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Development forecast of renewable energy power generation in China and its influence on the GHG control strategy of the country

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ABSTRACT

CO_2 emissions of the electricity supply sector in China account for about half of the total volume in the country. Thus, reducing CO_2 emissions in China's electricity supply sector will contribute significantly to the efforts of greenhouse gas (GHG) control in the country and the rest of the world. This paper introduces the development status of renewable energy and other main CO_2 mitigation options in power generation in China and makes a preliminary prediction of the development of renewable energy in the country for future decades. Besides, based on the situation in China, the paper undertakes a comprehensive analysis of CO_2 mitigation costs, mitigation potential, and fossil energy conversation capacity of renewable energy and other mitigation options, through which the influence of renewable energy on the mitigation strategy of China is analyzed.

1. Introduction

Increasing concentration of CO_2 and other greenhouse gases (GHG) is the main reason behind alarming environmental phenomena, such as global warming and sea level rising [1]. China, one of the world's largest producers of CO_2 emissions, is responsible for about a fifth of global CO_2 emissions [2].

The electricity supply sector, a major source of CO_2 emissions in the world, accounts for about 37% of global CO_2 emissions, which may continuously increase in the future [3,4]. In China, the situation is even more serious. The CO_2 emissions of the electricity supply sector in the country, coming mainly from enormous coal-fired power plants, make up almost half of the total emissions volume generated by China [5]. Thus, reduction of CO_2 emissions in the electricity supply sector of China will make a significant contribution to the country and even to the whole world.

CO_2 emissions are easier to monitor and control from a limited number of centralized, stationary and large power stations, compared with small or mobile emission sources, such as vehicles, small boilers, and residential buildings. Therefore, CO_2 mitigation in the electricity supply sector is also considered as one of the most feasible methods for future GHG control [1,3,4].

Generally, CO_2 mitigation in the electricity supply sector can be achieved through the following options: (1) a more efficient conversion of fossil fuels; (2) switching to low-carbon fossil fuels; (3) CO_2 capture and storage (CCS); and (4) utilization of renewable energy or nuclear energy. For existing conventional power plants, the first three options play important roles, but have some limitations. For instance, the potential of energy efficiency improvement is relatively limited. The mitigation cost of CCS is typically high and consumes enormous extra energy. Moreover, China is a country lacking in low-carbon fossil fuels such as natural gas, indicating that utilization of low-carbon-intensive fuels may also be limited.

Unlike the traditional fossil energy system, renewable energy systems cause low pollution and near-zero CO_2 emission; thus, they have received growing interest for a number of applications. At the same time, corresponding researches on the development, application, and evaluation of renewable energy systems have been conducted in recent years. For example, Rhodes et al. provided a new suite of opportunities for biomass energy systems (biomass-CCS), and presented a simplified engineering economic model as a means toward fossil fuel use without atmospheric CO_2 emissions [6]. Manish et al. analyzed the sustainability of renewable energy for climate change mitigation by computing GHG emission, net energy ratio, resource constraints, and life-cycle cost [7]. In a case study of Organization for Economic Co-operation and Development (OECD) member countries, Chiu et al. concluded that the share of renewable energy supply was more than 8.3889% of the total energy supplied, which might help resolve the dilemma between economic growth and CO_2 emissions [8]. Akella et al. had discussed the social, economical, and environmental impacts of renewable energy

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systems, and presented the trends of total emission reduction in different years [9]. And an attempt has been made to estimate the CO_2 mitigation potential of solar home systems under the clean development mechanism (CDM) in India by Pallav Purohit [10].

Many scholars have identified the importance of renewable energy for CO_2 mitigation and have proposed various criteria to assess the mitigation cost, mitigation potential, and other performance indicators of renewable energy systems. However, few studies have given comprehensive scenarios of the development status and long-term forecast of the renewable energy power generation in China, together with its techno-economic performance and impact on the GHG control strategy of the electricity supply sector in the country.

Therefore, the objectives of the paper are: (1) to introduce the development status of renewable energy and other main CO_2 mitigation options in China; (2) to make a preliminary prediction of the development of renewable energy in China in future decades; (3) to undertake a comprehensive analysis of CO_2 mitigation costs, mitigation potential, and fossil fuel conversation capacity of renewable energy and other main CO_2 mitigation options, based on the situation in China; and (4) to analyze the influence of renewable energy on the electricity industry mitigation strategy in the country.

2. Renewable energy and other CO_2 mitigation options in power generation

In this section, the development status of renewable energy and other CO_2 mitigation options in the electricity supply sector in China are briefly introduced. Although fossil fuels, especially coal, are still the main energy resources in China, the proportion of renewable energy have gradually increased in recent years—and will continue to do so in the future—due to the requirements of pollutants control, saving on fossil fuels, as well as GHG control.

2.1. Renewable energy power generation

Renewable energy power generation includes hydropower, wind power, solar energy, biomass energy, tidal wave, ocean currents, geothermal power, and so on. In recent years, the utilization of renewable energy has received attention in China. As we know, renewable energy resources are abundant, but utilizing them involves some special technical, economic and environmental problems. The following part will briefly introduce the development status of renewable energies in China [11–19].

2.1.1. Hydropower [11–22]

China has abundant hydropower resources that remain as the most developed renewable energy resources in the country. Hydropower resources are widely distributed and mainly concentrated in the central and western regions. The exploitable hydropower resources in the Yangtze, Lancang, and Yellow Rivers as well as in their tributaries account for about 60% of the country's total.

Small and middle-sized hydropower plants are widely accepted as outlets of an environment-friendly energy resource. Large-sized hydropower plants, on the other hand, cause some indirect negative impact to the environment. For example, land submergence caused by building a large-scale reservoir can lead to changes in hydro-geological conditions and cause damage to wildlife environment. Nevertheless, in China, the most common viewpoint at present is that, taking into full account the environmental impact of hydropower and minimizing this impact before and during hydropower projects, there is no doubt that hydropower is indeed a valuable and feasible renewable energy resource with near-zero CO_2 emissions.

2.1.2. Wind power [11–19,23–25]

China is a country with vast coastal and inland windy areas that are critical for the country to become a major producer of wind power. The southeast coast and the vast western regions, including Xinjiang, Inner Mongolia, Gansu Corridor and some areas of the Qinghai-Tibet Plateau, comprises the main wind-rich areas. With increasing wind-driven generator units being put into operation, the cost of wind power has continually reduced. For example, in high-wind areas, wind power has become a competitive mode of power generation, costing between 0.4 and 0.8 CNY/kWh (approximately 0.046–0.092 Euro/kWh). Although the intermittent nature and noise pollution of wind power have brought about some barriers to its development, wind power still receives wide attention. It has made significant development in recent years and will continue to do so in the future. Wind power is predicted to become the third largest energy resource in China, after thermal power and hydropower in the near future; it also has good prospects for long-term CO_2 mitigation.

2.1.3. Solar power [11–19, 26–28]

In China, Solar photovoltaic (SPV) technologies are more mature than solar thermal power generation technologies. Accordingly, SPV acquired many applications, including some in commercial SPV power stations in the country. However, solar thermal power generation technologies are still under research and have few applications. Therefore, solar power discussed in this paper mainly refers to SPV power generation.

Many areas in China, such as Tibet, Qinghai, Xinjiang, Gansu, Ningxia and Inner Mongolia Plateau, can produce vast supplies of solar energy. However, the growth of the solar power industry has been primarily restricted by its high electricity cost of about 4 CNY/kWh, which is over ten times higher than that of coal-fired power plants. Despite the high cost of solar power, it has rapidly developed in recent years and has become a promising source of energy due to its vast reserves, renewable property, near-zero pollutants and GHG emissions, as well as the expectation of greatly decreased price in the future. Therefore, solar power is definitely an important CO_2 mitigation option in the present and in the long-term.

2.1.4. Biomass power [11–19]

Biomass energy resources, including crop residues, biomass from grasslands, solid wastes and wood residues, are renewable if properly managed. Given that the carbon within biomass is collected from the atmosphere through photosynthesis, biomass can be considered as having zero CO_2 emission. Moreover, if the biomass carbon released during combustion (as CO_2) is captured and stored, the net quantity of CO_2 emitted to the atmosphere could be negative in principle. There is a large quantity of biomass energy resources in China, equivalent to 890 million tons of standard coal resources each year. However, the main challenge of developing biomass energy may lie in providing sustainable management, collection of raw materials and delivery of electricity to power plants. Biomass resources are scattered and are currently more expensive than fossil fuels in many applications. Presently, capital investment for a biomass power plant is approximately 10,000 CNY/kW, with electricity cost of 0.45–0.9 CNY/kWh, which is higher than that of a coal-fired power plant. On the whole, biomass is an important renewable energy, with great potential in reducing CO_2 emissions, and is currently being rapidly developed.

2.1.5. Other renewable energy power resources [11–19, 29–31]

Other renewable energies, such as tidal power, wave power and ocean currents, are currently being studied but rarely used for commercial power generation. Geothermal power technology is relatively mature and the geothermal resources in China are