, development targets, key areas and specific policies and measures to promote the development of industry. In addition, various local governments have also issued a number of related industrial development incentives, which have played a beneficial role in promoting the rapid development of the LED lighting industry. In 2017, efficiency of industrialization of Chinese power white LED has reached 160 lm/W, and the efficiency of industrialization of LED chips with independent intellectual property right is more than 150 lm/W. The scale of China's LED lighting industry rose from 120 billion yuan in 2010 to 521 billion 600 million yuan in 2017, of which the size of the upstream epitaxial chip was about 18 billion 200 million yuan, the scale of the middle reaches of the package reached 74 billion 800 million yuan and the downstream application was 428 billion 600 million yuan. With the expansion of the LED lighting industry in China, the industrial structure is constantly improving. The industrial pattern of small and medium-sized enterprises has changed greatly. The prelude of industrial integration has been opened. The pattern of industrial competition is becoming more and more obvious. The number of listed companies based on LED lighting business has increased from 2 in 2010 to 26 in 2017. Purchasing and integration has become an important trend in the development of the industry. The group with leading enterprises is gradually formed. At the same time, the industry begins to move from the coastal to the Midwest, the regional development features show, the industrial structure is further optimized and promoted, and China has entered the ranks of the big country in the production and application of the lighting industry.

3. DEVELOPMENT CHARACTERISTICS OF LED LIGHTING INDUSTRY IN CHINA

Looking at the progress of China's LED lighting industry in recent years, the growth rate of 20 %-30 % for a permanent year is determined not only by the strong support of national policy but also from the advanced characteristics of the industry itself. The following three points are summarized. First, characteristics of LED lighting industry conform to the direction of national development, and are conducive to obtaining industrial policy support. The theory of industrial economics holds

that the leading industry has five selection benchmarks, which are the benchmark of the industrial association effect, the growth potential benchmark, the technology intensive benchmark, the employment benchmark and the sustainable development benchmark [6]. Developing countries should first develop industries that conform to these five benchmarks and give priority to government support and development in order to promote the development of the economy as a whole. The LED lighting industry organization shows the dual characteristics of the application driving the entire industry chain, with the dual characteristics of technology intensive and labour intensive. After years of development, China's LED lighting industry has developed into a more complete system including the production of epitaxial LED, the preparation of LED chips, the package of LED chips, and the application of LED products.

3.1. Industrial Chain

Relevant data show that as of 2016, China's LED lighting industry employs more than 4 million people. In addition, the development of LED lighting industry cannot only form new industries and export growth points, but also save energy, reduce environmental pollution and give full play to the advantages of China's labour resources. At the same time, China is one of the major lighting production and exporting countries. The development of LED lighting industry can improve the proportion of high-end industries and high-tech products in China, enhance the international competitiveness of the lighting industry, and also meet the national policy of China's new road to industrialization. Therefore, as a new generation of revolutionary lighting technology, LED lighting has been favoured by the government with its advantages of energy saving, environmental protection, high scientific and technological content, strong industrial drive and so on. The state and various provinces and cities have issued relevant policies to support it and laid a good policy foundation for the rapid development of the LED lighting industry.

Second, thanks to the rapid progress of related science and technology, the core technology of LED lighting in China has been leaping forward. Since the beginning of twenty-first century, China has gradually increased investment in the field of LED lighting research and technology. During the period

of "fifteen", China invested more than 1 billion yuan in the field of LED lighting technology research and development, and promoted the research and development of LED lighting technology through the special major national scientific research plan. With the further development of China in the fields of new materials and technology, LED lighting technology has made breakthroughs in chip technology, and packaging technology, luminescence intensity and luminous efficiency, to achieve independent research and development, some areas have reached the leading level in the world. The development of LED lighting technology in China has made great achievements; LED lighting production the core technology of the upper reaches of the industry has made breakthrough progress. The middle reaches of the package have been achieved and maintained obvious advantages. The downstream application is sustained and the development of various kinds of application products is more active. This also creates excellent conditions and opportunities for the development of various functional LED lighting products at the same time, national semiconductor optoelectronic products. A batch of national LED lighting research institutions, such as the key laboratory and the national semiconductor lighting supervision and inspection centre, have been set up in succession, which further promoted the rapid progress of the development of LED lighting technology.

Third, the agglomeration effect of China's LED lighting industry is obvious, and gradually formed industrial agglomeration advantages and regional characteristics. At present, China's LED lighting industry has basically grown up in the triangle, Pearl River Delta, Bohai economic circle and the four major LED lighting industry areas in Fujian and Jiangxi. All the signs indicate that the agglomeration development has become the trend of the development of China's LED lighting industry. As an economic phenomenon, agglomeration development is very common in the industrial development of many countries. The theory of industrial economics holds that, under the guidance of the principle of resource benefit and benefit attracting resources, the industry is bound to form the agglomeration in the region with high benefit. This is the regional comparative advantage theory of industrial agglomeration [7]. The southeast coastal area is mainly distributed in the LED lighting industry gathering area is undoubtedly the consumption concentration area of

LED lighting products. At the same time, it is the first area of China's reform and opening up. The advantages of the policy are obvious, and the LED lighting enterprises in China are from dispersing to centralization to the scale development, which conforms to the law of industrial development. The LED lighting industry has gradually formed a complete industrial chain of substrate, epitaxial chip, chip, packaging, application and supporting equipment in the four major agglomeration areas, and has formed a certain scale effect in the field of packaging and application [8].

In the development process of the four major industrial agglomeration areas, the regional characteristics are gradually formed according to the different industrial forming time, regional conditions and policy orientation. For example, the overall characteristics of the Yangtze River Delta industrial zone and the Pearl River Delta industrial area are that the industrial chain is relatively complete, the industrialization is high, the market advantage is obvious, and the advantages of the Bohai Bay industrial zone. It is characterized by strong product R & D strength, but weak competitive edge. With its own advantages, the region has a clearer location for the development of LED lighting industry in the region, such as the area of the Yangtze River Delta in intelligent lighting, intelligent manufacturing, health lighting and other fields. The Pearl River Delta focuses on large-scale manufacturing and starts to pay attention to quality improvement; Jiangxi has optimized the industrial chain, innovation chain and service chain around the silicon based LED. To build Nanchang Optics Valley; Sichuan and Chongqing pay attention to the application of subdivision. With the increasing cost of enterprises in the eastern coastal areas, the industry began to transfer to the inland, and the central and western regions such as Nanchang and Chengdu became the principal industries.

4. PROSPECTS FOR THE DEVELOPMENT OF LED LIGHTING INDUSTRY IN CHINA

After more than ten years of rapid growth, China's LED lighting industry has formed a relatively complete industrial chain, expands industrial scale and agglomeration advantages, and has a good foundation for industrial development. With the increase of the state policy, the international related

industries have accelerated to the domestic industry, the domestic industry investment is increasing rapidly, the industrial technology level is rapidly increasing, and the LED lighting industry in China has a new period of development opportunities.

(1) Core technological fields will be made fundamental breakthroughs. A latest round of technological revolution and industrial change is creating new historical opportunities. From the current overall industrial technology level and trend, the technology of each link of the industrial chain is still at the stage of development, the improvement of production materials, the improvement of the efficiency of light production and the improvement of cost control are made in China. The development of the industry provides opportunities. With the increase of investment in the field of scientific and technological innovation, the bottleneck problem of capital talents will be cracked. The gap between the key technologies of China's LED lighting industry and the international advanced level will be narrowed, and the core equipment and principal raw materials will be fully realized in China.

(2) The effect of policy orientation will further strengthen the trend of deep integration of semiconductor lighting industry. With the gradual appearance of the policy effect, the accelerated landing of policy rules and regulations supporting the development goals of intelligent energy and intelligent cities, as well as the products of LED light, colour, light maintenance, colour stability and so on. The further improvement of performance will speed up the expansion of LED lighting application to the development of intelligent lighting, healthy lighting and other fields. LED lighting technology will deepen the integration with other technology fields, and continue to produce new applications, and the range of high-end applications will be greatly expanded.

(3) The growth rate of the industry is changing from super high speed to medium speed, and the acceleration of enterprise integration and upgrading. At present, the development of China has entered the new normal state. All industries have accelerated the pace of transformation and upgrading, and eliminated backward production capacity and backward enterprises. The upgrading of industrial integration will be the only way for the development of LED lighting industry. Most of China's LED lighting enterprises are still in the low end of the industry chain, with low product technology, small market share and backward production capacity. This

situation will be accelerated with the accelerated pace of industrial upgrading. The market environment and policy environment of the LED lighting industry are optimized and perfected, and then LED lighting production will be guided. The industry is developing healthfully.

5. CONCLUSIONS

In order to analyze the characteristics and experience of the development of China's LED lighting industry, this paper reviews the development course of China's LED lighting industry, sums up the characteristics of the economic development of China's LED lighting industry, and obtains the following conclusions: 1. The development course of China's LED lighting industry is divided into three stages, the first stage: 1969–2002 years, semiconductor lighting the product is beginning to appear. The second stage: 2003–2008 years, China gradually formed the LED lighting industry and the scale of the industrial economy. The third stage: 2009–2017 years, the industrial scale is improving and the industrial economic benefits are gradually emerging.

2. The development of LED lighting industry in China is characterized by industrial policy support, leap-forward breakthrough of core technology and obvious industrial agglomeration effect. The research conclusion has guidance and reference for the development of LED lighting industry in developing countries.

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