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Experience and Inspiration of Low-Carbon Transformation of Taiwan's Industry

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***Abstract*—** *As an island economy of China, Taiwan has successfully developed into one of Asia's four small dragons over the past few decades through the implementation of export-oriented strategies. As a high-speed economic growth, Taiwan's economic development has also brought about environmental pollution and energy inefficiencies and other thorny issues. Its energy consumption is increasing year by year, the power consumption of different industries is also increasing, from the supply side, the external dependence of energy is higher. Since the beginning of the new century, under the influence of global sustainable development and low carbon concept, Taiwan has also begun to promote low-carbon development model, which is embodied in encouraging the development of low-carbon industries and using environmental regulations to promote the low-carbon transformation of high-carbon industries. In addition, in the energy sector, the use of coal and associated pollution emissions are reduced by promoting technological innovation to reduce carbon emissions in high-carbon industries such as power plants. The characteristics and enlightenments of the low-carbon transformation of Taiwan's high-carbon industry are: legislation first, gradually increasing the intensity of environmental regulation, paying attention to the suitability with the pace of industrial upgrading, dynamically balancing the relationship between economy and environment.*

***Keywords*—** *Industrial transformation*: *Low-carbon development: Low-carbon industry.*

I. INTRODUCTION

As people's understanding of the Earth's climate change and its adverse effects deepened, countries reached the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, requiring developed countries to take the lead in reducing carbon emissions and providing financial support to developing countries. Subsequently, the Kyoto Protocol was signed on 11 December 1997, establishing three flexible cooperation mechanisms. At the end of 2018, the United Nations Climate Change Katowice Conference was successfully held, completing negotiations on the implementation rules of the Paris Agreement adopted in 2015. Although Taiwan does not have a clear agreed obligation to reduce emissions, its per capita carbon consumption has been more than twice the world average since 1997 (data from the *OECD*). According to the Taiwan Statistical Yearbook, Taiwan's carbon emissions are mainly derived from energy consumption and industrial development.

Before 1960, Taiwan's energy supply was mainly self-produced, but with the rapid economic development and the depletion of the island's energy, Taiwan is now mainly imported energy, imported energy about 50% of oil, so local energy prices are affected by world energy prices, Taiwan Province gradually began to adopt the "energy diversification" strategy. Taiwan Province, as a developed economic region, has stabilized its total energy consumption. As the island's energy policies advance, the shows a steady decline in the share of energy used by various sectors.

With the increasing calls to curb global warming and the growing energy and environmental crisis, the development of energy conservation and carbon reduction has gradually become a universal value, forming a model of social consumption and production patterns. As an island economy, Taiwan has successfully developed into one of Asia's four dragons over the past few decades through its export-oriented strategy. Although the economic growth is high, the negative effects of environmental pollution cannot be underestimated, such as inefficient energy use and other thorny problems need to be solved urgently. Since the beginning of the new century, under the influence of the global low-carbon concept, Taiwan has also begun to promote the low-carbon development model, which is embodied in encouraging the development of low-carbon industries and using environmental regulations to promote the low-carbon transformation of high-carbon industries.

Although Taiwan's energy consumption has been increasing year by year, Taiwan's greenhouse gas and carbon emissions have remained basically stable since 2005, basically meeting Taiwan's predetermined requirements. Especially in the nuclear power plant power generation decline significantly, and the coal-fired power generation gradually rising conditions, Taiwan's carbon emissions remain at a stable level is rare. Below, we analyze the experience, problems and characteristics of Taiwan's low-carbon development.

II. TAIWAN'S INDUSTRY LOW-CARBON TRANSFORMATION OF SPECIFIC MEASURES

Low carbon economy is generally called "green economy" and "sustainable development" in Taiwan, China. It is defined as: basically, refers to the type of sustainable operation industry which aims at ecological balance and economic development through the provision of relevant technologies, products or services to improve the efficiency of energy (resources). It can be seen that the interpretation of green industry in Taiwan is basically the same as that of low-carbon industry. In recent years, due to the lack of fossil energy in Taiwan, the construction of non-nuclear homeland, and the implementation of carbon tariffs on imported products, Taiwan has made a series of arrangements for sustainable development. In 2009, Taiwan set up the "New Energy Promotion Committee", which combines industrial

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development with energy use and is called green energy industry.

A. Taiwan's Policies, Regulations

Taiwan's provincial government first began to attach importance to low-carbon construction can be traced back to the "sustainable energy policy action party" issued in 2000, and began to review the legislation on greenhouse gas emission reduction law, the development of greenhouse gas emissions assessment method verification system, the establishment of greenhouse gas landing platform, the development of industrial efficiency standards and emission benchmarks, assessment of emission reduction targets and nuclear allocation principles, assessment of emission offsets and trading systems (Yu Tengyao and Lin Zhisen,2010). After completing a series of preparatory work, the Taiwan Province Energy Saving and Carbon Reduction Promotion Association was established in 2009 and the following year established the Energy Saving and Carbon Reduction Plan, which calls for an annual energy efficiency increase of at least 2% from 2010 to 2018, energy intensity in 2015 below 80% in 2005, and a return to 2005 carbon dioxide emissions in terms of carbon emissions reduction.

The Energy Saving and Carbon Reduction Plan sets out policies and regulations on energy development and management and promotes a green tax system. At the same time, low-carbon community, low-carbon city, low-carbon island carried out a general plan. In terms of industry, new requirements have been put forward for energy-intensive industries, agriculture, transportation and construction. One of the "low-carbon homes plan" plans to complete the goal of building low-carbon homes within 10 years, in 2011 each county and city set up two low-carbon demonstration communities; Low-carbon demonstration communities are voluntarily participated by communities, screened by research institutions for their carbon reduction capacity and investment return analysis, and qualified persons are provided with financial and technical support by the environmental protection department and evaluated for performance after the completion of their low-carbon transformation actions to determine how much financial support the community will provide when it re-applies for new projects. It can be said that the "Energy Saving and Carbon Reduction Master Plan" has opened a chapter in the formal management of carbon emissions by the Taiwan provincial government, and put forward an overall plan for future development.

In 2015, Taiwan Province issued the Greenhouse Gas Reduction and Management Law, which formed a regulatory framework centered on the principle of "mitigation and adjustment", with the planning system, the inspection and registration system, the cap-and-trade system, the fund system and the education system as the core (Zhou Shengyou and Li ainian, 2018). The regulation requires Taiwan Province to reduce greenhouse gas emissions to less than half of 2005 levels by 2050, but sets up a dynamic editing mechanism that allows plans to be updated and adjusted; Taiwan's greenhouse gas emissions quota is required to be gradually changed from free to distribution, and if manufacturers still exceed the nuclear quota outside the deadline, they will be fined three times the carbon market price per metric ton; The Greenhouse Gas Reduction and Management Law has made Taiwan's carbon reduction specific matters legal, more standardized implementation, and ushered in Taiwan's "carbon reduction era."

B. Taiwan's Power Industry Low-Carbon Transformation and Upgrading

In 2000, Taiwan proposed the establishment of a "non-nuclear homeland", and in 2003 Taiwan held a meeting to raise the idea of gradually reducing nuclear power generation and developing renewable energy, requiring that the installed capacity of renewable energy generation should account for 10% of the total in 2010. However, according to the chart below, the actual generation of renewable energy in Taiwan in 2010 was far from what was required. In 2005, Taiwan held an energy conference, which set a target of between 3 and 5 per cent of total energy for renewable energy promotion, reaching 4 to 6 per cent of renewable energy in the energy structure by 2020 and 10 to 11 per cent of renewable energy installed capacity by 2020.

After Japan’s nuclear disaster in 2011, Taiwan adjusted its energy policy under the three principles of "ensuring unlimited electricity consumption, maintaining reasonable electricity prices, and achieving international carbon reduction commitments", "ensuring nuclear security, steady nuclear reduction, building a green and low-carbon environment, and moving towards a non-nuclear home" (Du Qiang,2016). It can also be seen that the proportion of nuclear power generated in Taiwan will gradually decline between 2011 and 2017. In 2014, in order to solve the shortage of electricity due to nuclear power, Taiwan put forward higher demands on renewable energy, requiring that renewable energy installed capacity account for 34.2% of the total by 2030, generating about 11.7% of the electricity generation, and decided to focus on solar power generation and wind power construction, and vigorously promote the 2011 energy policy clearly put forward the "thousands of land and sea wind turbines" and "sunshine roof million" two major planning vision.

Taiwan's energy is highly dependent on imports, and according to Taiwan's economic sector, the province's crude oil supply in 2018 was 880,000 barrels per day, but since production was only 0.01 million barrels per day, the natural gas self-severity rate is less than 1%, since the closure of the last coal mine in 2000, coal consumption has all been imported, so international energy price fluctuations have a great impact on Taiwan's economy. As Taiwan’s largest energy industry, the power system is an independent power grid that cannot support each other's dispatch with neighboring regions, which means that other regions cannot be replenished in the event of a power outage in one part of Taiwan. In 2014, The backup capacity rate of Taiwan's power system was only 14.7%, well below the safety threshold of 25% to 30% of the maximum load of the power system in the international community (Du Qiang, 2016) and frequent power outages occurred throughout Taiwan Province in 2018 due to the DPP's hasty shutdown of nuclear power plants. Taiwan built the first nuclear power plant in 1971 and a second and third nuclear power plant in 1974 to ensure a stable energy supply,

but the Nuclear Four program was officially sealed in 2015 after construction was halted by the anti-nuclear movement. And according to the Wall Street Journal after the Fukushima accident assessment, Taiwan's densely populated, and the nuclear power plants are built in typhoons, earthquakes and other natural disasters in high-risk areas, there is a high risk of natural disasters. Moreover, the development of energy sources such as hydropower and land wind in Taiwan is nearing saturation.

As a result, Taiwan has been pushing for solar power since 2016, requiring 20GW by 2025, but the 17GW of ground-based solar power has decided to push for rooftop solar power because of problems such as land access and feeder setting. Taiwan authorities make full use of its distributed power generation structure, solar energy industry technology mature and complete industrial chain, can use the characteristics of large space, take the government, households zero-funded, technology, capital by the manufacturers responsible, and through preferential purchase rates, to pay the owner's roof rent, and give manufacturers a reasonable rate of return and other policies, hoping that by 2020 to 3GW set a volume target (Peng Xianzhong,2019).

In addition to the use of clean energy, in terms of energy supply, Taiwan rewards energy development, investment and acquisition outside the participating regions, promotes the use of natural gas, and innovates coal technology in low-carbon technologies. In the construction of power grid system, it is required to adjust energy and power supply and demand dynamically, recycle and reuse residual heat and cold, update power facilities, build intelligent power grid, improve scheduling and management process. In terms of market allocation, Taiwan seeks to rationalize energy prices and invest in technologies such as clean carbon reduction.

C. New Energy Industry Development Measures

In order to speed up the development of green technology, the Energy Bureau of the Ministry of Economy of Taiwan Province established the "Green Energy Industry Service Group" in 2009 to explore and analyze the development of new energy industries (mainly fuel cell technology such as photovoltaics, energy-based communications, LED, wind power technology, hydrogen energy and other fuel cell technology, biomass fuel six industries), promote cooperation in production and research, and also set up a "Green Energy Industry Information Network" to publish new energy market information and plan for the construction of new energy industries.

In terms of photovoltaic industry, Taiwan makes full use of its existing international petrochemical raw material plants and precision machining technology, as well as the complete industrial chain of semiconductor supporting, and uses special funds to subsidize the civil solar action. In terms of research and development of solar photovoltaic industry technology, Taiwan has made full use of its existing international petrochemical raw material plants and precision machining technology, Taiwan has made a great breakthrough in the research and development of thin silicon solar cells and the packaging technology of large-scale thin silicon solar cell modules (Huang Junling, 2011). Taiwan's solar energy companies have also been actively following the solar promotion boom, in 2017, The total solar capacity of Motech, Taiwan Province, China reached 3.6GW, becoming one of the world's largest professional solar cell manufacturers, but after 2018, due to increasing competition in the solar energy industry, and Low electricity prices in Taiwan, solar photovoltaic costs are still high and economic benefits are insufficient, Taiwan's demand is not enough to support the production of photovoltaic enterprises, Motech's share price fell from 985 to T$11.85.However, the Taiwan authorities are actively promoting the construction of photovoltaic projects, with a cumulative installed capacity of 3.8GW in September 2019 in Taiwan Province, in addition to actively changing the solar feed-in tariff, and are entitled to a 6% solar feed-in tariff incentive for projects that rely on locally manufactured solar modules, an initiative that effectively protects and promotes the development of local solar module suppliers, local battery and component manufacturing industries. In the wind power industry, Taiwan Province belongs to the island-type climate, has a wealth of resources suitable for wind power generation, and it has been studying wind power technology since 1980, the industrial supply chain is complete. By the end of 2017, 684 MW of on-land wind power had been installed in Taiwan and 8 MW of installed on water, a long way from the target of 4.2GW of wind power installed by 2025. However, Taiwan's Renewable Energy Development Regulations give preferential procurement rates, attracting a large number of international manufacturers to invest, in May 2020 Siemens, the world's largest offshore wind turbine SG 14-222DD applied to Taiwan, China's upcoming construction of 300 MW Hailong 2 project. In the area of biomass energy, Taiwan released in 2013 the Key Points of Subsidy operations for the Biogas Power System Promotion Program, which combines local authorities to promote the setup and operation of multi-source biogas power generation systems. In order to strengthen the implementation, in December of that year, the "Amendment Measures for the Promotion of Subsidy Operations" was issued to relax the restrictions on the annual approved subsidy scheme 2 and to adjust the requirement for each county and city to apply for 1 project per year to accelerate the spread of biogas power generation (Wang Zhigang and Xu Qiang,2015)In order to solve the problem of insufficient bio-fuel sources on the island, Taiwan Province, by rewarding the island's arable land to grow energy crops, strengthen the recovery of waste cooking oil, in order to solve the lack of bio-alcohol plants, Taiwan Province hopes that the industry will jointly develop related technologies to share the cost, in addition to Taiwan's development of biogas in many areas, rural areas have formed an efficient cycle of sustainable agricultural development model.

In addition, Taiwan Province of China began to develop organic agriculture and leisure agriculture after promoting the adjustment of agricultural production structure, training of agricultural construction personnel, large-scale operation of farms and land reform. In order to promote sustainable development, Taiwan put forward the "exquisite agriculture health excellence program" in 2009, which deepened the safety verification of agricultural products, adjusted the

production and marketing resume product system, and established the agriculture and forestry management system At the same time, the research team of various industries of animal husbandry and fishery has promoted the deep tourism of agriculture and forestry, and expanded the market of agricultural products and tourism products (Zhan Lizhu, 2019). Specifically, in the planting industry, it is required to plan fallow, promote the use of organic fertilizer, actively promote soil diagnosis and rational fertilization, control the use of pesticides, and recycle waste. We should adjust the industrial structure of animal husbandry, promote the reduction of livestock waste, reuse of organic waste, and assist in the establishment of agricultural and animal husbandry waste treatment center and forest green belt. In terms of fisheries, we should reduce freshwater aquaculture, promote mariculture, reward closed fishing, manage abandoned fishing boats, and promote the construction of ecological landscape fishing villages. In forestry, Taiwan Province actively encourages afforestation, optimizes forest management, maintains forest health and land restoration, and establishes a carbon estimation, investigation, monitoring and verification system. In terms of specific implementation, in order to implement the "sustainable energy policy guidelines - energy conservation and carbon reduction action plan", in 2008, Taiwan's "Council of agriculture" integrated its research institutions and administrative units in agriculture, forestry, fishery and animal husbandry, and established the "energy conservation and carbon reduction action plan" covering all fields of agriculture ”Key industry research team, through continuous research and development of pesticides and actively promote these new agricultural technologies, regularly guide farmers to timely, appropriate, effective and reasonable use of pesticides, to ensure the use of pesticides to control and reduce the harm of harmful substances. It can be seen that Taiwan has made great efforts in the construction of low-carbon agriculture.

III. The Difficulties and Problems Faced by Taiwan's Low-carbon Industry

Although Taiwan's low-carbon industry has a good basis for development, but with the world's investment in low-carbon industry research and development, as well as energy conservation and emission reduction technology continue to improve, low-carbon industry upgrading and development is also extremely rapid, Taiwan's low-carbon industry is full of opportunities, but also face no small challenges, mainly reflected in the following aspects.

Firstly, Renewable energy development is subject to various restrictions. Wind power and solar power are the main renewable energy sources in Taiwan, which are greatly affected by the climate. For example, the annual average utilization rate of photovoltaic power generation equipment is only about 14%. In addition, Taiwan lacks integrated policies, legislation and sustainable development goals in promoting renewable energy. Taking the promotion of biomass fuel as an example, although it announced that it would formulate the "incentive and subsidy measures for the production of biomass fuel by planting energy crops on fallow land" at the end of 2011, it was not released late. In 2013, it was in the consideration of driving safety, and the biodiesel blending standard was forced to be cancelled. At present, there is no independent renewable energy installation certification standard in Taiwan. In the cooperation with private enterprises, there is a lack of complete joint development mode and capital investment evaluation mode guidance. During the rapid construction, the equipment maintenance personnel are insufficient, so that the unit failure rate is high, and the power generation efficiency is not as good as expected (Zhou Liting, 2018).

Secondly, Low carbon energy-saving products lack of core innovation, and the technology is highly dependent on foreign countries. For example, in terms of energy saving and environmental protection industry, although Taiwan's LED photoelectric lighting industry is large, the key core patents are still in the hands of advanced manufacturers in Europe, the United States and Japan. In addition, the solar photovoltaic industry is developing rapidly, but the related supply chain key components and equipment support is very weak, lack of core competitiveness. Other industries, such as wind power, hydrogen energy and fuel cell industry, are similar, basically unable to meet international standards. Technology basically depends on the technology transfer of developed countries. Therefore, whether we can improve our core technology and reduce external dependence is very important for the future development of low-carbon industry in Taiwan.

Lastly, the small domestic demand and the lack of economic connection with the mainland restrict the development of Taiwan's low-carbon industry. Taiwan's low-carbon energy-saving products are highly dependent on technology, so they do not have obvious cost advantages, and their international market development ability is weak. For example, although more than 90% of Taiwan's solar cell products are exported, the market is mainly concentrated in Europe, while the island's domestic demand is insufficient. In addition, Taiwan's energy market is not sound, manufacturers' willingness to invest is weak, and there is a lack of large platform software manufacturers in the island, which makes the information exchange in Taiwan not smooth, and the competitiveness of system software is insufficient, which hinders the sustainable development in the future. In addition, Taiwan, after all, is narrow and small, and the industrial chain of many industries is not complete. Therefore, many incentive policies have to be limited to supporting services. Products are greatly affected by the world raw material market prices, and it is difficult to form competitive advantages. The relevance and benefits between industries are very limited, and it is difficult to sustain in the face of competition from large economies. Taiwan's economic subsidies are also relatively limited. For example, the annual budget for new energy vehicles is only NT $10 billion, and the main incentive measure is the exemption of goods tax, resulting in limited economic incentives.

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IV. The Characteristics and Enlightenment of Low-carbon Transformation of Taiwan's High-carbon Industry

A. Legislation First, Gradually Improve the Intensity of Environmental Regulation, Pay Attention to the Pace of Industrial Upgrading and Adaptability, Dynamic Balance Between the Economy and the Environment

The relevant laws to protect the environment should be highly targeted and operability. Taiwan's environmental protection industry began in the 1980s. Until then, there was no real environmental protection or low-carbon industry. But in the 1990s, under the trend of global sustainable development, Taiwan began to attach importance to and encourage the development of environmental protection industry. At present, industrial green and low-carbon supply chain management has begun to take shape. Although Taiwan's environmental protection products import dependence is high, economic export-oriented characteristics are obvious, low-carbon industry is still dominated by small and medium-sized enterprises, there are scattered characteristics, production, learning and research coordination capacity is insufficient. However, Taiwan has successfully achieved low-carbon development, the primary reason is the formulation and improvement of relevant policies, the formation of a long-term low-carbon development mechanism. Taiwan's low-carbon implementation program is often very specific, the implementation of the progress is basically in control. For example, in the implementation of the new energy vehicle policy in Taiwan, the various action plans are subdivided into annual implementation plans, and the corresponding objectives and funding estimates are formulated every year. In addition, the subsidy policy and regulations are also very clear, with strong operability, few disputes, and diversified subsidy methods. It can apply for tax subsidies, follow-up services or cash subsidies, and it can be widely promoted. After the implementation of the policy, Taiwan also stipulated the principle of dynamic editing, and adjusted the industrial deployment according to the actual situation. In terms of policy implementation results, some institutions in Taiwan have played an active role in monitoring. For example, the Taiwan Environmental Protection Alliance publishes the ranking of the implementation results of each city every year.

B. Pay Attention to the Collaborative Innovation of Industry, Science and Research, Encourage the Participation of Multiple Subjects, and Strive to Cultivate Ecological and Cultural Values

In the low-carbon transition, a higher degree of social participation is the guarantee. The implementation of a low-carbon society requires the joint efforts of government, industry, academic circles, consumption, circulation and other stakeholders. In order to make up for the market failure, Taiwan has actively promoted collaborative innovation in industry, education and research, encouraged multi-subject investment in research and development, and focused on the role of technological breakthroughs and knowledge spillovers in coping with sustainable energy transformation, and encouraged local voluntary organizations to play a guiding role in monitoring and guiding the development. At the same time, actively use the market mechanism to encourage enterprises to promote the full cycle of control from raw materials to production, and strive to internalize environmental protection costs. Cultivate people's awareness of low-carbon consumption from the aspects of environmental protection, health and responsibility, build key low-carbon demonstration cities, and actively promote cross-border cooperation, such as Yong An community demonstration points with remarkable results. The concerted push for these measures has significantly reduced greenhouse gas emissions in Taiwan.

C. Active Innovation to Break the Monopoly of Low-Carbon Technology in Developed Countries

As can be said above, although Taiwan's industrial low-carbon transformation has made great progress, but the development is still subject to the technology constraints of developed countries. In recent years, developed countries have brought a lot of troubles to developing countries' exports by raising import standards and levying carbon taxes, while developing countries' low-carbon technology started late. Blindly accepting low-carbon technology transfer from developed countries is not only very expensive, but also a big impact on local industries. Therefore, the author thinks that it is necessary to strengthen the cultivation of low-carbon technology related talents, improve laws and regulations, refer to Taiwan's experience, gradually replace the proportion of high-carbon industries from point to area, constantly supervise, dynamically balance the relationship between economy and low-carbon, and drive the whole society to form the awareness of sustainable development, so as to achieve high-quality sustainable development. In view of the problem of insufficient power output caused by excessive reform in Taiwan, we should pay attention to replacing and reforming high-energy consumption industries step by step in a planned and targeted way, ensure local supply, and promote in-depth cooperation between industries and countries.

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