Research on Carbon Emissions and Carbon Reduction Paths of Power Generation Enterprises under the Dual Carbon Target

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Abstract. Achieving the dual carbon goal is a profound and challenging social transformation. The difficulty is mainly reflected in the fact that economic growth is usually linked to energy consumption. In today's society, no country or industry can completely abandon traditional energy, and the use of traditional energy, namely fossil fuels, would bring carbon emissions. Therefore, reducing carbon emissions while ensuring economic growth and achieving the dual carbon goals is an important issue at present. This article conducted a series of carbon emission analysis and carbon reduction path research for power generation enterprises, which are the major emitters of carbon emissions, based on the background of dual carbon goals.

1. Introduction

As the power lifeline of a region or a country, power generation enterprises or the power sector have sufficient resources, so it is necessary to promote the reform of power generation enterprises. Therefore, this article hopes to reform some technologies and policies in the power sector to reduce carbon emissions to a certain extent, in order to meet the dual carbon goals.

In today's global warming environment, controlling carbon emissions is a protection of the Earth's ecological environment. Engel-Cox J A conducted modeling work on reducing carbon dioxide and other greenhouse gas emissions [1]. Morris J also established an economic forecasting and policy analysis model to study the factors behind carbon capture and storage deployment and their role in reducing carbon emissions [2]. However, Miner K R proposed that the Permafrost in the Arctic stored 17 million tons of frozen and melted carbon, and climate warming may lead to their release, which needed to be prevented [3]. Bruckner B proposed that the distribution of wealth and income among the global population is disproportionate, which can lead to carbon inequality. In order to promote the development of impoverished areas, developed regions need to significantly reduce emissions [4]. This indicates that emission reduction and development need to coexist.

As the main force of carbon emissions, many scholars have put forward suggestions for the reform of the power sector. Dindi A believed that the public power sector should produce a certain proportion of low-carbon electricity by 2030 [5]. Anderson J J proposed that the main challenge in achieving rapid decarbonization in the power sector in the short term is to achieve net zero emissions while maintaining grid reliability and reducing costs [6]. Borowski P F proposed innovative biomass that can utilize bamboo as a productivity energy source for power plants [7]. Bistline J E T proposed a carbon dioxide removal technology that has an impact on deep decarbonization in the power sector [8]. Psomopoulos C S believed that energy can be recovered from waste to help the power sector implement decarbonization work [9]. Gedam V V believed that the power department still needs to do a good job in internal human resource management [10]. This is a proposal for unrelated technological reforms, but it remains important.

2. Background Description of Dual Carbon Targets

The so-called dual carbon target refers to carbon peaking and carbon neutrality. The definition of carbon peak is that at a certain point in time, the emission of carbon dioxide reaches its peak, stops growing, and begins to decline. Carbon neutrality refers to offsetting carbon emissions over a period of time through afforestation, energy conservation, and emission reduction, forming a relatively "zero emission" situation and achieving neutrality. To achieve these two goals, it is inevitable that traditional fossil fuels will transition to new energy. Institutions that use fossil fuels, from power plants and factories to rural individuals who burn coal and firewood, are all targets that require energy reform in the current context of the dual carbon target.

Ren D W proposed that energy activities are the main source of carbon dioxide emissions, with employee

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activities accounting for 80% of the total emissions, with the electricity sector accounting for over 40% of the emissions [11]. The testing formula for the spatial spillover effect of carbon emissions is:

$$I = \frac{n\sum_{a=1}^{n}\sum_{b=1}^{n} s_{ab}(x_a - \bar{x})(x_b - \bar{x})}{\sum_{a=1}^{n}\sum_{b=1}^{n} s_{ab}\sum_{a}^{n}(x_a - \bar{x})^2} \quad (1)$$

In the above formula, I is the local spatial indicator of carbon emissions, and n is the number of cities in the country. s_{ab} is the spatial weight. x_a, x_b are the per capita carbon emissions of city a and city b, respectively. $\bar{x}$ is the per capita carbon emissions of cities nationwide. This formula can be used to comprehensively evaluate and detect the spatial correlation characteristics of carbon emissions in target cities.

3. Carbon Emissions of Power Generation Enterprises

As is well known, thermal power generation, as the main force of traditional energy today, emits a large amount of carbon dioxide and other gases during the production process. As mentioned earlier, power generation enterprises account for the vast majority of carbon emissions in all industries. Therefore, in order to achieve the dual carbon target, it is very necessary for power generation enterprises to reduce emissions. Gao Y proposed to use LCA (Life Cycle Assessment) to establish a carbon emission assessment system for the Prefabricated building industry [12].

Table 1. Life Cycle Assessment Objects

Purpose and scope	System function	System boundary	System units
Inventory analysis	Material input	Energy input	Carbon emission factor
Impact evaluation	Resources consumption	Energy consumption	Carbon emissions

The objects of life cycle assessment are shown in Table 1. It can be seen that the evaluation objects of the lifecycle assessment framework are mainly divided into purpose and scope, inventory analysis, and impact evaluation. The purpose and scope mainly include system functions, system boundaries, and system units, while inventory analysis mainly includes material inputs, energy inputs, and carbon emission factors. The impact assessment mainly includes resource consumption, energy consumption, and carbon emissions.

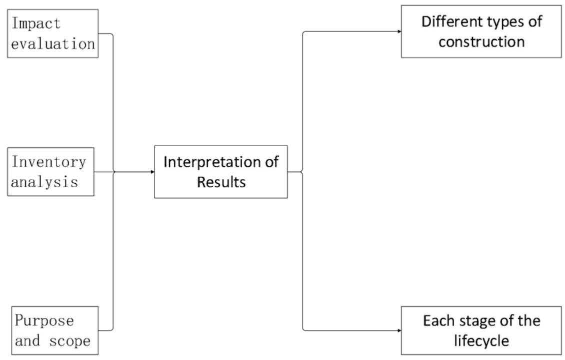

Figure 1. Life Cycle Assessment Framework

The lifecycle assessment framework is shown in Figure 1. The purpose and scope, inventory analysis, and impact assessment of these three evaluation objects explain their respective contents, and finally summarize and analyze the carbon emissions of different stages of the life cycle and different types of construction.

This framework can also be applied in the carbon emission evaluation and analysis of power generation enterprises. Resource consumption, material input, and carbon emission factors are important indicators for analyzing the carbon emissions of target enterprises, and can be calculated using the following formula:

$$P = \lambda \cdot x$$
$$\lambda = \eta \cdot y \cdot \mu \cdot \theta \quad (2)$$

In the above formula, P represents the emission of carbon dioxide. λ is the emission coefficient, and x is the consumption of fossil fuels. η is the carbon emission factor, and y is the low calorific value. μ is the carbon conversion coefficient, and θ is the carbon oxidation rate. After calculating the carbon emissions of the target enterprise, it can be counted and recorded. In the carbon emission analysis system, there is also a need for control and supervision of emission indicators. The government needs to develop emission indicators for each power generation enterprise to limit its excessive emissions. The government's formulation also needs to be based on the actual situation. For example, some areas are underdeveloped and need to obtain more emission indicators. Some areas have serious pollution problems and urgently need to limit emissions, or some areas of a city are densely populated and have more power supply needs. Therefore, emission indicators naturally need to be higher. Ramirez-Meyers K also proposed that the type of power plant needs to be classified and constructed according to different regions [13]. In summary, controlling carbon emissions is urgent in the current context of the dual carbon target, but it is also necessary to achieve a "soft landing" of energy conservation and emission reduction based on actual situations.

4. Carbon Reduction Paths for Power Generation Enterprises

4.1. Substitution of New Energy for Traditional Energy

Generally speaking, reducing carbon emissions leads to a reduction in energy acquisition, resulting in insufficient electricity supply, inadequate heating in some regions, and a slowdown in the development of some heavy industries. Therefore, energy conservation and emission reduction are not limited to simple emission reduction, but should seek various countermeasures to compensate for the energy shortage caused by emission reduction. Clean energy is naturally the preferred solution to this problem. Bhat A attempted to use clean energy in the production of two-dimensional materials [14]. Among many clean energy sources, wind power, solar power, and hydropower are the most representative new energy sources that people first consider. Kudria S pointed out that Ukraine has extremely strong wind energy potential and can carry out wind hydrogen power generation [15]. Alghamdi AS also conducted a series of studies on the efficiency of wind and solar energy [16]. The biggest advantage of these new energy sources is that they are environmentally friendly and renewable, without the need to eliminate greenhouse gases such as carbon dioxide. Moreover, compared to the slow generation rate of fossil fuels, the regeneration rate of new energy is extremely fast. Of course, in addition to these two points, some new energy sources also have great indirect value. For example, Geothermal energy, which is gradually widely used, can be directly used for heating in addition to power generation.

Li K also proposed that using nuclear energy for power generation under the dual carbon target is also worth considering [17]. The biggest problem of nuclear power generation is that at present, mankind only has mastered controllable Nuclear fission technology, not Fusion power, so nuclear power plants supported by Nuclear fission technology are at risk of nuclear leakage. Once a nuclear leakage accident occurs, its pollution and harm level far exceed conventional fossil fuel emissions. In history, such as the Chernobyl incident, it was a major nuclear leakage accident with profound harm. However, although nuclear leakage accidents pose significant risks, the accident rate is not high. Apart from the accident problem, nuclear power generation is considered a clean energy source under the premise of normal operation of nuclear power plants and proper disposal of nuclear waste, as it does not produce any greenhouse gases.

4.2. Improvement of Traditional Energy

Many people believe that renewable energy sources such as wind power and hydropower have considerable limitations. Zhu J H believed that these renewable energy sources did not have resource attributes and have low utilization rates [18]. Due to some technological limitations, the electricity provided by wind power, hydropower and other power generation methods is actually quite limited, and it is also limited by regions, and not all places can introduce these technologies. In his research, he proposed the use of biomass for power generation. In his view, biomass fertilizers such as straw, livestock and poultry discrimination, and household waste can all be used as fuel. China produces more than 5 billion tons of these Organic fertilizer every year. If they are treated by incineration, fermentation, composting or landfill, it would not only waste resources, but also produce more than 1 billion tons of carbon dioxide equivalent of greenhouse gases every year. Pal D B also proposed the use of biomass, and he believed that hydrogen can be produced from biomass. Hydrogen is a renewable energy carrier with great potential [19].

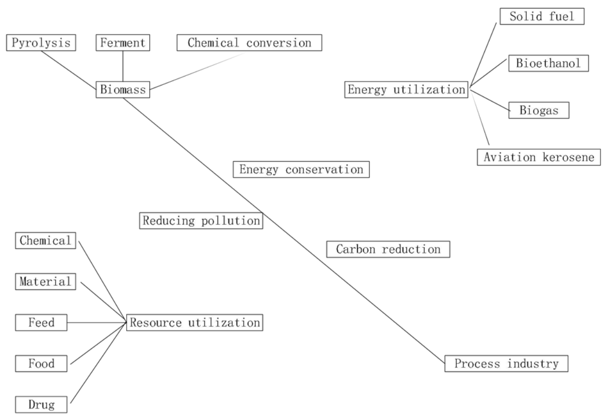

Figure 2. Schematic Diagram of Biomass Utilization

The utilization of biomass is shown in Figure 2. In this scenario, the ultimate goal is to apply biomass to the process industry. Under the overall policy of energy conservation, pollution reduction, and carbon reduction, biomass undergoes this process through high-temperature cracking, biological fermentation, and chemical conversion. In addition, in this process, some additional products can be generated, including chemicals, materials, feed and even food and medicine in terms of resources, and solid fuels, bioethanol, Biogas and aviation kerosene in terms of energy.

In addition, Ma X M also proposed to promote distributed photovoltaic power generation, improve fossil fuels, and appropriately shut down coal-fired power plants to achieve energy conservation and emission reduction in the capital [20]. He also used Shenzhen as an example in his research to analyze the expected emission reduction results of this series of reforms. This article selected a portion to showcase:

Table 2. List of Emission Reduction Technologies for Shenzhen Electric Power Department (Excerpt)

Technical Name	Emission reduction potential (10000 tons)	Emission reduction cost (10000 yuan)
Steam turbine seal modification	0.8	-1.7
Nameplate for unit capacity increase	4.5	-7.2

and modification		
Efficient motor replacement	1.0	1.1
Gas turbine intake cooling	1.6	-9.0
Renovation of Pure Condensing Steam Turbine Units	26.5	-359.5
Newly built gas turbine unit	72.0	775.2
Distributed photovoltaic power generation	415.3	2203.5
Improve the utilization rate of gas turbine units	22.5	-301.3
Other	593.0	1677.4
Total	1137.2	3978.5

The emission reduction technologies are shown in Table 2. In the selected list of technologies, this article lists technologies such as steam turbine seal modification, unit capacity increase and nameplate modification, efficient motor replacement, gas turbine inlet cooling, pure condensing steam turbine unit modification, new gas units, distributed photovoltaic power generation, and improving gas turbine utilization. It can be seen that these technologies either save money or spend money, or introduce new technologies or shut down or improve old technologies, and reform the power sector through various means to achieve emission reduction.

5. Conclusions

This article first explained the goals of each "energy individual" in this context by briefly describing the dual carbon goals, and then proposed that power generation enterprises are the main force of carbon emissions. To control carbon emissions, reforming power generation enterprises is essential. Finally, two methods were proposed, one is to use clean energy, and the other is to reform traditional energy to truly achieve energy conservation and emission reduction. At the end of this article, only a list of reform technologies and emission reduction expectations for the power sector in Shenzhen were listed. However, to truly achieve the dual carbon goal, relying solely on one province, one city, or one district is not enough, and Shenzhen, as a highly developed region, has different development and electricity needs compared to other regions. Therefore, this example cannot fully represent the actual situation in all regions.

Overall, the two major solutions proposed in this article are also the mainstream means of reducing emissions, and implementing emission reduction policies for power generation enterprises is also widely recognized. Therefore, future carbon reduction achievements are worth looking forward to. If all parts of the country can efficiently complete emission reduction work, then the achievement of the dual carbon target is just around the corner.

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