TYPES OF CO_2 EMISSION REDUCTION TECHNOLOGIES AND FUTURE DEVELOPMENT TRENDS

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Abstract. Global climate change is causing icebergs to melt, sea levels to rise, some islands to disappear, El Nino is rampant, and extreme weather occurs frequently. It profoundly affects the progress of human civilization and threatens everyone's living environment. It is the common task of all mankind to vigorously promote CO_2 reduction and deal with global warming. Among various carbon emission reduction measures and policies, CO_2 emission reduction technology has made rapid progress and has distinctive features in practical application. The potential economic benefits of further carbon abatement research are huge, as high value-added products can be obtained from cheap CO_2 sources, resulting in significant economic benefits. In addition, as a "renewable" carbon and oxygen resource, integrating CO_2 into the basic raw material of the production process is an important sustainable development strategy, so the environmental benefits of further strengthening CO_2 emission reduction cannot be ignored. From the perspective of the CO_2 emission cycle, this paper introduces the widely used CO_2 emission reduction technology and expounds on the trend of CO_2 emission reduction in the future.

Keywords: CO_2 emission reduction, technologies, sustainable development.

Introduction

In July 2021, BP (British Petroleum) released the latest BP Statistical Yearbook of World Energy (2021), which described 2020 as a very special year in the history of world energy. Global energy consumption fell by 4.5% in 2020, the biggest drop since the end of World War II, due to the impact of COVID-19. Renewable energy, led by wind and solar, maintained its momentum, with global carbon emissions falling 6.3% year by year. Oil consumption accounted for 31.2% of the global energy mix, followed by coal at 27.2%, natural gas at 24.7%, hydropower at 6.9%, renewables at 5.7%, and nuclear at 4.3%. It can be seen that by 2020 fossil energy will still be the absolute hegemon of energy consumption, accounting for up to 83.1%. According to the UN's Intergovernmental Panel on Climate Change, CO_2 levels in the atmosphere will reach 570×10-6 by 2100 [1]. The increase of CO_2 concentration promotes global warming and also causes a series of ecological and environmental problems.

As the terminal form of carbon-based energy, CO_2 can not only have a great impact on the environment but also be converted into energy products and realize the carbon cycle quickly, which is also of great significance to the energy field. In recent years, the rapid progress of CO_2 emission reduction technology is mainly reflected in: the traditional CO_2 emission reduction technology has been or is being commercialized demonstration; the life cycle evaluation, technical and economic evaluation and policy model research of CO_2 emission reduction technologies have been deepened, and the corresponding priority opportunities and market models have gradually become clear. To some extent, external conditions have been formed to promote the rapid development and deployment of technologies. Research on the significance of CO_2 emission reduction may become a feasible strategic measure to ensure energy security, promote sustainable development, reduce greenhouse gas emissions and promote the incubation of new low-carbon business forms. Therefore, low-carbon development should be regarded as a major strategy of social development and an important way of ecological civilization construction, and measures should be actively taken to effectively control greenhouse gas emissions [2].

Widely used CO2 reduction technologies

1. The source of CO_2 emissions

CO2 emissions come from a wide range of sources, mainly including the following.

- Oil and gas fields: some associated gas will be released during the exploitation of oil and gas fields, in which CO2 gas content is 15% ~ 99%.

- Ore decomposition process: some raw materials used in steelmaking, firebrick, and other production processes go through a series of chemical reactions to generate a large amount of CO2 gas.
- Hydrogen production process of chemical plants: refineries or chemical plants often need to use H2 in the production process, and when CH4, CO, and other substances react with H2O to generate H2, CO2 will also be generated, and most of this CO2 is directly discharged to the atmosphere without treatment.
- Food and pharmaceutical industries: alcohol and a large amount of CO2 gas are generated in the fermentation process, and these CO2 gases generally have a high concentration.
- Agriculture is the foundation of the national economy, but at the same time there is growing concern about its carbon footprint [3]. As open ecosystems, agricultural systems require large amounts of supporting inputs from outside sources, such as fertilisers and farm machinery, to continuously contribute to the smooth flow of energy, material and information and to maximise the flow of economic value [4]. However, these inputs contribute to the total greenhouse gas emissions from agriculture, which account for about 25% of global emissions and already exceed the carbon emissions of the transport sector and are even close to those of electricity production [5].

2. CO2 reduction technologies

The CO2 emission of coal-burning is 0.7 t, the CO2 emission of natural gas is only 0.39 t, and the nuclear power is zero. In China, for example, the majority of energy consumption is coal, with a small share of clean energy sources, such as natural gas. Therefore, an irrational energy structure is one of the main reasons for high CO2 emissions [6]. Controlling and gradually reducing the proportion of coal use from the source can effectively reduce or even avoid CO2 emissions. In addition to limiting the use of traditional fossil energy sources, such as oil and coal, it is important to identify and develop mitigation and production-balancing disincentives, including through carbon capture technology innovation, enhanced efficient hydrogen use from the most widely distributed resources, and wider commercial use. Through sensitive regulation of market mechanisms, the construction of the carbon market is promoted to achieve total emission control.

Process control is to further optimize the processing technology of some high energy consumption industries, improve energy efficiency, and ultimately achieve CO_2 emission reduction. CO_2 reforming CH_4 synthesis of syngas technology, its effective coupling with various coal chemical processes is expected to significantly reduce the emissions of coal chemical process, improve the overall economic benefits. The effective combination of this technology with hydrogen-rich processes, such as the salt halogen chemical industry, is expected to form a new methanol synthesis route, which has significant emission reduction potential. CO_2 synthesis of carbonate materials has formed a high value-added long-term carbon sequestration strategy [7]. In recent years, artificial photosynthesis technology based on CO_2 photocatalytic transformation has made rapid progress. This technique achieves CO_2 activation and directional conversion under mild conditions. Although its efficiency is far lower than that of traditional thermal catalysis, it is highly compatible with renewable energy and can directly take advantage of the huge advantage of ultra-low CO_2 concentration. It is a potential negative carbon technology with great potential. In addition, the development of unconventional oil and gas resources by CO_2 fracturing, as well as the new use of CO_2 characterized by metabolic engineering and synthetic biology, has greatly expanded the research and development ideas and applications. Therefore, adopting new technologies and new processes, updating equipment in time and controlling the CO_2 production process can effectively improve the energy utilization efficiency of energy-consuming industries and then reduce the CO_2 emissions of energy-consuming industries.

For terminal control, CO_2 reductions can be achieved by enhancing natural carbon sinks, using technologies such as carbon capture and storage (CCS), or a combination of both. Strengthening natural carbon sinks mainly refers to the process of absorbing CO_2 from the atmosphere through plant photosynthesis and fixing it in vegetation and soil through afforestation, forest management, vegetation restoration, and other measures, to achieve negative emissions. In addition to natural sinks, other negative emission measures include biomass energy-carbon capture and sequestration (BECCS), direct air carbon capture and sequestration (DACCS), biochar, enhanced weathering, marine alkalization, and marine fertilization. However, most of the current negative emission technologies are in the early stage of development, with the high cost and unproven effectiveness. The CCS is widely regarded as one of the most effective methods. CCS refers to the process of separating, capturing, transporting, and storing CO_2. The application of this technology does not cause energy loss or conflict with existing systems, so it is widely used in the industry [8]. But the technology does not allow for large-scale CO_2 sequestration.

Specific measures include appropriate field management, water and fertiliser regulation, and crop rotation to reduce greenhouse gas emissions and increase soil carbon sequestration to achieve the goal of carbon sequestration and emission reduction, taking into account the soil environment, microbial activity and nitrification and denitrification mechanisms [9]. Studies have shown that the application of slow-release fertilizers, water-saving irrigation and the combination of two measures can reduce CH4 emissions from rice fields by 19%, 21% and 41% respectively [10]. In addition, through the promotion of advanced and applicable low-carbon and energy-saving agricultural equipment, fossil energy consumption and CO2 emissions can be reduced, new energy sources, such as biomass and solar energy, can be developed, and the use of new energy sources for heating and cooking in rural areas and agricultural facilities can be accelerated to reduce fossil energy emissions. Through the physiological regulation of ruminants and feed technology, greenhouse gas emissions from the intestinal tract of animals and their manure can be reduced; through the pollution control and comprehensive use of livestock and poultry breeding waste, and the strengthening of environmental management of centralized disposal facilities for sewage and rubbish, greenhouse gas can be controlled in a concerted manner.

Future trends in carbon reduction

At present, under the influence of "carbon peak" and "carbon neutrality", traditional heavy industries, such as coal, smelting, and petrochemical industry, are greatly affected. They are not only negatively affected by high carbon emissions, difficult pollution prevention and control, and limited development space, but also positively affected by technology upgrading, equipment updating, and strong industrial correlation [11]. One reason for this is that it is difficult for scientists to visualize global warming intuitively because of the complexity of the factors that affect the global climate and the variety of its anomalies. From the perspective of future trends, low-carbon development needs to be explored and studied from the following three aspects.

First, expand the development and utilization of hydrogen energy. As the lightest chemical element, hydrogen has the highest energy density among all fossil fuels, chemical fuels, and bio-fuels, except nuclear fuel, which is 1000 times that of wood, 6.8 times that of coal, 3.4 times that of natural gas, and 3.3 times that of oil. Because of this, hydrogen conducts heat more than 10 times better than most gases. On the economic front, due to the limitation of cost, though it is hard to tell the price advantage of hydrogen in all aspects, but many areas have enough attraction, hydrogen fuel cells, for example, a car 5 kg of hydrogen can range of 650 km, the total price is 27 USD, and using gasoline 650 km, the fuel costs about 54 USD, that is half of the former. From a security point of view, the product of hydrogen combustion is water, with no negative externalities such as CO, CO_2, hydrocarbons, and dust particles that are harmful to the environment. Therefore, hydrogen can become the cleanest energy source in the world and the most promising way to help decarbonize humanity in the future. According to the Estimates of the International Hydrogen Energy Committee, by 2050, the proportion of hydrogen energy in global energy will reach about 18%, and the value of the hydrogen energy industry chain will exceed 2.5 trillion US dollars. Due to its advantages of high efficiency, economy, and safety, the global hydrogen energy industry will face great opportunities for rapid development in the next 10-20 years with the continuous investment of technology research and development and industrial capital. Therefore, hydrogen is considered the most promising alternative energy in the 21st century [12].

The second is to develop the carbon capture technology. If we want to achieve zero emissions, in addition to the limited use of traditional petrochemical and expanding renewable energy, such as solar energy, wind energy, and hydropower proportion, also is to increase vegetation and soil and water conservation, improve the strength of the nature to absorb CO_2, however, land plants absorb only 33% of the world's CO_2, the ocean absorbs 24% of the remaining 43% emissions into the atmosphere. It is difficult to replace fossil fuels quickly and effectively with renewable energy sources in short supply. Experts predict fossil fuels will remain a major part of global energy use until 2040. Under current technology, the captured CO_2 is processed into a liquid, which is then stored via pipelines in rock formations 2000 m below land or 3000 m below the ocean floor. Energy experts estimate that large plants using CCS could reduce carbon emissions per unit of electricity by 85% to 90%. An analysis by the International Energy Agency also suggests that full-scale CCS could reduce total carbon emissions by 14% and the cost of human emissions by 30%. Captured CO_2 can also be commercially exploited, extending the concept of CCUS for CO_2 capture, storage, and utilization. In addition, CCUS can greatly address the anxiety and concern about possible leakage of CO_2 after storage. According to an authoritative report from the IEA, CCUS technology can be used to produce low-carbon hydrocarbons from fossil fuels. It is predicted that by 2070, CCUS will produce 40% of global hydrogen production from low-carbon hydrocarbons.

The third is to strengthen the regulation mechanism function of energy storage. According to the technical route of energy storage, energy storage is mainly divided into electrochemical energy storage and mechanical energy storage. Electrochemical energy storage includes lithium-ion batteries and lead batteries, while mechanical energy storage mainly includes pumped storage and compressed air energy storage. Statistics show that by the end of 2020, the accumulative installed capacity of energy storage projects in the world has reached 191.1GW, among which pumped storage is the largest, accounting for 90.3%. The installed scale of electrochemical energy storage followed, accounting for 7.5%. Now, although the electrochemical energy storage proportion is not big, but compared with the pumping energy storage is not restricted by regional conditions, low cost and long service life and so on commercial advantages, at the same time, the world has put into operation in electrochemical energy storage projects installed the largest lithium-ion batteries, but due to the cost of battery accounted for over 50% of the energy storage system, in addition, the cost of lithium-ion batteries worldwide has fallen rapidly in recent years (Bloomberg statistics show that the average price of lithium-ion batteries worldwide has dropped to USD 137/KWH in 2020, down nearly 80% compared with 2013), and with the continuous decline in cost, the application space of lithium battery energy storage has been opened up. The data show that the installed capacity of global electrochemical energy storage increased from less than 1GW to more than 13GW from 2012 to 2020, contributing to the main increase of installed capacity of global electric energy storage. In the future, the application scale of electrochemical energy storage will continue to expand year by year and is bound to become the mainstream direction of energy storage.

Conclusions

After launching the Framework Convention on Climate Change and the Kyoto Protocol, the United Nations organized 197 countries to sign the Paris Agreement, which made major economies around the world accelerate the pace of emission reduction and carbon control. Although the research on CO_2 utilization has made great progress, there are still many difficulties:

- Sequestration is still the main treatment method of CO_2. The controversy about CCS mainly comes from the "exact sequestration capacity" and "leakage risk after sequestration". Therefore, it is necessary to continue to strengthen the exploration of evaluation methods for sequestration potential and improve the credibility of evaluation results. On the other hand, the study of monitoring means and methods should be strengthened to further understand the long-term sequestration, flow, and leakage process of CO_2 in geological structures.
- The research scale is small, the research mainly stays at the laboratory scale, the scale of pilot-scale is very low, and industrialization is rare. The research and transformation of CCS and CCUS should be continued to control costs, develop more efficient and easy-to-operate technologies, and promote their widespread application.

In general, the significance of CO_2 emission reduction is not only to offset the high cost of the carbon capture process, but more importantly, it may become a feasible strategic technology choice to guarantee energy security, promote sustainable development, reduce greenhouse gas emissions and promote the incubation of low-carbon new business forms.

Author contributions

Conceptualization, H.R. Wei; methodology, H.R. Wei; validation, H.R. Wei and P. Liu; formal analysis, H.R. Wei and P. Liu; investigation, H.R. Wei, L. Xin and P. Liu; data curation, H.R. Wei and P. Liu; writing – original draft preparation, H.R. Wei; writing – review and editing, H.R. Wei; project administration, H.R. Wei. All authors have read and agreed to the published version of the manuscript.

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