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A REVIEW STUDY ON THE EFFECTS OF USING RENEWABLE ENERGY ON CARBON DIOXIDE EMISSIONS IN CHINA

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ABSTRACT: As a major solution to climate change, the low-carbon transition of energy systems has received growing attention in the past decade the low-carbon transition of energy systems is becoming an increasingly important policy agenda in most countries. The Paris Agreement signed in 2015 calls for substantial reductions in anthropogenic carbon dioxide emissions during the 21st century, with ambitious decarbonization targets set up globally .Based on the literature review, the Chinese government should pay more attention to renewable and non-renewable energy consumption in order to realize the continuous growth trend of renewable energy consumption. As we all know, greenhouse gas emissions from non-renewable energy consumption have an adverse effect on ecosystem activities. However, the economic benefits of non-renewable energy consumption in life and production are more obvious, and the electricity consumption from non-renewable energy sources is also more common. But considering clean energy, carbon emission reduction, and energy security, increasing renewable energy consumption is inevitable. At the same time, in order to achieve the ultimate goal of energy conservation, emission reduction, and ecological environment construction, we still face a large uncertainty in dealing with climate change. For this reason, the Chinese government should provide financial, legal, and policy support, from the perspective of government policy and investment incentives to increase the proportion of renewable energy in energy consumption, so as to reduce the consumption of non-renewable energy.

Key words: Renewable energy, energy consumption, on CO_2 emissions.

INTRODUCTION

Energy is the basic support for the development of modern society and the foundation for human survival. With the development of the global economy and population growth, the demand for energy in human society has also increased substantially (**Xu *et al.*, 2019**). In addition, due to its non-renewability, fossil energy, which is the main source of energy for human society, is gradually facing the danger of exhaustion with the consumption of human life and social development, and it will cause serious environmental problems because of long-term dependence and use of traditional fossil energy (**Belaïd and Zrelli, 2019**).

China surpassed Japan to become the world's second largest economy in 2010. However, China's carbon emissions and energy consumption have surged, and the conflict between energy consumption, carbon emissions, and economic growth has become increasingly prominent. On the one hand, the current high per capita carbon emissions put China under enormous domestic and international pressure; on the other hand, China's coal-based consumption structure has resulted in low levels of consumption of major renewable energy sources such as nuclear and wind power. Therefore, driven by the background of green development, it is imperative to vigorously develop renewable energy. According to the statistics of China's National Energy Administration (NEA), the renewable energy

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industry investment will reach US$800 billion from 2016 to 2030 in China. At the same time, it is expected that, by 2030, renewable energy will account for at least 20% of total energy consumption. According to a report released by the World Greenpeace Organization (Greenpeace), China plans to increase the share of solar and wind energy as primary energy consumption. Total renewable energy consumption in 2020 is 186 million tons of oil equivalent, accounting for 5.36% of total energy consumption, an increase of 15.41% from 2019. By the end of 2030, renewable energy will account for at least 20% of total energy consumption, which is higher than the 12% in 2015. In addition, around 2030, China's CO_2 emissions are expected to reach peak. If wind and solar energy goals can be achieved by 2030, China can reduce fossil fuel consumption by nearly 300 million tons of standard coal each year, which is equivalent to France's total primary energy consumption in 2015. On the basis of the Analysis Report on Development Trends and Prospects of China's Renewable Energy Industry from 2021 to 2027, in terms of electricity, by the end of 2020, China's cumulative installed capacity of non-aqueous renewable energy power generation has reached 25.6%, of which the installed capacity of wind power is 280 million kilowatts, accounting for 13%; the installed capacity of solar power is 250 million kilowatts, accounting for 12%. In addition, in 2020, China's wind power and photovoltaic power continue to maintain rapid growth. The newly installed wind power capacity is 71.67 million kilowatts, accounting for 38% of the newly added power generation installed capacity; the newly installed photovoltaic power generation capacity is 48.2 million kilowatts, accounting for 25% of the newly added power generation installed capacity. In this context, the Chinese government is expected to complete the goal of energy conservation and emission reduction and to a certain extent promotes the sustainable development of the economy and the environment.

LITERATURE REVIEW

Does Renewable Energy Improve the Environment?

In recent years, energy consumption relying on burning fossil fuels has led to a rapid increase in global greenhouse gas emissions, causing climate change and environmental degradation (**Hu *et al.*, 2021**). **Riti *et al.* (2017)** have used different estimation methods, such as ARDL (autoregressive distributed hysteresis) model, FMOLS, DOLS, and impulse response and variance decomposition to examine the relationship between CO_2 emissions, economic growth, and energy consumption in China (Fig. 1 and Table 1). The study has found that China's extensive economic development and rapid growth in energy consumption are the main reasons for the increase in greenhouse gas emissions (**Murshed *et al.*, 2021**). **Apergis *et al.* (2018**) have examined the relationship between renewable energy consumption and CO_2 emissions in sub-Saharan Africa countries from 1995 to 2011 and found that there is a short-run two-way causal relationship between renewable energy consumption and CO_2 emissions (supporting the feedback hypothesis), while long-run elasticities suggest that renewable energy consumption helps reduce CO_2 emissions. This finding is similar to existing energy literature such as **Zhang *et al.* (2021)** for the case of China. In response to this view, **Hu *et al.* (2021)** found a unidirectional causal relationship between renewable energy consumption and CO_2 emissions by examining the effects of disaggregated energy consumption, technological innovation, and capital on economic output and CO_2 emissions in India over the period from 1990 to 2018, although renewable energy consumption can significantly reduce CO_2 emissions in India.

In line with rapidly increasing levels of renewable energy consumption, many studies have examined the impact of renewable energy consumption on CO_2 emissions. They conclude that increasing renewable energy consumption mitigates CO_2 emissions for the economies of the USA (**Baek, 2016**); China (**Chen *et al.*, 2019**) and OECD economies (**Ahmad *et al.*, 2021**). For instance, **Baek (2016)** used the US data to examine the effects of renewable energy on CO_2 emissions and found that renewable energy consumption only has a negative impact on reducing CO_2 emissions in the short run.

Renewable Energy and Carbon Emissions

It is now common knowledge that if the rate of global warming is not slowed down by implementing effective countermeasures, the entire world will inescapably be forced to deal with ferocious and environmental catastrophes. According to **Feng *et al.* (2022)**, the reduction

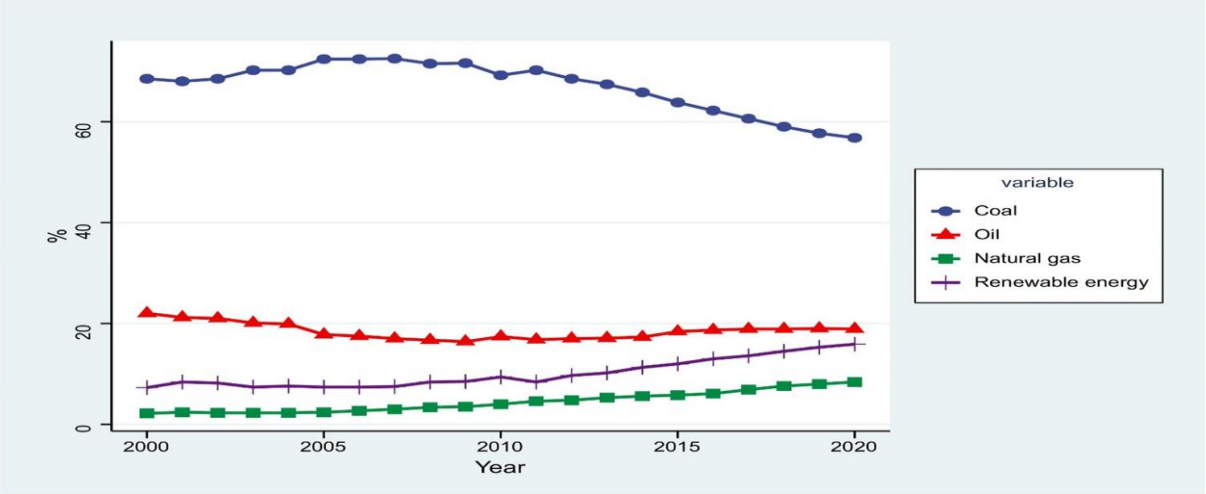

Fig. 1. China's energy consumption structure

Source: Hao, (2022)

Table 1. Variable description

Variables	Description	Data source	Measure
RE	Renewable energy consumption	Energy Statistical Yearbook of China, and IEA	% of primary energy
CE	Carbon emissions	World Bank	Tons per capita
OTP	Total output of industrial and agricultural sectors	World Bank	% of GDP
EXP	Total value of export of and agricultural sectors	National Bureau of Statistics of China	% of GDP

Source: Hao, Y. (2022).

of 25% of world GDP due to uncontrolled greenhouse gas emissions is likely, while limiting emissions will only cost about 1% of GDP. In addition to endangering people's ability to feed themselves and their families, the continued increase in CO_2 emissions, the primary cause of climate change, will cause temperatures to soar even higher. It is important to remember that the world's energy landscape is dynamic and ever-changing, and this poses a serious problem for countries that rely on imported energy.

Furthermore, (**Handayani and Surachman, 2017**), researched CO_2 emissions have a long-term and short-term impact. According to the results of their study, renewable energy can be regarded as an important factor in reducing carbon dioxide produced during the process of power generation. This was the conclusion of their investigation into the long-term and short-term causality of the CO_2 emissions. According to research carried out by **Sharma *et al.* (2021)**, renewable energy can serve as a viable replacement for conventional forms of energy derived from fossil fuels and cut down on CO_2 emissions significantly. In addition, According to, there appears to be a significant negative impact on CO_2 emissions from increased consumption of RE and other forest plantations over a long period of time (**Xiang *et al.*, 2022**). A reduction in carbon dioxide emissions will follow after an increase in the proportion of renewable energy in the energy consumption function, which will cause the intensity of renewable energy to rise.

As the three countries that produce the most carbon dioxide emissions in the world, India, China, and ISA have all begun competing in a green energy race in an effort to find practical answers to the issue of global warming. In each of these three nations, energy is not only the most significant contributor to overall carbon emissions but also an essential component in laying the groundwork for continued economic and social advancement (**Ye *et al.*, 2022**). The transformation of energy to green and low in carbon in the wake of this, the two nations are striving to alter the energy policy trend by focusing more on renewable energy (RE). However, because of the expense of decarbonization, it is unclear whether or not RE can serve as a useful tool in pursuing the organization's objective of reaching carbon neutrality. As a result, we have decided to investigate the possible cause-and-effect relationship between RE and CO_2.

Renewable Energy Development: What Driving Forces Are at Work?

RE has become an important part of the human energy supply system due to its reproducibility. The history of energy use is a history of continuously seeking alternative and enriching energy sources. Many scholars are optimistic about the future development of RE. **Dequn *et al.* (2021)** believed that RE would be the pillar energy of the earth in the future. The scale of global RE development and utilization continues to expand. The cost to develop RE is rapidly decreasing. RE development has become a core approach for advancing energy transitions in many countries and is a key way to mitigate climate change. The important measures for China include advancing the revolutions in energy production and consumption and improving energy transitions (Fig. 2 and Table 2).

RE development has its own general laws and characteristics. Accurately understanding these rules and characteristics will help us advance the transformation of the energy system and steadily mitigate climate change. Existing literature has mainly focused on identifying the forces driving RE development.

Dequn *et al.* (2021) and **Zhou *et al.* (2023)** A series of studies have been conducted on RE development, with many important results and achievements. The existing research has found several important trends as follows:

First, a key question for future studies relates to identifying the forces driving RE development and their resulting effects. Different factors affect RE development, including policy, economic, and technology. Most studies have focused on the influences of a single factor.

Second, future studies on RE development should consider the contextual factors. The political, economic, and environmental situations in different countries form the context of RE development. Past studies have comprehensively compared and discussed the national energy system transition in different countries. These studies have been at the macro level, with few completing in-depth discussions about the contextual factors.

Third, subjective preferences and behaviors are important topics for future RE developmental studies. Studies have started to focus on the conflict and synergy between different agents in RE development. Most studies have concentrated on the choices and decisions of agents at the micro level. Few studies have discussed the diversity and complexity of the different agents in RE development.

Fourth, the contributions of RE development preferences and their effects should also be assessed Few studies have addressed this area.

Fifth, further research is needed with respect to RE development goals and paths. The low carbon energy transition concentrated on RE development has attracted worldwide attentions.

This study contributes to an enhanced understanding with respect to the driving forces of RE development. A systematic literature review highlights the needs for future studies in RE development.

Hydro

China's hydroelectricity potential by 2030 is 400 gigawatts-electric (GWe). Already envisaged in the business-as-usual scenario, this will require significant cross boundary coordination, as well as enhanced river and water management. Total pumped hydro capacity, crucial for energy storage, should reach 100 GWe.

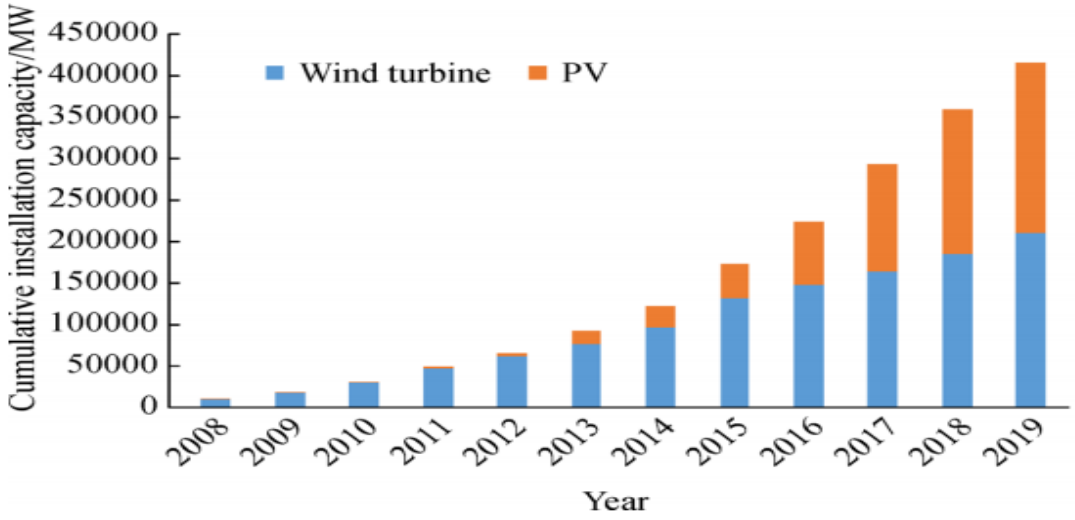

Fig. 2. Cumulative installation capacities of wind turbines and PV in China.

Source: China Electricity Council).

Source: Dequn *et al.* (2021)

Table 2. Examples of China's RE developmental goals and real achievements

Goals and real achievements	Wind turbine (MW)	PV (MW)	Biomass power (MW)
10th Five-Year Plan			
Goal	1200	53	
Real achievement	1260	70	
11th Five-Year Plan			
Goal	10000	300	5500
Real achievement	31000	800	5500
12th Five-Year Plan			
Goal	100000	21000	13000
Real achievement	129000	43180	10300
13th Five-Year Plan			
Goal (by 2020)	210000	105000	15000
Real achievement (by 2019)	210000	204000	22540

Source: Dequn *et al.* (2021)

Wind

Wind became China's second largest source of renewable power in 2013 and has potential to grow further. The best wind resources are found in the northwest and northeast. REmap 2030 envisages a fivefold increase in onshore wind capacity, from 91 GWe in 2013 to 500 GWe by 2030 (twice the current installed capacity worldwide) and an additional 60 GWe capacity in offshore wind. For this to occur, the realisable resource potential by 2030 in northern China would need to be deployed, and the early retirement of some coal capacity would be necessary (mainly in western China). New grid and transmission capacity (including 100 new DC power lines) will be needed to link wind power with demand in southern and eastern China.

Solar PV

China installed 13 GWe of solar PV capacity in 2013, a substantial increase which resulted in a total installed capacity of 20 GWe. 1 GWe came from distributed projects, such as rooftop solar PV on residential or commercial buildings. China aims to raise the total to 70 GWe by 2017, with equal contributions from utility-scale and distributed projects. Remap 2030 envisages a total installed capacity of 308 GW by 2030e which is twice the current installed capacity worldwide. Nearly 40% of this would be distributed.

As of 2021, China has an installed solar power capacity of over 300 gigawatts. China has made enormous strides in building up its solar power capacity within the past decade, growing cumulative capacity from only 4.2 gigawatts in 2012 to 306.56 gigawatts in 2021.

Renewables on Target for 2030

China continued to account for a large share of the world's installed renewable energy in 2021. China's hydro, wind, and solar generation capacity exceeded the 1,000 GW threshold last year. Thus, China should easily meet its target of 1,200 GW of renewable capacity by 2030. It could also be exceeded by 300 GW with today's expansion figures. The development since 2010 is shown in Fig. 11.

2030 and 2060 "Dual Carbon" Targets

In 2021, the Chinese government has also increasingly communicated its "dual carbon" target internationally. Firstly, CO_2 emissions are to peak in 2030**,** and secondly, the country is to achieve climate neutrality in 2060. Figs. 5 and 6 show the development of CO_2 emissions from China's energy sector (data: Our World in Data).

China cannot regain its greatness in the world if its people continue to breathe polluted air, drink toxic water, and eat tainted food.

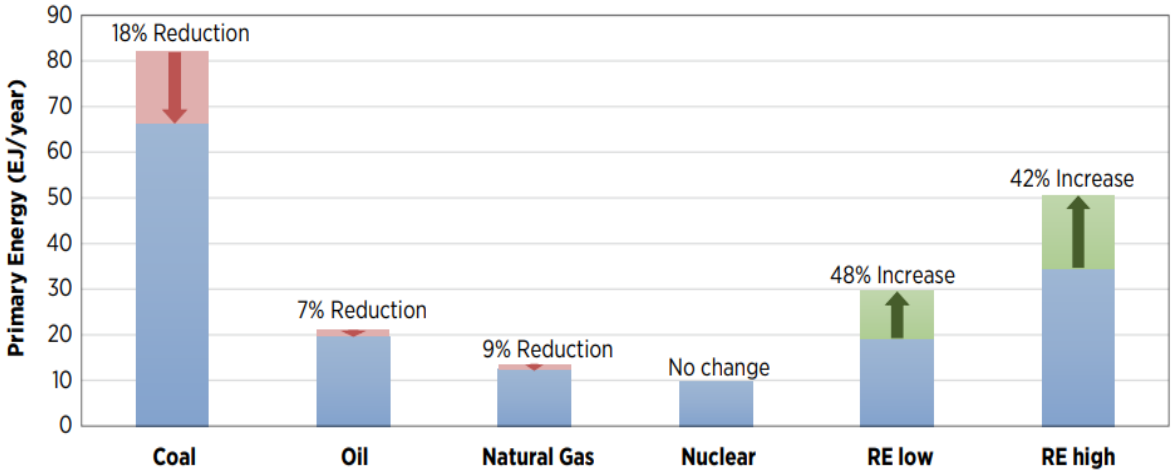

Fig. 3. In RE map 2030 coal use will be reduced to today's levels and renewable energy could become the second largest source of energy

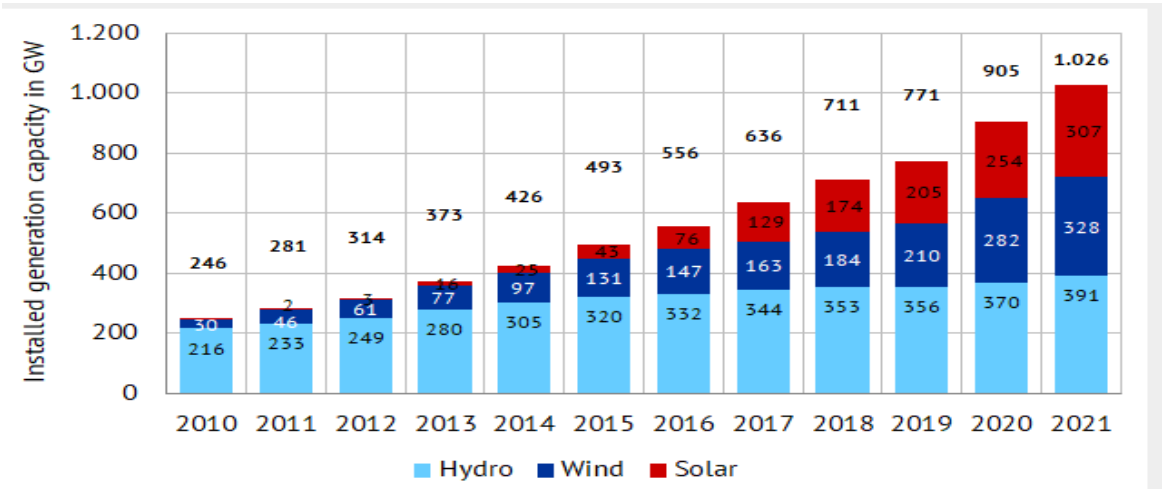

Fig. 4. Installed renewable energy capacity in China in GW per year

Source: Energy Brainpool

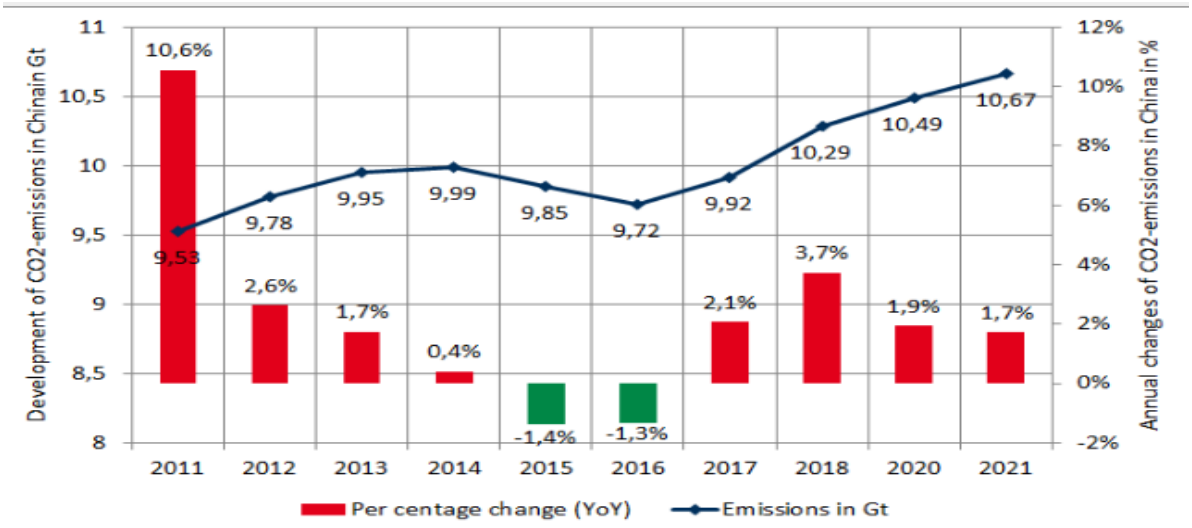

Fig. 5. China's energy-related CO_2 emissions over time in Gt (blue line) and the annual percentage change (red and green bars)

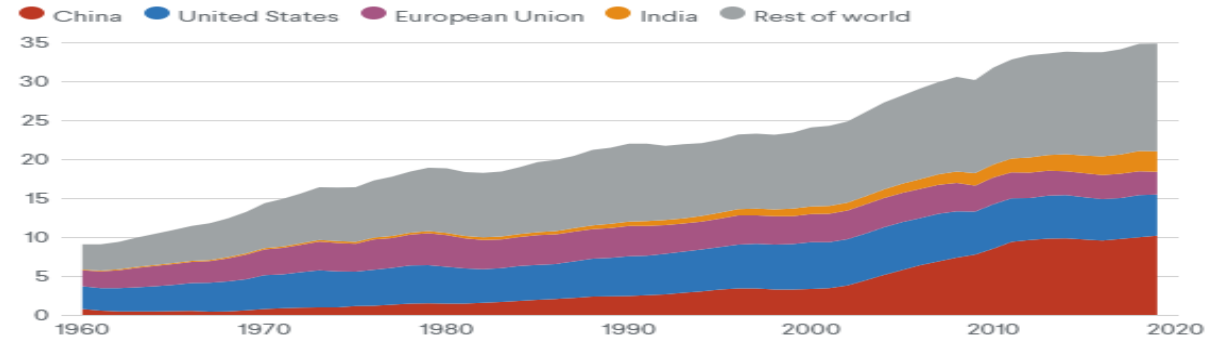

Fig. 6. Carbon dioxide emissions in gigatons

Source: Global Carbon Project.

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Zhou, P., Y. Lv and W. Wen (2023). The Low-Carbon Transition of Energy Systems: A Bibliometric Review from an Engineering Management Perspective. In Press, J. Pre-Proof What's this?

دراسة مرجعية حول اثار استخدام الطاقة المتجددة على انبعاث ثانى اكسيد الكربون فى الصين

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كحل رئيسي لتغير المناخ، حظي التحول المنخفض الكربون لأنظمة الطاقة باهتمام متزايد في العقد الماضي. أصبح التحول منخفض الكربون لأنظمة الطاقة أحد أجندة السياسات ذات الأهمية المتزايدة في معظم البلدان. تدعو اتفاقية باريس الموقعة في عام 2015 إلى إجراء تخفيضات كبيرة في انبعاثات ثاني أكسيد الكربون البشرية المنشأ خلال القرن الحادي والعشرين ، مع وضع أهداف طموحة لإزالة الكربون على مستوى العالم ، واستناداً إلى مراجعة الأدبيات ، يجب على الحكومة الصينية إيلاء المزيد من الاهتمام لاستهلاك الطاقة المتجددة وغير المتجددة في من أجل تحقيق اتجاه النمو المستمر لاستهلاك الطاقة المتجددة. كما نعلم جميعًا ، فإن انبعاثات غازات الاحتباس الحراري من استهلاك الطاقة غير المتجددة لها تأثير سلبي على أنشطة النظام البيئي. ومع ذلك ، فإن الفوائد الاقتصادية لاستهلاك الطاقة غير المتجددة في الحياة والإنتاج أكثر وضوحًا ، كما أن استهلاك الكهرباء من مصادر الطاقة غير المتجددة أكثر شيوعًا. ولكن بالنظر إلى الطاقة النظيفة وخفض انبعاثات الكربون وأمن الطاقة ، فإن زيادة استهلاك الطاقة المتجددة أمر لا مفر منه. في الوقت نفسه ، من أجل تحقيق الهدف النهائي المتمثل في الحفاظ على الطاقة ، وخفض الانبعاثات ، وبناء البيئة البيئية ، ما زلنا نواجه قدرًا كبيرًا من عدم اليقين في التعامل مع تغير المناخ. لهذا السبب ، يجب على الحكومة الصينية تقديم الدعم المالي والقانوني والسياسي ، من منظور سياسة الحكومة وحوافز الاستثمار لزيادة نسبة الطاقة المتجددة في استهلاك الطاقة ، وذلك لتقليل استهلاك الطاقة غير المتجددة.

المحكمـــــون:

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