Study of low-carbon energy development in China: the case of Fujian Province

Hongye Gao
Fuzhou University of International Studies and Trade, Fuzhou 350202, China
gaohongye@fzfu.edu.cn

Abstract. Carbon emissions caused by energy consumption have a serious impact on global climate change, causing serious environmental problems. As one of the world’s largest energy consumers and carbon emitters, China needs to attach great importance to low-carbon energy development, and address major environmental issues such as ecological destruction and climate warming. In the process of energy low-carbon development, Fujian Province is faced with a series of challenges in terms of energy structure, social and economic development, capital and technology, etc. However, at the same time, Fujian Province in China also has opportunities to develop energy low-carbon in terms of emission reduction space and rich forest resources. This paper firstly describes the energy consumption situation in Fujian Province and emphasizes the necessity of using low-carbon energy, then analyzes the energy structure of Fujian Province and the relationship between low carbon development and the adjustment of industrial structure in Fujian Province. Finally, this paper proposes that Fujian Province should make use of the advantages of renewable resources to develop a reasonable low-carbon energy development strategy.

Keywords: Energy Consumption; Low-carbon Energy; Fujian Province; Carbon Emission.

1. Introduction
So far, there have been three revolutions in the field of energy. The first one took place 400,000 years ago, marked by the discovery and use of fire; the second one took place in the 18th century England, marked by the large-scale use of coal; and the third one began in the 19th century. In the second half of the century, the main sign is the use of electricity and internal combustion engine, which represents that energy utilization has entered an era dominated by electricity and oil [1]. Fossil energy represented by coal and oil has promoted the second and third energy revolution.

According to the data of China Greenhouse Gas Inventory, China’s total carbon dioxide emissions in 1994 were 3.073 billion tons, of which 93.14% were from energy activities. Therefore, this paper mainly studies energy-related carbon emissions. In 2006, China’s energy-related carbon emissions exceeded that of the United States [2]. China is facing more and more pressure of emission reduction. The Chinese government has taken a variety of policy measures to change the mode of economic growth and adjust the economic structure to reduce greenhouse gas emissions. The research on carbon emission in China mainly includes the relationship between carbon emission and economic growth [3], energy
utilization and carbon emission [4], the effect of CO₂ collection and storage on carbon emission reduction [5] and the impact of carbon emission reduction on the economy [6].

Overall, China’s energy low-carbon development has regional characteristics, and the characteristics of each city are different. Fujian is located in the southeast coast of China, facing Taiwan Province across the Taiwan Strait in the East. Fujian Province has long been a region vulnerable to extreme climate, and global warming has a great impact on it [7]. Such low-carbon environment is another factor which requires Fujian to develop low-carbon energy. Therefore, the adoption of emission reduction strategy is conducive to mitigating the impact of climate change on people’s health, socio-economic development and ecosystem, and is the only way to realize the leap-forward development of economy in the west coast of the Straits. This paper analyzes the energy consumption of Fujian Province, and explore the characteristics and trends of energy carbon emissions. Then, it studies the internal relationship between carbon emissions and industrial structure. Finally, the paper puts forward some suggestions on how to develop low-carbon energy in Fujing Province. This will help explore the certain path of low-carbon energy development, and also provide a reference for the construction of low-carbon economy in the areas with rapid economic development and low energy self-sufficiency rate.

2. Energy Consumption in Fujian Province

According to 2020 Fujian Statistical Yearbook [8], the total energy consumption of Fujian Province increased year by year from 83.5367 million ton standard coal equivalent in 2009 to 137.1831 million ton standard coal equivalent in 2019. The growth rate and elasticity coefficient of energy consumption in recent years are shown in Table 1.

| year  | Growth Rate of Energy Consumption over Preceding Year (%) | Elasticity Ratio of Energy Consumption |
|-------|----------------------------------------------------------|----------------------------------------|
| 2010  | 10.00                                                    | 0.72                                   |
| 2011  | 8.61                                                     | 0.70                                   |
| 2012  | 5.00                                                     | 0.44                                   |
| 2013  | 6.78                                                     | 0.62                                   |
| 2014  | 8.22                                                     | 0.83                                   |
| 2017  | 4.31                                                     | 0.53                                   |
| 2018  | 4.59                                                     | 0.55                                   |
| 2019  | 4.47                                                     | 0.59                                   |

Note: Due to the negative Growth Rate of Electricity Consumption, Elasticity Ratio of Electricity Consumption in 2015 cannot be calculated, which also influences the data of 2016. So the data of these two years are excluded.

3. Status Quo of Carbon Emission in Fujian Province

According to the calculation methodology adopted by the IPCC (2006) [9] and the characteristics of Fujian Province energy statistics, the following formula is used to calculate the amount of carbon emissions due to energy consumption.

\[ C = \sum C_i = \sum_i N \times S_i \times F_i \]

Where \( C \) is the CO₂ emissions; \( i = 1, 2, 3, 4 \) which represent Coal, Petroleum, Natural Gas, Hydro-power & Wind Power respectively; \( C_i \) is the amount of carbon emission by different types of energy; \( N \) stands for total energy consumption of Fujian Province, \( S \) is structure of energy consumption; \( F_i \) is carbon emission factor (assuming \( F_i \) is fixed).

The carbon emission factor comes from the default value of IPCC carbon emission calculation guidelines. The original data is in J unit. In order to make the statistical data unit identical, the energy
unit is converted into standard coal equivalent unit, and the specific conversion coefficient: $1 \times 10^4 \text{t standard coal equivalent equals } 2.93 \times 10^5 \text{ GJ}$. Table 2 shows carbon emission factor for different types of energy.

| Carbon emission factor | Coal   | Petroleum | Natural Gas | Hydro-power & Wind Power |
|------------------------|--------|-----------|-------------|--------------------------|
| $F_i(10^4/10^4 \text{t standard coal equivalent})$ | 0.7669 | 0.5854    | 0.4478      | 0                        |

According to the data from 2020 Fujian Statistical Yearbook, the carbon emission each year of Fujian Province can be calculated by using formula (1). Fig. 1 shows the carbon emissions from 2009 to 2019 in Fujian Province.

![Fig. 1 Carbon emission and GDP in Fujian Province between 2009 and 2019](image)

The increase of carbon emission is due to the increase of energy consumption. By comparing carbon emission with GDP in Fig. 1, it can be seen that the growth trend of carbon emission and GDP is the same. Since 2009, carbon emission of energy consumption has increased significantly, and GDP has continued to grow in the same period, but the growth rate of carbon emission is slightly less than that of GDP. Overall, the economic development has a positive relationship with carbon emissions.

Moreover, the carbon emissions due to energy consumption in Fujian Province have a growing trend on the whole from $5.202 \times 10^7 \text{t}$ in 2009 to $7.118 \times 10^7 \text{t}$ in 2019. But the figure appears to decrease from 2014 to 2016. This is mainly due to three reasons. First, the energy structure of Fujian Province has been adjusted, and the proportion of coal and crude oil in that stage has decreased year by year. According to 2020 Fujian Statistical Yearbook, the proportion of coal and crude oil decrease to 43% and 23.8% in 2016, respectively. The proportion of clean energy, such as hydropower, wind power and nuclear power, increases. Second, in terms of policy, the energy structure of Fujian Province is gradually changing from high-carbon energy such as coal to clean or low-carbon energy (such as natural gas) due to the strict national environmental protection policy year by year. Third, as discussed above, there is a positive relationship between the economic growth and carbon emission. The economic growth of Fujian Province is still rapid, but with the large fluctuation. The average annual growth rate of GDP after price adjustment during the period is 12.16%. The economy maintains rapid growth at large, but the growth rate has changed greatly, so the economic growth slowed down from 2014 to 2016 and the amount of carbon emissions also reduces during the period. This also explain why the the carbon emissions due to energy consumption increases again from 2017.

4. Analysis of Energy Structure
The energy structure consists of low-carbon energy and high-carbon energy. According to the carbon emission factor of energy consumption in Table 2, the carbon emission factor of natural gas is lower than that of coal and oil, and the carbon emission factor of primary power and others (nuclear power, wind power, hydropower) is the smallest. Therefore, the adjustment of energy structure can affect the carbon emission. In Table 3, from 2009 to 2019, the proportion of high-carbon energy is decreasing, so
the average carbon emission factor will decrease. This indicates that the energy structure of Fujian Province has been optimized to some extent during the period. In Table 4, in the energy consumption structure of Fujian Province in 2019, coal accounts for 47.3%, and then come oil, natural gas and primary power and other energy at 23%, 4.8% and 24.9% respectively. The energy consumption structure of Fujian Province is slightly better than the national counterpart (See Table 4). But compared with the energy consumption structure of the major developed countries in the world, its structure has the obviously lower proportion of natural gas. Therefore, Fujian Province must further increase the proportion of low-carbon energy such as natural gas and primary power in the energy structure.

Table 3. Consumption Composition of Different Types of Energy

| Year | Coal (%) | Crude Oil (%) | Natural Gas (%) |
|------|----------|---------------|-----------------|
| 2009 | 65.5     | 19.5          | 1.4             |
| 2010 | 55.4     | 24.8          | 4.2             |
| 2011 | 62       | 24            | 4.6             |
| 2012 | 57.1     | 23.5          | 4.8             |
| 2013 | 56.8     | 23.3          | 5.8             |
| 2014 | 53       | 25.8          | 5.7             |
| 2015 | 49.9     | 24.8          | 5.1             |
| 2016 | 42.9     | 23.3          | 5.4             |
| 2017 | 45.1     | 24.1          | 5.3             |
| 2018 | 48.4     | 22.5          | 5.1             |
| 2019 | 47.3     | 23            | 4.8             |

Table 4. Energy Consumption Structure for Some Countries, the World and Fujian Province in 2019

| Country Or region | Oil (%) | Natural Gas (%) | Coal (%) |
|-------------------|---------|-----------------|---------|
| Fujian            | 23      | 4.8             | 47.3    |
| China             | 19.7    | 7.8             | 57.6    |
| Canada            | 31.7    | 30.5            | 3.9     |
| US                | 39.1    | 32.2            | 12.0    |
| Russian           | 22.0    | 53.7            | 12.2    |
| Germany           | 35.6    | 24.3            | 17.5    |
| World             | 33.1    | 24.2            | 27.0    |

According to the type of energy, the source of carbon emissions in Fujian Province can be divided into five categories: coal, oil, natural gas, electricity and heat. The main energy for power generation and heating consumption is coal. As a result, the proportion of coal in energy consumption has always been the largest and been much higher than that of other energy (See Table 3). Coal is also one of the energy sources with a large proportion of carbon emissions. But with the development of wind power and hydropower, there is still a lot of space for Fujian Province to reduce carbon emission [10]. Table 3 shows that the consumption of coal due to power generation shows a downward trend, but that of oil increases rapidly after 2017, accounting for 23% of energy consumption in 2019. Therefore, seeking alternative fuels of oil is an important way to reduce carbon emissions.

5. Relationship between Industrial Structure Adjustment and Low Carbon Development

First, low carbon development and industrial structure adjustment in Fujian Province are mutually conflict. At present, the industrialization of Fujian Province has not been completed, and it is in the middle stage of industrialization. Resource-dependent and high-energy consumption industries account for a large proportion of the total. However, the adjustment of industrial structure still needs to deepen
the degree of industrialization, which will usually bring more energy demand, more serious pollution and other problems, and eventually increase carbon emissions. Moreover, the technology, system, capital and other conditions that support the development of low-carbon economy need a certain period of time to be met, so the development of Fujian’s industrial structure from high carbon to low carbon needs more time.

On the other hand, low carbon development and industrial structure adjustment in Fujian Province can promote each other. The development of low-carbon technology as well as the formation and evolution of low-carbon industry will bring new impetus to the adjustment of industrial structure and new growth point to the economy of Fujian Province. Low-carbon development inevitably requires more investment and independent innovation in clean energy power generation such as solar energy and wind energy, smart grid, electric vehicles and battery energy storage technology research. But these not only provide strong support for low-carbon transformation, but also help the industrial structure adjustment of the whole province. Furthermore, the adjustment of industrial structure in Fujian Province will promote low-carbon development. First of all, the adjustment of industrial structure is an inevitable way of low-carbon development. Low-carbon development has three ways: low-carbon society, low-carbon market and low-carbon industry. Low-carbon industry is the core support platform for the development of low-carbon economy. Secondly, the industrial structure adjustment of Fujian Province is evolving along the path of the first, second and third industries, low value-added industries to high value-added industries, as well as the path of low processing industries to high processing industries. This can reduce carbon emissions and promote low-carbon development to a certain extent. Whether it is to reduce the total amount of carbon dioxide emissions or reduce the intensity of carbon emissions, it is necessary to adjust and optimize the industrial structure of Fujian Province.

6. Suggestions on Low-Carbon Energy Development

6.1. Optimization of Energy Structure
Comparing with the energy structures of developed countries and Fujian Province, the proportion of natural gas with low carbon emission factor in energy consumption of Fujian Province is too low, and the carbon emission of coal-fired power generation is very high. Therefore, vigorously developing renewable energy and new energy will help to optimize the energy structure, improve the efficiency of energy use and reduce carbon emissions. First of all, Fujian has good conditions for new energy such as solar energy and wind energy, and it can promote the development and utilization of new energy to supplement the energy demand of Fujian’s future development.

6.2. Taking Advantage of Rich Forest Resources to Increase Carbon Sink Capacity
Fujian should vigorously develop biomass energy. There are many kinds of biomass energy, including forestry biomass energy and agricultural biomass energy. In Fujian, forestry biomass energy have great development space. The important role of forestry in coping with climate change has been paid special attention. In December 2007, at the 13th Conference of the Parties to the United Nations Framework Convention on Climate Change, carbon emission reduction by forest is listed as an important part of the Bali road map. At present, the world bank, together with other institutions, is planning to establish a forest carbon partnership fund to help developing countries get international carbon financing in terms of activities such as protecting forests and curbing deforestation [11]. Therefore, Fujian should make full use of rich forest resources to maintain and increase the absorption, fixation and storage of carbon dioxide in the atmosphere by protecting or expanding the forest area, maintaining or increasing the carbon density at the forest level, so as to fully play the role of carbon sink of forestry.

6.3. Setting a Mechanism to Encourage Enterprises to Save Energy
To ensure the coordination of all parties in the process of implementing low-carbon development, the government should improve the deficiencies of some legal system design, provide clear rights and obligations boundaries for the parties to the agreement, and establish a directly applicable liability for
breach of contract and dispute resolution mechanism. Fujian Provincial Development and Reform Commission, Finance Department, Taxation Department, Industry Department and Environmental Protection Department should coordinate to provide a feasible policy system and work out feasible plans, such as giving priority to the arrangement of energy-saving technological transformation expenditure, increasing project loan discount, income tax preference, tariff preference for imported energy-saving equipment, reduction or return of sewage charges, preferential verification system, discount loan of national debt or investment subsidy, etc. In this way, most of enterprises tend to employ energy-saving technology and energy-saving equipment, and make contributions to carbon emission reduction.

7. Conclusion

China’s energy supply and demand are generally stable. Also, in China, the energy consumption structure is continuously optimized, and the construction of energy storage and transportation facilities is continuously improved. From the perspective of 2020, the next 10 years will be a key stage of China’s energy development and transformation, and an important period for China to realize its commitment in 2030. Low-carbon industry is to establish a new industrial structure and energy structure in order to achieve sustainable economic development. Low-carbon industry is not only the future economic growth point, but also an important measure to seize the commanding height of the industry in the future. Only by raising the awareness of low carbon, adjusting the development strategy and the structure of industries that are against the low carbon economy as soon as possible, as well as actively developing the industries that are suitable for the low carbon economy, can Fujian seize the opportunity to develop low carbon economy and realize the sustained and rapid economic growth. At the same time, in the process of low-carbon adjustment of industrial structure, Fujian should pay attention to coordinating the relationship between local industrialization and low-carbon economic development, and make full use of their own advantages in renewable energy and policy environment. The development model and route explored by Fujian Province will provide an important reference for other provinces in China to achieve low-carbon economic development, which is more conducive to the sustainable development of China’s future economy.

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