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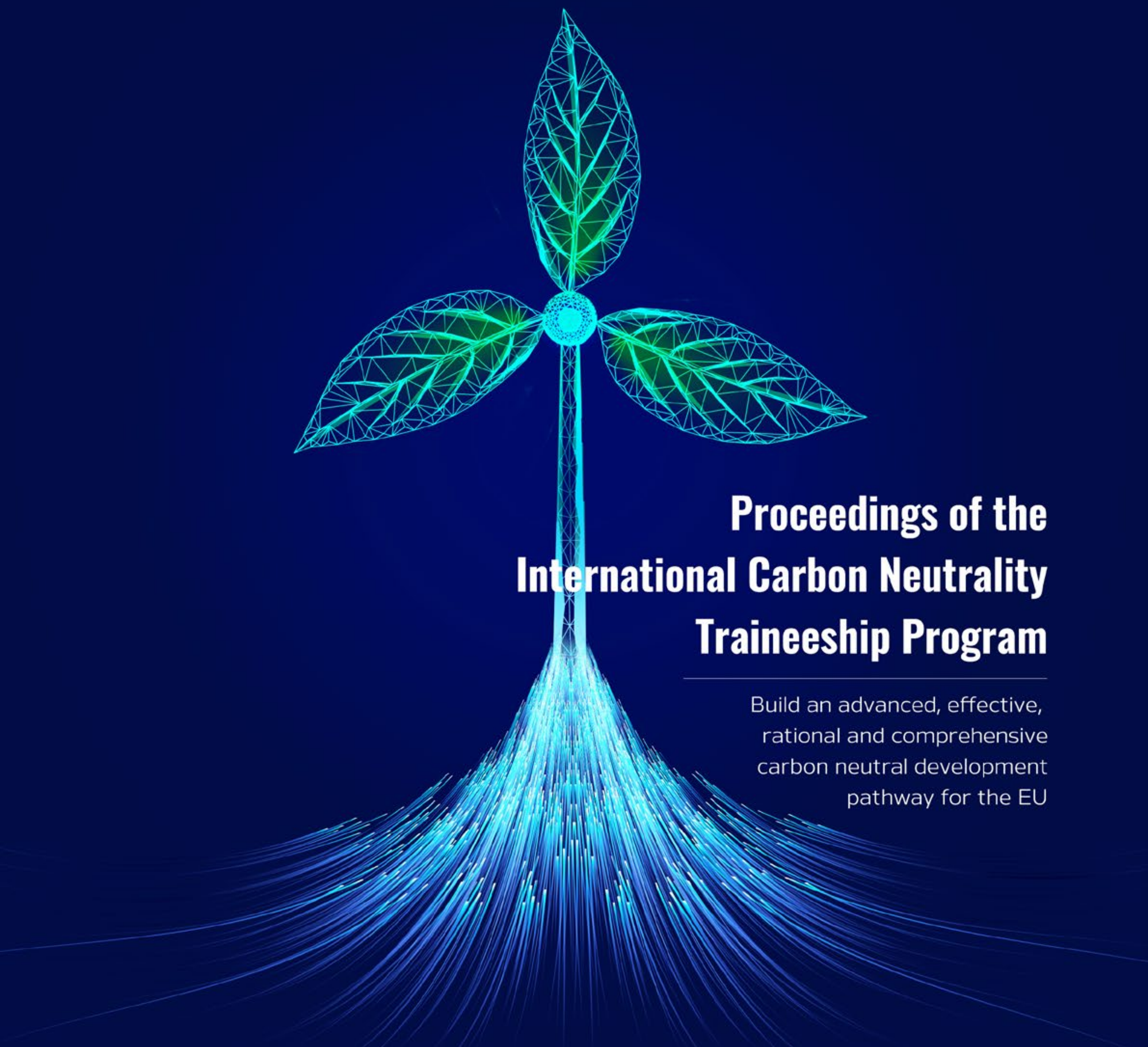
EXCHANGE



Proceedings of the International Carbon Neutrality Traineeship Program

Build an advanced, effective, rational and comprehensive carbon neutral development pathway for the EU

Development and Performance Optimization of A Low-Carbon Environment Friendly Bio-Based Material

Principles and ways to enhance forest carbon sink under the background of carbon neutrality

The practice and challenges of carbon neutrality in the EU

Research topics and trends in European union energy policy: a structural topic model

PREFACE

The following is a collection of research papers that were elaborated as an initiative by the Institute of International Exchange, which is a leading international organization that is primarily focused on achieving the goals of carbon neutrality and sustainability through fostering cross-cultural understanding, friendship and collaboration. The Institute of International Exchange organized a three-month Carbon Neutrality course that started in the summer of 2022. This comprehensive course was attended by the students belonging to various Chinese universities. The primary objectives of the modules were raising awareness of the urgent nature of the issue of climate change, familiarizing the students with the concept of carbon neutrality, and stressing the importance of collective global action in addressing this great challenge.

The enthusiasm and curiosity that the students manifested is an extension of China's unwavering resolve to tackle climate change. China’s determination to grapple with the complex issue of climate change and carbon neutrality serves as an example of leadership, strength, and commitment, with the nation emerging as a key player on the world stage. In the past years, the actions of the Chinese government have attracted widespread acclaim from the international community. By implementing innovative policies and heavily investing in renewable energy, China affirms its determination to lead the transition towards a low-carbon economy. The nation's remarkable progress in areas such as marine carbon sink research, electric vehicle technology, public transportation, environmental protection, and the development of more sustainable cities and ground-breaking technologies serve to exemplify China's dedication to fostering innovative and sustainable solutions for a greener and more resilient future.

We should also point out that the initiative of organizing this course on carbon neutrality, not only underscores China’s commitment to tackling climate change, but also emphasizes China’s dedication towards advancing global cooperation and international friendship.

In addition to the broader efforts of the Chinese government, we would also want to commend the Chinese universities for also playing a crucial role the nation's response to climate change. They do that by enabling rigorous research and by shaping the future generations and equipping them with the intellectual tools necessary to rise to the challenges of our time. The Chinese universities are highly respected institutions by the international community. The pursuit of excellence, rigorous interdisciplinary programmes and world-class facilities have allowed Chinese universities to establish themselves as international centres of knowledge and innovation. In addition to reinforcing China’s position as a global leader, those remarkable achievements are setting a new standard that other educational institutions around the world can aspire to.

As a follow-up to the Carbon Neutrality course, a considerable number of students opted to participate in a supplementary module geared towards furthering their understanding of the problems that our world is confronted with. This additional module created an opportunity for students to explore areas of particular interest to them.

As a culmination of their learning journey, the students developed and submitted research papers that explored various aspects of climate change, carbon reduction strategies, and sustainable development. These insightful and innovative studies, which are now featured in this collection, underscore the transformative impact of the Institute of International Exchange's educational initiative and the students' unwavering dedication to creating a more sustainable future for all.

Climate change poses a significant global challenge, demanding innovative solutions and collaborative efforts across various industries and sectors. This collection of research papers, authored by a group of students with diverse intellectual pursuits, showcases a comprehensive exploration of equally diverse topics within the broader subject of climate change. The studies presented here cover an array of themes, including carbon neutrality, green marketing, green finance, sustainable transportation, and environmental policy.

All those papers offer very valuable insights into the intricate nature of climate change. Reflecting the diverse academic backgrounds of the students who have contributed with their research, those papers stress the importance of cross-disciplinary collaboration, and the need for a holistic approach when it comes to tackling the urgent issues related to our climate. The collection contains studies that focus on specific industries (food, shipping, and clothing) as well as studies that focus on much broader policy frameworks within the European Union (EU) and beyond.

Quite evidently, carbon neutrality is a recurring theme throughout the collection, with several papers analysing the challenges that arise as the world tries to implement this ambitious goal, while other strive to bring forth creative solutions. Those studies examine the impact of carbon neutrality on various sectors, including energy-saving and emission reduction in the shipping industry, the transition towards carbon-neutral practices in the clothing industry, and the commercialization potential of transparent photovoltaics. They also explore carbon neutrality pathways for specific institutions, such as universities, as well as regional efforts in countries like China.

Lastly, we would like to extend our gratitude to the students who have graciously contributed to the advancement of learning in this field through their diligent research efforts, the fruits of which can be seen in the ensuing papers. Their extraordinary intellect and unwavering determination demonstrate their profound commitment to addressing climate change and gives current generations hope for the future. It is their passion and their knowledge that will ultimately put the world closer to achieving the goal of carbon neutrality, sustainability and lasting prosperity for all.

Introduction to Papers

In pursuit of a comprehensive understanding of carbon neutrality, this collection of research papers submitted by our talented students has been carefully organized into six distinct, yet interrelated themes. These themes aim to provide a structured overview of the multifaceted nature of carbon neutrality:

1.Industry specific approaches
2.Carbon sequestration and offsets
3.Technological advancements
4.Policy and regulation
5.Education
6.Case studies concerning specific regions

This methodical categorization serves to elucidate the breadth and depth of the research undertaken, while offering a cohesive and accessible framework for our readership. By presenting these themes in a clear and concise manner, this introduction aims to facilitate a thorough and engaging exploration of the complexities surrounding carbon neutrality.

Industry Specific Approaches

In this era of fervent calls for carbon neutrality, precocious students have endeavored to explore industry-specific approaches to this goal. Their detailed investigations, though varied, are unified in their commitment to securing a sustainable future.

A study on Nestlé's green marketing through the STP model highlights the exigency for food companies to adapt to environmentally friendly practices. Meanwhile, an investigation into British universities' carbon management plans provides insights for their Chinese counterparts, offering pragmatic emission reduction targets.

In the shipping industry, a thorough examination of low-carbon and zero-carbon ship power energy sources reveals potential impacts of carbon neutrality on this vital sector. Concurrently, the clothing industry in Europe faces the imperative of transitioning towards carbon neutrality, with a shift in business strategies and consumer attitudes.

Lastly, sustainable public transportation planning is championed through transit-oriented development (TOD), with Seoul's successful implementation serving as an exemplar. These sagacious inquiries offer a wealth of strategies for industries to achieve carbon neutrality, a journey we must embark upon for our planet and future generations.

Carbon Sequestration and Offsets

Moving on to a topic that has been of great interest throughout the academic community, some research papers delve into the quintessential aspect of carbon sequestration and offsets, a matter of profound importance in the pursuit of carbon neutrality. The papers provide a comprehensive understanding of the subject matter, illuminating the ingenious methods and innovative approaches that contribute to this laudable goal.

One of the papers, "Marine Carbon Sink Research in China" highlights the indispensable role of marine carbon sinks in attaining carbon neutrality. The concept of "blue carbon" is brought to the fore, encapsulating carbon sinks resulting from biological carbon sequestration and storage in oceans, coastal zones, estuaries, and wetlands. The ocean, as the Earth's most prodigious active carbon pool, graciously absorbs approximately 30% of CO_2 emissions engendered by human activities each annum. In this regard, the paper accentuates the urgency of protecting and enhancing coastal wetlands, as they possess remarkable carbon sequestration efficiency, and thereby making a more substantial contribution to the carbon-neutral strategy.

Moving on to another, equally as edifying paper, "Principles and ways to enhance forest carbon sink under the background of carbon neutrality," we explore the underlying principles and methods to improve forest carbon sinks, which play a crucial role in achieving carbon neutrality. This knowledgeable piece of research proposes five primary ways to augment the potential of forest carbon sinks:

1. increasing forest area,
2. strengthening scientific and fine management of forests to boost net productivity,
3. preventing forest diseases, insect pests, and forest fires to avoid diminishing net productivity,
4. employing mineral clay to safeguard organic carbon and escalate forest soil carbon sink, and

5. preserving forest resources and adhering to the harmonious development concept between humans and nature.

Technological Advancements

In the ever-growing quest for carbon neutrality, a troves of groundbreaking studies have emerged, shedding light on innovative approaches and technologies that aim to mitigate the adverse effects of climate change. Adding to this ongoing scientific conversation, our own students brilliantly explore this fertile domain, delving into the intricate tapestry of carbon-neutral solutions.

The first of these studies presents a novel 3D printing material crafted from biochar and polylactic acid, poised to replace traditional petroleum-based alternatives. Through the judicious addition of PBAT as a compatibilizer, there may be an enhancement in the biochar content, resulting in improved mechanical properties and a reduction in the overall environmental impact. This innovative material holds great promise for the future of sustainable manufacturing and a greener world.

Turning our gaze towards the realm of green finance, a paper investigates its impact on enterprise innovation. The author eloquently expounds upon the synergistic relationship between green finance development and government subsidies, revealing their capacity to significantly bolster R&D, innovation, resource utilization, and the mitigation of environmental pollution. This vital research underscores the necessity of robust intellectual property protection and the prudent allocation of green financial resources.

In the sphere of wastewater treatment, a timely examination of carbon emissions and combined benefits beckons. The study calls for a comprehensive review and analysis of underground sewage treatment plants, examining their carbon, environmental, and economic aspects. By accounting for carbon emissions and energy consumption at every stage, the author paves the way for a green and low-carbon transformation in the wastewater treatment industry.

Another piece of outstanding scholarly work draws our attention to the fascinating intersection of digital technology and eco-city planning within the European Union. This paper elucidates the crucial role of digital technology in constructing urban models and basic information platforms, enabling scientifically informed, green, and low-carbon urban design. Yet, challenges abound, from lagging digital infrastructure to the complexities of political forces and variations in digital standards among member countries.

Finally, we venture into the realm of transparent photovoltaics and their commercialization potential. The researchers provide a compelling overview of the latest advances in this field, emphasizing the need for further investigation into device lifetimes, colour combinations, module design, and efficiency. In our pursuit of carbon neutrality, it is of the utmost importance that transparent photovoltaics mature from an embryonic technology into a well-established industry. As we wrestle with the prodigious challenges climate change presents, it behoves the scientific community to answer the call for action and wield the transformative prowess of innovation and technology.

Policy and Regulation

As the pursuit of carbon neutrality emerges as a most pressing endeavour in the political arena, it sets demands for unwavering dedication and the application of innovative stratagems. The compendium of papers presented herein casts a revealing light upon the multifaceted dimensions of this formidable challenge, illuminating both the strides taken and the obstacles yet to be overcome. Encompassing a diverse array of perspectives, the works falling under this theme serve as a call to arms, summoning governments, industries, and individuals to join forces in the collective quest for a carbon-neutral future. However, for such endeavours to bear fruit, they must be guided by an overarching political and regulatory framework.

Two papers, namely "Report on Proposals for a Carbon Neutral Development Pathway in the EU" and "The practice and challenges of carbon neutrality in the EU," delve into the ambitious goals pursued by the European Union. While underscoring the necessity of substantial financial investment, groundbreaking technological advances, and steadfast consideration of social equity, these papers do not shy away from confronting the challenges that imperil the EU's progress. They advocate for the creation of self-reliant green industrial chains, fiscal support for less affluent member countries, and the nurturing of green technology innovation, all in the service of a sustainable, carbon-neutral future.

INTRODUCTION TO PAPERS

"A Study on the Current Development of Carbon Neutrality and the Impact of the Epidemic on Carbon Emissions" proffers a timely reminder that even amid a global pandemic, the quest for carbon neutrality must not falter. The paper cautions against complacency in the face of ephemeral emissions reductions and underscores the need for meticulous planning in anticipation of a post-pandemic economic resurgence.

"Report on the EU's progress towards Carbon Neutrality: Current achievements and challenges" presents an overview of the EU's commendable low-carbon development and transformation, whilst acknowledging the energy crisis that has hindered the pursuit of carbon neutrality. Despite these setbacks, the paper reaffirms the EU's unwavering commitment to combating climate change and fostering an expeditious global energy transition.

The concluding pair of papers offer insights into the academic sphere, as "Research topics and trends in European Union energy policy: A structural topic model" employs the innovative technique of Structural Topic Modelling to analyse the evolution of EU energy policy research. Meanwhile, "The Suggestions Report Based on the Development of CCUS in Europe" delves into the vital role of Carbon Capture, Utilisation, and Storage technology in achieving carbon neutrality, emphasising the importance of strategic planning, technological innovation, and public awareness.

Bound together by the overarching theme policy and regulation for carbon neutrality, these papers provide a comprehensive examination of the strategies, policies, and research moulding the path toward a sustainable future. As our world contends with the existential threat of climate change, it is imperative that we take heed of these scholarly contributions' wisdom and rally our collective resources and ingenuity to attain a carbon-neutral world.

Education

Addressing the considerable role of education in carbon neutrality and sustainable development is of paramount importance. The paper "Educational Measures Contribute to the Carbon Neutrality goal of EU" elucidates the indispensable part education plays in fostering a sustainable future, drawing attention to a subject often overshadowed by the focus on energy transition and technological innovation.

This paper sheds light on the necessity of nurturing professional talents and raising environmental awareness across all age groups. It asserts that schools ought to serve as models for achieving carbon neutrality goals and advocates for a shift in focus from individual learning to human ecology. In order to accomplish this noble endeavour, the paper emphasizes the need for top-level education policy design, comprehensive teaching systems, and climate change teaching plans. By fortifying pedagogy within our schools and broadening the reach of public-oriented practices, we shall pave the way for a harmonious societal endeavour to curtail carbon emissions and champion sustainable development. This calls upon the distinguished members of the academic community to acknowledge the profound influence that education can wield upon our collective desire for a carbon-neutral tomorrow.

Case Studies Concerning Specific Regions

The final paper we are going to preview is entitled "A Report on the Sustainability of Transportation in Botswana, Gaborone: Suggestions for Solving Traffic-Related Water Pollution, Air Pollution, and Soil Pollution". It touches upon the pressing environmental quandaries afflicting Gaborone, the capital of Botswana, with particular regard to transportation. This vibrant city grapples with formidable issues such as traffic congestion, inefficiencies in waste transportation, and a surge in vehicle ownership, culminating in water, air, and soil pollution. The paper underscores the imperative for enhanced legislation, vigilant monitoring systems, and robust infrastructure as means to confront these challenges head-on.

Expounding upon a range of practical solutions, the report advocates for measures including distancing urban development from lakes and rivers, augmenting drainage systems, adopting low-cost air quality monitoring techniques, and fostering cultural exchanges with other nations to jointly unearth sustainable transportation resolutions. Furthermore, it enjoins the establishment of an efficient waste management system to optimize recycling and the implementation of a comprehensive pollution management system to regulate pollution levels. This paper accentuates the criticality of synergistic collaboration amongst governments, regulatory bodies, and global counterparts to confront environmental pollution and ultimately secure sustainable transportation for the flourishing city of Gaborone.

Introduction to papers

In conclusion, this compendium of research papers, organized into six interrelated themes, offers a comprehensive exploration of carbon neutrality's multifaceted dimensions. Through their collective wisdom, these papers equip us to confront formidable challenges ahead. The paramountcy of industry-specific approaches, carbon sequestration and offsets, technological advancements, policy and regulation, education, and regional case studies must be acknowledged. We hope this collection inspires the academic community, policymakers, and citizens to unite in a steadfast pursuit of a carbon-neutral and sustainable future.

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PROCEEDINGS OF THE
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Development and Performance Optimization of A Low-Carbon Environment Friendly Bio-Based Material

Huaqing DING[1]* and Tao JIANG[2]*

[1]Dalian Maritime University, Dalian City, Liaoning Province, China, 116000
[2]China National Offshore Oil (China) Limited. Tianjin Branch, China, 116026

E-mail: dinghq2021@163.com[1], 18734670564@163.com[2]

***Corresponding author**

Abstract

Global warming and environmental deterioration are common problems faced by human beings at present. Therefore, environmental protection and sustainable development have become the mainstream of development in the world today. Greenhouse gas emissions are the main cause of global warming (Sun et al,2013), while 80% of the world's energy demand is still supplied by traditional fossil fuels such as coal, oil and natural gas (Woolf et al,2010). In order to reduce the use of fossil fuels, we developed a new 3D printing material made of biochar and polylactic acid, which is expected to replace traditional petroleum-based materials in various fields. The purpose of this study is to improve the properties of materials by adding PBAT and modified biochar, and to evaluate the life cycle of composites.

We prepared the above composite materials and characterized them by SEM, FTIR and mechanical tests. The experimental results show that the addition of PBAT can increase the amount of biochar in the composite by 50%, increase the hardness of the material by 0.4%, and increase the tensile modulus by 69.12%; Sample S3 has the maximum bending strength of 61.89 MPa. Electron microscopy and functional group analysis showed that PBAT/PLA was well embedded and bound in biochar. This indicates that PBAT can increase the amount of biochar added to the composite and improve the interfacial compatibility of the composite.

Silane coupling agents can graft onto biochar, enhancing the polarity of biochar and reducing its water absorption by 50.32%; Modified biochar was applied to the composite, and functional group analysis showed that the characteristic peaks of silane coupling agent grafted biochar existed in the composite. The hardness of the composite material increased by 0.13%, the tensile strength increased by 9.83%, and the bending strength increased by 34.97%. The addition of PBAT reduced the total environmental impact potential value of the composite by 23.32%, and the modification process of biochar reduced it by 12.87%.

Keywords: Biochar; polylactic acid; PBAT; KH570; 3D printing; composite material; LCA.

The extensive use of traditional fossil energy is an important cause of global warming and environmental deterioration, which obviously does not conform to the theme of green sustainable development. Therefore, the replacement of traditional fossil energy by renewable biomass resources has become a hot spot of social research (Babu et al,2013). Biomass has the characteristics of large reserves, renewability, good cleaning performance and low price. However, the conventional way of using biomass is easy to cause resource waste and secondary pollution. Further conversion of biomass into biochar can greatly reduce the environmental problems caused by direct combustion of biomass (Bolan et al,2021). We have developed a new 3D printing material with biochar as raw material (Patent Number: 202210209057.7), which is expected to replace traditional petroleum-based materials in various fields. The purpose of this study is to improve the properties of materials by adding compatibilizer and modified biochar. On the one hand, it can solve the problem of poor mechanical properties of single polymer, improve material properties and realize the substitution of traditional petroleum-based materials; On the other hand, through the rational use of biochar, carbon sequestration can be realized and carbon neutrality can be achieved. This research is of great significance to the global carbon neutrality process.

1. The role of PBAT with different proportions in increasing the amount of biochar in composites and the effect of improving the interface compatibility of composites

1.1. Introduction

Poly (butylene adipate-terephthalate) (PBAT) is an aliphatic aromatic copolymer composed of aliphatic hydrocarbons and aromatic compounds. Because of its excellent mechanical and thermodynamic properties, it is considered as the best biodegradable material to toughen PLA (Wang et al.,2011). Many researchers have reported the blending of PBAT with polylactic acid (Pietrpsanto et al., 2020; Yu et al., 2019). PLA/PBAT blends were prepared by melt blending technology. It was found that with the increase of PBAT loading, the impact strength and tensile properties of PLA matrix were improved. The elongation at break of PLA/PBAT blends was 3%, which was lower than that of pure PLA (4.5%) and PBAT (500%) (Kumar et al.,2020). In the molten state, the interfacial transesterification reaction of PLA/PBAT blends (Coltelli et al.,2011) mixed two kinds of biodegradable materials, and the biodegradable materials with better performance and wider application range could be obtained. Therefore, the compatibilization modification of PLA/PBAT composites has become a research hotspot.

1.2. Methods

This experiment mainly explores the influence of PBAT on the addition of biochar, mechanical properties and water absorption of composites, so as to prove the improvement effect of PBAT on the compatibility of composites and determine its applicability as a compatibilizer for polylactic acid composites.

In this study, two factors and three levels L9 (3×3) orthogonal experimental design was adopted to explore the role of different proportions of PBAT in increasing the amount of biochar added in the composites and improving the interface compatibility of the composites. The experimental materials are shown in Table 1.The preparation method of that carbon/polylactic acid composite material is as following.

Pretreatment of Raw Materials. The biomass is dried at 105°C for 24h, then added into a pyrolysis furnace, and pyrolyzed in an oxygen-free environment to prepare biochar; After cooling, the biochar is put into a ball mill for crushing, then passed through a 200-300 mesh sieve, and the biochar sieve is collected and dried at 45-50℃ to constant weight.

Mixing raw materials. Mix the dried PLA raw materials, PBAT and biochar sieve according to the proportion in the orthogonal experimental table in Table 2, and place them on a shaker to vibrate uniformly for 60s.

Preparation of Composite Wire. The evenly mixed raw materials are added into the barrel of the extruder, and melted and extruded under the electric heating action of the screw of the extruder and the heating device.

FDM 3D Printing. According to the standards of GBT1040-2006 and GBT9341-2008, draw the tensile standard.

specimen and the bending standard specimen for printing, and set the packing density at 20%, the printing speed at 60mm/s, the nozzle temperature at 200°C and the hot bed temperature at 60 ℃. After setting, print out the required tensile standard specimen and bending standard specimen entities for tensile, bending and hardness testing. The experiment scheme is shown in Table 2.

1.3. Testing and characterization

According to the national standard GB/T1040-2006 for tensile property measurement, the 1BA dumbbell tensile test standard sample was made by 3D printing, and then the tensile test was carried out on a universal testing machine (TY8000, CN) with 50 KN tensile sensor at room temperature at a speed of 5mm/min. According to the national standard GB/T9341-2008 for measuring bending performance, the standard bending test sample was made by 3D printing, and then the bending test was carried out at room temperature at the speed of 2mm/min on universal testing machine (TY8000, CN) with 50 KN compression sensor. Shore hardness gauges are used to measure the hardness of composite materials by measuring at least five samples and reporting their mean values and their standard deviations.

The functional groups on the surface of the composite were determined by Fourier transform infrared spectroscopy (FTIR). The test mode was ATR mode, and the scanning wave number ranged from 600 cm^{-1} to 4 000 cm^{-1}.

The density test method of composite material is to intercept 2cm length wires in different parts, measure their diameters and weights, repeat at least three times, and calculate the density of composite material. The test results are expressed as the arithmetic average of at least three results obtained under the same conditions.

According to the National Standard GB/T1034-2008 of plastic water absorption, dry the sample to be tested at 50℃ for at least 24h, and control the room temperature at 23℃-25℃. Then, after immersing the sample in water for 24h±1h, take out the sample and dry the water droplets attached to the surface of the sample. Weigh the weight changes of the sample before and after immersion, and calculate the water absorption mass fraction of the composite material. The test results are expressed as the arithmetic average of the three results obtained under the same exposure conditions.

1.4. Results

Figure 1 shows the scanning electron microscope of the composite material, and the fracture cross section SEM of the composite material prepared with different PBAT additions is shown in Figure 1. When the content of PBAT is low, there are more irregular pores in the composite, and the interfacial adhesion between PBAT and PLA is poor, which can be seen from a large number of voids penetrating the fracture surface of the composite. With the increase of PBAT content, the composite material has a strong bond between the filler and the matrix. There is no significant phase separation between the biochar and the matrix. With the increase of PBAT content, the interfacial interaction between PBAT/PLA and biochar is improved, and PBAT/PLA is well embedded and bound in biochar.Figure 2 shows the FTIR spectrum of the composite. The FTIR results show that the characteristic peaks of PLA (1745cm^{-1}, 1180cm^{-1}, 1040 cm^{-1}) and PBAT (730cm^{-1}, 870cm^{-1}, 1392cm^{-1}) are the main features of the composite. The peak at 590 cm^{-1} is caused by the tensile vibration of the carbon-carbon double bond (C=C) of biochar (characteristic peak of biochar), which indicates that PBAT, PLA and biochar are well combined in the composite.Figure 3 shows the mechanical properties of the composite. The results show that the content of biochar in the composite is increased by 50% by adding PBAT. The mechanical properties test showed that the hardness of the material increased by 4% compared with that when the addition of biochar was 10%. The tensile modulus, bending strength and bending modulus of the material increased. Figure 4 shows the density and water absorption of the composite. The results show that the addition of PBAT improves the density and water absorption of the composite.

2. Effect of silane coupling agent (KH570) modified biochar on compat ibility of composites

2.1. Introduction

The properties of composites are highly related to biochar, PLA matrix and the interface compatibility between them. Increasing the polarity of biochar in a certain range can effectively improve the mechanical properties of composites (Sudarisman et al.2015). The interface compatibility between carbon and PLA matrix is the key factor to determine whether the composite can bear the load. Modification of biochar is an effective way to obtain good interface compatibility of composites. Conventional modification methods, such as heat treatment (Sreekumars et al.2009) and alkali treatment of fiber (Huang et al.2019), can enhance the compatibility between biochar and composites, but at the same time, it will also damage the structure of biochar. Silane coupling agent can produce more chemical bonds between composites without damaging the structure of biochar, thus enhancing the interface compatibility of composites (Xie et al.2010). In this study, silane coupling agent KH570 was selected to modify biochar, so as to improve the surface adhesion between biochar and composites, improve its mechanical properties and make the material system have good stability.

2.2. Methods

The purpose of this study is to explore the effect of silane coupling agent (KH570) on modified biochar and the influence of modified biochar on the compatibility of composites.

Silane Coupling Agent Modified Biochar. Biochar was modified by KH570. The mass percentages of the modified solution were KH 570: 20%, absolute ethanol: 70% and water: 10%, respectively. The mass ratio of KH570 to biochar is 5: 1, 10: 1 and 15: 1, respectively. Immerse the pretreated biochar (300 mesh) in the modified solution, put it in a magnetic stirrer, stir for 1h, rotate at 20r/min at 30℃, fully mix the biochar with the modified solution, and stand at 30℃ for 12h; Standing and filtering the modified solution with a funnel, and washing the modified biochar with absolute ethanol to remove the residual silane coupling agent, so that the modified biochar is dispersed; The washed biochar was placed in an oven and dried for 4.5h, and the obtained samples were subjected to subsequent analysis, test and characterization experiments. Table 3 shows the experimental proportions and numbers.

Preparation of Composite Materials. The modified biochar was used to prepare composite materials, which was the same as the first part of the experiment, the prepared material is denoted by S9-2, and the composite materials were tested and characterized.

2.3. Testing and characterization

The water absorption and surface groups of biochar modified by silane coupling agent were tested to explore their physical and chemical characteristics and microstructure evolution. The influence on the compatibility between biochar and composites was analyzed, and its influence on the surface groups, mechanical properties, water absorption and density of composites was tested. The specific test method is the same as the first part.

2.4. Rusults

Figure 5 shows the FTIR spectrum and water absorption rate of the modified biochar. The results show that the peak at 1150 cm^{-1} is the stretching vibration peak of Si-O-C, which is the covalent bond formed by the condensation reaction between silanol and hydroxyl groups in biochar during heating, and the asymmetric vibration peak at 1 078 cm-1 is the overlap of Si−O−C and C−O−C. Compared with untreated biochar, the intensity of this peak is higher. The new peak at 795 cm-1 is the stretching vibration peak of Si−O−Si. These two characteristic peaks indicate that silane coupling agent has been successfully grafted onto the surface of biochar. The process of biochar modification enhanced the polarity of biochar, which reduced the water absorption rate and density of biochar by 58%. Figure 6 is a scanning electron microscope image of a biochar modified composite material. It can be seen that the composite material without modification by silane coupling agent is easily distinguished from each other and has many pores. This is because biochar is a polar molecule, while PLA is a nonpolar molecule. Due to differences in polarity, the compatibility between biochar and the matrix is poor. The modification with silane coupling agents has changed the polarity of biochar, resulting in a tighter binding of the components of the composite material, a large number of pores, and a uniform dispersion of PLA between the pores of biochar. This is also the reason why the addition of silane coupling agents enhances the mechanical properties of the composite. Figure 7 shows the FTIR spectrum of biochar-modified composites. The results show that the characteristic peaks of silane coupling agent grafted biochar exist in the composites. The results of composite performance test in Figure 8 show that the repulsion between the modified biochar and the components of the composites is weakened, and the compatibility between biochar and matrix is improved. The maximum tensile strength and bending strength of the composites reach 34.3MPa and 71.1MPa respectively. The maximum tensile strength reached 78.6HD, and the tensile strength, bending strength and hardness of the composites increased by 9.83%, 34.97% and 0.13% respectively. Figure 9 shows that the density and water absorption of the composite material are reduced by modification treatment.

3. Life cycle assessment of composite materials

3.1. Research objective

Through the life cycle assessment of composite materials, we can calculate the carbon footprint of products and provide a reliable scientific basis for the environmental sustainability of products. Make a reasonable explanation of the main stages and substances in the processing and production process that cause pollution, and then put forward a reasonable optimization and improvement scheme to promote the green and sustainable development in the field of composite materials.

The benchmark flow of the life cycle assessment model is "producing and printing 1kg composite materials", and the system boundary is "cradle to gate". The relevant data of polylactic acid particle production process, PBAT particle production process, biochar powder preparation process, wire processing and printing process and raw material transportation process are collected, and the environmental impact potential of adding PBAT and biochar modification process on composite materials production is analyzed.

3.2. Life cycle inventory analysis

In this study, the relevant data of biochar powder preparation process, wire processing process, wire printing process and raw material transportation process were collected, and the life cycle list was established. The input raw materials mainly include: production raw materials; electricity and diesel oil. Energy consumption mainly involves electric energy consumption. The output mainly includes: waste water, waste gas, solid waste, etc. During the operation of the equipment, it is inevitable to produce certain noise pollution, which is temporarily ignored in this research model. The resource consumption, energy consumption and emission data of PLA and PBAT are all from Swiss Ecoinvent database; Background data about electricity, diesel oil and production process come from CLCD (Chinese life cycle database) database and Ecoinvent database developed by e-Footprint online platform; The energy consumption emission in the biological production process comes from the experimental field records. The life cycle assessment models of PLA/biochar composite (S0), PLA/PBAT/biochar composite (S9) and PLA/PBAT/modified biochar composite (S9-2) were established, which is used to explore the environmental impact of the modification process of PBAT and biochar on the composites.

3.3. Life cycle impact assessment

Life cycle impact assessment (LCA) refers to the transformation of input and output data in the whole production process of biochar/polylactic acid composites into designated environmental impact categories to determine the impact on the environment. Characterization is to classify the input and output according to the environmental impact category. According to the selected calculation model, multiply it by the corresponding characterization factor, and the data in the life cycle list will be converted into the corresponding environmental impact characterization indicators. In the characteristic index analysis, the most important environmental problem in the production process of biochar/polylactic acid composites is the high energy consumption. Therefore, 13 environmental impact characterization indicators, such as global warming potential (GWP), primary energy consumption (PED) and water resource consumption (WU), were selected in the study, and the environmental impact of composite materials was comprehensively analyzed. The basic principle of normalization is to make the environmental impact indicators dimensionless by introducing the corresponding national benchmark values, so that different environmental impact categories can be compared and the main environmental impact types can be determined. The normalized benchmark value in this paper comes from the per capita data calculation (He et al.,2016) of China National Bureau of Statistics (NBS 2000), and is calculated by the weight factor (Wang et al.,2006). The weight factor is determined by the expert group appraisal method, and the weight factor has been approved by the expert group and widely used. Divide the characterization index by the corresponding normalized reference value to get the normalized value, multiply the normalized value by the corresponding weighting factor, and then add all the weighted results in each scene to get the comprehensive environmental impact potential value. The larger the normalized value is, the more serious the environmental impact of this category is. Similarly, the higher the comprehensive environmental impact potential in which scenario is, the greater the potential impact of this scenario on the environment is (Ding et al.,2022). Five environmental impact indicators, namely global warming potential (GWP), primary energy consumption (PED), water resources consumption (WU), acidification (AP) and eutrophication (EP), were selected for normalization and weighted analysis. Sensitivity analysis is mainly used to characterize the key part of the impact of input and output data in the life cycle assessment system on the results of LCA characterization indicators. Sensitivity analysis is conducted according to the percentage change of input and output data during the main process changes (Guo et al.,2021). The greater the sensitivity of the process, the greater the contribution of the environmental load generated by the process to the environmental impact characterization index. If corresponding improvement is needed, this process unit can be selected first.

3.4. Explanation of life cycle assessment results

The characterization results in Figure 8 show that the electrical energy loss in the production process of composite materials is the main contribution to the composition of life cycle results; The production loss of poly (lactic acid) particles is second only to the power loss in the life cycle results of S0 and S9. The contribution rate of production loss of polylactic acid particles in S9-2 to the life cycle results of composites decreased significantly. The normalized results in Figure 9 show that the total environmental impact potential of the composite material decreases by 23.32% after adding PBAT, that is, adding PBAT can effectively reduce the environmental impact of the composite material production; Compared with PLA/biochar composites, the total environmental impact potential of the composites decreased by 12.87% during the process of carbon modification. The sensitivity results in Figure 10 show that the process that contributes the most to the environmental impact is the production of composite materials; Under the production scenarios of three materials, the sensitivity of electric energy consumption in the production process of composite materials is the highest, so reducing the electric energy consumption in the production process of composite materials and biochar is the key to reduce the overall environmental burden.

4. Conclusion

By adding PBAT, the biochar content in the composite was increased by 50%. As the content of PBAT increases, the PBAT/PLA melt is well embedded and bound in the biochar, resulting in an increase in the density of the composite material and no obvious fracture through holes on the surface; The mechanical properties were improved, and the hardness of the material increased by 4% compared to that when the amount of biochar added was 10%. The tensile modulus, flexural strength, and flexural modulus of the material increase.

During the modification process of biochar, silane alcohol and hydroxyl groups in biochar undergo a condensation reaction during heating to form a covalent bond, and KH570 is successfully grafted onto the surface of biochar; After preparing the composite, infrared spectroscopy analysis showed that the modified carbon was well present in the composite; Scanning electron microscopy (SEM) showed that the components of the composite modified by silane coupling agent formed a closer bond, and PLA was evenly dispersed among the pores of the biochar; The results of mechanical properties show that the modified biochar improves the tensile strength, flexural strength, and hardness of the composite by 9.83%, 34.97%, and 0.13%, respectively, compared to the untreated composite; Water absorption decreased by 34.29% and density decreased by 8.98%.

By comparing the environmental characteristics of composite materials under three different production scenarios, the following conclusions were obtained: the addition of PBAT reduced the total environmental impact potential value of the composite material by 23.32%, and the biochar modification process increased the total environmental impact potential value of the composite material by 13.67%, but compared to the PLA/biochar composite material, it still decreased by 12.87%.

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Table 1 Experimental materials

Material name	Specification/Model	Manufacturer
Mongolian pine- biochar	300	control oneself
polylactic acid	210	Zhejiang Haizheng
Poly- butyleneadipate-co- terephthalate	801t	Xinjiang lanshan tunhe- polyester co., ltd

Table 2 Sample proportion and number

PBAT addition ratio	Carbon addition ratio	Number
Pure polylactic acid		S0
5%	5%	S1
	10%	S2
	15%	S3
7.5%	5%	S4
	10%	S5
	15%	S6
10%	5%	S7
	10%	S8
	15%	S9

Table 3 Sample proportion and number of biochar modified by silane coupling agent

Number	KH570/g	Carbon/g	Ethanol/g	Deionized water/g
K0	-	-	-	-
K1	5	1	17.5	2.5
K2	10	1	35	5
K3	15	1	52.5	7.5

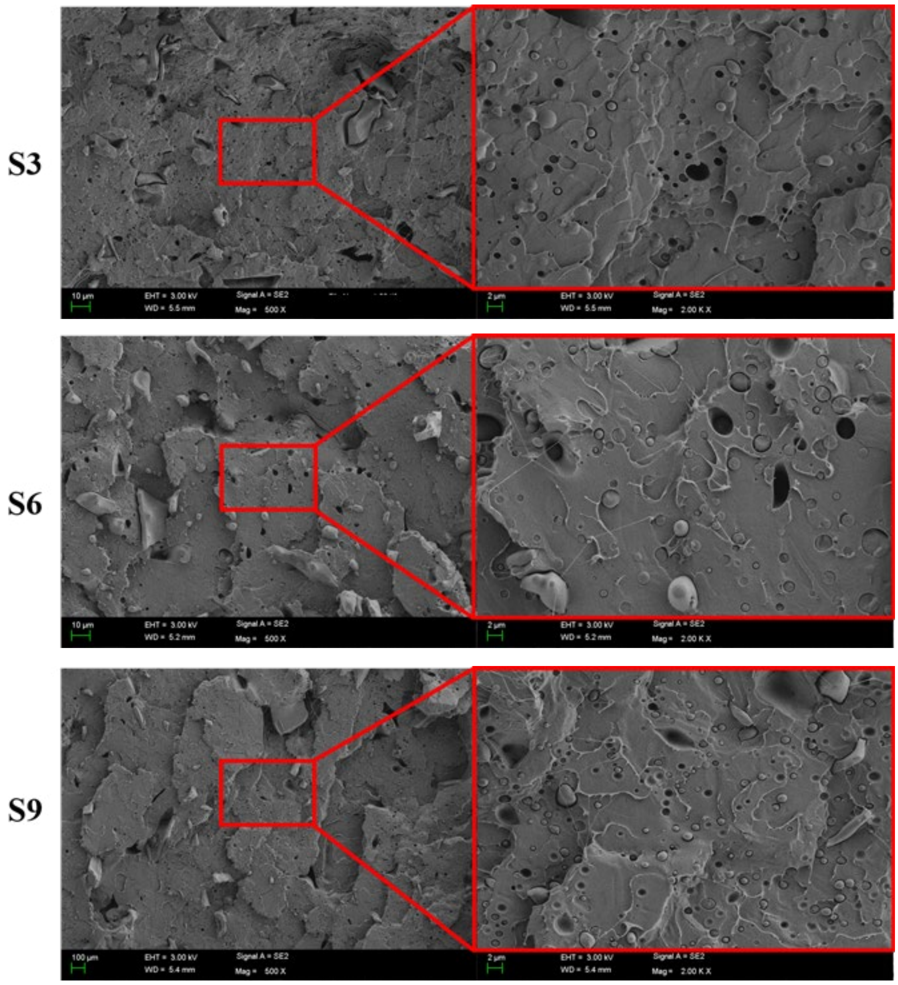


Figure 1 SEM of composite materials

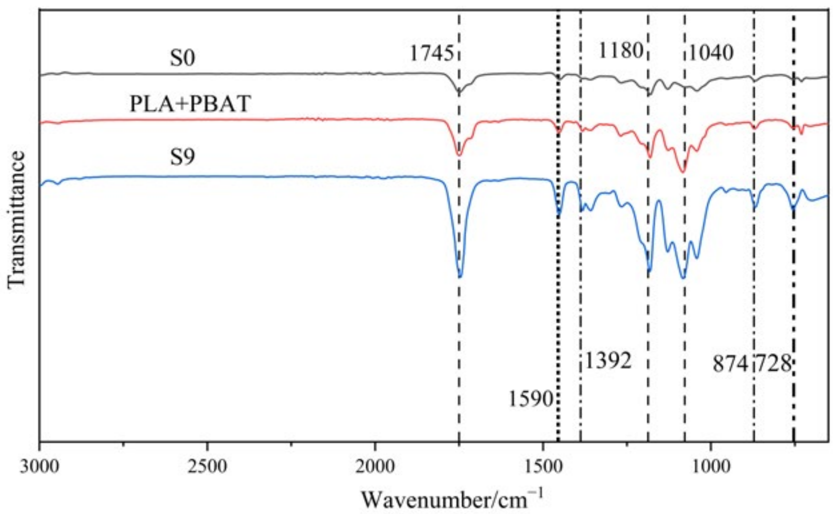


Figure 2 FTIR spectra of composites

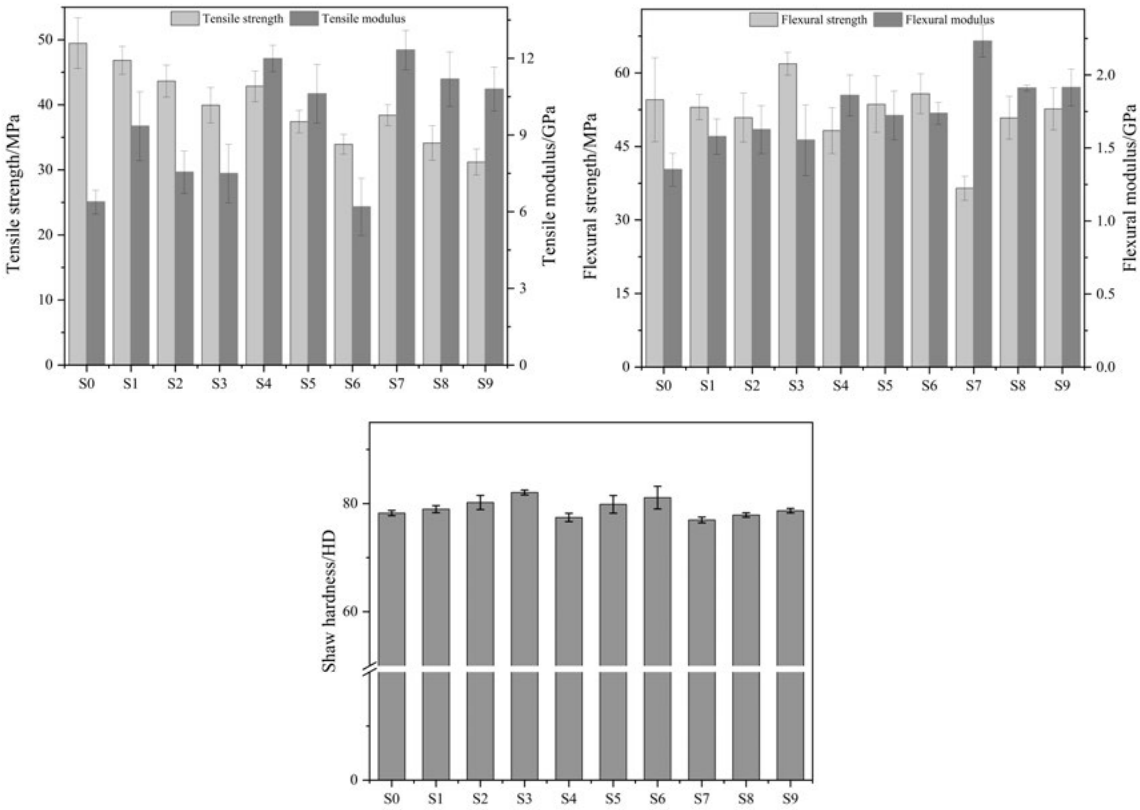


Figure 3 Mechanical properties of composites

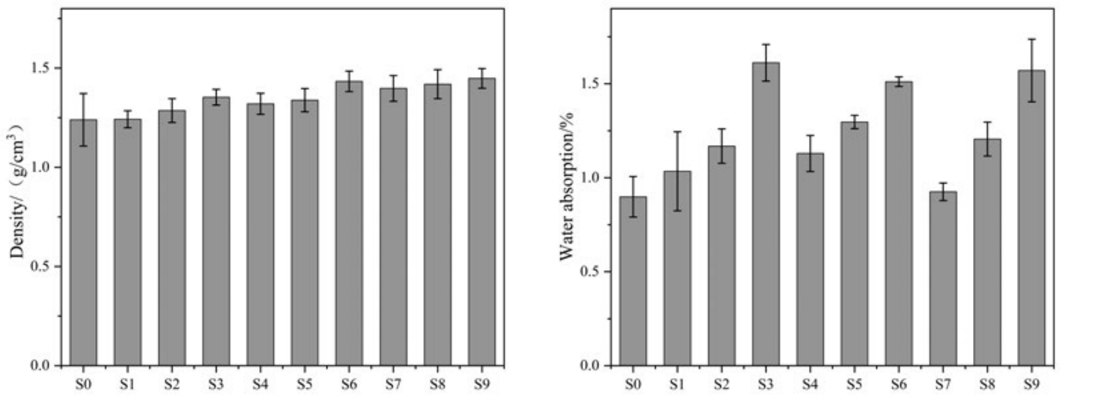


Figure 4 Density and water absorption of composite materials

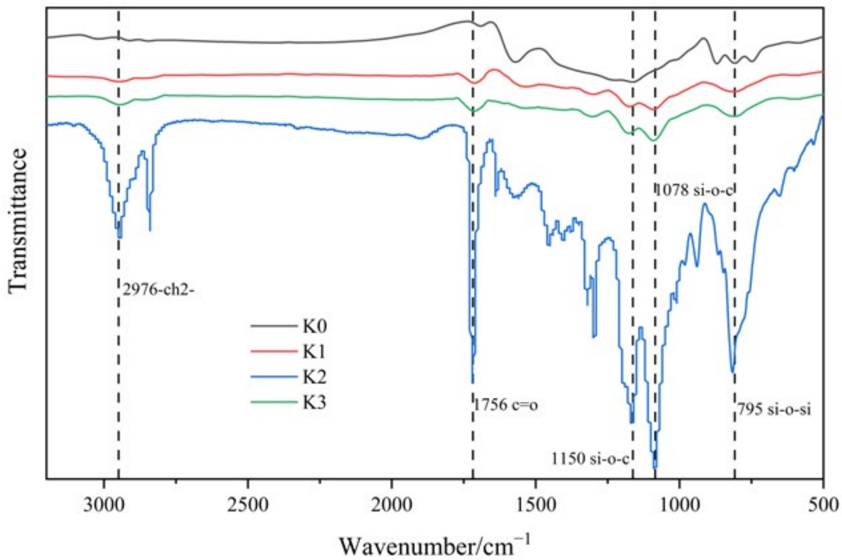


Figure 5 FTIR spectra and water absorption of modified biochar

S9

S9-2

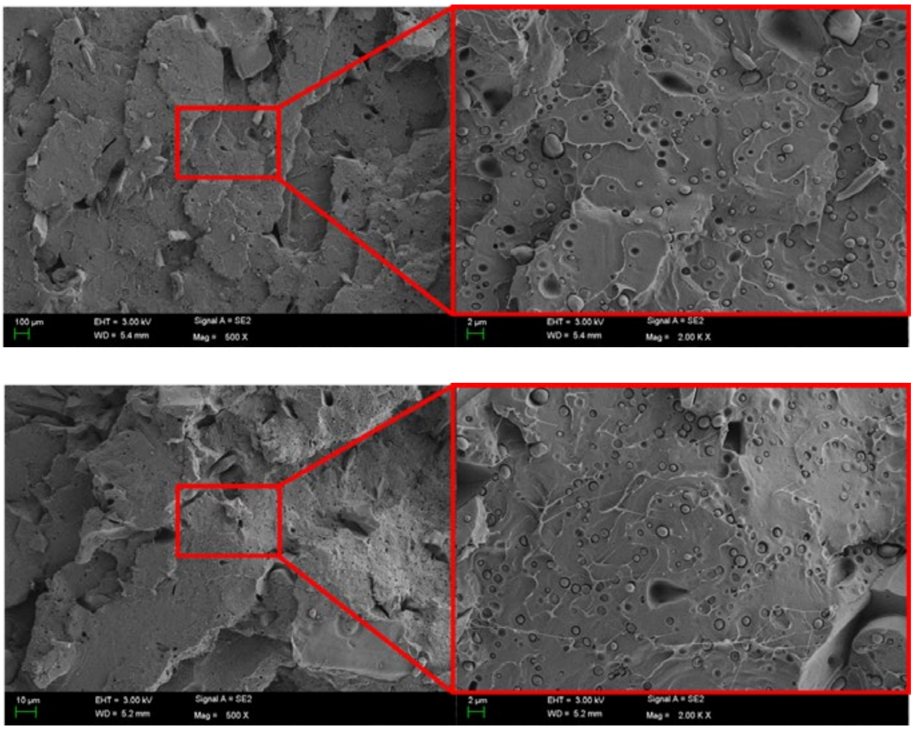


Figure 6 SEM scanning of modified composite materia

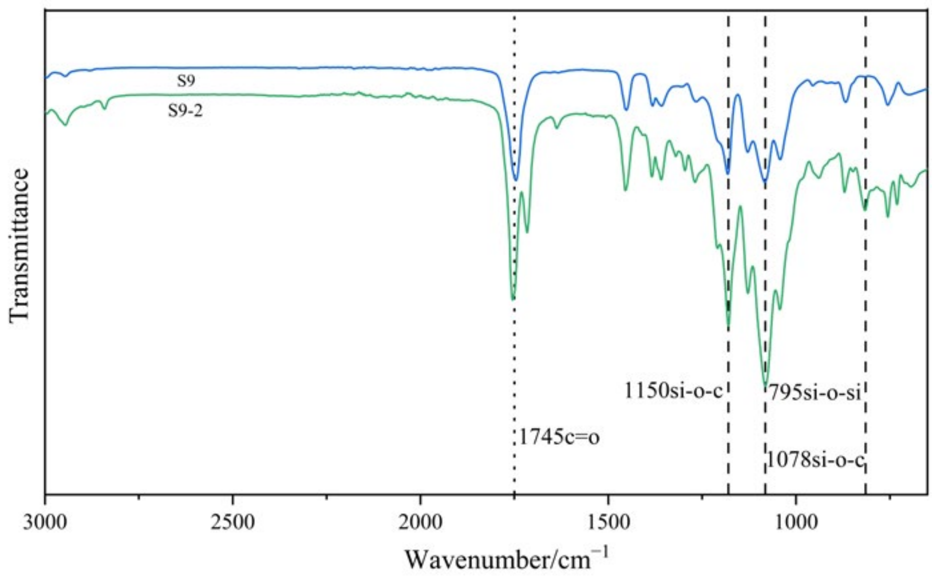


Figure 7 FTIR spectra of biochar modified composites

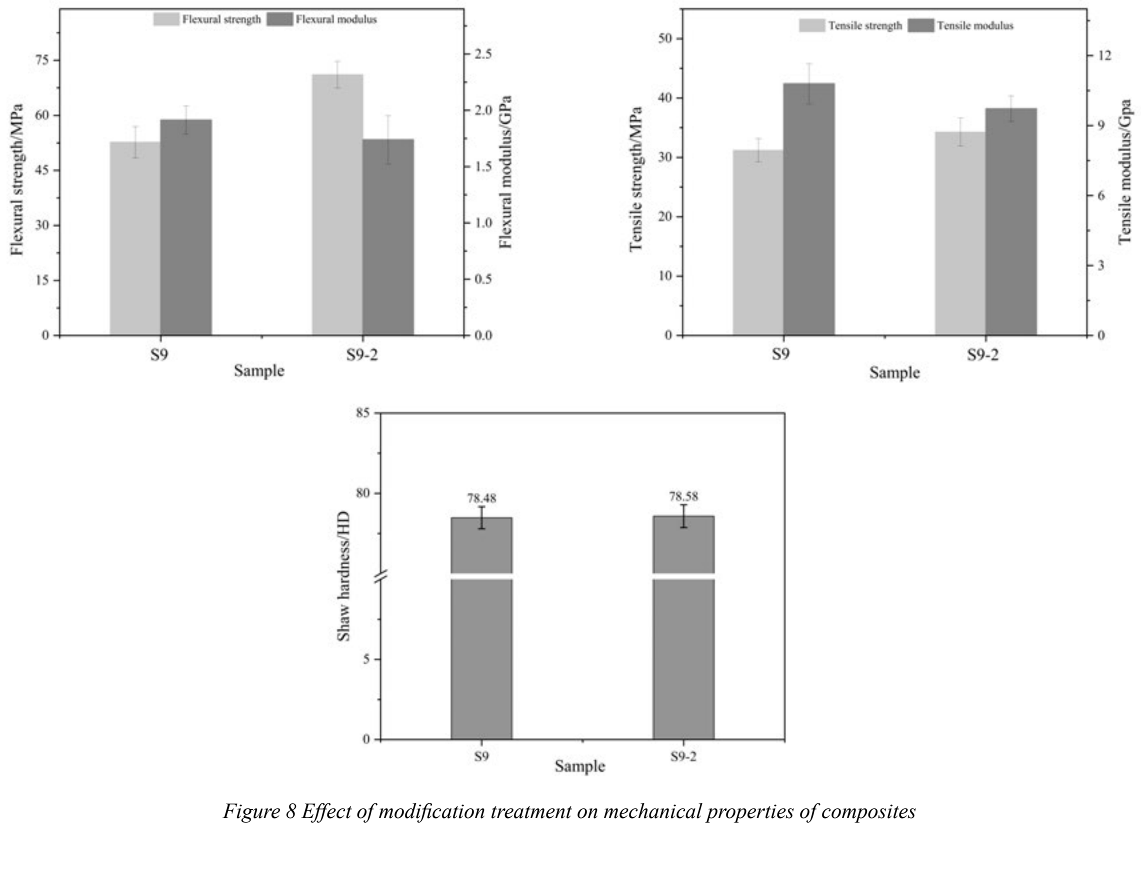


Figure 8 Effect of modification treatment on mechanical properties of composites

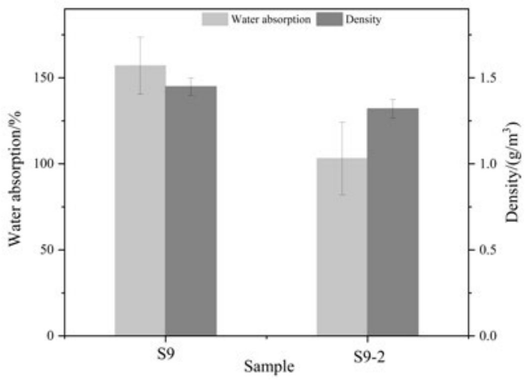


Figure 9 Effect of modification treatment on density and water absorption of composites

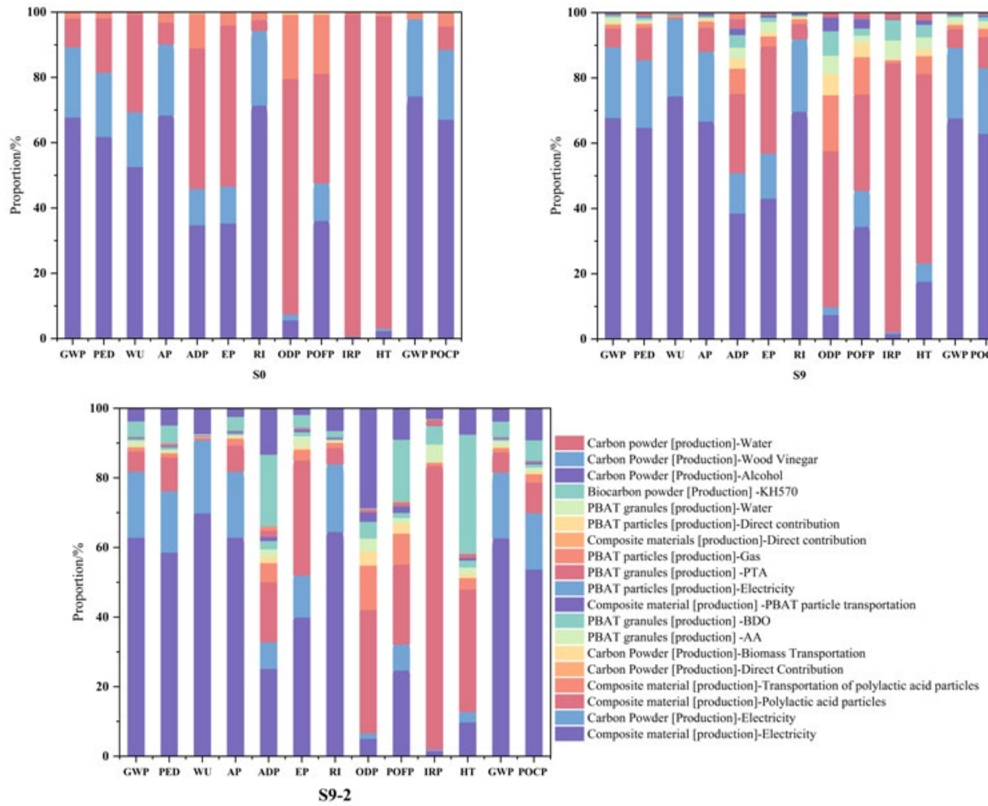


Figure 10 Cumulative contribution percentage of composite material characterization

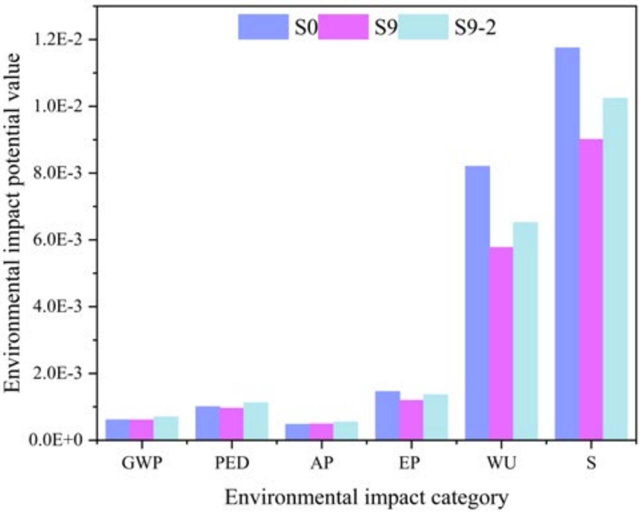
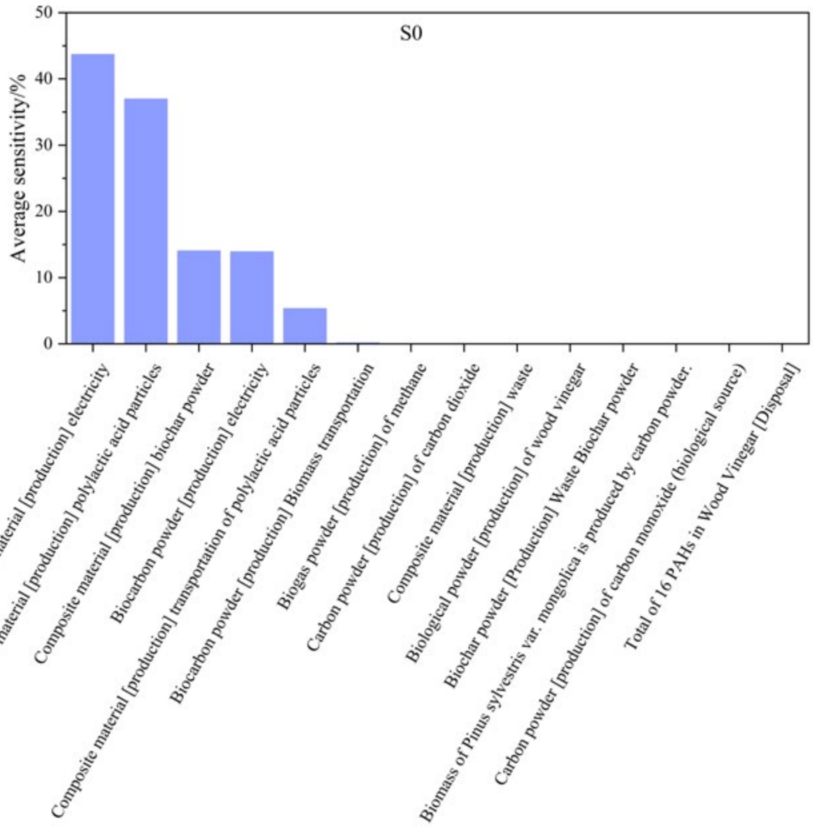
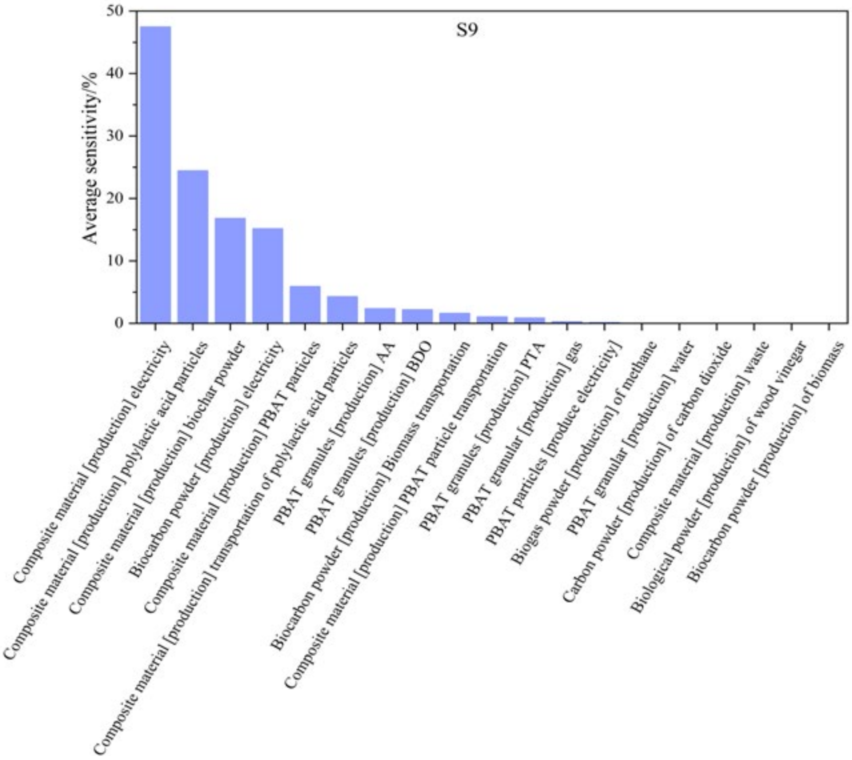


Figure 11 Normalized values of composite material





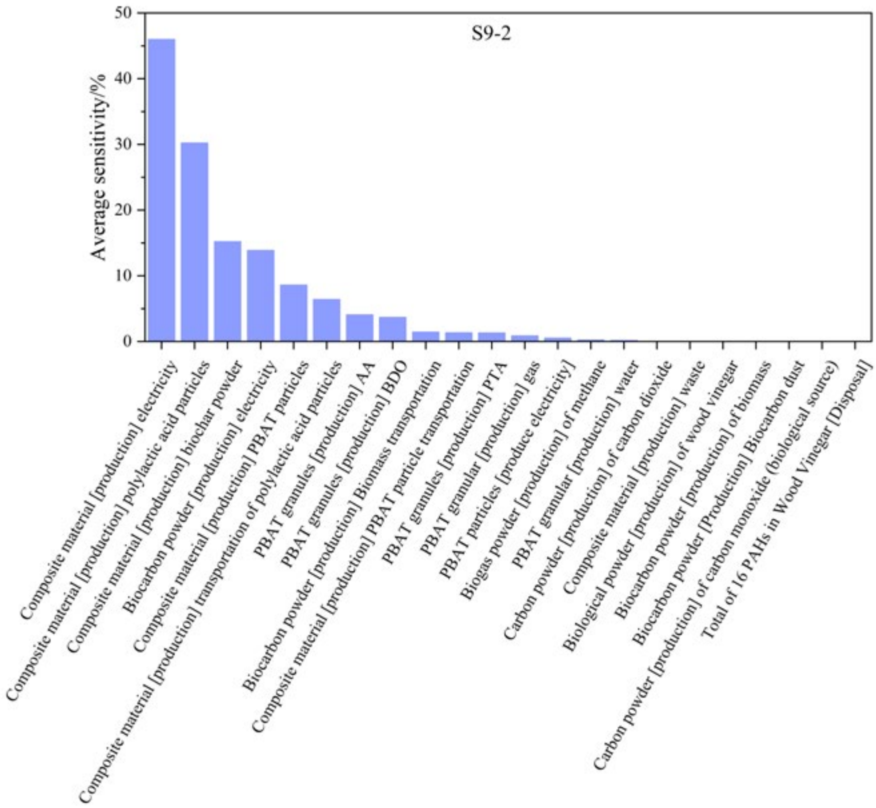


Figure 12 Sensitivity of composite materials

**PROCEEDINGS OF THE
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Principles and Ways to Enhance Forest Carbon Sink Under the Background of Carbon Neutrality

Tingting DING

Suzhou University of Science and Technology, Suzhou City, Jiangsu Province, China, 215009

E-mail: t_mail117@163.com

***Corresponding author**

Abstract

Reducing atmospheric CO_2 content and mitigating climate warming has become a frontier hot issue of widespread concern in the scientific community and the international community. There are many options for achieving "carbon peak and carbon neutral", among which forestry carbon sequestration is an important way to play a fundamental, strategic, and unique role in addressing global climate change. The enhancement of forestry carbon sink potential is a process of regulating the balance of net carbon budget in the forest ecosystem, mainly including the regulation principles of plant fixation of inorganic carbon (photosynthesis process, net productivity, etc.), turnover and fixation of soil organic carbon (decomposition of animal, plant and microbial residues and clay fixation), etc. The author expounds the main principles, methods or ways of improving forest carbon sink from the perspective of forest carbon sink. The main ways to enhance the potential of forest carbon sink include:

(1) The first way to increase forest carbon sink is to increase forest area.

(2) Strengthening the scientific management and fine management of forests to increase forest net productivity is the core of improving forest carbon sink.

(3) Prevent forest diseases and insect pests and forest fires to avoid reducing forest net productivity.

(4) Use mineral clay to protect organic carbon to increase forest soil carbon sink.

(5) Protect forest resources, always adhere to the concept of harmonious development between human beings and nature, and increase forest area through suitable sites, trees, and artificial afforestation.

Keywords:

1. Introduction

Over the years, climate change has gradually evolved into a global issue, forcing the world to study it to explore targeted measures to solve the problem. Existing research can clarify the uncertainty of climate change, but researchers believe that preventive measures can have a certain impact. Trutnevyte et al. (2019) proposed that climate change is not just a field of research, but should be based on the establishment of climate models, encouraging scientists from different fields to conduct interdisciplinary learning and research, and jointly develop reasonable, feasible, and effective solutions to climate challenges. In addition, they called on countries around the world to participate in the cause of addressing climate change, and countries should not be left out. To alleviate this problem, two approaches can be taken: carbon emission reduction and carbon sequestration. At present, both of them have become the focus of research by scientists. The main research directions for carbon emission reduction are adjusting the energy structure and researching and developing clean energy; In the field of carbon sequestration, researchers believe that the ability of biomass to fix carbon dioxide should be explored to achieve greater carbon sequestration.

The terrestrial ecosystem mainly absorbs CO_2 through photosynthesis and fixes it in vegetation and soil to regulate regional carbon cycle and maintain global ecological balance. One of the core contents of global change research is the carbon cycle at global and regional scales, and climate change is also affected by carbon cycle feedback (LU et al., 2018). The terrestrial ecosystem fixes 1/3 of the carbon in the atmosphere, and different types of terrestrial ecosystems have different carbon capture capacities. The area of forest and grassland ecosystems accounts for more than half of the land ecosystem. At least 40% of global soil carbon is stored in forest ecosystems and 10%~30% is stored in grassland ecosystems (Li et al., 2021). The area of agricultural ecosystem accounts for 38.5% of the terrestrial ecosystem, and it is the most active carbon pool in the carbon cycle process of the terrestrial ecosystem. The universality of agricultural activities and the remarkable dual attributes of carbon fixation and carbon release have aroused widespread concern of scholars at home and abroad in carbon cycle research (Lv et al., 2019). Although wetlands account for the least area, they still occupy a place in the terrestrial ecosystem carbon cycle with their ultra-high carbon fixation efficiency. To sum up, forests have enormous application value for carbon storage. Therefore, various departments should strive to improve forest carbon sinks in the context of carbon emission reduction policies (Mu et al., 2013). The forestry department believes that there are two key directions for improving forest carbon sinks, one is to protect forest biodiversity, and the other is to improve energy efficiency (Sepp ä l ä et al., 1998; Yang et al., 2019). This also reflects the importance of forest carbon sinks. Therefore, studying the factors that affect forest carbon sinks plays an important role in improving forest carbon sinks (Singh et al., 2011).

2. Method: literature review

2.1. Principle of improving forest carbon sink

Forest carbon sink includes forest plant (including living/dead trees) biomass carbon and soil (including surface litter and mineral soil layer) organic carbon. The level of carbon sink depends on the carbon turnover rate (reciprocal of turnover cycle) and carbon input and output (Fang et al., 2021). In a balanced ecosystem, input equals output. The carbon input of forest comes from its net productivity, which is mainly represented by the growth of biomass and the annual production of litter. The carbon output of forests is mainly reflected in the harvest of raw materials of forest products and the output of CO_2 and soluble organic carbon (DOC) from the decomposition of animal, plant and microbial residues (YANG et al., 2022). In a balanced forest ecosystem, the turnover rate is the ratio of carbon input to carbon sink (YANG et al., 2022). The net productivity and harvesting age of forests, especially the input and turnover rate of forest soil carbon, have a significant impact on forest carbon sinks. Therefore, we want to improve forest carbon sink, that is, increase forest plant biomass carbon and soil organic carbon.

2.2. Ways to improve forest carbon sequestration

2.2.1. Increase afforestation area

Forest biomass carbon is proportional to forest area, so the first way to increase forest carbon sink is to increase forest area. The global terrestrial ecosystem has a net carbon sequestration of 60 Pg per year (PAN et al., 2013). In 2020, the global forest area will be 4.06 billion hm2 (FAO, 2018), forest carbon sequestration accounts for up to half of the carbon sequestration of the entire terrestrial ecosystem (PAN et al., 2013), so the average carbon sequestration of global forests will be about 7.4 t/(hm2. a). If the forest area is increased by 3.4%, the carbon fixation amount of 1 Pg can be increased every year.

On the contrary, cutting down forests and planting crops or economic forests will reduce forest carbon sinks. Ten years after the conversion of forest land into agricultural land, the soil organic carbon decreased by 30.3% on average, becoming the carbon source of the atmosphere (Li et al., 2016). Compared with temperate and cold zone forests, the carbon storage of tropical rainforest vegetation is higher, the frequent occurrence of deforestation in tropical rainforests has also led to significant carbon emissions, accounting for 20% of global greenhouse gas emissions.

2.2.2. Increase forest net productivity

Strengthening the scientific management and fine management of forests to increase forest net productivity is the core of improving forest carbon sink. Proper irrigation or fertilization can increase the net productivity of forests and achieve the goal of increasing carbon sequestration of forests. Also on a global scale, an increase of 3.4% in forest net productivity can generate an additional 1 Pg of carbon sequestration each year. The net productivity of tropical forests is twice that of temperate forests (PAN et al., 2013). Increasing the net productivity of tropical forests can effectively reduce atmospheric CO_2 content. The latest research shows that compared to a single pure forest, in addition to providing a richer habitat environment and more effectively preventing the occurrence of diseases and pests, the biomass is also significantly higher than that of pure forest, with an average increase of 25.5% (FENG et al., 2022). Therefore, focusing on the construction of mixed forests is also one of the important ways to increase forest carbon sink.

In order to effectively improve forest carbon sequestration capacity, forest management can adopt afforestation and reforestation to renew forest resources. Afforestation refers to the conversion of wasteland into forest land for artificial tree planting and planting or natural seeding. Reforestation is to convert the land originally covered by forest but damaged by natural or human factors into forest land after later planting and seeding or natural seeding. That is, replanting or supplementary planting of forest land within a large space between trees, so as to promote the regeneration of forest trees and improve the forest carbon sink capacity (Chen, 2018).

In addition, the amount and capacity of fixed carbon of forests are closely related to the life and business cycle of forest trees. The longer the natural life of forest trees, the longer their carbon dioxide fixation time, and the carbon fixation amount and carbon fixation capacity will gradually improve. Therefore, managers related to forest management can cultivate long-lived trees with a long growth cycle, which can continuously strengthen the vitality of forest resources, thus increasing carbon storage. When managing forests, we should maximize the cultivation of forest tree species and the replacement of tree species, focusing on the cultivation of basically formed tree species and top tree species. At the same time, we should accelerate the transformation of pioneer tree species, so as to cultivate and manage high-quality forest trees and promote the sustainable development of forest resources (Xiang, 2021).

2.2.3. Prevention of pests and diseases and fire to reduce the loss of forest net productivity

Forest diseases and pests often reduce forest net productivity. The loss of forest net productivity can also be reduced through chemical, physical and biological control of pests and diseases. When pests and diseases break out, the loss can often reach 5%~20% of the forest net productivity (Hu, 2019). Different pest damage modes and mechanisms are different (CHI, 2022). At the stand level, leaf loss usually leads to a decrease in carbon storage (Jing et al., 2016); Leaf pests directly affect photosynthesis by eating leaves or absorbing juice to destroy chlorophyll; Stem borers such as bark beetles kill trees and turn forests from carbon pools to carbon sources. Kurz et al. of the Natural Resources Agency of Canada (KURZ et al., 2008) published shocking research results in the journal Nature by calculating the impact of the mountain pine caterpillar epidemic on the pine forests of British Columbia: in the worst years of pest damage, the affected forests have become a large source of CO_2 emissions, and its total carbon emissions are 3/4 of the carbon emissions caused by Canadian fires.

Forest fire reduces forest carbon sink. Strengthening the monitoring of forest fires and reducing fires can reduce the loss of forest net productivity (He, 2021). Disturbance causes a large area of forest loss, which is an important factor affecting forest carbon flux (Tian et al., 2003) and one of the main sources of global greenhouse gases (Hu et al., 2013). In 2019, there was a serious forest fire in Australia. High temperatures and drought caused the forest fire to rage for several months, and the area of forest burning exceeded 80000 km^2.

2.3. Ways to increase soil organic carbon content

According to Zhou's research (Zhou et al., 2004,2008,2013; Huang et al., 2011; Xiong et al., 2020,2021), external environmental changes (such as global temperature rise, N deposition, acid deposition, etc.) do not play a leading role, that is, endogenous driving process. Under the endogenous drive, the source of soil organic carbon increases with the increase of forest maturity. Even in the zonal forest stage, there is much higher source of soil organic carbon than that of immature forests.

Changes in the external environment (such as global temperature rise, N deposition, acid deposition, etc.) can not only directly affect the dynamics of soil organic carbon, but also regulate the dynamics of soil organic carbon by changing the driving factors such as the water and heat status of the ecosystem, the quality of plant residues (such as C/N ratio, lignin content), and plant diversity. The former is obviously an exogenous driven process, and its basic characteristics should be that it plays a role in both immature and mature ecosystems, but there are exceptions; The latter is difficult to be directly classified as exogenous drive, because the natural succession of the ecosystem will also cause changes in these driving factors, that is, internal and external combined drive.

Therefore, we can increase soil organic carbon from the following aspects. The global soil data shows that the higher the soil clay content, the higher the soil organic carbon content (ZHOU et al., 2005). The decomposition of plant residues can form small particle size organic matter, but most of the small size organic matter comes from microbial residues. Microbes first decompose plant residues, and then produce new microbial residues after death. 50%~80% organic carbon in mineral soil layer is microbial residue carbon (LIANG C et al., 2019). In other words, the important way to increase soil carbon sink is to increase the amount of microbial residues in the soil with high clay content.

Underground carbon input from plant roots is more conducive to the formation of microbial residual carbon than aboveground litter input, and is more stable (JIA S X et al., 2022). Therefore, it can be considered to bury the litter on the forest land surface into the soil, and then cultivate microorganisms in the mineral soil layer. The resulting microbial residues can be directly protected by soil clay particles, so as to increase the fixation of soil organic carbon and increase the soil carbon sink. For example, every 1-3 years, plough and dig ditches (about 30 cm deep) between the rows of trees in the already closed forest land, and bury the dead branches and fallen leaves of adjacent plants. If the operation measures are implemented in the soil with wet expansion and dry shrinkage or the area with alternate freezing and thawing, the protection effect of clay will be doubled; This business measure is also very suitable for areas where mechanized operations can be carried out.

In humid areas, it can be considered to plant nitrogen fixing plants between tree rows, which is conducive to increasing the number of earthworms. Earthworms are cultivators of forest soil, which contribute to the formation of soil organic matter and clay particle complexes. One kind of endogenous earthworms lives in the mineral soil layer but feeds on the surface litter layer, which can bury the surface plant litter into the soil and increase the soil carbon fixation effect. In relatively dry areas, termites and ants that nest underground also have similar carbon fixation effects (BONACHELA J A et al., 2015). Therefore, protecting soil biodiversity and increasing the number of earthworms, ants and other animals can promote the fixation of soil organic carbon.

This requires doing a good job of protecting forest resources, adhering to the balanced development of human beings and nature, and achieving the goal of harmonious development of ecological civilization. The harmonious development of man and nature should not only protect forests, but also maintain ecological balance and promote the unified and harmonious development of human, nature and society (Yuan, 2019). Therefore, when carrying out forest management, relevant managers should take a broad view of the overall situation. While doing well in forest management, construction and management, they should also strengthen the concept of forest carbon sequestration, strengthen publicity and guidance, so that people can be aware of the role of forest resources in promoting sustainable social development and the positive role of improving forest carbon sequestration capacity in protecting the natural ecological environment. Improve the consciousness of human and society on forest resources protection, thereby improving the forest carbon sink capacity and promoting the harmonious development of humans, nature and society.

3. Conclusion

In order to achieve the carbon neutral vision and control CO_2 emissions, this article focuses on the carbon storage capacity of forests, and specifies that to enhance forest carbon sinks, it is necessary to increase forest plant biomass carbon and soil organic carbon. By elaborating on the principles of enhancing forest carbon sinks, suggestions for improving forest carbon sinks are proposed.

(1) Forest biomass carbon is proportional to forest area, so the first way to increase forest carbon sink is to increase forest area. If the forest area is increased by 3.4%, the carbon fixation amount of 1 Pg can be increased every year. On the contrary, cutting down forests and planting crops or economic forests will reduce forest carbon sinks.

(2) Strengthening scientific management and fine management of forests to increase forest net productivity is the core of improving forest carbon sink. Proper irrigation or fertilization can increase the net productivity of forests and achieve the goal of increasing carbon sequestration of forests. Managers related to forest management can cultivate long-lived trees with a long growth cycle, cultivate and manage high-quality forest trees, and promote the sustainable development of forest forest resources.

(3) Forest diseases and pests often reduce forest net productivity. The loss of forest net productivity can also be reduced through chemical, physical and biological control of pests and diseases. And forest fire reduces forest carbon sink. Strengthening the monitoring of forest fires and reducing fires can reduce the loss of forest net productivity.

(4) The important way to increase soil carbon sink is to increase the amount of microbial residues in the soil with high clay content. It can be considered to bury the litter on the forest land surface into the soil, and then cultivate microorganisms in the mineral soil layer to increase the fixation of soil organic carbon, so as to increase the soil carbon sink. Protecting soil biodiversity and increasing the number of earthworms, ants and other animals can promote the fixation of soil organic carbon.

(5) Protect forest resources, adhere to the concept of harmonious development between man and nature, and achieve the goal of harmonious development of ecological civilization. The harmonious development of man and nature should not only do a good job in forest protection, but also maintain ecological balance and promote the unified and harmonious development of human, nature and society.

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The Practice and Challenges of Carbon Neutrality in the EU

Gengrong JIA

Inner Mongolia University, Hohhot, Inner Mongolia, China, 010021

E-mail: jiagengrong@163.com

***Corresponding author**

Abstract

In response to the tide of global climate change, the EU has earlier put forward the goal of carbon neutrality and regarded green development as a "systematic project" that combines policy-making, technological iteration, industrial transformation, social reform and ideological construction and an important path to create "competitive advantage". Through the analysis of EU green development, it is found that over the years, the EU has strengthened legal and policy guarantees, set up green development goals, set market rules, regulate enterprise behavior, put forward a series of transformation goals and development plans, and played a pioneering role in the international climate policy. We should support green technology innovation, establish a variety of research and development mechanisms, and invest a large amount of public finance to realize the renewal and iteration of green technology. Build a self-sufficient green industrial chain system, break through all links of the industrial chain, and gradually form a green industrial chain system suitable for the future; We will leverage the synergistic effect of finance and soft power to create sustainable demand for green development in the whole society. Despite many obstacles, the EU started green development early, is systematic and has plenty of room for strategic manoeuvre. In the future, a series of measures can be taken to address this problem. Promoting green development and building a new round of global competitive edge will be an unwavering strategic choice of the EU.

Keywords: Green development; carbon neutral; the European Union; policy framework.

1. Introduction

Climate warming has had a negative impact on industry, agriculture, transportation, coastal zones and even national security. Therefore, the concept of carbon neutrality, which is closely related to climate warming, came into being. Carbon neutrality means that the carbon dioxide (CO_2) emissions caused by human activities and the global anthropogenic CO_2 uptake reach a balance within a certain period of time[1]. Since the mid-20th century, studies have shown that human activity may be the main driver of global warming, with a probability of more than 95 percent[2].

It can be seen that achieving carbon neutrality is a necessary process for human beings to cope with the existential crisis. As of January 2021, about 130 countries around the world have proposed carbon-neutral targets[3]. The global consensus on carbon neutrality marks the end of the traditional industrial era and the beginning of a new era of development. Carbon neutrality is not only a reshaping of energy structure, but also a redefinition of human development paradigm and a "self-revolution" of production and lifestyle. Therefore, not only will the future natural environment and social state of humanity be affected by carbon neutrality, but the economic, political and military power of global economies will also inevitably be affected by carbon constraints.

2. The main policy framework and objectives of EU carbon neutrality

The EU's carbon neutral policy framework includes the deployment of focused measures to reduce emissions in key sectors, supporting scientific and technological research and development projects, and diversified fiscal and financial safeguards. For example, in November 2018, the European Commission first set out its vision for a carbon-neutral Europe by 2050; In March and December 2019, the European Parliament and the European Council approved proposals for this vision. In order to achieve the goal of carbon neutrality, the European Commission published the European Green Deal in December 2019[4], which put forward seven major transformation paths towards carbon neutrality in Europe. In March 2020, the European Commission adopted the European Climate Act proposal[5], which aims to ensure that Europe is carbon neutral by 2050 from a legal perspective. In July 2021, the European Commission published its "Fit for 55" package[6] and adopted nine proposals. Under the framework of the European Climate Act, the Carbon Reduction 55 Package and the European Green Deal[7], the EU has built and improved its carbon neutral policy framework mainly from seven aspects: increasing the greenhouse gas emission reduction target by 2030 from 50%-55% to 60%; Revision of climate-related policies and regulations; To co-ordinate all European Commission policies and new initiatives based on the European Green Deal and sectoral strategies; Constructing digital intelligent management system; Improving the EU emissions trading system; Constructing a just transformation mechanism; Standardizing the EU's green budget.

3. EU measures to reduce emissions in key sectors

According to the EU's 2030 Climate Target Plan, the energy industry is one of the industries that is expected to achieve emission reduction breakthroughs in the future, while industry, transport and forestry are relatively potential industries. Therefore, this study will focus on the energy, industrial, transport and forestry sectors to review the emission reduction measures taken by the EU.

3.1. Energy industry

Energy system transformation is a key driving force for economic decarbonization. The European Union's "Promoting a Climate-Neutral Economy: EU Energy System Integration Strategy" Outlines key actions to decarbonize the energy system, and identifies six pillars of key actions:

(1) Building an energy system that puts "energy efficiency first" and focuses more on recycling;
(2) Build a power system based on renewable energy to accelerate energy electrification;
(3) Promoting the use of renewable energy and low-carbon fuels in industries that are difficult to decarbonize;
(4) Improve energy market compatibility;
(5) Building an integrated energy infrastructure;
(6) Build an innovative digital energy system.

3.2. Industry

European industry is a global leader in many areas.In order to maintain its leading position, the EU published Our Vision for a Clean Planet for All[8]: Industrial Transformation, which describes the EU's industrial transformation vision from six aspects.

(1) climate change action to improve energy efficiency;
(2) Significantly reduce energy import dependence by 2050;
(3) Economic transformation enjoys first-mover advantage;
(4) Continue to increase the proportion of renewable energy;
(5) Strengthening infrastructure development;
(6) Focus on electrical migration for technological innovation.

3.3. Transportation industry

Transport accounts for a quarter of the EU's greenhouse gas emissions and is still growing. The Sustainable Transport -- Europe Green Deal[9] sets a target of reducing greenhouse gas emissions from the transport sector by 90% by 2050 and proposes the following key measures:

(1) digitizing traffic management systems to improve energy efficiency in the transport sector;
(2) Reduce or eliminate aviation and fossil fuel subsidies and incorporate environmental impacts into the pricing system;
(3) Build 1 million public charging stations and gas stations (currently 140,000), and improve the sustainable fuel supply system.

3.4. Forestry

With 43.52% of the EU covered by forests, forests are expected to play an important role in driving Europe towards carbon neutrality by 2050. On July 16, 2021, the European Commission issued the European Union 2030 Forest Strategy[10], which proposed the following four main measures:

(1) Protect and restore primary forests, proposing the goal of planting 3 billion more trees by 2030;
(2) Develop forest-based eco-tourism, prolong the service life of wood products, and improve the ecological, social and economic benefits of forests;
(3) Encourage people to understand forests better;
(4) Develop coordination a coherent framework for forest governance.

4. EU carbon neutral scientific and technological innovation research and development safeguards

From 2021 to 2030, the EU will mobilize at least 1 trillion euros to support the European Green Deal. The EU will support the R&D and demonstration of low-carbon technologies in the following key industries through the coordination of large-scale scientific programs such as the "Innovation Fund" and the "Horizon Program" [9], aiming to achieve carbon neutrality by 2050.

4.1. Key innovative technologies for clean energy and security transformation

(1) Renewable energy generation technology. Next-generation wind turbines, solar power generation, enhanced geothermal energy, offshore oscillating wave surge converters, advanced biofuels, tidal and wave energy technologies, offshore floating renewable energy generation equipment and large-scale integrated systems.
(2) Energy storage technology. Ultra-fast charging infrastructure, lithium-ion or new chemical battery technology, organic solar cells, heat storage technology, heat extraction and electricity storage technology.
(3) Power network infrastructure and transmission technology. Large offshore HVDC grid technology, inter-

device / inter-array dynamic cable and offshore substation connection facilities, port energy management systems and charging facilities.
(4) Hydrogen energy technology. Clean hydrogen terminal components, 100 MW electrolytic cell technology.
(5) Intelligent management and service technology. Blockchain technology, artificial intelligence technology, innovative digital energy system.

4.2. Key innovation technologies for industrial transformation

(1) Production of coke and refined petroleum products -- research and development of low-carbon tire production technology and alternative raw materials;
(2) Ferrous metal production -- direct reduction technology based on low hydrocarbon, electric furnace steelmaking, stove top gas recovery;
(3) Non-ferrous metal production -- low emission electrolysis, inert anode/wet drain cathode, magnetic billet heating, waste heat recovery;
(4) Manufacture of cement and concrete products -- composition optimization of low-carbon cement and concrete;
(5) Production of lime and gypsum products -- improving CO_2 concentration and oxygen-rich technology;
(6) Glass and its products manufacturing - electric furnace, oxygen rich combustion, low hydrocarbon and other alternative fuels;
(7) Manufacturing of clay products and refractories -- low carbon product design, electric furnaces and dryers;
(8) Paper and paper product production - new drying technology, fiber foaming, enzyme pretreatment, heat recovery, electrochemical depolymerization of lignin;
(9) Chemicals and chemistry.

4.3. Key technologies of high energy efficiency building

Key technologies of high energy efficiency building.
(1) Scalable design of renewable energy communities;
(2) From design to construction workflow monitoring;
(3) Design of energy-efficient buildings that adapt to the local environment and climate;
(4) Volatile renewable energy generation and service infrastructure technology portfolio;
(5) Renewable energy heating and cooling solutions;
(6) Building and equipment safety energy-saving intelligent operation system based on digital technology;
(7) Low-carbon habit cultivation of citizens;
(8) Research and release of building and high voltage AC technical standards.

4.4. Key technologies of intelligent transportation

(1) Research and development of key components for electric vehicles;
(2) Automated and intelligent traffic management system development;
(3) Research and demonstration of large-scale technical solutions for green airports, oceans and inland green ports.

5. EU carbon neutral fiscal and financial safeguards

5.1. The EU has included climate-change-related spending in its main budget

Towards a modern clean economy and a fair society, the EU's Multi-Annual Financial Framework (2021-2027), the European Sustainable Investment Plan and other major fiscal and financial transformation measures include seven:

(1) At least 108 billion euros will be raised from the European Cohesion Fund and the European Regional Development Fund in 2021-2027 to support integrated demonstration of renewable energy and low-carbon fuel production and consumption, financing of flagship projects of carbon-neutral industrial clusters, infrastructure development, and research and development of key components of electric vehicles.
(2) Under the Investment Plan for Europe, the European Investment Bank will develop a financial instrument for the efficient operation of buildings, using EU grants as guarantees to attract 10 billion euros of financing to improve the energy efficiency of buildings and lift 3.2 million households out of energy poverty.
(3) At least 60% of the budget of the Connected European Infrastructure Initiative is allocated to support transport, energy and digital infrastructure.
(4) Formulate an "outward investment plan" to attract additional investment of up to 44 billion euros using 4.1 billion euros from the EU budget. Three of the scheme's five investment Windows will be directed towards the goal of carbon neutrality.
(5) The EU will take structural support actions for coal and carbon-intensive regions.
(6) Compared with 2014-2020, the LIFE programme will increase spending by 72% (to 5.4 billion euros), with more than 60% of the increase going towards achieving climate goals.
(7) The Common Agricultural Policy and the Horizon Programme plan to allocate at least 40% and 35% of the budget respectively to support the priorities of the European Green Deal.

5.2. The EU Emissions Trading System (ETS) and carbon price mechanism help promote equitable transformation

In the practice of global greenhouse gas emission reduction, the EU carbon emissions trading system and carbon price mechanism are considered to be the most effective market economic means. In the early stage of operation, the allocation of free carbon credits in the EU ETS adopts the historical method, which has less binding effect on industrial carbon emissions. The problems exposed are the failure of the carbon price and the inefficiency of the EU's emissions trading system. The market stability reserve mechanism improves the effectiveness of the EU emissions trading system, but also creates the problem of industrial constraints. Up to now, although the EU carbon emissions trading system has gone through three stages of improvement, there are still problems. In February 2018, the EU approved the reform plan for the fourth phase of the EU Emissions Trading System (ETS) (2021-2030). By 2030, the total number of free carbon allowances in the EU ETS is expected to be 43% lower than in 2005, the first year of the scheme's operation, and the ETS will be extended to new sectors.

The main reform measures for Phase 4 of the ETS include:

(1) the market stabilization reserve will reduce overquota emissions by 24% per year from 2019 to 2023;
(2) From 2021, the annual decline rate of the total carbon quota will increase from 1.74% to 2.2%;
(3) Update the total amount of free carbon quota regularly according to technological progress;
(4) Encourage industry innovation;
(5) Ensuring affordable energy prices;
(6) 2% of the EU ETS reserve funds will be used to address the additional investment needs of low-income member states (GDP per capita is less than 60% of the EU average);
(7) 10% of the carbon allowances auctioned by member States in the EU ETS will be allocated to countries whose per capita GDP is less than 90% of the EU average, and the rest will be allocated among all member States based on verified emissions;
(8) We will extend the EU emissions Trading System to the maritime sector through the carbon boundary adjustment mechanism and the market stabilization reserve mechanism, and build new ETS for the construction and transport industries, so as to achieve the goal of reducing the emissions of the industries covered by the EU emissions Trading system by 61% from 2005 by 2030;
(9) Use the carbon Offset and Emission Reduction Scheme for international aviation for flights outside the EU Emissions Trading System.

6. Key features of the EU carbon neutral policy system

The European Union has been at the forefront of efforts to achieve carbon neutrality. At present, the EU carbon neutral policy system has been relatively complete, and its main characteristics are as follows:

6.1. A sound policy framework

The EU has set up a top-down carbon neutral policy framework in three main forms, namely, setting up targets, enacting legislation and issuing strategic plans, which has pointed out the direction for the EU's short - and medium-term economic decarbonization.

6.2. Measures to reduce emissions in key industries with clear priorities

The EU has defined the key industries that give priority to decarbonization, issued medium - and long-term transformation and development strategies for key industries, and deployed emission reduction measures for key industries.

6.3. Science and technology first

By launching large-scale scientific programs, the EU has deployed a structured system of science and technology innovation focusing on key scientific issues and technologies such as renewable energy generation technology, energy storage technology, power grid infrastructure and transmission technology, hydrogen energy technology, intelligent management and service technology, research and development of key components of electric vehicles, research and development of alternative raw materials, and research and development of industrial decarbonization process.

6.4. A complete set of financial and financial safeguards

The EU has introduced corresponding large-scale investment and financing plans, actively explored and improved fiscal and financial safeguards, and promoted the development of the EU economy, society and industry along the set direction.

6.5. The development of new nuclear power generation technologies and CCUS technologies still faces challenges

The emission of chemical industry and electric power industry is inevitable. CCUS technology and new nuclear power generation technology may become difficult to reduce emissions.Key technologies for carbon neutrality. However, there are still security risks and high costs in the large-scale application of the above technologies. Therefore, how to improve and promote relevant technologies is an important challenge facing the EU at present.

6.6. The emissions trading system and the carbon price mechanism are still being improved

Up to now, although the EU carbon emissions Trading system has been in operation for 16 years, how to find a balance point between the carbon emissions trading system and carbon price, while increasing the carbon emission reduction efforts, minimize the constraints on the development of the industry, and seek for the fair and just transformation of different member states and different industries is still an issue worthy of in-depth discussion.

7. Conclusion: EU green development prospect analysis

As the main policy direction of European Commission President Ursula von der Leyen since she took office, implementing the "green New Deal" and promoting green development are the means and potential advantages for the EU to participate in global competition. In the future, continuing to promote green development and build a new round of global competitive advantages will be the unswerving strategic choice of the EU. Green development has became a consensus in the EU and is regarded as a "core value". Despite development obstacles, the EU has more room for strategic manoeuvre in the future.

To address the challenges of heterogeneity in green development within the EU, and to further bridge the "green development gap", the EU has set up the Modernisation Fund and the Just Transition Mechanism in 2020. Help low-income member countries or hard-to-transition regions transition to carbon neutrality through targeted financing and transfer payments. The modernisation Fund represents 2 percents of the carbon allowances auctioned in the EU's Emissions Trading System from 2021 to 2030, with the aim of helping low-income member states achieve energy systems[11].

In response to the challenge of insufficient capital input to encourage enterprises to meet the green transformation, the EU emission trading system and green finance and other investment and financing mechanisms have been deployed in place, and the carbon border adjustment mechanism has been put on the agenda, leaving room for guiding the "induced technological change" of traditional carbon emission intensive industries and supporting the long-term development of low-carbon industries in the future. In addition, the €750 billion "Next Generation EU" recovery Fund has strengthened the EU's public finance position, and the implementation of the carbon border adjustment mechanism has expanded financing channels. In the EU, multinational companies and financial institutions have increasingly formed a consensus on green development

In terms of meeting the challenges of green technology selection and deployment, the EU has an early start in green development and a strong industrial foundation. Once it achieves breakthrough technological innovation or locks in the path of technological iteration, its already established green industrial chain system can be quickly compatible, and it is expected to seize the "commanding heights" of global green development in a short time and form a new round of international competitiveness. At present, the selection and deployment of green technologies in the EU are more concerned with the long-term application and social effects of green technologies based on the long-term effects of achieving carbon neutrality, social changes, ecosystem integrity and the situation of vulnerable groups. Therefore, the EU also conducts in-depth research and steps by steps in the deployment of technology, rather than blindly pursuing short-term economic benefits and "big and fast" projects.

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Research Topics and Trends in European Union Energy Policy: A Structural Topic Model

Yeye LI

Hainan University, Haikou City, Hainan Province, China, 570228

E-mail: liyeye0320@126.com

***Corresponding author**

Abstract

Energy policy is considered a key factor in achieving carbon neutrality in the EU. In recent decades, a substantial number of academic articles have been published on EU energy policy. This study aims to provide a comprehensive review of the development of energy policy research in the EU. We utilized Structural Topic Modeling (STM) to analyze research topics and trends in EU energy policy literature. STM is an unsupervised machine learning method that facilitates large-scale unstructured text mining and reveals research topics and evolutionary trends. We collected and analyzed 1777 articles published between 1975 and 2022. Our findings indicate that the primary academic focus of EU energy policy is related to port management, container operations, and liner shipping management. Furthermore, our analysis reveals that in the early days, researchers focused on energy performance and alternative energy sources such as wind and bioenergy. Later, research shifted towards broader topics such as renewable energy, climate change, and energy efficiency. More recently, CO_2 emissions, sustainability, energy management, energy consumption, carbon pricing, decarbonization, energy poverty, and energy equity are hot topics of research. The major research topics and emerging trends identified from STM can assist researchers, funding communities, and policymakers in identifying contemporary research issues and making more informed decisions.

Keywords: European union; energy policy; text mining; structural topic model; research trends.

1. Introduction

Climate change is one of the most pressing global issues of our time, and the energy sector plays a significant role in contributing to carbon dioxide emissions that have a major impact on it. Therefore, improving energy efficiency and reducing energy demand are crucial tools for mitigating climate change (Bertoldi, P., 2018). The European Union (EU) has been actively pursuing a climate policy for the past few decades, recognizing that energy production and use account for 80% of all greenhouse gas emissions in the region (Economidou et al., 2020). Thus, the development of effective energy policies is crucial to the EU's energy transition and to achieving the goal of carbon neutrality. A comprehensive understanding of current market conditions and developments is necessary to ensure the effectiveness of energy policies.

In recent years, EU energy policy has attracted significant attention from researchers, and efforts have been made to review research content and trends in this area. For example, Economidou et al. (2020) reviewed 50 years of EU policies on building energy efficiency and provided insights and recommendations for achieving complete decarbonization of buildings in the future. Kanellakis et al. (2013) outlined the historical evolution and current status of EU energy policy from 1950 to 2012. However, due to the coexistence of different perspectives, the scientific opinion on EU energy policy remains highly fragmented. Traditional analytical methods are limited by a small number of studies and are subject to researcher subjectivity and selective bias. To overcome these limitations, this study aims to gain an overview of the research profile in the field of EU energy policy and to predict future research trends using artificial intelligence technology and text mining techniques.

The Structural Topic Model (STM) is used to analyze research topics and trends in EU energy policy literature by collecting and examining metadata from publications in the 27 EU member states. This study seeks to provide insights and recommendations to support researchers, policymakers, and entrepreneurs. The remainder of this study is organized as follows: Section 2 describes the research methodology, Section 3 presents the results of the structural topic model analysis, including visualization and discussion of the findings, and the paper concludes with a summary and discussion of the key findings.

2. Methodology

2.1. Structural Topic Model (STM)

Structural Topic Modeling (STM) is an unsupervised machine learning approach that enables the discovery of the latent topic structure within a given corpus of text data. It has become a popular method for exploring the key themes and trends within various research fields due to its efficiency and ability to handle large volumes of unstructured data. For instance, scholars such as Farrell (2016) and Sietsma et al. (2021) have used STM to investigate topics related to corporate finance and ideological polarization about climate change, and scientific literature on climate change adaptation, respectively. Surprisingly, however, STM has yet to be employed in the realm of energy policy research.

2.2. Research outline

The research outline presented in Figure 1 illustrates the various steps involved in the research process. The first step is data collection, which forms the foundation for all subsequent research activities. Following data collection, the collected data is pre-processed, including case conversion, punctuation removal, stemming, among other techniques. The aim of this step is to ensure that the modeling results are accurate. Finally, the research requires determining the number of topics (K) and gaining insights from the model results. Each step will be elaborated upon in the following sections.

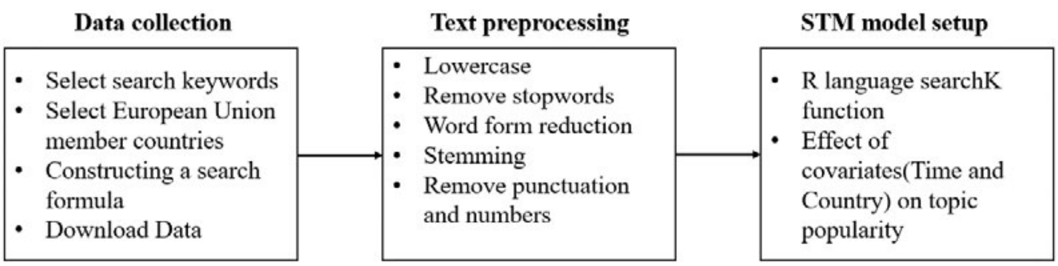


Fig.1 Research outline

2.3. Data collection

The research literature on energy policy in the 27 EU member countries was retrieved by conducting a search on the Web of Science (WOS). The search was conducted using the following search formula: (TI=ENERGY AND TI=POLICY) AND (DT==("ARTICLE") AND SILOID==("WOS") AND CU==("AUSTRIA" OR "BELGIUM" OR "BULGARIA" OR "CROATIA" OR "CZECH REPUBLIC" OR "DENMARK" OR "ESTONIA" OR "FINLAND" OR "FRANCE" OR "GERMANY" OR "GREECE" OR "HUNGARY" OR "IRELAND" OR "ITALY" OR "LATVIA" OR "LITHUANIA" OR "LUXEMBOURG" OR "MALTA" OR "NETHERLANDS" OR "POLAND" OR "PORTUGAL" OR "ROMANIA" OR "SLOVAKIA" OR "SLOVENIA" OR "SPAIN" OR "SWEDEN" OR "CYPRUS")). The search yielded a total of 1777 research papers. The number of research papers retrieved for each EU member country is presented in Table 1. It is important to note that, due to cooperation between some countries, an article may have been counted for more than one country.

Table 1. Number of articles by Country

Country	Number of Articles	Country	Number of Articles
GERMANY	382	LITHUANIA	36
ITALY	236	HUNGARY	30
NETHERLANDS	203	CZECH REPUBLIC	27
FRANCE	153	ROMANIA	27
SPAIN	153	LATVIA	22
SWEDEN	140	CROATIA	20
FINLAND	97	CYPRUS	17
AUSTRIA	96	SLOVENIA	14
GREECE	91	LUXEMBOURG	11
POLAND	90	SLOVAKIA	11
DENMARK	89	ESTONIA	10
BELGIUM	86	MALTA	4
PORTUGAL	56	BULGARIA	3
IRELAND	47		

2.4. Data preprocessing

We utilized the "stm" package in the R language to perform data pre-processing tasks as outlined in Roberts et al. (2019). Data pre-processing is a crucial step that involves cleaning the text data to make it more normalized. This involves converting all capital letters to lowercase (e.g., Energy to energy), removing stopwords (e.g., a, an, the, of and other words that are often found in the text but do not carry any substantive meaning), reducing word forms to their root form (e.g., reducing plural or morphologically different words to their prototype form such as energies to energy), stemming (i.e., removing suffixes from words to reduce them to their root form), and eliminating punctuation and numbers.

2.5. STM model setup

One of the most critical tasks in constructing an STM model is to determine the appropriate number of topics, denoted as K. This is because the choice of K is linked to the degree of interpretability of the model. Nevertheless, there is no definitive method for selecting the optimal number of topics in the STM algorithm. Therefore, we will employ the R language "searchK" function to assist us in determining the number of topics.

The STM model enables us to examine the impact of covariates on topic prevalence by utilizing a generalized linear model. In this study, we contend that researchers' attention towards different topics varies over time, while the degree of attention given to topics differs among countries. As such, we have defined two covariates, Time and Country, to represent the year of publication and the country where the article was published, respectively. Equation (1) depicts the relationship between topic prevalence and these two covariates. Additionally, we have considered the interaction of time and country, hypothesizing that the pattern of change in attention towards topics varies across countries over time.

$$Prevalence = g\,(Time,\ Country,\ Time \times Country) \qquad (1)$$

3. Results

3.1. Descriptive analysis

Table 2 presents the details of the literature data, including the year of publication, the source of the literature, and the average number of publications per year. Figure 1 shows the annual distribution of papers, indicating that the first article was published in 1975, and the number of papers has been slowly increasing. However, the number of papers started to rapidly increase in 2002, and by 2021, the number of papers published has exceeded 150, suggesting an increasing attention to research on EU energy policy. Table 3 provides information on the top 10 cited papers. Figure 3 illustrates the distribution of papers by journal, where *Energy Policy* is the top journal with 336 publications, followed by *Energie* and *Renewable&Sustainable Energy Reviews* with 86 and 68 articles, respectively. Figure 4 shows the word cloud of author keywords, where the font size represents the frequency of occurrence. It can be observed that keywords such as "energy transition", "climate policy", "climate change", and "renewable energy sources" are widely mentioned and important research topics in this field. Figure 5 presents the keyword dynamics over time, revealing the evolution of research in this field. Initially, the research mainly focused on energy performance and alternative energy sources such as wind and bioenergy. Later, the research expanded to broader topics such as renewable energy, climate change, and energy efficiency. In recent times, hot research topics include CO_2 emissions, sustainable development, energy management, energy consumption, carbon pricing, decarbonization, and social issues such as energy poverty and energy equity.

Table 2. Article statistics

Description	Results
Timespan	1975:2023
Sources (Journals, Books, etc)	527
Documents	1754
Document Average Age	7.02
Average citations per doc	22.11
References	71569
Keywords Plus (ID)	2100
Author's Keywords (DE)	4041
Authors	4075
Authors of single-authored docs	339
Single-authored docs	385
Co-Authors per Doc	2.94
International co-authorships %	40.82

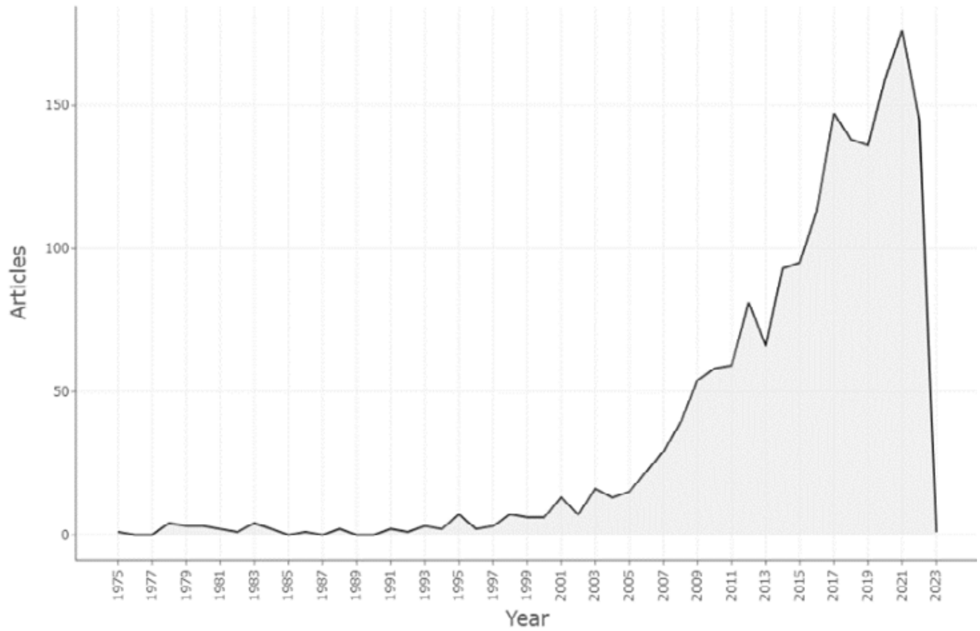


Fig.2 Annual distribution of Articles

Table 3 Most cited Articles

Article	DOI	Total Citations	TC per Year	Normalized TC
JOHNSTONE N, 2010, ENVIRON RESOUR ECON	10.1007/s10640-009-9309-1	797	61.31	14.45
JACOBSSON S, 2006, ENERG POLICY	10.1016/j.enpol.2004.08.029	611	35.94	9.60
STEG L, 2005, J ENVIRON PSYCHOL	10.1016/j.jenvp.2005.08.003	597	33.17	7.71
MENANTEAU P, 2003, ENERG POLICY	10.1016/S0301-4215(02)00133-7	465	23.25	9.38
LINDEN AL, 2006, ENERG POLICY	10.1016/j.enpol.2005.01.015	228	13.41	3.58
DE GROOT HLF, 2001, ENERG ECON	10.1016/S0140-9883(01)00083-4	218	9.91	5.41
FOUQUET D, 2008, ENERG POLICY	10.1016/j.enpol.2008.06.023	207	13.80	5.12
POLZIN F, 2015, ENERG POLICY	10.1016/j.enpol.2015.01.026	204	25.50	8.02
NESTA L, 2014, J ENVIRON ECON MANAG	10.1016/j.jeem.2014.01.001	203	22.56	7.12
SCARLAT N, 2015, RENEW SUST ENERG REV	10.1016/j.rser.2015.06.062	197	24.63	7.74

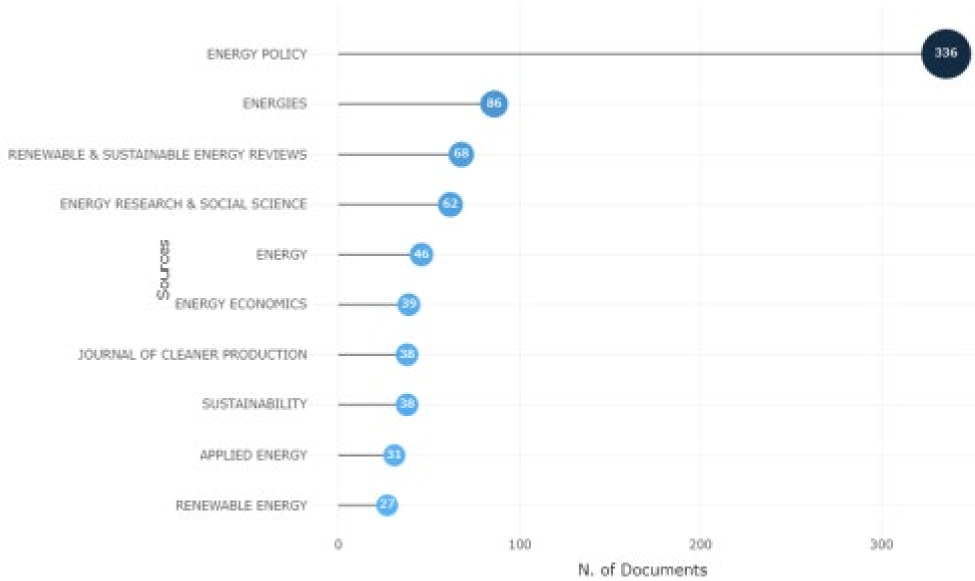


Fig.3 Journal distribution of Articles

Fig.4 Keyword word cloud

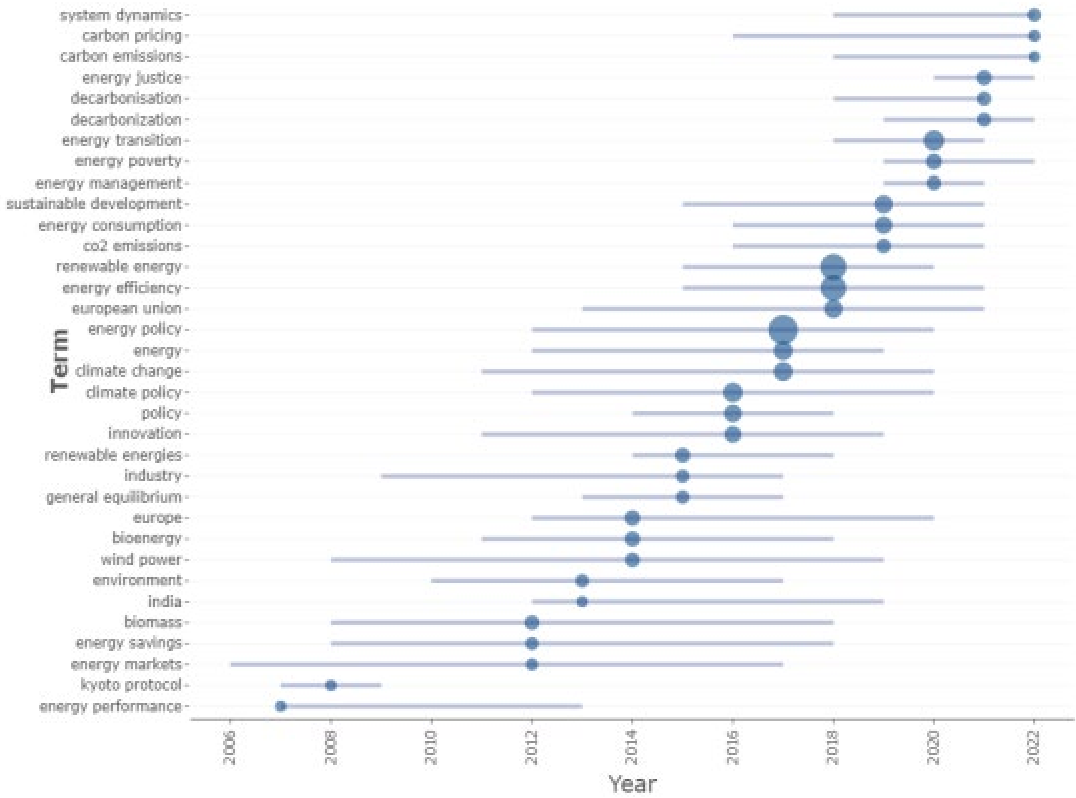
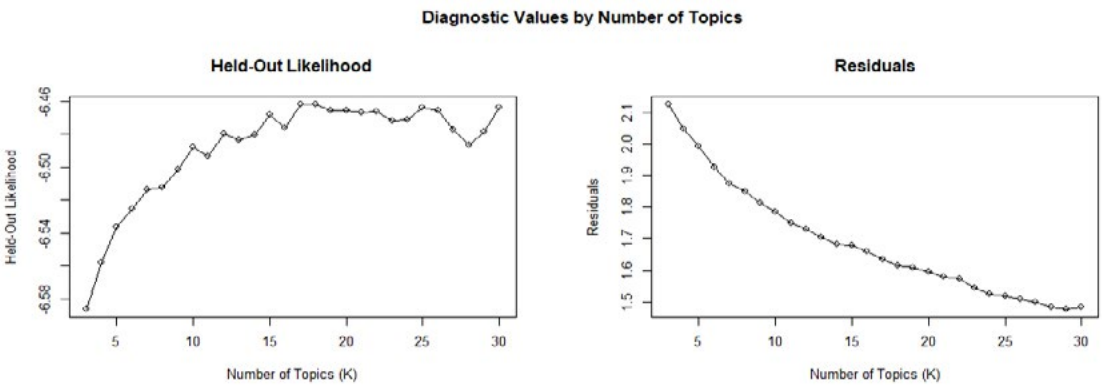


Fig.5 Keyword dynamics

3.2. Structural Topic Model (STM) Results

3.2.1. Choosing the number of topics

Figure 6 displays the diagnostic values for topic count. The top-left plot, "Held-out Likelihood", is used to estimate the final performance of the model after training and validation on the dataset. The bottom-left plot, "Semantic Coherence", is used to assess the coherence of the extracted topics. The bottom-right plot, "Lower Bound", represents the lower bound of the model convergence. It can be observed that both "Held-out Likelihood" and "Semantic Coherence" exhibit an inflection point at K=10, indicating that the optimal number of topics is 10.



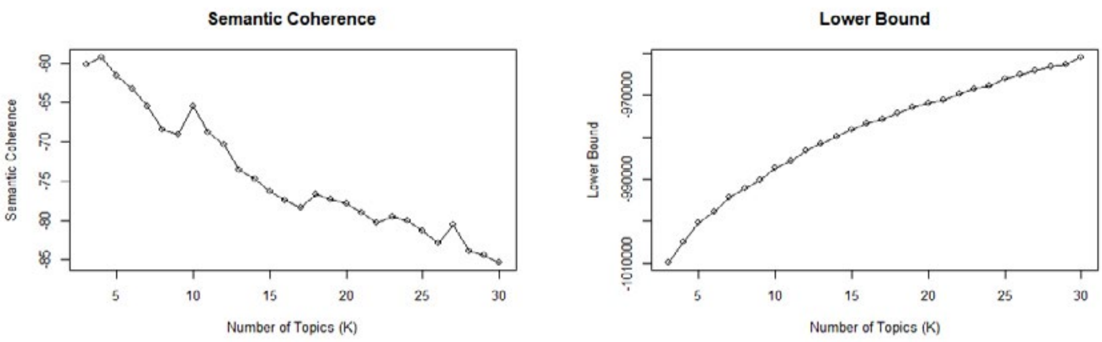


Fig.6 Topic number diagnostic value

3.2.2. Topic summary and validation

Table 4 shows the results of the STM model. The second column shows the top 10 words for each topic and the STM package provides four topic word outputs: Highest Prob is a high frequency word; FREX is a word with a high interpretability based on the probability and exclusivity ratio; Lift is a word with a high probability and high exclusivity with high discriminability; Score is the log frequency of the word in the topic divided by the log frequency of the word in other topics. Please refer to Roberts et al.(2019) for the exact calculation. The first column shows the names of the topics grouped according to keywords.

Table 4 displays the results of the STM model. The second column lists the top 10 words for each topic, and the STM package provides four different topic word outputs:

"Highest Prob" represents a high-frequency word.

"FREX" represents a word with high interpretability based on the probability and exclusivity ratio.

"Lift" represents a word with both high probability and high exclusivity and high discriminability.

"Score" represents the log frequency of the word in the topic divided by the log frequency of the word in other topics.

The exact calculation can be found in Roberts et al. (2019). The first column shows the names of the topics, which are grouped according to their respective keywords.

Topic 1 explores the impact of energy policy on both the environment and the economy. Topic 2 is primarily concerned with energy efficiency. Topic 3 examines public opinion on energy policy. Topic 4 focuses on nuclear energy. Topic 5 explores the energy consumption associated with computing, algorithms, and big data. Topic 6 discusses the development of renewable energy policy. Topic 7 is centered on climate change. Topic 8 examines the renewable energy markets. Topic 9 analyzes policies related to energy. Topic 10 primarily deals with energy consumption in buildings, house renovation, and similar topics.

The significance of each topic varies, and Figure 7 depicts the distribution of topic percentages. The analysis reveals that Topic 9 receives the highest research attention, followed by Topic 6 and Topic 3. In contrast, Topic 10 is the least explored area in the field.

Figure 8 presents the interrelationships between the ten topics, indicating that Topic 5 and Topic 6 are relatively independent. Topic 9 exhibits strong linkages with Topics 3 and 4, as it pertains to policy analysis that must consider public opinion, which is particularly crucial in the context of nuclear energy. Additionally, Topic 2 is linked to Topic 10, where energy-efficient design, house renovation, and other measures are essential for reducing energy consumption in buildings. Furthermore, Topic 7 is linked to Topic 8 and Topic 1, which primarily address climate, environmental, and economic issues.

The preceding analysis demonstrates that our model possesses a high degree of interpretability.

Table 4 Topic summary

Topic	Keywords
Topic 1:The economic and environmental impact of energy policy	Highest Prob: energi, effect, polici, use, result, product, impact, countri, environment, econom

Topic 1:The economic and environmental impact of energy policy	FREX: incom, tax, subsidi, panel, bioga, posit, regress, effect, elast, relationship
	Lift: irrig, ordinari, farmer, cointegr, autoregress, cge, asymmetr, short-run, capita, crop
	Score: irrig, household, tax, crop, elast, price, bioga, subsidi, agricultur, incom
Topic 2：Energy efficiency	Highest Prob: energi, effici, polici, measur, industri, paper, effect, save, use, improv
	FREX: effici, save, barrier, measur, industri, residenti, behaviour, standard, improv, end-us
	Lift: properti, smes, rebound, voluntari, applianc, white, dutch, effici, end-us, money
	Score: properti, effici, residenti, save, rebound, industri, smes, applianc, barrier, audit
Topic 3:Citizens' views	Highest Prob: energi, transit, research, polici, develop, innov, sustain, social, studi, technolog
	FREX: transit, citizen, research, social, societi, communiti, innov, attitud, expert, dimens
	Lift: postal, everyday, gender, sdg, media, conscious, finnish, justic, democraci, synthesi
	Score: gender, transit, citizen, democraci, justic, everyday, poverti, innov, narrat, communiti
Topic 4:Nuclear Energy	Highest Prob: energi, govern, state, region, polit, polici, articl, power, intern, european
	FREX: german, cooper, germani, nuclear, chines, govern, russia, reform, intern, coalit
	Lift: fukushima, ideolog, lobbi, vote, bilater, began, accid, salienc, state-own, amend
	Score: lobbi, nuclear, polit, german, govern, chines, germani, coalit, russia, feder
Topic 5:Data calculation and energy consumption	Highest Prob: model, energi, polici, system, optim, use, propos, network, result, can
	FREX: optim, model, simul, comput, batteri, machin, algorithm, paramet, network, stochast
	Lift: idl, radio, throughput, traffic, algorithm, determinist, energy-awar, markov, outperform, sensor
	Score: idl, optim, algorithm, model, sensor, batteri, machin, wireless, simul, traffic
Topic 6:Renewable energy policy developments	Highest Prob: energi, renew, develop, european, countri, polici, sourc, union, nation, sustain

Topic 6:Renewable energy policy developments	FREX: res, union, poland, european, lithuania, sourc, member, situat, countri, india
	Lift: lithuania, lithuanian, inland, polish, lignit, eurostat, poland, czech, disclos, ghana
	Score: inland, european, lithuania, renew, res, union, poland, lithuanian, countri, sourc
Topic 7:Energy and climate change	Highest Prob: emiss, energi, climat, global, fuel, scenario, carbon, gas, sector, reduct
	FREX: emiss, global, mitig, greenhous, fuel, fossil, ghg, carbon, transport, gas
	Lift: safeti, pledg, emit, sequestr, food, co-benefit, ghg, passeng, greenhous, net-zero
	Score: emiss, safeti, fuel, carbon, scenario, ghg, fossil, transport, climat, food
Topic 8:Renewable energy market	Highest Prob: electr, renew, technolog, cost, market, invest, power, system, wind, support
	FREX: electr, wind, tariff, solar, invest, feed-, deploy, plant, risk, investor
	Lift: cost-effici, fleet, motor, turbin, onshor, premium, investor, tariff, bid, tradabl
	Score: motor, wind, electr, renew, cost, feed-, power, solar, tariff, price
Topic 9:Policy analysis	Highest Prob: polici, climat, instrument, differ, approach, chang, process, analysi, integr, framework
	FREX: interact, prefer, mix, instrument, integr, outcom, coher, nexus, coordin, qualit
	Lift: contest, incoher, fossil-bas, intermediari, nich, cross-sector, horizont, uncov, enact, coher
	Score: contest, instrument, polici, climat, nexus, conflict, actor, prefer, intermediari, nich
Topic 10:Building renovation	Highest Prob: build, energi, heat, local, urban, citi, perform, studi, use, hous
	FREX: build, hous, citi, urban, retrofit, heat, municip, renov, stock, local
	Lift: metropolitan, retrofit, epc, hous, renov, mayor, epbd, coven, citi, municip
	Score: epc, build, heat, hous, citi, urban, retrofit, renov, municip, dwell

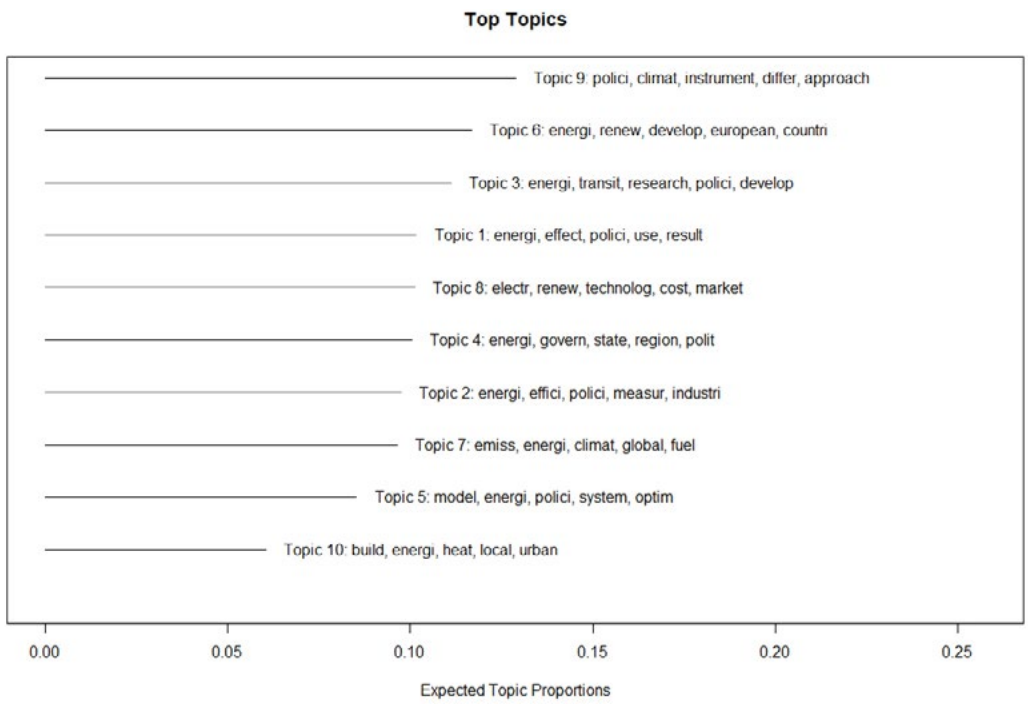


Fig.7 Topic distribution

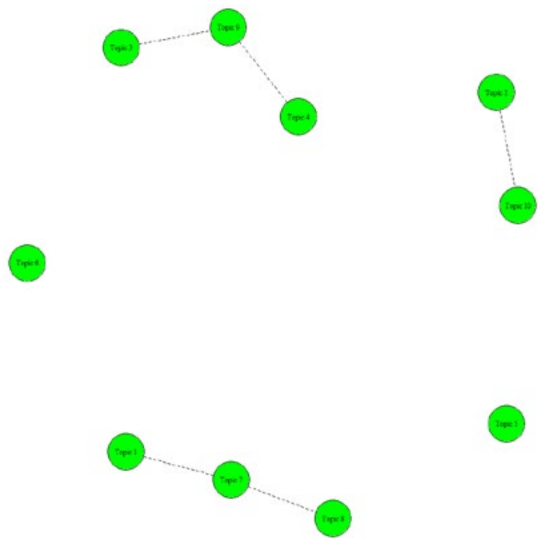


Fig.8 Thematic relationship diagram

3.2.3. Effect of covariates (Time and Country) on topic popularity

We have conducted a temporal analysis of the trends in topics, as presented in Figure 8. Our findings indicate that Topic 2 and Topic 4 have exhibited a declining trend, whereas Topic 5, Topic 7, and Topic 10 have shown an increasing trend. Additionally, Topic 3 and Topic 9 have trended upwards, but have experienced a significant decline in recent times. Other topics have displayed fluctuating changes. These changes may be related to policy enactments and significant social events, which warrant further investigation in future studies.

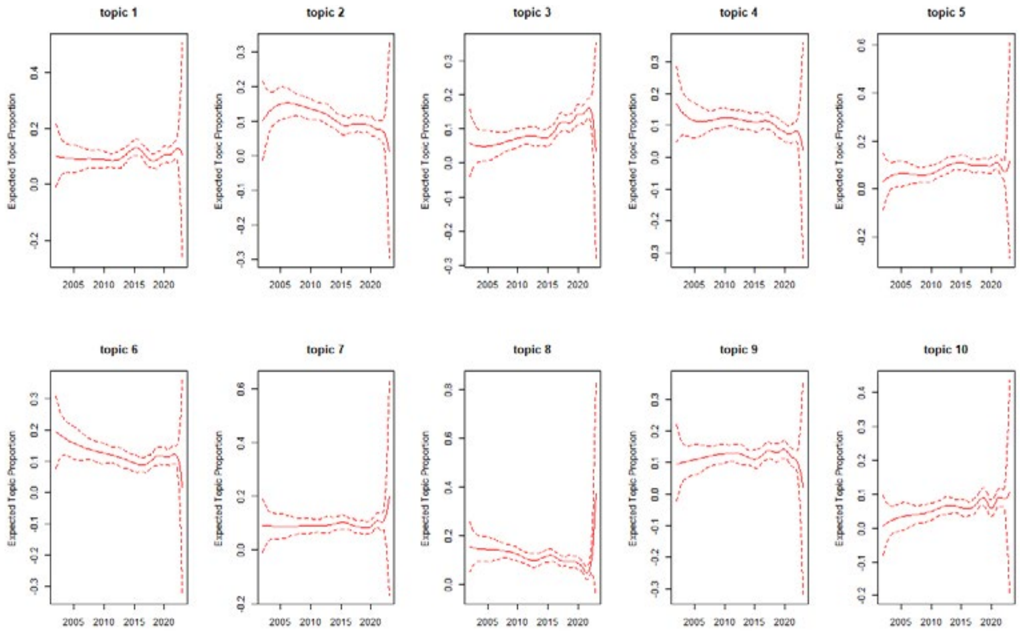


Fig.9 Trend of topics over time

The research focus varies across different countries. In our STM model, we added countries as covariates and compared the differences between Germany and Italy, as illustrated in Figure 10. Germany and Italy were selected for comparison because they have the highest number of publications in the field. Nonetheless, it is also possible to compare any two countries using the R language STM package. Our analysis shows both similarities and differences in the research focus of these two countries. Specifically, there is little difference in their focus on Topic 3 and Topic 4, while significant differences exist in their focus on Topic 5, Topic 10, Topic 4, and Topic 9, as well as in Topic 1, Topic 2, Topic 7, and Topic 8.

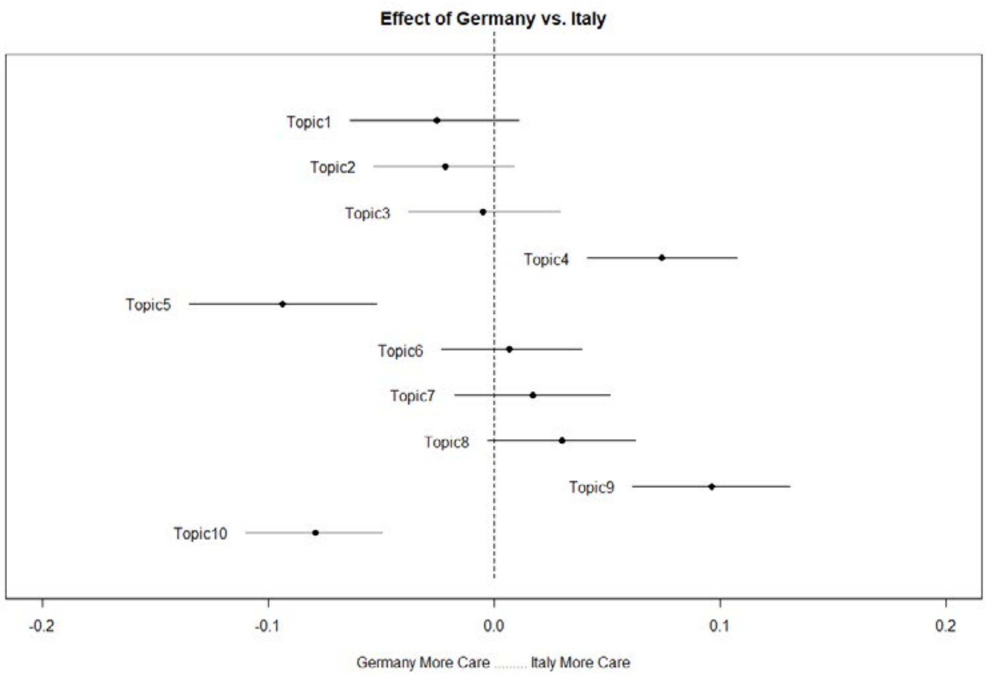


Fig.10 Similarities and Differences in Country Topics Focus

4. Conclusions

We conducted unsupervised machine learning using STM topic modeling on the abstract sections of 1777 articles related to energy policy published in 27 EU member states. We identified ten topics based on diagnostic values, which are detailed in Section 3.2.2. Through visual presentation of the topic distribution and interrelationships, we not only gained a better understanding of the model results but also confirmed the model's interpretability. Moreover, we analyzed how the topics evolved over time and compared the similarities and differences in research focus among different countries. We provided a detailed account of our data collection and processing procedures, the R language packages employed, and the key functions used in our study.

To our knowledge, our research is the first to apply STM topic modeling to the field of energy policy. The major research topics and emerging trends we identified through STM analysis can assist researchers, funding agencies, and policy makers in identifying current research issues and making well-informed decisions. However, our study has some limitations. For example, further investigation is needed to determine the factors contributing to the growth or decline of certain topics.

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PROCEEDINGS OF THE
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Educational Measures Contribute to the Carbon Neutrality goal of EU

Xinyi CAI

Southwest Jiaotong University, Chengdu City, Sichuan Province, 611756

E-mail: caixinyiette5523@163.com

***Corresponding author**

Abstract

To achieve the goal of the carbon neutrality, creating ultimately a clean, pollution-free world is the responsibility of every individual on the earth. In this era, people from different countries have realized that the significance of the carbon emissions, and organizations like EU have taken steps to tackle this problem. From the publication of the agreement to the introduction of the decree, the 27-member bloc has vowed to become carbon neutral by 2050. All fields like energy, architecture, transport are working on playing their part in the progress. However, the role of education is in many cases ignored. This paper analyzed the role of education in achieving a sustainable future and different educational measures for the students and the public, providing insightful implications for carbon neutrality related policy development and educational outreach for EU.

Keywords: Carbon neutrality; carbon neutrality education.

1. Introduction

The achievement of carbon neutrality has become increasingly significant worldwide. Achieving peak carbon and carbon neutrality is a multi-dimensional project involving all aspects of economic and social development. Without the new inventions and development of the technology, educators seem to play a tiny role in the pathway to achieve the carbon neutrality goal. In fact, education connects all the industries and provides strong efforts to the blueprint of EU.

Education itself is an important part of the rapid development of modern society and is responsible for important educational tasks and social change. Using education campaigns to raise public awareness of carbon neutrality and promote low-carbon behaviour is an urgent priority. Enhancing the construction of sustainable development teaching system in elementary education and higher education is just one part, raising the awareness of the general public is the key to making a huge difference to the world. Science and technology innovation and science popularisation are the ‘two wings’ of innovation and development. Thus, popularizing and promoting the concept of carbon neutrality have an important supporting role in achieving the goals of carbon peaking and carbon neutrality. In order to, the EU should urge all its member states to accelerate the process of achieving carbon neutrality and promote sustainable development.

2. Improving the carbon neutrality education in the educational systems

It is true that developing carbon neutral education does not have the same direct effect on action to reduce emissions as other areas, but in the long run, by raising carbon neutral awareness among a wide range of students, it provides a strong human resource guarantee to accelerate the process of achieving carbon neutrality. The true essence of education is to guide students to put into practice what they know, and carbon neutral education also works in this way, as schools are not only a place to promote ideas and advanced concepts, but also a place to guide students to take action and put energy saving and carbon reduction into practice. Thus, it is necessary to develop education activities about carbon neutrality.

2.1. Teachers and instructional resources

As a person of imparting knowledge, the professionalism of a teacher directly affects the quality of education and teaching. We need to strengthen the construction of highly qualified teachers in the field of carbon neutrality and promote the teaching ability of front-line teachers. Educators Scientific research institutions can provide a number of scientific research instructors, such as climatologists, chemists, physicists, biologists, etc. Professionals from these different research areas are brought together for regular seminars, and teachers from various schools in each country are invited to participate. The expertise of the researchers provides the teachers with cutting-edge theory and technical support, while the teaching skills and communication skills of the teachers facilitate the promotion of the researchers' research results. The cutting-edge theory and knowledge are taught to students and the public in an easy-to-learn and easy-to-understand way.

Increasing the construction of teaching resources is also a necessary measure. Based on the analysis of the knowledge of carbon neutrality and the talents needed, co-produce textbooks, teaching materials, tests, teaching cases and experimental and practical training projects to form a high-quality shared teaching resource library.

2.2. School curriculum

In general terms, the syllabus of the courses and curriculums about the carbon neutrality could be added into the existing EU education policy. In 2005, the EU proposed and implemented "Carbon Schools Scheme". Before the implementation of the programme, the European Commission discussed the aims and objectives of the project. It concluded that imparting students with systematic scientific knowledge at secondary school would help them to develop a correct world outlook and view of development, and encourage them to be involved in the protection of the environment and sustainable development. One of the objectives of the Carbon Schools Programme is to provide secondary school students across Europe with a better understanding of global change and education for sustainable development. It also provides a platform and opportunities in order to increase students' interest in natural science research.

Education itself has a powerful function of publicity and education. To promote carbon-neutral education, from basic education to higher education, the concept of green should be highlighted in textbooks, content and syllabus, and relevant standards should be improved. In basic education to promote primary and secondary school students to form a correct consumption concept, to develop a green consumption pattern. Primary education is a critical period for children to develop behavioral habits. Teachers should strengthen their own awareness of carbon neutrality, actively integrate carbon neutral education into the education reform activities, and cultivate children's awareness of energy saving and carbon reduction. Take Sweden as an example. From a young age, kids have been inculcated into important environmental education. There is a wide range of environmental education programmes in schools, with students being taught how to save electricity and how to recycle and reuse the items. In Sweden, nine of the sixteen compulsory courses are linked to the requirements for education on the environment and sustainable development. Inspired from this, the EU should encourage all its member states to introduce courses on carbon emissions and sustainable development to school curriculum.

In junior and senior high school, the education about carbon emissions should also be integrated into the teaching of various subjects. For example, in chemistry lessons, teachers can focus on issues related to carbon emissions and encourage students to actively use their knowledge to invent some small emission reduction models; in geography lessons, teachers can explain issues such as climate change and environmental degradation. Linking global change and climate science to education in school enhances secondary school students' understanding and research on environmental issues such as carbon foot print and to develop education for sustainable development for students. Moreover, through this kind of teaching activity, an effective measure given to teachers to promote students' interest and enthusiasm and to improve adolescents' attitudes toward carbon neutrality education and their willingness to participate in it.

In terms of higher education, colleges and universities are encouraged to set up general courses on carbon neutrality and integrate the concept and practice of carbon neutrality into the talent training system. The high quality development of higher education serves the needs of cultivating carbon neutral talents. We should aim to develop a large number of talents who possess a solid foundation in basic science and have a strong innovation ability. The transition of carbon emissions is driven by the technological revolution and based on science and technology in order to achieve sustainable development. It requires universities to put emphasis on the basic science education, focusing more on the technologies and disciplines related to the renewable energy sources and the subjects such as the chemistry, biology need to be strengthened as well.

At the same time, universities should put a high value of the integrated innovation, which is necessary to reform the original teaching system and to teach new staff on existing disciplines. As there are few carbon neutral disciplines at present in most of universities, we can start with improving the existing disciplines. Universities need to improve on the existing foundation by adjusting or upgrading some similar disciplines to build disciplines suitable for the education of carbon neutrality.

3. Different ways to strengthen public education

3.1. Science reading materials

Educators can edit and promote a number of high quality reading materials in which educators can spread the knowledge and concept of carbon neutrality. In this book, main issues about carbon peaking and carbon neutrality should be explained the in an easy-to-understand way in order to produce knowledgeable and accessible popular science books for the public. Also, through highlighting the significance of achieving carbon neutrality and the impact on scientific development, economic development, social development and personal life, it helps raise awareness and understanding of carbon peaking and carbon neutrality throughout society. Selecting issues of common concern and calls on everyone to participate and contribute to the achievement of carbon neutrality.

3.2. Social activities

Governments could conduct extensive science outreach and adopt a variety of approaches such as activities, lectures and thematic exhibitions, in which educators are essential. The public can be made aware of the relationship between the environment and our lives, as well as the relationship between the environment and the earth, and fully understand the various carbon emission phenomena that occur in real life, such as traffic, energy combustion, waste emission, etc., to raise people's awareness of energy saving and carbon reduction, with a view to encouraging more people to adopt good habits. It is also convenient for the public to enjoy science popularisation services conveniently through both online and offline lectures. Educators also serve as intermediaries between experts and the public. The government should organise regular academic events. The ideas and policy advice discussed by experts at the academic conference then could be translated into simpler and more understandable ideas through professors. Thus, we create a strong synergy for the whole society to achieve the goal of carbon peaking and carbon neutrality.

Setting up a Carbon Neutrality Week which aims to raise awareness of environmental problems, promote investment in water and promote water conservation and the rational use of water in kitchens and toilets. In addition, European countries are also very much involved in environmental protection, especially with NGOs. NGOs use their strengths to provide the public with the latest environmental information, disseminate advanced ideas on environmental protection and interact with the public through various social activities to raise their environmental awareness. In Germany, for example, the government and civil society organisations have joined forces to provide environmental education, and the state government has incorporated the "No Packaging" performing arts group to promote environmental protection through cultural performances.

3.3. Social media and television programme

Educators and experts can post some short videos on social media such as Twitter, Youtube, increasing the influence in an entertaining, informative way. For instance, they can simply tell the public about the harmful effects of vehicle emissions on urban air quality and encourage them to switch to the public transport. In this way, an increasing number of people would place more importance on the carbon emissions, commuting to work by taking the subway, riding the electric vehicles or riding the shared bikes, which certainly be of much help in reducing the carbon footprint, mitigating or curbing global warming. Or, governments could produce national TV programs for professors to impart the knowledge of carbon neutrality to the public generation. They could also invite celebrities and use celebrities' popularity to attract the audience's attention. The public figures can successfully generate and amplify public awareness regarding the environmental problem, which results in wider moral concern from the audience and massive responses from both home and abroad. Especially for some fans of the celebrities, they tend to value celebrities very highly and thus can be easily influenced by celebrity power in charity. During the TV programme, celebrities can work with the educators to show some simple lifestyle habits. Their actions would encourage many fans to change their views and to do the same.

4. Conclusion

It can not be denied that energy transition and technological innovation are top priorities in the path to carbon neutrality for EU. But education still plays a significant role in the way to the achievement the goal and improve the sustainable development in the long term. Through education, a large number of professional talents enter into the circle of carbon neutrality. What's more, people of different ages, not only the students, but the working adults and the older generation realize the importance of environmental protection. With the concern of the whole society, it would be far easier to form a concerted effort to reduce carbon emissions, making a huge difference to the world. However, due to the many deep-level basic scientific problems involved in carbon peak and carbon neutrality, and the cross-integration of various influence mechanisms such as resources, energy and environment, there are problems such as insufficient personnel preparation and inadequate understanding of the problems in the implementation of carbon neutrality strategy in all industries, and it is urgent to strengthen education and training.

Schools should be models for achieving the goals to shape the future we want. Educational ideas should be changed from a focus on the individual to a focus on the group, and from a focus on learning itself to a focus on human ecology. Top-level education policy design which should be ensured by and the introduction of relevant laws and regulations is the first step. In the teaching of schools at different education stages, a complete teaching system, teaching plans and practices for climate change should be designed. Eventually, a good moral and social atmosphere should be encouraged in the whole society to strengthen the awareness of the whole society to achieve the goal of carbon neutrality and promote sustainable development. Only by strengthening school-oriented teaching and public-oriented practices in the field of education can we achieve a steady and orderly response to carbon neutral development.

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A Study on the Current Development of Carbon Neutrality and the Impact of the Epidemic on Carbon Emissions

Heng DU

Nanjing University of Science and Technology, Nanjing City, Jiangsu Province, China, 210094

E-mail: 928214093@qq.com

***Corresponding author**

Abstract

As global industrialization continues to grow and the exploitation of fossil fuels continues, climate warming is becoming more and more serious and poses more and more problems. Carbon neutrality has become an important strategy for global climate governance. Currently, some countries and regions around the world have adopted climate change-related legislation to provide legal safeguards for achieving the "two-carbon" goal. However, some countries have adopted a conservative attitude towards the carbon neutrality target. This paper summarizes decarbonization technologies and initiatives, such as switching from fossil fuels to renewable energy and developing low-carbon technologies, in the context of the relevant documents published to date. However, the impact of the sudden epidemic on global environmental pollution since 2019 requires us to rethink carbon neutrality in this context. COVID-19 has both positive and negative impacts on global pollution and carbon neutrality. Under the epidemic, carbon emissions have been reduced due to the closure policy, which is beneficial for air governance. At the same time, the heavy use of masks and the packaging waste generated caused soil deterioration. We need to pay special attention to the possibility of an acute rebound of carbon emissions after the epidemic. Countries need to develop relevant strategies to control pollution and achieve sustainable development of environmental governance to improve environmental quality and human health.

Keywords: Carbon neutral; national policies; governance strategy; COVID-19.

1. Addressing the social context of climate change

Carbon neutrality is defined as a state of net zero CO_2 emissions, which can be achieved by using new energy technologies, saving energy and reducing emissions. Transportation, energy production, agriculture, industry and even economic sectors are closely related to carbon neutral processes (Auffhammer 2018, Hu, Raghutla et al., 2021). This suggests that human activities directly or indirectly lead to greenhouse gas (GHG) emissions, and global warming is becoming increasingly serious (Change 2014).

In recent decades, the international community has begun to pay close attention to the issue of global warming, aiming to solve the fundamental problems in the current economic development model and trying to establish a low-carbon and environmentally friendly model. The world signed the Paris Climate Agreement in 2015, which states that countries will "hold global average temperature increases below 2°C above pre-industrial levels and work to limit temperature increases to 1.5°C above pre-industrial levels.", (Wang, Wang et al. 2017).

To combat climate change, the Chinese government has set a clear goal of reaching peak carbon by 2030, achieving carbon neutrality by 2060, and striving to gradually achieve net zero CO_2 emissions. To achieve this goal, each country should achieve a global peak in its greenhouse gas (GHG) emissions as soon as possible, which has the potential to achieve a carbon-neutral world by the middle of this century.(Zeng, Ma et al. 2022).

2. International policy background

Ensuring the stability and long-term nature of climate action is important because carbon neutrality is defined as a long-term goal. Therefore, it is critical to ensure that legislation is in place to support this process. For example, the U.S. withdrawal from the Paris Agreement in 2018 (Zhang, Chao et al. 2017) and the Brazilian government's abandonment of deforestation control policies have prevented the countries from achieving their emission reduction targets consistent with the global 2°C goal (Rochedo, Soares-Filho et al. 2018). Climate legislation can make international agreements more meaningful (Rochedo, Soares-Filho et al. 2018).

Over the decades, climate law has evolved and improved at a rapid pace. The World Climate Change Law Database shows that there are more than 1,800 laws and policies on climate change around the world (Farber and Peeters 2016). The Climate Change Act (CCA) was passed in 2008, making the UK the first country in the world to have a legally binding, long-term framework for reducing greenhouse gas emissions and adapting to climate change (Dong, Liu et al. 2022). The Act sets ambitious targets, strengthens the implementation of mandates, strengthens the institutional framework, and clarifies the specific, normative responsibilities of the UK House and the top legislature, creating a new approach to addressing and responding to climate change.

In addition, major European countries such as Germany, France and Sweden have also adopted legislation to limit greenhouse gas emissions(Duwe and Evans 2020). The German legal system for carbon neutrality is systematic, and since the beginning of the 21st century, the German government has introduced a series of national long-term emission reduction strategies, plans and action plans, such as the 2008 German Strategy for Climate Change Adaptation, the 2011 Adaptation Action Plan and the Climate Protection Plan 2050. On this basis, the German government has adopted a series of laws and regulations, such as the Federal Climate Legislation, the Renewable Energy Priority Act, the Renewable Energy Act and the National Hydrogen Energy Strategy, etc. Among them, the Climate Protection Act, which was adopted on November 15, 2019, sets Germany's medium- and long-term greenhouse gas emission reduction targets in legal form for the first time, including that the total greenhouse gas emissions should be reduced by at least 55% by 2030 compared to 1990. In addition, to further implement the concrete action plan, the German government adopted the Climate Action Plan 2030 on September 20, 2019, which plans to specify specific action measures for each industrial sector.

In August 2015, the French government adopted the Green Growth Energy Transition Act, which established a timeline for green growth and energy transition in France. In addition, the French government proposed the National Low Carbon Strategy in 2015, which led to the establishment of a carbon budget system. From 2018 to 2019, the French government revised the strategy, adjusting the 2050 greenhouse gas emissions reduction target to a carbon neutral target. On April 21, 2020, the French government finally adopted the National Low Carbon Strategy by decree. In recent years, some countries have taken a conservative approach when faced with carbon neutrality targets. For a long time, the United States has been uncertain and erratic in its carbon neutrality goals.

However, some countries are taking a conservative approach when faced with carbon neutrality targets. For a long time, the U.S. has been uncertainty and erratic in its carbon neutrality goals. However, the new U.S. administration is recently changing its attitude and approach. After successively withdrawing from the Kyoto Protocol and the Paris Agreement, it is rejoining the Paris Agreement in 2021, joining the ranks of carbon emission reduction and actively participating in the implementation of the Paris Agreement, committing to achieve carbon neutrality by 2050. At the state level, six states have now passed legislation setting a goal of achieving 100% renewable energy by 2045 or 2050. The Australian government has not been very enthusiastic about climate reduction and its climate policy is wavering. The Australian government rejected the Kyoto Protocol when it was signed, and did not sign it until 2007.

There is uncertainty about Japan's actions and attitudes toward carbon neutrality, with a commitment to achieve carbon neutrality by 2050, a more comprehensive technology deployment for long-term emission reductions in carbon neutrality-related documents, and an emphasis on technological innovation. International Energy Agency data show that Japan was the sixth largest contributor to global greenhouse gas emissions in 2017 and has made efforts in energy efficiency technologies since the Fukushima disaster in 2011, but remains dependent on fossil energy. In response to climate change, the Japanese government announced its "Green Growth Strategy" on October 25, 2020, confirming the goal of achieving net zero emissions by 2050, which aims to accelerate the transition to a low-carbon society through technological innovation and green investment (Eskander, Fankhauser et al. 2020).

3. Strategies related to carbon neutrality

Accelerated global industrialization and overexploitation of non-renewable energy sources have resulted in the release of large amounts of greenhouse gases and rising global temperatures (Wang, Harindintwali et al., 2021). These developments have had serious impacts on the human living environment, including loss of biodiversity, species extinction, forest fires, glacier melting, and sea level rise (Mora, Spirandelli et al., 2018; Yang, Chen et al., 2022). Achieving net zero emissions requires not only reducing CO_2 emissions, but also reducing the amount of CO_2 in the atmosphere through various technological measures. By net zero emissions, we mean balancing the total amount of carbon dioxide or greenhouse gas emissions produced directly or indirectly by a country, company, or individual over a certain period of time through carbon offsetting or removal initiatives.

3.1. Reduce the use of fossil energy

Currently, different countries, regions and cities have developed strategies to improve carbon removal or sequestration and achieve carbon neutrality (Hepburn, Qi et al. 2021, Huang and Zhai 2021). Under the general trend of development with carbon neutrality as the goal, developed countries and countries with large carbon emissions have to take the lead. It is not only necessary to have reasonable policies, but also to implement them into action. Countries around the world need to reduce the use of fossil fuels and provide clean energy technology support to developing countries (Laybourn-Langton and Smith 2022). Mitigation strategies that implement distributed solar power in buildings rather than fossil fuel energy lead to low carbon emissions in the energy sector. The use of distributed solar energy has synergistic effects with adaptation, as solar energy leads to a more resilient power supply system than the terrestrial grid, which is vulnerable to temperature changes due to storms and climate change (Ripple, Moomaw et al. 2022).

3.2. Reduction of airborne pollutants

The World Health Organization has released a report calling on countries to take immediate steps to reduce emissions of short-term climate pollutants in order to reduce the health risks caused by such pollutants. The so-called short-term climate pollutants are black carbon (soot), methane, ozone and HFCs, of which black carbon is the main component of fine particulate matter (PM2.5). Among the pollutants, black carbon has the shortest residence time of a few days, while methane can reach 12 to 15 years.

It is well documented that these pollutants have a serious impact on the atmosphere and that climate has an impact on public health, food, water and economic security. In an effort to raise awareness of the dangers posed by short-term climate pollutants, WHO has released a report entitled "Reducing Global Health Risks by Reducing Short-Term Climate Pollutants". The report points out that short-term climate pollutants are not only contributing to global warming, but are also largely responsible for the premature deaths of more than 7 million people each year due to air pollution.

Therefore, controlling these short-term emissions can effectively mitigate global warming. For example, reducing black carbon emissions will improve the health of several people and save lives, especially in low-income areas that rely on biomass burning. Thus, reducing methane and black carbon pollution reduces the harm to humans and allows for better adaptation to climate change pressures (Swart and Raes 2015).

3.3. Emphasis on forestry ecological construction projects

Maintaining natural ecosystems has climate mitigation potential and, at the same time, is the first line of defense against natural hazards. We need to implement favorable forest management policies. This entails allowing existing forests to continue to grow and reach their ecological potential (Moomaw, Masino et al. 2019).

Strengthen the development and implementation of laws and regulations. Accelerate the development, revision and cleaning of forestry laws and regulations. Develop special laws and regulations such as regulations on natural forest protection, regulations on the transfer of forest trees and forest land use rights; increase law enforcement efforts, improve the law enforcement system, strengthen law enforcement inspections, expand social supervision, and establish a dynamic monitoring mechanism for law enforcement. Reform and improve the existing industrial policy. Continue to improve the target management responsibility system for afforestation and greening at all levels of government and the departmental greening responsibility system, further explore various forms of compulsory tree planting for all people under market economy conditions, and formulate relevant policies to promote the further development of compulsory tree planting and departmental greening work (Frey, Hadley et al. 2016). Through the adjustment of relevant industrial policies, promote the further development of afforestation work and increase forest resources and forestry carbon sinks. Grasp the key ecological construction projects in forestry. Continue to promote the protection of natural forest resources, the return of farmland to forest (grass), protection forest system, wildlife protection and nature reserve construction and other key ecological construction projects in forestry, grasp the construction of biomass energy forest base, through the effective implementation of the above key projects to further protect the existing forest carbon storage, increase terrestrial carbon storage and sinks (Buotte, Law et al. 2020).

3.4. Economic measures

In addition to developing measures for low carbon related aspects, economic activities need to be modified. These measures can be supported by economic cycles. In a circular economy, investments in non-renewable energy sectors such as fossil energy and forest bioenergy are curbed. Increase investments in alternative industries, solutions (Seddon, Chausson et al. 2020). This will contribute to climate change adaptation and mitigation.

The financial and investment sectors play an important role in achieving the goal of carbon neutrality (Norris and Joshi 2005). Governments need to adapt by imposing carbon taxes, removing tax incentives for climate-destroying industries, incentivizing climate-friendly industries, and ideally requiring climate mitigation measures to include an adaptation component.

4. Carbon neutrality under epidemic conditions

Since January 2020, the fight against Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV-2) has become a top priority for countries around the world. COVID-19 has had an impact on environmental pollution and carbon emissions in countries around the world. These impacts include both positive and negative effects. Positive impacts such as the reduction in air pollution witnessed in many countries. During the pandemic, greenhouse gases that contribute to global warming were reduced (Rupani, Nilashi et al. 2020). At the same time, water pollution was temporarily mitigated and was generally lower than in the pre-COVID-19 period(Yunus, Masago et al. 2020). It is noteworthy that carbon emissions were significantly reduced during the period of the Corona Virus Disease 2019 (Praveena and Aris 2021).

In addition to the positive effects, COVID-19 has also caused a number of negative effects. For example, some urban areas have suspended their recycling programs. Sustainable waste management has been limited and soil contamination has become more severe (Patlolla, Smith et al. 2022).

Carbon emissions and other greenhouse gas emissions are changing around the world as a result of the embargo caused by COVID-19 (Patlolla, Smith et al. 2022). Overall, the International Energy Agency's World Energy Report 2020 notes a 3.8% decline in global energy demand, resulting in a 5% decline in global carbon emissions in the first quarter of 2020 compared to 2019. Surveys have shown that non-essential travel is prohibited during the COVID-19 embargo. As a result, fewer trips are made by cargo and passenger ships and carbon emissions are reduced (Duran-Grados, Amado-Sanchez et al. 2020). Similarly, with the closure control policy in place for the necessary period, there are fewer vehicles on the road and carbon dioxide emissions drop significantly (Zhang, Li et al. 2021). A survey conducted in Xi'an, China, showed a 7.5% reduction in CO_2 concentration during the period of full containment compared to the previous period (Wu, Zhou et al. 2021). In addition to this, a study made by Bournemouth University in the UK shows that campus carbon emissions are significantly reduced in 2020. This is due to campus lockdowns and online courses, resulting in a reduction in commuting and campus energy use (Filimonau, Archer et al. 2021).

In summary, carbon emissions have been reduced in different cities around the world. The policies implemented by the government to prevent the spread of novel coronavirus pneumonia have had a huge impact on global energy demand.

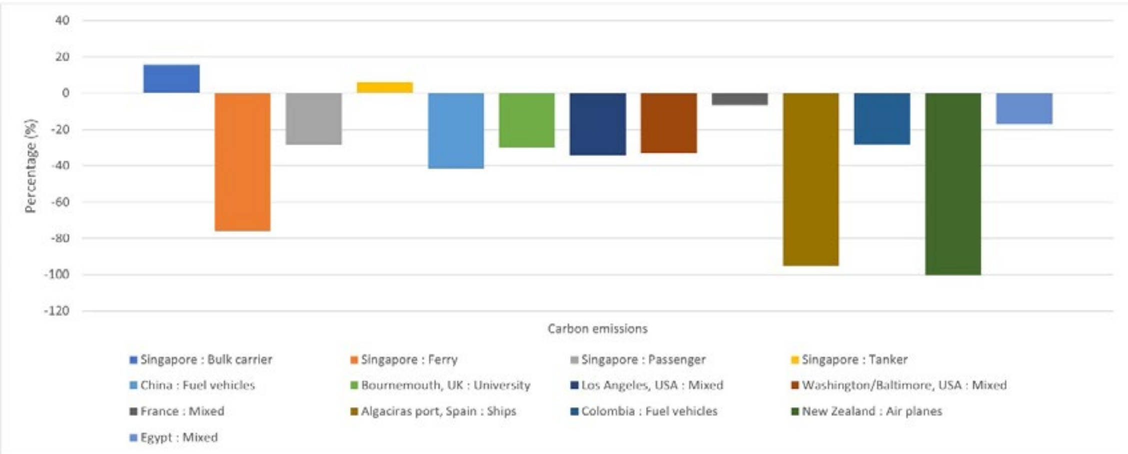

Fig.1 Percentage change of global carbon emissions (Yang, Chen et al. 2022)

We must recognize that the reduction in carbon emissions due to the epidemic is not sustainable. The relevant data show that in December 2020, CO_2 emissions not only picked up, but actually rose by 2% compared to the same month in 2019. The epidemic does act as a buffer for carbon emissions, but it is absolutely impossible to rely on it to achieve "net zero" carbon emissions. What has to be considered is the retaliatory increase in carbon emissions after COVID-19. It is necessary to think ahead of time to deal with this challenge.

First, further improve the energy efficiency. Strengthen the research and development and promotion of energy-saving technologies to improve the efficiency of energy use. Reduce the use of fossil energy and make greater use of renewable energy sources such as solar and wind power. Strengthen the research and development and promotion of low-carbon technologies (Anh Tuan, Nizetic et al. 2021). Second, encourage governments to open up trade, as adherence to free trade will help the world achieve its emissions reduction targets. Regulations include imposing minimum energy efficiency standards for residential buildings, imposing zero carbon emission targets for new construction, limiting access to clean air zones for highly polluting vehicles, and banning the sale of new diesel and gasoline vehicles (Wang and Wang 2020, Wang, Wang et al. 2021). It is worth noting that the strict control of travel during the epidemic has reduced carbon emissions. This indicates that adopting an optimal travel structure can also reduce carbon emissions. For example, the use of high-speed rail instead of air travel. Therefore, controlling the traffic flow after the epidemic is also an effective approach (Hudda, Simon et al. 2020).

5. Conclusion

Global industrialization is accelerating and the burning of fossil fuels is leading to significant greenhouse gas emissions. Global temperatures are rising. Environmental issues and human health are under serious threat. Extensive research has been conducted to mitigate the effects of climate change caused by anthropogenic greenhouse gas emissions. The issue of carbon emissions needs to be addressed in the technical, economic, environmental, and policy fields.

With the trend of carbon neutrality as a target, it is extremely important to develop relevant policies. First, from the perspective of climate governance system design, the Paris Agreement under the United Nations Framework Convention on Climate Change has formed a basic system and corresponding general rules. This introduced policy requires consumers, businesses and governments around the world to work collectively to achieve carbon neutrality by the middle of the 21st century. In addition, different countries have also published corresponding laws and regulations according to their actual situation. For example, in 2008, the UK passed the Climate Change Act. The Act makes the UK the first country in the world to have a legally binding long-term framework for reducing greenhouse gas emissions and adapting to climate change. In addition, the German Bundestag passed the Climate Protection Act and the Renewable Energy Act to strengthen climate protection and develop renewable energy. However, some countries have taken a conservative approach when faced with the goal of carbon neutrality. Addressing climate change is not the obligation of a single country, but a shared responsibility of the international community. In the face of the "double carbon" target of the century, countries should take the "community of human destiny" as a guideline. They should firmly establish the new development concept, enhance their awareness of climate change, improve their ability to grasp green and low-carbon development, and make every effort to promote the work of carbon peaking and carbon neutrality, so as to make greater contributions to promoting high-quality development and building a modernization in which people and nature coexist harmoniously.

Global carbon emissions decrease due to the impact of the novel coronavirus pneumonia. Global carbon emissions from the fossil fuel industry could fall by a record 2.5 billion tons in 2020, down more than 5 percent year-on-year, according to Robe Jackson, a professor of earth system science at Stanford University, The Guardian reports. In order to contain the new coronavirus, several countries have imposed embargo policies, and large-scale industrial production and residential life are at a standstill. Carbon emissions from fossil fuels show a significant decline. National urban blockades isolate and reduce carbon emissions, giving the planet a chance to catch its breath. But we cannot see the dramatic drop in carbon emissions as a victory for climate change. This decline is due to the economic collapse, not to the right decisions made by governments in terms of climate policy. Fatih Birol, executive director of the International Energy Agency (IEA), warned that global carbon emissions could disappear in an economic rebound once the novel coronavirus pneumonia is under control. Countries around the world should prepare and plan for this early on. Future efforts could focus on the impact of changes in human lifestyles on environmental pollution and carbon emissions once the epidemic is successfully contained. Prolonging the positive impacts of COVID-19 and minimizing its negative impacts will lead to future sustainability.

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A Brief Analysis and Suggestion Report Based on the Development of CCUS in EU

Yuhao GAO

China University of Petroleum, Qingdao City, Shandong Province, China, 266580
E-mail: gaoyuhao823@163.com
***Corresponding author**

Abstract

As a carbon neutralization method with large-scale carbon dioxide emission reduction, CCUS technology has attracted close attention from the EU. The European Green Agreement sets the goal of reducing greenhouse gas emissions by 50-55 per cent below 1990 levels by 2030 and achieving climate neutrality by 2050. The EU now incorporates CCUS into the technology required for the transition to climate neutrality, and gradually takes a low-carbon development path in many fields such as energy, industry, construction, transportation, agriculture, ecology and environment. This paper investigates and sorts out the strategic planning of CCUS technology development in the EU, and puts forward suggestions on the priority of CCUS project infrastructure and the distribution of multi-industry clusters in combination with the development trend of related technologies in Europe.

Keywords: CCUS; carbon neutralization; suggestions on countermeasures.

1. Introduction to CCUS/CCS

CCUS (Carbon Capture, Utilization and Storage) is the new development trend of CCS (Carbon Capture and Storage) technology, which is to purify the carbon dioxide emitted in the production process and then put it into the new production process, which can be recycled. For example, the use of chemical or physical methods (Porous carbon-based material adsorption, membrane technology capture, low temperature distillation and microalgae separation, chemical cycle combustion method, amine solution absorption method, etc.) to adsorb and capture carbon dioxide (Gunawardene, Gunathilake, Vikrant, & Amaraweera, 2022) followed by projects such as geological storage (Czernichowski-Lauriol et al., 2018). Compared with CCS, carbon dioxide can be used as a resource, which can produce economic benefits and is more practical. For example, the miscible mechanism of carbon dioxide can be used to reduce the surface tension of oil and formation rocks, thereby improving the flow environment of reservoirs underground. It is also through the use of carbon dioxide that Europe has also carried out the CO_2-EOR project for many years (Holz et al., 2021), which is a rapid development in the application of CCUS technology.

However, the key to achieving these goals lies in the construction of three CCUS chains: carbon capture, storage and utilization chains. In these systems, carbon dioxide is captured from large point sources and is usually transported by pipeline, first to storage, second to utilization, and finally to storage and/or utilization. (Hasan, First, Boukouvala, & Floudas, 2015) Each element in the supply chain must be connected to other elements in an optimal way. It is a combinatorial problem to correctly connect carbon sources through efficient capture technology. The available solutions increase with the number of locations (Leonzio, Foscolo, & Zondervan, 2019). It is important to choose a solution with the lowest total cost and / or carbon dioxide emissions.

2. Partial progress of the European CCUS projects

In June 2021, the European Commission adopted the 'Horizon Europe' major work plan for 2021-2022. Topics to be funded in the CCUS area include: integration of CCUS as an industrial hub or cluster; reducing carbon capture cost through new or improved technologies; industrial decarbonization through CCUS; direct air carbon capture and conversion. In October of the same year, the EU launched the PyroCO_2 innovation project, which aims to build and operate a facility capable of capturing 10,000 tons of industrial CO_2 per year and using it to produce chemicals. (Anning et al., 2022) The United Kingdom, Denmark and other countries have introduced enhanced oil recovery (EOR) technology and CCUS technology in the North Sea area for traditional oil and gas exploitation. There are two benefits: (1) hydrocarbon expulsion through carbon dioxide, enhanced oil recovery through miscible flooding; (2) Treatment of excess carbon dioxide and other greenhouse gases. (Suicmez, 2019). Germany plans to use CCUS technology to convert CO_2 into various energy carriers, chemicals and inorganic carbonates. And plan its CCUS industry chain (Schmid & Hahn, 2021). In addition, the European "Strategic CCUS" project uses the method of the US Department of Energy to find that the carbon dioxide storage capacity of the geological layer of the Greek trough is large, and it is planned to carry out a geological carbon dioxide geological storage project, which provides potential for implementing a promising method to reduce carbon dioxide emissions in Greece. Norway, Switzerland, France and other EU member states actively participate in the network construction of CCUS projects. Through knowledge sharing and mutual learning, member projects are promoting the delivery and deployment of carbon emission control systems, so that European member states can reduce emissions from industrial, power, transportation and heating sectors. (Koukouzas et al., 2021) .

3. Noteworthy aspects of European CCUS development

3.1. Priority to develop CCUS technology in specific industries

At present, CCUS projects are mostly demonstration projects. The common ones are carbon dioxide geological storage, carbon dioxide enhanced oil recovery, thermal power carbon dioxide capture, carbon dioxide water gas or synthetic methanol and so on. Europe is currently calling for energy conservation, the development of CCUS technology, plans to phase out thermal power, the development of new energy and so on. However, the cost of new technology and new energy is generally higher than the price of traditional energy, and the energy density is smaller than that of traditional energy such as oil, natural gas and thermal power generation. People tend to be more willing to consume traditional energy. Europe is currently a large energy demand, such as thermal power and can not completely give up, but this way of producing electricity and a large amount of carbon emissions, so the development of CCUS direction still have to pay attention to the main and secondary, according to the actual needs of the design CCUS development direction, more conducive to commercialization.

3.2. The development level and speed of CCUS in EU member states are not synchronized

Although the EU promulgated the CCUS technology development roadmap and strategic planning, but in the short term to achieve the goal still needs time, but also to strengthen the national level of technical guidance and macro-control. The R & D strength is relatively scattered, which may lack sufficient information and resource sharing to a certain extent, making it difficult for CCUS to form a complete and stable industrial chain. As mentioned above CCUS projects need to give priority to the construction of infrastructure in order to strengthen the integration of CCUS network projects. For example, carbon dioxide capture and transportation links, or involved in carbon dioxide geological storage projects are required pipeline transportation, the EU countries in the CCUS co-sharing, co-ordination, in order to ensure the steady progress of the project.

3.3. Long construction period and high cost problems

The cost of CCUS is affected by technology and project size. For example, in carbon capture, chemical and physical methods sometimes consume a large amount of chemicals or materials depending on the capture mechanism, and the capture integration is also closely related to the concentration of the emission source. The distribution of carbon sources and the construction of their capture infrastructure cost more, such as the construction of CCUS project network, and the completion of the commercialization of the project may take a long time.

4. Suggestions for the development of CCUS

4.1. Strengthen cluster planning and establish CCUS development path for carbon neutrality

Clarify the strategic positioning of CCUS technology and incorporate it into the European carbon neutrality action plan. Clarify the development focus and key links of CCUS technology, and systematically arrange a number of CCUS projects with industrial chains. For example, traditional carbon emission industries such as thermal power generation, steelmaking, and cement manufacturing (Perez-Fortes, Moya, Vatopoulos, & Tzimas, 2014) are interconnected with a series of carbon sequestration and carbon utilization industries. Specifically, by connecting carbon dioxide production sources to geological storage sites through pipelines, or by merging with carbon dioxide enhanced oil well networks to improve the comprehensive application of CCUS technology, such as exploring recycling paths for the hydrogenation of carbon dioxide to fuels such as methane and methanol, industrial clusters, and the development of CCUS development roadmaps and medium- and long-term development plans.

4.2. Strengthen the CCUS investment and financing policy to solve the high cost problem of the project

Improve the green financial system, promote the innovation of green financial products, and effectively guide the investment of social capital in CCUS through green bonds, green assets and other products and combinations; incorporating CCUS into the carbon trading market, formulating a CCUS emission reduction pricing mechanism, and promoting a virtuous cycle of increasing investment and financing and continuous cost reduction; for investors of low-cost, low-energy technologies and negative emission technologies coupled with new energy, increase financial support and form a clear incentive environment.

4.3. Accelerate CCUS industry innovation and establish an intelligent monitoring mechanism

Building a bridge between laboratory research and large-scale industrial demonstration; integrate the upstream and downstream industrial chains, promote the joint research of related enterprises on key common technologies and the construction of large-scale CCUS technology demonstration projects, establish a large-scale carbon dioxide emission source database and monitoring system, intelligent control system, and quantify CCUS technology application information.

4.4. Carry out industrial co-construction and sharing mechanism, strengthen infrastructure construction, and break through the technical difficulties related to large-scale CCUS projects

Holz et al. (2021) argued that the deployment of CCUS (CCS) in Europe depends on two factors: 1) the development of low-cost carbon capture power generation technologies (coal and / or gas), and 2) a sufficiently high CO_2 price to compensate for the cost of deploying CO_2 transport infrastructure. Once the carbon dioxide transport infrastructure is built, CCUS (CCS) will become the preferred choice for carbon reduction in the industrial sector.

Carry out CCUS co-construction and sharing mechanism to promote cooperation in the field and facilitate the coupling and integration of technology and industry; increase the scale of infrastructure investment and construction such as carbon dioxide transportation and storage, optimize and integrate resources, improve and upgrade equipment, and gradually improve infrastructure; co-build carbon dioxide collection, transportation network, hubs and other facilities to reduce costs and enhance economies of scale.

4.5. The necessity of strengthening the publicity of CCUS to the public

A cross-country study from France and Spain on public perception of CCUS technology, (Oltra et al., 2022) argued that with the development of CCUS projects in Europe, public participation at the national and regional levels may play a crucial role in the success of CCUS projects. Once the public is aware of the benefits of CCUS and related technologies, they will support rapid deployment and implementation. Decision makers and supporters of CCUS need to invest resources to inform the public about the benefits of the technology and build trust and a sense of participation in such projects.

5. Summary

CCUS is the most important emission reduction measure to achieve carbon neutrality and is irreplaceable for high-quality economic and social development. For example, the combination of CCUS and power system helps to improve the resilience and reliability of the power grid, and also helps to create and provide new jobs in the project. It can also promote economic growth through technological innovation and realize infrastructure reuse.

This paper describes the technical development status of CCUS capture, transportation and utilization, and storage, and expounds the current development of CCUS in Europe. On this basis, the author analyzes that carbon dioxide capture technology alone is difficult to achieve the goal of carbon neutral fossil energy activities. Therefore, it is proposed to accelerate the construction of CCUS project capital cluster layout and industry coupling development, form an emerging carbon economy with commercial value, and promote the development of the project. Based on natural conditions, industrial cluster distribution and infrastructure configuration, the necessity of pipeline network construction in carbon dioxide utilization and storage projects is analyzed. In order to deepen and strengthen the promotion and development of CCUS projects, suggestions are made from six aspects: industrial cluster layout, policy incentives, technological innovation, infrastructure construction and public awareness.

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Current Status of Research on Carbon Emissions and Combined Benefits in Wastewater Treatment

Lailai HUANG

Suzhou University of Science and Technology, Suzhou City, Jiangsu Province, China, 215009

E-mail: 1443112138@qq.com

***Corresponding author**

Abstract

According to the United Nations, the global carbon footprint of the water treatment industry, including wastewater treatment, accounts for approximately 2% of global carbon emissions. As a result, it is becoming increasingly critical to reduce carbon emissions from the wastewater treatment sector. Wastewater treatment plants (WWTPs) currently exist in two forms: above-ground and underground. With the development of urbanization, increased population density, and land constraints, the trend is gradually shifting towards underground WWTPs. But there are many challenges. The investment costs during the construction phase, building materials, and energy requirements are much higher for underground sewage treatment plants compared to above-ground ones. Additionally, during the operation phase, energy consumption is higher and there are high risk factors to consider. The aforementioned elements will undeniably affect the complete life span of carbon emissions from sewage treatment facilities. Additionally, the advantages, both environmentally and economically, of subterranean WWTPs do not necessarily surpass those of above-ground WWTPs. At present, the lack of a systematic approach towards accounting and assessing the carbon footprint of underground WWTPs is a significant issue. This not only prevents an accurate understanding of the environmental impact of such facilities but also hinders efforts to reduce their carbon emissions. Moreover, the absence of a comprehensive review of the benefits of these facilities further compounds this problem. Therefore, a thorough analysis of the carbon, environmental, and economic aspects of underground WWTPs is necessary to reveal the true relationship between their comprehensive benefits, carbon emissions, and energy consumption.

Keywords: Wastewater treatment plant; carbon footprint; underground; combined benefits.

1. Introduction

High temperatures are a direct result of the global climate crisis. As global temperatures continue to rise, extreme weather events like heat waves and dramatic changes in precipitation patterns are becoming more frequent. These events can lead to natural disasters such as sea level rise, droughts, and forest fires, with serious socio-economic and developmental consequences. It is estimated that the global economy could incur a cost of US$178 trillion per year as a result of these impacts (Spotlight Resources). Global warming, a phenomenon that is currently affecting our planet, is primarily caused by the massive amount of greenhouse gases. According to the WMO report, concentrations of CO_2 and temperature have been continuously increasing since 1850. In 2020, atmospheric CO_2 concentrations of 414.24 ppm were recorded at several stations around the world, which represents a 30% increase from the pre-industrial level of 280 ppm. In the same period, the global average temperature has risen by approximately 1°C (IPCC, 2022; UNFCCC, 2018). The reality of global climate change is indisputable and has become a shared crisis for the survival and progress of humanity.

In various regions around the world, wastewater treatment plants in northern Italy emit between 0.04 to 0.20 t CO_2-eq/PE per year (Mojtaba, 2022). Laura et al. (2018) estimated the carbon emissions from artificial wetlands treating winery wastewater in Spain to be 1.2 kg CO_2-eq per m^3. Gu estimated that the carbon emissions from power consumption of nine different WWTPs in southern China to be 0.23 kg CO_2 per m^3. It is worth noting that the carbon emissions from water treatment industries, including wastewater treatment, make up roughly 2% of the world's total carbon emissions, according to UN statistics cited by Chunli in 2021(Chunli, 2021). This emphasizes the importance of taking a holistic approach to reducing carbon emissions, not only in the water treatment industry but also in other sectors that contribute to climate change. There are two main types of greenhouse gas emissions associated with wastewater treatment: direct and indirect. As noted by the Intergovernmental Panel on Climate Change (IPCC) in 2006, the two most significant direct GHG emissions from these processes are CH_4 and N_2O. These gases are produced as byproducts of various biological and chemical reactions that occur during wastewater treatment, the amount of CO_2 generated from the degradation of organic matter or endogenous metabolism of sewage sludge is not included in this category. These organic emissions are considered to be biological sources that do not contribute to the increase in the relative concentration of CO_2 in the atmosphere and are therefore not counted as carbon emissions (IPCC, 2006). However, certain daily products such as toiletries, cosmetics, and medicines are now synthesized from carbon sources extracted from mineral deposits such as oil and coal by humans. During the treatment process, these products enter wastewater and emit CO_2, known as fossil carbon (FC), which can significantly contribute to the atmospheric carbon cycle and cause warming (Law et al., 2013). According to the research findings, the proportion of fossil carbon in raw sewage ranged from 2.1% to 27.9%, in secondary effluent from 7.4% to 48.5%, in biogas from 0.6% to 2.7%, and in digested sludge from 10.2% to 15.5% (Tseng et al., 2016; Nara et al., 2010; Gwen et al., 2010; Griffith et al., 2009). N_2O emissions mainly occur during the biological denitrification process of wastewater treatment, whereas CH_4 emissions occur in significant quantities during effluent transfer and anaerobic treatment processes (Guisasola et al., 2008). The atmospheric greenhouse effect contribution per unit weight of N_2O and CH_4 emissions is 298 and 25 times greater than the Global Warming Potential (GWP) over 100 years, respectively. These two gases have a significant impact on global warming, with Massara et al. (2018) reporting that N_2O emissions alone can affect carbon emissions from wastewater treatment plants by 60-75%. As such, even minor emissions require a comprehensive evaluation. Indirect emissions resulting from the use of energy, chemicals, and other resources are also a significant concern. For example, in China, WWTPs consume about 4-6% of the country's total energy consumption, while in the United States, it accounts for approximately 3-4% (National Renewable Energy Lab, 2012; Simon-Várhelyi et al., 2020). These findings emphasize the need for more sustainable and efficient approaches to wastewater treatment that minimize the environmental impact and reduce the overall energy consumption of these critical facilities.

With economic growth, urbanization, and increased population density, human demand for water resources has escalated. This has resulted in an increase in the volume of urban wastewater as well. Consequently, urban wastewater treatment plants play a critical role in reducing pollutant emissions, recycling resources, and enhancing the ecological environment. However, high-density urban areas have limited land availability, making traditional above-ground wastewater treatment plants expensive. These facilities are typically surrounded by commercial and residential areas, causing negative impacts on the environment, such as noise and unpleasant odors (Wang et al., 2018). In contrast, underground wastewater treatment plants have a small footprint, generate minimal secondary pollution, and do not affect the surrounding environment. Compared to above-ground sewage treatment plants, underground sewage plants require additional requirements for excavation of pits and construction of large underground frame structures during the construction phase, requiring far more building materials and energy consumption than above-ground sewage treatment plants, and are more difficult; during the operation phase, lighting systems, deodorisation systems, and sludge off-loading all have increased energy consumption (Yang, 2021; Wang et al., 2018; Wang et al., 2018;Hou, 2017;), and Hao et al. (2021) found that the full life-cycle cost of a domestic fully underground WWTP is approximately 1.31 times that of an above-ground WWTP, while Wang (2019) reported that the combined environmental impact index of underground WWTPs is 3.0% higher than that of above-ground ones. However, there is currently no systematic accounting or assessment of the carbon emissions of underground WWTPs, and there is also a lack of systematic reviews of comprehensive benefit analysis studies. To accurately understand the relationship between the comprehensive benefits of underground WWTPs and carbon emissions and energy consumption, a comprehensive evaluation and analysis of the carbon emissions, environmental effects, and economic considerations associated with underground WWTPs is imperative.

2. Research related to carbon emissions and energy consumption in wastewater treatment

Experts and scholars from around the world have conducted extensive research on carbon emissions and energy consumption in the field of wastewater treatment. With 136 countries worldwide having set targets for carbon neutrality, including China's aim to reach carbon neutrality by 2060, the wastewater treatment sector has also made significant progress in adopting technologies that reduce carbon emissions, such as renewable energy sources, and conducting energy efficiency studies on wastewater treatment plant equipment to reduce energy consumption.

Mojtaba and Antonio found that electricity consumption of energy grids powering plants had a significant impact on CFP, with Danish WWTPs having higher CFP due to their higher electricity consumption (16-28%) than Swedish WWTPs (2%). This is because Sweden has a smaller CFP potential in their electricity mix (Mojtaba et al., 2020; Antonio et al., 2019), highlighting the need for renewable energy sources. Laura et al. (2018) and Garfi et al.(2017) compared the carbon footprint of an artificial wetland scenario, a high proportion of algal ponds and an activated sludge system by accounting for the higher GHG emissions from chemical products and power consumption in the activated sludge scenario.

Zhang et al. (2017) determined the carbon emissions of different biological treatment processes at Xi'an No. 4 Wastewater Treatment Plant, which had 45.9% direct emissions and 53.8% indirect emissions, with energy consumption being the focus of emission reduction; Several researchers have studied the carbon emissions of various combinations of wastewater and sludge treatment technologies using an emission factor approach. They concluded that anaerobic co-digestion of kitchen waste and sludge can be carbon neutral with carbon emissions of -9223 kg CO_2-eq/d, and that the most effective way to recover energy and reduce carbon emissions is to use chemically enhanced primary treatment and anaerobic digestion of sludge, which can reduce greenhouse gases by 70% (Wu,et al.,2022;Zhuang,et al.,2020). However, it has been shown that the current options for using anaerobic digestion to minimize sludge and generate energy are challenging to evaluate when considering wastewater treatment on a system-wide scale. Direct incineration of sludge has been found to have lower energy deficits and input-output costs compared to conventional anaerobic digestion, which typically requires pretreatment through thermal hydrolysis (Xiaodi et al., 2020). The study on the Kakolanmäki WWTP in Finland discovered that the plant achieved carbon neutrality primarily through the recovery of heat and its contribution to the carbon sink from the TSE heat pump station, rather than from the energy recovery of the wastewater treatment process (Xiaodi et al., 2021). In comparison to above-ground facilities, underground wastewater treatment plants consume more energy than they should. However, China's wastewater treatment plants built to high standards are now equipped with hardware that is no less advanced than those found in foreign countries. Ban et al. (2022) designed and developed a horizontal piston flow ductless ventilation technology. It requires less engineering, has low noise, small investment, small installed power, low operational energy consumption, and convenient construction. Hou (2017) introduced a next-generation FBBR process suitable for underground wastewater treatment plants. The process omits the secondary sedimentation tank from the biochemical treatment unit, has a higher treatment load compared to the AAO process, and proposed an innovative lighting system combining natural and indirect lighting, which was shown to reduce power consumption by 41.7% in engineering practice.

From the above studies, it is evident that the primary emphasis of present research is on carbon emissions in conventional wastewater treatment. There is a greater emphasis on analyzing the impact of different emission factors, carbon reduction technologies, energy consumption, and energy recovery on achieving carbon neutrality.

3. Research related to urban underground sewage treatment

Developed countries such as Finland, Japan, Sweden, and Norway have been able to construct underground WWTP is notable for its ongoing efforts to enhance the energy efficiency of its underground WWTP. By doing so, it has successfully improved the local water environment, conserved land resources, and reduced the number of WWTPs needed. The Gèolide WWTP, located in the center of Marseille, France, treats sewage from the city and 16 surrounding areas annually, providing significant ecological benefits to the region. (WATER NEWS EUROPE, 2016). Daseung et al. (2019) quantified the GHE of subsurface WWTPs except for the demolition phase, using the life cycle assessment (LCA) method and the emission factor method. And the main contributors were the energy consumption of the bioreactor and aeration and ventilation, which were 81.0%.

Initially, research on wastewater treatment plants focused mainly on their engineering construction and design characteristics. This involved summarizing practical experience and exploring development trends. However, with the construction of practical projects and advancements in technology, scholars began to increasingly emphasize research on the adaptability, safety, economy, and ecology of underground wastewater treatment plants. Hou Feng and Niu Xin have addressed several problems related to the construction of underground sewage plants, such as high investment costs, imperfect standards and norms, and limited above-ground usage. They propose to optimize the treatment process and reduce the CFP of underground WWTPs. By integrating the functions of urban forest parks, sports and fitness, leisure and entertainment, science education, and technology research and development, an ecological complex can be created, enabling above-ground and underground material circulation, energy use, and information transfer. Wang et al. (2018) and Hou (2017) used the double-difference distribution method to study the impact of above-ground sewage treatment plants on land values in Beijing. They found that conventional above-ground sewage treatment plants suppressed the rise in residential prices nearby, resulting in significant economic losses. The closer the residences were to the sewage plant, the stronger the environmental disincentive. However, the underground sewage treatment plant drove up the value of the surrounding land by 12.235 billion yuan, 11.4 times its total investment. Based on an underground wastewater treatment plant in Shaanxi, Wang Rui compared various sludge treatment technologies from a techno-economic standpoint and concluded that the bioleaching dry sludge treatment technology is more suitable for local underground subsurface WWTPs (Wang et al., 2018). Zheng et al. (2019) conducted an economic analysis of the construction phase of an underground sewage treatment plant in Yueyang City, Hunan Province. The project cost indicator was 5,862.15 RMB/m^3, and the total investment indicator was 7,008.89 RMB/m^3. Although the indicator was about 2,000 RMB/m^3 higher than that of a conventional above-ground sewage treatment plant, it saved a significant amount of land resources, preserving 0.00246 hectares of engineering area and resulting in substantial land benefits.

Although there have been individual studies on the effects of underground sewage treatment plant operation on the surrounding population, landscape design within the plant, and carbon emissions, comprehensive research on the overall impact of these plants is lacking. With the rising global ecological problems and land resource scarcity, there has been a recent emergence of studies exploring the environmental and economic aspects of underground WWTPs.

4. Environmentally and economically relevant research in the field of wastewater treatment

Buonocore et al. (2018) conducted a study on the environmental impact of five improvement options using the LCA method. They relied on a wastewater treatment plant located in southern Italy. The study revealed that reusing effluent water for plant production or adopting residual sludge incineration for electricity generation significantly reduced eutrophication potential and human toxicity potential. Sadegh et al. (2019) assessed the environmental and economic aspects of various treatment strategies for two wastewater treatment plants in the city of Mashhad using energy value and LCA methods. The LCA option was found to reduce energy consumption by 10%, thereby achieving sustainability. The results of the energy value analysis indicate that constructing two wastewater treatment plants is the most sustainable option, but this difference is attributed to the fact that the energy value analysis doesn't account for operational costs and environmental degradation. From 2016 to 2019, Santos et al. (2021) employed financial metrics to evaluate the economic viability of 222 WWTPs in the Pyrenees. The study results indicated that the viability of resource recovery technologies heavily relies on economic feasibility; Fallahiarezoudar used a window-based data envelopment analysis model to evaluate the ecological efficiency of five WWTPs in Malaysia. The model utilized labor costs, operating costs, utility costs, and chemical consumption costs as inputs, while pollutant removal rates and greenhouse gas emissions were used as desired and undesired outputs, respectively. The analysis revealed a direct relationship between the amount of pollution removed and the cost (Fallahiarezoudar et al.,2022); Numerous research endeavors have sought to evaluate the financial worth of detrimental environmental impacts that stem from greenhouse gas emissions through the use of CO_2 shadow prices. Ramon implements stochastic frontier analysis methodologies to gauge the incremental expense of decreasing GHG emissions within the water and wastewater industry. His analysis found a CO_2 shadow price of £0.181/kg CO_2 eq for ten water and wastewater companies in the UK over 2010-2019.María used a directional distance function to estimate the CO_2 shadow price for 25 wastewater treatment plants, which represented 17.7% of the price of treated water (María et al., 2012; María et al., 2015).

A comprehensive analysis of the benefits in the wastewater treatment field involves various methods, such as whole life cycle assessment, energy value analysis, and eco-efficiency. Studies that quantify the benefits of environmental externalities of wastewater treatment include evaluating its environmental performance throughout the entire life cycle and using shadow price methods to measure the external benefits of wastewater treatment. The application of this method in the wastewater treatment industry originated from foreign research and has become widely used since its proposal. Additionally, this method has some applicability in studies related to the cost of reducing pollutants.

5. Conclusion

With global environmental issues such as the greenhouse effect becoming increasingly prominent, it is important to explore the construction of underground WWTPs. This exploration should involve not only an economic cost analysis but also a comprehensive environmental impact assessment, particularly in terms of accounting for their carbon emission systems. There is no systematic study of the carbon emissions and energy consumption of underground WWTPs, and it is necessary to account for the carbon emissions of each treatment unit at all stages, as well as to analyse the relationship between carbon emissions and energy consumption according to the special characteristics of underground WWTPs in terms of increased energy consumption during the construction and operation phases, and to make a scenario analysis with reference to different resource and energy recovery options for above-ground WWTPs, so that the carbon reduction of underground sewage treatment plants can be made. This will serve as a reference for reducing carbon emissions in underground wastewater treatment plants and supplementing greenhouse gases in the wastewater treatment sector. It quantifies carbon emissions at each stage, promoting the industry's green and low-carbon transformation.

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Changes Must Happen in the Clothing Industry-the Transition Towards Carbon Neutral in Europe

Ruolin LIAO

Guilin University of Electronic Technology, Guilin City, Guangxi Province, China, 541004

E-mail: 2257916516@qq.com

***Corresponding author**

Abstract

Nowadays, the clothing industry is found to make big contributions to climate change, stepping the way towards carbon neutrality in Europe. Leading fashion companies are driven by the desire to make more money and tend to accelerate their product cycle to produce more unnecessary clothes, sell more clothes and make more profits. These strategies perfectly correspond to the nature of capital, which is to chase more money in endless time, being the easiest and the cheapest way to satisfy the growing profiting desire of these companies. Even if these companies have already made some efforts to be more sustainable, the effects remain unknown in the uncertain future. Those strategies that brought false prosperity to the clothing markets impacted the environment largely. From the perspective of consumers, they tend to buy new clothes instead of using old ones or buying second-hand products. Though more consumers started to buy products made from recycled materials, vintage or second-hand products, these consumption ways are still not mainstream. The reasons behind those options are comprehensive. It is believed that chasing profits, which is rooted in the depth of human nature accounts for part of it. Consumers tend to be attracted to cheaper products. However, regardless of the hard work, it is necessary to change the strategies of those leading clothing companies and consumers' thoughts towards buying clothes. So, thoughts of carbon neutrality can permeate into people's lives and thus gradually impact all kinds of lives. To tackle this problem, consumers should take the role of educating companies, and leading clothing companies should be clearer about the current situation and take real action.

Keywords: Carbon neutral; Europe; clothing industry; changes.

1. Current situations in european clothing industry

1.1. Leading companies' marketing strategies are out of date

Nowadays, leading companies are still using the old tricks of the last century to attract consumers to buy more clothes. That is to squeeze designers' last piece of creativity, accelerate the cycle of the new product and advertise to make consumers buy more unnecessary clothes. Those marketing strategies can be summarized into just one short phrase, that is to create unnecessary needs. However, in the era of energy transition, the whole world is turning its energy mood from largely depending on coal and oil fuel to multiples of clear energies. The strategies based on the permitted huge waste and pollution can no longer exist anymore. Apparently, the old strategy is deemed to die with the old energy mood. The new shall be born in the doom towards carbon neutrality. Fighting climate change is a huge and difficult task for all the people on this beautiful green planet.

1.1.1. Reasons behind the situations

It is believed that the strategies last for reasons. First, from the perspective of psychology, these strategies perfectly correspond to the nature of capital, which is to chase more money in endless time. Leading companies are driven by the desire to make more money. So they have to sell more products and make more profits. But, in a short term, in fact, according to the cult of thrift arising from human nature, people will not have new needs if they already have the things they need, and the things still perform very well. To encourage consumers to buy their products, companies tend to design new types of products, such as changing the color or the materials, launching co-branded styles, or changing other small details of the former products to encourage people to buy the new ones. Or companies can create fancy pictures of people who use these products. They say if you buy their amazing clothes, your life will be much better. Clothes thus change their nature from keeping warm to becoming the symbol of certain lifestyles. These are called Consumption Traps, the rebellion to the core of rational man that rescue people from the darkness of medieval. For a very long time, those arrogant companies have been trying to wipe out the truth, making people forget that they are the one and only people who can define their own value. Once the wrong thought is put into people's minds, the inertia is huge.

Second, from the perspective of realistic factors, those strategies are the easiest and the cheapest way to satisfy the growing profiting desire of the leading companies. Also, for those smaller companies that tend to follow the leading companies. Any type of truly eco-friendly product costs a huge amount of investment if companies still want to sell new products. And for all those years, they have spent too much money educating consumers that the new will be better, and their products represent certain types of lifestyles. Of course, many leading clothing companies such as H&M and Adidas have already launched many products that are made from recycled materials.

But does it make a real contribution to the transition of carbon neutrality in Europe? Can things made from recycled materials mean that they cost less energy and do less harm to the environment?

Sometimes, it is believed that those companies are playing some sorts of games of disguising replacements of concepts. Besides, many European leading clothing companies, except the luxury companies such as LVMH and Kering, have already transferred the highly polluting manufactories to Africa and Asia, which allowed them to escape environmental responsibilities to some extent. Even if these companies have already made some efforts to be more sustainable, the effects remain unknown in the uncertain future.

In conclusion, the cost of transformation is too much compared to the uncertain future for clothing companies.

1.1.2. Outcomes

Those strategies that brought false prosperity to the clothing markets impacted the environment largely.

It produced large amounts of waste. Clothing manufacturing which produces kinds of toxic chemical waste usually sets their factories in developing countries. Those wastes are likely to get into the water, thus producing or worsening water pollution in these countries. Plus, workers exposed to those toxic and harmful substances are likely to get sick. And after these high-cost clothes come into the hands of consumers, they might only serve for a couple of seasons and end up being thrown away or lying on the bottom of the closet.

1.2. Consumers tend to buy more clothes instead of using the old ones

Though more and more consumers have started to buy products made from recycled materials, vintage, or second-hand products, so far, these consumption ways are not mainstream. Many consumers, especially those in Asia who care about 'Feng Shui, insist on buying new ones rather than second-hand products. Will things be better in Europe? Regretfully, though many consumers prefer ethical purchases, considering the higher price of those products, the answer might be "No". And obviously, there are several more explanations for this phenomenon.

1.2.1. Reasons behind this phenomenon

It is believed that chasing profits, which is rooted in the depth of human nature accounts for part of it. According to Bentham, people tend to pursue profits. Every human being, as long as he is a rational one, has the desire of owning more and new. This kind of desire might have existed since ancient times. Regarding safety, more and newer properties support the feeling of it. It supports not only physical security in the traditional sense but also in the social sense. This is proof of wealth growing, which can be called financial security. The basic need for security always stands in front of the need for self-actualization like fighting climate change and contributing to the transit toward carbon neutrality.

Another thing that accounts for this phenomenon is that consumers tend to be attracted by cheaper products. There are always many big signs like 'bargain' or 'on sale' hanging in conspicuous positions in a shopping mall or any type of shop. Consumers think that they bought the same products with less money, without realizing they are paying for illusions created by capitalists. Forget about the tricks of the prices, here, the question is, are they really getting a bargain or just getting excited the moment they see the price and creating a nonexistent need in an instant? Sometimes, it is easy for full consumers.

The most important thing is that the marketing strategies of those leading clothing companies are working right now. The worst is that it has been working for too long for consumers to remember that the nature of life is very simple, and basic living needs are easy to satisfy. Many options are created by companies, not rising from a sense of scarcity in life.

1.2.2. Outcomes

Leading clothing companies spend huge amounts of money every year to study consumers' psychology. They knew consumers' needs and desires and designed tricks many years ago to make more money. These old marketing strategies brought companies huge profits. They might be stuck in their glory days as the transition from the petroleum industry to carbon neutralization would cost a lot. Besides, it produces too much waste. Tons of used clothes were placed in the bottom of people's closets or lying on dust heaps. Those clothes could be used in a more proper way. Though a lot more post-consumer recycled products appear in markets, the trends boost the prosperity of vintage clothes markets. The energy they have been saved still is far from wasted energy. And those clothes only take very small parts of useless clothes. Its function might not be as good as we thought.

Consumers lose their right to self-decision in these old marketing strategies. They have been fooled for too long.

2. How to tackle the questions in the clothing industry in Europe?

2.1. Consumers take the role to educate companies

Fast fashion is out, sustainable fashion is in. These trends appear on luxury stages in Paris, Milan, and New York. For example, Gucci changed its chief designer for more elegant and sustainable clothes. As the economy is still declining and consumers prefer more sustainable clothes to save money. This means that the change in consumers' psychology results in these changes. So, in this way, consumers should take positive ways to educate companies. As consumers, we should use our own voice and take our own moves to make clothing companies realize that markets would abandon those companies failing to satisfy consumers' elevated expectations.

2.1.1. Educate the consumers in a new way

The educators can be the consumers themselves. Consumers should change the way they think. Contributing towards carbon neutrality in Europe does not mean just buying more clothes made from recycled materials, but also means buying fewer clothes with high quantities that can be worn for a longer time. Also, wearing the same clothes for many years is not a shame but a medal. As it means you make the right choice of buying the right thing in good quantity, classical color, and pattern. And it proves your good taste, sense of your own style, and the good shape of your body. As we all know, keeping the shape of bodies is not that easy.

Furthermore, buying second-hand clothes is not a shame. It does not mean consumers' poverty. On the opposite, it shows that consumers have already stepped outside the zone that was drawn by those companies, starting to realize that good products can be the old ones placed in vintage or second-hand stores rather than in the new-arrival counters. Thoughts of recycling should sink into people's daily lives. Above all, this is a unique time – circularity touches on how people rethink design and implementation.

2.2. Leading companies should be clearer about the current situation

2.2.1. Policy in the European Union ("the EU") is much tougher than we think

The Green Deal shows Europe's environmental ambition. Its goal can only be achieved through global cooperation. As climate change and biodiversity loss are global issues. They should not be limited by national borders. During the transition to carbon neutrality, the EU's neighbors and partners can be mobilized by its influence, expertise, and financial resources to join it on a sustainable path. Also, the EU will keep the leading role in international efforts and wants to build alliances with like-minded. Even when others are unwilling to act.

The war in Ukraine and the economic decline have been wiping out the industry in Europe and swab-offing the money which could be used in this transition. During the transition, Europe needs to maintain its security of supply and competitiveness. To deliver the European Green Deal, policies are needed to rethink for clean energy supply across the industry, production, and consumption. To achieve the three aims, the priority of increasing the value given to natural ecosystems protection and restoration, resources sustainable use, and human health improvement exists. Besides, COP 27 showed that the EU chose to take a tougher way though facing a serious energy crisis due to the Russia-Ukraine conflict and epidemic the lasted for almost three years.

2.2.2. Consumers are paying more attention to climate change

In a research covering most of the European countries to investigate consumers' attitudes towards climate change, the results suggested that they are paying more attention through the years go by.

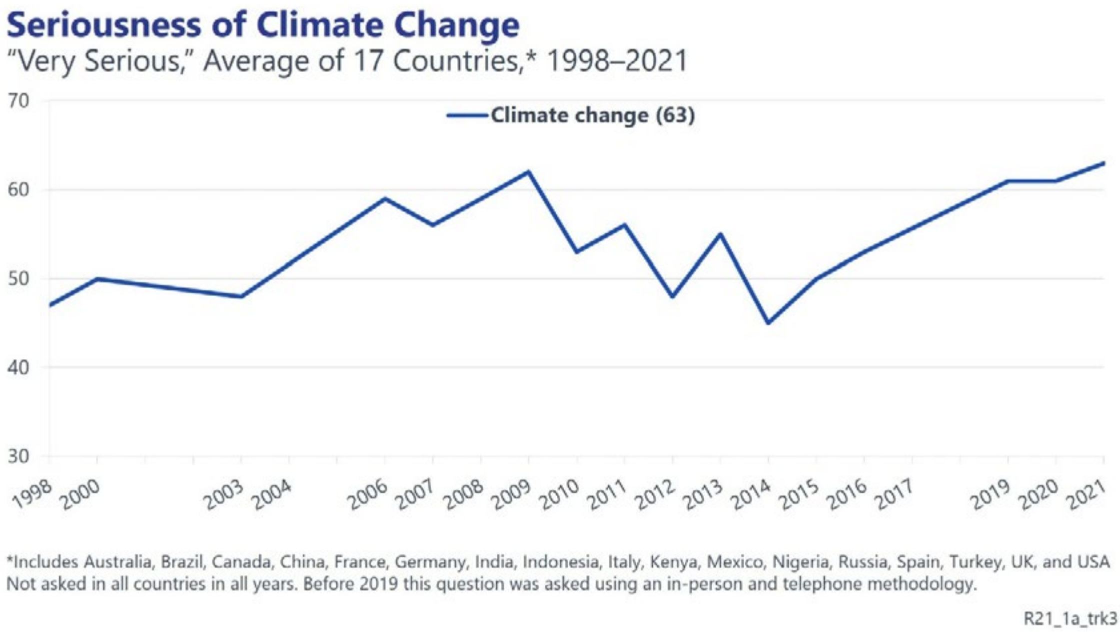

Chart 1

According to the Healthy & Sustainable Living study, the researchers recorded heightened environmental consciousness in 2020, the first year of the pandemic, and it seems like that this shift has been locked in ever since (chart 1). Seventy-three percent of consumers globally agree that we need to reduce consumption to protect the environment for future generations, while 52 percent say that their negative impact brings them guilt, similar to 2020 after a large increase compared to 2019 (chart 2).

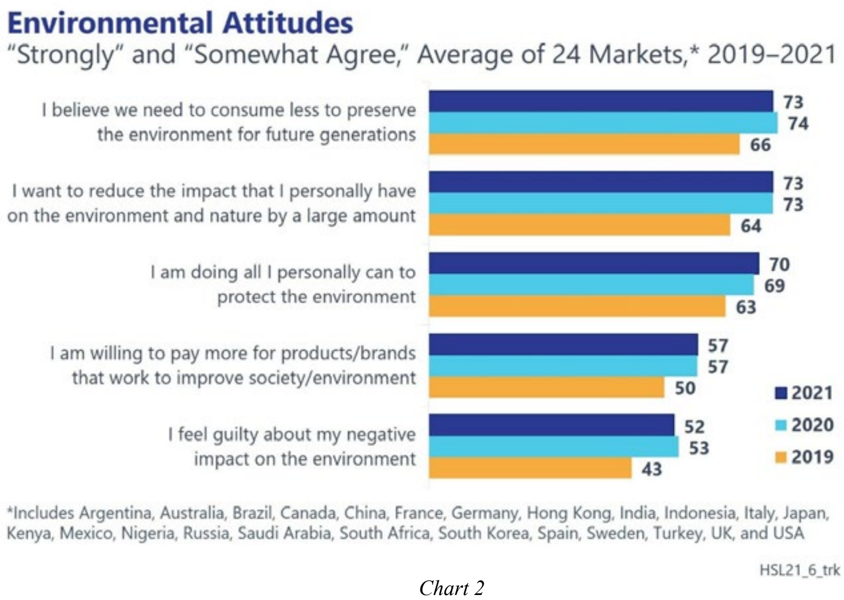

Chart 2

The research also finds that across 24 markets surveyed in 2019 and 2021, there have been only marginal increases in sustainable behaviors over the past two years, despite remarkable increases in environmental consciousness, looking at a large range of sustainable behaviors in the areas of shopping, home energy use, mobility, and food.

This research also studies attitudes towards sustainability vary across countries. When looking at consumers who have either made significant changes to their purchasing behavior or completely changed their way of living to be more sustainable, Austria leads the way (42 percent), followed by Italy (41 percent), Spain (35 percent), and Germany (34 percent). As for the US, 22 percent of consumers indicate major changes to their behaviors, but that number jumps to 55 percent when including those who say they've at least made some modest changes. "Millennials and Gen Z are becoming a force to be reckoned with as they continue to represent a larger share of the consumer demographic. Companies that do not have sustainability as part of their core value proposition need to act now to protect against future reputational impacts and loss of market share," said Shikha Jain, author of the study and Partner at Simon-Kucher & Partners. "We've been on this journey for a while, but the clock is ticking and failure to think through the implications could have long-term consequences for traditional firms."

2.2.3. Companies should extend their product cycle

The policy and consumer's preferable products are changing. Companies should adapt to it and change their strategies, not just in marketing, but also in product developments. This means that clothing companies should slow down the speed of launching new products to the market and extend their product cycle.

Of course, it does not mean that companies should decelerate innovations. They should balance innovations and the need to make the change towards carbon neutrality in Europe. And companies should avoid Greenwashing, which refers to a company's practice of marketing green efforts but failing to share information on its business practices that are damaging to the environment.

3. Conclusion

The World Economic Forum's own analysis puts nature's value to the global economy at $44 trillion – more than half of the global GDP. With the business case clear, what more can clothing companies do to reverse nature loss and realize the promise of a nature-positive global economy? They can commit to protecting nature and natural systems by setting science-based targets for nature and ambitious greenhouse-gas emissions reductions. They can deliver on these commitments by protecting nature and natural systems in the landscapes where they operate, or from which they source commodities, by using tools and approaches such as the Accountability Framework, and importantly, through reshaping markets. And during this big energy transition, consumers should take their own responsibilities to change their old psychological and behavioral patterns and help to build a more environmentally friendly market. Further, clothing companies and consumers can call for an ambitious Paris-style global agreement for nature that helps secure a nature-positive world by 2030.

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Analysis of Commercialization Potential of Transparent Photovoltaics in the Context of Carbon Neutrality

Xin LIU

Nanjing University of Science and Technology, Nanjing City, Jiangsu Province, China, 210094

E-mail: liuxin_njust@163.com

***Corresponding author**

Abstract

The increasing global industrialization and over-exploitation of fossil fuels has led to the release of greenhouse gases, resulting in higher global temperatures and environmental problems. As a result, there is a growing demand for renewable energy in order to achieve net zero carbon emissions. Building-integrated photovoltaics (BIPVs) can replace building structures, such as roofs or walls. Among others, transparent photovoltaics (TPVs), which combine visible light transparency and solar energy conversion, are being developed to complement BIPVs for applications such as windows in buildings or vehicles. In this paper, we collate the latest advances in TPVs and strategies for achieving conventional PVs transparency, including thin-film technology, selective light transmission technology and luminescent solar concentrator technology. We further discuss possible research directions for the commercialization of TPVs.

Keywords: Transparent photovoltaics; organic photovoltaics; perovskite solar cells; crystalline silicon solar cells; luminous concentrator solar cells.

1. Introduction

Global climate change is already having a clear impact on the environment.(F. Wang et al., 2021) In response to rising global greenhouse gas concentrations and temperatures, on 12 December 2015, 197 member countries of the United Nations Framework Convention on Climate Change (UNFCCC) agreed at the Paris Climate Change Conference (PCCC) to adopt the Paris Agreement, which sets out a global action plan to combat climate change after 2020. Under the Paris Agreement, each country agreed to limit global temperature increases to less than 2°C and to work towards limiting global temperature increases to less than 1.5°C (2015 agreement). As of February 2021, 124 countries/regions worldwide have declared their intention to be carbon neutral and achieve net zero carbon emissions by 2050 or 2060 (Chen, 2021). In order to achieve the targets set out in the Paris Agreement and to support sustainable development, it is important not only to reduce CO_2 emissions but also to remove CO_2 to achieve net zero or negative carbon emissions from the atmosphere through various social, economic, environmental and technological measures. 135 GW of photovoltaic modules were produced in 2020 (95% of the total for 2020). Crystalline silicon solar cells dominate the world PVs market due to their highly power conversion efficiency (PCE), high stability and low cost, and silicon-based PV solar is expected to be one of the main sources of power generation by 2050.

Due to the increase in urban population and the amount of time people spend in buildings, buildings and cities contribute to the large carbon emissions that contribute to climate change. For cities, one strategy to adapt to climate change is to develop resilient designs that can withstand natural hazards while minimizing the impact on the natural environment (Chen, 2021). In addition, mitigation can be achieved by deploying decentralized energy systems for cities; however, this option has a high initial cost. Buildings can achieve a carbon-free future by utilizing improved building envelopes, renewable materials and 3D printing. In addition, this can be achieved by developing heating and cooling systems powered by renewable energy and using energy efficient technologies (Fawzy, Osman, Doran, & Rooney, 2020). In addition, the use of sensors to monitor and regulate intelligent building equipment such as lighting, and the development of electrical and thermal energy storage systems are promising approaches. In addition, the electromechanical equipment in buildings should be eco-labelled and minimum standards for heating, ventilation and air conditioning systems should be implemented.

Rooftop solar installations in cities, often on high-rise buildings competing with concepts such as green or cool roofs and infrastructure related to heating, cooling and air handling (Y. P. Wang, Tian, Ren, Zhu, & Wang, 2006). In order to increase solar energy production in urban centers, either the amount of electricity generated per unit area needs to be increased, or the collection area needs to be increased by using the building envelope for solar power generation. Due to the predominant use of glass as a building material, the conversion of this building envelope into a power generation source will allow for local energy harvesting and use. In addition to generating electricity, the solarization of window glazing can also provide energy savings through heat dissipation while providing visual comfort. BIPV includes solar panels mounted on the roof and facade, as well as solar windows, forming an overall strategy to achieve a zero energy, zero carbon building. In the current BIPVs market, crystalline silicon (c-Si) PV still leads and dominates the global market, with a market penetration of over 70% in the overall market segment (including roof and façade applications), which remains the trend in the BIPVs market for several years, mainly due to the predictable decline in crystalline silicon cell prices.

With the current market demand shifting towards smart technology for near-zero energy buildings, an increase in demand for building photovoltaics can be foreseen and solar cells are expected to be developed directly on the structure of the building. Evolving thin-film technologies such as copper indium gallium selenide (CIGS), copper zinc tin sulphide (CZTS), organic photovoltaics (OPV) and perovskite solar cells (PSC) are well compatible with such customizable building modules. So far, all semitransparent photovoltaics based on thin-film technology have not yet offered high PCE (>15% at module level), as well as transparency (>20%), stability (ideally >20 years) and color tunability (across the visible spectrum). It is conceivable that in future urban planning the development of commercial high-rise building surfaces in fast growing cities and residential units represent a huge potential for transforming the built environment into a decentralized generator, unlocking the solar potential of unused vertical and horizontal building surfaces and promoting self-consumption through on-site energy production (Figure 1). This paper explores the commercialization potential of several mainstream transparent photovoltaics.

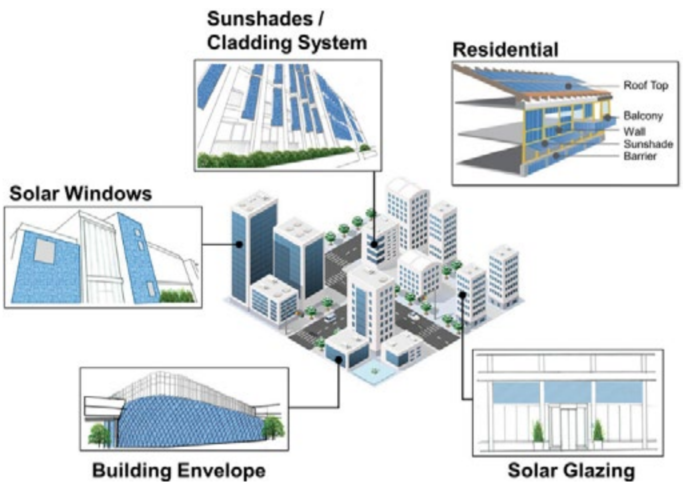

Figure 1
Building-integrated photovoltaics (BIPVs) may include solar cells mounted on roof tops, skylights, balustrades, and façade.

2. Transparent PVs technology classification

In this article we have compiled the latest advances in transparent photovoltaics, including thin film technology, selective light transmission technology and luminescent solar concentrator technology.

3. Thin film technology

BIPVs are connected to commercial and residential homes to enable solar energy harvesting. Although conventional silicon solar cells dominate the current market, second and third generation thin film solar cells based on amorphous silicon, CdTe, CIGS, perovskite or organic photovoltaics (OPVs) are usually regarded as substitutes for BIPVs applications because of their significantly lower costs compared to silicon solar cells. The potential applications of organic and chalcogenide photovoltaics in BIPVs are highlighted.

In recent years, the rapid development of OPVs has achieved PCE of over 19%.(Zhu et al., 2022) At the same time, OPVs show great advantages in terms of light weight, ease of manufacture, low cost and environmental friendliness compared to conventional silicon solar cells. By choosing the right organic material, photon capture in the near infrared (NIR) range and transmission in the visible range can be well optimized to meet the requirements of window and greenhouse applications and to collect photons sufficiently in the NIR range to maintain a high PCE. With the construction and operation of buildings currently accounting for one-fifth of global carbon emissions, it has become crucial to develop innovative technologies to improve the energy efficiency of buildings. Considering that there are over 100 billion square meters of window glass in buildings, replacing ordinary glass with transparent power-generating windows has energy-saving features (Zhou et al., 2019), in addition to energy-saving methods such as low-e glass and thin films. Li et al. developed high-performance transparent power generation windows with excellent power generation and light transmission properties for multifunctional semitransparent organic photovoltaics (ST-OPVs) with excellent optical and photovoltaic properties in the visible to infrared range of the solar spectrum, along with an AVT of 32%, a color rendering index of 90, a near-infrared reflectance of 0.90 and a power conversion efficiency of over 11%. More importantly, large area modules with manufacturing feasibility were successfully obtained with an energy conversion efficiency of 16.04% for opaque (certified at 15.46%) and 11.28% for transparent modules, reaching a new efficiency record for current organic solar modules.(D. Wang et al., 2022) The best current ST-OPVs devices have light utilization efficiency (LUE = PCE * AVT) to 5.35%.(Liu, Zhong, Zhu, Yu, & Li, 2022) In addition to generating window references, the use of ST-OPVs on greenhouse structures offers the opportunity to offset the greenhouse energy demand and also maintain the light requirements of plants. ST-OPVs are particularly promising for greenhouse integration, with attributes such as spectrally tunable transparency and compatibility with thin film flexible profiles for simple module integration.(Emmott et al., 2015) Ravishankar et al. developed a detailed greenhouse system model that combines detailed accounting of the greenhouse environment (temperature, humidity, lighting) with a functional plant growth model, solar power generation from ST-OPVs and system economics. This holistic model allows an assessment of how adding ST-OPVs to greenhouses may be part of a more sustainable solution for the agricultural food industry.(Ravishankar et al., 2022)

Perovskite solar cells (PSCs) have attracted much attention for their low cost and high energy conversion efficiency. In 2009, Miyasaka and his colleagues first reported the use of organic-inorganic lead halide perovskite semiconductors as active light absorbers in solar cells. In this ground-breaking work, the best performing device produced a power conversion efficiency (PCE) of 3.8%.(Kojima, Teshima, Shirai, & Miyasaka, 2009) Researchers have found that perovskite photoactive layers exhibit promising photovoltaic properties such as tunable band gaps, high absorption coefficients, high charge carrier mobility and long charge diffusion lengths. Recent perovskite devices can produce energy conversion efficiencies comparable to those of silicon solar cells.(Jiang et al., 2022; Zhao et al., 2022) Meanwhile, due to their large absorption coefficients and color tunability, perovskite materials hold great promise for use in energy-efficient smart windows and other building-integrated technologies .(Batmunkh, Zhong, & Zhao, 2020) One of the most widely researched is the semitransparent perovskite solar cell (ST-PSCs), which can be applied directly to building facades, windows and glass roofs for solar energy harvesting.(Bing et al., 2022; Eggers et al., 2022) Colored PSC is another attractive BIPVs that has shown good suitability for building walls, fences and car park roofs.

(Y. Wang et al., 2021) A more challenging BIPV combines solar energy harvesting functions with electrochromic layers to form electrochromic functional photovoltaics. The same can be combined with thermochromic to produce thermochromic solar cells.(Ling, Wu, Su, Tian, & Liu, 2021; S. Liu et al., 2022) The main purpose of these dual-function BIPVs is to prepare smart windows that assist in cooling the building through photovoltaic conversion.

As thin film photovoltaic technology is made transparent by reducing the thickness of the active layer, it can be applied to all types of semiconductor materials without restriction. Previous research into thin film TPVs has focused on achieving high PCE using a variety of materials. However, the commercialization of TPVs also requires consideration of long-term stability and appropriate aesthetics of the device. Although organic and chalcogenide TPVs exhibit relatively high PCE, these materials lead to poor stability even in opaque photovoltaics as they exhibit inherent instability to water and oxygen.(Cha & Wu, 2021; Nazir et al.)

4. Selective light transmission technology

Another method for the preparation of high-performance TPVs is the selective light transmission technique. This method achieves light transmission in the visible region through selective light transmission regions. As early as 2014, Henry J. Snaith et al. formed ST-PSCs with neutral color and relatively high efficiency by using morphology control of perovskite films. By controlling the pores of the perovskite film, the island of perovskite film was thick enough to absorb all visible light, while the pore regions were transparent. The overall optical appearance of this film is neutral in color, resulting in the preparation of neutral ST-PSCs (Eperon, Burlakov, Goriely, & Snaith, 2014); Using this method, Henry J. Snaith et al. also prepared neutral-colored ST-PSCs with a PCE of 6.1% and an AVT of 38% through a systematic study over a two-year period.(Hörantner et al., 2016) Recently Sang Hyuk Im et al. fabricated effective neutral ST-PSCs by controlling the aperture ratio using laser patterning. The AVT was controlled by increasing the aperture ratio and finely tuning the neutral coloring. Successfully prepared 2.00 cm^2 perovskite devices with a high efficiency PCE of 12.83% and 36.00 cm^2 devices with a PCE of 9.30%, while achieving an AVT of 21.74%.(H. J. Lee et al., 2022) Similar technical approaches have been used to achieve uniformly transmissive transparent photovoltaic devices in already commercialized monocrystalline silicon solar cells. Kwanyong Seo et al. developed neutrally transparent crystalline silicon substrates and demonstrated their application for TPVs. The transparent crystalline silicon substrates were fabricated by placing micro-aperture shaped light transmitting windows onto bare crystalline silicon wafers. The transparent crystalline silicon substrate shows a completely neutral color without transmission cut-off wavelengths and its transmittance can be easily adjusted by controlling the filling section. In addition, the 1 cm^2 neutral-colored TPVs fabricated using this transparent crystalline silicon substrate show a maximum efficiency of 12.2%.(K. Lee et al., 2020) Further, Kwanyong Seo et al. used a simple and effective chemical surface treatment method for removing surface damage from crystalline silicon micropores. TPVs with a large area of 25 cm^2 with chemical surface treatment showed a transmittance of 20% PCE of 14.5% by removing the damaged surface of crystalline silicon micropores. (Park, Lee, & Seo, 2022)

The above collations reveal the use of micro-nano structures to control the pore size ratio of the micro-nano pores of the active layer films to achieve uniform and high transmission across the full spectrum. There are obvious advantages to this technology, which can be prepared by laser and wet chemical methods with a simple process. But the disadvantages are also obvious, such TPVs devices have full spectral transmission, the spectrum is not selective, and the TPVs device performance cannot reach the ideal value. As the c-Si TPVs are manufactured using the same structure as the commercial c-Si PVs, they have a similar high stability. Therefore, a rapid commercialization of c-Si TPVs is expected to be possible.

5. Luminescent solar concentrator technology

The Luminescent Solar Concentrator (LSC) is a novel photovoltaic technology with simple construction, angle independence, high defect tolerance and design flexibility.(Yang, Barr, & Lunt, 2022) LSC-type TPV technology uses luminescent materials that absorb and emit light in the UV/near IR region. The emitted light from the light emitting material is directed to the edges of the transparent polymer substrate. c-Si, GaAs and InGaP PVs are mainly used as edge PVs. Since the edge region is negligible, LSC-type TPVs have the advantage of being able to achieve perfect transparency with almost no absorption of visible light. Recent literature has reported very high AVTs of over 74% for LSC-type TPVs.(Yang et al., 2020) The size of the LSC is determined by the area of the transparent polymer substrate that includes the light emitting material. Transparent polymer substrates with light emitting material can be manufactured on a large scale using inexpensive methods such as casting, coating and roll-to-roll processes. In addition, solar cells mounted on the edges of LSCs are already commercially available on a large scale. LSC-type TPVs are therefore advantageous for building-integrated photovoltaic or vehicle-integrated photovoltaic applications that replace large-scale glass substrates. The reported efficiency of LSC-type TPVs technology is much lower than the theoretical efficiency, as current technology is far from ideal conditions. The lifetime of LSC-type TPVs depends mainly on the stability of the light-emitting material.(Yang & Lunt, 2017) This is because the other components of the LSC type TPVs, the clear polymer and the edge mounted PVs have a long life span of several years or more. Examination of the variation in absorbance of the dye embedded in the transparent polymer substrate shows that very few materials are relatively stable over a two-year period, attributed to the fact that most luminescent materials are sensitive to oxygen and moisture under atmospheric conditions, resulting in a short lifetime.

Table 1 High performance TPVs with different types

The types of TPVs	PCE (%)	AVT (%)	LUE (%)	CRI
c-Si (Park et al., 2022)	14.5	20	2.9	100
Perovskite (J. Lee et al., 2021)	12.7	25.2	3.21	-
Organic (X. Liu et al., 2022)	11.43	46.79	5.35	85.39
LSC (Huang et al., 2022)	1.57	84	1.3	88

6. Conclusion

Although TPVs have been extensively studied as a renewable energy source in urban areas, high performance TPVs have not yet achieved commercial use. When windows in buildings with a window-to-wall ratio of 55% are replaced with 30 W TPVs (AVT of 15%), more than 40% of the energy consumed in the building can be generated from PV, TPVs can be applied to vehicles in addition to this. To the end, this paper presents several key elements as important considerations for TPVs development, including (1) high PCE at the same AVT, (2) glass-like neutral color and low haze ratio, (3) modular preparation, and (4) high stability. The best candidate to meet these requirements commercially among the TPVs already developed is c-Si TPV. c-Si TPVs has a PCE of up to 14.5% (20% for AVT, Table 1), the highest among neutral colored TPVs. In addition, the stability is expected to be the same as for commercial c-Si PV. Therefore, the development of higher performance photoactive materials and roll-to-roll compatible interlayer materials and electrodes are required for several other new transparent PVs technologies. Also intensified research efforts on device lifetime, color combinations, module design and efficiency will help to make a significant impact on the transition of new PV from a new technology to a mature industry status.

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Carbon Neutrality Pathways for Universities: A Case Study of the UK University Carbon Management Plan

Jiaying RONG

Capital Normal University, Beijing, China, 100048

E-mail: erin.celeste.r@gmail.com

***Corresponding author**

Abstract

Our life and production have been seriously threatened by the problem of global warming. Global warming has become an important problem in the world. It urgently needs to be solved and carbon emissions urgently need to be lowered. Over the past years in China, higher education had rapid development. There is no doubt that colleges and universities have become large consumers of energy. So, if we can reduce carbon emissions, our society will certainly benefit. This paper focuses on the analysis and summary of the carbon management plan in British universities, hoping to be helpful to the future development of carbon management and carbon neutrality in domestic universities after the accounting of carbon emissions.

Keywords: Higher education institutions; accounting for carbon emissions; IPCC factor method; carbon management.

Global warming has seriously threatened the production and life of mankind, and has become a major problem facing mankind. Continued intensification of climate change will have serious impacts on future freshwater resources, ecosystems, agricultural coastal zones and low-lying areas, as well as human health. As society pays more and more attention to the problem of global warming, greenhouse gases, the source of this problem, have also aroused widespread concern at home and abroad. People realize that if we want to deal with climate change, we must take corresponding emission reduction measures. In the Paris Agreement adopted in December 2015, all countries promised to take active actions in the future and formulate specific measures and emission reduction plans to prevent climate warming and strive to achieve zero net emission of greenhouse gases at an early date. Colleges and universities are the backbone of today's society. If students can be aware of greenhouse gas emissions at the early stage of education, they will have an important influence on society in the future. In addition, evaluating the carbon emissions of colleges and universities and determining their emission reduction potential can also give full play to the leading role of colleges and universities in the field of carbon emission reduction.

1. Introduction to the carbon management plan

In 2008, Britain passed the Climate Change Act, which plans to reduce its greenhouse gas emissions by 80% by 2050, compared to that of 1990. However, this target was made more ambitious in 2019 when the UK became the first major economy to commit to a ‘net zero’ target. The new target requires the UK to bring all greenhouse gas emissions to net zero by 2050.

According to the UK government’s targets, the Higher Education Funding Council for England (HEFCE) encourages the UK higher education sector to take a leading role in carbon reduction, aiming to reduce carbon emissions by 43% based on 2005/6 levels. UK universities are also required to develop their own carbon management plans, including project descriptions, baseline data, reduction targets, carbon emissions in the three scopes of the IPCC, reduction plans, emission forecasts, financing needs for implementation plans, stakeholder management and communication, and risk management. Through various incentives, more than 50 UK universities have developed their own carbon management plans based on government targets, their own carbon emissions, and their capacity for reduction, hoping to contribute to national carbon reduction. Under the supervision of HEFCE, universities have ensured that the plans are implemented smoothly through sponsorship and fundraising. As of now, most university plans have been implemented and produced benefits. Articles by Muhammad Usman Mazhar, Mark Lemon, and others have also reviewed the carbon management plans of the UK higher education sector and their success factors. In addition, many universities in countries such as the US, Japan, and Australia have voluntarily developed comprehensive and detailed carbon management plans and implemented them. It can be seen that foreign universities attach great importance to carbon emissions and carbon management. The author has reviewed the carbon management plans of most UK universities and summarized some of the indicators in their plans, hoping to provide inspiration for the development of carbon management plans in Chinese universities.

2. Characteristics of carbon management plan in British universities

(1) Determination of accounting scope

In order to address the serious consequences of global climate change, the International Organization for Standardization (ISO) has established a series of norms for the accounting of product carbon footprints, to urge organizations to take emission reduction measures. In this process, the ISO has fully exerted its international influence, forming some mature carbon footprint accounting norms, and achieving good results in practice. To better calculate carbon emissions, the IPCC divides carbon sources into three scopes and accounts for them separately to identify the potential for carbon reduction.

Scope 1	Direct emissions - emissions from direct fuel and energy use within the organization's boundaries.
Scope 2	Indirect emissions - emissions from imported electricity, heat or steam consumed by the organization.
Scope 3	Other indirect emissions - emissions from commuting and business travel, transportation of materials, personnel or waste; waste generated by the organization but managed by other organizations; emissions from the production and distribution of energy products other than electricity, steam, and heat consumed by the organization; and emissions from the procurement of raw materials.

Currently, there is controversy over which sources of emissions should be included when accounting for Scope 3, and there are many emission sources included in Scope 3, making it difficult to calculate and expensive to account for. Through reading relevant literature, we have learned that currently, most universities at home and abroad choose to abandon the accounting of Scope 3 and only account for Scope 1 and 2. Only a few countries account for Scope 3, mainly including travel, commuting, catering, procurement, and other areas.

By summarizing, we can find that the accounting scope adopted by British universities is different when accounting for carbon emissions. Some schools only account for Scope 1 or Scope 2, some schools only account for Scope 1 and Scope 2, and some schools account for all. Overall, the vast majority of universities only account for Scope 1 and Scope 2, and do not account for Scope 3.

(2) The time to conduct a carbon management plan

By reading the carbon management plans of British universities, this paper finds that the time when these universities began to develop their carbon management plans also varied. A few schools developed carbon management plans before 2010, and most schools began developing carbon management plans in 2010 and 2011, with some schools developing plans gradually thereafter.

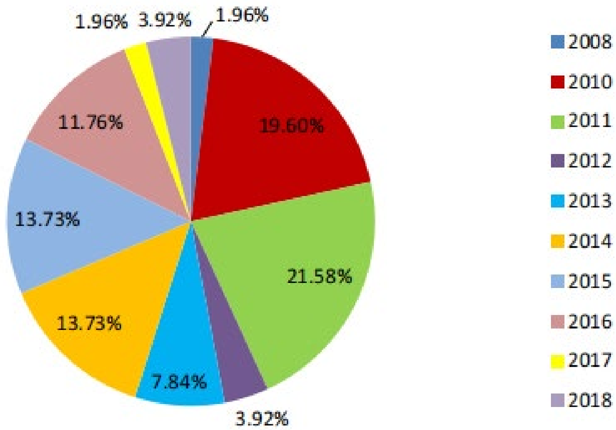

Figure 1 When British universities began to formulate carbon management plan

(3) Target year set by carbon management plan

Table 1 summarizes the target years set by universities. Since the same university may adopt several different target years, the number of universities included in the statistics is duplicated. It can be found that most universities have set short-term targets for 2015 and midterm targets for 2020, with a few schools setting long-term targets for 2030 or 2050.

Table 1 When British universities began to formulate carbon management plans

Target year	Number of universities	Proportion
2012	1	1.41%
2014	1	1.41%
2015	7	9.86%
2016	3	4.23%
2017	3	4.23%
2020	36	50.70%
2021	9	12.68%
2025	3	4.23%
2026	3	4.23%
2030	2	2.82%
2025	3	4.23%
Total	71	100%

(4) Difference of baseline

Table 2 presents the baselines adopted by different universities. "2004-2007" includes four cases: "2004/05, 2005, 2005/06, 2006/07", with "2005/06" being the most common; "2008-2009" includes two cases: "2007/2008, 2008/2009", with "2008/09" being more common; "2009-2011" includes two cases: "2009/10, 2010/11", with "2009/10" being more common; "2014-2016" includes two cases: "2014/2015, 2015/16", with "2015/16" being more common. From the table, we can see that most universities use the period of "2004-2007" as the baseline year, with "2005/06" being the most common. Most universities use the carbon emissions in 2005/06 as the baseline, on which they set their emission reduction targets and compare their emission reduction results.

Table 2 Baselines adopted by different universities

Baseline year	Number of universities	Proportion
1990	6	11.11%
2004-2007	35	64.81%
2008-2009	8	14.81%
2009-2011	3	5.56%
2012-2016	2	3.70%
Total	54	100%

(5) Time span of carbon management plan

The implementation time of most schools' carbon management plan is set between 5-7 years and 8-11 years.

(6) Emission reduction targets

The following tables summarize the different emission reduction targets of different universities in different time spans. It can be seen that most universities have emission reduction targets of around 30% within 5-7 years and around 40% within 8-11 years. A very small number of universities have set long-term targets to reduce emissions by 80% within 40 years.

Table 3 Emission reduction target for 1~4 years

Emission reduction target	Number of universities
52%	1
43%	1
30%	2
10%-12%	3
3%	1

Table 4 Emission reduction target for 5~7 years

Emission reduction target	Number of universities
5%	1
13%-15%	3
20%-21%	4
29%-35%	7
40%-45%	5
48%-50%	3
60%	2

Table 5 Emission reduction target for 8~10 years

Emission reduction target	Number of universities
5%	1
11%	1
22.5%-25%	2
29%-34%	4
40%-44%	9
48%-50%	2

Table 6 Long-term Emission reduction target

Time span	Emission reduction target	Number of universities
14	40%	1
15	48%	1
19	50%	1
24	34%	1
40	78%-80%	3

3. Conclusion

According to the previous analysis, we know that making carbon management plans is beneficial to colleges and universities to carry out carbon management work and reduce carbon emissions. For the convenience of accounting and easy comparison, it is best to only account for scope 1 and scope 2 in the current carbon management planning of colleges and universities. We can set a short-term emission reduction target of 5-7 years based on 2022, such as reducing emissions by 30% by 2027; Then set a medium-term emission reduction target for 8-11 years, such as a medium-term target of reducing emissions by 50% by 2035, and regularly check the implementation effect of the planned projects. Of course, in addition to accounting school carbon emissions and setting emission targets, carbon management planning also needs to provide some clear and detailed measures. Due to the limited time and conditions of research, this paper has not made specific plans for the measures, but based on the action measures of UK universities, the following carbon reduction recommendations for universities are summarized:

(1) Direct energy

Direct energy sources include gasoline, oil, and natural gas. In this regard, universities are encouraged to use clean energy as much as possible and find more alternative energy sources. Details such as timely maintenance of gas stoves and regular cleaning of iron pots to reduce energy consumption should be taken into account. Gasoline and diesel are used exclusively as fuel for university fleets, so the travel arrangements of the fleet should be as reasonable as possible to reduce unnecessary travel. At the same time, to reduce the traffic emissions of the entire school, universities can establish more bicycle sheds and appropriately control the number of private cars on campus.

(2) Electricity consumption

In recent years, due to the expansion of the campus, the electricity consumption has also increased, resulting in an increase in greenhouse gas emissions from Scope 2 electricity. Therefore, preventive measures need to be taken at the university level to optimize the energy use of various consumers on campus and reduce the environmental burden. The following aspects can be considered:

1) dormitory electricity use can be limited and timed power outages can be carried out at night;
2) voice-activated power switches can be used in public areas;
3) energy-saving systems can be installed;
4) computer energy-saving measures can be implemented, such as shutting down unused computers on non-working hours and timely sleep mode.

(3) Water use

We know that carbon emissions produced by water use are minimal. However, we still need to conserve water and minimize energy consumption. At the university level, the overall water use should be monitored and measures should be taken to reduce water consumption. For example, the water supply pipes need to be thoroughly inspected and leak detection instruments installed in a timely manner to avoid unnecessary water loss. Water meters should be installed on the main buildings of the university for real-time dynamic monitoring and data analysis. If possible, water-saving devices can be upgraded.

(4) Environmental education

As a higher education institution, universities should make contributions to energy conservation, water conservation, environmental protection, and resource utilization, and become a sustainable organization. In this vision, we cannot ignore our identity as educators. Environmental education for university students can encourage them to participate in carbon reduction actions and contribute to sustainable development. For example, students can be encouraged to produce a film to showcase their ideas on sustainable development in universities. Each major can establish an environmental working group and set up environmental courses related to their major to enhance environmental awareness through education. A series of lectures related to "green" research can be held, and regular green initiatives such as competitions can be organized every semester. Universities can actively respond to international initiatives such as Earth Day or "Earth Hour" activities, and promote resource conservation and environmental protection in the media.

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Annexes: 50 UK universities referenced in the paper

1	Aston University
2	University of Bedfordshire
3	University of Birmingham
4	Bournemouth University
5	University of Cambridge
6	Cardiff University
7	University of Chester
8	City University London
9	De Montfort University
10	Durham University
11	Edinburgh Napier University
12	University of Glasgow
13	University of Greenwich
14	Harper Adams University
15	Heriot-Watt University
16	University of Hull
17	Keele University
18	University of Leeds
19	University of Leicester
20	Liverpool John Moores University
21	London Metropolitan university
22	London South Bank University
23	Manchester Metropolitan University
24	Newcastle University
25	Northampton University
26	Northumbria University
27	University of Nottingham
28	University of Oxford
29	University of Plymouth
30	Queen's University Belfast
31	University of Reading
32	University of Roehampton
33	University of Salford
34	University of Scottish
35	University of Sheffield Hallam
36	University of Sheffield
37	Southampton Solent University
38	University of St Andrews
39	University of Staffordshire
40	University of Strathclyde
41	University of Sunderland
42	University of Sussex
43	University of Swansea
44	University of Warwick
45	University of Ulster
46	University of Bath
47	University of Exeter
48	University of West of England
49	University of Worcester
50	University of York

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A Study on the Green Marketing in Food Industry Based on STP Marketing Strategy- Focusing on Nestlé

Beiya SHI

Hainan University, Haikou City, Hainan Province, China, 570228
E-mail: 956097791@qq.com
***Corresponding author**

Abstract

With the development of the global economy and the progress of science in recent decades, the demand for healthy, high-quality, and nutritional diets and food is ballooning dramatically. Furthermore, climate change has drawn more sight and concerns owing to the increasing number of climate disasters and intricate interests web which involved most countries in the international community. Carbon neutrality, one of the most heated topics among politicians and businesspersons, is placed on the agenda of a myriad of enterprises. Without exception, food companies must conform to the demand of consumers by launching green products and deploying green marketing strategies. To approach this theme with a scientific and detailed perspective, the STP marketing model will be applied to analyze the current market situation against Nestlé and how it capitalizes on the environmental conservation mania to earn a larger market share for itself. The report is divided into three parts. The first one will briefly introduce the backdrop of the green food market and the motivation of the research, as well as the theoretical model used in the paper. In the second part, the specific conditions in the food industry will be delineated and exemplified by Nestlé based on the STP marketing model. Lastly, the conclusion will cover some lessons drawn from Nestlé's experiences and point out where the food industry should move forward.

Keywords: The green marketing; STP; Nestlé.

1. Background and motivation of the study

Climate change manifests its urgency through the higher frequency of extreme weather and natural catastrophes, which have exerted pronounced pernicious effects on human beings' work and life. Hence, the issues of climate governance were placed on the top agenda in the international community, and developed countries, especially European Union, play a vital role in the process of greening industries for a cleaner world in the future.

According to the *Corporate Net Zero Pathway* (Boston Consult, 2021), food products almost emit greenhouse gases in the entire industrial chain from research, harvesting, processing, distribution, retail, and storage, among which farming activities can account for more than 60% of the total emissions of agri-food enterprises, and more than 90% of the emissions of food manufacturers mainly come from raw materials, procurement, packaging, and logistics.

Enterprises and their chief executive officers should also be fully aware that carbon neutrality is usually a cumulative result of more than ten or even decades, which requires considerable manageable effort and financial investment throughout research and development, production and marketing processes. From the cost of technological transformation to the certification of carbon footprint, the tremendous inputs may become an obstacle for the supply chain partners to carry out carbon neutrality practices, and eventually affect the identification of the carbon emission of food enterprises in the whole life cycle of products. Despite the difficulties, driven by the continual preferential policies pertaining to carbon neutrality and the shift in the consumption habits featured by green orientation, food firms have seen carbon reduction as a key match point to win the future.

For instance, zero-carbon or negative-carbon agricultural products, which refer to agricultural products with net greenhouse gas emissions of less than or equal to zero, are gaining popularity in the food industry. China's first zero-carbon milk, Yili SATINE A2 beta-casein organic pure milk has obtained the carbon neutral Verification Statement (PAS 2060) issued by Bureau Veritas, a world-renowned international inspection and certification group, and achieved carbon neutrality in its whole life cycle. Its NOC ice cream also rose to stardom in the Chinese market, which is labeled as a "zero-carbon" product. In late 2020, Mondelēz's SnackFutures innovation arm debuted NoCOé, a French carbon-neutral snack brand. EverGrain, an ingredients company buttressed by Anheuser-Busch, and Post Holdings subsidiary Bright Future Foods announced a partnership in 2021 to develop products that have a negative carbon footprint, implying that their production would remove more carbon from the atmosphere than they emit. They plan to use EverGrain's repurposed barley protein and fiber and Bright Future Foods' "climate-positive" oats. In May of the same year, the first product from the partnership, Airly Oat Clouds crackers, was launched.

Given these actions against risks and hindrances faced by the decarbonization of the food industry taken by giants, there is a wide space for green products to go deeper into the market with the help of green marketing.

2. Theoretical basis - STP strategy model

The theory of Market Segmentation was first proposed by marketing scholar Wendell Smith and further developed by Philip Kotler, who extended it into the complete STP theory in the book *Marketing Management* (Philip Kotler, 1996). It mainly includes market segmentation, as well as target market selection and market positioning, which together serve as the core of strategic marketing.

Market segmentation theory. Consumers tend to have similarities in their behaviors, demographics, buying patterns and other factors that enable businesses to group them into segments. This enables smarter, more appropriate targeting and messaging within marketing communications. These groups will have different uses for products and varying perspectives on services. Their lifestyles will be inherently different based on their needs, aspirations, opinions and much more. Thereby, enterprises in a specific market segmentation should identify their target market and position their products or services accordingly (Kingsnorth, 2016). Specifically speaking, the enterprise or sales personnel subdivide the whole market of a certain product or service into several different consumer groups on the basis of market research about consumer demand, purchase behaviors, and consumption habits. Each consumer group is equivalent to a specific market segment that is composed of consumers with similar demand tendencies (Aaker D. A., 1996). There are five common forms of segmentation, that is, geographic, demographic, behavioral, benefit, and psychographics.

Target market. The enterprise assesses which segments it will eventually enter into among the segmented ones. It is a key point to identify the target market accurately, as well as products and services that can meet customers' needs. The undifferentiated market strategy, differentiated market strategy, and concentrating marketing are applicable during the selection of the target market (Steven Silbiger, 2005). Moreover, when evaluating the potential and commercial attractiveness of each segment, customer lifecycle marketing could work and deserve detailed observation via demand analysis.

Position. Al Ries and Jack Trout proposed that positioning starts with a specific product, which may be a good or service, an institution, or an individual. However, the first step is to figure out what customers' expectations are. In

Trout's viewpoint, positioning distinguishes your business and products from competitors and creates a core competency. You should ensure that your customers have a clear picture of and a deep impression of the brand (Phillip Kotler, et al., 2022). Iris claims that positioning is to find a space in the customer's mind and occupy it as a "base". Virtually, marketing activities are competing for the customers' attention in modern society. Furthermore, enterprises should grasp the target consumers' characteristics, and the common ones are that customers can only receive a small amount of information, prefer simplicity instead of complexity, tend to hold a stereotype of their impressions of a brand, and shift their focus rapidly (Al Ries, Jack Trout, 2001). In this way, firms will benefit from occupying the best position in the brain of customers.

3. Analysis of the green marketing based on Nestlé

3.1. The market segmentation of the green food industry

As an international giant in the food industry, Nestlé sets foot in substantial food ranges, from instant coffee, and healthy nutrients to milk powders. Actually, "green" is a neutral label that can be attached to manifold products, while this concept has been deeply interwoven with "healthy" and "high-end" as well.

Nestlé consumers can be divided from the psychological dimension into the group concerned about climate change issues, the group holding a neutral stance, and the group who show little care about it. The first category of customers mainly constitutes environmentalists, vegetarians, vegans, or people with tertiary education and respectable income, who keep a sharp lookout for quality and are relatively low sensitive to price. What they genuinely take heed of regarding products is whether the company honors its promise of reducing carbon emissions through the process from farm to table. They are also keen on understanding the sourcing of raw materials, the production process, and the company's social and environmental impact. That could account for the finding of Wheeler et al. (2013) that insufficient information sources negatively affect consumers' intentions to purchase green products, while advertisements that stress the importance of the cause stimulate their willingness to buy a product.

The second category is composed of individuals who show a weak preference for the environmental value of the food offerings or low interest in climate change problems. Nevertheless, in light of the agenda-setting function of media, the masses, now, are more frequently informed of the deplorable aftermaths of climate disasters. This type of customer hesitates to pay for green products, for their determinations are swayed by plenty of external factors, among which price is critical one, which means that they are more apt to take green food into account within their affordability, though it does not ensure ultimate purchase still. On top of that, out of certain purposes, such as the pursuit of premium goods or recognition from peers or society for their environmentally-conscious consumption choices, they may pay for zero-carbon products from time to time.

The last category is, in the main, consumers who have little awareness of environmental protection and have extremely limited consumption choices because of meagre earnings. For one thing, probably they have acquired knowledge about the urgency of green transition but the messages are distorted owing to their deep scepticism and inherent prejudice, the conflict with their established cognitive systems, and so forth. For another thing, a slender income that sets a restriction on their consumption capacity begets an averse attitude towards relatively expensive green products. No matter which class they fall into, obviously they are not major customers of green foods.

3.2. The marketing targeting of green products

Nestlé puts numerous greening efforts into its high-end product portfolio. In that greening the whole industrial chain gave rise to the surge in costs, the "zero-carbon" products tend to emerge as a premium pearl in each line.

Take Nestlé Nan milk powder as an example. The mothers' great concerns about baby food products rest on the safety, in particular ingredients and nutrients, which means that, to a large degree, parents are more likely to purchase baby food products moderately beyond their consumption level and less sensitive to the prices of high-quality products. Meanwhile, according to a survey conducted by Nestlé and JD.com, nowadays, the vast majority of mothers are apt to have natural birth, breastfeeding, and natural organic food to follow the baby's natural growth, which reflects that the parenting concept of following the law of nature is gaining popularity among the young generation of mothers. And breast milk, by its advantages of purity, safety, and enhancement of communication with babies, has become the vivid embodiment of a mother's natural view of parenting (iiMedia Research, 2020). However, such a desire failed to be satisfied due to the fact that females at work would be overwhelmed by striking a balance between family and work. It creates a huge market for organic baby food. Since this group of women with a job are more common in middle-income families with dual earners, middle-end or high-end organic milk powder for upmarket is just the ideal alternative for babies up to 12 months. Such descriptive traits correspond to the aforementioned first type of customers with high environmental awareness stemming from the tertiary education they received and the effective response to social messages.

From the case, Nestlé's green products should take the consumers with an eye on climate change spontaneously and ones who have psychological motivators of conserving the environment but are still sensitive to prices as targets. As for the former, high green premiums are justified, and they could be the chief source of current rising profits generated from green products. In terms of the latter, they can perform as future mainstream customers with a high potential to purchase and repurchase green products. The key is to cultivate their consumption habits of premium green foods by leveraging the customers' psychology of the desire for the recognition of green consumption and enhancing the performance-to-price ratio.

3.3. The marketing positioning of green products

Nestlé's market position is high-income people who pay attention to climate change and healthy lifestyles. The price serves as a significant factor to posit Nestlé's green products as high-end goods. A case at hand is Nestlé's Garden Gourmet plant-based foods and Garden of Life dietary supplement brands. The supplements as unnecessaries do not have a wide customer base, while this feature of concentrating on the fitness-focused group is beneficial for Nestlé to devote to the premium products, and catch a large proportion of customers in this niche market. For instance, its SPORT Organic Plant-Based Protein Vanilla Powder and Raw Organic Perfect Food Green Superfood Original Powder with special organic certificates are sold at a price over $45 ($56.99 and $45.99 respectively), while its Dr. Formulated Magnesium Raspberry Lemon Powder or Mykind Organics Golden Milk Powder are about $25.99 to $29.99. (The nuances of net weight within 50g are negligible here). The former lines of green products are priced some 70% or 90% higher than the ordinary or middle-end ones.

3.4. Measures for green transition

The task of achieving zero-carbon agricultural products is formidable. Ordinary farming uses pesticides and fertilizers, which produce enormous greenhouse gases such as methane and nitrogen. Research data shows that agriculture and animal husbandry contribute about 17% to global greenhouse gas emissions, ranking third only after the energy industry and construction industry. According to the *Corporate Net Zero Pathway* (Boston Consult, 2021), the food needs to be developed, raised, harvested, processed, distributed, retailed, and stored before reaching the table, each of which produces greenhouse gas emissions. Global food consumption is expected to grow by as much as 70% in the coming decades as populations grow and diets shift toward meat, making it potentially challenging to cut down carbon emissions in agriculture and food while meeting basic human needs. To tackle the dilemma, multiple food enterprises are highly vertically integrated, integrating product processing and sales with independent farm operation. Carbon emissions from breeding activities can account for more than 60% of the total emissions, and methane emissions from livestock manure cannot be ignored. More than 90% of food manufacturers' carbon emissions mainly come from indirect emissions, including raw materials, procurement, packaging, and logistics.

From the carbon emission reduction measures taken by Nestlé, it enlightens the producers to curtail carbon emissions from farming activities in the upstream agricultural and animal husbandry links, use fertilizers scientifically and efficiently, improve the soil environment, increase the use of clean energy in processing and manufacturing links, and improve packaging recycling. These measures aim to whittle down the carbon emissions in transportation and distribution of raw materials and products, which are hidden behind the products and cannot be detected by consumers for a long period.

Nestlé takes a whole-life cycle approach to determine the carbon footprint of its products. At the same time, since most of the carbon emissions come from outside Nestlé's business operations, efforts are supposed to be made to identify carbon reduction projects in all links of the value chain and implement them to the fullest, which will increase the challenges and costs. So far, Nestlé has invested 1.2 billion Swiss francs globally to promote renewable agriculture in its supply chain, part of a total investment of 3.2 billion Swiss francs by 2025. The adoption of new technologies also increases costs. Plus, Nestlé is accelerating its work in the areas of product production, packaging, and carbon-neutral branding in part by taking steps internally to pare down costs and improve performance to absorb the increased costs of new investments.

It is estimated that nearly two-thirds of the overall emissions of Nestlé's products come from land use and agriculture, so Nestlé resorts to the promotion of regenerative agriculture and reforestation and regards it as a key issue for their carbon reduction commitment. Their target is to source 20% of key ingredients through regenerative agriculture by 2025, and 50% by 2030, which means that over 14 million tonnes of ingredients will be supported by regenerative practices. The goal is advanced by cooperation with more than 500,000 farmers and 150,000 suppliers. Also, they are moving towards a Forest Positive approach and entertain an ambition of maintaining 100% deforestation-free primary supply chains by the end of 2025 for coffee and cocoa. Another investment project, the Global Reforestation Program, targeting 200 million trees planted by the end of the decades is steadily making strides, in order to further regenerative farming and coordinated collaboration with local farmers in source areas.

On the operational side, Nestlé expects to run 100 percent renewable electricity in its 800 workplaces in 187 countries within the next five years. Nestlé is working to transform its global fleet into a low-emission one and will reduce travel or offset the resulting emissions by 2022. In addition, Nestlé has adopted water conservation and regeneration measures, as well as efforts to address food waste in its operations.

In terms of product mix, Nestlé constantly introduces new plant-based foods and beverages and adjusts the formula to make the products more environmentally friendly. The organization is also working to create more "carbon neutral" brands to give consumers a chance to contribute to the fight against climate change ("Nestlé's Net Zero Roadmap", 2021).

The current food market witnesses a leap in the number of companies that are committed to sustainability and heavily inject capital into the concept of "green food" during market campaigns. When new technologies are adopted more broadly, the cost will naturally come down and the loyal consumers of green products will spike as well. It should be realized that carbon neutrality results from years of investment and accumulation, not overnight, but the boost of the green food market will reward all endeavors one day.

4. Conclusion

The world's response to climate change is confronted with the tough hindrance of the rocketing price of energy, the turbulent international landscape, and the slugging global market incurred by the persistent pandemic and following inflation. The food industry which boasts a huge customer base for its role as essentials remains a large growth space, though the sales of green products may face a sag in the short term. On the other side, the rebounding demand for healthy organic food is expected to be strong in that the pandemic enables people to pay more attention to their diet and personal health and prods more into environmental conservation by bringing them home that ecosystem health is inextricably linked to human existence. Nestlé, as a business tycoon, has developed an approximately comprehensive roadmap of carbon neutrality and is implementing it step by step. Other food companies can learn from their experiences through each line from farm to table to mitigate their carbon footprints, such as responsible procurement, zero plastic packaging, smart and green logistics, and recycle labels and recycle systems. There is little doubt that green food is the new battlefield as well as the promising growth point for all food players. The pioneers in this field enjoy more advantages to seize a larger share of the market for sustainable development in the coming future.

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Analysis of the Impact of Carbon Neutrality on Energy Saving and Emission Reduction in the Shipping Industry

Runxin XU

Dalian Maritime University, Dalian City, Liaoning Province, China, 116026
E-mail: xuexixin22@163.com
***Corresponding author**

Abstract

Carbon neutrality is the focus of the world's attention in terms of green energy efficiency and emission reduction, and is a measure developed by all mankind to mitigate unusual weather conditions such as climate change. The IMO's stricter carbon regulations, which will come into force in 2023, will make it imperative for the world to focus on reducing emissions from ships in order to meet the 2030 carbon peaking and 2060 carbon neutral targets.

By analyzing three types of currently mainstream low-carbon and zero-carbon ship power energy representatives, namely: LNG-powered ships, hydrogen-fuelled-powered ships and nuclear-powered ships. This paper illustrates the disadvantages, current applications and future prospects of these ship power energy sources, as well as some measures to reduce greenhouse gas emissions from ships in addition to energy sources. With the expectation that this paper will provide a reference for the cause of energy saving and emission reduction in the shipping industry.

Keywords: Carbon neutrality; GHG; IMO regulations; nautical science.

1. Introduction

Maritime transport is a crucial part of the global economy, carrying over 85% of the world's commodities trade and more than that in most developing countries, as well as large volumes of goods such as crude oil and ores. [1-3] Maritime transport is divided into cargo and non-cargo, with cargo ships including container ships and bulk carriers and non-cargo ships including ferries and passenger ships. However, large ships, such as those of 400 gross tonnage and above for international voyages, are required to implement Annex VI to the MARPOL Convention, which imposes certain limits on the emission of carbon dioxide and air pollutants such as sulphur dioxide during the operation of such ships.

The researchs have shown that emissions from burning fossil fuels account for 33% of total global shipping emissions and 3.3% of global CO_2 emissions. [1-4] NOx and SOx from global ship transport account for 10% and 15% of total human pollution sources each year [5]. As one of the players contributing to the greenhouse effect and air pollution, the shipping industry should be taken seriously in its efforts to reduce carbon emissions.

2. IMO 2050's objectives

The IMO is a UN (United Nations) organization whose objective is to increase safe, secure, ecologically sound, efficient, and viable shipping through partnership. [6] The IMO has played a positive role in the adoption of many conventions for the shipping industry, such as the SOLAS Convention, the STCW Convention and the MLC Convention.

In April 2018, the IMO adopted the world's first preliminary strategy for GHG emission reductions from shipping. The goal is to reduce the intensity of GHG emissions from shipping to 40% by 2030 compared to 2008, and to 50% by 2050 compared to 2008, with a 50% reduction in total carbon emissions. And to phase out GHG emissions from shipping as soon as possible within this century. [7]

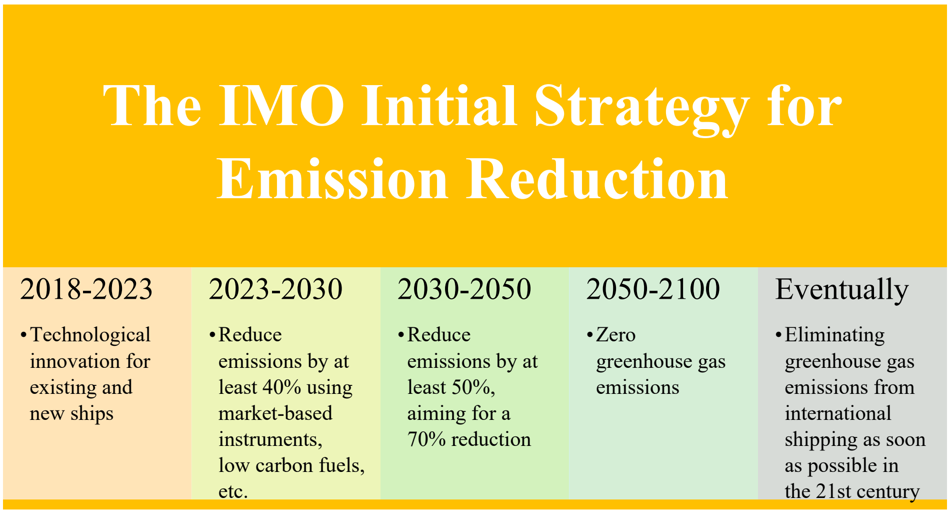

Figure 1. The IMO Initial Strategy for Emission Reduction

Emissions from shipping reached 961 million tonnes of CO_2 in 2012, compared to 816 million tonnes in 2007, an increase of around 18% in five years. And on 4 August 2020, the IMO released its GHG4 (Fourth Greenhouse Gas Study 2020) report, stating that while the global carbon intensity of maritime transport fell by about 11% between 2012 and 2018, annual GHG emissions, at 1,076 million tonnes, are still on an upward trend, with CO_2 emissions expected to rise by 50% by 2050 compared to 2018 and about one times higher than in 2008. [8]

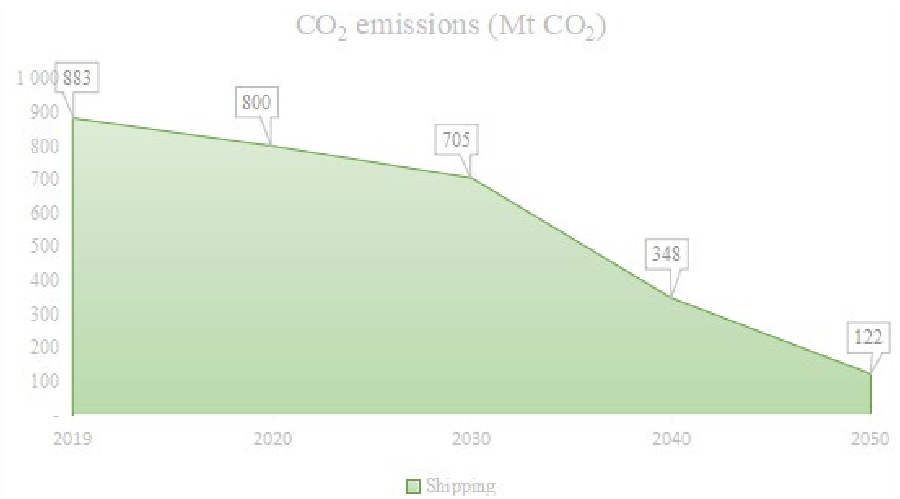

Figure 2. Carbon Emissions Projections for The Shipping Industry (Source: IEA)

According to an analysis by the IEA (International Energy Agency), shipping is expected to reduce its carbon emissions to 122 million tonnes in 2050, representing approximately 9% of the combined emissions of industry, transport and construction.

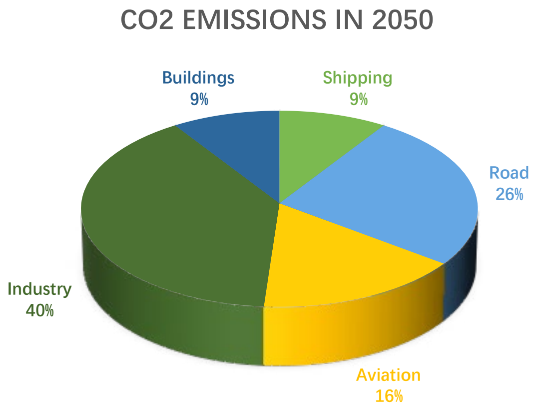

Figure 3. Carbon Emissions from Shipping, Industry and Building in 2050 (Source: IEA)

3. LNG

A ship's bunker type, power type, engine type and engine efficiency all have an impact on GHG emissions. Shipping accounts for 3% of global GHG emissions and is expected to improve the greenhouse effect by limiting GHG emissions. Low or zero carbon technologies for ships are proliferating, but large-scale applications are not yet clear. Current low or zero carbon power technologies are divided into three main groups:

a) LNG and methanol, with mature technology and competitive costs.

b) Biofuels and power cells, with mature technology and high costs.

c) Helium, hydrogen and nuclear power, with exploratory technology and expected lower costs.

3.1. LNG meets the MARPOL

LNG is recognized as the cleanest fossil energy source on the planet, with very little air pollution after combustion [9], while the energy released is high and is gradually being used for power generation, heating in small and medium-sized towns, and as a fuel for vehicles.

Table 1. according to [6,9], CO_2 emissions reduction by using alternative fuels

Types of alternative fuels	CO_2 emissions reductions
LNG	0-20%
Wind	1-32%
Solar	0-12%
Electricity	0-100%
Hydrogen	0-100%
Nuclear	0-100%

In July 2011, the IMO adopted Annex VI to the MARPOL Convention, which increases the standards for NOx and SOx emissions from ships. The ships entering the ECAs (Export Control Areas) must have less than 0.1% sulphur in their bunker by 2015, and all ships entering the ECAs will have implemented the NOx Tier 3 standard by 2016, reducing emissions by 80% compared to Tier 1.

The new MARPOL requirements, combined with the safety and economics of long-term investment, have led to a preference for the use of LNG as a clean energy source to completely solve the SOx and NOx emissions problem. LNG can reduce NOx emissions by 80-90% and achieve zero SOx emissions compared to the same calorific value of traditional bunker.

However, LNG still produces CO_2 during combustion and releases a certain amount of methane (CH_4, a greenhouse gas) due to incomplete combustion. There are already two types of LNG single-fuel engines and LNG-diesel dual-fuel engines. However, as multi-point injection LNG supply systems have not yet been developed, most LNG-fueled ships currently use mixed intake fade-point injection engines.

3.2. LNG vs. other bunkers

For bunkers, converting conventional bunkers such as MDO (Marine Diesel Oil), MFO (Marine Fuel Oil), and HFO (Heavy Fuel Oil) are examples of bunkers [3], to natural gas can be more effective in reducing greenhouse gas emissions. However, the effect will be counterproductive if the use of LNG causes leakage.

3.3. LNG carrier

LNG carriers are specialized vessels for the transportation of natural gas. The current LNG carriers are all fully refrigerated, i.e. the pressurised LNG is filled in a pressure vessel and transported at atmospheric temperature, and there are two types of vessels: Moss Spherical type and Membrane type.[10] When the LNG carrier is sailing in the ocean, as the outside temperature is higher than the container temperature, the LNG vaporizes into natural gas, causing the pressure of the container to rise. The LNG carrier will lead the generated natural gas into the main engine, avoiding the pollution caused by the direct discharge of natural gas into the atmosphere and enhancing the economic efficiency of the voyage.

3.4. Non-LNG carriers

For non-LNG carriers on long voyages, the loading of LNG will be a problem because there are no special pressure containers. In addition, LNG is a hazardous chemical in the liquefied gas category, and its fire protection requirements for ships and ports are greatly increased. Therefore, it is not easy to convert diesel consuming vessels to LNG consuming vessels and likewise some private ship owners are not very motivated to convert their vessels and remain on the fence. This fuel transition is more easily achieved on inland waterway vessels, which are smaller in comparison to ocean-going vessels, and likewise inland waterway vessels are more likely to meet the requirements of LNG-powered vessels in terms of range. In 2020, China's inland waterway transport has built 20 LNG refueling stations and 290 LNG-powered vessels.[11]

4. Hydrogen powered ships

4.1. Hydrogen in bunker

When hydrogen is added to the bunker, the reaction equation is:

$C_{m+n}H_{2x}+\left(m+\frac{n+x}{2}\right)O_2=mCO_2+nCO+xH_2O$ (1) Burning of bunkers

$2H_2+O_2=2H_2O+\text{energy}$ (2) Burning of hydrogen

Compared to burning MDO, MFO and HFO as bunker, the hydrogenation results in less CO_2 in the combustion products.

4.2. Hydrogen direct combustion

When hydrogen is burned directly in the main engine, the reaction equation is: $2H_2+O_2=2H_2O+\text{energy}$.

When it is burned directly, only H_2O is produced in the combustion products and there is no CO_2, which reduces carbon emissions by 50-70%. The thermal energy generated through the reaction is converted into mechanical energy to drive the piston to do work, but there is a large energy loss in this conversion process, with an energy conversion rate of up to 40%.[12]

4.3. Hydrogen fuel cells

Fuel cell ships are also expected to decarbonize the shipping industry.

In ship power generation, fuel cell systems are cleaner and more efficient than traditional power units such as diesel engines, while possessing features such as low noise, low vibration and less heat radiation, which can improve the living and working environment on ship. At present, it also has a number of disadvantages such as a high initial investment cost, a short service life and the difficulty of meeting the requirements of ocean voyages. PEMFCs (Proton Exchange Membrane Fuel Cells) are used directly as a power source on short-haul passenger ships, small yachts and ro-ro ships with relatively short voyage cycles, but are less commonly used on ocean-going transport vessels and are only used as auxiliary power units on board. [13]

The hydrogen fuel cell is a power generation device that converts chemical energy from Hydrogen at the anode and oxygen at the cathode into electrical energy through a redox reaction. The reaction equation is:

$H_2 \rightarrow 2H^+ + 2e^-$ (3) Cathodic reaction equation

$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$ (4) Anodic reaction equation

$H_2 + \frac{1}{2}O_2 = H_2O$ (5) Total reaction equation

In the hydrogen fuel cell reaction process, there is no CO_2 emission and the energy loss during the reaction is minimal, with a theoretical conversion efficiency of over 80% and in practice over 60%. Hydrogen fuel cells are therefore expected to be widely used in ships in the future.

Picture 1. China's first hydrogen energy fuel cell yacht sailing in Dalian port
(Source: DMU, Dalian Maritime University)

5. Nuclear propelled ships

Nuclear propulsion ships have existed since 1955, mainly for use by naval forces. The advantages of nuclear energy focus on high power density, low greenhouse gas emissions and the ability to operate for long periods of time without additional bunker[2, 15], making the ship less constrained by endurance factors and increasing its independence.

5.1. Technical limitations

Although it has advantages that are unique to other types of bunkers, the disadvantages of nuclear propulsion for ships are also obvious. From a technical point of view, nuclear power is a cutting-edge technology compared to other ship technologies, mastered by only a few countries in the world and kept strictly secret. In the absence of technology disclosure, other countries can often only achieve results through lengthy and costly project development. The high costs often exclude developing countries from the program.

5.2. Safety restrictions

Nuclear propulsion is achieved by creating a fission reaction in an on-board nuclear power reactor, releasing huge amounts of energy which is absorbed and heated by circulating cooling water to produce steam which drives steam turbines and generators. However, many port authorities refuse to allow foreign nuclear-powered ships into their ports because of concerns about radioactive contamination of shipping lanes, ports and coastal cities, or even the hijacking of nuclear-powered ships by unscrupulous elements to attack ports. The certification and licensing of nuclear-powered ships, safety regulations and the suppression of terrorist acts are obstacles that cannot be ignored.

5.3. Management constraints

As carbon neutrality continues to progress, nuclear power is expected to be used in commercial vessels.

Nuclear-powered ships require experienced technicians with knowledge of both nuclear reaction principles and engineering to maintain the ship's main engine, which undoubtedly raises the shipowner's recruitment standards and personnel costs. In addition, the impact of the radioactivity of natural uranium on the health of the crew, drinking water, etc. should be considered in detail. Used nuclear waste will also need to be properly stored or disposed of to avoid significant environmental impacts from leaks.

6. Navigational efficiency

The use of bunkers can be reduced by improving navigational efficiency, for example by optimizing the navigation route, reducing resistance to sailing, improving propulsion efficiency and keeping the ship clean.

This requires the 2/O to keep the ship on the best possible course that satisfies both the shortest route and safety. The OOW should be aware of situations that will reduce the ship's navigational efficiency and try to avoid them, such as the shallow water effect which reduces the ship's navigational efficiency and increases the ship's bunker consumption.

The following disadvantages will occur when a ship is sailing in shallow water:

a) According to Bernoulli's law, the current around the ship accelerates while the pressure around the ship decreases, causing the ship to sink, the draft to increase, the contact area between the ship and the water to increase, and the frictional resistance of the ship to increase, reducing the navigational efficiency. [14]

b) In shallow water the wave is enhanced and the wave resistance increases.

c) Stern eddies are enhanced and propeller efficiency is reduced.

d) In addition, marine sinister organisms growing on submerged hulls, such as barnacles and oysters, can also reduce the efficiency of ship propulsion and consume additional bunker. Where permissible, reduce the time spent at anchor and clean the hull in time to improve energy efficiency and reduce emissions.

7. Summary

Ocean-going vessels will have to use higher energy density bunkers and more powerful engines. As vessels become larger, with more and more 200,000 to 300,000 DWT vessels such as VLCCs (Very Large Crude Carriers), the energy density of the bunker carried and the power of the main engine used for a given volume have also increased. In order to meet the requirements of low-carbon navigation and at the same time save the cost of shipowners to retrofit their ships to a certain extent, ships should focus on encouraging the development and application of biofuel ships such as LNG and methanol on a pilot basis before 2030 when the age of the ships is relatively small and the replacement cost is high. Ships are expected to be commercially available after 2030, when the age of in-service ships generally reaches 15 years or more and replacement costs are significantly lower, when ammonia, hydrogen, and even nuclear-powered ships are expected to be commercially available. [15]

Retrofitting of ships to reduce emissions in the manner described above, to a large extent to ensure the implementation of IMO shipping industry GHG emissions reduction strategy. The transformation of ships in accordance with the above-mentioned program has largely ensured the implementation of the IMO Shipping Industry GHG Reduction Strategy and the Global Carbon Neutral Plan.

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Abbreviations

IMO, International Maritime Organization; LNG, Liquefied Natural Gas; GHG, Greenhouse Gas; MARPOL, International Convention for the Prevention of Pollution from Ships; CO_2, Carbon Dioxide; NOx, Nitrogen Oxides; SOx, Sulfur Oxides; UN, United Nations; SOLAS, International Convention for the Safety of Life at Sea; STCW, International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers; MLC, Maritime Labour Convention; GHG4, Fourth Greenhouse Gas Study 2020; IEA, International Energy Agency; ECAs, Export Control Areas; MDO, Marine Diesel Oil; MFO, Marine Fuel Oil; HFO, Heavy Fuel Oil; O_2, Oxygen; CO, Carbon Monoxide; H_2O, Water; H_2, Hydrogen; PEMFCs, Proton Exchange Membrane Fuel Cells; DMU, Dalian Maritime University; 2/O, Second Mate; OOW, Officer of the Watch; DWT, Dead Weight Tonnage; VLCCs, Very Large Crude Carriers.

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Green Finance for Green Innovation

Jun YANG

Shandong University, Jinan City, Shandong Province, China, 250100

E-mail: siriusyang03@outlook.com

***Corresponding author**

Abstract

Green finance plays an essential role in the progress of the world's green economy as a financial instrument that can achieve harmonious economic and environmental development. By summarizing the existing literature on green finance and green innovation, this paper explores the impact of green finance development on enterprise innovation and its influencing mechanism from the micro-enterprise level. It explores the internal mechanism of the effect of green finance development and enterprise innovation from the perspective of the impact of enterprise innovation on economic effect and environmental effects. Provide a policy basis for the development of green finance. The study finds that the development of green finance combined with government subsidies can significantly improve the R&D and innovation of enterprises, thus improving the competitiveness of enterprises. In addition, green innovation can improve resource utilization efficiency, reduce enterprises' energy consumption, reduce energy costs, and significantly reduce environmental pollution.

Keywords: Green Finance; green patent; corporate innovation; business.

1. Introduction

Innovation is the driving force of economic growth, and green innovation can make this growth sustainable. Unlike ordinary, innovative behavior, green innovation can not only reduce environmental pollution and improve the environmental performance of enterprises, but more importantly, it can enable enterprises to produce diversified products and effectively improve their competitiveness, thus achieving a "win-win" situation in terms of economic benefits and environmental protection. " Green innovation is a crucial way to achieve harmonious development of economic growth and environmental protection, mainly including new technologies and services that can reduce environmental pollution and promote sustainable development and so on(Rennings, 2000), which can help enterprises to achieve a win-win situation in terms of both economic and environmental benefits and is a meaningful way to mitigate the negative environmental impacts of economic activities (Horbach, 2008; Song & Yu, 2018). Amore and Bennedsen (2016) argue that green innovation has become a central tool for companies to save resources and mitigate pollution. A sustainable development approach based on ecological security and green concepts is now a common path explored by scholars and policymakers worldwide (OECD, 2008). Following the promotion of the Kyoto Protocol and the

Eco-Innovation Plan, the UN and the EU have further proposed the 17 Goals for People and Planet and the Post-2015 EU and Global Development Framework to integrate ecological conservation and sustainable development into long-term development strategies, of which green innovation is an integral part.

Based on the vital perspective of green finance, this paper will discuss whether green finance can stimulate corporate green innovation and the theoretical mechanisms by which green innovation promotes the green development of the economy, drawing on the literature and economic phenomena. The research of this paper has the following values :

(1) Exploring the impact of green finance development on enterprise innovation and its influencing mechanism from the micro-enterprise level;
(2) Based on the perspective of the impact of corporate innovation on economic effect and environmental effect, this paper explores the internal mechanism of the role of green finance development and corporate innova tion.

2. Literature review

In the relationship between finance and economic development, financial support for technological innovation is an ‘old topic’; however, there is still relatively little theoretical research on the sub-sector of green finance. The most recent studies provide some empirical evidence but must directly address the relationship between green finance and economic development. This paper explores how green finance can contribute to the green development of the economy by supporting green innovation. Only some existing studies directly address this issue, including classical sustainable growth theory and the recent emergence of research on the environmental and economic impacts of green finance. Firstly, sustainable growth theory has explored the issue of long-term sustainable growth under ecological and resource constraints. A consensus in the field is that technological progress is the basis for long-term sustainable development (Shuijun & Qun, 2006; Menetetal, 2021). The modeling of sustainable growth theory has developed a relatively mature framework, and in recent years, some literature has explored green finance based on sustainable growth theory. However, the existing studies still need to address the role of finance in supporting green innovation and its impact on economic growth. Secondly, theoretical research on green finance has progressed slowly, particularly concerning the relationship between green finance and economic development.

In the last five years, as the topic of green finance has received increasing attention, the macroeconomic effects of green finance has become an important trend in this area of research. In the last three years, with the enrichment of empirical samples, scholars are increasingly inclined to believe that green finance does have the critical function of promoting green economic development(Liueta, 2019). The studies of Liu Xiliang and Wenwen Yang (2019) and Donge (2019) were early attempts to incorporate financial factors into the theoretical framework of sustainable growth. However, their studies mainly focused on the relationship between credit discrimination and environmental pollution and did not address green finance in its current sense. Meanwhile, Wen and Yang (2021, 2022) provide a theoretical model of sustainable growth in the financial sector but need to explore the internal aspects of green finance. Wen and Yang (2021, 2022) gave theoretical models of sustainable development in the financial sector, but the issue of endogenous abatement technologies still needs to be explored. The theoretical mechanisms of the relationship between green finance and economic development have yet to be explored, and there needs to be more theoretical literature that specifically addresses the mechanisms underlying the impact of green finance on economic growth through green innovation.

On the other hand, in sustainable growth theory, green innovation and technology are the core factors affecting the green development of the economy. There is currently some theoretical literature incorporating green finance into the framework of sustainable growth theory. However, it needs to consider the issue of the impact of green finance on green innovation.

3. Path analysis

Green innovation is an innovative behavior that aims to alleviate environmental problems and promote sustainable development. Under the current non-optimistic ecological situation, it is imperative to encourage and support enterprises to carry out green innovation, and enterprises also follow the trend to innovate. Enterprises generally enhance research and development to achieve innovation and technological progress and then improve the competitiveness of enterprises. This kind of innovation that can significantly promote the technological advancement of enterprises is called "substantive" innovation. However, due to the limited R&D capabilities of some enterprises, to obtain certain benefits, the management of the company usually carries out a kind of "strategic" innovation (Tong et al.,2014). Wang and Zhou (2022) used green utility model patents to represent the "strategic" innovation behavior of enterprises, pointing out that while green finance provides financial support to enterprises, enterprises face strict supervision rather than "substantive" innovation that is difficult and of high quality. Using the unbalanced panel data of 2058 listed companies in Shanghai and Shenzhen A-share markets from 2011 to 2020 for empirical analysis, it concluded that the development of green finance could significantly improve the R&D innovation of enterprises, and the effect on the "strategic" innovation of enterprises is more significant.

Achieving the goal of enterprise innovation requires sufficient financial support, and the difficulty of financing is still a critical issue that restricts the development of enterprises, especially SMEs(Small and Medium-sized Enterprises). Green finance has come into being to promote enterprises' green development. The development of green finance is mainly to alleviate the financing constraints through government subsidies, promote the green innovation activities of enterprises, and promote the economic and environmental effects of corporate green innovation. Let us take green bonds as an example to illustrate the mechanism of green finance: (1) For investors, due to the strong support from the government and strict supervision and screening by the regulatory authorities, the credit rating of enterprises issuing green bonds is higher, and the risk of default is lower, so investors are willing to buy green bonds at a lower coupon rate. (2) For enterprises, issuing green bonds can obtain funds at a lower cost than the average debt financing in society, thus reducing the risk of green innovation. (3) In the context of the government's efforts to promote "green" development, investors' recognition and investment enthusiasm for green bonds and high market attention can reduce the issuance cost of green bonds and bring "green" incentives to the financing side. From the above three aspects, we can see that green financial instruments can reduce the financing constraints of enterprises by reasonably matching risks and returns, thus increasing the source of funds for green R&D activities with higher risks and providing protection for enterprises' green innovation activities, and making external investors more willing to provide funds for enterprises' R&D. support, thus promoting enterprises' innovation inputs and outputs. If such a mechanism exists, it can infer that the development of green finance has a more significant impact on enterprises' innovation activities for those enterprises with more severe external financing constraints.

Public finance policy is one of the basic policies of the state to regulate economic activities. The development of green finance is inseparable from the support of fiscal policy, which can promote the development of green finance through tax policy and financial subsidies. Government subsidies to enterprises are free of charge, which can alleviate the financing constraints of enterprises and encourage them to carry out innovative activities (Lu & Li, 2016). Due to the existence of information asymmetry, the government does not have a good grasp of the actual situation of enterprises' business projects, and the government has limited access to information, so there may be bias in deciding which enterprises to give subsidies to, and some enterprises with green innovation potential have difficulties in receiving policy preferences. Studies have also shown that government subsidies have a clear tendency to favor large-scale enterprises in the allocation process. This policy bias can weaken the driving force of green finance policies for firms to undertake innovative activities.

The direct purpose of developing green finance is to reduce environmental risks and create new economic growth points. The impact of green finance on the economy and environment is mainly realized through the green innovation of enterprises. The effect of green innovation on enterprises is primarily reflected in the following aspects: First, green innovation can improve the utilization efficiency of resources, reduce the energy consumption of enterprises, and lower energy costs (Jiang & Ma, 2019); second, green technology innovation can significantly reduce environmental pollution and lower the ecological compliance costs of enterprises (Xu & Zhang, 2021). Third, green technology innovation can improve the competitiveness of enterprises and, at the same time, create an image for enterprises to fulfill their social responsibility, which helps them gain public support and increase their market share, thus enhancing their value (Chen et al., 2006; Xie & Zhu, 2021). However, to improve the environment, companies usually need to make green innovations to reduce pollution, lower energy consumption, and lower environmental management costs, which require innovative technologies. Green non-invention patents still dominate green patents in China, and the technology level of green non-invention patents may be higher, which is challenging to meet the requirements for improving corporate environmental performance. Therefore, the role of green innovation in improving corporate environmental performance needs to be revealed. For example, Li et al. (2019) found a significant U-shaped relationship between corporate innovation and environmental performance, while the effect of corporate innovation on short-term ecological performance was not significant.

4. Conclusion

The development of green finance has a significant promotion effect on corporate innovation. However, the promotion effect of green finance development on corporate green invention patents is insignificant, while the impact on corporate green non-invention patents is significant. In addition, compared with other regions, the development of green finance plays a more substantial role in promoting innovation in areas with a high degree of intellectual property protection and non-heavy polluting enterprises. The story of green finance can also encourage enterprises to carry out green innovation activities by alleviating their financing constraints, providing impetus for innovation activities.

In green finance development, laws and regulations on intellectual property protection should be strengthened to provide a good external environment for green finance to support enterprise innovation. In the process of implementing green financial policies, we should rationally allocate green financial resources, dynamically adjust the intensity of environmental protection punishment and incentive policies, strengthen the investment and financing of heavily polluting enterprises, and give more opportunities and support to heavy polluting enterprises that want to realize transformation and upgrading.

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Sustainable Public Transportation Planning: An Integrated Subway Uses Design Model for TOD

Tianyi YE

Chang'an University, Xi'an City, Shaanxi Province, China, 610000

E-mail: 764621409@qq.com

***Corresponding author**

Abstract

With the advancement of urbanization in our country, the situation of increasingly congested road in large cities is increasingly serious. Transit-oriented development (TOD) creates urban development plans based on transit systems, thus improving land use and transit operations. Urban public transportation is the main effective way to solve the problem of increasingly congested city ground traffic, and public transport priority is the important guarantee to realize the way. This essay analysis the successful urban rail transit policy in Tokyo and some suggestions have been proposed for the implementation of China's large cities public transport priority strategy.

Keywords: TOD; subway systems; urban rail transit policy.

1. Introduction

To what extent can TOD use in improving integrated subway design in sustainable public transportation?

Transportation infrastructure profoundly influences urban development. Automobile-based development strategies increase commuting distances and reduce land-use efficiency (Lin, 2006). Since sustainable public transportation systems promote more efficient resource usage, cities are increasingly applying transit-based strategies to solve urban planning problems. A sustainable public transportation system designed to encourage public transit has been rapidly constructed to the effects of urbanization, such as urban congestion and excessive air pollution. Transit-oriented development (TOD) creates urban development plans based on transit systems, thus improving land use and transit operations (Lin, 2006). The cities which don't follow TOD-type planning may have negative impacts on public transportation, urban congestion, and excessive air pollution problems will be serious. This essay aims to analyze to what extent TOD can be used in improving integrated subway design in sustainable public transportation. This essay shows how developed countries made the successful integrated subway model designed by TOD and how developing countries such as China can use the successful experience of Seoul to create subway sustainable public transportation. This essay also analysis the issue of the experiences and achievement of Tokyo in implementing the public transport priority strategy which is donated by urban rail transit, and experiences are summed up.

2. The definition and basic situation of TOD

American scholar Peter Calthorpe first proposed Transit-Oriented Development (TOD) in the late 1980s (Jamme et al.,2019). It is widely recognized as one of the most effective ways to reduce traffic congestion and environmental pollution. TOD is a planning policy of designing that concentrates on urban growth around transit stops to support higher public transportation usage. TOD is usually defined by comfortable walking distances to a designated transit stop (Calthorpe,1993). Transit professionals have established heuristics of 5 to 10-minute walking distances to transit stops. Walking distances is usually a radius of 300–400 m (about a quarter-mile) or 600–800 m (a half-mile) around bus stops and rail stations (Stojanovski, 2020). It is suggested that a majority (50%) of travel movements need to be accommodated by the sustainable modes (walking, cycling, and public transit) for a location to assume the label of 'genuine' TOD (Hale, 2012). It is argued in ITDP (2022) that TOD has several vital features, for example, access for all to local and citywide opportunities and resources by the most efficient and healthful combination of mobility modes, at the lowest financial and environmental cost, and with the highest resilience to disruptive events. Through many years of practice and theoretical exploration, TOD has become a relatively mature principle of urban planning and design to harmonize urban traffic and development effectively (He, 2014).

3. The success of TOD at transit stations

Following the publication by Calthorpe (1993) between mobility and urbanization, the TOD concept was popularised in urban planning and city development (Tamakloe, 2021). Developed countries such as the US, Canada, and Australia applied TOD projects during the 1990s and 2000s. The success of TOD in cities in the USA and developed counties of Europe generated a positive effect. As a result, transportation managers and policymakers have implemented TOD strategies in many urban cities worldwide (Tamakloe, 2021). However, not only the developed countries, Seoul, the capital of South Korea, was a successful case of TOD efficiency at transit stations.

3.1. The efficiency of TOD at transit stations in Seoul

Seoul, in South Korea, has one of the most complicated and robust public transportation networks in the world. In the case of Seoul, TOD at transit stations show dense development patterns and a compact land-use mix (Tamakloe et al., 2021). A study written by Sung and Oh (2011) identified that aspects of western-based TOD features are applicable in Seoul despite its unique features. Station design, land use, and transit supply are the planning factors which increase public transit ridership. Sung and Oh (2011) also proposed the development of well-designed street networks and selecting appropriate land-use strategies. Developing well-integrated public systems of buses and subways would help boost TOD performance. Seoul has one of the most advanced and extensive transit systems globally (Tamakloe et al., 2021). Advanced and extensive transit system is the successful result of an integrated distance-based fare system which provides fare discount according to distance. The other two reasons are the well-planned transit stations based on TOD planning factors, and the Government keeps on investing a lot in the public transit system.

3.2. Implement urban rail transit policy in Tokyo

Japanese cities implement the policy of public transport strategy which is dominated by urban rail transit. Tokyo is a typical representative city. Tokyo has the world's most complicated urban railway transport system with a dense flow of people and commuter station groups (Zhang,2014). Urban sprawl has led to longer travel times and higher travel costs. In this case, the people living on the less convenient travel are very inconvenient. Yaolong Zhao and Yuji Murayama (2006) discussed the early urban layout, that is, the commercial district is located in the centre of the city, and the residential district is distributed around the commercial district. As the city continues to grow, commercial areas expand outward, and the residential land in the city centre gradually decreases. People on low incomes have to live far from their workplaces. Remote communities and poor transportation will result in unemployment for low-income people.

The development of urban rail transit is an important measure to solve the inequalities in transportation accessibility among people in different areas. Suburbanites spend less money and time on transportation, according to the report. People with low incomes are more likely to find jobs in the city centre (Yao-lung Cho and Yuji Murayama, 2006). Japanese cities carry out the public transport strategy policy with urban rail transit as the leading. Tokyo is a typical representative city. Tokyo has the most complex urban rail transit system in the world, and a dense group of commuter stations (Zhang, 2014). Figure 1 is the Tokyo subway route map, it shows the high-density distribution of Tokyo subway stations. The Tokyo government attaches great importance to the construction of subways and trams, integrating light rail, monorail, automatic rail and other forms of urban rail transit in the centre of Tokyo. In addition, Zhang (2014) discussed that the coverage rate of the central area of the railway network in the Tokyo metropolitan area is close to 100%, and the high-density rail transit ensures the high efficiency of transportation. The table1 shows line scale and density, network speed combination, the coverage rate of the central area, number of transfer nodes of Tokyo urban rail transit.

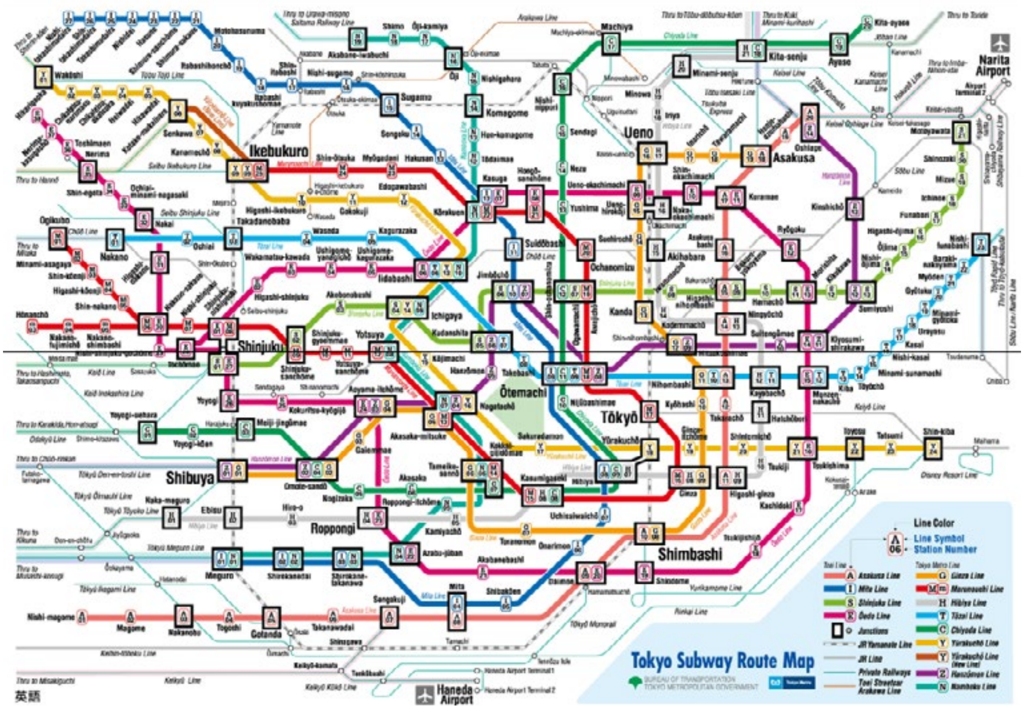

Fig. 1. Tokyo subway route map (Zhang, 2014)

Table. 1 . Overview of Tokyo urban rail transit

	Line scale and density	Network speed combination	Number of transfer nodes	Coverage rate of central area
Tokyo	2.2 km/km²	260 km/h	112 one line	100%

The ground public transport system is dominated by buses and taxis, which are closely connected with rail transit stations. For long-distance traffic, the efficiency of traffic transfer needs to be solved. The transportation hub building built by the government not only solves the traffic transfer problem but also forms a unique Tokyo urban hub public building. For example, Figure 2 describes the Shibuya station transfer system carefully. Different types of vehicles are designed to be parked in different places. It can ensure railway traffic security and rapidity. Passenger flow is organized reasonably, efficiently and orderly. In addition, as a complement to the subway line network, Tokyo has a large number of bus lanes. This helps to ensure the priority of the bus transportation system, and the bus operation is fast and efficient.

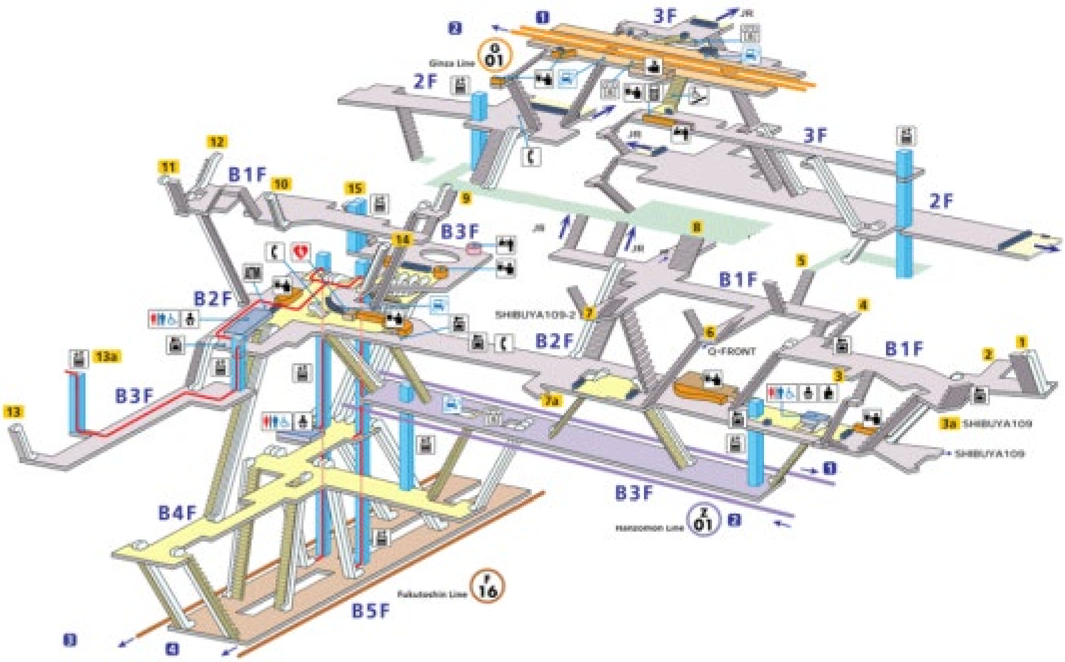

Fig. 2 Shibuya station transfer system (Zhang, 2014)

In conclusion, a perfect urban rail transit system is of great significance. It will not only reduce the distance between the city centre and the suburbs but also provide employment opportunities for low-income people, thus alleviating the transportation equity problems caused by regional differences.

3.3 Construction toll and subsidies in Tokyo

Tokyo is a densely populated large city, depending on highway transportation alone is far from adequate and is easily jammed. On the other hand, a high level of private vehicle related expenses is impractical. Based on the situation of development, Tokyo had formulated the development strategy, mainly to develop rail transit network and supplement the network by vehicles.

Data from World Bank showed that the total railway system is privately owned. In the early stage, the railway system of Tokyo was invested by government. With the construction of the whole system, the operation of railway becomes private gradually. The largest private company JR, was formed after the resolution of Japan National Railways in 1987. The construction consumption was paid by those private companies, which leads to great financial pressure. On the other hand, Li (2010) mentioned that the government stipulated that transportation companies are not allowed to raise prices until they make a loss. The price adjustment rate should be based on the change of price growth index, with a maximum of 20%. This makes those companies have less or no profit. Thus, some companies may close routes to remote areas and do harm to equity.

Government can adopt public support policies to ensure public welfare and marketability of private railways. Subsidies can be offered in construction and maintenance to encourage the investigation in public transportation construction. Li (2020) encouraged that as railway system is positioned as main mode of transportation, the scope of subsidies can be extended to construction and maintenance for all railways whether built by government or private. In addition, subsidies can be available for renovation projects used to expand rail capacity and reduce traffic congestion.

4. TOD used in developing countries

TOD has been used in dozens of projects in the US, Canada, and Australia since the 1990s. In Europe, it is considered the best practice for controlling urban sprawl. TOD has been widely used in developed countries in the last forty years. After the 2000s, the concept of TOD was promoted in Chinese cities. In addition, Johannesburg and Cape Town in South Africa has begun using the TOD concept (Ogra & Ndebele, 2014; Wilkinson, 2006). However, TOD is now decades old, and interested practitioners need to face the future with a firmer quantitative base. Hale (2012) calls it "a more dexterous approach to analysis and conceptualization". It shows that developing countries apply a more dexterous TOD system to urban congestion and excessive air pollution. However, as a developing country, Seoul has one of the most advanced and extensive transit systems globally. China and other developing countries will gain experience from the successful case in Seoul.

4.1. How to improve the situation of traffic in developing countries

Developing countries usually build an integrated transit system by TOD in capital or megacities. There will be a problem that the neighbouring cities primarily rely on capital or megacities because of their social-economic needs. Seoul is an especially example of it. Seoul's neighbouring cities primarily rely on it for their social-economic needs, just like many other capital cities worldwide (Jang et al., 2017). This dependence relationship leads to congestion in the city. However, the Seoul Metropolitan Government formulates a TOD strategy in Seoul to encourage residents to go out by public transportation. This strategy can be used in China's capital, Beijing capital, or in megacities such as Shanghai, Shenzhen, and Hangzhou. The Seoul Metropolitan Government also built an integrated transit system of subways and buses as an intervention to solve the congestion problem. In recent years, an integrated transit system of subway and bus has been rapidly built in China. The best-designed Bus rapid transit (BRT) systems worldwide offer service comparable to rail transit and at a lower cost(Deng & Nelson, 2011). However, BRT is not a single technology. A bus network adopts many features that are usually only used in subways. BRT applied successfully in Korea, and China might be an excellent policy for Africa's developing countries. Currently, the transport system covers most parts of Seoul.

Moreover, Seoul has a mature shared-bicycles system in the public transport system to help solve the first-and last-mile problem. The first-and last-mile problem usually means how to get to and from the public transit stops to the final destination. Solving this problem successfully is also a perfect solution for developing countries to solve close range of traffic problems.

4.2. Change the way of travel and build a multi-core city

As the political center and the largest economic center of Japan, Tokyo's geographical location and political and economic status make it a region connected with the surrounding cities, known as the Tokyo Metropolitan Area (TMA). As a center, Tokyo is closely connected to surrounding cities for life, freight and many other commercial activities, and transportation is the link that builds these links. In addition, the formation of TMA has made people from surrounding cities are more willing to come to Tokyo. As a result, several "dormitory cities" were built around Tokyo, that is, people here go to Tokyo during the day and return to "dormitory cities" at night (Hideo, 1995). People tend to travel by car, and the large number of private cars and relatively concentrated travel times have resulted in severe traffic congestion in Tokyo.

Some cities have tried to vigorously develop car sharing and online car hailing to ease the pressure brought by private cars. However, due to the space limitation of car sharing and the peak period of online car hailing, these measures are not effective (Ikezoe, 2021). Ikezoe et al. (2021) found through the survey that 66.8% of residents only need 10 minutes to get to the station, but still insist on driving. It is not difficult to see that convenient public transportation and shared transportation do not strongly attract private car owners. To alleviate this problem, it is an effective way to reduce residents' desire to use private cars to travel. For example, reducing the number of parking Spaces in the central area, raising parking fees, establishing a congestion charge system and restricting private cars from entering the city center are all good choices.

The reduction of car ownership can improve traffic congestion, and more people will choose to share transportation, which will cause the congestion of public transportation and the difficulty of taking a taxi. In addition, as a relatively novel way of travel, shared transportation has the fairness problem of low usability of special groups such as the low class and the elderly. Eppenberger and Richter (2021) mention that only a small number of people are good at sharing transportation services, and most of them are middle and upper income people with higher education.

To solve the contradiction between private cars and shared transportation, it is important to change the urban form. Zhou and Gao (2020) mentioned that the future development trend of Tokyo is to build a multi-core and multi-level city cluster. The change of traffic mode will affect the choice of functional location, thus redistributing the economic, cultural and commercial activities of the city, leading to the aggregation and decentralization of urban functions, and promoting the formation of new urban forms.

5. Conclusion

This essay has discussed how TOD can be used to improve integrated subway design in sustainable public transportation. This essay gives Seoul's sustainable public transportation planning designed by TOD as a successful example to developing countries. The analysis of TOD policy in Seoul here has extended our knowledge of TOD and the solution to urban congestion and excessive air pollution problems. The research has also suggested that developing countries can gain the successful experience of Seoul and develop their particular policy on public transportation. The successful experience in Seoul has five essential factors. 1. Seoul Metropolitan Government formulates a TOD strategy for Seoul. 2.The development of well-designed street networks and selecting appropriate land-use strategies. 3. Developing well-integrated public systems of buses and subways. 4. An integrated distance-based fare system provides fare discounts according to distance. 5. Mature shared-bicycles system to solve the first-and last-mile problem. These five factors can improve the situation of TOD in developing countries, and the government formulating a suitable TOD strategy is the most important. This essay also analysis the issue of the experiences and achievement of Tokyo in implementing the public transport priority strategy which is donated by urban rail transit, and experiences are summed up. It effectively alleviates the urban ground traffic congestion problem by using advanced rail transit. On the basis of it, some suggestions have been proposed for the implementation of China's large cities public transport priority strategy. A perfect urban rail transit system is of great significance. It will not only reduce the distance between the city center and the suburbs, but also provide employment opportunities for low-income people, thus alleviating the transportation equity problems caused by regional differences. Developing countries which want to develop their public transportation systems by TOD can gain successful experience in Seoul. A dexterous TOD strategy helps solve problems of urbanization, such as urban congestion and excessive air pollution.

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Report on the EU's Progress Towards Carbon Neutrality: Current Achievements and Challenges

Wanqing YU

Capital University of Economics and Business, Beijing, China, 100070
E-mail: yuwanqing_athena@yeah.net
***Corresponding author**

Abstract

European countries that industrialized earlier had about 60 years to complete the transition from carbon peak to carbon neutrality, and had accumulated much experience in the field of carbon emission management. As the vanguard of carbon emission reduction in the world, EU have many good strategies to learn from in low-carbon development and transformation. Through the analysis of the EU low-carbon transformation, it is found that the important measures are to increase the proportion of renewable energy in the power system, accelerate the low-carbon development of the transport sector, accelerate the improvement of energy efficiency in the building sector, and accelerate the green upgrading of the industrial sector. The current energy crisis in the EU has hindered the progress of carbon neutrality. The unitary energy types and aggressive carbon market policies have failed to regulate energy prices. By the energy crisis triggered by the economic crisis will force the EU forgo short-term to achieve the target of SDGs requirements, but the global response to climate change and to speed up the transformation of energy is the irreversible trend.

Keywords: carbon neutrality; achievements; challenges.

1. Introduction

As a global leader in tackling climate change, the EU has long been the pioneer of the carbon neutral goal. The different carbon neutrality targets set by the EU countries are inseparable from their energy resource endowments and economic development levels. But more attention should be paid to the sustainability ambitions conveyed by these advanced economies. By 2022, 126 countries had committed to achieving carbon neutrality by the middle of the 21st century through policy declarations, legal provisions or submission to the United Nations. These include The Long-term low greenhouse gas emission development strategies and The United Nations Framework Convention on Climate Change submitted by 12 countries to Secretariat set out a carbon neutral goal. Eighteen economies, including Germany, Sweden, the European Union, Japan and France, have enshrined carbon neutral targets in law.

2. Europe: the green transition is accelerating

The EU’s green and low-carbon development is closely related to the flourishing of green political parties. European Green political parties are the products of the pursuit of sustainable economic and social development in the process of European integration. It emerged in the post-industrial period of Western Europe, and its influence on the EU and its member states has risen rapidly in recent years. In the European Parliament elections on 23 May 2019, the European Green political parties won a total of 55 MEPs, an increase of about 50% compared to 2014 and reaching its own all-time high. Meanwhile, green parties are moving to the political center in a succession of EU member states. In Finland, for example, The Green League became a coalition party in the new government in 2019. France’s Europe Ecologie les Verts emerged as the biggest winner in the French municipal elections on June 28, 2020. The greening of Europe’s political ecology has laid a solid political foundation for the EU’s green and low-carbon development.

The EU and its member states are actively drawing up a carbon neutral development blueprint. In November 2018, the European Commission first put forward the vision of achieving carbon neutrality by 2050. The draft—— European Climate Law, will be submitted to the European Parliament in March 2020, aiming to ensure that EU institutions and member states achieve climate neutrality through secondary legislation. In October 2020, the European Parliament voted to reduce greenhouse gas emissions by 60 percent from 1990 levels by 2030. In addition, different EU member states have developed different carbon neutral plans. For example, Norway, Finland and Iceland have set 2030, 2035 and 2040 as the target years for achieving carbon neutrality respectively. Sweden, Denmark, Germany, France, Spain and Hungary have all passed legislation to set carbon-neutral development goals by 2050. Slovakia and Portugal, in their LST (Long-term Low Emission Strategy) documents submitted to the UNFCCC secretariat, set a carbon neutrality target time before 2060.

In order to achieve sustainable development, with green development and carbon neutrality as the core, the European Commission launched European Green New Deal on December 11, 2019, as a key guidance document to guide the future social development of the EU. It proposed to realize green transformation from seven aspects and supplement it with financial support plans. The following four points are directly related to carbon emission control.

2.1. Provide clean, affordable and secure energy

The transformation of the energy system is the most important step towards achieving the EU’s 2030 and 2050 climate goals. Among them, improving energy efficiency is particularly critical, and the electric power sector, as an important energy conversion and utilization sector, proposes to quickly eliminate the use of coal. Mainly rely on renewable energy, and decarbonize the use of natural gas. Germany, for example, has accelerated the process of phasing out coal power capacity in order to promote low-carbon development. The first “decommissioning bid” was launched on September 1, 2020, offering subsidies over the next 10 years to coal-fired power plants that were commissioned before 1990 and were willing to retire early. In 2020, about 52.5 percent of Germany’s electricity generation will be generated from renewable sources, and it is expected to reach 65 percent by 2030.

2.2. Promote industrial transformation into a clean and circular economy

Industry will remain an important part of the EU's long-term economic development. The EU stressed that energy-intensive industries such as steel, chemicals and cement, as important raw material suppliers, are indispensable to economic development, and explicitly stated that it will strengthen the development of low-carbon technologies on the premise of ensuring industrial security. Climate neutrality and digitalization of the industrial sector were highlighted in the EU Industrial Strategy published in March 2020. However, no specific route has been given for the transformation of these energy-intensive industries. As is known to all, Germany is an important exporter of chemical products in the world. It has gradually realized the green and low-carbon transformation of the chemical industry by persisting in the research and development of energy-efficient technologies for the chemical industry, reducing the cost of raw materials, implementing green marketing strategies and using government incentive policies and other measures.

2.3. Building energy-saving upgrading and renovation

Building energy consumption accounts for about 40 percent of the terminal energy consumption in the EU.

Reducing building energy consumption and improving the energy consumption structure of buildings will be the two main directions to achieve low-carbon transformation. Belgium and Germany are in a leading position in ultra-low energy green buildings. Ultra-low energy buildings and near-zero energy buildings represented by "passive houses" have become a common trend, and the application scope has expanded from the initial small projects in the middle and low floors to large public building cases. At the same time, existing buildings such as old urban areas and industrial parks have also been included in the transformation schedule.

2.4. Speed up to the wisdom of sustainable transportation

Transport contributes about a quarter of the EU's greenhouse gas emissions, and the EU has focused on expanding rail and river capacity to speed up low-carbon road transport. At the same time, it is committed to increasing the proportion of renewable transportation fuels. The French government issued the LOM (La loi d'orientation desmobilités) on December 24, 2019, which stipulates that the total carbon dioxide emissions in the transportation sector will be reduced by 37.5 percent by 2030. And stop selling vehicles-using fossil fuels ,such as petrol, diesel and natural gas, by 2040 to ensure the transport sector achieves carbon neutrality by 2050. To promote public transport, cycling and other green mobility, the Future-oriented Transport Act also provides 13.7 billion euros by 2023 to transform transport infrastructure, increase the number of charging points for electric vehicles by five times by 2022, and increase the number of charging points for electric vehicles by five times by 2022. They set up 3 500 million euro fund to manage travel of bicycles, electric scooters.

2. Europe: doubts and challenges

As autumn and winter approaches, how Europe will survive the winter in the face of soaring energy prices and widening supply gaps is under scrutiny. European imports nearly half of natural gas from Russia, sales to Europe accounted for one-third of the Russian gas exports of natural gas. Germany gets 55 percent of its gas imports, 50 percent of its hard coal and 30 percent of its oil from Russia, and Astora, a subsidiary of Russian energy giant Gazprom, owns more than a third of Germany's gas storage facilities. The uncertainty in energy suppliers has led to panic buying in European gas and electricity markets, with sharp price swings in the eurozone electricity market. The economic strain of the energy crisis is spreading across Europe. Facing the pressure of insufficient energy supply, Germany, Austria, the Netherlands, France and other European countries have announced in recent months to restart coal-fired power generation or delay the process of retiring coal. The Netherlands, for example, said at the end of June that it planned to lift its cap on coal-fired energy production and allow coal-fired power plants to operate at full capacity until 2024. Germany in early July abandoned its goal of "close to 100% renewable energy" in its grid by 2035 and said its carbon-neutral energy target for the energy sector would be reached after coal-fired power was phased out. The side effect of energy policy adjustment in many European countries is also obvious, and doubts about the carbon neutrality target are gradually growing.

The Russia-Ukraine conflict has exposed the weakness of EU countries' dependence on Russian energy, reflecting that under the circumstances of profound changes in the international situation and intensified regional conflicts, the unity of national energy supply will inevitably lead to the harm of their own energy security and economic security. Europe while trying to increase the energy supply diversification, energy investment and energy-saving measures to reduce dependence on Russian energy, speed up the green energy transformation, but this doesn't happen overnight, Europe's dependence on fossil fuels is not variable. The pursuit of green energy in European countries is too aggressive. When the demand changes little, the policy reduction of energy supply pushes up the price of energy and raw materials, while the increase in the price of carbon credits also pushes up the price of energy which increases the financial burden on people's lives.

3. Conclusion

In order to get rid of dependence on Russian energy, EU countries have to restart coal power, which is not conducive to the global energy transition and carbon neutrality process but a helpless choice. However, judging from the general trend, the global response to climate change and accelerated energy transition are irreversible trends, and EU will not change its positive position on curbing global warming. It is regrettable to see little progress on Global GHG emissions relative to Paris targets in the SDGs, but EU's past contribution should not be overlooked.

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Report on Proposals for a Carbon Neutral Development Pathway in the EU

Di ZHANG

Henan Normal University, Xinxiang City, Henan Province,China, 453007
E-mail: zd1219736@163.com
***Corresponding author**

Abstract

There is now a universal understanding that addressing climate change is one of the greatest challenges confronting humanity today. In light of this, the paper focuses on the process of developing an all-encompassing, cutting-edge, practical, and logical approach to carbon neutrality in the EU. It briefly discusses the establishment of carbon neutrality throughout the world within the context of the problem of the global climate, describes the state of carbon neutrality in the EU at the present time, and discusses the current issues, the EU is facing, using the energy crisis in the winter of 2021 as an example. On this foundation, the analysis is presented from various angles, and suggestions are made, such as the increasing financial investment in carbon neutrality, looking for ongoing technological breakthroughs, attempting to take social equity into account, continuing to provide funds to developing nations, and speeding up carbon trading and pricing systems. The EU's route toward carbon neutral development does need to be enhanced and optimized; if this is not done in a timely manner, it will not only have an adverse effect on the EU's development but also negatively impact global carbon neutrality.

Keywords: Carbon peaks; carbon neutrality; EU; policy framework; development pathways; recommendations.

1. Report on proposals for a carbon neutral development pathway in the EU background

With the economy and society's continued growth in recent decades, there have been an increasing number of global climate issues. Among these are high global temperatures, ocean acidification, sea level rise, extreme precipitation, and other issues that have repeatedly surfaced and raised concern around the world. Data show that compared to the years 1980 to 1999, the frequency of natural disasters, the number of persons affected, and economic losses have all grown dramatically in recent years (Reduction, 2020). The United Nations Intergovernmental Panel on Climate Change has assessed that atmospheric CO_2 concentrations will increase from 285 ppm in 1860 to 414 ppm (IPCC, The fifth assessment report of the intergovernmental panel on climate change., 2013) in 2020 and that the global average surface temperature over land and sea will rise by 1.09°C (IPCC, The sixth assessment report of the intergovernmental panel on climate change., 2021). The 2015 Paris Agreement sets the goal of "holding the global average temperature rise to within 2°C of pre-industrial levels, and to achieve 1°C warming. "Keeping the global average temperature increase from pre-industrial levels to under 2°C and working towards a limit of 1.5°C," reads the 2015 Paris Agreement. (UNFCCC, 2015). However, it forecasts that between 2030 and2052, the average global surface temperature would increase to 1.5°C. (IPCC, Special Report on Global Warming of 1.5°C., 2018).

There is no question that the greenhouse effect in the atmosphere has been increased and accelerated by human activities. Three landmark international legal documents, the Kyoto Protocol, the United Nations Framework Convention on Climate Change, and the Paris Agreement, have been introduced internationally to shape the global climate governance landscape beyond 2020 in order to effectively control carbon emissions and address the numerous problems caused by global climate change. In light of this, the Paris Agreement, which has received international acceptance, sets goals for combating climate change.

With a carbon neutrality target in 2019 and the release of the European Green Deal to combat climate change by the end of 2019, the EU is one of the first economies in the world to propose a carbon neutrality plan. The EU is a steadfast supporter and implementer the Paris Agreement and is a global leader in climate governance. By the end of the previous year, more than 130 nations/regions had declared carbon neutrality goals or plans, which accounted for around 83% of the world's CO_2 emissions, 91% of its economic output, and 80% of its population (Unit, n.d.).

2. Current status of carbon neutral development in the EU

The EU has a well-developed carbon neutral policy framework, which includes the deployment of focused measures to reduce emissions in key sectors (energy, industry, energy), science and technology first, supporting scientific and technological research and development projects, and the adoption of diversified fiscal and financial protection measures. These include promoting industrial transformation, creating new jobs, and seizing employment opportunities. Low-cost green technologies, stronger infrastructure development, global adoption of clean energy technologies, and a reduction in the price premium associated with clean technologies are also mentioned. The "dual carbon" plan is viewed as a crucial chance for post-epidemic economic recovery.

These include promoting industrial transformation, creating new jobs, and seizing employment opportunities. Low-cost green technologies, stronger infrastructure development, global adoption of clean energy technologies, and a reduction in the price premium associated with clean technologies are also mentioned. The "dual carbon" plan is viewed as a crucial chance for post-epidemic economic recovery. The vulnerability of Europe to unanticipated climate change has exposed the weakness of its energy security system, despite the fact that this is intimately related to the numerous catastrophic weather occurrences of recent years. A number of industries have been impacted, and some energy and electricity companies have even filed for bankruptcy as a result of Europe's extreme dependence on imported gas. At the same time that gas prices in Europe are expected to triple by 2021, the price of electricity and related energy sources have increased at an unprecedented rate. Despite repeated assurances that the EU's carbon neutrality targets remain unaltered, the difficulties are formidable, and there is still a long way to go before achieving them. EU countries have already broken their obligations to reduce carbon emissions in order to address the energy crisis.

3. EU carbon neutral development pathway proposal

3.1. Expanding relevant funding inputs

Achieving carbon neutrality will require significant financial investment, with the EC estimating that an additional €260 billion per year will be needed just to meet the 2030 target (European Commission, n.d.). There is a significant difference between the funds that the member states contribute to and receive from the EU because a significant portion of the EU's income, which is primarily derived from the contributions of member states based on their national income, is used to help develop the economies of underdeveloped regions and to provide subsidies to some local industries. The European Commission said in January 2020 that it would devote 25% of its budget to environmental and climate change initiatives over the following seven years. In addition, it suggested raising €1 trillion over the following 10 years to ensure that the agreement would be carried out. The EU's long-term budget will account for about half of the entire budget of €1 trillion, of which €100 billion will come from contributions from national governments and another €300 billion from the private sector. Additionally, the EU will use €7.5 billion of its budget for 2021–2027 for seed capital and employ strategies like financial leverage to attract €100 billion of investment.

The gap between the funds needed to implement the agreement and the EU budget will be made up by matching funds from member states' projects and public and private sector contributions (Kevin, 2020). It is anticipated that the EU will invest significant financial resources in new infrastructure and research and development because achieving carbon neutrality and the technological transformation of society are challenging goals to meet in a short period of time. In addition, achieving carbon neutrality necessitates not only the widespread implementation of carbon capture and storage, but also the effective reduction of emissions from electricity systems and the electrification of transportation. All of these initiatives will necessitate significant and ongoing investment from the EU. Despite the benefits of EU membership for individual member states, taxpayers, who have long made a sizable net financial contribution to the EU, have questioned the fairness of the EU's funding rules and objected to the increase in EU funding, especially in hard economic times when EU member states have had to spend significant sums of money to combat the Newcastle pneumonia epidemic and prevent business closures and unemployment. Government spending and economic growth in the upcoming years may be impacted because of the significant economic losses and fiscal burden that arise. In light of this, it will be challenging for EU member states to avoid cutting their government budgets, which would have an impact on implementation funds.

3.2. Seeking continuous breakthroughs in key technologies

Whether it is the steel industry, the energy industry, or the automobile industry, reforming and upgrading a sector will take time. To get past the challenges that still stand in the way of the development of new nuclear power generating and CCUS technologies, even more thorough long-term, scientific and technical study is required. To achieve carbon neutrality in the new power supply system, the majority of future electricity must come from wind and solar generation, and the installed capacity of thermal power must be greatly reduced by other small stabilizing, regulating, and emergency power sources. Future "revolutionary" advancements in transmission, storage, and generation technologies will require support. Theoretically, it is simple to make the energy industry, carbon-neutral, but it is challenging to rebuild equipment and processes. Another possibility is that the cost of the finished good would increase due to the replacement or rebuild. Rebuilding and replacing therefore take time. On the other hand, since emissions from the chemical and energy sectors cannot be prevented, new nuclear power generating technologies and CCUS technology may prove to be essential for reaching carbon neutrality in industries known for having large emissions. The aforementioned technologies are still hampered by safety risks and expensive costs in a large-scale deployment, which presents a big challenge for the EU in figuring out how to advance and promote them.

3.3. Striving for social equity

Regions are projected to face considerable economic and social challenges as a result of the low carbon transition. The fact that the economies of these areas rely so heavily on industries that are anticipated to contract or require transformation presents a particular problem. It is obvious that many more places will be impacted given the industries that will need to change. Traditional businesses like the coal industry are suffering as a result of new energy sources, and the loss of many jobs will have an impact on the economy as a whole. The European Green Deal will endanger 11 million employment in the extractive, energy-intensive, and automotive industries, according to the General Confederation of Global Industries (Elisabeth, 2015). The union is particularly concerned about the risk of a social and economic split between Eastern and Western Europe that could be brought about by the green agenda (Industriall, 2020). In response, the EU launched a recovery package in July 2020 totaling more than 1.8 trillion euros, of which at least 30 percent, or around 550 billion euros, will be used to support member states that are severely affected by the green transition. Only a small number of places are heavily dependent on declining industries, and many more on industries that must transition to low-carbon production. Low-income areas are likely to have more difficulty with this since they frequently have inadequate corporate organizations, low levels of technology, a skilled workforce, and the brain drain. Numerous middle-income regions are dealing with weak development, manufacturing unemployment, and demographic issues due to an aging population. In contrast, more dynamic regions, cities, and metropolitan areas must contend with growing population demands, increased congestion, and the need for more resource- and energy-efficient practices.

The radical plan based on decarbonization of the energy sector seeks to achieve net zero CO_2 emissions by the middle of the century through significant reductions in greenhouse gas emissions. It was unveiled by the European Commission on July 14, 2021, and commits to reducing carbon emissions to 55% of 1990 emissions by 2030 (Commission, 2021). Because the proposal would affect typical consumers, member state governments are looking for alternative ways to resist it in order to avoid upsetting people and imposing additional fees on businesses, households, and car owners. However, playing this game is not simple.

3.4. Sustained funding for developing countries

In recent years, developed nations, including the EU, have started to step up their policy efforts to support the fight against climate change based on a global vision of carbon neutrality. This has resulted in a number of encouraging developments in a short amount of time and demonstrates how the post-Paris Agreement era of global climate governance is being reshaped and innovated. A crucial determinant of whether wealthy countries are accepting international responsibility and carrying out their climate aspirations is the size of climate money. According to the Organization for Economic Co-operation and Development (OECD) in June 2020, using climate finance as an indicator, the total amount of funds provided and mobilized by developed countries for developing countries reached the US$78.9 billion in 2018, setting a record high. Of this amount, official funds made up US$62.2 billion, or 78.8%, of the total, representing a record high (OECD, 2020). In 2018, 70% of the cash allocated for climate change was used for mitigation, 21% for adaptation, and 9% for both. The trend in help from industrialized nations is generally on the rise, but it constantly falls short of the US$100 billion target for 2020.

Additionally, loans make up the majority of climate funding in several affluent nations. An NGO, Oxfam, calculated external official climate finance from 13 developed nations and the European Union in 2017–2018 ($119 billion over two years), and discovered that loans accounted for 79% of the total ($94 billion), or $94 billion, and that half of those loans were not made at preferential interest rates (International, 2020). Climate finance in the form of loans can increase the financial burden on developing nations at a time when many of them already have unmanageable debt loads. It can also result in an uneven distribution of funds between projects that focus on addressing immediate problems and avoiding those that are more long-term in nature.

3.5. Accelerating carbon trading systems and carbon pricing mechanisms

Although the EU ETS has been in operation for 17 years, a change of EU climate policy architecture is necessary to meet the 2030 climate target and the 2050 carbon neutrality target. It will be challenging to establish fully functional ETS (EU Carbon Emissions Trading System) given that political and regulatory reform in each Member State takes between 12 and 18 months. This is because minimizing restrictions on sectoral development while increasing carbon emission reductions, and seeking a fair and equitable transition across Member States and sectors will require a complex and time-consuming process. It will be challenging to establish a fully operational independent ETS by 2025, and it is still important to consider how to speed up the carbon trading system and carbon pricing mechanism.

4. Conclusion

The EU is actively accelerating its development and progress toward carbon neutrality in the context of this goal, as well as actively attempting to seize control of the global development and governance landscape, furthering the organic integration of resources, the environment, and global politics. At the same time, the EU's carbon neutral pathway has a number of issues that, if not resolved, will negatively impact the global response to climate change and its collective efforts to promote carbon neutrality, deter nations from taking part in governance and bearing the costs of governance, and thwart the realization of the global carbon neutrality process.

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Marine Carbon Sink Research in China

Haiyang ZHANG

Guangxi University, Nanning City, Guangxi Province, China, 530004

E-mail: 1191090301@qq.com

***Corresponding author**

Abstract

Since the Industrial Revolution, a large amount of carbon dioxide has been emitted by human activities, which has aggravated climate change and caused a series of environmental and social problems, threatening the sustainable development of human society. The key to dealing with these changes is to achieve carbon neutrality, which includes "emission reduction" and "replenishment". As a large carbon emitter and a developing country, China should try its best to reduce emissions and at the same time increase foreign exchange, that is, develop negative emission technologies and ways. The ocean is the largest active carbon pool on Earth, with abundant carbon sink resources and huge negative emission potential. The theoretical research on China Ocean carbon sink is at the forefront of the world and is expected to play an important role in implementing the national carbon neutrality strategy. This paper introduces carbon sink products such as:coastal wetland and their trading.

Keywords: Carbon sink products; blue carbon; coastal wetland.

1. Introduction

The ocean has efficient carbon sequestration capacity and huge carbon sink potential. It can absorb about 30% of CO_2 emitted by human activities every year, and the carbon storage cycle can reach thousands of years. It is the largest active carbon pool in the world(FRIEDLINGSTEIN P et al.,2020;BOYD P W et al.,2019).In contrast to the concept of a carbon source, a carbon sink is a process, activity or mechanism that removes carbon dioxide from the atmosphere. At present, carbon sinks mainly include two categories, among which terrestrial carbon sinks are carbon sinks increased by terrestrial afforestation, also known as "green carbon"; Marine carbon sinks, also known as "blue carbon", are carbon sinks increased by biological carbon sequestration and storage in oceans, coastal zones, estuaries and wetlands. The concept of "blue carbon" was first proposed by the United Nations in 2009. Compared to "green carbon", "blue carbon" sequesters carbon larger volume, higher carbon sequestration efficiency, longer carbon storage cycle, but the associated carbon reduction methodology is still under construction.

The oceans store about 4 trillion tons of carbon dioxide, the largest carbon sink on Earth. The three major coastal "blue carbon" ecosystems are mangroves, seagrass beds and coastal salt marshes, where carbon dioxide is stored in the sea floor in the form of biomass and biodeposition. Blue carbon has a higher carbon uptake rate and storage density. Although the biomass of coastal plants is only 0.05% of that of terrestrial plants, they sequester the same amount of carbon every year, removing more than 30% of the carbon dioxide emitted into the atmosphere every year. The storage cycle of “green carbon” is mostly several decades. When terrestrial vegetation dies and Withers, organic matter in the sediment will be microorganism with the participation of oxygen. When it breaks down, the trapped carbon goes back into the air. However, the soil environment of the “blue carbon” ecosystem is usually anaerobic, which is better sealed. Without the help of oxygen, the organic carbon in the sediment is less affected by microbial decomposition, and the “blue carbon” can be buried for thousands of years. In addition to carbon fixation, the lush roots and branches of plants in the “blue carbon” ecosystem can also fix sediments, reduce waves, effectively prevent coastal erosion, mitigate the impact of disastrous weather, cope with sea level rise, and provide fertile ground and habitat for many Marine organisms, which is of great significance for nitrogen and phosphorus removal, Marine ecological protection, and seawater purification.

In general, most of the existing researches discuss the process and mechanism of Marine carbon sequestration from the perspective of natural science and technology, while the researches on economic management focus on the integration of Marine carbon sink as the policy goal and the existing policy framework. In the context of the “dual carbon” goal, Marine carbon sink trading can fully stimulate the value and potential of Marine carbon sinks, and is a positive response to the strategic goals of becoming a Marine power and achieving carbon peak carbon neutrality.

2. Blue carbon research

Coastal wetland is a wetland ecosystem composed of coastal salt marsh wetland and mangrove forest. Due to the impact of periodic tidal inundation of seawater, coastal wetlands have a powerful carbon sink function, which is an important way to reduce atmospheric carbon dioxide (CO_2) concentration and mitigate global climate change (Bonan G B,2008).

Marine blue carbon is believed to store carbon at different time scales mainly through physical solubility pump (atmospheric CO_2 dissolves into seawater), biological pump (plants absorb and transform CO_2 through photosynthesis and deposit it to the seabed), and Marine carbonate pump (Marine organisms such as shellfish and coral reefs absorb, transform and release carbon) (Tang Jianwu et al.,2018). According to the assessment of the United Nations (Nature,2016), half of the carbon held by living organisms in the world’s oceans is located in the coastal blue carbon ecosystem. As a kind of important coastal blue carbon ecosystem(Lovelock C E&Duarte C M,2019), coastal wetland has a huge carbon absorption capacity(McLeod E et al.,2011). It belongs to the practice category of “nature-based solutions” and is one of the important ocean-based climate change governance means. Coastal wetlands can bring economic and social benefits to coastal countries and the world at large while mitigating greenhouse gas emissions. Studies show that the annual carbon buried per square kilometer of coastal wetland is expected to reach 0.22 Gg C, which is equivalent to the CO_2 emitted by 3.36×10^5L gasoline combustion(Davis J L et al.,2015). Coastal wetland is an important way to achieve the goal of carbon neutrality.

3. Carbon emission trading

Blue Carbon, jointly published by the United Nations Environment Programme (UNEP), the Intergovernmental Oceanographic Commission of UNESCO (IOC/UNESCO) and the Food and Agriculture Organization of the United Nations (FAO) in 2009 The Assessment Report on the Sequestration of Carbon in Healthy Oceans used the term "blue carbon" for the first time to clarify the role of Marine ecosystems in climate change and carbon cycle(NELLEMANN C et al.,2009). In 2010, the International Union for Conservation of Nature (IUCN), IOC/UNESCO and Conservation International (CI) jointly launched the Blue Carbon Initiative, which aims to mitigate global climate change through the restoration of coastal ecosystems and the sustainable use of Marine ecosystems by setting up scientific and policy working groups. IOC/UNESCO and the United Nations Development Programme Organization jointly issued the Blueprint for the Sustainable Development of Marine and Coastal Areas, confirming to strengthen cooperation with the existing international carbon market, formulate and implement a global blue

carbon market plan, set up a blue carbon transformation fund, and explore a monitoring and certification standard system. In 2013, the Intergovernmental Panel on Climate Change (IPCC) released the IPCC National Greenhouse Gas Inventory Guide: Supplementary Wetlands, which listed the important type of "coastal wetlands", marking that blue carbon was officially included in the emission reduction mechanism of the United Nations Framework Convention on Climate Change(Bai Y ＆ Hu F,2021;Zhao P ＆ Hu X D,2019). The signing of the Paris Agreement in 2016 confirmed the status of "Reducing Greenhouse Gas Emissions by Reducing Deforestation and Degradation" (REDD) mechanism from the perspective of international law, laying a foundation for the development of mangrove carbon sinks in blue carbon ecosystems. In response to the policy call of Marine carbon sink, the international community has tried to establish a methodology system of Marine carbon sink and carried out practical exploration. According to different emphases, the standards or methods of Marine carbon sinks can be divided into national greenhouse gas inventory preparation, carbon stock investigation and monitoring, and carbon trading methodology (Zhao P et al.,2019). The IPCC Guidelines for National GHG Inventories: Supplementary Wetlands provides the methods for the preparation of GHG inventories for three blue-carbon ecosystems, namely seagrass beds, mangroves and coastal marshes. Coastal Blue Carbon: Assessment Methods for Carbon stocks and Emission Factors in Mangroves, coastal salt marshes and seagrass beds released by the Blue Carbon Initiative working group introduced the scheme design for field investigation of carbon stocks in three major blue carbon ecosystems, and methods for investigation, analysis and monitoring of carbon stocks in sediment and biomass pools and annual carbon sequestration rates.
In the carbon trading market methodology, Afforestation and Reforestation of Degraded Mangrove Habitats (AR-AM0014) and Small-scale Afforestation and Reforestation Project Activities on Wetlands (AR-AMS0003) belong to the CDM methodology system and involve the development conditions of mangrove projects. Methodologies for the Construction of Coastal Wetlands (VM0024) and Methodologies for the Restoration of Tidal Wetlands and Seagrass (VM0033) belong to the VCS methodology system and stipulate the conditions for the development of carbon sink projects in coastal wetlands. In practice, the United States, Australia, Kenya and other countries have explored Marine carbon sink trading, among which the most instructive strategy is the "three-step" strategy proposed by the US state of Georgia in 2015 for the construction of Marine carbon sink trading market, that is, clarifying the legal status of blue carbon, issuing blue carbon accounting standards, and reviewing the investors in carbon sink projects that meet the requirements. Provides experience for constructing the framework of Marine carbon sink trading market(PAN X B,2018).

Carbon sequestration products refer to the development of carbon sequestration products from forests, grasslands, wetlands, farmland, oceans and other ecosystems into recordable and managable carbon sequestration products through a set of nationally recognized accounting, testing and management methodologies for the subsequent carbon market, carbon finance and other value realization mechanisms. At present, the methodology is mature and incorporated into the Chinese Certified Emission Carbon sinks under the Reduction (CCER) mechanism mainly include afforestation carbon sinks, forest management carbon sinks, bamboo afforestation carbon sinks, bamboo forest management carbon sinks, sustainable grassland management carbon sinks and conservation farming carbon sinks, which are in urgent need of development of wetland carbon sinks, farmland carbon sinks, grassland carbon sinks, Marine carbon sinks, and other types of forest carbon sinks.

The realization of the value of carbon sink products is to convert the social benefits or social costs of the carbon sink production and development system into private benefits or private costs through market trading or policy means, which is an important means to solve market failures and protect the ecosystem. The value realization mechanism of carbon sink products mainly includes investigation and monitoring, development and transformation, operation and development, value realization guarantee, value realization promotion and other conversion mechanisms. The value realization path of carbon sink products includes trading, mortgage, compensation, etc., to promote the conversion of carbon sink products into economic benefits. As carbon sink product is a special kind of public goods, in order to reduce the "free rider" behavior, solve the problem of market failure, and realize the effective allocation of resources, market and sum are needed.

The government should work together to establish an effective mechanism for realizing the value of carbon sequestration products and an efficient path for realizing the value of carbon sequestration products.

There are three major "blue carbon" ecosystems in China: mangroves cover an area of about 25,000 hectares, mainly in the waters south of Zhejiang; Seagrass beds cover an area of about 20,000 hectares and are distributed in the coastal areas of China. The area of coastal marsh is about 12,000 ~ 34,000 hectares. China's "blue carbon" development has achieved initial results. China's policy on "blue carbon" started early. In 2011, the Shandong

Peninsula Blue Economic Zone Development Plan was the country's first national strategy for the development of Marine economic regions. After 2015, requirements for the construction of Marine carbon sinks began to appear in the national policy system. At the same time, the state has issued a number of documents to establish a Marine carbon sink mechanism, carry out the Marine ecosystem carbon sink pilot, establish a Marine carbon sink standard system and trading mechanism. Since September 2022, when China proposed the goal of achieving peak carbon neutrality, the emphasis on Marine carbon sinks has been increasing. Hainan Province, a large Marine resource province and a national ecological civilization pilot zone, registered and established the Hainan International Carbon Emission Trading Center (hereinafter referred to as the "Sea Carbon Center") in July 2022. The Sea Carbon Center will become the first Chinese carbon market mainly characterized by internationalization and the connecting point of domestic and foreign carbon markets, promote the marketization of "blue carbon" products, promote Hainan's "blue carbon" methodology to become an internationally recognized standard, and strive to be included in the international Marine governance system.

International "blue carbon" methodology certification provides technical support for the construction of national "blue carbon" standard system. In terms of "blue carbon" trading, China's first mangrove carbon sink trading project was completed in Zhanjiang, Guangdong Province, in June 2021, and the initial trading of 380 hectares of mangrove forests reduced carbon dioxide emissions by 5,880 tons. In July 2021, Xiamen, Fujian Province set up China's first Marine carbon sink trading platform, and completed the first carbon sink trading, which resulted in 2,000 tons of carbon dioxide emission reduction. In January 2022, Lianjiang County, Fuzhou City, Fujian Province, completed the 15,000 tons of mariculture and fishery Marine carbon sink trading project.

In a short,“Blue carbon”plays an important role in carbon neutralization,and can improve related economy.

4. Discussions

In the future, it is urgent to strengthen the scientific research of coastal wetland, protect the integrity of its ecosystem structure and service function, stop destructive coastal wetland development activities, avoid the rapid loss of its blue carbon function, promote the ecological restoration of coastal wetland, rebuild and build new coastal wetland ecosystem, restore and enhance its blue carbon function, and benefit from the carbon sink gain while protecting nature. Let coastal wetland blue carbon make greater contribution to carbon neutral strategy.

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Digital Technology Helps EU Eco-city Conduction The Eco-city Conduction Achieves Carbon Neutrality

Xiaoyan ZHAO

Xiangtan University, Xiangtan City, Hunan Province, China, 41110

E-mail: 202005820525@smail.xtu.edu.cn

***Corresponding author**

Abstract

Digital technology can digitally collect and store, deeply integrate and mine, dynamically monitor and process, and comprehensively transmit and distribute various kinds of information about the city's geographical environment, infrastructure, natural resources, ecological environment, population distribution, cultural landscape, social and economic status, etc. (Liao, 2011).

Integrate the digital technology into the construction of ecological city, and facilitate the urban resource and energy subsystem, the ecological settlement environment subsystem, and the ecological industry subsystem to be designed more scientifically and greenly. Meanwhile, utilize the digital technology to construct urban model and basic information platform, and build professional application model base, rule base and corresponding application systems suitable for different functional departments of the city. It will assist the government in making macro-decision and ensuring the allocation and daily supervision of the energy and resources, and then contribute to a carbon neutral city finally.

Keywords: digital technology; Eco-city; carbon neutrality.

1. Introduction

Since the beginning of 2020, the European Union has successively released a number of strategic planning documents aimed at promoting "digital transformation". These include "Shaping Europe's Digital Future", "The White Paper on Artificial Intelligence" and "A European Strategy for Data" in February 2020, "A New Industrial Strategy for Europe" in March 2020, "Digital Sovereignty for Europe report" in July 2020, and "2030 Digital Compass plan" launched in 2021. How to seize the opportunity to complete the two core motions, which was put forward by the new European Commission headed by Ursula von der Leyen-"Digital Transformation" and "Green Transformation" is an important issue that the European Union is facing at present (Cai & Zhang, 2022; European Commission, 2020).

Eco-city, is a city that tends to minimize the demand for energy, water, food and other necessities, as well as the emission of waste heat, greenhouse gases (carbon dioxide, methane, etc.), and wastewater (UNESCO, 1966). The ultimate goal of carbon neutrality is to realize the harmonious coexistence between man and nature, and its realization should also be implemented to build ecological cities. As early as 2005, the EU put forward the "Eco-city Plan", and it has been in a leading position in the world in the construction of eco-cities. Making full use of digital technology will greatly help the EU to improve the eco-city construction and achieve carbon neutrality.

The eco-city system can be divided into three parts: resource and energy subsystem, ecological settlement environment subsystem and ecological industry subsystem. From the above three aspects, this paper puts forward the following suggestions on how the EU can use digital technology to build ecological cities to help carbon neutrality.

2. Suggestion

2.1. The resource and energy subsystem

A city's resource and energy subsystem is the lifeblood of urban development. It provides the necessary elements for the city, regulates its development speed, scale and direction, and plays a "supporter" role to the maximum extent. Urban resource and energy subsystem construction mainly includes three aspects: green energy system construction, green transportation system construction and water system construction (Wen, 2013, p.2). Against the backdrop of the EU's vigorous development of clean energy for electricity, using digital technology to accelerate the structural adjustment of power grids and improve utilization efficiency in the EU will play an important role in the socio-economic and urban ecological environment development of cities. Therefore, this paper will put forward the following suggestions from the three aspects: water resources, electric power and green traffic.

(1) Water Resources. Based on the Internet, digital earth, virtual reality, and mobile internet technology, develop intelligent water resources management systems, enrich and improve the business application of water resources, and realize the optimal allocation, efficient utilization, and scientific protection of water resources. The intelligent water resources management system needs to do the following:

a) Pollution monitoring and accurate measurement. Implement online monitoring of water quality and quantity at urban pollution monitoring sites, and implement accurate measurement of water resources at water consumption units within the region, and transmit the collected data to the water supply resource monitoring center through signal lines for computer control and management.

b) Automatic control. It will give local or remote alarm when water quality, water level, water pressure and other data exceed the limit. At the same time, through GPRS positioning function, the location of alarm points will be accurately displayed on the map and related information will be displayed. Operators or automatic system itself can utilize the operating system platform to remotely and wirelessly control the on-off of the power supply and the electric valve of the on-site metering equipment.

c) Information visualization. Make use of professional software functions to display the data in statistics and charts, so as to intuitively reflect the situation of water resources in the basin, the real-time measurement of each monitoring point, historical data, statements, etc. And reserve interfaces for the upcoming digitalization, networking and sharing data construction of smart cities.

d) Daily management and optimization decision-making. Making water demand forecast, water supply capacity analysis, water resources supply and demand balance analysis, etc. on the data provided by the monitoring terminal, establish water resources supply and demand model. Base on that, the intelligent water resources management system can generate a series of feasible plans for water allocation, and regional comprehensive development and macro-management of water resources for the government.

e) Convenience services. Customize the special water rights trading and delivery platform software to provide people with management functions such as water conservancy information interaction, disaster warning and rescue.

(2) Electric Power. Accelerate the construction and optimization of UHV power grids in Europe. Using digital technology to establish energy internet, realize the energy interconnection of "source-network-load-storage", and make the power grid have intelligent decision-making functions, so that the power grids can intelligently regulate and control electricity resources, which promote the power system a safer and stabler one, and strengthen the energy storage of power grid.

(3) Green transportation system. Use digital technology to ensure the daily management level of transportation infrastructure, improve the quality and experience of citizens' green travel, and promote citizens' willingness to travel green.

a) Build the Transportation Internet. In proximity travel, cities can use digital technology to connect subway, bus, online car-hailing, bike-sharing and other modes of travel, and present vehicle information (such as bus route number, station, arrival time, etc.) in the form of app and electronic platform; in long-distance travel, cities can set up a transportation organization service platform to strengthen the information sharing of transportation routes, shifts, passenger load factors among passenger transport enterprises. Besides, related institutions can strongly promote online ticket purchase and through AI intelligently calculate the optimal combined ticket under limited conditions. So that the convenience of green travel will be well improved, and the no-load rate of passenger transport will be reduced.

b) Digital Technology Helps Daily Maintenance of Transportation Public Facilities. Many residents don't choose low-carbon travel is not because there is no intention of low-carbon travel, but because the city has not created good conditions for low-carbon travel. In order to promote residents' green travel, cities can build weather-free and barrier-free cycling corridors for commuting, through digital technology to realize the public transport facilities' management, such as parking regulation, the daily supervision of shared cars, road surface, the charging station system's safety of new energy vehicles, and etc., which provides favorable conditions for residents' green travel.

c) Use AI, big data, cloud computing, Internet of Things and other means to optimize traffic construction and operation schemes, improve traffic flow and reduce energy waste.

Case: " the Big Data Platform for Public Transport Travel "-jointly created by Tencent and Research Institute of Highway Ministry of Transport of China.

It integrates Tencent's big data with the data of public transport industry, establishes a multi-dimensional evaluation system of traffic network based on the characteristics of cities, and uses advanced technologies such as machine learning and cloud computing by combining the temporal and spatial laws of urban population, to conduct overall analysis, management and optimization evaluation of urban network. The platform gives full play to the advantages of multiple data sources to provide technical support to local transportation administrations, bus companies, MaaS service providers, etc., promotes the principle of "travel as a service", improves the operational efficiency and service level of public transportation, and helps urban transportation become more intelligent, green, and convenient. (Zhang, Liu & Liu, 2021, p.372).

2.2. The ecological settlement environment subsystem

The construction of the ecological settlement environment system is mainly to build a multi-dimensional ecological network in the urban complex ecosystem by using the principles of landscape ecology. Its function is not only to provide visual aesthetic effects or simply create a place for urban residents to have a rest and have fun, but also to participate in the material circulation and energy flow of the whole urban social and economic complex ecosystem (Wen, 2013, p.3). Therefore, in ecological settlement subsystem, this paper will make the following recommendations in terms of UPD (Urban Planning and Design) and the regulatory accounting system for carbon emissions.

(1) Urban Planning and Design. The industrialization of EU countries started early and the urbanization level was high, so most of their city models were fixed. Therefore, satellite image recognition, remote sensing, geographic information and other technologies can be used to construct an intelligent platform for urban green design optimization. Calculate the carbon emission and carbon sink balance of the design scheme in real time, and scientifically assist to optimize the design of ecological layout of carbon-neutral cities.

Case: City intelligence Mapping Alliance (CiMA)-Global Scientist Program

On the basis of 13,861 cities in the world, a three-dimensional map of global cities with cross-city communication and multi-agent participation is established. The CiMA 1.0 technical standards include five elements: architecture, roads, topography, water system and green space, and the data accuracy is below meters. Through the integrated calculation of city data such as hydrogeology, climate environment, construction projects, municipal engineering, etc., the carbon balance path of urban development can be deduced intelligently, and the dynamic allocation of single construction project level in local areas can be realized, urban design can be optimized, and scientific decision-making of urban planning, construction and management can be assisted.

(2) Carbon emission control accounting.

a) Use digital technology to improve the carbon emission accounting system.

b) Use online monitoring technology to improve the carbon emission regulatory system. On the basis of unified carbon emission accounting system, monitor the carbon emissions such as urban sewage collection and treatment system in real time by adopting online sensing technologies including infrared gas analyzer and microelectrode sensor, which helps the central government to establish MRV mechanism.

c) Use the blockchain technology to transform the enterprise wastewater and exhaust emission monitoring system. Based on the decentralized nature of blockchain technology and the difficulty of data tampering, the enterprise sewage and exhaust gas emission monitoring system can be modified to achieve carbon emission transparency in the process of goods production and transportation to a certain extent. In addition, based on carbon emission information, the carbon trading market completes fast transactions and payments without third-party intermediaries.

d) Make use of digital technology to improve environmental rule of law. As early as March, 2004, the Council of the European Union issued the Directive 2004/35/CE on environmental liability with regard to the prevention and remedying of environmental damage, which unified the criteria for environmental damage determination. On this basis, we can use digital technology to build an environmental damage data sharing platform, objectively quantify the amount of environmental damage compensation through the powerful vocabulary capture, common categorization and unique algorithmic logic of artificial intelligence, limit the "arbitrariness" of discretionary power, and improve the effectiveness and quality of environmental rule of law (Li & Liu, 2022).

Case: the "Smart Green Energy Cloud" platform designed by Hebei Province in China

Relying on the "Smart Green Energy Cloud" platform (provincial energy data center), Hebei Province, China, refines and filters the electricity consumption of the whole society, establishes mathematical correlation between electricity consumption and energy data such as coal, oil and gas according to the production process and operation characteristics of various enterprises, and realizes the monitoring of certain time dimensions (annual, quarterly, monthly, daily and real-time). The energy consumption of enterprises can be converted into carbon dioxide emissions. In terms of carbon sink, it collects and collates meteorological and ecological environment data, such as ocean, forest, grassland, lake, forest coverage, background value of environmental quality, and level of CCUS technology development, etc., and analyzes the level of carbon sink in Hebei Province based on these data. Then, the platform can conduct a comprehensive comparison and analysis of carbon emission and carbon sink in Hebei Province, which can scientifically assess the real-time carbon emission level of the whole society and carry out trend prediction, so that the government and relevant departments can know the carbon emission situation of each region and industry, and grasp the whole society's "carbon peak and carbon neutral" process in a timely manner (Lu et. al., 2021).

2.3. The ecological industrial subsystem

Economic system is the lifeblood of a city. The construction of ecological industrial system in eco-cities construction focuses on optimizing industrial layout, adjusting industrial structure, encouraging the establishment of industrial parks, and forming a complete ecological industrial system (Wen, 2013, p.3). Therefore, with the establishment of ecological park as the core, this paper puts forward the following suggestions.

a) Deepen industrial intelligent manufacturing and automation of processing flow.

b) Promote the construction of eco-industrial parks and build virtual industrial parks. Different enterprises can rely on the Internet platform to exchange raw materials, by-products, capital, talents and other resources and share information, just like the "producer-consumer-decomposer" cycle, seeking to close the loop of materials, multi-level energy utilization and information feedback, so as to achieve zero or low emissions and promote circular economy.

c) Reduce process pollution. Companies can use digital technology combined with real-time data of their own product production to design carbon emission analysis and process optimization tools based on LCB (Life Cycle Assessment), EPD (Environmental Product Declaration).

Case: Research Triangle Park in North Carolina, the USA

The Research Triangle Park in North Carolina, USA, in its vast area (about 7770km2, including Raleigh, Durham, Chapel Hill and other areas), has built a virtual industrial symbiosis network to break through the traditional fixed geographical boundaries and complete the exchange of talents, technology, capital, by-products and other resources. As of 2013, a total of 1382 enterprises have participated in the virtual network, and 1249 different materials have been exchanged. (Wen, 2013, p.119).

3. Summary

Digital technology can digitally collect and store, deeply integrate and mine, dynamically monitor and process, and comprehensively transmit and distribute various kinds of information about the city's geographical environment, infrastructure, natural resources, ecological environment, population distribution, cultural landscape, social and economic status, etc. (Liao, 2011).

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While digital technologies have the potential to build eco-cities and contribute to carbon neutrality for the EU, to achieve the above expectations, the EU still needs to face the following problems:

a) The production level of key digital equipment and the construction of digital infrastructure in the EU are relatively lagging behind.
   Accelerate the deployment of IPV6 infrastructure construction.
b) The relevant technicians are short of layers.
   Introduce high-tech talents.
   Vigorously develop education.
c) The construction and maintenance of data centers also consume a lot of energy.
   Use renewable energy power generation.
   Minimize data center site.
   Use heat pump, indirect evaporation and other technologies to recover heat.
d) The internal political forces of different member countries are complicated, and the status quo and interest need of digitalization are different, which makes it difficult to realize the digitalization policy and improve the level.
e) There are differences in digital standards among member countries and market segmentation.

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ARTICLE

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RESPONSIBLE EDITOR: Liviu Carstoiu
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TYPESETTING: Xiangxiang WEI
COVER IMAGE DESIGN: Xiangxiang WEI

SECRETARIATE (OFFICE)

Adress: Bulevardul Ion Nistor Blvd., Nr. 2, Apt. 1, Sector 3, Bucharest, Romania.
E-mail: info@iexchange.world
