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EXCHANGE

Proceedings of the International Carbon Neutrality Traineeship Program

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

Carbon Capture and Storage Technologies: Current Advancements and Future Potential

The Importance of Urban Green Infrastructures for Realizing Carbon Neutrality in Cities: A Synthesis and Meta-analysis

The potential of public transport to reduce carbon emissions in urban areas - a Singapore-based study

The Impact of Refrigerant Recycling on Reducing Carbon Emissions

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.

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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Fighting a Global Scourge: The Rise of Anti - Greenwashing Efforts Across Borders

Yanzhuo CHEN

Northeast Forestry University, Harbin city, Heilongjiang Province, 150040

E-mail: 46454273@qq.com

***Corresponding author**

Abstract

Deceptive environmental marketing, also known as "greenwashing," has prompted governments along with other stakeholders to step up their efforts to counteract it globally. This paper presents a general summary of greenwashing, its effects on consumers and the countermeasures several nations have taken. It cites issues with and weaknesses in existing strategies, including insufficient enforcement mechanisms and consumer awareness. In order to improve anti-greenwashing initiatives, the analysis emphasizes the significance of improving regulatory frameworks, accountability, and transparency, empowering consumers through education and digital technologies, and fostering international cooperation. The most recent studies on responsible business behavior, public policy, and sustainable consumerism have influenced this paper's conclusions. In light of the urgency of confronting climate change and the global objective of carbon neutrality, this paper highlights the vitality of these findings. The topic of sustainable development and the value of cooperation and creativity in solving this problem continues to go on, and this study contributes to the conversation.

Keywords: Carbon neutrality; greenwashing; sustainable consumerism; international cooperation.

1. Introduction

Carbon neutrality has become an increasingly important issue as the world grapples with the effects of climate change. However, some businesses have taken advantage of this trend by engaging in deceptive environmental marketing practices, also known as greenwashing, the practice of deceiving customers about a company's environmental policies (at th·e firm level) or the environmental advantages of a product or service (at the product- or service-level) (Delmas et al,2011). In recent years, governments and other stakeholders around the world have stepped up their efforts to counteract greenwashing. The main research question of this paper is: How effective are current anti-greenwashing efforts in countering deceptive environmental marketing practices, and what improvements can be made to strengthen these initiatives? The issue of greenwashing is not only detrimental to consumers who may be misled into purchasing products that do not meet their environmental standards, but it also undermines efforts towards achieving carbon neutrality.

This paper will explore the rise of anti-greenwashing efforts across borders and discuss the importance of these initiatives in achieving carbon neutrality. It will provide a general overview of greenwashing, its effects on consumers and the environment, and the countermeasures several nations have taken. The paper will then analyze the weaknesses in existing strategies, including insufficient enforcement mechanisms and consumer awareness. The significance of improving regulatory frameworks, accountability, and transparency, empowering consumers through education and digital technologies, and fostering international cooperation will also be discussed. Finally, the paper will conclude by highlighting the vitality of these findings in light of the urgency of confronting climate change and the global objective of carbon neutrality.

2. The Rise of greenwashing

2.1. The greenwashing phenomenon

Due to the increasing environmental issues and the consequent public awareness, many stakeholders have become more conscious of environmental considerations. (Chen Y et al,2012) Over the past decade, stakeholders such as investors, consumers, governments, and corporate clients have been exerting growing pressure on companies to disclose information about their environmental performance and eco-friendly products in green markets. (Polonsky, M. J,1994) The green market has grown rapidly, with consumers, capital markets, products, services, and companies expanding their focus on environmental concerns. However, with the growth of the green market comes the phenomenon of greenwashing. (Majláth M et al,2014) According to Lyon T et al, greenwashing can be seen as a form of selective disclosure: Maintain the withholding of unfavorable information about the company's ecological footprint and highlight advantageous data regarding such. And there are two main types of greenwashing: claim greenwashing and executional greenwashing, as described in de Freitas Netto et al 2020. There is a classification called "the seven sins of greenwashing" created by TerraChoice (2010), which includes:

(1) Sin of the hidden trade-off: A product is green based on a small number of characteristics without taking into account other significant environmental challenges.
(2) Sin of no proof: A claim about the environment that isn't supported by reputable third - party certification or by readily available supporting data.
(3) Sin of vagueness: A claim whose true meaning is likely to be misconstrued by the consumer because it is inadequately defined or overly general.
(4) Sin of worshiping false labels: A product that, via the use of either words or graphics, suggests third-party endorsement when none exists
(5) Sin of irrelevance: A claim about the environment that, while it might be true, is meaningless or useless to customers looking for environmentally friendly products.
(6) Sin of lesser of two evils: A claim that, while perhaps accurate for the product category, runs the risk of diverting attention from the category's broader environmental effects.
(7) Sin of fibbing: Simple fabrications regarding the environment.

The seven sins of greenwashing, according to Baum, are the primary ways in which a business might deceive customers with environmental claims, and they serve as a foundation for advertising analysis. The goal of the seven sins, according to Antunes et al, is to dissuade businesses from using these green marketing methods by arming consumers with the knowledge they need to be cautious when making purchases.

2.2. Effects of greenwashing on consumers

2.2.1. Green confusion

Consumer Confusion could be known as a lack of accurate and suitable perception of many characteristics of an item by consumers. Mitchell, Walsh, and Yamin (2005) identified three different categories of green consumer confusion:

(1) Unclarity confusion: Characterized by a lack of comprehension that compels customers to rethink their prior opinions of a certain product. Technical complexity, confusing information or dubious product claims, contradicting information, or wrong interpretation may all contribute to this type of perplexity (Mitchell, Walsh, and Yamin, 2005).

(2) Similarity confusion: The potential adjustment of a consumer's decision or wrong brand evaluation brought on by the apparent physical likeness of items or services(2005) Mitchell, Walsh, and Yamin.

(3) Overload confusion: Too much information that is relevant to making decisions about the brands to choose from causes overload confusion.

2.2.2. Green skepticism

Customers' intents to make green purchases have directly increased as a result of both environmental knowledge and environmental worries. According to Leonidou, C.N. et al (2015), consumers' perceptions of industry standards, corporate social responsibility, and corporate history all play a significant role in explaining why they attribute various motivations to businesses' environmental initiatives. Yet Masayu N.S et al (2021) shows that consumer interest in buying green personal care products is decreased by green skepticism. Customers are prompted to research the products more, spread unfavorable information about them to colleagues and acquaintances, and have their purchasing aspirations dashed (Leonidou, C.N. et al(2015)).

2.2.3. Green perceived pisk

Green perceived risk is the anticipation of unfavorable environmental effects related to purchasing decisions. (Juliana et al (2020)) Several types of perceived risk are categorized by Assae [2004]:

(1) Financial risk: a proportional relationship between a product's price and the consumer's available budget.

(2) Social risk: Inability of the purchase to satisfy the requirements of a significant reference group.

(3) Psychological risk: loss of confidence when a consumer recognizes they've made an oversight.

(4) Performance risk: The potential for the product to perform differently than expected.

(5) Physical risk: the potential for physical injury as a result of how a product performs.

3. Countermeasures

3.1. General measures

3.1.1. Anti-greenwashing framework

(1) Regulatory Framework for Environmental Advertising in the US

1) Federal Trade Commission (FTC) Act (1914): The FTC Act prohibits "unfair or deceptive acts or practices in commerce," including false or misleading environmental claims.

2) Federal Trade Commission Green Guides (1992, updated in 2012): These guidelines provide businesses with recommendations on how to make truthful and non-deceptive environmental claims. They cover specific topics such as certifications and seals, biodegradable claims, and carbon offsets.

(3) The National Advertising Division (NAD) (1971): NAD is a self-regulatory body that investigates complaints about advertising, including environmental claims. It operates under the Council of Better Business Bureaus.

(4) State Laws: Some states have their own laws governing environmental advertising, such as California's Green Chemistry Initiative (2008).

5) The Sustainable Chemistry Research and Development Act (2020): This Act aims to promote research and development of sustainable chemistry, including the development of safer and more sustainable chemicals and materials.

6) The Climate and ESG Task Force (2021).
7) Environmental Alliance and Regulations (2022).

(2) Regulatory Framework for Environmental Advertising in the EU

1) The Unfair Commercial Practices Directive (2005): This Directive prohibits misleading and aggressive commercial practices, including false or deceptive environmental claims.

2) The Consumer Protection Cooperation Regulation (2006): This Regulation establishes a network of national authorities responsible for enforcing consumer protection laws, including laws related to environmental advertising.

3) The Green Claims Guidance (2018): This guidance document was developed by the European Commission and provides detailed recommendations on how to make accurate and transparent environmental claims. It covers topics such as the use of eco-labels and the measurement and verification of environmental impacts.

4) The European Advertising Standards Alliance (EASA) (1992): EASA is a self-regulatory organization that coordinates advertising standards across Europe. It has a specific code of conduct on environmental advertising, which includes requirements for substantiation and clarity.

5) The Product Environmental Footprint (PEF) initiative (2013): This initiative aims to develop a standardized method for measuring the environmental impact of products.

6) The EU Ecolabel (1992): The EU Ecolabel is a voluntary label that businesses can use to highlight the environmental performance of their products. It covers a wide range of product categories and has specific criteria for advertising and marketing claims.

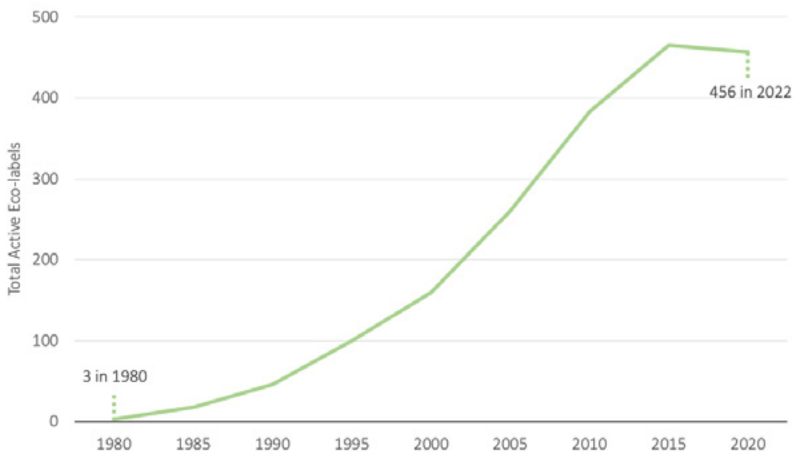
7) The General Data Protection Regulation (GDPR) (2018): Although not specifically related to environmental advertising, the GDPR regulates the collection and use of personal data, which may be relevant to certain types of targeted environmental advertising.

8) Green Claims Directive (GCD)(2023): The European Commission aims to crack down on greenwashing by regulating how companies substantiate and communicate their green claims.

3.1.2. Green labels and certifications

Governments have created certification programs that evaluate the environmental impact of products and services. These certifications allow consumers to easily identify environmentally friendly products and avoid ones that are falsely advertised. Green labels and certifications are third-party verification programs that provide consumers with information about the environmental performance of a product or service. These programs are designed to help consumers make more informed purchasing decisions and to encourage companies to adopt more sustainable practices.

One example of a green label program is the Energy Star program, which is administered by the US Environmental Protection Agency (EPA). The Energy Star label can be found on products such as appliances, electronics, and



Rise of Eco-labels over the past 4 decades (Data from Eco-label Index) lighting, and indicates that the product meets certain energy efficiency criteria.

Another example of a green label program is the Forest Stewardship Council (FSC) certification, which verifies that wood and paper products come from responsibly managed forests. This certification ensures that the forests are not being over-harvested, that wildlife habitats are being protected, and that local communities are being respected.

Green labels and certifications are becoming increasingly important in today's marketplace as consumers become more environmentally conscious. Companies that participate in these programs can use them as a marketing tool to differentiate themselves from competitors and to appeal to environmentally minded consumers.

3.1.3. Legal regulations

In response to the demand of transparency and credibility in companies' environmental claims from customers, governments have enacted legal regulations to protect consumers from greenwashing and ensure that they can make informed choices when purchasing products.

In the United States, regulatory agencies like the Federal Trade Commission (FTC) enforce laws and guidelines that restrict deceptive environmental advertising claims. The FTC has implemented the Green Guides, which outline specific criteria that a product or service must meet to make an environmental claim. For instance, a product claiming to be "eco-friendly" must have a significant environmental benefit compared to similar products in its category.

Legal regulations governing environmental claims vary across different countries and jurisdictions. For example, the European Union established the EU Ecolabel, a certification program that provides a label for products that meet rigorous environmental standards. Other countries have established similar programs, such as Japan's Eco Mark and Taiwan's Green Mark.

Enforcing these regulations is essential to ensure that companies do not engage in deceptive practices that mislead consumers while also damaging the environment. When a company violates environmental advertising regulations, regulatory agencies may take enforcement action against them, including issuing fines, injunctions, and corrective advertising measures.

3.1.4. Public awareness campaigns

Governments have launched public awareness campaigns that educate consumers about greenwashing and how to identify it. These campaigns aim to encourage consumers to make informed choices when purchasing products.

3.1.5. Consumer complaint mechanisms

Governments have set up mechanisms to allow consumers to submit complaints about false or misleading environmental claims. These complaints can lead to investigations and legal action against companies that engage in greenwashing.

3.1.6. Corporate disclosure requirements

Governments have required companies to disclose information about their environmental practices and the impacts of their products. This enables consumers to make more informed decisions and holds companies accountable for their environmental impact.

3.2. Specific measures

3.2.1. Environmental audits

Companies could conduct regular environmental audits to evaluate their performances and identify areas for improvement. Thus, they can make data-driven decisions to reduce waste, conserve resources, and mitigate risks to the ecosystem. Walmart conducts environmental audits and assessments of its suppliers to ensure they comply with the company's sustainability standards. The audits evaluate suppliers' environmental impact, water and energy use, and waste management practices.

3.2.2. Life cycle assessments

The sustainability should be integrated into every aspect of company's business, from product design to end-of-life disposal. Conducting life cycle assessments to evaluate the environmental impact of the products throughout their entire life cycle could reduce environmental footprint, for creating more sustainable products. Patagonia conducted a life cycle assessment of one of its best-selling products, showing that the majority of its environmental impact comes from raw materials production. As a result, the company shifted its focus to using recycled materials in its products.

3.2.3. Supply chain management

The companies could make the management of the flow of goods and services and includes all processes that transform raw materials into final products turn greener.Unilever implemented a Sustainable Living Plan, which includes sustainable sourcing goals and a commitment to reduce the environmental impact of its entire supply chain. Through this plan, the company works with suppliers to reduce greenhouse gas emissions, improve water management, and promote sustainable agriculture.

3.2.4. Carbon footprint reduction

Carbon footprint reduction involves measuring and reducing greenhouse gas emissions associated with a company's operations, products, and services. This can include adopting renewable energy sources, implementing energy-efficient technologies, and offsetting emissions through investment in carbon credits. Google is committed to achieving neutrality and sourcing 100% renewable energy for its operations. The company invests in wind and solar projects and purchases carbon offsets to offset its remaining emissions.

3.2.5. Sustainable packaging

This can include using biodegradable or recyclable materials, minimizing packaging size and weight, and designing packaging that is easy to recycle. The Body Shop introduced refill stations in some of its stores, allowing customers to refill their own containers with the brand's shampoo, conditioner, and shower gel. This reduces the need for single-use plastic bottles and promotes a circular economy.

3.2.6. Renewable energy use

This involves replacing fossil fuels with renewable energy sources such as solar, wind, or hydropower. By transitioning to renewable energy, companies can significantly reduce their carbon emissions and demonstrate their commitment to sustainability. Ikea has installed over 700,000 solar panels on its buildings and owns several wind farms, allowing the company to generate renewable energy and reduce its reliance on fossil fuels.

4. Issues with ongoing solutions

4.1. Flawed framework

4.1.1. The difficulty in enforcing the rules

The resources available to the law are typically constrained, and it can take time and money to investigate and prosecute businesses for making false or deceptive representations. Furthermore, the penalties for breaking environmental advertising regulations are frequently mild, which might not dissuade businesses from using dishonest tactics. The Volkswagen "Clean Diesel" scandal is an example of the challenge in enforcing environmental advertising rules. The scandal involved the installation of software that allowed cars to cheat on emissions tests and false environmental claims by Volkswagen. It took several years and extensive investigations to uncover the fraud, highlighting the difficulty in detecting and punishing such violations.

4.1.2. The lack of clarity

Several of the guidelines are proposals rather than hard-and-fast standards, which can be confusing for businesses and difficult for consumers to evaluate the veracity of environmental claims. Furthermore, not all areas of environmental advertising are covered by the standards, such as statements about packaging or water consumption. The Fiji Water "Green" campaign is an example of the lack of clarity surrounding environmental advertising standards. The campaign claimed to be "carbon negative" and environmentally friendly, but did not provide clear evidence to support these claims. This lack of clarity can enable companies to make vague or misleading claims about their environmental impact, which can confuse consumers and undermine the credibility of environmental advertising standards.

4.1.3. Loopholes and inconsistencies

The rules and guidelines governing environmental advertising can be complex, with different standards applying to different product categories or types of claims. This can create loopholes or inconsistencies that businesses may exploit, resulting in misleading or confusing messages for consumers. One event that highlights this problem is the case of Walmart's "Sustainability Index" program. While it covered some aspects of sustainability, such as energy efficiency and waste reduction, it did not address other important issues, such as labor practices or supply chain transparency. Additionally, the index did not apply to all products sold by Walmart, creating loopholes that allowed some products to be marketed as sustainable despite lacking comprehensive sustainability data.

4.1.4. Lack of coordination

The regulatory framework for environmental advertising involves multiple entities, including national authorities, self-regulatory organizations, and industry associations. However, there can be a lack of coordination between these groups, which can result in gaps or overlaps in regulations and enforcement.

4.1.5. Limited consumer awareness

Despite efforts to educate consumers about environmental claims, many people still struggle to understand the meaning behind terms like "sustainable," "eco-friendly," or "green." This can make it difficult for consumers to evaluate the veracity of environmental advertising and make informed purchasing decisions.

4.1.6. Limited international scope

While the EU has developed a comprehensive regulatory framework for environmental advertising, this framework only applies within its borders. This means that businesses operating outside of the EU may not be subject to the same rules and guidelines, creating potential discrepancies in how environmental claims are made and evaluated globally.

4.2. The problems of eco-labels

Due to the abundance of eco-labels, the market is unregulated, oversaturated, and competitive, with eco-labels competing for customers and visibility by lowering their prices as low as possible.

(1) Not every eco-label is created equal.
(2) Numerous consumers struggle to perceive and comprehend labels.
(3) Due to increased label rivalry brought on by the proliferation of eco-labels, obtainability is the deciding factor in whether a business will choose one eco-label over another.

4.3. Problematic regulations

4.3.1. More green hushing

Greenhushing is a result of a low moral intensity that hides potentially harmful effects of perceived lesser competence while shielding businesses from skeptical customers who could view their claims as disingenuous. (Xavier F et al (2015)) Corporate firms are becoming more afraid of being exposed for making false, inflated, or both environmental and sustainability claims as authorities crack down and hold them accountable for greenwashing. Thus, corporate climate objectives become harder to assess and knowledge sharing on decarbonization is restricted. As a result, less aggressive targets may be set, and possibilities for industry collaboration may be lost.

4.3.2. Transition-washing

Transition-washing is a problem when companies only invest in the green transition in nations where regulations restrict carbon-intensive finance. It occurs when companies provide so-called green finance to bankroll carbon-intensive firms that do not use the capital to change their business models away from fossil fuels. If left unchecked, it will pose long-term concerns and inhibit progress by limiting efficient resource allocation for meaningful climate action - and, in the short term, a loss of public trust.

4.3.3. ESG and Antitrust

Companies have increasingly incorporated ESG goals into their decision-making and reporting and examine the possible environmental and social implications as part of business or investment choices. Whether directly or through trade groups or other organizations, collaboration among competitors can violate antitrust laws, regardless of how socially, ecologically, or financially beneficial the outcome is.

5. Conclusion

This paper lists the widely accepted concept of greenwashing and its main types that could be found in papers before. Additionally, it provides an summary of how consumers evaluate deceptive corporate green marketing messages that employ greenwashing techniques, as well as how this impacts their impression of the businesses and their desire to buy. By displaying current solutions in anti-greenwashing campaigns,Both governments and corporations need to devote greater focus towards implementing comprehensive green initiatives and making genuine green claims while keeping in mind the possible negative effects of greenwashing. Additionally, they need to look for genuine solutions rather than relying solely on present initiatives like third-party certifications that only require the goods to fulfill specific requirements. While these efforts assist in maintaining legitimacy in the eyes of customers in some ways, they still leave many issues unresolved. I expect that the research findings from this study will be beneficial to managers, practitioners, consumers, and readers from other fields and that it will significantly advance future carbon neutrality actions by acting as a reference.

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Carbon Capture and Storage Technologies: Current Advancements and Future Potential

Leilei LI

Xi'an Petroleum University, Xi'an, Shaanxi,China, 710065

Email:2287295567@qq.com

***Corresponding author**

Abstract

With the growth of the global economy and the expansion of industrial activities, greenhouse gas emissions have become one of the main causes of global warming and climate change. Carbon dioxide is one of the most common greenhouse gases, and the increase in its emissions leads to irreversible impacts such as global warming and sea level rise. Therefore, reducing carbon dioxide emissions is an urgent task in addressing climate change. Carbon capture and storage (CCS) technology is a key technology aimed at reducing greenhouse gas emissions and achieving carbon neutrality. This technology captures carbon dioxide generated during industrial processes and stores it in underground storage to prevent its release into the atmosphere. This article will cover four parts: introduction to CCS technology, research methods, research results, and discussion of results. This article mainly introduces the specific content and challenges of CCS technology, and proposes solutions based on one’s own understanding. With the development of society and technological progress, CCS technology will continue to improve and progress, and its influence will also increase.

Keywords: Global warming; greenhouse gases; carbon capture and storage; carbon neutrality.

1. Carbon capture and storage technologies: current advancements and future potential

Global carbon emission is now becoming an urgent global climate issue. The main purpose of “Paris Agreement” is to control the global average temperature increment less than 2°C in comparison to the pre-industrial (Zhao Rui,Zhang Yi,Zhang Shuai,Li Yan,Han Tao & Gao Li, 2021). Carbon capture and storage (CCS) technology research has been ongoing for several years with the aim of mitigating greenhouse gas emissions and addressing climate change and it is an emerging technology to promote global carbon neutrality. While the technology shows promise, there are still significant challenges that need to be overcome.

Firstly, for carbon capture technology, CCS involves capturing carbon dioxide (CO_2) emissions from power plants and industrial facilities before they are released into the atmosphere (Wang Rutian,Wen Xiangyun,Wang

Xiuyun,Fu Yanbo & Zhang Yu, 2022). Various capture technologies have been explored, including post-combustion capture, pre-combustion capture, and oxy-fuel combustion. Post-combustion capture, which involves capturing CO_2 from flue gases, is the most mature and widely deployed technology. Secondly, in terms of carbon storage (Yang Yinan,Li Jing,Wang Li,Wang Zihao,Ling Yun,Xu Jialong... & Zhao Lixia, 2022) and utilization, Once captured, the CO_2 needs to be stored or utilized to prevent its release into the atmosphere. The most common method of storage is geological storage, where CO_2 is injected into deep underground formations such as depleted oil and gas reservoirs or saline aquifers (He Zhili,Lin Lu,Wang Xin,Qin Wei & Zhang Chuanlun, 2022). Research has focused on assessing the long-term storage capacity and potential leakage risks associated with geological storage. Additionally, efforts have been made to explore the utilization of CO_2 in enhanced oil recovery (EOR) and the production of building materials or fuels. Thirdly, Monitoring and verification techniques are crucial to ensure the integrity of stored CO_2 and to detect any potential leaks. Research has been conducted to develop reliable monitoring technologies, including geophysical methods, geochemical monitoring, and remote sensing techniques. These monitoring techniques help assess the behavior of CO_2 over time and provide early warning of any leakage. Fourthly, regarding the cost and energy consumption of CCS technology, one of the major challenges of CCS technology is its cost and energy requirements. Capturing, transporting, and storing CO_2 can be energy-intensive and expensive. Research efforts have focused on improving the efficiency and cost-effectiveness of capture technologies, as well as optimizing transportation and storage infrastructure. Technological advancements and scale-up of CCS projects are expected to drive cost reductions in the future. Finally, the development and deployment of CCS technology require supportive policy and regulatory frameworks. Governments and international organizations have been working to establish regulations, financial incentives, and carbon pricing mechanisms to encourage CCS deployment. Research has examined the effectiveness of these policies and identified ways to enhance their implementation and coordination across regions (Matthew Billson & Mohamed Pourkashanian, 2017). Overall, CCS technology research has made significant progress in understanding the technical aspects of capturing, storing, and utilizing CO_2. However, challenges such as high costs, energy requirements, and public acceptance remain (Subraveti Sai Gokul,Rodríguez Angel Elda,Ramírez Andrea & Roussanaly Simon, 2023). Continued research, development, and large-scale demonstration projects are crucial for improving the efficiency, affordability, and scalability of CCS technology to play a significant role in reducing greenhouse gas emissions and addressing climate change.

The structure of this article mainly consists of three parts: methods, results, and discussion. Firstly, in the method section, introduce the search strategy for CCS technology and the main research directions that will be introduced (most of which are popular technologies). In the result part, after reading a lot of relevant articles, I found my understanding of CCS technology (mainly the basic principles) and the importance of CCS technology to carbon neutrality. In addition, identify the shortcomings of existing CCS technology, as well as the challenges and opportunities it brings. In the discussion section, we mainly formulate and propose suggestions on how to address the aforementioned shortcomings and challenges, and provide suggestions for future research.

2. Method

2.1. Search strategy

Start with general search terms, for example: Carbon capture and storage technology, CCS technology research, Feasibility of CCS technology, Source standards for carbon capture and so on. Then, use more specific terms to narrow down the search scope: advanced capture technologies for CCS, techno-economic analysis of CCS projects, public acceptance of CCS technology, policy and regulatory frameworks for CCS, geological storage of CO2, Carbon capture from industrial processes, monitoring and verification techniques for CCS, life cycle assessment of CCS technology. In addition, there are some useful exploration academic databases and research platforms: Google Scholar (scholar.google.com), IEEE Xplore (ieeexplore.ieee.org), ScienceDirect (www.sciencedirect.com), ResearchGate (www.researchgate.net), ACM Digital Library (dl.acm.org), SpringerLink (link.springer.com). Finally, review relevant scientific articles, research papers, and conference proceedings and consult reports and publications from international organizations and governmental bodies. Such as look for recent publications (last 5-10 years) to ensure up-to-date information,pay attention to studies conducted by reputable research institutions, universities, and government agencies; check for review papers or meta-analyses that provide a comprehensive overview of CCS technology research and feasibility assessments.

2.2. Important technologies

Research on CCS technology is a dynamic field that continues to evolve as scientists and engineers strive to improve its effectiveness and overcome existing challenges. Here are some ongoing research areas and developments in CCS technology:

(1) Advanced capture technologies:

Researchers are exploring novel capture technologies to enhance efficiency and reduce energy requirements. This includes the development of advanced solvents and sorbents for post-combustion capture, as well as the investigation of new pre-combustion and oxy-fuel combustion processes. Additionally, research is being conducted on membrane-based separation technologies and solid sorbents that can offer cost-effective and energy-efficient capture solutions.

(2) Carbon capture from industrial processes:

Beyond power plants, research is expanding to capture CO_2 emissions from various industrial processes, such as cement production, steel manufacturing, and chemical production. These sectors contribute significantly to global emissions, and developing effective capture technologies for these industries is a focus of on going research. Strategies include optimizing process integration, exploring alternative feedstocks, and implementing tailored capture approaches.

(3) CO_2 storage and enhanced storage techniques:

Research is being conducted to better understand and optimize CO_2 storage methods. This includes studying the behavior of CO_2 in different geological formations, evaluating the potential for offshore storage, and improving the modeling of CO_2 behavior over the long term. Enhanced storage techniques, such as carbon mineralization (transforming CO_2 into stable mineral forms) and injecting CO_2 into deep saline formations, are also being investigated for their feasibility and long-term stability.

(4) Monitoring, verification, and risk assessment:

Efforts are underway to enhance monitoring and verification techniques to ensure the integrity of CO_2 storage sites and detect potential leaks. This involves the development of advanced monitoring tools, such as distributed sensor networks, satellite-based monitoring, and real-time data analysis. Risk assessment methodologies are also being refined to evaluate the environmental and social impacts of CCS projects and develop robust regulatory frameworks.

(5) Integration with renewable energy systems:

Researchers are exploring the integration of CCS with renewable energy systems, such as bioenergy with carbon capture and storage (BECCS). BECCS involves capturing CO_2 emissions from biomass combustion and storing it underground, resulting in negative emissions. The synergistic use of renewable energy and CCS can help decarbonize multiple sectors and contribute to achieving climate targets.

(6) Life cycle assessment and techno-economic analysis:

Comprehensive life cycle assessments and techno-economic analyses are being conducted to evaluate the overall environmental and economic viability of CCS technology. These assessments consider the entire CCS chain, from capture to storage, and assess factors such as energy consumption, cost, environmental impacts, and potential benefits.

(7) Public acceptance and policy research:

Understanding public perceptions, concerns, and acceptance of CCS technology is an important area of research. Studies are being conducted to identify barriers to public acceptance, assess the social and cultural dimensions of CCS deployment, and develop effective communication strategies. Policy research focuses on designing supportive frameworks, evaluating financial mechanisms, and exploring international collaborations for the deployment of CCS technology.

3.Results

3.1. Basic principles

CCS stands for carbon capture and storage, which is a technology aimed at reducing carbon dioxide emissions from industrial processes and power generation by capturing carbon dioxide and storing it underground or for other purposes. The basic principles of CCS include three main steps: capture, transportation, and storage.

Firstly, carbon capture: The first step of CCS is to capture carbon dioxide emissions from large point sources such as power plants, cement plants, or industrial facilities. There are different CO_2 capture methods, such as post combustion capture, which includes capturing CO_2 from the flue gas after the combustion process. It usually uses chemical solvents or adsorbents to separate CO_2 from other gases. For pre combustion capture, in this method, carbon capture is carried out before fuel combustion. The fuel is converted into a mixture of hydrogen and CO_2, and CO_2 is separated from the hydrogen for storage. There is also oxygen fuel combustion, which involves burning fuel with pure oxygen instead of air, producing smoke mainly composed of carbon dioxide and water vapor. Then CO_2 can be captured from the flue gas. Next is carbon transportation, once carbon dioxide is captured, it needs to be transported to suitable storage locations. Typically, pipelines are used to transport CO_2 from capture facilities to storage locations. These pipelines are similar to those used for natural gas transportation, but due to the nature of carbon dioxide, they may require additional safety measures. The last is carbon storage. The captured carbon dioxide is stored in the tectonics deep underground to prevent it from entering the atmosphere. The most common storage method is geological storage, which includes injecting carbon dioxide deep underground, such as depleted oil and gas reservoirs, aquifers, or nonexploitable coal seams. A better way to utilize CO_2 is to increase oil recovery rate (EOR), which not only generates economic benefits but also permanently stores CO_2. According to research, the potential for CO_2 flooding is enormous, with 13 billion tons of crude oil stored in geological structures suitable for CO_2 flooding, which can simultaneously store approximately 5-6 billion tons of CO_2 during oil displacement. This shows that there is a great potential for the development and utilization of CO_2 through EOR, which provides a prerequisite for promoting carbon capture and storage in the world through market driving.

Carbon dioxide is trapped in these formations for a long time, reducing the risk of release into the atmosphere. CCS technology is still being developed and implemented on a large scale. Although it has the potential to significantly reduce carbon dioxide emissions, there are also some challenges that need to be overcome, such as implementation costs, ensuring safe storage, and monitoring potential leaks.

In addition, research is currently underway to explore alternative methods such as direct air capture (DAC), which aims to directly capture carbon dioxide from the ambient air.

3.2. Application examples

CCS (Carbon Capture and Storage) technology is a key technology for addressing climate change, used to reduce greenhouse gas emissions such as carbon dioxide (CO_2) and store them to prevent their release into the atmosphere. Give a few practical examples of CCS technology application: coal-fired power plants: CCS technology can be applied to coal-fired power plants by capturing and separating CO_2 from flue gas, compressing it into a liquid or supercritical state, and storing it in underground reservoirs or other underground spaces to reduce CO_2 emissions in the atmosphere. Industrial production process: CCS technology can be applied to high carbon emission industrial production processes, such as steel, cement, chemicals, and petroleum refining industries. By capturing and storing the generated CO_2 in these factories, the negative impact of industrial processes on climate can be reduced. Natural gas processing plants: CCS technology can be used to capture and treat CO_2 generated during natural gas processing, in order to reduce greenhouse gas emissions. These captured CO_2 can be transported to storage sites through pipelines or reused for industrial purposes. Biomass energy power generation: CCS technology can be combined with biomass energy power generation to capture and store the CO_2 generated during the power generation process, thereby achieving net zero emissions. Biomass energy includes wood, crop waste, and other renewable biomass. Drilling and oil and gas extraction: CCS technology can also be applied to the oil and gas extraction industry. By capturing and storing CO_2 released during drilling and oil and gas production processes, greenhouse gas emissions can be reduced and energy sustainability can be improved. These are just some examples of the application of CCS technology, and there are other areas where CCS technology can also be used to reduce greenhouse gas emissions and reduce the impact on climate change. However, it should be noted that CCS technology is still constantly developing and improving, and there are still some challenges and cost issues in practical applications.

3.3. Existing problems and challenges

With the improvement of new energy power generation technology and the decrease in power generation technology costs, the development of CCS has been controversial. Some research institutions believe that CCS technology is generally expensive and cannot reach commercial scale. There are also serious practical problems with the transportation, injection, and storage of captured CO_2 after carbon capture. There are two basic operating modes to reduce CO_2 generated by coal combustion: one is to remove CO_2 before coal combustion; The second option is to choose the post combustion method to remove the flue gas before entering the atmosphere. There are three main technical options: pre combustion, post combustion, and enriched combustion. CCS technology is mainly concentrated in industries such as oil and gas production, fertilizers, and power generation. For example, in the North African region, the In Salah project can separate CO_2 from the natural gas produced and inject it back into the oil and gas reservoirs produced. Sleipner in Norway is the world's first fully operational offshore natural gas field capable of CO_2 injection. In the United States, Koch Nitrogen captures CO_2 generated during fertilizer production at its factory in Enid, Oklahoma, and then transports it to improve oil recovery rate (EOR).

CCS policy is mainly aimed at addressing climate change, but it is far from sufficient for investing in the development of CCS technology. In fact, without strong and sustainable policies, global investment in CCS cannot be sustained. In the context of ensuring global population growth and wealth growth, reducing greenhouse gas emissions will incur huge costs, and in the long run, the benefits are uncertain. The public usually does not weigh the gains and losses of CCS technology on their own, so global policies towards CCS must be sufficient to change the actions of all stakeholders. For example, it is widely believed that releasing CO_2 into the atmosphere is easier and cheaper than capturing permanently stored CO_2. The CCS capital market has not received sufficient returns to meet the required investment return rate. Unclear policies still pose significant challenges to the future development of CCS. A new project has emerged in CCS, and established business models, structures, and practices in mature industries will be applied to CCS projects. However, these aspects of CCS are not yet mature, and high risks lead to high investment returns. Therefore, CCS financing is also very difficult. In addition, CCS investment requires long-term capital asset investment. A single project can slow down millions of tons of CO_2 emissions annually, requiring an initial investment of billions or billions of dollars. After decades of operation, investors must have sufficient confidence to understand the current and future policy environment, effectively carry out projects, optimize risk investment strategies, and achieve positive financial investment decisions.

3.4. Importance for carbon neutrality

CCS (carbon capture and storage) technology is a key tool to achieve global carbon neutrality. Firstly, in terms of reducing carbon emissions, CCS technology helps to reduce carbon dioxide emissions from industrial processes and power generation, which is the main cause of global greenhouse gas emissions. CCS technology can help reduce emissions by up to 90% by capturing and storing carbon dioxide. Secondly, CCS technology supports renewable energy. CCS technology can support the growth of renewable energy sources such as wind and solar energy by providing a way to store excess energy. These stored energy can be used when renewable energy is not available, helping to balance the energy grid. It is worth noting that in promoting the development of carbon neutrality industries, CCS technology can help cement, steel and chemicals industries become carbon neutrality industries by capturing and storing carbon dioxide emissions. This is particularly important in industries where it is difficult to reduce emissions through other means. In addition, CCS technology can create new industries that focus on capturing and storing carbon dioxide. These industries can provide new employment and economic opportunities for regions affected by the decline of traditional industries. Finally, CCS technology is a key tool for achieving global climate goals, such as the Paris Agreement's goal of limiting global warming to below $_2$ degrees Celsius. Without CCS technology, achieving these goals and avoiding the most severe impacts of climate change will be even more difficult.

In short, CCS technology is a key tool to achieve global carbon neutrality. CCS technology can help pave the way for a more sustainable future by reducing emissions, supporting renewable energy, supporting carbon neutrality industries, creating new industries and supporting climate goals.

4. Discussions

4.1. This study found problems encountered by CCS technology

The first and most important and practical issue is high cost. The high cost of CCS technology is the main obstacle to its practical application. The high cost of CCS technology mainly includes the following aspects: firstly, the cost of carbon capture, which requires additional equipment and processes to separate and capture gases. The construction, operation, and maintenance of these equipment and processes require considerable investment, increasing the cost of industrial sites. Secondly, there is transportation cost, which also requires a certain cost to transport the captured carbon dioxide from industrial sites to underground storage locations. Special pipelines or transportation equipment are required during the transportation process, and the construction and maintenance of these equipment will also increase costs. Furthermore, the cost of storage requires the selection of suitable geological layers, sealing, and monitoring to safely store carbon dioxide in underground storage locations. These processes involve complex engineering and geological requirements, and the reliance on equipment and technology increases costs. Finally, there is the cost of monitoring and management, ensuring the safety of storage locations and monitoring emissions also requires a certain amount of cost investment. It is necessary to monitor the stability of underground storage points and the risk of carbon dioxide leakage to ensure the effectiveness of technology and environmental safety.

Secondly, CCS technology is in the development stage and is not yet mature, with many not yet fully validated. Although this technology is theoretically feasible and has some demonstration projects, there are still some challenges and limitations in practical application. Further research and testing are needed to ensure its safety and reliability. CCS technology requires the collaborative operation of various equipment, processes, and systems to capture, transport, and store carbon dioxide. At present, the maturity of these technologies is still improving, and more research and practice are needed to solve technical problems, improve efficiency and reliability. As mentioned earlier, the high cost of CCS technology remains a challenge for commercial applications. In practical applications, more research and innovation are needed to reduce costs and improve economic feasibility. In addition, permanently storing carbon dioxide underground requires selecting suitable geological layers and ensuring their safety and stability. More research is still needed on the feasibility of long-term storage and the monitoring and evaluation of geological layers. At present, CCS technology is mainly applied to a few demonstration projects and large industrial sites, but to achieve comprehensive benefits of carbon emissions reduction, it is necessary to promote and expand the technology on a broader scale. This involves more investment and infrastructure construction.

Although CCS technology has received extensive research and discussion in the academic and technological communities, it is not well-known to the general public. The first reason for the low public awareness is that CCS technology is relatively new and has a relatively short development history compared to traditional energy and environmental protection technologies. Therefore, there is relatively little public understanding and awareness of this technology. However, some governments lack publicity and education, and the promotion and education efforts of CCS technology are relatively low. The public's attention to climate change and environmental protection is mainly focused on renewable energy and energy efficiency, while CCS technology is often not sufficiently promoted and promoted, resulting in limited public understanding. In terms of cognition, CCS technology involves complex processes and scientific principles, and involves knowledge in many fields such as chemistry, engineering, geology, etc. For the general public, these technical content may be difficult to understand and accept. Moreover, CCS technology involves sensitive issues such as carbon emissions, energy development, and environmental protection, and there is some controversy. Some people hold a skeptical attitude towards the effectiveness and feasibility of CCS technology, which may also affect the public's understanding and acceptance of the technology.

4.2. Measures to address issues

In order to address the high cost of CCS technology and the urgency of promoting technological innovation, the following measures and methods can be taken: the government can formulate policies and regulations to support the development of CCS technology, and provide economic incentives, such as subsidies, tax incentives, and incentive mechanisms, to reduce the cost of technology and encourage relevant industries to adopt CCS technology. Increase investment in the research and innovation of CCS technology, including improving the efficiency of capture, transportation, and storage technologies, reducing equipment costs, and exploring new materials and methods to reduce overall costs. By promoting the scale and centralization of CCS projects, economies of scale and cost reduction can be achieved. In addition, cooperation and sharing of CCS facilities and infrastructure among multiple related industries can also reduce costs. Attracting public and private investment to provide financial support for the research and development, demonstration projects, and commercial deployment of CCS technology. Investors and financial institutions can participate in the investment and risk sharing of CCS projects, thereby reducing the cost of technology. International cooperation and knowledge sharing can accelerate the development and application of CCS technology, reduce duplicate efforts, and share experiences and lessons learned. Cooperation between international organizations, governments, and research institutions can reduce the cost of technology and accelerate its maturity. In addition, continuous monitoring and evaluation of CCS projects are carried out to promptly identify and address issues and risks. By optimizing and improving the project, technical efficiency can be improved and costs can be reduced. The implementation of these measures requires the joint efforts and support of the government, industry, academia, and society. With the advancement of technology and the utilization of scale effects, the cost of CCS technology is expected to gradually decrease, providing more opportunities for its widespread application. Encourage cooperation and exchanges between researchers and experts in different fields, including chemistry, engineering, geology, materials science and other fields. Cross disciplinary cooperation can promote the emergence of new ideas and innovative solutions. Some commercial institutions can organize innovation competitions and incentive mechanisms to encourage research institutions, enterprises, and individuals to propose innovative CCS technology solutions. By rewarding outstanding innovators, we can accelerate and break through technological innovation. International governments promote knowledge sharing and cooperation, including cooperation between academia, industry, and government, in the field of CCS technology. Conducting collaborative research projects, organizing international conferences and seminars, and other activities can promote knowledge exchange and technological innovation. Of course, academic training and talent reserve are also very important, strengthening academic training and talent reserve in the field of CCS technology. Support education and training in related majors, cultivate more professional talents and technical personnel, and provide strong support for technological innovation.

To increase public awareness of CCS technology, the following measures can be taken: to carry out education and publicity activities targeting the public, explaining the principles, applications, and potential benefits of CCS technology to them. Utilize various channels such as media, social media, websites, public lectures, etc. to convey information about CCS technology. Some research teams can showcase existing successful cases and demonstration projects, showcasing the actual effectiveness and potential of CCS technology to the public. This can include visiting CCS facilities, organizing open day events, and producing promotional materials and videos to showcase the application of technology. The government can encourage public participation in the discussion and decision-making process of CCS technology. Public hearings, symposiums, and workshops can be held to solicit public opinions and involve them in technology planning and decision-making, increasing public recognition. Strengthen communication and exchange with the public, and maintain transparency. Answer public questions and doubts, explain technical risks and measures, and timely update progress and achievements to establish public trust in CCS technology. Create easy to understand science popularization materials and information in education, and introduce CCS technology in a concise and concise manner. Explain the principles and processes of technology to the public through easily understandable charts, animations, and examples, helping them understand and accept relevant concepts. In today's internet age, partnerships with media, non-governmental organizations, and community organizations can be established. Collaborate with them to carry out promotional activities, hold lectures and seminars, and utilize their resources and networks to expand the dissemination of CCS technology. These measures require the joint efforts of the government, research institutions, enterprises, and non-governmental organizations to increase public awareness and understanding of CCS technology. Through extensive publicity, education, and participation, the public can better understand the potential of CCS technology.

With the increasing confidence in CCS policies in various countries around the world, more and more projects are entering different development stages. CCS has become an indispensable and important part of addressing climate change issues. Most importantly, CCS has been proven to be a safe and effective technology, the only one that can effectively reduce fossil fuel emissions, and also an important technology to solve emissions problems in the power industry. The cost of CCS will continue to decrease with the commercialization of more facilities. Against the backdrop of the rapid development of global new energy, CCS is a transit channel for realizing the new energy economy. Promising technologies such as CCS and hydrogen production, bioenergy and CCS technology, and direct air capture will further promote the commercialization and scale of new applications of CCS.

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Research on Methodology of Carbon Neutrality from the Perspective of Philosophy

Chengji QU

Huaqiao University, Xiamen, Fujian, China, 361021

Email: andy_chengji_qu@126.com

***Corresponding author**

Abstract

The goal of carbon neutrality is a major issue for the development of human society today, and it is also an important topic closely related to all countries and nations in the world. The smooth realization of the carbon neutrality goal is an important goal that all human beings look forward to, and it is also an important issue related to the fate and development of all human beings. This article studies and analyzes the methodology of carbon neutrality from the perspective of philosophy, and tries to study the methodology in the process of carbon neutrality with philosophical methods. Through the philosophical refinement and summary of the carbon neutrality methodology, it points out the development direction of the thinking methods and practical methods used in the process of achieving the carbon neutrality goal on schedule.This article summarizes the methodology of carbon neutrality through six parts and perspectives. This includes: accelerating the green transformation of traditional industries; Vigorously developing green and environmentally friendly industries and production methods; Accelerate the construction of carbon neutrality legal system; Promote the transformation of green living concepts and lifestyles; Grasp the future development trend of carbon neutrality; Promote international carbon neutrality exchange and operation. By summarizing and combing the above contents, we can summarize the methodology in the process of carbon neutrality, and further guide our practice in the process of carbon neutrality through this methodology, so as to ensure the smooth realization of the carbon neutrality goal on schedule.

Keywords: Carbon neutrality; philosophy; methodology.

1. Research on methodology of carbon neutrality from the perspective of philosophy

Carbon neutrality is the need of human social development, and carbon neutrality is also the inevitable result of human social development. As one of the important themes of today's era, carbon neutrality is gradually becoming an important problem that needs to be solved all over the world. Refining and summarizing carbon neutrality from a philosophical perspective will help us to use the correct thinking mode and realization path in the process of achieving carbon neutrality, so as to promote the realization of carbon neutrality development goals on schedule.

Carbon neutrality is a term for energy conservation and emission reduction. Carbon neutrality refers to the total amount of carbon dioxide or greenhouse gas emissions directly or indirectly generated by a country, enterprise, product, activity or individual within a certain period of time. Through afforestation, energy conservation and emission reduction, it can offset its own carbon dioxide or greenhouse gas emissions, achieve positive and negative offset, and achieve relative "zero emissions".

According to the AR6 Synthesis Report: ClimateChange 2023, although there has been some progress in global policies and legislation to mitigate climate change since the previous report was released in 2014, "in the 21st century, global warming may exceed 1.5 °C. According to the assessment of National Independent Contributions (NDCs) in October 2021, the expected level of global greenhouse gas (GHG) emissions will lead to a warming of over 1.5 ℃.The climate target set by the Paris Agreement, which limits global warming to "well below 2 ℃" by 2030, will be difficult to achieve, but it is still possible to limit it to below 1.5 ℃.

Human activities have caused an average global warming of 1.1 ℃, leading to unprecedented climate change on Earth.The global temperature has risen by 1.1 ℃, and various regions of the world are facing unprecedented climate system changes, from sea level rise, frequent extreme weather events, to rapid melting of sea ice. Further increases in temperature will further exacerbate these changes. For example, for every 0.5 ℃ increase in global temperature, extreme high temperatures, heavy rainfall, and regional droughts will become more frequent and severe. In the absence of human activity, heatwaves only occur once every 10 years on average. When the average temperature increases by 1.5 ℃, 2 ℃, and 4 ℃, the frequency of high-temperature heat waves may increase by 4.1 times, 5.6 times, and 9.4 times, respectively, and their intensity may also increase by 1.9 ℃, 2.6 ℃, and 5.1 ℃, respectively.

The impact of climate on humans and ecosystems far exceeds expectations, and risks will rapidly escalate as climate warming intensifies.One of the most worrying conclusions of the report is that the adverse climate impacts have become more profound and extreme than expected. Currently, about half of the global population faces severe water shortages for at least one month each year, and rising temperatures have exacerbated the spread of vector borne diseases such as malaria, West Nile virus, and Lyme disease. Climate change has also hindered the growth of agricultural productivity in mid to low latitude regions. Since 1961, the growth rate of crop productivity in Africa has decreased by one-third. Since 2008, extreme floods and storms have forced over 20 million people to leave their homes every year.

The issue of loss and damage is becoming increasingly severe and urgent as climate change intensifies. For example, if the global temperature rises by more than 1.5 ℃, regions that rely on ice and snow melting water may face unadaptable water resource shortages; If the temperature increases by 2 ℃, the risk of corn yield reduction in important planting areas will sharply increase; If the temperature rises by more than 3 ℃, the high summer temperatures will threaten the lives of residents in some parts of southern Europe.

Global greenhouse gas emissions need to peak before 2025 to ensure the achievement of the 1.5 °C temperature control target.The various research scenarios in the report show that between 2021 and 2040, the likelihood of global temperature rise reaching or exceeding 1.5 ℃ is more than 50%. Especially under high emission paths, global temperatures may reach this critical point faster (between 2018 and 2037); By 2100, global temperatures may rise by 3.3 °C to 5.7 °C, while the last time global temperatures exceeded pre industrial levels by 2.5 °C was more than 3 million years ago.To limit global temperature rise to within 1.5 °C and not exceed or only slightly exceed this range, greenhouse gas emissions need to peak before 2025 at the latest, then rapidly decline, with a 43% decrease from 2019 levels by 2030 and a 60% decrease by 2035.

This article explores the realization path of carbon neutrality from the perspective of philosophy, respectively from accelerating the green transformation of traditional industries; Vigorously developing green and environmentally friendly industries and production methods; Accelerate the construction of carbon neutrality legal system; Promote the transformation of green living concepts and lifestyles; Grasp the future development trend of carbon neutrality; Promote international carbon neutrality exchange and cooperation, and analyze the realization path of carbon neutrality from these six aspects.

2. Method

This paper studies the methodology used in the carbon neutrality process from a philosophical perspective, summarizes and refines the basic methods that should be adopted by people in all countries in the carbon neutrality process, so as to play a beneficial role in promoting the development of carbon neutrality. Through the method of collecting information, this paper extensively collects the carbon emission data and literature related to carbon neutrality published by the world's major well-known institutions, so as to have a clearer understanding of the problems faced by carbon neutrality development. The article also uses the method of comparative analysis to compare and analyze the development status and goals of carbon neutrality in different countries and regions, and summarizes the differences and links among them from the perspective of philosophy to study the driving force behind carbon neutrality. This article summarizes the trends and problems that need to be faced and solved in the process of carbon neutrality through the philosophical method, so as to make a beneficial contribution to the formation of carbon neutrality methodology.

3. Results

This paper summarizes the methodological principles that should be adhered to in carbon neutrality through refining the methodology of carbon neutrality from the philosophical level. This includes: accelerating the green transformation of traditional industries; Vigorously developing green and environmentally friendly industries and production methods; Accelerate the construction of carbon neutrality legal system; Promote the transformation of green living concepts and lifestyles; Grasp the future development trend of carbon neutrality; Promote international carbon neutrality exchange and cooperation. These methodological principles are the core principles in the process of promoting carbon neutrality, and also the methodological principles that must be adhered to in order to successfully achieve the goal of carbon neutrality on schedule.

4. Discussion

Through philosophical refinement, we have summarized six methodological principles on carbon neutrality.

4.1. Accelerate the green transformation of traditional industries

Traditional industries, due to their high carbon emissions, pose serious environmental pollution. The main problems faced by traditional industries are low environmental protection and incomplete green facilities. This has led to traditional industries causing more severe environmental damage and more serious environmental pollution than emerging industries. Especially in heavy industry, steel industry, traditional energy industry, etc., they continue to transform towards environmentally friendly enterprises.

Natural pollution sources refer to places or areas where pollutants are released into the environment due to natural causes, such as volcanic eruptions, forest fires, hurricanes, tsunamis, weathering of soil and rocks, and biological decay. Artificial pollution sources refer to pollution sources formed by human activities.

(1) Domestic pollution sources refer to air pollution caused by burning fossil fuels and emitting soot into the air due to people's daily needs such as cooking, heating, and bathing. Such pollution sources are referred to as domestic pollution sources, such as stoves, boilers, etc.

(2) Industrial pollution sources refer to air pollution caused by soot, dust, and inorganic or organic compounds emitted into the air during industrial production. Such pollution sources are referred to as industrial pollution sources, such as waste gases emitted during production and fuel combustion by industrial and mining enter prises such as thermal power plants, steel plants, chemical plants, and cement plants.

(3) Transportation. Cars, trains, planes, and ships are the main means of transportation in modern times, and the exhaust gases generated by burning coal or oil are also the main pollutants. The pollutants emitted from automobile exhaust can directly attack people's respiratory organs, causing serious air pollution in cities. The main exhaust gases emitted by automobiles include carbon monoxide, sulfur dioxide, nitrogen oxides, and hydrocarbons.

The impact of air pollution on health is divided into acute hazards and chronic hazards.Acute hazards are mainly caused by the sharp increase in the concentration of atmospheric (especially outdoor ambient air) pollutants in a short period of time (such as severe haze), and the acute hazards caused by large amounts of inhalation of pollutants by the population, mainly manifested in respiratory and eye irritation symptoms, cough, chest pain, dyspnea, sore throat, headache, vomiting, cardiac dysfunction, pulmonary failure, and acute episodes of chronic cardiovascular and cerebrovascular diseases.

Chronic hazards mainly include:

(1) Chronic inflammation of the eye and respiratory system caused by long-term irritation, such as conjunctivitis, pharyngitis, and tracheitis, can seriously cause chronic obstructive pulmonary disease (COPD), which can lead to cor pulmonale.
(2) The immune function of the body has decreased. In areas with severe air pollution, the contents of lysozyme and secretory IgA in saliva of residents have significantly decreased, and other immune indicators have also decreased.
(3) Aggravate chronic cardiovascular and cerebrovascular diseases.
(4) It can exacerbate allergic reactions or allergic diseases. Certain pollutants in the atmosphere, if they have sensitization effects, can exacerbate diseases such as asthma and allergic rhinitis.
(5) To increase the risk of lung cancer, the International Institute for Cancer Research (IARC) has classified air pollutants, including particulate matter, as category A carcinogens. According to a review article published internationally, although the overall risk of cancer from air pollution is relatively low, for lung cancer, air pollutants, especially particulate matter, often contain carcinogens such as benzo (a) pyrene (BaP) and arsenic, which pose a high risk.

In addition, international studies have found that long-term air pollution is also associated with adverse birth outcomes such as low birth weight, premature birth, and birth defects. Air pollution can not only directly affect health, but also affect our health through long-term indirect effects, such as affecting solar radiation and the microclimate, generating a greenhouse effect, destroying the ozone layer, and forming acid rain.

Facing the goal of carbon neutrality, the traditional industry must realize its green transformation as soon as possible, further save energy and reduce emissions, improve equipment use efficiency, reduce equipment emissions, eliminate old equipment and facilities that cause heavy environmental pollution, and explore new ways for the green transformation of traditional industries. As one of the main sources of environmental pollution, the green transformation of traditional industries will greatly reduce greenhouse gas emissions, thus eliminating the main obstacles of carbon neutrality.

4.2. Develop green and environmentally friendly industries and production methods

Environmental friendly industries and undertakings are an important way to achieve the goal of carbon neutrality. Green and environment-friendly industry is an inevitable requirement and approach for the development of carbon neutrality. Environmental friendly industry can not only save energy and reduce emissions and further reduce emissions, but also promote the development of the whole industry chain towards low-carbon and environmental protection. Green production methods are diverse, and through the application of new energy and materials, industrial upgrading and transformation can be achieved, further reducing carbon emissions.

According to the data of the United Nations Environment Programme, the carbon dioxide emissions from construction and construction in 2021 will account for 37% of the global total emissions, which is much higher than the 23% of the transportation system. It is one of the main sources of greenhouse gases.

At present, many countries around the world have begun to implement the zero-carbonization transformation of buildings in order to achieve the goal of reaching the carbon peak. At the beginning of July, Paris, France announced that it would carry out energy transformation of 47000 apartment buildings in the city by 2050. The International

Energy Agency suggested that if the goal of the Paris Climate Agreement is to be achieved, the construction industry will be generally zero carbonized by 2050. From 2017, the annual building renovation rate in all regions should be at least about 3%.

The reduction of the demand load rate of buildings corresponds to the reduction of carbon emissions, that is, the use of building space layout planning, window layout, etc., to reduce the electricity use of building operation. In terms of supply, adjusting the energy structure corresponds to carbon compensation and increasing the supply of renewable energy. For example, building a "light storage, direct and flexible" building is actually to convert solar energy into electrical energy by installing photovoltaic panels, and solve some flexible electricity needed for building operation, such as charging piles and some electrical appliances, and then DC.

Example 1: Present carbon neutral building construction (Commercial headquarters for Gazprom Neft).

As of spring 2020, MVRDV designed the largest timber building in the world for Saint Petersburg's historic Okhta Cape. Once thick with trees and marshland, the site has been home to fortresses, a tree nursery, shipyards, and factories. After many years lying dormant, this design inspires its fruition as the commercial headquarters for Gazprom Neft.

A celebration of the embankment landscape context, its rich and storied history, the carbon-neutral building stands 28 meters high, and is supported by a forest of 119 wood columns. This "forest floor" is free and open to the public with a park and plaza that highlight the history of the site, while the office space lies above in the columns' "tree" canopy. A roof-scape with native vegetation crowns this commercial complex, helping to rehabilitate the cape's biodiversity, as in the landscaping of the park below. This way, building is landscape and landscape is building; a clear embodiment of the 'green shift' MVRDV strives for in all designs.

Example 2: Future carbon neutral building planning (Carbon Neutral Tower in Hong Kong).

Arup recently announced the design of a zero-carbon commercial tower in Hong Kong, with a height of 230 meters. The tower is called "Taikoo Green Ribbon" It aims to embrace and promote Hong Kong's goal of achieving carbon neutrality by 2050. The integration of technology and nature has created a new intergenerational sustainable working space and established a complete urban ecosystem. The facade of the tower is made of curved PV material, equipped with aerial garden, algal wall and various renewable energies. The project is a high-performance building. It is planned to achieve the goal of carbon neutrality within ten years after completion. Through this project, Arup demonstrated its commitment to decarbonization design, and made full use of the company's professionalism in sustainability, technology and cycle design, setting up a beacon for the development of environmental protection in Hong Kong.

The shape design of the tower is intended to respond to the conditions of the base site with the optimal solution, including a series of green cooperation spaces, forming a penetrating ascending path inside. This path network also has water-cooled gardens and squares on the lower floors, and includes a landscape airstrip equipped with kinetic energy pads, a naturally ventilated garden with edible plants, and a rooftop theater that can accommodate 500 people. The office floor of the tower is cut by the eccentric core tube and the atrium, while the cooperation space connects the working areas with different heights. The tower is almost completely naturally ventilated, providing a healthy office environment. The automatic air sensing device will also assist the indoor air circulation, and the intelligent facade system controlled by AI can filter the air and adapt to the microclimate environment of the tower. The east and west facades of the tower are self-operated windows equipped with PV panels, and 3D printing shading elements with raw materials from recycled plastic bottles. The south facade contains a series of tubular modular units wrapped in curved PV, which can accommodate conference space, coffee shop and other related facilities.

The project is an exploration of advanced technologies and materials, including more than 40 different energy systems, sufficient to generate a large amount of excess energy. In addition, the project's extensive green space network system has created a greening rate of 350% on the site area. The project is the winning plan to promote the net zero creative competition.

The development of green industry is an inevitable trend for the smooth realization of the goal of carbon neutrality. Accelerating the construction of green industry, constantly developing green production mode, and actively exploring new forms of green industry are strong guarantees for the smooth realization of the carbon neutrality goal.

4.3. Accelerate the construction of carbon neutrality legal system and regulations

An important factor to ensure that the carbon neutrality goal can be achieved on schedule is to establish relevant legal systems and regulations as soon as possible. While accelerating the transformation of traditional industries and the development of green industries, it is necessary to formulate corresponding laws and regulations to constrain and guide the green development of society. As the legal guarantee for the realization of the carbon neutrality goal, the legal system and laws and regulations play a vital role in regulating and guiding the development of green economy.

Therefore, accelerating the formulation of climate change response law has become the only way to achieve the goal of carbon neutrality. At the same time, key systems such as carbon emissions trading, green bonds, publicity and education should be included, and the legal system should be connected and coordinated. The legal and regulatory system should not only involve the entire industry chain, but also penetrate into every individual in society, guiding and influencing people towards the direction of energy conservation and environmental protection.

In the process of achieving the goal of carbon neutrality, on the one hand, laws and regulations should be used to regulate and punish enterprises and individuals who violate the principles of energy conservation and environmental protection. On the other hand, it is also necessary to effectively establish and apply reward mechanisms, and provide certain rewards and compensation to enterprises and individuals who comply with regulations. This form can come in many ways, such as reducing taxes or issuing consumption vouchers. The effective application of the reward and punishment mechanism is an effective guarantee to ensure the smooth progress of the carbon neutrality goal.

4.4. Promote the transformation of green living concepts and lifestyles

Green life philosophy and lifestyle are another important factor to achieve the goal of carbon neutrality. The development of human society cannot be separated from the existence of humans. The total carbon emissions of each individual in their daily lives cannot be ignored. While promoting the upgrading and transformation of the manufacturing industry, the production and lifestyle of everyone is also very important.

Household greenhouse gas emissions come from burning fuel in buildings for heating or cooking and using electricity in homes. In 2020, global household direct carbon emissions accounted for 6% of global total emissions, and indirect carbon emissions accounted for 11%. Direct emissions include fossil fuels used for heating or cooking, waste and wastewater treatment, and leakage of refrigerant from air conditioners. The use of natural gas and oil products for heating and cooking can emit a certain amount of carbon dioxide, methane, and nitrous oxide. Domestic waste generated in household daily life will emit a certain amount of methane when sent to a garbage disposal site for treatment and disposal. Wastewater treatment also emits a certain amount of methane and nitrous oxide. Global waste and wastewater disposal accounts for 1.9% and 1.3% of global greenhouse gas emissions. Fluorinated greenhouse gases (mainly hydrofluorocarbons or HFC) used in air conditioning and refrigeration systems may be released during maintenance or from leaking equipment. The way people travel can also generate carbon emissions. For example, taking a car or airplane can lead to an increase in emissions, while using a bicycle to travel can reduce a lot of carbon emissions.

Saving water and electricity in daily life can effectively reduce carbon emissions. Choosing more ways to travel, such as cycling or walking, can also reduce carbon emissions. Reduce the use of non recyclable items and use more recyclable items. When selecting products, purchase as many green and environmentally friendly products as possible. These methods can effectively reduce carbon emissions.

Mass- production will inevitably cause conflicts with environmental protection, and consumerism will make people ignore the importance of environmental protection. This has caused environmental pollution and destruction in the process of development, and further led to a global crisis. In recent years, various natural disasters such as global warming and water resources crisis are exacerbating the global ecological crisis. The living environment of mankind is deteriorating further. If the pollution and damage to the environment cannot be effectively controlled, the damage to the environment will become more serious and ultimately affect the development of the whole human being.

In the process of protecting the environment, the role of individuals is also very important. As we all know, industrial manufacturing and human needs are inseparable. And enterprises manufacture products around consumer needs. That is to say, enterprises manufacture products according to the needs of consumers for the use of products. This also means that if individual consumers change their consumption habits and form a trend, enterprises will change their manufacturing products accordingly, and the manufacturing mode will also change accordingly.

Individual consumers can also take corresponding measures to transform enterprise manufacturing into an environment-friendly direction. For example, consumers can buy more green goods and reduce the purchase of goods with more serious pollution. Consumers can also buy more degradable goods or degradable packaging. Consumers can also recycle the used products. Through these ways, enterprises can pay more attention to energy conservation and environmental protection and protect the ecological environment.

Individuals can use persuasive facts to spread climate action through friends, family, colleagues, and online social networks around them. You can do something within your power, such as driving less and flying less, choosing more "green" energy suppliers, changing your diet and consumption habits, and so on. Infect others and involve them in the camp of change. Everyone has the right to enjoy their rights as citizens and consumers, and pressure should be placed on governments and businesses to ensure that they make the necessary systemic changes. By promoting and implementing their own energy conservation and emission reduction initiatives, they will affect more people around them, ultimately driving changes in the entire industry and related policies.

4.5. Look forward to the future development trend of carbon neutrality

Looking forward to the future development trend of carbon neutrality, effectively using the development opportunities brought by the carbon neutrality goal, and constantly exploring the possibility of future carbon neutrality development are the development requirements of carbon neutrality goal.

Just like feedback loop is important when constructing climate models.Climate feedback refers to an interaction mechanism between various physical processes in the climate system. When an initial physical process triggers a change in another process, which in turn affects the initial process, such interaction is called climate feedback. Positive feedback enhances the initial physical process, while negative feedback weakens it. Positive climate feedback, such as the melting of arctic ice under high temperature, causes the reflection of solar radiation to weaken, thus causing temperature rise. Negative climate feedback, such as temperature rise, leads to cloud thickening, which will reduce solar radiation and limit climate warming.

The climate system is the whole of the interaction and interaction of the atmosphere, hydrosphere, ice and snow sphere, lithosphere and biosphere. The change of one factor in the climate system may cause a series of changes of other factors, leading to climate change. Climate change will also have an effect on the change of this factor. This is the interaction of various factors in the climate system. This effect is called feedback mechanism. The feedback mechanism in the climate system is of great significance to climate change.

The climate system feedback mechanism can not only enhance the final output (positive feedback), but also weaken the output (negative feedback).The feedback mechanism is an important climate process in the climate system. The result is to strengthen the positive feedback of the pilot process, which is an unstable factor in climate change, and in turn is called negative feedback. The existence of both positive and negative feedback is called multiple aftereffects.

Positive feedback example like water vapor-radiation feedback Under the condition that the relative humidity remains unchanged, the rising temperature increases the water vapor content, thus increasing the absorption of long-wave radiation emitted from the surface, resulting in a further increase in the temperature of the bottom atmosphere.

Negative feedback example like Cloud cover - ground temperature feedback The ground temperature increases with the absorption of more solar radiation, which will promote the evaporation of the ground, resulting in the increase of water vapor content in the atmosphere, and promote the development of clouds. The increase of cloud cover will reduce the solar radiation incident to the surface, and the ground temperature will decrease.

The impact of green transformation on the world market is enormous. Green development means an important change in human industrial production mode. The development of industry is in the direction of green, low-carbon and environmental protection. This change is of epoch-making significance. The labor market will also change with the change of demand. The number of new jobs related to green development will increase further.

The green transformation of industry is full of challenges. The transformation of existing industries to green production needs a difficult process. For example, it is difficult to transform the traditional coal industry and other industries with serious pollution. At the same time, people's consumption needs also need a gradual change process. The adjustment of government policies also needs some time to be promoted and improved.

With the green transformation of industry, some emerging occupations have also followed. Especially in the recycling industry, with the deepening of the concept of low-carbon environmental protection, waste utilization is an important means of energy conservation and environmental protection. Some new energy industries, such as wind energy and solar energy, will also demand more people. The demand for practitioners in the energy-saving service industry will also increase. The number of scientific researchers and educators studying the green development mode also needs to increase.

4.6. Promote international carbon neutrality exchange and cooperation

Addressing climate change is a global public issue. The Earth's atmospheric resources have the attribute of public goods, and the impact and governance of climate change are global. It is difficult to effectively address climate change relying on the efforts of a single country.

International cooperation plans goals and paths for the global response to climate change. On the one hand, international cooperation can promote climate awareness and technological innovation, enhance international community's understanding of climate issues and establish action goals through exchange and cooperation, and promote the development, popularization and application of climate friendly technologies; On the other hand, we should guide investment, market, and economic development through international cooperation, and promote the establishment of a climate and environmental friendly market system through financial support models, international trade rules, and other means, leading to the establishment of a low-carbon economy.

4.6.1. Challenges to effective climate action

(1) Countries have serious differences in their positions on climate governance.

Due to the impact of highly endogenous factors such as the geographical location and economic development strategies of various countries, there are complex differences in governance willingness and capacity in addressing climate risk issues among different countries and regions. Due to the different interests and demands of various countries, there are also significant differences in some policies and perspectives. In general, developed countries believe that climate change is a by-product of the rapid development of the global economy, and countries should bear common responsibility for reducing emissions, without discrimination; Developing countries emphasize the differentiated treatment of greenhouse gas emission reduction responsibilities, believing that developed countries not only bear historical responsibility for global climate change issues, but also provide economic and technological support to developing countries because their economic and social development has reached a relatively mature and stable state, and they have more sufficient funds and advanced technology to cope with climate risks compared to countries with lagging development, To improve the ability of developing countries to adapt to and mitigate climate change. Due to the different interests and demands of different subjects, the legal effectiveness of allocating greenhouse gas emission reduction responsibilities under the framework of international law has always been a focus issue in the United Nations climate change negotiations, and there are many disputes among countries on this issue.

(2) The uncertainty of climate risk has become a barrier for countries to make climate governance decisions.

Scientific uncertainty is a major feature of climate risk and a major challenge to global climate governance. The impact of climate risk involves natural, social, economic, political, and life fields, which increases the uncer tainty of climate risk as a whole, and puts forward corresponding requirements for countries to take climate governance measures.

(3) The synergy of climate risk response paths faces the test of global governance systems.

Climate risk is a systemic risk that endangers human society and ecosystems, and requires coordinated responses by countries.The synergy of climate risk response paths is mainly reflected in legal policies, sanctions measures, response timing, and other aspects. Climate governance is always based on specific policy and legal grounds. Although countries may have different legislative traditions, legislative techniques, and legal systems, due to the world wide characteristics of environmental law, it is easy for countries to form consensus on the content, policy framework, and institutional aspects of environmental law and coordinate their actions at the practical level based on this. However, due to differences in the ability of different countries to respond to risks, it is difficult for countries to reach a unified value position on climate governance issues, making it even more difficult to adopt coordinated response measures.

4.6.2. Countries' actions

(1) Early warning system

Research has shown that just providing a 24-hour warning of upcoming heat waves or storms can reduce subsequent losses by 30%. An early warning system that provides climate forecasting is one of the most cost-effective adaptation measures, with a total benefit of approximately $9 per dollar invested.

(2) Ecosystem restoration

The United Nations Environment Programme and its partners launched the “United Nations Decade for Ecosystem Restoration” in 2021, triggering a global campaign to restore the world’s ecosystem. This global recovery effort will not only absorb carbon, but also increase “ecosystem services” to protect the world from its most destructive impacts.

(3) Infrastructure for adapting to climate change

Climate change adaptation infrastructure refers to assets and systems that can withstand extreme climate shocks, such as roads, bridges, and power lines. Infrastructure accounts for 88% of the estimated cost of adapting to climate change.

(4) Water supply and security

Investing in more efficient irrigation will be crucial, as agriculture accounts for 70% of global freshwater extraction. In urban centers, by 2030, by reducing leakage, approximately 100 to 120 billion cubic meters of water can be saved globally. Governments are being encouraged to develop comprehensive water resource manage ment plans that take into account the entire water cycle: from water sources to distribution, treatment, reuse, and return to the environment. Research has shown that investments in rainwater harvesting systems need to be sustainable in order to make them more widely available. The United Nations Environment Programme is working with government partners to build over 1000 rainwater collection systems around the world and provide expert guidance on the construction and use of solar wells, boreholes, micro-irrigation technologies, or water reuse systems.

(5) Long-range planning

It would be more effective to incorporate climate change adaptation solutions into long-term strategies and policies. National adaptation plans are important governance mechanisms for countries to plan for the future and give strategic priority to adaptation needs.

As the common goal of human society, carbon neutrality has a profound impact on the development and continuation of human civilization. The common development goals of humanity cannot be achieved without the participation and contribution of every country and individual in the world. Only by constantly strengthening international exchanges and cooperation can we ensure that the carbon neutrality goal is achieved on schedule and create a better future for mankind.

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The Importance of Urban Green Infrastructures for Realizing Carbon Neutrality in Cities: A Synthesis and Meta-analysis

Liyuan WANG

Hainan Normal University, Hai Kou, Hainan, China, 571158

Email: wang_liyuan_icnt@iie.world

***Corresponding author**

Abstract

To evaluate the importance of urban green infrastructure in achieving carbon neutrality. Methods: The relevant articles about urban green infrastructure were searched in foreign language database (Science Direct). The search period was from 2015 to 2023, when the most research results were obtained. Literature screening, using RevMan5.4 software for Meta analysis of data. Results: Finally, 26 literatures were included. According to Meta analysis, compared with other traditional infrastructures, urban green infrastructure can effectively improve urban heat island effect, rainwater treatment, air pollutants and noise pollution. Conclusion: Compared with traditional infrastructure, urban green infrastructure is more conducive to urban sustainable development. Therefore, urban green infrastructure plays a very important role in achieving the goal of carbon neutrality.

Keywords: Urban green infrastructure; conventional infrastructure; carbon neutrality; meta analysis.

1. Introduction

Since the Industrial revolution in the 1760s, with the rapid development of urbanization, a large number of ecological and environmental problems began to emerge. Such as ozone layer destruction, acid rain pollution, water and soil loss, the sustainable development of human society has been seriously threatened, especially the emission of greenhouse gases, which is also one of the main problems leading to global warming. According to the statistics of the World Meteorological Organization (WMO) in the state of the Global Climate 2020 report, 2020 is one of the hottest single years in the history of complete meteorological observation records. The average global temperature in the last five years (2015-2020) and the last ten years (2011-2020) has also reached the highest levels on record, making them the warmest five and ten years on record. Climate changes dramatically over time (IPCC. 2014). The Earth has warmed every decade since 1850. Globally, the evidence of climate change is already clear. In the 20th century, the global mean temperature increased by 0.74℃, the ice sheet decreased by 40%, and the natural sea level rose by 17 cm (Berthold J, 2013).

The global change caused many regional and local impacts which varied significantly between sites (UNFCCC, 2019). These impacts formed real risks to the entire world and especially to the cities where people mainly concentrate. At the same time, many cities around the world suffer from the phenomenon of 'urban heat island'. In general, urbanization processes lead to change the surface's climate within cities and form what is called (urban climate) (Ren G, 2015).

In an effort to combat climate change, 137 countries have pledged to become carbon neutral. As an important part of carbon neutrality, green infrastructure can effectively improve urban heat island effect, regulate urban micro-climate, remove air pollutants and improve water quality, thus helping people to achieve carbon neutrality. GI can be defined as all engineered features with natural elements (e.g. vegetation) or natural features, such as remnant habitat, that are within or around urban development and that support ecological services(Tzoulas et al., 2007). We chose to examine GI type that are completely human designed with natural elements (Table 1 in supporting information). The benefits of GI for regulating ecosystem services have been proven and are frequently recommended (Lepczyk et al., 2017; Schilling & Logan, 2008; Tzoulas et al., 2007). For example, vegetation on GI types such as green walls or roofs, reflect and redistribute heat in ways that lead to cooler buildings and cities, both having positive impacts on human health and well-being (Coutts & Hahn, 2015; Miles & Band, 2015; Norton et al., 2015; Sookhan, Margolis, & MacIvor, 2018). GI is also frequently utilized for stormwater regulation and is among the most common reasons for implementation (Jayasooriya & Ng, 2014; Lewis, Simcock, Davidson, & Bull, 2010). Understanding the difference in carbon neutrality between GI and conventional infrastructure or natural counterparts is crucial for improving imple-mentation. Quantifying the benefits of GI on urban environment is a necessary step to find the implications of green infrastructure for carbon neutrality. The materials used in GI construction can be refined in different environments. For instance, Replacing traditional brick roofs with green roofs can help mitigate greenhouse gases since a green roof can reduce the indoor temperature up to 19.9 °C, save 28 % annually in electricity consumption and remove 80 % of rainwater pollutants (Tiago, 2020). The GI case of "tree canopy only" can be a potentially viable choice to reduce particle concentrations on the pathways due to the fact that its better ventilation conditions are more favorable for particle diffusion than other GI configurations (Yue-Ping Jia, 2021). However, there is relatively less quantitative ev-idence for the contribution of GI to carbon neutrality. Both positive and negative effects of GI on urban environment have been implied and documented, but no comprehensive study has quantified these effects using comparison to con-ventional counterparts in the urban environment (Table 1). With the expansion of constructed GI research, conducting a synthesis of the available literature can improve GI implementation to optimize contribution to carbon neutrality. In this study, we review the literature and conduct a meta-analysis to improve understanding of GI and its relative contri-butions to change urban environment compared to natural and conventional counterparts in cities. Meta-analyses are a useful tool to synthesize research findings across studies and quantify estimates of effect sizes for a given hypothesis (Koricheva, Gurevitch, & Mengersen, 2013). Using a systematic review of the literature and extracted datasets from relevant studies, we set out to answer the following objective, and test one hypothesis using a meta-analysis. From our literature review, we describe and highlight research gaps that are present within GI. My hypothesis was that GI will more carbon neutral than conventional counterparts (e.g. green roof vs. bare roof) because GI can provide a higher quality to urban environment. Through Meta analysis, this paper compares green infrastructure with conven-tional infrastructure to prove that urban green infrastructure can effectively improve urban heat island effect, regulate urban microclimate, remove air pollutants, improve water quality, and explore the importance of urban green space in maintaining urban carbon neutrality. Our systematic review and meta-analysis can identify trends across studies that are generalizable and provide new insight into strategies to support carbon neutrality.

2. Methods

2.1. Systematic literature review

2.1.1. Retrieval strategy

The literature search was conducted using Science Direct for all peer-reviewed journal articles (i.e. studies) between 2015 and 2023. This time frame was chosen because it captures the majority of the literature on urban green space (see Fig. 1 in supporting information) and included all English-language studies from around the world. We used the following search terms to capture all studies that have documented both the types of GI implementation and Carbon Neutrality: (green infrastructure OR green roof OR rain garden)AND (low carbon OR sustainability). These terms were generated with the assistance of subject matter experts on green infrastructure in academia, government, and industry. The terms returned 2066 results (Fig. 1 in supporting information). All studies were screened for their relevance to the study and 1959 were excluded for reason such as 1) not about green infrastructure, 2) no relationship between green infrastructure and carbon neutrality, 3) presenting a conceptual framework and no data collected (Fig. 2 in supporting information).

2.1.2. Data collection and extraction

Data collection and extraction: Researchers searched the literature independently, read the title, abstract and full text of the articles, and screened the articles according to the inclusion and exclusion criteria. After the inclusion of the literature was determined, the data were extracted, including: article title, author, publication year, research object, research method, data collection period, sample size, outcome index, etc.

2.1.3. Quality evaluation of literature: types of literature included

The 107 selected studies were then reviewed to extract the type of GI, the environmental impact parameters of different types of green infrastructure. We also obtained criteria relating to each city (name, coordinates, current policies of GI, current measures of carbon neutrality). The full list of examined studies and data that were extracted from each can be found in an open-access repository (Filazzola, Maclvor, & Shrestha, 2018). From the review, we identified a multitude of GI types (vegetated roadsides, green roof, rain garden, green wall).

2.2. Green infrastructure definitions

The type we included for comparative analyses included green roofs, green walls, yards/gardens (community & allotment), wetland detention basins, vegetated roadsides (Table 1). Features of GI were defined by the authors of the respective manuscript and we have included a general description of these features in Table 1. Comparisons of GI to conventional and natural counterparts were conducted within an individual study by calculating the Hedge's g effect-size estimate before be compared among studies. Some of the studies had multiple comparisons that would be used in the meta-analysis, such as the role of GI in different climate issues (e.g. heat island effect, air pollution, noise pollution, rainwater treatment).

2.3. Meta- analysis

We conducted a meta-analysis to statistically compare GI to conventional counterparts using data extracted from relevant studies. All analyses and data aggregation was conducted in Revman 5.4. We followed an approach similar to Koricheva et al. (2013) that provides a clear workflow including data aggregation, calculating effect sizes, and conducting statistical models. Studies that were included in the meta-analysis had to include the following criteria: 1) description of the GI and comparable feature (i.e. conventional counterparts), 2) the improvement of environmental problems, and 3) data reported/provided as either means with standard deviation or raw data where means and error could be calculated. The number og replicates in each study was recorded to be used as the n value in analyses. I also extracted any physical characteristics that described the GI including the age post-construction, height (for green roofs and green walls), depth (for vegetated roadsides), pH of soil/water, and area (m^2) of GI. To compare similar metrics within each study, we summarized data to the taxa and measured estimate of environmental improvement. Data was summarized across all sites within a study but separated by the type of GI.

3. Result

3.1. Green infrastructure research trends

We reviewed 2,512 GI studies, of which 107 provided some qualitative description of the effects of carbon neutrality and sustainable development, and 26 had empirical data available for analysis (*Figure 1*). North America (36%) and Europe (41%) are more frequently studied. Only 33 percent of the studies were conducted outside North America and Europe. The qualitative studies came from 69 different cities in 32 different countries. This study found that the most frequently inspected cities (i.e. more than 5 times) were densely populated cities, such as Melbourne (7), Toronto (7), London (5). The number of studies testing GI has increased significantly over the past 5 years, with 68% (N=1283) using defined search term extraction. Before 2005, the average number of GI studies published per year was about five.

Most of the studies reviewed (91.4%) did not include measures to improve environmental quality and were therefore excluded. These excluded studies mainly focus on the following aspects: 1) the impact of green infrastructure on biodiversity; 2) The impact of green infrastructure on human physical and mental health. In addition, a small number of studies were excluded because they were review literature, conceptual frameworks or policy studies.

3.2. Green infrastructure vs. conventional infrastructure

In the study about the heat-island effect between green infrastructure and traditional infrastructure, a total of 7 studies were included for meta-analysis. The results showed that Heterogeneity: $I^2 = 98\%$. The random effects model (RE) was used to make the forest map. The results showed that green infrastructure and traditional infrastructure had statistical significance in alleviating heat island effect (Fig.2). Among the studies on rainwater treatment by green infrastructure and traditional infrastructure, a total of 6 studies were included for meta-analysis, the test results: Heterogeneity: $I^2 = 94\%$. Among the studies on air pollution from green infrastructure and traditional infrastructure, a total of 7 studies were included in the meta-analysis, and the test results showed that Heterogeneity: $I^2 = 80\%$. Among the studies on noise pollution from green infrastructure and traditional infrastructure, a total of 6 studies were included for meta-analysis, and the Heterogeneity: $I^2 = 96\%$.

Therefore, it is concluded that green infrastructure and traditional infrastructure have statistical significance in alleviating heat island effect, rainwater treatment, air pollution and noise pollution. Through data analysis, it is found that compared with traditional infrastructure, green infrastructure is more conducive to alleviating urban heat island effect, storm water treatment problems, air pollution and noise pollution. So green infrastructure is more conducive to achieving carbon neutrality.

4. Discussion

This study found that compared with traditional infrastructure, green infrastructure can better mitigate urban heat island effect, thus regulating urban temperature and urban microclimate. By ysung ENVI-met, a computer climate simulation program, the temperature of the study area surface was assessd according to four UGI scenarios which involved the use of the cooler materials and the addition of different green and blue assets to the existing grey uses. It was found that UGI has an effective role in reducing the SUHI intensity by 4 to 22°C in one city (Maryam, 2021). Green infrastructure also improves water quality by filtering pollutants from rainwater.Green infrastructure (GI) revitalizes vegetation and soil, restores hydro-ecological processes destroyed by traditional urbanization, and naturally manages storm water on-site, offering numerous sustainability benefits (Krishna P., 2023). Green infrastructure can better control the amount of water on the ground during the rainy season, thus preventing water accumulation and flooding caused by excessive rainfall. Urban flooding is one of the greatest threats to life and property, further exacerbated by the impacts of a warming climate. A study show that green infrastructure remains effective during more frequent storms (~ 80th percentile) that can occur in warmer climatic conditions and retrofitting or converting a smaller than expected percentage of the urban landscape (up to 5 %) can yield appreciable benefits (Suresh. 2022). Green infrastructure cleans the air by better removing pollutants from it. A study investigated the potential performance of air pollution removal by the green infrastructures and urban forests in the city of Florence, central Italy, with a focus on the two most detrimental pollutants for human health: particulate (PM10) and ozone (O3). The spatial distribution of green infrastructures was mapped using remote sensing data. A spatial modeling approach using vegetation indices, Leaf Area Index, and local pollution concentration data was applied to estimate PM10 and O3 removal. The results are discussed to highlight the role and potential of green infrastructures and urban forests in improving air quality in Southern European cities (Francesca, 2016). To sum up, urban green infrastructure is of great significance for achieving carbon neutrality.

4.1. The limitations of green infrastructure in achieving carbon neutrality

Results show GI is an improvement over conventional infrastructure in most cases, but it still has some limitations for achieving carbon neutrality. The first limitation is that while green infrastructure can mitigate urban heat island effects better than conventional infrastructure, it has a limited effect on carbon neutrality. The second limitation is that because carbon neutrality is a very complex issue, it includes economy, policy, technology and many other areas.

4.2. The research prospect of urban green infrastructure

Existing studies show that urban green space plays a prominent role in social, environmental, biological and economic aspects. It is an important place to relieve pressure, enhance communication, cultivate emotions and exercise the body in modern society, and it is irreplaceable in the future urban development. In addition, the dense population and crowded buildings lead to constant contradictions and conflicts in modern cities. The existence of urban GI is not only an ideal way to realize the construction of an ecological city, but also an effective way to alleviate various contradictions and conflicts in the process of urban development. As an important part of urban landscape, urban green space is the “glue” between urban buildings. It connects isolated buildings organically. It not only forms the “face” of the city, but also serves as the lubricant for each building unit (Wilson et al, 2011). From the perspective of research content, geographical knowledge plays a special role in the cognition of urban green space location and regional differences, so urban green space should be one of the main research contents of urban geography. Based on the scale, size and landscape characteristics of green space, this paper makes a comprehensive analysis of its ecological, social and economic functions, understands and measures the contribution and role of green space to the social, economic and environmental aspects of the city in combination with the distribution characteristics of urban residential and economic activities, and analyzes the interaction between the natural and social economic aspects of the city. So as to optimize the urban layout and enhance the sustainability of urban development (Zhenshan Yang, 2015) (Figure 3).

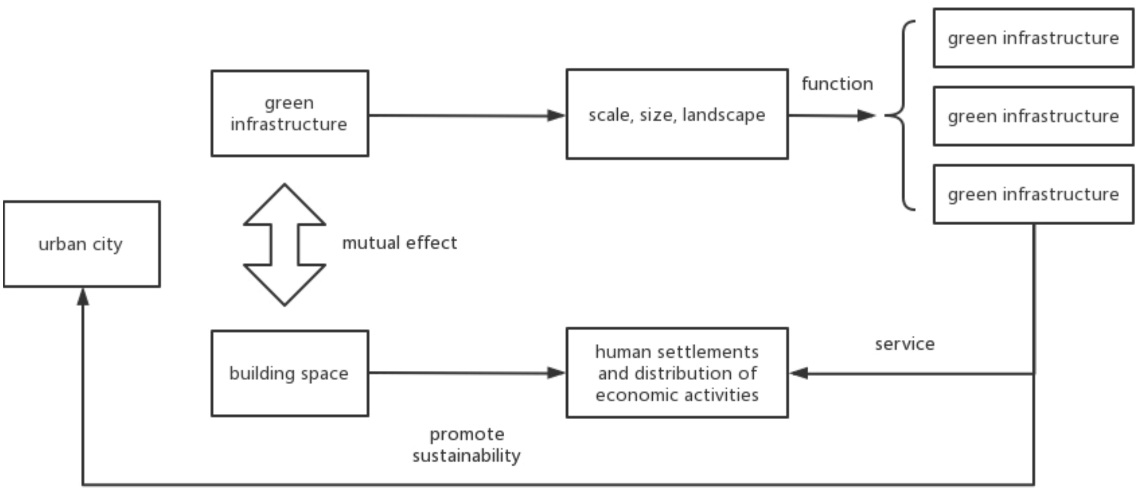

Figure 3. Role of urban green space in sustainable urban development

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Support Information

Table 1: Definitions of constructed green infrastructure (GI) types used for comparisons with conventional and natural counterparts.

GI Type	Definition	Conventional Infrastructure	Key reference
Green roof	Roofs with a vegetated surface and substrate that supports the vegetation. The vegetation can be of any type.	Asphalt roof	(Oberndorfer et al., 2007)
Green wall	Vegetation that grows on the side of a building and relies on support structures (e.g. trellises)	Concrete or brick wall	(Hunter et al., 2014)
Rain garden	Rain gardens are shallow, vegetated depressions that are decentralized micro-scale control measures for rainwater management.	The rain collection system or the drain	(Ewa, 2023)
Yards/gardens	Residential properties and local gardens for growing food, i.e. community and allotment gardens	A vacant lot within a city that has vegetation and is unmanaged besides mowing	(Cameron et al., 2017)

Table 2: The frequency of studies that were examined for each green infrastructure (GI) type and the urban environmental problems that were explored

GI Type	Number of Studies	Heat Island Effect (%)	Rainwater Treatment (%)	Air Pollution (%)	Noise Pollution (%)
Green roof	151	40%	28%	30%	2%
Green wall	41	46%	0%	32%	22%
Rain garden	10	0	100%	0	0
Yards/ gardens	16	31%	62%	0	7%
Vegetated roadsides	16	19%	0	81%	0

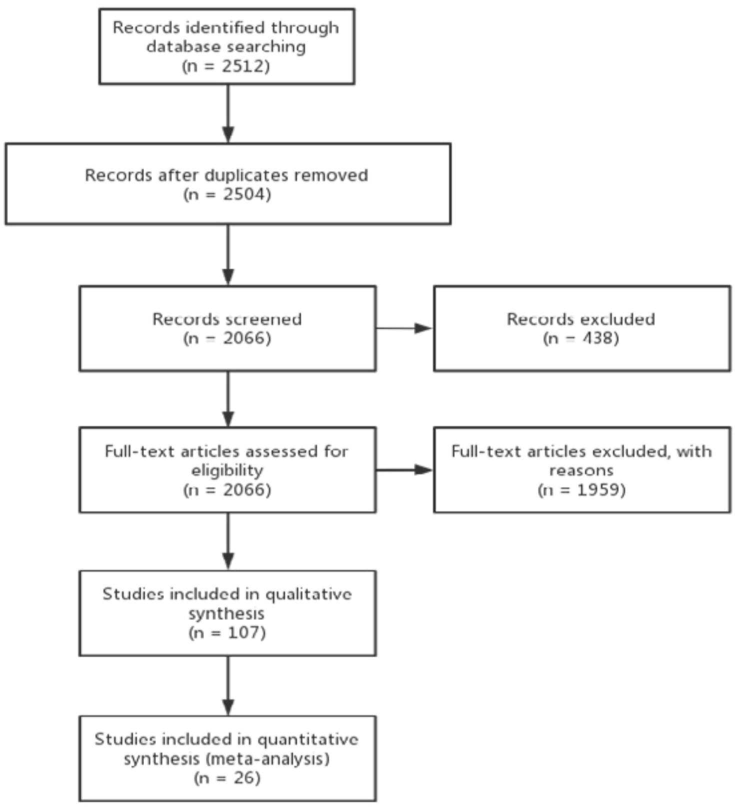

Figure 1. report on the number of studies examined and retained through the systematic review

Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio M-H, Random, 95% CI
2.1.1 heat island effect						
Carlos Ba 2020	72	253	116	120	4.1%	0.29 [0.24, 0.36]
Carlos Ba 2021	86	160	123	160	4.2%	0.70 [0.59, 0.83]
Federica 2022	144	150	150	208	4.3%	1.33 [1.22, 1.46]
H. M. P. I. K. Herath 2018	63	280	43	280	3.7%	1.47 [1.03, 2.08]
L. Zardo 2017	58	60	60	135	4.1%	2.17 [1.79, 2.64]
Maryam F 2021	30	93	30	107	3.4%	1.15 [0.75, 1.76]
Richard Le 2022	60	85	100	120	4.2%	0.85 [0.72, 0.99]
Subtotal (95% CI)		**1081**		**1130**	**28.1%**	**0.97 [0.61, 1.55]**
Total events	513		622			
Heterogeneity: Tau² = 0.38; Chi² = 287.08, df = 6 (P < 0.00001); I² = 98%						
Test for overall effect: Z = 0.12 (P = 0.91)						
2.1.2 rain water treatment						
Cary Co 2021	60	05	100	120	4.2%	0.05 [0.72, 0.99]
Jingming Hou 2020	68	196	68	271	3.9%	1.38 [1.04, 1.83]
Josefina Herrera 2017	52	165	165	240	4.0%	0.46 [0.36, 0.58]
Kyoung Jin An 2015	342	415	342	445	4.4%	1.07 [1.00, 1.15]
Newton Célio 2017	100	121	100	196	4.2%	1.62 [1.38, 1.90]
Sara Perales-Momparler 2017	179	316	183	398	4.3%	1.23 [1.07, 1.42]
Subtotal (95% CI)		**1298**		**1670**	**25.0%**	**1.03 [0.80, 1.33]**
Total events	801		958			
Heterogeneity: Tau² = 0.09; Chi² = 89.51, df = 5 (P < 0.00001); I² = 94%						
Test for overall effect: Z = 0.22 (P = 0.83)						
2.1.3 air problem						
Ashutosh Kumar Pandey 2015	35	235	34	120	3.4%	0.53 [0.35, 0.80]
Ashutosh Kumar Pandey 2016	37	160	54	160	3.6%	0.69 [0.48, 0.98]
Mare Orbinovska 2020	33	342	40	342	3.3%	0.02 [0.53, 1.20]
Margareth Viecco 2021	59	150	60	150	3.9%	0.98 [0.74, 1.30]
Naomi J. Paull 2018	37	280	67	280	3.6%	0.55 [0.38, 0.80]
Nathalie Tomson 2021	46	60	60	60	4.3%	0.77 [0.67, 0.89]
V. M. Jayasooriya 2017	28	30	30	38	4.2%	1.18 [0.98, 1.43]
Subtotal (95% CI)		**1257**		**1150**	**26.3%**	**0.78 [0.62, 0.99]**
Total events	275		345			
Heterogeneity: Tau² = 0.07; Chi² = 30.72, df = 6 (P < 0.0001); I² = 80%						
Test for overall effect: Z = 2.07 (P = 0.04)						
2.1.4 noice problem						
Chang Liu 2022	60	85	100	120	4.2%	0.85 [0.72, 0.99]
Lan-Ting Chang 2022	68	196	68	271	3.9%	1.38 [1.04, 1.83]
M. Connelly 2015	52	165	165	240	4.0%	0.46 [0.36, 0.58]
Myung-Jun Kim 2014	100	121	100	196	4.2%	1.62 [1.30, 1.90]
Z. Azkorra 2015	46	60	60	60	4.3%	0.77 [0.67, 0.89]
Subtotal (95% CI)		**627**		**887**	**20.6%**	**0.92 [0.62, 1.38]**
Total events	326		493			
Heterogeneity: Tau² = 0.20; Chi² = 95.57, df = 4 (P < 0.00001); I² = 96%						
Test for overall effect: Z = 0.39 (P = 0.69)						
Total (95% CI)		**4263**		**4837**	**100.0%**	**0.92 [0.78, 1.08]**
Total events	1915		2418			
Heterogeneity: Tau² = 0.16; Chi² = 522.33, df = 24 (P < 0.00001); I² = 95%						
Test for overall effect: Z = 1.05 (P = 0.29)						
Test for subgroup differences: Chi² = 2.58, df = 3 (P = 0.46), I² = 0%						

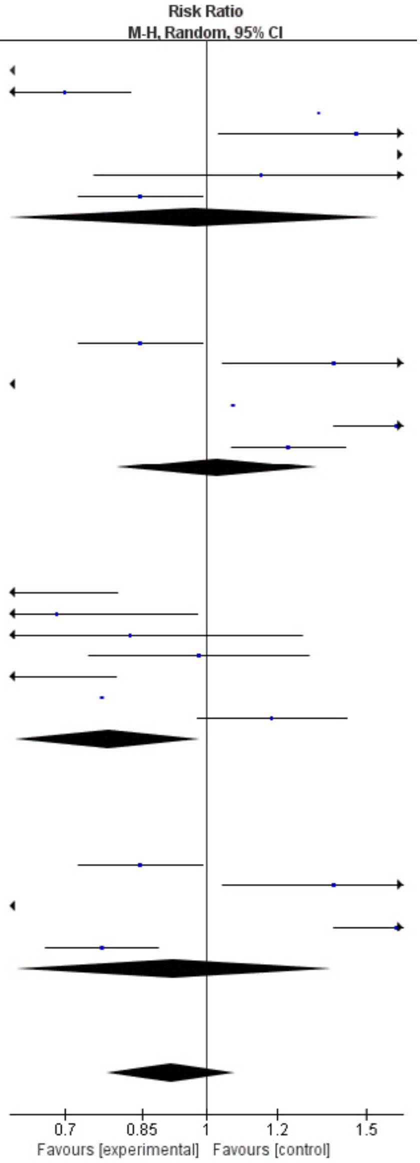

Figure 2. Mean effect sizes (Hedges'd) of green infrastructure (GI) on biodiversity relative to conventional counterpart separated by GI type

The study number represents a unique identifier from the list of manuscripts that were systematically reviewed (Filazzola et al., 2018). The measure is the estimate of carbon neutrality used that study. Error bars represent 95% confidence intervals and bars not overlapping zero (dashed line) are considered significant. To assess bias in the selection of studies, we calculated the Rosenthal's fail-safe number to be 432, suggesting there would need to be a significant number of unpublished studies to reduce these findings to insignificant.

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The Potential of Public Transport to Reduce Carbon Emissions in Urban Areas - A Singapore-Based Study

Chi ZHANG

Dalian Maritime University, Dalian, China, 116026

Email: forzhangchi@dlmu.edu.cn

***Corresponding author**

Abstract

The transportation industry as an important source of global carbon emissions has been confirmed by many authorities. This paper studies the impact of public transport on achieving carbon neutrality. After summarizing the literature review process, we have gained a lot. Some suggestions are as follows: use systematic search after screening, analysis, comparison, comprehensive extraction and summary of research methods, findings and conclusions. Based on the data of Singapore from 2004 to 2014: Public transport has a strong correlation with carbon emissions. When the indicators of public transport rise and urban carbon emissions and other pollution indicators show a downward trend, however, when the city faces the goal of carbon neutrality, there are still challenges in knowledge and data gap, funding, technology and cultural habits. Therefore, this paper puts forward suggestions to increase investment and support for public transport, formulate policies and promote technological innovation.

Keywords: Carbon neutrality, public transport, carbon emission, transportation industry, urban construction.

At present, the world is facing increasingly serious environmental problems caused by climate change and greenhouse gas emissions. Numerous scientific studies have shown that excessive greenhouse gas emissions will cause global temperatures to rise, triggering severe consequences such as extreme weather events, rising sea levels and ecosystem collapse. Carbon neutrality refers to the goal of reducing net carbon emissions to zero and achieving climate change mitigation by reducing and offsetting emissions. Its significance is to mitigate global climate change. Carbon neutrality advocates stabilizing the accumulation of greenhouse gases in the atmosphere below a safe level by reducing carbon emissions and taking measures to compensate for the remaining emissions, so as to avoid further exacerbating the impact of climate change.

The public transport sector's role in making the world carbon neutral is too important to ignore. As one of the major sources of global greenhouse gas emissions, the transport sector must take proactive measures to reduce its environmental impact. Authorities such as the International Energy Agency have identified the transport sector as a significant source of global carbon emissions. The transportation sector contributes about 23% of global energy-related carbon emissions, according to the IEA. In its report, the UNFCCC recognizes the significant impact of the transport sector on carbon emissions: the transport sector accounts for about 14% of total global CO2 emissions. Research by the International Transport Forum shows that the transport sector is one of the biggest growth sectors in global greenhouse gas emissions, with carbon emissions from the transport sector projected to grow by nearly 60 percent by 2050.

With the acceleration of global urbanization and the increasing threat of climate change, reducing urban carbon emissions has become an urgent task. As an important part of urban transport system, public transport plays an important role in achieving carbon neutrality. Public transport can not only provide people with sustainable means of travel, reduce the need for personal car use, and reduce the total carbon emissions of the transport sector; It can also reduce reliance on limited resources by encouraging people to choose public transport, reducing carbon emissions while improving transport efficiency. This helps to improve urban air quality, reduce traffic noise and improve citizens' quality of life, while driving urban planning and development in a more sustainable direction.

This paper first introduces the background and significance of carbon neutrality, as well as the importance of the transportation industry in carbon emissions. Secondly, combined with specific urban development data, it demonstrates the main problems and challenges faced by the transportation industry to achieve the goal of carbon neutrality, and puts forward solutions and suggestions. Finally, the main findings of the study are summarized and the importance and significance of the transport industry in the context of carbon neutrality are highlighted. The paper comprehensively explores the role and challenges of public transport in carbon neutrality, providing valuable insights and suggestions for sustainable transport development.

1. Method

1.1. Search strategy:

The search strategy is mainly based on authoritative journal literature. Includes Nature Climate Change, Global Environmental Change, Environmental Science & Technology, Transportation Research Part D: Journals such as Transport and Environment, whose publications in the fields of carbon neutrality and environmental science are widely recognized and cited; Key words: "Carbon neutrality", "carbon neutral transportation", "public transportation" etc.

1.2. Source selection criteria:

First of all, the date of the first edition is limited to after 2010. The importance of recent literature is higher than that of long-term literature, because short-term references can better reflect the current actual situation. In addition, the topics of the literature should include topics related to carbon neutrality and transportation to prevent excessive divergence and ineffective reading. For the consideration of credibility, this paper tries to select more journals and official institutions accepted by peers to obtain various kinds of information.

1.3. Literature analysis process:

Literature analysis includes the comparison and synthesis of literature, summarizing the keywords and research methods of each literature in the form of a list, so as to summarize the commonalities and differences. Of course, some appropriate methods can also be used to analyze the literature: subject analysis, content analysis or meta-analysis.

1.4. Discuss specific recommendations:

Based on the analysis of public government data from 2004 to 2014 in Singapore, it is found that the number of registered green public transport has a high negative correlation with carbon monoxide emission, PM2.5 and other environmental pollution indicators, indicating that public transport has an important impact on the realization of urban carbon neutrality.

However, based on the urban status quo of Singapore, there are still many challenges, such as: the efficiency of public transport operation still needs to be improved, and the penetration rate of electric public transport is not high, which is lower than that of comparable developed countries. Based on this, this paper puts forward the following suggestions: promote electric public transport vehicles, accelerate the promotion of electric buses, electric taxis, and other electric public transport vehicles. Improve the operational efficiency of the public transport system, optimize bus routes, improve vehicle scheduling and passenger management measures. Enhancing the integration of public transport with other modes of transport, for example by promoting seamless connection with shared transport, to improve the overall efficiency of the transport system. The above recommendations are intended to help Singapore's public transport sector achieve its goal of carbon neutrality. A comprehensive approach combining technological innovation, policy support and public engagement can move public transport systems towards greener and more sustainable development and reduce their impact on climate change.

2. Results

Based on the study of Singapore, this paper finds that the operation quantity, quality and running status of public transport have a strong correlation with environmental pollution indicators such as carbon dioxide, carbon monoxide and PM2.5, indicating that public transport has an important impact on the realization of urban carbon neutrality. Singapore's public transport is moving towards a more environmentally friendly, efficient and sustainable development direction: the Singapore government vigorously promotes electrification, intelligence, digitization, shared transport, light rail network expansion, and implements the sustainable development strategy into the transport industry. Therefore, the contribution of Singapore's environmental status to carbon neutrality increases year by year. The gaps and challenges are as follows: Although Singapore has taken many measures and promulgated relevant policies in the field of public transport, there are still problems such as low operating efficiency of public transport and lower penetration rate of electric public transport than that of the same developed countries. Singapore has room to promote the development of public transport by improving operational efficiency, enhancing the integration of multi-modal transport (especially with shared transport), and introducing innovative technologies to achieve carbon neutrality.

In conclusion, the implications of public transport in the process of carbon neutrality are as follows:

2.1. Reduce energy consumption and improve overall efficiency

Public transport, which mainly uses a centralized mode of transport, can carry more passengers than private cars. According to the Singapore Land Transport Authority (LTA), each public transport can replace about 12 private cars. Therefore, by promoting the use of public transport, a significant amount of exhaust emissions can be reduced. Reducing air pollution and greenhouse gas emissions will help mitigate climate change. At the same time, the planning and management of public transportation help to optimize the utilization of transportation resources. Reasonable design of bus routes, vehicle scheduling and passenger flow management can reduce vehicle congestion and traffic jams and improve the overall traffic efficiency. This not only saves energy and time, but also reduces energy waste and carbon emissions.

2.2. Forming a closed loop of sustainable development

The development of public transport is closely related to urban planning and sustainable development. By building an efficient public transport system, urban traffic congestion and waste of land resources can be reduced. Public transport also helps to improve the travel experience of residents and increase the accessibility and social inclusion of cities. Shaping green travel and promoting the use of public transport can cultivate people's awareness and habit of green travel. The formation of this green travel culture will further promote the process of carbon neutrality and reduce the negative impact of individual carbon footprint.

Therefore, the development of public transport is of great importance in achieving the goals of urban sustainability and carbon neutrality. By continuing to improve the reliability, accessibility and environmental quality of public transport, we can encourage more people to take public transport, reduce reliance on private cars, and reduce carbon emissions and environmental burdens on cities. This requires governments, transport authorities and society to work together to develop and implement policies to invest in and improve public transport infrastructure to achieve sustainable and green urban transport systems.

3. Discussion

Public transport is important in the context of carbon neutrality. With the growing threat of global climate change, reducing greenhouse gas emissions is a top priority. As a centralized transportation mode, public transport vigorously promotes the construction of a low-carbon transportation system that can reduce exhaust emissions, optimize the allocation of transportation resources, promote sustainable urban development, and realize low-carbon transportation.

First of all, the promotion and use of public transport can reduce a lot of exhaust emissions, air pollution and greenhouse gas release. Singapore's public transport system saves millions of tonnes of carbon dioxide emissions every year, according to official figures. This has significant implications for improving air quality, protecting people's health and mitigating climate change.

Secondly, the planning and management of public transportation helps to optimize the utilization of transportation resources. Through rational design of bus routes, dispatching vehicles and managing passenger flow, vehicle congestion and traffic jams can be reduced and the overall traffic efficiency can be improved. This not only saves energy and time, but also reduces energy waste and carbon emissions.

In addition, public transport can contribute to sustainable urban development. By building an efficient and convenient public transport network, private car use can be reduced, traffic congestion and parking needs can be reduced, and land resources waste can be reduced. This provides the city with more space for public space, greening and community facilities, improving the quality of life of residents.

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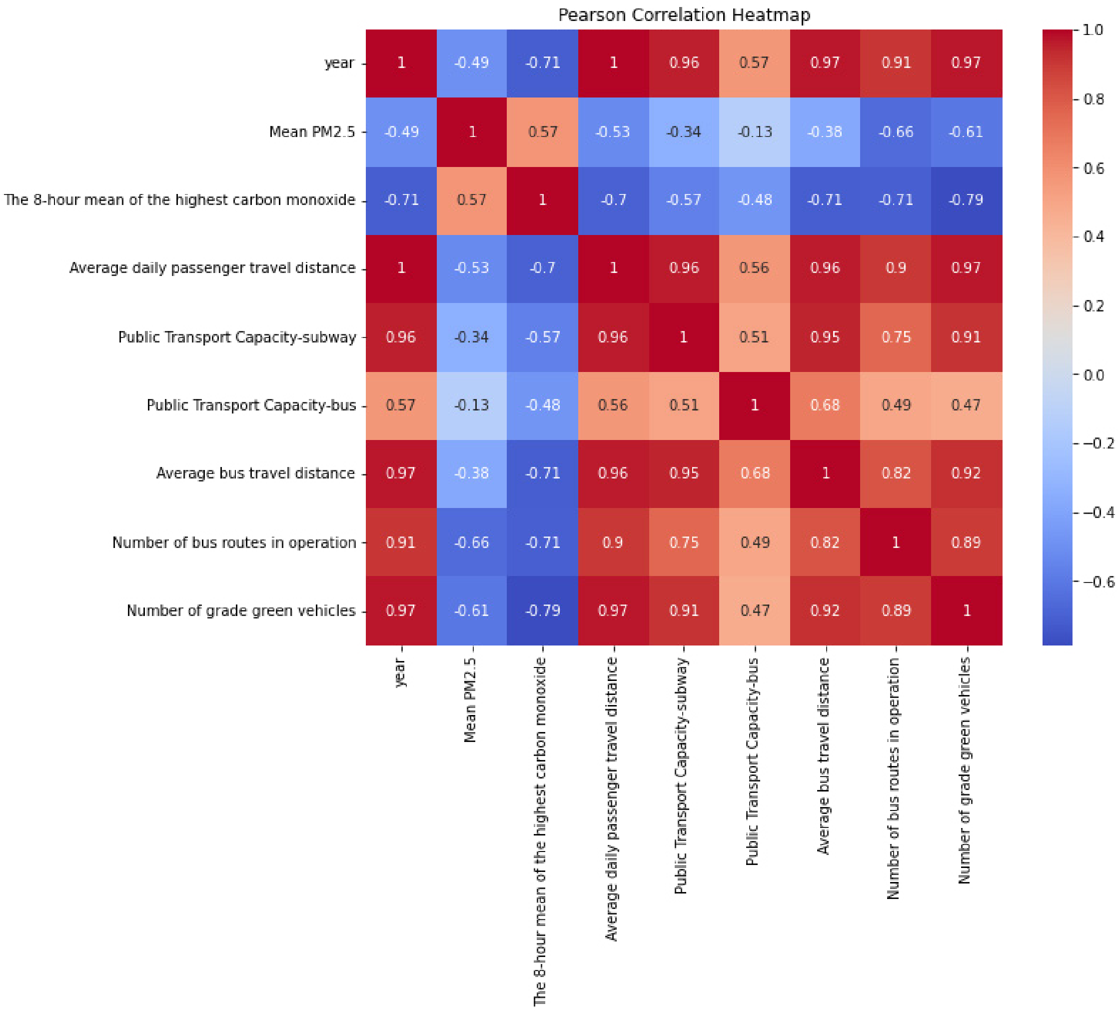

Figure 1. shows the correlation between data on Singapore from 2004 to 2014

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The Impact of Refrigerant Recycling on Reducing Carbon Emissions

Jiaxin ZHAO

Dalian Maritime University, Dalian, China, 116026

Email: 15515108892@163.com

***Corresponding author**

Abstract

Climate change is a serious global environmental problem currently facing humanity, and greenhouse gas emissions are an important cause of global climate change. Refrigerant recovery and treatment are of great significance in reducing greenhouse gas emissions. In order to reduce the ozone layer destruction and global warming caused by refrigerants, this paper analyzes the status quo of refrigerant recovery and disposal in the United States, the European Union and Japan, aiming to effectively manage refrigerants to reduce their environmental hazard. On the basis of in-depth industry research, this article focuses on the recovery and regeneration process of refrigerants as the main research object. Based on the LCCP climate performance model, a carbon emission assessment model for the refrigerant recovery and regeneration process is constructed. Taking the recovery and regeneration of automotive air conditioning refrigerant R134a as a case, its carbon emissions are calculated. The results indicate that in this case, recycling and regenerating the refrigerant can reduce equivalent CO_2 emissions by approximately 42%.

Key words: Climate change; refrigerant recovery; carbon neutrality.

1. The Impact of refrigerant recycling on reducing carbon emissions

Faced with the threat of climate change, controlling greenhouse gas emissions has become the primary task of protecting the global ecological environment. The refrigerant related policies formulated by the United States include: Standard for Recycle/Recover Equipment, Performance and Safety of Flammable Refrigerant Recovery and Recycling Equipment, Performance of Refrigerant Recovery, Recycling, and Reclaim Equipment. At the same time, it is legally stipulated that enterprises engaged in refrigerant recovery and utilization must obtain qualification certification from the United States Environmental Protection Agency in order to legally carry out refrigerant recovery. Currently, EPA recognized institutions for certification of recovery and recycling equipment include AHRI, UL (Air Conditioning, Heating, and Refrigeration Institute (AHRI) and Underwriters Laboratories (UL)).

The EU Regulation on F-gases, have been introduced by the EU to regulate the recycling, treatment, and destruction of ODS, with the aim of reducing HFCs within Europe. Similarly, refrigerant recovery, recycling, or destruction in Europe requires certification from an EU recognized certification body and qualification to carry out the above operations. Each member state has different requirements for the recycling and disposal of refrigerants based on compliance with EU regulations.

Japan's legislation on the recycling of chlorofluorocarbons includes CFC recycling and destruction methods, automobile recycling laws, household appliance recycling laws, etc. The regulation prohibits the direct discharge of refrigerant from air conditioning into the atmosphere. When dealing with and disposing of refrigeration air conditioners, it is an obligation to recover the refrigerant. The recycling and reuse of refrigerants in Japan is a national leading organization under the guidance of the government, with associations as the main body. It is the Japan Refrigeration and Air Conditioning Industry Association, which focuses on refrigeration recycling work in Japan, the Japan Refrigeration and Air Conditioning Equipment Industry Federation, which focuses on engineering services, and the Fluorinated Hydrocarbon Association, which mainly produces fluorinated hydrocarbon enterprises. It has been approved by the Machinery Intelligence Bureau of the Ministry of Economy and Industry of Japan to establish the Fluorine Refrigerant Regeneration Center, Starting from 1995, the qualification certification of refrigerant recovery and recovery technicians was carried out, and it was renamed as the Refrigerant Recovery Promotion Technology Center in 1988.

For unusable waste refrigerants, they are disposed of through destruction. The United States, the European Union, and Japan have rich ODS destruction technologies, achieving environmentally friendly disposal of ODS. Table 1 lists the current commercial destruction facilities in the United States, the European Union (some countries), and Japan, as well as the types of technologies used, as well as the capabilities and costs of ODS destruction. At present, there are 11 ODS commercial destruction facilities in the United States with a disposal capacity of 318 tons/year, and over 47 ODS commercial destruction facilities in the EU member states listed in the table have a disposal capacity of over 3600 tons/year, while there are 80 such facilities in Japan. Japan is currently the country known to have the most abandoned ODS disposal facilities.

Table 1. Refrigerant Destruction Facilities

different countries	Number of ODS facilities destroyed	Technology used	ODS Destruction Capability
America	11	Rotary kiln method Plasma method Fixed furnace unit Liquid injection unit method Cement kiln method Light aggregate kiln method	318 tons/year
Belgium	2	kiln process	-
The Czech Republic	1	kiln process	40 tons/year
Denmark	4	Catalytic cracking method	-
Finland	1	kiln process	545 tons/year
Germany	7	Hazardous Waste Incineration Reaction furnace cracking Porous reactor method	1600 tons/year
Hungary	5	kiln process	75 tons/year
Sweden	4	Air plasma method	100 tons/year
Japan	80	Rotary kiln method Nitrogen plasma arc method	36 tons/year

There are currently three main methods for evaluating carbon emissions. Global Warming Potential (GWP), evaluating the greenhouse effect of refrigerants, their ability to absorb infrared radiation, atmospheric lifespan, and time of use compared to CO_2; Total Equivalent Warming Impact (TEWI), proposed by the Kyoto Protocol, evaluates the climate performance of refrigerants operating in refrigeration systems for a certain period of time, calculates the direct/indirect emissions of refrigerants, energy consumption of refrigeration system operation, energy consumption of refrigeration system and refrigerant transportation, and the impact of total carbon emissions on the greenhouse effect during the process; The Full Life Cycle Climate Performance Index (LCCP) was proposed by Arthur D Little in 1999 to comprehensively evaluate the greenhouse effect of refrigerants and refrigeration systems during their operational life cycle. On the basis of TEWI, LCCP evaluation indicators include the production and recovery processes of refrigerants and refrigeration systems, as well as the impact of refrigerant decomposition products on the greenhouse effect.

With the upgrading of global environmental requirements and the deepening of environmental protection work, the refrigerant regeneration process has become an indispensable part of the refrigerant life cycle. The energy consumption and corresponding carbon emissions during the refrigerant regeneration process, as well as the evaluation of carbon reduction in the replacement of newly produced refrigerants with regenerated refrigerants, need to be explored. This article constructs a carbon emission assessment model for the refrigerant recovery and regeneration process based on the refrigerant recovery and regeneration technology and disposal process; Analyze the economic benefits of refrigerant regeneration treatment, including resource and energy consumption, environmental protection benefits, etc. during the refrigerant treatment process.

2. Method

2.1. Participants

Incorporate the indirect carbon emissions caused by the production, transportation, recovery, and regeneration of refrigerants, as well as energy consumption, into the full lifecycle model.

2.2. Design

The calculation process of the traditional carbon emission assessment method LCCP model is shown in Figure 2. The main data inputs in the calculation process include refrigerant leakage, production energy consumption of various system component materials, system cooling capacity, energy conversion efficiency ratio (customized cooling capacity/heating capacity to rated power ratio, abbreviated as energy efficiency ratio), and annual system operating meteorological parameters. The model does not include carbon emission calculations for refrigerant recovery and regeneration processes. In the refrigerant industry, in order to achieve the goal of carbon neutrality, the recovery and regeneration of refrigerants in units to be repaired or disassembled is one of the important ways to reduce carbon emissions. Therefore, this article attempts to supplement the carbon emission model of the refrigerant recovery and purification process with the traditional LCCP model, modeling two scenarios: refrigerant recovery and regeneration, and refrigerant non-recovery. Among them, in the case of refrigerant recovery and regeneration, different refrigerant recovery and regeneration disposal methods are modeled.

Refrigerant recovery and regeneration require the use of energy consuming equipment such as recovery/purification regeneration equipment and transportation equipment. At the same time, some refrigerant leaks inevitably occur during the process. Data such as energy consumption and leakage loss of each equipment are important input data for model solving.

During transportation, use, and other processes, direct leakage and discharge of refrigerant into the atmosphere result in direct emissions, while indirect emissions are caused by energy consumption during refrigerant production, transportation, recovery, purification, and regeneration. According to the SAE J2766-2019 Refrigerant Life Cycle Climate Performance Assessment Index, the direct and indirect emissions that cause greenhouse effects are shown in Table 1. The direct emissions are expressed as CO_2 equivalent emissions, and their values are evaluated based on

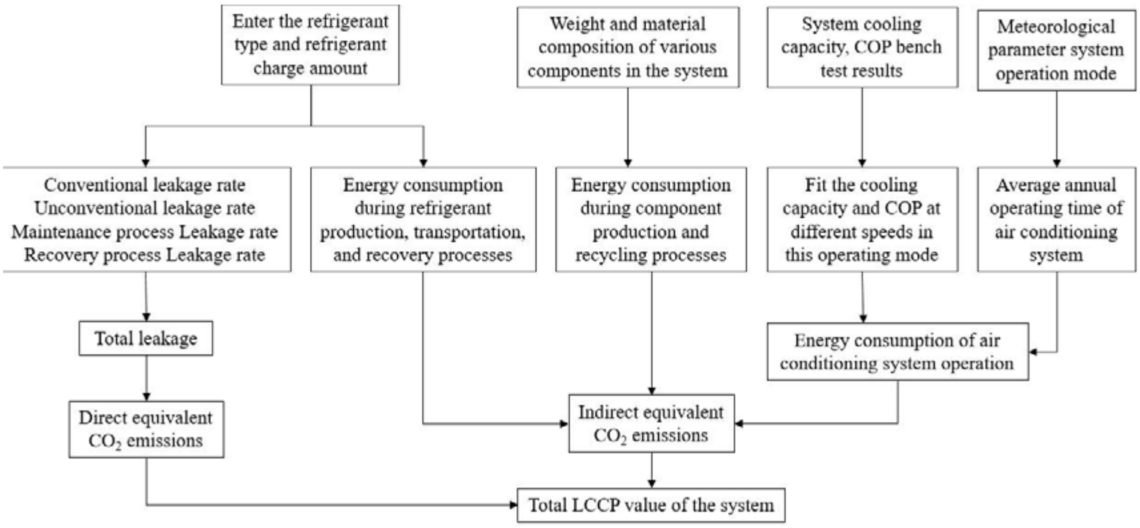

Figure 2. LCCP model composition

the global warming potential (GWP) of each chemical and the amount of refrigerant released into the atmosphere. Indirect emission calculation is related to the energy consumption of manufacturing, use, and treatment refrigeration systems, and the sum of CO_2 equivalent corresponding to this energy consumption is calculated. Refrigerant total equivalent CO_2 emissions = direct equivalent CO_2 emissions + indirect equivalent CO_2 emissions.

In the refrigerant recovery, purification, and regeneration process, some refrigerants directly leak into the external environment during the recovery and purification process, and the recovered refrigerant

There is still a small amount of residual refrigerant leaking into the environment during maintenance, which together constitute direct emissions that affect the greenhouse effect; The operational energy consumption of recycling and purification equipment constitutes indirect emissions that affect the greenhouse effect.

2.3. Materials

This article takes R134a, a refrigerant used in automotive air conditioning, as the research object to analyze its carbon emissions throughout its entire life cycle. The refrigerant charge capacity of an ordinary car air conditioner is about 600-900 g, and the car air conditioner normally loses 10% to 15% of the refrigerant every year. Every year, approximately 250 g of refrigerant is replenished for each car air conditioning repair.

The leakage of refrigerant is composed of the amount of refrigerant directly discharged into the atmosphere, including conventional leakage, unconventional leakage, maintenance process leakage, and recovery and regeneration process leakage. Referring to the leakage data related to the emission rating of refrigerant R134a in the automotive air conditioning system, it is estimated that the average conventional leakage of R134a is 115 g/a, the unconventional refrigerant leakage is 17 g/a. The leakage caused by professional maintenance is about 35 g, and the leakage caused by user self-repair is about 52 g. The refrigerant leakage during the recycling process of each scrapped vehicle is 100-450 g, and the actual leakage depends on the degree of refrigerant recovery and treatment.

2.4. Procedure

Assuming that the two extreme cases of refrigerant recovery are calculated separately: 1) The residual refrigerant in the automotive air conditioning should be recovered as much as possible, and the recovery rate of the agent is 90%, and only 10% is discharged into the atmosphere; 2) The refrigerant was not recovered and was directly discharged into the atmosphere, resulting in a refrigerant leakage rate of 100%. The service life of car air conditioning is consistent with the service life of the car. This article calculates the average of cars service life is 10 years. The indirect equivalent carbon emissions related to refrigerants are caused by the energy consumption of fossil fuels and electricity consumed in the production, transportation, recovery, purification, and other processes of refrigerants. This article takes the indirect equivalent CO_2 emissions caused by the production of R134a as 8 kg. The indirect equivalent CO_2 emissions in the refrigerant production process are 159 kg.

The calculation process of establishing a carbon emission assessment model for the refrigerant life cycle in a refrigeration system is as follows:

1) Obtaining the type and amount of refrigerant charged into the refrigeration unit;
2) Consult literature and industry materials to obtain data on conventional leakage, unconventional leakage, maintenance process leakage, and recovery process leakage of refrigerants. Calculate the equivalent CO_2 emissions directly emitted based on the total leakage of refrigerants;
3) Obtain the energy consumption of the production, transportation, recovery, purification, and regeneration processes of refrigerants, and calculate the equivalent CO_2 emissions indirectly emitted;
4) Calculate the total equivalent CO_2 emissions during the refrigerant life cycle. The extended refrigerant life cycle carbon emission calculation process is shown in Figure 3.

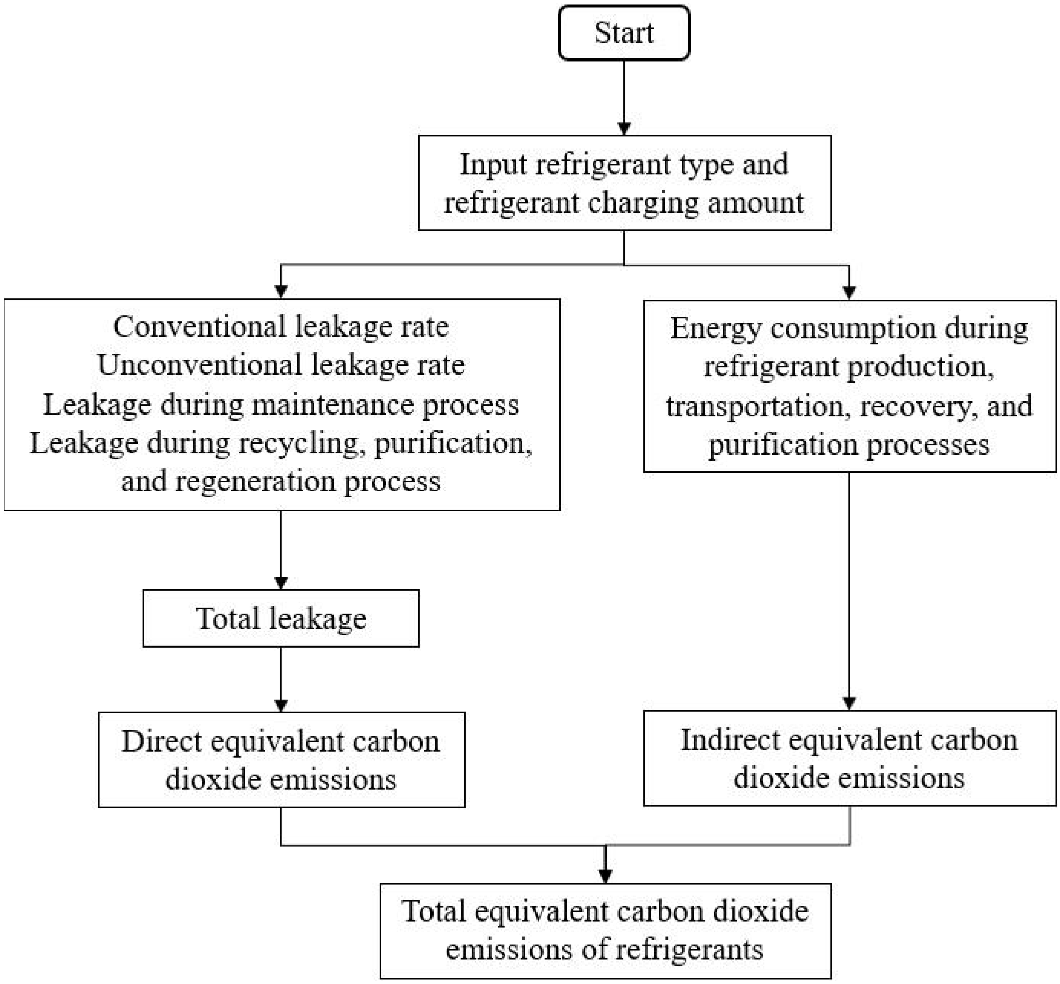

Figure 3. Flow chart of calculation of refrigerant life cycle model

3. Results

Based on the above model, the climate performance evaluation of the R134a refrigerant recovery and purification process was conducted, and the calculation results are shown in Figure 4.

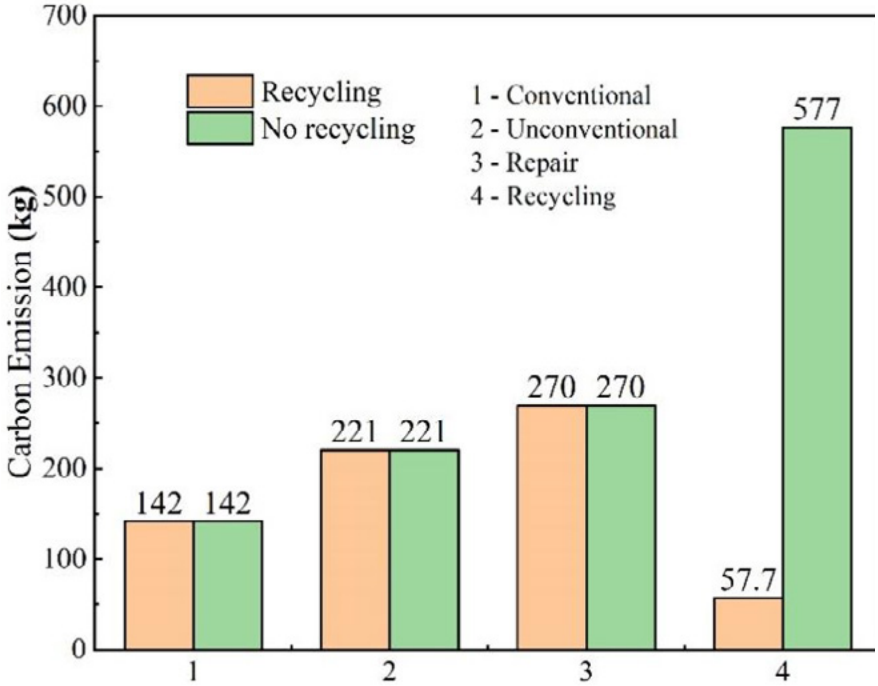

Figure 4. Carbon emissions caused by different refrigerant treatment methods

When recovering residual refrigerant from car air conditioning, the total equivalent CO_2 emissions of R134a are calculated as 704.6 kg, when the refrigerant is not recycled, the total equivalent CO_2 emissions of R134a are calculated as 1224.8 kg, recycling and purifying the refrigerant can reduce equivalent CO_2 emissions by approximately 42%.

4. Discussion

The widespread application of refrigerants has led to a large amount of emissions of Freon substances in the atmosphere, causing the problem of ozone hole and exacerbating the global greenhouse effect. To solve the environmental problems caused by the discharge of Freon substances, it is necessary to reduce refrigerant emissions. The most effective way is to establish a complete refrigerant recovery system and apply advanced refrigerant treatment technology to achieve refrigerant recovery and regeneration.

Developed countries and regions such as Japan, the European Union, and the United States started early on refrigerant recovery, with a large amount of recovery. The methods adopted by these countries are that the government and judicial authorities encourage refrigerant recovery and standardize the recovery process through legislation and the formulation of administrative regulations; Establish a refrigerant recovery organization within the refrigeration industry, develop recycling and regeneration technologies, and promote refrigerant recovery.

Finally, this article takes the process of refrigerant recovery and regeneration as the research object, and based on the LCCP climate performance model, constructs a carbon emission assessment model for the refrigerant recovery and regeneration process. Taking the recovery and regeneration of automotive air conditioning refrigerant R134a as a case, the carbon emissions are calculated. The calculation results show that recycling and purifying automotive air conditioning waste refrigerant can reduce equivalent CO_2 emissions by about 42%.

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The Development of Various Industries in the Context of Carbon Neutrality

Jiaming WU

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

Email: wu_jiaming_icnt@iexchange.world

***Corresponding author**

Abstract

In order to mitigate climate change, protect ecosystems and biodiversity, promote sustainable development, achieve economic stability and growth, and promote global cooperation and sustainable development, major industries around the world are undergoing significant changes in the context of carbon neutrality. Among them, there are significant changes in the renewable energy industry, electric vehicle industry, sustainable construction industry, agriculture and industrial sector. In these industries, most of them are trying to get closer to the goal of carbon neutrality through continuous technological innovation and changes in production and operation methods. These changes will bring new growth opportunities to the global economy, create more green jobs, and drive technological innovation and cross-industry cooperation. Achieving carbon neutrality requires a global effort to build a solid foundation for a more sustainable world through cooperation and innovation.

Keywords: Renewable energy industry; electric vehicle (EV) industry; sustainable construction industry; agriculture industry; industrial sector; a global effort.

1. Introduction

In recent years, carbon neutrality has attracted the attention of more and more countries, and many countries are taking many measures to achieve carbon neutrality. The concept of carbon neutrality is achieving a balance between the amount of greenhouse gases emitted into the atmosphere and the amount removed from it. It is an important concept in the context of climate change mitigation. More and more countries are paying more attention to environmental protection, and many have plans to become carbon neutral by 2050. Limiting global warming to 1.5°C would require humanity to significantly reduce carbon emissions by $10 billion. This includes cutting emissions to at least 49% of 2017 levels by 2030 and achieving carbon neutrality by 2050.[1] This paper will investigate and analyze the problems encountered by various industries in the context of carbon neutrality and make appropriate suggestions for the problems that arise. We mainly understand the basic situation of renewable energy industry, electric vehicle industry, sustainable construction industry, agriculture, industry and other industries.

2. Carbon emission status and technological innovation in various industries

2.1. Renewable energy industry

It is increasing crucial to improve the sustainable use rate of energy and contribute to carbon neutrality and environmental footprints reduction.[2] The current state of carbon emissions in the energy sector is a global concern. Traditional energy industries such as coal, oil and natural gas have become one of the major sources of carbon emissions due to greenhouse gas emissions such as carbon dioxide generated by their combustion processes. In order to address climate change and reduce carbon emissions, the energy industry has begun to actively carry out technological innovation. Here are some of the technological innovations currently driving carbon reduction in the energy industry: Production of new biofuel from waste cotton cellulose activated by phosphoric acid. [3]A hybrid two-stage multi-objective optimization algorithm is used to minimize the transformation of heat exchanger network.[4] And other technological innovation such as Renewable energy technologies and Energy storage technology.

These technological innovations are important for the sustainable development of the energy sector and the reduction of carbon emissions. However, technological innovation still faces some challenges, including economic costs, large-scale deployment and policy support, and global cooperation is needed to drive the transformation of the energy industry.

2.2. Electric vehicle (EV) industry

Electric vehicles have an advantage over traditional fuel vehicles as they do not produce exhaust emissions during their operation, making them a more environmentally friendly option to reduce carbon emissions and improve air quality. Moreover, many countries have introduced relevant policies to support the development of the electric vehicle industry. As a result, electric cars are more popular than ever. The promotion of electric vehicles and the reduction of greenhouse gas emissions provide important policy directions.[5] The electric vehicle industry still has carbon emissions issues due to the manufacturing process and power source. The production of electric vehicles requires energy and emits carbon emissions through mining, processing, transportation, and assembly. Furthermore, the carbon emissions of electric vehicles are influenced by their power source, with higher emissions likely if the electricity comes from coal compared to conventional fuel cars. So there are a lot of companies that are working on solving the energy problem of electric vehicles.

2.3. Sustainable construction industry

The construction sector is one of the most important sources of greenhouse gas emissions worldwide, accounting for about 39% of total global emissions. The sustainable building industry is working to reduce carbon emissions and mitigate the effects of climate change. In the sustainable building industry, technological innovation plays a key role. The sustainable building industry uses a variety of low-carbon materials such as renewable, recycled and carbon-neutral materials. A collaborative research team from Sungkyunkwan University (SKKU) and the Korea Institute of Science and Technology (KIST) has made new achievements in the research of carbon-neutral advanced materials. Materials that can better convert solar energy into electricity and heat have been explored.[6] There are also many technological innovations in the sustainable building industry, such as smart building management systems and smart grids with renewable energy.

2.4. Agriculture industry

Agriculture is one of the important sources of carbon emissions, the main carbon emissions from land use change, fertilizer use, agricultural machinery use, irrigation, animal husbandry and other processes. Because of its important contribution to carbon emissions, agriculture also has the opportunity to reduce its carbon emissions through technological innovation. Some possible technological innovations to reduce carbon emissions from agriculture include precision fertilization, improved irrigation, and food processing and storage. Agricultural innovation will play an important role in the coming decades. Agricultural research and development must not only increase agricultural productivity amid the environmental challenges of drought and warming, but the technologies and practices that underpin agricultural production must reduce emissions in the coming decades. If the profitability of agriculture cannot be maintained, or emissions cannot be reduced, the cost of achieving carbon neutrality in agriculture in the region through reforestation will only increase.[7]

2.5. Industry

Industry is one of the main sources of global greenhouse gas emissions, among which the energy sector, manufacturing and construction are the main sectors of carbon emissions. At present, global industrial carbon emissions continue to increase, causing serious impacts of global climate change. In order to meet the challenges of climate change, the industrial sector needs to carry out technological innovation and reduce carbon emissions. In industrial production, enterprises can improve in many aspects, such as improving energy efficiency, using clean energy, actively developing carbon storage technology, and improving production processes. Through technological innovation and the implementation of measures, the industrial sector can reduce carbon emissions and mitigate the impact of climate change.

3.Results and Discussion

Carbon emissions in the energy industry are still high, but with the advancement of clean energy technology and the implementation of policies, there is hope for reducing emissions and achieving carbon neutrality. The electric vehicle industry also faces emission challenges, but technological innovation can help in reducing emissions. By improving vehicle energy efficiency, promoting renewable energy, and exploring new energy technologies, electric vehicles can become more environmentally friendly. The sustainable building industry aims to reduce emissions through innovations such as low-carbon materials, improved energy efficiency, and integration of renewable energy. Similarly, agriculture can reduce emissions by promoting climate-smart practices and increasing mechanization. Governments and agricultural institutions can support this through technical assistance and incentives. Technological innovations in reducing industrial carbon emissions are key to achieving sustainable development. Collaboration between government, enterprises, and academia is needed to invest in these innovations and steer industries towards low-carbon practices.

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The Role of Renewable Energy in Achieving Carbon Neutrality

Yuxin ZHU

Northeast Forestry University, Harbin city, Heilongjiang Province, 150040

Email: zhu_yuxin_icnt@iexchange.world

***Corresponding author**

Abstract

With the global population growth and economic development, the demand for energy continues to increase, and the utilization of traditional fossil energy is having a serious impact on the environment. Renewable energy sources such as solar and wind power, as a clean and environmentally friendly form of energy, have gradually become the focus of attention worldwide. Therefore, the use of renewable energy has become an important way to achieve carbon neutrality. This paper expounds the contribution of renewable energy utilization to achieving carbon neutrality from the aspects of reducing greenhouse gas emissions, safeguarding the security of ecological and environmental and promoting sustainable development.

Keywords: Renewable energy; carbon neutrality.

1. Introduction

Energy is the material foundation of human civilization and socio-economic development [1]. At the end of the 20th century, the United Nations Framework Convention on Climate Change was adopted due to the global deterioration of the climate system. This convention aims to reduce greenhouse gas emissions and address climate change through measures such as improving energy efficiency and developing renewable energy [2].

Renewable energy, also called clean energy, derived from natural sources or is automatically replenished/regenerated without human intervention. Generally speaking, the hydroelectric power, wind power, solar energy, biofuels, and geothermal energy are five main types of renewable energy (Figure. 1) [3]. It has been pointed out that promoting the development of these renewable energy should play a crucial role in achieving carbon neutrality and creating a more sustainable future for modern cities and society [4]. By 2022, 166 Parties to the Paris Agreement that submitted Nationally Determined Contributions referred to renewable energy, about 70% of the total included quantified renewable energy development goals [5].

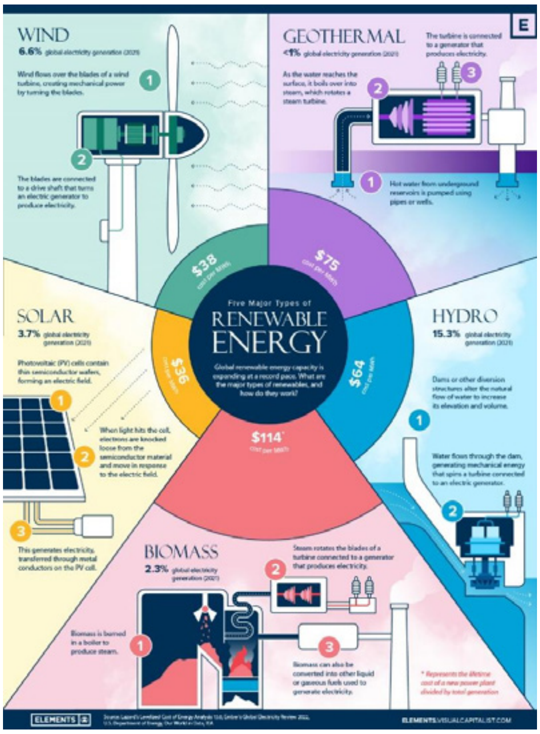

Figure 1. The percentage of the five types of renewable energy for global electricity generation and cost of energy per MWh.

2. Results

2.1. Reducing greenhouse gas emissions

The primary goal of renewable energy sources like hydro-power, wind, and solar energy is to generate electricity with minimal or no greenhouse gas emissions at all. This helps to combat climate change and air pollution and improve overall air quality. The European Union (EU) has always been a leader in the field of renewable energy, and the installed capacity of wind, solar, hydropower, and bioenergy has reached at about 240.6 GW, 194.5 GW, 255 GW, and 41.7 GW as of 2022, respectively [6]. Wind power is the largest renewable energy source in EU, accounting for 16.05% of the total electricity generation. European wind power is mainly which is mainly affected by the Arctic Ocean and the North Atlantic sea breezes, and is mainly distributed along the coast of Danish and around Greenland. The wind shows the characteristics of “big in winter and small in summer” affected by the seasons. Offshore wind power is mainly distributed in the North Sea, the Baltic Sea, the Norwegian Sea and the Barents Sea and other sea areas, but due to the high development cost, the installed capacity accounts for less than 10% of the total. In 2022, the top five countries of the EU-27 countries in cumulative wind power installed capacity are Germany, Spain, the United Kingdom (UK), France, and Sweden in descending order. Among them, Germany has the largest wind power market in Europe, accounting for one-third of the total power generation and installed capacity. The UK has the largest number of offshore winds turbines and has been expanding offshore wind projects in recent years [7]. The Large-scale utilization of renewable energy sources has made some progress in reducing greenhouse gas emissions in the EU. Alola et al. examined the impact of renewable energy and immigration on CO_2 emissions from the largest EU economies, France, Germany, and the UK, over the period 1990-2016. The results show that both the least squares correction and the dynamic ordinary least squares correction are consistent, i.e., renewable energy leads to a decrease in carbon emissions by 0.13% and 0.14%, which is significantly higher than the increase in carbon dioxide emissions caused by immigration (0.04% and 0.05%) [8].

2.2. Resilience to climate change

As climate change poses challenges like global warming and extreme weather events, renewable energy can provide a more resilient energy infrastructure and is less susceptible to disruptions caused by these events. As mentioned above, the impact of renewable energy on climate change is mainly reflected in the reduction of greenhouse gas emissions. Compared with traditional fossil energy sources, renewable energy produces almost no greenhouse gases in the production process, so it can significantly reduce carbon emissions. Several scientific and technical methods are often used to quantify their carbon emission reductions and environmental impacts [9]. 1) Life Cycle Analysis (LCA): Assess the carbon emissions of renewable energy sources throughout its life cycle, including production, operation, and end-of-life. 2) Carbon Footprint Analysis (CFP): the impact of human activities on the environment is measured by using CO_2equivalent (CO_2eq) to represent the total greenhouse gas emissions from human production and consumption activities. 3) Data model analysis: Simulate the impact of renewable energy on climate change in different scenarios through data modeling. 4) Remote sensing technology: With the advantages of objectivity, continuity, stability, large-scale and repeated observation, it has become an indispensable technical means for monitoring the global carbon inventory and an internationally recognized method for global carbon verification.

Definitely, these methods are not used alone in practical research. Arvesen and Hertwich [10] reviewed the life cycle and carbon footprint studies on wind power generation, estimating 19 (±13) grams of CO_2 emissions per kWh, which has low carbon emissions compared to fossil energy sources. However, which link in the life cycle of wind power brings the most carbon emissions have not been finally determined, after all, the calculation method and assessment objectives are not completely consistent. Sherwani et al. [11] summarized all previous PV full life cycle studies and found that the carbon footprints of three types of solar PV systems, amorphous, monocrystalline and polycrystalline silicon, ranged from 15.6-50 g, 44-280 g, and 9.4 -104 grams per kilowatt hour (gCO_2e/kWh). Additionally, some scholars have complemented remote sensing data from three satellites to investigate a single source of methane emissions as one of the world's largest methane hotspots, located on the west coast of Turkmenistan. It was found that there are 29 different active emission sources with emission rates greater than 1800 kg/h during the period from 2017 to 2020. All sources were associated with oilfields that are mainly used to produce crude oil, of which 24 are inactive natural gas flares. At the regional level, the number of methane plume detected in 2020 increased significantly compared with previous years [12].

2.3. Environmental preservation

Unlike fossil fuel extraction and combustion, the renewable energy production has a much lower impact on the on the environment. It reduces habitat destruction, water pollution, and land degradation.

Rahman et al. [13] reviewed the influences of each renewable energy on all the environmental. Although major renewable energy sources produce less greenhouse gas emissions than non-renewable energy sources, they still have some impact on the environment during the installation, maintenance, and dismantling stages (Table 1). Hydroelectric power plants, for example, which require large tracts of land, not only lead to drying up of downstream rivers, causing drought, soil erosion and even soil degradation, but also contribute to eutrophication and an increase in suspended sediments, altering lagoons and deltas, triggering floods, and altering water temperatures and oxygen levels. Compared with other renewable energy sources, hydroelectric power plants have the greatest impact and damage to the environment and ecosystems. On the other hand, Solar photovoltaic and centralized solar power generation will produce ozone depletion, and dust, heavy metals and other harmful substances will be produced during the production and disposal of solar panels. Even wind turbines and biomass power plants, which have negligible impacts on the environment, have some disadvantages, such as affecting agricultural land, causing noise, and visual impact on wildlife.

Table 1: Impacts of different renewable energy sources on various types of environment[14].

	Environmental impact	Solar	Solar thermal	Wind	Biomass	Geothermal	Hydropower
Air	Greenhouse gas emis sion	Moderate	Moderate	Negligible	Negligible	Moderate	High
	Ozone layer depletion	Moderate	Negligible	Negligible	Negligible	Negligible	Negligible
	Air pollution	Moderate	Negligible	Negligible	Negligible	Moderate	Negligible
	Air toxification	Moderate	Moderate	Negligible	Moderate	Moderate	Negligible
	Change in air temperature	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Change in air precipitation	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
Water	Water pollution	Moderate	Moderate	Moderate	Negligible	Moderate	Moderate
	Water toxification	Negligible	Negligible	Moderate	Negligible	Moderate	High
	The mating process of fish	Negligible	Negligible	Moderate	Negligible	Negligible	Moderate
	Fish migration	Negligible	Negligible	Moderate	Negligible	Negligible	Moderate
	Change in water temperature	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Impact of water flow	Negligible	Negligible	Negligible	Negligible	Negligible	High
	Change in water salinity	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	Effect on suspended sediments	Negligible	Negligible	Negligible	Negligible	Negligible	High
	Eutrophication	Moderate	Negligible	Negligible	Negligible	Negligible	High
	Affecting aquatic habitat	Negligible	Negligible	Moderate	Negligible	Negligible	Moderate
	Fish decline	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Flooding	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Dried up rivers	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Water oxygen level	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Affecting deltas and lagoons	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Fisheries influences	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Coastline defense	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

Soil	Land requirement	Moderate	Moderate	Moderate	High	High	High
	Soil pollution/ disturbance	Moderate	Negligible	Moderate	Negligible	Negligible	Negligible
	Soil toxification	Moderate	Negligible	Moderate	Negligible	Negligible	Negligible
	Desiccated soil	Moderate	Negligible	Moderate	Negligible	Negligible	High
	Soil erosion	Negligible	Negligible	Moderate	Negligible	Negligible	High
	Affecting irrigation	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Mangrove forests	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate
	Affects soil efficacy	Moderate	Moderate	Moderate	Negligible	Negligible	Negligible
	Deforestation	Moderate	Negligible	Moderate	Negligible	Negligible	Negligible
	Effect on vegetation	Moderate	Moderate	Moderate	Negligible	Negligible	High
	Seismic activity	Negligible	Negligible	Negligible	Negligible	Negligible	High
	Relocation of wild animals	Moderate	Negligible	Negligible	Negligible	Negligible	Negligible
	Affecting terrestrial habitat	Moderate	Moderate	Negligible	Negligible	Negligible	Negligible
Human	Human health	Moderate	Negligible	Moderate	Negligible	Moderate	Moderate
	Disturbance to humans	Negligible	Moderate	Moderate	Moderate	High	High
	Relocation of native residents	Moderate	Negligible	Moderate	Negligible	High	High
	Visual disturbance	Negligible	Moderate	Moderate	Negligible	Negligible	Negligible
	Unpleasant smell	Negligible	Negligible	Negligible	High	Moderate	Moderate
	Natural esthetic affected	Negligible	Negligible	Moderate	Negligible	Negligible	Negligible
	Tourism potential affected	Negligible	Negligible	Moderate	Negligible	Negligible	Negligible
	Archeological places affected	Negligible	Negligible	Negligible	Negligible	Negligible	Moderate

Miscellaneous impacts	Availability based on time	Moderate	Moderate	Moderate	Beneficial	Beneficial	Beneficial
	Availability based on area	Beneficial	Moderate	Moderate	Moderate	High	High
	Power reduction after installation	Beneficial	Beneficial	Moderate	Negligible	Beneficial	Beneficial
	Dependency on non-renewable energy	Moderate	Moderate	Moderate	Moderate	High	High
	Battery dependency	Moderate	Negligible	Negligible	Negligible	Negligible	Negligible
	Installation noise	Moderate	Moderate	Moderate	Moderate	High	High
	Operation noise	Beneficial	Moderate	Moderate	High	High	High
	Recycling complexity	Negligible	Beneficial	Negligible	Negligible	High	High
	Chance of accident	Moderate	Moderate	Moderate	Negligible	Negligible	Negligible
	Water for cooling	Moderate	Moderate	Negligible	Negligible	Negligible	Negligible
	Susceptible to storms	High	High	Moderate	Negligible	Negligible	Negligible
	Communication of species affected	Negligible	Negligible	Moderate	Negligible	Negligible	Negligible
	Predator inefficacy	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	Collision or entanglement	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	Miscellaneous impacts	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	Impingement	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	Biodiversity	Negligible	Negligible	Moderate	Negligible	Negligible	Negligible

2.4. Sustainable development

Renewable energy supports sustainable urban development by providing a clean energy source that doesn't deplete finite fossil fuel reserves. It also reduces the environmental impact associated with energy production and consumption. European countries have adopted a series of policies and practices in the field of energy geography and renewable energy development. Some countries have set renewable energy targets and provided fiscal and tax incentives to encourage investment and innovation.

Denmark is one of the first countries in the world to make large-scale investment in renewable energy and one of the world's leading wind power generation countries, which generate more electricity than natural gas and coal [15]. With its abundant wind energy resources, Denmark has established advanced wind power technologies and facilities to achieve a high proportion of renewable energy consumption through policy support and technological innovation. Denmark has also made important breakthroughs in cross-border energy trade and power grid interconnection through international cooperation and energy alliances to strengthen its capacity for sustainable development [16]. Besides, the municipality of Frederikshavn in northern Denmark has developed a variety of renewable energy sources, including offshore wind, waste and low-temperature geothermal energy, and designed energy systems accordingly. Østergaard and Lund [17] surveyed low-temperature geothermal renewable energy heating system in the area to assess the potential for 100% renewable energy city. The results showed that the integration of geothermal energy using absorption heat pumps could meet the needs of urban sustainable energy system.

Germany is the largest energy consumer in Europe, and the total energy consumption reaching 286 million tons of oil equivalent in 2021 [18]. In order to achieve its carbon neutrality goal, Germany has developed an energy transition strategy that relies on 100% renewable energy supplies by 2050. In 2021, renewable energy in Germany accounted for about 41% of electricity consumption. Therefore, Hansen et al. conducted a study to simulate the one-year operation of all energy sectors in Germany using the EnergyPlan model (hourly resolution) to develop a viable strategy for the transition towards 100% renewable energy. The study found that in order to maintain the sustainable resource potential of renewable electricity and biomass, energy saving is very important. Especially in the heating sector, the great potential for energy conservation is feasible, while the industrial and power sectors may achieve more energy conservation [19]. And Pata et al. [20] assessed the impact of renewables on the load capacity factor (LCF) in terms of intensity and share for Germany between 1970 and 2018 using autoregressive distributed lag modeling. In this study, the load capacity factor (LCF) represents how renewable energy intensity and renewable energy share improve environmental sustainability, while the impact of the Kyoto Protocol is used as a pseudo-variable. The results show that a 1% increase in the share of renewable energy intensity in the total energy mix and a 0.48% increase in LCF does not have a statistically significant effect. In contrast, a 1% increase in human capital increases LCF by 3.49%. Based on this study, it is recommended that the German government should consider human capital development and increasing the share of renewable energy as policy instruments development goals to achieve sustainable development.

2.5. Conclusion

Renewable energy plays an important role in global greenhouse gas emission reduction and sustainable development. Representative countries on all continents, including Europe, Asia and the Americas, made some achievements in renewable energy development and carbon neutralization. However, it should be noted that there are differences in renewable energy development, greenhouse gas emission reduction path, technical method evaluation and so on in different countries and regions. On the one hand, there is a need to strengthen international cooperation and exchanges, and on the other hand, there is a need to develop more efficient and environmentally friendly renewable energy technologies to jointly promote the in-depth development of renewable energy and carbon neutralization.

3. Discussion

3.1. The transition to renewable energy is becoming a consensus and pursuit direction in the international community

The signing of the Paris Agreement promotes the transformation of green and sustainable growth in all directions, reverses the growth pattern of the past few decades due to heavy reliance on petrochemical products, avoids continuing to pose a threat to natural ecosystems, and encourages global investment to further tilt towards renewable energy and other fields [21]. Major countries around the world are implementing new energy development strategies one after another.

3.2. Future development trends of renewable energy

Throughout history, the United Kingdom has created an empire that never sets on the sun through the transformation of coal energy, while the United States has upgraded to a superpower based on fossil fuels. Today, we have entered the early stage of a new round of energy technology transformation. Countries should change their thinking, plan ahead, take necessary measures, and seize the opportunity of energy transformation [22].

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The Advantages and Lessons to be Learned from the Development of New Energy Vehicles in European Countries in the Context of Carbon Neutrality and Carbon Neutrality-Taking Norway and Sweden as an Example

Weiyu LI

Capital Normal University, Beijing, China, 100048

Email: li_weiyu_icnt@iexchange.world

***Corresponding author**

Abstract

A stable climate is the environmental basis for the progress of modern civilization and the development of agriculture. From the perspective of sustainable economic and social development, "carbon neutrality" means that people's way of production and life will further move from rough to fine; economic development will fundamentally change the mode of high-carbon development towards "low carbon and green", and will be transformed from resource-driven to science and technology-driven, and society will further shift towards resource-driven and science and technology-driven.

The future direction of global automobile development is new energy, which has become the consensus of countries and enterprises all over the world. There are four major types of new energy vehicles: hybrid electric vehicles (HEV), pure electric vehicles (EV/BEV, including solar vehicles), fuel cell electric vehicles (FCEV), and other new energy vehicles.

This paper adopts a case study approach to analyze the development market of new energy vehicles and the factors affecting the application of new energy vehicles in the context of carbon neutrality. There are three parts to this paper, in addition to the abstract and references. The first part introduces in detail what carbon neutrality is, the generation and classification of new energy vehicles; the second part focuses on the commitments given by various countries in fulfilling their carbon neutrality obligations, as well as the application market of new energy vehicles in various countries; the third part focuses on the European market, taking Norway and Sweden as examples, and comparatively analyzes the similarities and differences between the two countries in the field of new energy vehicles.

The purpose of this paper is to summarize the different practices of Norway and Sweden in the application of new energy vehicles, summarize the common points, compare the differences, and thus trigger a reference to think about.

Keywords: Carbon neutrality; new energy vehicle; high-carbon development; application market.

1. Introduction

1.1. An overview on carbon neutrality

Carbon peak is the peak of carbon dioxide emissions, which is used to consider a carbon emission organization at a certain point in time, carbon dioxide emissions peaked and no longer grow, and then gradually reduce the indicator. Carbon neutrality is a measure of the total amount of carbon emissions generated directly or indirectly by a carbon emitting organization over a period of time, and the relative "zero" emission of carbon dioxide is achieved by offsetting its own carbon dioxide emissions through other carbon reduction behaviors, such as the use of green energy, energy saving and emission reduction, and planting of trees and forests. At present, carbon neutrality is an important goal and direction to prevent greenhouse gases from affecting climate change.

Decades of research by scientists have shown that human activities cause climate change. After the industrial revolution, human economic activities have emitted huge amounts of greenhouse gases into the earth's atmosphere, and the rising concentration of greenhouse gases in the atmosphere has had a significant impact on the earth's climate system. A variety of climate and environmental problems have arisen, including rising global temperatures, rising sea levels, melting glaciers, and frequent occurrence of extreme weather. The gradual emergence of these catastrophic consequences, and the vocalization of scientists, environmentalists, politicians, and other knowledgeable people, have contributed to the gradual awakening of environmental protection awareness in countries around the world, and have led to the embarkation of countries on a journey of environmental governance and carbon neutrality.

In order to better understand and respond to climate change, the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) jointly established an organization of scientists called the United Nations Intergovernmental Panel on Climate Change (IPCC), which is dedicated to collating and reporting on the results of scientific research on climate change, and contributed to the adoption of a landmark international convention, the United Nations Framework Convention on Climate Change (UNFCCC). -The United Nations Framework Convention on Climate Change (UNFCCC) was adopted by the United Nations General Assembly in 1992 and signed by more than 150 countries and the European Economic Community. The goal of the Convention is to maintain greenhouse gas concentrations in the atmosphere at a stable level in order to avoid dangerous anthropogenic interference with the climate system. In accordance with the principle of "common but differentiated responsibilities", the Convention requires developed countries to take specific measures to limit greenhouse gas emissions and to provide financial resources to developing countries to meet the costs of fulfilling their obligations under the Convention. Developing countries, on the other hand, are only obliged to provide national inventories of sources and sinks of greenhouse gases, and are not obliged to make legally binding reductions.

In 1997, the parties to the United Nations Framework Convention on Climate Change convened the Third Climate Conference. After arduous negotiations, the participants finally adopted the Kyoto Protocol, which for the first time established legally binding mandatory emission limits for greenhouse gases. This landmark agreement specifies the types of greenhouse gases to be reduced by major developed countries by 2012, as well as the timetable and quota for such reductions.

In December 2015, at the Paris Climate Conference, the Paris Agreement was adopted. It is a legally binding agreement on a wider range of member states, requiring countries to voluntarily submit emissions reduction targets and to regularly assess and review the targets at least every five years; developed countries are obliged to continue to provide climate finance to developing countries. For the first time, the Paris Agreement formally sets "reducing the risks of climate change by limiting the increase in global average temperature to less than 2°C and moving towards a temperature control goal of 1.5°C as the objective of the world's climate change mitigation efforts". This is a long-term cooperation that transcends national boundaries and marks the transition of mankind to a low-carbon world.

The 1.5°C temperature control target in the Paris Agreement requires the world to achieve zero emissions, or carbon neutrality, in most countries around the world in about 30 years. The autonomous emission reduction commitments in the Paris Agreement, on the other hand, can only slow the rate of increase in global greenhouse gas emissions and fall far short of the carbon-neutral target by 2050. This requires parties to build on their original plans to reduce greenhouse gas emissions more vigorously, and the world still has a long way to go on the topic of climate governance.

1.2. An overview on new energy vehicle

Pure electric vehicles were used long before the advent of fuel cars. Early electric car batteries were relatively simple and non-rechargeable. With the development of engine technology, the invention of the internal combustion engine and the improvement of production technology, fuel cars developed a definite advantage at this stage. Advantage points are mainly manifested in that fuel is easy to carry, and can carry enough fuel to travel a long distance. Electricity, on the other hand, is not easy to carry, and the capacity of the battery is limited, so the distance traveled is limited, and charging is also inconvenient. The biggest problem hindering the development of electric vehicles is the lagging development of battery technology, no major breakthroughs in batteries have led to no breakthroughs in the charging box range, so that electric vehicle manufacturers are facing huge challenges. Traditional automakers, under market pressure, began to develop hybrid vehicles to overcome the problems of batteries and short range. This time is best represented by PHEV plug-in hybrids and HEV hybrids.

1.3. Types on new energy vehicle

There are four major types of new energy vehicles: Hybrid electric vehicles (HEVs), pure electric vehicles (EV/BEVs, including solar-powered vehicles), fuel cell electric vehicles (FCEVs), and other new energy vehicles.

Hybrid electric vehicle (HEV)), is a fuel vehicle that is simultaneously equipped with an electric motor to improve low-speed power output and fuel consumption. This type of vehicle, based on the traditional engine, is equipped with an electric drive system that allows for hybrid drive. It is capable of driving in electric-only mode, fuel-only mode, and hybrid mode. It will also store and charge the vehicle's battery. Compared to fuel vehicles, hybrids have low gas mileage and quick acceleration. Hybrid vehicles are equipped with a smaller battery capacity and do not require an external power source to charge the battery. Daily use is no different from traditional fuel vehicles and it is considered the most practical model at this stage.

Pure electric vehicles contain an electric motor and a power battery. The electric motor provides power to drive the car forward, and the driving process is completely zero-emission, typically represented by Tesla in the United States. Most of the vehicles powered by electric drive are directly driven by electric motors, and the driving process is almost zero emission. Taking China as an example, due to the relatively low manufacturing threshold of pure electric vehicles and the gradual maturity of battery technology, etc., the government has given a lot of support in terms of manpower, material and financial resources as the main way to reduce carbon emissions, and has made it a key focus of China's strategic emerging industries to develop. Currently China's new energy vehicle market has entered a stage of rapid development, mainstream manufacturers have launched pure electric models, pure electric vehicles are gradually approaching the cost-effectiveness of traditional fuel vehicles, the first and second-tier cities infrastructure is gradually improved, fast-charging technology is gradually improved, electric vehicle range has basically met the needs of consumers. Under the joint action of many factors, the sales of pure electric vehicles show a high-speed growth trend.[5]

Fuel cell vehicles are automobiles that rely on electric motors to drive them, using hydrogen, methanol, etc. as fuel and generating electric current through a chemical reaction. The energy of its battery is directly turned into electricity or by the chemical action of the gas, not by combustion. Fuel cell vehicles have the advantages of zero or near-zero emissions, smooth operation and no noise.

2. Results

2.1. Promises from countries on carbon neutrality

There remains a gap between the commitment of members of the international community to carbon neutrality and its implementation. At present, the carbon neutral commitments of most countries still lack policy documents to support their concrete implementation, and among the countries that have explicitly put forward carbon neutral policy documents, there are large differences in the expected degree of implement ability and strength of the carbon neutral commitments of various countries.

In general, carbon emissions in the world are in three stages. Developed countries such as the United Kingdom, France, and the United States reached their peak in the 1970s and 1980s, and are now in a declining stage; developing countries such as China are in the stage of industrialization and upgrading, and their emissions have entered a plateau; emerging countries such as India have gradually increased their emissions due to the rapid development of their industries and economies, and have not yet initiated carbon-neutralization. Therefore, we analyze European countries as representatives of developed countries, China as representatives of developing countries, and India as representatives of emerging countries.

Europe, as an industrial pioneer in the 19th century, has far exceeded the world's average total emissions, both in terms of total emissions and incremental emissions, until the middle of the 20th actual year. Europe not only developed an industrial economy based on coal, steel and oil in the early stage, but also shifted the responsibility of carbon emissions to developing countries in the later stage.

Europe has a well-designed carbon-neutral planning system at the global top level, and the management system is divided according to the type of carbon emissions. Europe is the economy with the earliest start and the best legal system for carbon neutral action in the world, and plans to achieve carbon neutrality by 2050. Although developed countries are ahead of other countries in terms of their carbon emission systems, carbon emission intensity and carbon emission targets, this does not mean that developed countries have agreed to take on responsibilities that they should have taken on due to historical reasons.

China, as a representative of developed developing countries, the requirements of the times and its own development have determined its pivotal role in carbon neutrality, and it is committed to achieving carbon neutrality by 2060. The stage of China's economic development has entered the stage of industrialization and upgrading, changing from development at the expense of the environment to energy green development. Moreover, China's development in space exploration, cutting-edge military technology, and artificial intelligence cannot be left out of the picture in the area of carbon emissions. In addition, our economy is expected to continue to grow, playing a leading role compared to the climate stance of emerging and developing economies.

India is still in a rapid development phase and the energy transition is not yet complete, with a commitment to achieve carbon neutrality by 2070. Adequate energy supply is necessary to ensure urbanization. India's indigenous coal resources are abundant, but its oil and gas reserves are insufficient. If the price of coal increases and coal imports decrease, India faces an energy crisis at the same time. Therefore, in order to ultimately achieve the large goal of carbon neutrality, India needs to first complete the goal of ensuring a stable energy supply and improving the energy mix by 2030, while reducing carbon emissions. This is more difficult to achieve.

2.2. Fields on carbon neutrality

Carbon neutrality involves a wide range of fields, covering a series of industries such as electric power, chemical industry, iron and steel, cement, transportation, construction, etc., and is closely related to the national energy structure and industrial structure. To realize the reduction of anthropogenic carbon emissions and the enhancement of anthropogenic carbon sinks involves energy, resources, ecology, atmosphere, oceans, engineering, technology, management and many other disciplines and their comprehensive research, and at the same time, this major issue that has lasted for decades will also lead to the iterative development of cutting-edge technologies and subversive technologies.

2.3. Application on new energy vehicle

The Global Electric Vehicle Outlook 2023 reports that the vast majority of global EV sales are now concentrated in 3 major markets - China, Europe and the U.S. In 2022, the Chinese market accounted for 60% of global EV sales, and more than half of the world's sold EVs are now in China. In the same year, electric vehicle sales in Europe and the U.S. increased by 15% and 55% year-on-year respectively, with electric vehicles accounting for more than 1/5 of the new cars sold in Europe, and electric vehicle sales in other regions also showing rapid growth.

Relative to the United States, China and Japan, European car companies in general in the field of new energy vehicles started late. The reason for the late start is closely related to the advantages of European car companies in the field of traditional automobiles. On the one hand, the European Union and European governments by the pressure of environmental protection organizations, through the formulation of harsh carbon emission regulations to promote the development of new energy vehicles; but on the other hand, European car companies, especially German car companies, due to their own fuel car emission reduction technology has the advantage of a delay in choosing the electrification of the development of the road. Until 2015 Volkswagen "diesel door" event broke out, only to force the Volkswagen Group to change its strategy, abandon the traditional diesel car route, completely embarked on the road of electrification, and formulated a comprehensive electrification development goals. Similar to the Volkswagen Group's electrification layout late, Germany's Daimler Group and France's Peugeot Citroën Group also began to shift the focus of development to the electrification route only in 2016.

On the electrification path of European car companies, it is worth mentioning the French Renault Group. Renault Group's pure electric vehicle development strategy was formulated the earliest. With the advantage of the alliance with Nissan, Renault Group announced its development strategy in 2008, clearly focusing its development on pure electric vehicles, and began mass production of four pure electric vehicles in 2012, of which the small passenger car Zoe was very popular. Zoe adopts a pure electric exclusive platform, and it is the first modern version of pure electric passenger cars in Europe. In addition to Renault, BMW and Volvo's electrification layout is also earlier, but their focus on plug-in hybrid vehicles. 2013, BMW launched the 1st pure electric car BMW i3. with the local advantage, Renault, BMW in the European new energy market for many years has been at the top of the list, and with the United States of America's Tesla, Japanese Nissan, Mitsubishi, share the top 5 brands in the European market. Tesla has occupied the top sales position in the European new energy vehicle market for many years. Compared with fuel vehicles, European new energy vehicle brands obviously lack advantages, even in the local market can not occupy a dominant position.[4]

According to IEA projections, the global outlook for the 2030 sales share of electric vehicles has increased to 35% based on existing policies and automotive industry targets. In China, the European Union and the United States, the average share of electric vehicles in total vehicle sales is expected to rise to around 60% by 2030.

The process of automobile life cycle assessment is to collect and summarize the data on the inventory of material extraction, component manufacturing and fuel production and use of different power types of automobiles, to comprehensively derive the environmental impacts of different power types of automobiles, and to summarize the evaluation opinions based on the impact results. The full life cycle assessment of automobiles provides powerful technical support for the green ecological development and optimization of automobile products, the formulation of strategic planning by automobile enterprises and the formulation of standard policies by the government, and provides reference opinions for the formulation of carbon neutral action plans in the field of transportation to achieve carbon peak. [1]Accurate calculation of energy consumption of new energy vehicles is the basis of carbon emission accounting. Due to a variety of factors, the energy consumption of new energy vehicles during driving is often different from the declared standard energy consumption value. This is mainly due to three factors: driver-related factors, environmental factors and the performance of the vehicle itself. Compared with traditional fuel vehicles, new energy vehicles are less expensive to use because they are powered by cleaner and more environmentally friendly energy sources. At the same time, they cause lower carbon dioxide emissions and contribute less to greenhouse gases in the air. During driving, new energy vehicles are smoother and quieter, so they can also reduce noise pollution and give consumers a better ride.

3. Discussion

In this paper, two European countries, Norway and Sweden, will be selected for comparison to analyze the similarities and differences between the two countries in the field of new energy vehicles, so as to provide experience for both sides to learn from, promote the better development of new energy vehicles in their own countries, and help achieve the goal of carbon neutrality.

3.1. Similarity

3.1.1. Geography

Located in the Nordic Scandinavian Peninsula on the west side of Norway covers an area of 324,000 square kilometers, less than two Beijing large countries mountainous area of 70%, and rich in water resources, abundant rainfall throughout the year, the average annual precipitation of 1380mm, water resources can be developed up to 38 million kW, is the world's per capita water resources, one of the richest countries.

Sweden's hydroelectric power generation capacity is relatively advanced. Rivers are short and fast flowing, with abundant water, small navigable value, and abundant hydraulic resources. One of the world's largest lakes, a total of 92,000 large and small lakes, many lakes have rivers between the communication, but because of the water level is not equal, often forming rapid waterfalls, conducive to the development of hydropower. It is possible to utilize 80% of this power, which is enough to satisfy the country's needs, and to export it to foreign countries.

3.1.2. Charging Highway

European countries are stepping up preparations for the infrastructure needed to achieve fossil-fuel-free travel after the European Union passed a landmark law in April requiring all new cars sold from 2035 to emit zero carbon dioxide, according to a recent report by Euronews.

In response to the new EU law, Sweden has decided to open the world's first permanently electrified highway in 2025. The electrification of the E20 highway follows a series of successful ERS pilot projects that have allowed electric cars and trucks to be recharged on the go and travel longer distances between charging stations, thus eliminating "mileage anxiety" and promoting sustainable mobility. The electrification of the E20 highway follows a series of successful ERS pilot projects. The Swedish Transport Administration is still considering whether to use conductive or inductive charging for the road.

In Norway, an Israeli company called Electreon has been awarded a tender to build wireless charging highways in both France and Norway. Electreon will use its Electric Road System technology, which helps to wirelessly charge local electric buses, on a road near a bus station operated by AtB AS. Their ultimate goal is to create a complete electric road in Trondheim, Norway that can charge electric buses, trucks and cabs.

3.1.3. Consumption tendencies

Global turmoil has increased the price of fossil fuels and made internal combustion engine vehicles more expensive compared to electric vehicles, which has fueled an increase in demand for electric vehicles globally. At the same time, Sweden is a country where the gap between the purchase cost of an electric car and an internal combustion engine car is small. On average, electric cars in Sweden are only 21% more expensive than combustion engine cars. At the same time, Swedish consumers are to a large extent willing to pay a premium for electric cars; on average, Swedish consumers are willing to pay 18% more for a tram than for a combustion engine car. The match between willingness to pay and the price difference may be one of the reasons why Swedish consumers prefer electric vehicles.

3.2. Difference

3.2.1. Government subsidies

As of October 2021, Norway's new energy vehicle penetration rate has reached 81.6%, ranking first in the world! With the penetration rate of new energy vehicles increasing, Norway has announced that it will ban the sale of fuel vehicles by 2025.

In addition to the nearly 100% private pile installation ratio, the Norwegian government has spared no effort to build more than 73,335 public charging piles, so that the Norwegian people travel to realize 0 anxiety. It is worth noting that with the arrival of the power exchange leader, Azera, in Norway, Azera will build 20 power exchange stations in 2022, so that Norwegian users can also enjoy the quality service of "5 minutes, the feeder becomes full power". The high penetration rate of new energy vehicles and the construction of convenient energy supply facilities cannot be separated from the government's promotion. In order to promote new energy vehicles to achieve zero emissions road traffic, help the national carbon neutral, the Norwegian government is worried about. Since 1990, the Norwegian government has introduced a series of incentives, including tax breaks, free parking, access to bus right-of-way, etc., sparing no effort to make the user's new energy travel costs down to attract more people to choose new energy vehicles.

In the electric car purchase policy, the Norwegian government to reduce the electric car purchase tax, which directly allows electric car consumers to save 7 to 10 million yuan, plus the use of cost and parking concessions, Norway electric car consumers will enjoy than fuel car consumers cheaper than nearly 150,000 yuan of affordable, known as the world's cheapest electric car prices in the country.

Since 1990, the Norwegian government has introduced a series of financial incentives and subsidies for electric vehicles, which have effectively reduced the cost of purchasing and using electric vehicles in Norway. Thanks to this, Norway has become the most receptive country in the world to electric vehicles. According to the Norwegian Road Traffic Information Committee (OFV) data, in 2021, Norway sold a total of 176,276 new cars, up 25% year-on-year, including 113,715 electric vehicles, accounting for 64.5%, significantly higher than the 54.3% in 2020, the new energy vehicle market penetration rate ranks first in the world. Moreover, Norway does not have a local electric car brands, for foreign car companies on an equal footing, there is no policy to protect the local industry, natural attraction of new energy vehicle enterprises layout here. Norway is one of the earliest countries in the world to establish a carbon trading system, located in Oslo, Norway, the Nordic Power Exchange was established in 1993, is Europe's first exchange to provide carbon emission allowances and CERs, mainly to provide CO_2 spot contracts and some futures derivatives contract transactions, Norway is also the first country to levy a carbon tax, after several decades of accumulation, Norway has accumulated a wealth of experience in carbon trading as well as carbon pricing. After decades of accumulation, Norway has accumulated rich experience in carbon trading and carbon pricing.

Sweden's subsidy policy for new energy vehicles is mainly to reduce the purchase tax and carbon emission tax for green vehicles. Under the definition of green car, depending on the displacement, the use of biogas and ethanol cars can get 20 to 50 kronor/100km tax relief. Some local governments, e.g., Stockholm City, offer reductions on parking fees for green cars and on the running costs of green cabs. In Sweden, the Green Vehicle Incentive Policy stipulates that during the period from April 1, 2007 to December 31, 2009, purchasers of electric vehicles that meet the Green Vehicle Standard are entitled to a purchase subsidy of 10,000 kronor and exemption from the vehicle CO_2 emission tax. Other than this, there is currently no other supportive policy in Sweden. In order to promote electric cars and plug-in hybrids to the market, to increase the subsidy for them is the trend of the future development of electric cars in Sweden. The most likely option is to provide subsidies to car buyers. At present, the additional cost of an electric car or plug-in hybrid vehicle in Sweden is estimated at 50,000 to 150,000 kronor. The Swedish Energy Agency predicts that in the next few years, as the technology matures, the additional cost will be reduced.[3]

According to foreign media reports, the new Swedish government has canceled the state subsidies for pure electric cars and plug-in hybrids. The Swedish government announced that it will no longer provide incentives for the purchase of electric cars. The reason given by the Swedish government is that the cost of buying and driving such cars is now comparable to the cost of gasoline or diesel cars, and therefore the state subsidies introduced to the market are no longer justified.[2]

3.2.2. Hydroelectric power plants

In Norway, electricity is almost free for civilian use, while the development of power-consuming industries such as aluminum and magnesium using cheap hydroelectric power earns foreign exchange, while the trading of electricity through the sale and purchase of electricity, staggered storage of water resources, and neighboring countries to carry out power trading, to achieve good economic results. Even so, electricity is still a surplus in Norway as a country. "This opens the door for Norway's electric cars, free charging has become the most fundamental reason for Norwegian electric car consumers to buy an electric car, rather than the so-called environmental protection that many people keep describing," and Norway's neighboring many Swedish locals described, "and Norway than, Sweden in environmental awareness can be no worse than Not bad, but the God of electricity did not favor the other Nordic countries, the God of electricity to Norway nearly 1.5 Three Gorges hydroelectric power plant.

3.3. Outlook

As time goes by, more countries will realize the goal of carbon neutrality, and the application of new energy vehicles will become more widespread. At the same time, many new zero-emission technologies will emerge to continuously improve and develop the new energy vehicle market. Therefore, the country should continue to enhance government subsidies, actively create more infrastructure to facilitate the construction of new energy vehicles, do not engage in trade protectionism, and actively update the concept of consumers to adapt to the concept of low-carbon green, to help achieve the goal of carbon neutrality, and ultimately build a harmonious and beautiful world.

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Examining the Role of Individual Lifestyle Changes in Achieving Carbon

Amina

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

E-mail: 542464356@qq.com

***Corresponding author**

Abstract

There are many ways to achieve carbon neutrality. It is not difficult to find that the change of lifestyle has a potential impact on promoting the transition to a low-carbon lifestyle. This paper is divided into three parts. The first part briefly introduces EU carbon neutrality strategy and the influence of lifestyle on carbon emissions. The second part elaborates the important role of the change of personal lifestyle in the aspects of resource saving, transportation, consumption and education. Finally, the conclusion section covers the difficulties of individual lifestyle change and points out more possibilities for low-carbon development in the future.

Keywords: Carbon neutrality; carbon emissions; the European Union; individual lifestyle; low-carbon lifestyle.

1. Introduction

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. It can be seen that individual lifestyle changes play an important role in achieving carbon neutrality.

1.1. The EU is committed to achieving carbon neutrality

Under the European Climate Law, the EU has pledged to become carbon neutral by 2050. In order to limit global warming to 1.5C - the threshold considered safe by the Intergovernmental Panel on Climate Change (IPCC) - achieving carbon neutrality by the mid-21st century is crucial. The Paris Agreement, which was signed by 195 countries, including the European Union, also stipulates this goal. In December 2019, the European Commission proposed the European Green Deal, its flagship plan to achieve climate neutrality in Europe by 2050. The EU is committed to an ambitious climate policy. Under the “Green Deal”, it aims to become the first continent to reduce carbon dioxide emissions by as much as it produces by 2050. On 7 October 2020, the European Parliament backed climate neutrality by 2050 and a 60% reduction in emissions from 1990 levels by 2030, which is more ambitious than the 55% proposal put forward by the European Commission.Members of the European Parliament asked the commission to set an additional interim target for 2040 to ensure progress towards the final goal. In addition, members called for all EU countries alone to become climate neutral and insisted that more carbon dioxide should be removed from the atmosphere after 2050 than emitted. All direct and indirect subsidies for fossil fuels should be phased out by 2025 at the latest. In April 2021, Members of the European Parliament reached an agreement with the Council on the EU's obligation to become climate neutral by 2050. On June 24, Parliament approved the new Climate Law, which increases the current 2030 emissions reduction target from 40% to 55% and makes the 2050 climate neutrality target legally binding. In line with Parliament's recommendations, an independent European Scientific Advisory Committee on Climate Change will be established to monitor progress and assess whether policies are consistent. Currently, five EU countries have legally set climate-neutral targets: Sweden aims to achieve net zero emissions by 2045, and Denmark, France, Germany and Hungary by 2050.

1.2. Impacts of lifestyle on carbon emissions

Everyone's daily behavior is producing carbon emissions, which has some impact on achieving carbon neutrality. The aspects of personal life such as resource saving, transportation, consumption and education are all worth investigating. The Association des Constructeurs Europeans (ACEA) has released its 2023 report on car use in Europe,in 2021, the EU passenger car fleet grew by 1.2% compared to 2020, with nearly 250 million cars on the road in total. With the exception of Slovenia (-4.1%), all EU countries expanded their car fleet, with the highest growth seen in Slovakia (+8.2%). Luxembourg has the highest car density in the EU (698 per 1,000 people), while Cyprus has the highest density of commercial vehicles (135 per 1,000 inhabitants). By contrast, the lowest density of cars can be found in Romania (396). Lithuania has the lowest density of commercial vehicles (49). 96.4% of all trucks in the European Union run on diesel, while petrol fuels 0.5% of the fleet. Only 0.1% of trucks on EU roads have a zero-emission powertrain.

Globally, residential and commercial buildings, consume over half of all electricity. Phasing out fossil fuels for home heating is crucial, for instance by banning on new gas-fired boilers and introducing electric heat pumps. Increasing the thermostat setting from 24°C to 28°C during the cooling season can reduce annual cooling energy use by more than a factor of three for a typical office building in Zurich, Switzerland.Switching to renewable energy sources, x as solar, wind or hydroelectric power, also means less pollution and new and better jobs. Currently, around 80% of global energy and 66% of electrical generation are supplied from fossil fuels.Every year, an estimated 11.2 billion tonnes of solid waste is collected worldwide, and decay of the organic proportion of solid waste is contributing about 5% of global greenhouse gas emissions.Where waste cannot be avoided, recycling leads to substantial resource savings. For every tonne of paper recycled, 17 trees and 50% of water can be saved.Recycling also creates jobs: the recycling sector employs 12 million people in Brazil, China and United States alone.With one shower of about 10 minutes a day, an average person consumes the equivalent of over 100,000 glasses of drinking water every year.It takes about 7,500 litres of water to make a single pair of jeans -- from the production of the cotton to the delivery of the final product to the store. 85% of textiles end up in landfills or are incinerated although most of these materials could be reused. Every second, the equivalent of one garbage truck full of textiles is landfilled or burned.

It can be seen from the above data that the status quo of lifestyle will still increase urban carbon emissions, so people must change their lifestyle to promote carbon neutrality.

2. Results and discussion

Any human activity may cause carbon emissions. All kinds of fuel oil, gas, paraffin, coal and natural gas will produce a lot of carbon dioxide in the process of use. Urban operation, people's daily life, transportation (planes, trains, cars, etc.) will also emit a lot of carbon dioxide. The study here focuses on carbon emissions from everyday life.

2.1. In terms of resource saving

The consumption of resources in life generally includes forest resources, mineral resources, water resources, land resources, marine resources and so on.On July 16, 2021, the European Commission issued the European Union 2030 Forest Strategy, which proposed protect and restore primary forests, proposing the goal of planting 3 billion more trees by 2030. Saving paper and reducing the use of disposable utensils and packaging are indicative of lifestyle changes that have greatly increased vegetation cover and reduced the use of trees. People learn about forests from these small lifestyle changes and can consider adding tree-planting activities to their daily recreational activities. This can not only enrich the lives of individuals, but also call on more people to save forest resources.

Encourage people to learn more about and use clean and alternative energy, and reduce the use of gasoline, oil and natural gas in daily life. For example, new energy vehicles can well replace gasoline or diesel cars.

In terms of the optimization of electricity consumption, there are two main points: Firstly, people can choose to install voice-controlled lights in the corridors and other areas of individual residential buildings to reduce the emissions of greenhouse gases generated by electricity. Secondly, in public places, people consciously save electricity.

The use of water resources to develop the good habit of saving water. People in daily life to develop a regular inspection of their own water leakage problems. Also, try to wash your face with a clean washbasin instead of running water for a long time. Even if you wash your face and hands with running water, turn off the faucet when using face wash or hand sanitizer and turn it on when you need to flush. Irrational habits can waste valuable water resources, so change bad habits. Recycle water, water the flowers with rice water, and scrub the floor with water from washing clothes. Making full use of water resources can not only reduce daily living expenses, but also save water resources.

2.2. Transportation

The Sustainable Transport - Europe Green Deal sets a target of reducing greenhouse gas emissions from the transport sector by 90% by 2050. Transport accounts for a quarter of the EU's greenhouse gas emissions and is still growing. In addition to macro-control at the policy level, individual efforts are also essential. It is worth mentioning that the frequency of daily commuting is very high, so it is necessary for people to replace driving with low-carbon bicycles. People riding bicycles to and from work can not only exercise, but also contribute to carbon neutrality, so this behavior deserves to be encouraged. The government can set up more bicycle parking spots to nudge more people to ride bicycles.

2.3. Consumption

People should be encouraged to spend the holidays at home with friends and family. This way can well replace the previous lifestyle of comparison tourism consumption. It is not only a low-carbon behavior, but also can improve people's happiness.

Besides, as consumers, people are more inclined to buy new goods rather than second-hand ones. Although more and more people are turning their consumption to products made from recycled materials or second-hand goods, these consumption modes are still not mainstream. Changing consumption attitudes requires not only individual efforts, but also policy guidance.

For profit purposes, businesses employ many strategies to stimulate consumption, which are designed to induce consumers to buy more things rather than things they need more. In the face of this situation, individuals need to keep calm and do a comprehensive understanding of their needs, learn to spend money wisely. People should buy food according to the actual use to prevent it from expiring.

2.4. Education

The role of education permeates every aspect of personal lifestyle change. At present, it is imperative to use educational activities to popularize and promote low-carbon lifestyle. The purpose of education is not only to teach carbon neutral knowledge to students at basic or higher education level, but also to create awareness of low carbon lifestyle among the wider population. There are mainly four aspects:

Firstly, by teaching students about carbon neutrality, schools can cultivate more human capital for future societies. Students who learn about the theory and practice of carbon neutrality in school will bring this impact to a wider understanding when they enter the world.

Secondly, as institutions of higher education, schools, especially universities, should practice the concept of sustainable development and teach students to practice low-carbon ways in energy saving, resource utilization, travel, environmental protection, water saving and other aspects. Schools can arrange a series of lectures on carbon neutrality in students' daily courses and invite professors from relevant majors to give lectures to students to broaden their horizons.

Thirdly, students can spontaneously establish a low-carbon life practice group, which can promote the communication among students and impart knowledge about low-carbon life style to each other.

Finally, authorities can spread the specific operation of low-carbon lifestyle more widely through social media, so that people can get carbon neutral knowledge more easily in the fragmented time.

In the context of such rapid development, there is no doubt that carbon-neutral education can permeate the wider population.

3. Conclusion

Individual lifestyle changes play an important role in achieving carbon neutrality. Increasing individual awareness of carbon neutrality is crucial to achieving the overall goal of carbon neutrality across the EU. However, there are still some challenges for individuals to change their lifestyles in a low-carbon direction.

Firstly, it takes a long time for individuals to make the transition to a low-carbon lifestyle, because it takes some time for deliberate practice to abandon old habits and establish new ones. So it will take a long time for the whole society to shift to a low-carbon lifestyle. Secondly, due to the path dependence of individual concept, it is difficult for people to immediately change their dependence on the old way of life to the new direction.

Finally, to get rid of the first two difficulties, people still need to have lasting patience to continue to practice low-carbon lifestyle, so that they can truly contribute to the realization of carbon neutrality.

In the future, when it comes to the utilization of forest resources, people still need to reduce paper waste in daily life. They can use electronic invoice instead of traditional paper invoice after every meal in a restaurant to practice the concept of low-carbon life. In addition, people are encouraged to use recycled tableware and daily necessities. People using bicycles or walking instead of cars can make a big contribution to carbon neutrality. As consumers, individuals consciously practice low-carbon consumption, such as buying second-hand goods, goods made from recycled materials and goods in real demand, which will educate enterprises to shift to a more low-carbon production mode. The positive impact of this operation on achieving carbon neutrality is long term. Colleges and universities actively respond to the concept of sustainable development, and set up lectures on carbon neutral knowledge to popularize low-carbon lifestyle to the young generation of society. It's also important to plan for the future while making lifestyle changes, because the path to carbon neutrality still has to be explored and pursued.

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The Impact of NGO on the Ecological Protection

Lingyan FAN

China University of Petroleum, Beijing, China, 102249

Email: fan_lingyan_icnt@iie.world

***Corresponding author**

Abstract

This article studies the impact of non-governmental organizations on the ecological protection of the Serrado grassland. In order to protect the Serrado Grassland and effectively delay climate change, many social groups and enterprises launched an appeal and jointly issued a declaration, trying to prevent the agricultural and fragmentation of the Serrado savanna through the alliance of non-governmental organizations. We predict that such measures are effective and can avoid excessive development of the Serrado grassland. However, after data comparison, it was found that simply signing the declaration did not have a significant impact on the grassland area. It may be necessary to cooperate with financial policies such as bank interest rates and government mandatory intervention in an independent market to effectively play a role.

Keywords: NGO; ecological protection; Serrado grassland; agriculture; supply chain.

1. The Impact of NGO on the Ecological Protection

According to the statistics of the International Union for Conservation of Nature in 2018, the number of threatened species in Brazil ranks second in the world. The main reason for this phenomenon is that agricultural expansion has damaged the ecological environment of the Amazon rainforest and the Serrado grassland. At the same time, Brazil is the second largest food producer in the world. The main reason for the development of Amazon rainforest and Serrado grassland is the expansion of soybean planting and cattle farms. At the beginning of the 21st century, scholars began to pay attention to the overexploitation of the Amazon rainforest, and a series of restrictive policies have played a certain role in protecting the Amazon rainforest. However, the development of the Serrado savannah, the second largest ecological region in Brazil, is showing a rapid expansion. In recent years, more and more scholars have begun to pay attention to the Serrado Grassland. Governments around the world have made efforts to improve climate through mandatory policies or macroeconomic regulation. To some extent, government measures are useful. However, what about non-governmental organizations and social forces? Can non-governmental organizations effectively protect the Serrado grasslands through joint action?

The concept of non-governmental international organizations was first seen in the United Nations Charter. Article 71 of the 1946 United Nations Charter stated the role of non-governmental organizations in international affairs. In 1968 and 1996, the United Nations Economic and Social Council resolutions recognized the expansion of its scope to non-governmental organizations operating nationwide and in various regions. Non governmental international organizations with a focus on environmental protection include specialized intergovernmental organizations specializing in environmental protection fees, purely academic international legal organizations, and other non-governmental international organizations engaged in environmental protection activities. Non government organizations usually exert pressure on countries or government groups through public speeches, media campaigns, demonstrations, attending meetings, providing advice and information, and participating in international organization projects, in order to change policies. Non government organizations also participate in international litigation proceedings as litigants or legal advisors, in order to participate in dispute resolution.

Brazil is the second largest soybean producing country in the world, with a planting area of 33347 hectares in the 2017/18 crop year, distributed in the Pampa Grassland, Atlantic Forest, Cerrado, and Amazon biomes. Through remote sensing technology, we indicate that the new agricultural frontier of soybeans is no longer in the Amazon region, but in the last contiguous area of Serrado, located in the area known as MATOPIBA. The soybean production chain has been striving to showcase soybeans produced in a sustainable manner to overseas customers without deforestation. Our data challenges its main plan, the Amazon soybean suspension order, and we call for attention to the protection needs of MATOPIBA Cerrado, which is not monitored by the soybean suspension.

Public and private anti deforestation policies have been proven to effectively reduce forest loss, but the conditions for adopting such policies are rarely reviewed (Christoph Nolte., 2017). Targeted investments in Amazon's border supply chain infrastructure can promote intensification and alleviate the pressure of deforestation, but must be combined with substantial long-term negative incentives for deforestation, including more effective public forest governance and private zero deforestation commitments (R. D. Garrett., 2018). We emphasize that any policy that threatens this mentality of "deforestation rights" may lead to erosion of producers' protective behavior, as unnecessary land clearing occurs before such policies are implemented. The implementation of commitments to reduce deforestation is hindered by different perceived financial risks, differences in influence and power levels held by different participants, and a sense of urgency that the perceived rights of deforestation outweigh environmental sustainability (Angela M. Guerrero, 2020). We identified a total of 170 conservation NGOs that were implementing 378 projects at 518 sites across the breadth of the Amazon region As a sector, conservation NGOs have successfully implemented projects throughout the Amazon region and are carefully placed to meet future conservation challenges (Ana C. M. Malhado., 2020). Collective targets set by private, government, and non government organizations to achieve global "zero net defense" by 2020 have been missed Reforming ZD will not solve deforestation, but reflecting on its limitations could support more effective and equitable tropical forest conservation beyond 2020 (Joss Lyons White., 2020), Unnecessary land clearance (Finn Mempel., 2021). All wetlands in Serrado should be unified in the legend of official large-scale maps supporting environmental legislation (Giselda Duriga., 2022). The independent environmental service fee (PES) and independent market exclusion mechanism (MEM) have different advantages and challenges, and it is best to combine them. In the future, soybean deforestation control work focused on the supply chain in Serrado must be complemented by broader jurisdictional methods to address deforestation and sustainable development issues (R. D. Garrett., 2022).

Through a series of studies, it has been found that there has been relatively little research on the role and significance of non-governmental organizations in the environmental protection of the Serrado grassland by previous scholars. Prior to 2012, there were few specialized studies on the role of non-governmental organizations in the protection of the Serrado grassland. From 2013 to 2020, scholars gradually began to explore, mainly focusing on research on deforestation policies, and less analysis was conducted from the perspective of the supply chain of enterprises involved in deforestation. After 2021, More scholars have begun to explore the role of non-governmental organizations in the protection of the Serrado grassland, mainly focusing on the interaction with government behavior and the effectiveness of financial policies. However, compared to the research on technical means and institutional policies for protecting the Serrado Grassland, scholars have paid little attention to the effectiveness and mechanism of non-governmental organization actions.

Through literature, it can be found that non-governmental organizations have significant importance in protecting the Serrado Grassland, but there is controversy over their effectiveness. In addition, there is little literature that systematically summarizes the measures taken by non-governmental organizations in protecting the Serrado grasslands. Therefore, a systematic study of the effectiveness of key actions taken by non-governmental organizations in protecting the Serrado Grassland has strong practical significance in exploring how to promote non-governmental organizations to achieve environmental protection goals in an independent market environment.

2. Method

2.1. Study area

The Cerrado (Figure 1.) is the second largest biome in Latin America, covering an area of over 200 million hectares, equivalent to 22 % of Brazilian territory,Larger than the combined land area of Germany, France, Spain, Italy, and the United Kingdom, home to approximately 5% of the world's biodiversity. The biome is a global biodiversity hotspot , containing springs from Latin America's three major watersheds and habitat for endemic species.

Economically, the Cerrado is the largest national soybean producer, accounting for 52 % of Brazilian yield. The area of agriculture in the region grew by 9.5 million hectares between 2000 and 2017 (102 %), 5 million of which between 2007 and 2014 . From this area, 90 % corresponds to soybean crops.

Currently, only 20% of the original vegetation in Serrado remains intact. Currently, approximately 46% of the Serrado savannah has been completely converted into soybean fields or artificial pastures, with only 19.3% remaining in its original vegetation state, of which only 7.5% are officially designated as protected areas (46% in Amazon). According to Brazilian forest laws, 20% of privately owned land in Serrado is designated as protected land (while in Amazon it is 80%). According to WWF's 2019 assessment, the average annual grassland reclamation rate in Serrado over the past four years was 680000 hectares, equivalent to losing an area of grassland the size of London every three

Figure 1. Study area location.

months.

2.2. Important actions

In 1996, the Candier Act of the Brazilian government started the rapid agriculture of the rainforest in the Amazon rainforest region. After that, international non-governmental organizations took a series of actions to save the Amazon rainforest rainforest. However, because the Serrado grassland is adjacent to the Amazon rainforest, the restrictive policy of the Amazon rainforest has affected the vegetation destruction in the Cerrado region to some extent. Therefore, the important actions of non-governmental organizations on the Amazon rainforest and Cerrado Grassland are put together for observation in this paper.

Table 1: Important actions affecting the Brazilian rainforest

Time	Organization	Action	Objective
1996	Brazilian Federal Government	Candier Act	Promote Amazon's agricultural and animal husbandry product trade
2006	Four major multinational grain merchants	Amazon Soy Moratorium	Call for Abandoning Deforestation and Reclamation in the Amazon
2009	Central Bank of Brazil	Resolution No. 3545	Prohibit banks from providing loans to any individual or unit engaged in illegal deforestation in the Amazon region
2017	Brazilian Social Team	Cerrado Declaration	Call on governments, buyers, and investors from all countries to take immediate action to jointly protect Brazil's savannah
2017	23 European companies	Send Cerrado Declaration support statement (grow to 150 companies in 2020)	They hope to work together with other global stakeholders to stop the cultivation of sparse tree vegetation on the Serrado grassland in Brazil
2017	WWF China and China Meat Association, as well as 70 leading Chinese meat industry enterprises, jointly released	China Meat Sustainable Development Declaration	Promise to provide various types of meat produced in a sustainable manner to the Chinese market, while protecting the ecological environment of tropical rainforests and grasslands, by managing the supply chain
2021	COP26	Glasgow Leaders' Declaration on Forests and Land Use	Glasgow Leaders' Declaration on Forests and Land Use
2021	IFACC	Announced investment of 3 billion US dollars	Accelerate deforestation in South America and avoid planting soybeans and raising cattle on land formed through deforestation

2.3. Agricultural land and forest area in brazil

Based on the action objectives of non-governmental organizations, we can assess the effectiveness of their actions by taking into account the changes in agricultural and forest land areas in Brazil(Figure.2). At the same time, we can also use carbon dioxide loss indicators(Figure.3) to preliminarily assess the potential climate damage that Brazil's economic policies may bring to the country.

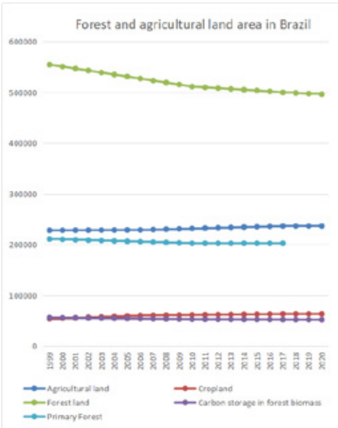

Figure 2. Study area location

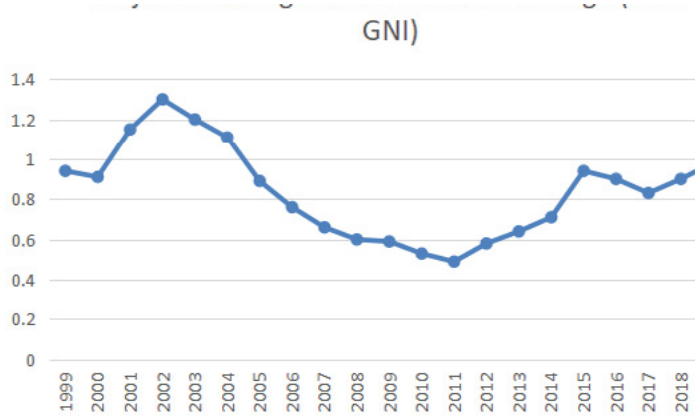

Figure 3. carbon dioxide damage in Brazil

2.4. Agricultural trade of important participating countries

The main reason for the destruction of the Amazon and Serrado grasslands is the expansion of agricultural land, so we can analyze the main influencing factors from the main export targets of Brazilian agricultural products. The European Union, China, and the United States, as the main export targets of Brazilian agricultural products, studying their absolute export value and proportion has certain significance for analyzing the main influencing forces on the Serrado Grassland in the future.

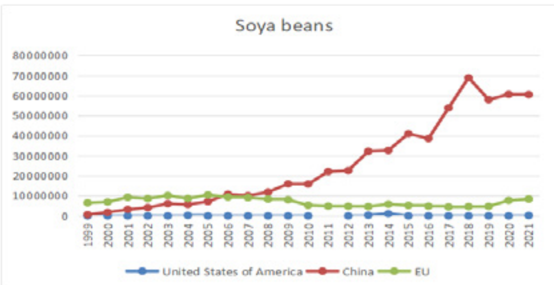

Figure 4. Brazil's soybean exports

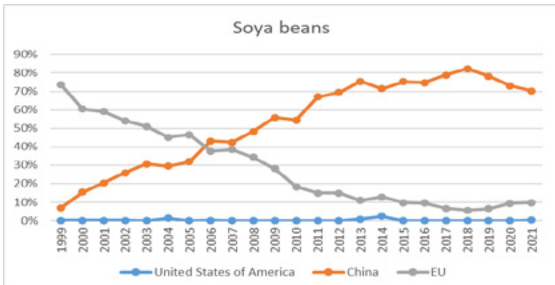

Figure 5. Brazil's soybean export proportion

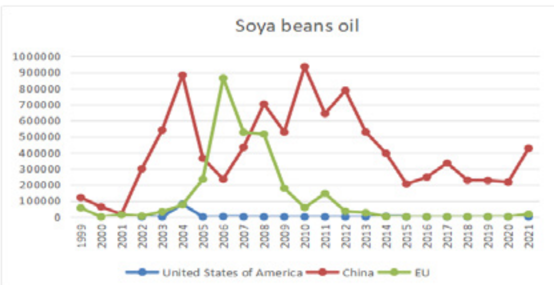

Figure 6. Brazil's soybean oil exports

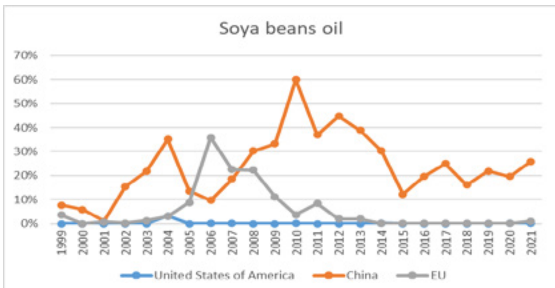

Figure 7. Brazil's soybean oil exports proportion

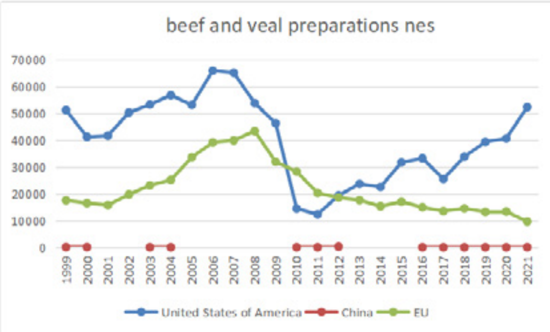

Figure 8. Beef and veal preparations nes exports

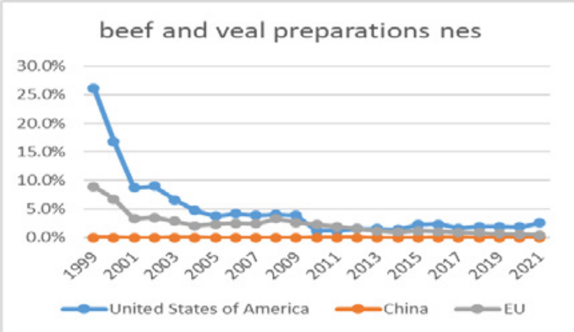

Figure 9. Beef and veal preparations nes exports proportion

3. Results

3.1. Effectiveness of climate action

From Figure 2, it can be seen that there was no significant change in the trend and magnitude of changes in agricultural land and forest area in Brazil from 2006 to 2009, indicating that "Amazon Soy Moratorium" has not yet played an effective role or the effect is not significant at this stage. From 2010 to 2017, agricultural land continued to show an upward trend and forest area continued to show a downward trend, but the changes were gradually flat compared to before 2010. After 2018, the trend of change has further flattened.

3.2. Carbon dioxide loss

Figure 4 shows that from 2002 to 2011, carbon dioxide losses in Brazil gradually decreased. From 2011 to 2020, except for the special value in 2015, the overall trend showed an upward trend.

3.3. The influence of important countries

From Figures 4 and 5, it can be seen that China has the highest proportion of Brazilian soybean exports, but since 2018, the total growth rate has been slow and the proportion has decreased. Since 1999, the proportion of soybeans imported by the European Union into Brazil has continued to decline. Prior to 2006, it was higher than China, and later lower than China. However, there has been a slight increase since 2019. The United States is at a lower level.

It can be seen from Figure 6 and Figure 7 that China still has a high proportion in the export of Brazilian soybean oil, but from the trend, the proportion has declined more since 2015, and it will show an outlier in 2021. The EU has experienced a significant decline since 2006 and has been at a relatively low level since 2010. The United States continues to be at a relatively low level.

From Figures 8 and 9, it can be seen that in terms of beef product exports from Brazil, the United States has long been at a relatively high level, but the proportion has decreased. Since 2008, the EU's imports of Brazilian beef have significantly decreased, and the ratio is also at a relatively low level. China continues to be at a relatively low level. In addition, there are certain special phenomena in the export of beef products, and Brazil's three main agricultural export targets have a relatively small impact on beef products compared to soybeans. Brazil's beef products also have important export targets.

3.4. Summarize

It can be seen from this that the "Amazon Soy Moratorium" launched by the EU in 2006, a mechanism that gradually transmits pressure from the lower reaches of the soybean supply chain to most of the upstream producers, had no obvious effect on the Amazon rainforest at the initial stage, but it promoted the change of government behavior. After the Brazilian central bank banned loans for deforestation, the climate action initiated by the European Union had a significant effect.

However, because the Amazon rainforest is adjacent to the Serrado Grassland, focusing only on the Amazon rainforest cannot eradicate the ecological protection of Brazil, but in a sense, it has intensified the development of the Serrado Grassland. Since 2010, the protection of the Serrado Grassland has gradually received attention. In 2017, the Cerrado Declaration initiated by Brazilian social groups was of crucial significance. The Cerrado Declaration has prompted the participation of the European Union and China. During this period, as a major exporter of soybeans, China's declaration on sustainable development of meat had little impact on beef products, but the import of soybeans, an important source of feed, was greatly affected, thus playing a certain role in promoting the protection of Brazil's rainforest and grasslands. The EU is in a state of continuous improvement.

From the above summary, it is not difficult to find that the climate action of non-governmental organizations has a certain positive significance, but its indirect effect on the protection of the Serrado grassland may be greater than its direct effect. The climate action of non-governmental organizations is likely to require government involvement to enhance its effectiveness. At the same time, the initiators of climate action have stronger action power, which also indicates that in future ecological protection, non-governmental organizations need to take various measures to attract more individuals and organizations to participate in non-governmental organization climate action, or form more climate action non-governmental organizations.

4. Discussion

The purpose of this study is to explore whether non-governmental organizations' climate action on the Serrado Grassland is effective and how it may have an impact on the ecological protection of the Serrado Grassland.

We predict that non-governmental organizations can influence Brazilian rainforest and grassland developers through consumers or downstream enterprises in the agricultural supply chain, while the initiators of climate action have stronger action capabilities. In this study, we found that the European Union, as the initiator of climate action, plays a crucial role in Brazil's ecological protection, and its effectiveness is long-lasting. As a developing country, after issuing the China Meat Sustainable Development Declaration in 2017, China quickly adjusted its agricultural supply chain, changed the structure of livestock feed products, and reduced the import ratio of soybeans. However, due to the strong consumption inertia of Chinese consumers towards soybean oil, the impact of this declaration on soybean oil imports is significantly lower than that of soybeans. In our research, it is rare to see the United States actively initiating climate action. Therefore, the impact of climate action by non-governmental organizations on the United States is relatively weak, with a decrease in the proportion of imports of Brazilian beef, but the absolute value is still on the rise. In addition, once the ecological environment is destroyed, the difficulty of repairing its carbon sequestration capacity is often high. Although the rate of forest destruction tends to stabilize, carbon dioxide loss in Brazil is still rapidly increasing. In addition, in the early stages of climate action by non-governmental organizations, due to their non mandatory nature, the number of participants is relatively small, and their influence is not significant. However, as the number of participants gradually increases, it will gradually encourage the government to participate. Through legislation or financial policies, it will be more effective to influence directly participating enterprises or individuals in ecological destruction to change their behavior. Therefore, the initial ban on soybean deforestation initiated by the European Union did not have a significant effect, But after two to three years, its social influence has significantly improved.

Therefore, our conclusions and assumptions are basically consistent, and non-governmental organizations contribute to the ecological protection of the Serrado grassland, but their pathways of action are slightly different. Due to the controversial research results of previous scholars, this conclusion differs from some scholars' views that non-governmental organizations have not effectively promoted ecological protection, and is similar to some scholars' views that ecological protection in Serrado requires the cooperation of non-governmental organizations, governments, and financial institutions. In fact, based on the literature and the conclusions of this study, we can find that in independent markets, relying solely on non-governmental organizations to take climate action has limited influence and requires effective promotion of government participation in order to better achieve the goal of ecological protection.

This study helps to reveal how non-governmental organizations (NGOs) use the supply chain for ecological protection, and also helps to further clarify the role paths of NGOs, government organizations, and financial institutions in ecological protection, providing reference for how to improve the effectiveness of NGO climate action in the future.

Due to the significant differences in data disclosure among different countries in international exchanges, I have insufficient knowledge of agricultural land and pasture data in the Serrado region, as well as feedback data from local businesses and consumers on international non-governmental organization climate action. Therefore, this article lacks quantitative analysis of the interrelationships between direct and indirect participants in non-governmental organization climate action, and further research and exploration are needed.

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Based on Consumer Theories: What can Companies do to Accelerate Carbon Neutrality.

Wenqing HUANG

Dalian Maritime University, Dalian, China, 116026

Email: huang_wenqing_icnt@iie.world

***Corresponding author**

Abstract

According to the Sheth-Newman-Gross consumption value model, a product or service provides consumers with five aspects of value: functional value, social value, emotional value, cognitive value, and situational value. Based on this theory, this paper explores the strategies of Tesla and tries to find out its way to better achieve the worldwide goal of carbon neutrality. Tesla, one of the new energy vehicle manufacturers, is a pioneer in accelerating carbon neutrality. It manufactures products that qualify for all the features of the consumption value model, which to some extent account for its success worldwide. More importantly, I conclude its experience so that other companies can learn and apply it for practice themselves and better achieve carbon neutrality. That is to make their goods or services full of functional value, social value, emotional value, cognitive value, and situational value. And social value has been more and more important in the Internet era.

Keywords: Carbon neutrality; Sheth-Newman-Gross consumption value model; tesla company.

1. Based on consumer theories: what can companies do to accelerate carbon neutrality

According to the IPCC's Special Report on Global 1.5°C Temperature Rise, carbon neutrality means that net zero CO_2 emissions can be achieved when anthropogenic CO_2 removal offsets anthropogenic CO_2 emissions on a global scale over a defined period of time. The report also emphasizes that only by achieving the goal of net zero carbon emissions - carbon neutrality - on a global scale by the middle of the 21st century will it be possible to limit global warming to 1.5°C and thus mitigate the extreme hazards of climate change. However, the Emissions Gap Report 2019 released by the United Nations Environment Programme (UNEP) points out that there is a large gap between the current ambitions of countries to reduce emissions and the requirements of the 1.5°C target.

European Union and the United Kingdom regard carbon neutrality as an important opportunity to enhance their future economic competitiveness and ensure the maximum achievement of carbon neutrality targets through technology pathway planning, policies and regulations, and financial support. (Zhang et al,2021).

Governments and enterprises generally recognize that energy conservation and renewable energy are the main directions for future technological development in the industry. In the automotive industry, an important way to improve and alleviate the current situation is to develop new energy vehicles, especially pure electric vehicles. Tesla, as a benchmark brand of pure electric vehicles, has refreshed the concept of new energy vehicle manufacturing and opened up the idea of new energy vehicle manufacturing and a new segment of the new energy vehicle market (Sun Jie & Dong Jianjun, 2022).

Therefore, the analysis of Tesla's "green path" to achieve development has certain significance for other industries.

The Sheth-Newman-Gross consumption value model (Sheth et al., 1991) argues that a product or service provides consumers with five aspects of value: functional value, social value, emotional value, cognitive value, and situational value.

Functional value refers to the actual, material, functional value of the good itself. A product or service has functional value when it has certain functional attributes and satisfies the purpose of use for the consumer.

Social value refers to when a product or service provides utility by connecting consumers with other social groups, i.e., whether the product can bring social status, social image enhancement or satisfy consumers' self-needs, if it can, the product has social value.

Emotional value refers to the emotional resonance of the product or service for the consumer, if the consumer can get the favorite feeling from the product or service, it has emotional value.

Cognitive value can also be understood as novelty value, which refers to whether the product or service satisfies consumers' curiosity and novelty, and if it does, the product has cognitive value.

Situational value refers to the choice consumers make when faced with a specific situation. In a given situation, a product or service can temporarily provide greater functional or social value, so that it produces external utility and changes the consumer's original behavior, and situational value is not held for a long time but for a short time.

2. Method

2.1. Materials

This article focuses on consumer theory and how it explains the consumption of Tesla, especially the part that relates to carbon neutrality.

Most of the references are found in China National Knowledge Infrastructure. I filed and compared relevant articles, and combined them with other information on the official website of Tesla.

Due to a lack of access to some of the articles like the book Why we buy what we buy: A Theory of consumption values, I got the view about it from an article from someone else.

3. Results

Tesla is producing products of functional value. Rather than adapting to competition by lowering prices, Tesla Motor is using a pricing customer-perceived value pricing method, by adding value-added services to develop its differentiation by adding value-added services. With this pricing approach, consumers evaluate the price of a product by its perceived value. It is greater than its actual selling price, and customers are motivated to buy. In terms of increasing perceived value, Tesla has made a refined calculation for its customers than traditional gasoline. A conventional gasoline car consumes about 8.1 liters of fuel per kilometer, and at 8.55 yuan/liter, the fuel consumption is 69 yuan per 100 kilometers. The Model S consumes 0.183 units of electricity per kilometer, and the cost of electricity is 0.53 yuan per unit. The Model S consumes 0.183 kilometers of electricity per kilometer, and at a cost of 0.53 yuan per kilometer, the electricity consumption is 9.7 yuan per 100 kilometers. (Zhang et al,2015).

Moreover, Tesla is thought highly of its emotional value. It is a purely electric new energy company with no fuel consumption and no emissions, which is the new logo of today's environmental protection. What's more, it has become the purchase target of environmentally conscious consumers. Although few consumers are currently buying because of environmental awareness, when these people realize the real meaning, such as the strong emotional meaning, parents want their young children to live in a better world, they will actively join the "buy" team. Thus, the rising awareness of environmental protection has made more and more consumers join the team to call for a blue sky.

What's more, Tesla is considered full of cognitive value. With its "environmental protection, intelligent technology" product concept, Tesla quickly swept the global electric car market, just like the original Apple iPhone, and has continuously topped the sales of luxury cars in the United States. Tesla has become the Apple of the automotive world, renewing the myth of the American auto industry.

Meanwhile, Tesla has both high social value and situational value. Because of these myths, many big names in the technology world, like Google's Sergey Brin, domestic Sina's head Cao Guowei, Xiaomi's founder Lei Jun, and finally Oscar-winning Leonardo, Morgan Freeman, Steven Spielberg and other Hollywood big names are all famous users of Tesla. These people not only have a voice and influence in their circle of friends. In the world outside their circle. There is a large number of loyal fans, and such an opinion leader's influence really should not be underestimated. Microsoft founder Bill Gates has posted a viral video on his private blog of test-driving the Model X with his friends. In addition to the marketing caused by the celebrity effect, other ordinary consumers of Tesla also voluntarily formed a circle, they either set up a Tesla owners' group or a WeChat public number, following the official information dissemination footsteps, and subconsciously influencing their friends or relatives around them. these people are the best salesmen, they tell 10 or 20, or 100 people who are willing to trust them, listen to what they say, and listen to what they have to say (Liu Jing, 2016). We should notice the significant influences led by its social value and make good use of it in marketing.

4. Discussion

The experience learned is that companies should try to improve the value of their product or service in five aspects, among which the social value should be emphasized.

As we all know, the choices of consumers and policies of government can greatly influence enterprises and therefore all the bodies in society are motivated to do something for a better world. Nowadays, people have done a lot of research on what consumers can do in daily life and what kind of tools government can use to accelerate the process of carbon neutrality. But to some extent, the decision of carbon neutrality for companies is more likely to be forced. We may ponder, is there a way for companies to turn to carbon neutrality with willingness? So we should pay some attention to think what companies can do voluntarily.

What's more, previous articles are mainly focused on how to promote carbon neutrality technically. It is significant to deal with this question from some other perspectives. Therefore, this article views it from a consumption value and tries to collect some experience from the success of Tesla. In this way, we can go deeper into the concept of carbon neutrality.

However, there are some drawbacks to this article. Firstly, it is done with the analysis of former papers for lack of access to get into the company and conduct field research. Secondly, limited materials can be found for the combination of consumer value and Tesla, which may affect the reliability and validity of the article. Thirdly, there are not enough direct data to guarantee the companies' success of how long in the future.

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Analysis of Sustainable Development Issues in the Fashion Industry

Meihui LI

Nanjing Forestry University, Nanjing, Jiangsu, China, 210037

Email: li_meihui_icnt@iie.world

***Corresponding author**

Abstract

With the proposal of the goal of carbon peak and carbon neutrality, China's clothing industry has entered the sustainable development stage of industrial transformation and upgrading. The article analyzes the sustainable fashion development of the global clothing industry under the dual carbon goal from three aspects: the relationship between the dual carbon goal and the sustainable development of China's clothing industry, the meaning of sustainable fashion, the principles and concepts of sustainable fashion design, and the practices, difficulties, and paths of sustainable development of the global clothing industry. With the rapid development of the social economy, environmental pollution has become increasingly serious, and sustainable development has received widespread attention from all sectors of society. Faced with the serious environmental pollution problem in the fashion industry, many fashion companies are gradually applying the concept of sustainable development to supply chain operations.

Keywords: Climate change; carbon neutrality; policy recommendations; fashion industry.

1. Introduction

The Pollution Status of the Fashion Industry the fashion industry has always been one of the most polluting industries, with pollution levels second only to the petrochemical industry and ranking second globally. The fashion industry wastes a large amount of resources every time a piece of clothing is made, and improper recycling of clothing can also lead to secondary waste of resources. Especially in recent years, the rise of fast fashion brands has greatly increased the speed of clothing updates. Old clothes are quickly discarded, and discarded clothing takes 200 years to degrade, posing a huge burden on the environment. Although the fashion industry has brought great value, it still leads to serious environmental pollution and social issues.

1.1. The impact of environmental climate change

The impact of global warming and the COVID-19 has made people pay more attention to the relationship with the surrounding environment, and the awareness of environmental protection has gradually increased. From 2023, Europe will be fully electrified. China has announced that it will achieve carbon peak in 2030 and carbon neutrality in 2060. Social development is also undergoing a comprehensive green transformation, including clean low-carbon, resource recycling, etc. The burning of waste clothing in the fashion industry will aggravate the greenhouse effect, which is not only detrimental to ecological stability, but also harmful to people themselves, and will increase the incidence rate of cardiovascular, cerebrovascular and respiratory diseases. The use and discharge of chemicals in the fashion industry can cause damage to both biology and the environment, leading to land pollution, water pollution, and air pollution, all of which ultimately have a direct impact.To the living environment of humans. Based on this, the pressure of the fashion industry in various sectors of society. We are gradually emphasizing the impact on the environment and promoting the concept of sustainable fashion.

1.2. Differentiated needs of brands

With the exposure of pollution issues behind the fashion industry on social media, consumers have begun to enhance their awareness of sustainable consumption, and their liking for brands with severe waste and deep pollution has decreased. Therefore, some brands, in order to maintain and improve their brand image, have begun to introduce sustainable fashion concepts, develop and adopt sustainable fabrics, and plan brand sustainable development goals. Simultaneously promoting the concept of sustainable fashion can create a difference from traditional clothing brands and reduce the moral burden on consumers when consuming. Sustainability has become a survival solution for many brands in the fashion industry in differentiated competition.

2. Method

Fashion brands have always been one of the important sources of environmental pollution, and after disclosure by social media and environmental protection organizations, people's criticism of the fashion industry, especially the fast fashion industry, has intensified. In order to maintain brand image and regain consumer favor, various fashion brands have launched environmental slogans, adopted sustainable fabrics, sponsored public welfare undertakings, and improved worker benefits through a series of measures. But with the increasing awareness of environmental protection among consumers, some brands are also engaging in more and more "greenwashing" behavior. These brands often only contain a small amount of recyclable ingredients in their products, but publicly claim that their products meet sustainable development standards. However, general consumers are not careful about the specific ingredients when shopping, leading to being misled into placing orders. In addition, there are still many problems that need to be solved urgently in the path of sustainable fashion brands.

2.1. Sustainable marketing or leading to excessive consumption

Nowadays, sustainable fashion has become a differentiated survival solution for fashion brands, but some brands often promote their products through "degradable, recyclable, and renewable" aspects, hoping to win the favor of consumers. However, the principle that sustainable fashion should adhere to is to reduce waste. When fashion brands promote the sustainability of their products, they will correspondingly reduce the psychological burden and moral pressure on consumers, making them believe that purchasing the product is beneficial for environmental protection, but instead promoting consumption. This is not only detrimental to sustainable development, but also causes certain damage to the environment. The brand's promotion of "degradable and recyclable Recycling and recycling"require a certain amount of time and not 100% degradation and recycling, but brands often overlook the technical barriers, environmental limitations, and actual environmental footprint involved in the actual degradation and recycling process when promoting these, which are much larger than imagined. Over time, sustainable fashion will only become a marketing slogan and means for fashion brands, and cannot achieve true sustainable development.

2.2. Sustainable products with high prices and small audience

The biggest challenge faced by the sustainable development of the fashion industry is that adopting sustainable development measures usually means investing more costs in technological innovation to eliminate pollution, reduce emissions, increase worker wages, and improve working conditions. In other words, the required costs are higher. Therefore, within a certain period of time, the profitability of enterprises may decrease, so sustainable development transformation is not an easy task for enterprises. Brands, in order to maintain their own interests, price some sustainable products on the market at a higher price. However, most consumers are unwilling to pay more than the value of the products due to factors such as limited consumption levels or different consumption concepts, which hinders the circulation of sustainable products. It can be seen that sustainability is crucial for fashion brands challenging.

2.3. Difficulty in product recycling and utilization

Nowadays, consumerism is prevalent, and people are constantly pursuing a lifestyle that can meet their own consumption, while the consumption of fashionable products is often the choice of most consumers. The emergence of fast fashion meets people's desire for novelty and is in line with the concept of consumerism. Fast fashion clothing is usually presented to the public with first-class design, second-rate quality, and thirdrate prices. More consumers do not have clear purchasing goals, but enjoy fashionable and affordable consumption experiences, thus purchasing a large number of fashion items. Continuous production and sales can bring huge profits to fashion companies, so companies constantly introduce new products and marketing methods to stimulate consumers' shopping desire. However, the quality of the product is at the middle and lower levels, resulting in huge waste. Many clothing items are thrown away after being worn several times, resulting in a high loss rate of used clothing fabrics and difficulties in large-scale recycling.

3. Results

3.1. Sustainable Development Status of Fashion Brands

With the increasing reduction of social resources and the current attention to sustainability from all sectors of society, various industries are starting to embark on a sustainable development path. The fashion industry has also launched various measures to reduce the consumption of resources and environmental damage caused by products. Some relatively niche brands themselves are positioned as green and sustainable, such as Rejuvenating Bank of Clothes and ICICLE Zhihe; Fast fashion giants such as ZARA and UNIQLO, which update their clothing products quickly, have also launched sustainable measures in order to regain the favor of consumers and establish brand image; Luxury brands are also continuously building their own green and sustainable brand image. The shaping of green clothing brand image can not only promote sustainable social and economic development, but also guarantee the long-term development of enterprises. The trend of green sustainability is becoming increasingly popular in the fashion industry.The blow is getting stronger.

3.2. Sustainable commitment of fashion brands

3.2.1. Sustainability of niche fashion brands

In a fiercely competitive market, many niche brands differentiate themselves from traditional mass brands by positioning themselves as sustainable and winning development opportunities. At present, niche fashion brands promote their sustainable stance from aspects such as brand philosophy, product materials, worker benefits, and brand influence. For example, the Swedish children's clothing brand Mini Rodini was founded by artist Cassandra Rodin in 2006, dedicated to creating children's clothing that is completely different from the existing market. In addition to emphasizing design and aesthetics, it also injects sustainable concepts into the brand's soul. In terms of materials for children's wear, Mini rodini mostly uses biodegradable environmental materials such as organic cotton, organic wool, modal, recycled polyester, etc. On the official website, each material section has a detailed introduction, and on the recycled polyester page, all materials listed for recycling have passed the GRS certification (global recycling standard). In addition, Mini Rodini has also released the "Mini Rodini Living Wage Plan" to ensure the rights and quality of life of factory workers. Mini Rodini promises that "our goal is to have a living wage for all of our sewing factories, not a minimum wage. Since 2014, Mini Rodini has released its sustainability report every year, showcasing the brand's commitment and achievements in sustainable work to consumers.

In recent years, with the increasing awareness of environmental protection among Chinese consumers, the number of sustainable fashion brands in China has gradually increased. For example, ZaiYi Bank - a sustainable fashion brand founded by independent designer and founder of the FAKE NATOO women's clothing brand Zhang Na in 2011. The original intention of the brand was not to focus on environmental protection, but to use design to connect the memories of the past, present, and future carried in old clothing. But ZaiZai Yi Bank itself has a strong environmental gene, with three series of brands: "Zhong, Le, and Zai". Each series adopts sustainable methods and principles. Starting from the selection of materials, it is necessary to evaluate whether there will be pollution to the environment and excessive energy consumption. Zai Yi Bank promises to be a brand that fully adheres to sustainable fashion, while niche brands such as Zai Yi Bank and Mini Rodin i that are based on sustainable fashion include ICICLE Zhihe, FoDays, Da Yi Yan, REVERB, AbasiRosborough, Patogonia, and others.

3.2.2. Sustainability of fast fashion brands

The main measure taken by fast fashion brands is to accurately identify the latest trends when they appear, and introduce relevant clothing styles. They design clothing as quickly as possible and sell it at a lower price, while maintaining first-class design The core principles of second rate quality and third rate price are based in the market However, with the exposure of social media on the huge pollution and energy consumption issues behind fast fashion, it has become less glamorous and has been condemned by various sectors of society.

According to data from consulting firm McKinsey, the global clothing industry manufactures 100 billion pieces of clothing annually, accounting for 10% of the global carbon emissions caused by clothing manufacturing. In the face of difficulties, the fast fashion industry quickly proposed sustainable solutions. In July 2019 Zara's parent company, Inditex Group, announced that 100% of the products of all brands including Zara, Pull&Bear, and Massimo Dutti will be made of sustainable fabrics by 2025. All brand stores will be equipped with old clothing recycling devices, and the group will use these materials and innovative technologies to remake clothing and put it into the market. In April 2022, UNIQLO released the 2022 Sustainable Development Report, which described the sustainable development policy of Fast Retailing Group and promoted the spread of the brand concept that "LifeWear suits life" represents "sustainability". Global Retail Apparel Leader Gap.

4. Discussion

4.1. Sustainable development solutions for fashion brands

Actively assume social responsibility and eliminate the phenomenon of "greenwashing"Fashion brands should actively take on the social responsibility of protecting the environment and saving resources, and strive to integrate sustainable concepts into the entire process of fashion product selection, production, and circulation. Starting from the material selection stage, it is necessary to consider whether the material is sustainable, minimize the harm to nature, and implement the concept of sustainability in subsequent treatment, striving to achieve maximum sustainability. When promoting products, it is important to comprehensively introduce product information and refuse to use sustainable fashion as a gimmick or marketing to change one's brand image. To achieve a green and healthy environment from the inside out, rather than "drifting green", allowing consumers to pay for unnecessary greenery.

4.2. Increase investment in technology research and development, seek sustainable new fabrics

Du Yijia, the manager of the Sustainable Fashion Laboratory, said in an interview: "The rapidly changing innovative technology has become the driving force and key technology for innovation in the fashion industry. The relationship between technology and fashion is inseparable and mutually successful. Fashion, as a carrier, has always demonstrated technological innovation, and technology will in turn affect various aspects of the fashion industry such as design and retail. The most important aspect of sustainable fashion is the research and development of technology. Currently, many technologies are applied to search for new fabrics and improve the service life of clothing fabrics. The application of some biological fibers requires high technical requirements and requires continuous investment from brands.

4.3. Develop efficient recycling plans to improve resource utilization

The recycling of old clothing and textiles has existed since ancient times, especially in times of material scarcity, where people would maximize the effectiveness of their use, whether in Western countries or China during World War II. But with the stability of society and the improvement of people's living standards, people have begun to enter the consumption era. After a large amount of waste textiles lose their use value, they cannot be effectively recycled, and most of them are buried or burned, seriously polluting the social environment.

The recycling of waste textiles is a major project that requires the joint efforts of relevant government agencies, consumers, and fashion brands. For fashion brands, establishing a recycling mechanism for branded products is a more effective method. Since 2006, UNIQLO, the world's third largest fast fashion brand, has achieved remarkable results in recycling old clothes of its own brands through the "full commodity recycling activity", and has realized a closed-loop recycling system of production sales consumption recycling recycling. This move can effectively practice sustainable fashion and is worth learning from by other fashion brands. For fashion brands, redesigning after recycling is an effective way to revitalize recycled products, including secondary design, upgrading and reuse, redesign, and regenerative design. The redesign concept has gradually been recognized by fast fashion brands, independent designer brands, as well as young artists and fashion enthusiasts, and has been put into practice, which is of great significance for the development of sustainable fashion.

Sustainable fashion has become an inevitable choice of the times. If the Earth is not green and the future is not sustainable, then fashion will inevitably disappear. Therefore, taking the path of fashion sustainability is not only the social responsibility of fashion brands, but also the path of self-help. But the sustainability of fashion requires active participation in every aspect of society, and consumers need to raise their awareness of sustainable ethics and reduce unnecessary consumption; Environmental protection agencies should play a supervisory role; Fashion brands also need to bear social responsibility, adhere to the sustainable path of fashion, and make a difference. Although enormous waste and pollution have already occurred, actively taking effective measures to restore the status quo can reduce losses and promote sustainable progress. The above brief overview of the current status of sustainable fashion is hoped to provide some inspiration for the development of domestic fashion brands.

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The Impact of Starting a Housing Subsidy Program for Low-Income Households on Achieving Carbon Neutrality in South Korea

Fang LIU

Capital Normal University, Beijing, China, 100048

Email: liu_fang_icnt@iie.world

***Corresponding author**

Abstract

Carbon neutral building, a building that is designed, constructed, and operated to produce zero net carbon emissions over its lifetime. The goal of carbon neutral buildings is to reduce the negative impact of buildings on the environment and to mitigate climate change. In order to promote the achievement of carbon neutrality goals by building carbon neutrality buildings, South Korea employs the Green Standard for Energy and Environmental Design (G-SEED) and designed Green Building Certification System (GBCS) to evaluate environmental performance of buildings and promote the dissemination of green buildings. However, low-income households are particularly vulnerable to the impacts of climate change and face challenges in accessing affordable, energy-efficient housing. A housing subsidy program for low-income households can help address these challenges and contribute to achieving carbon neutrality. Measures such as allocating more funds, establishing clear eligibility criteria, monitoring and evaluating the program, and promoting the benefits of sustainable living to the public can help achieve carbon neutrality goals in South Korea.

Keywords: Housing subsidy; carbon neutral buildings; carbon neutrality; policy recommendations.

The world is facing the challenge of climate change, which is caused by excessive greenhouse gas emissions, including carbon dioxide, methane, and nitrous oxide. According to the Intergovernmental Panel on Climate Change (IPCC), human activities have caused approximately 1.1°C of warming since 1850-1900, and global temperatures are expected to reach or exceed 1.5°C of warming over the next 20 years (IPCC, 2021).

South Korea, which was the world's 15th largest carbon emitter in 2018, has moved higher and higher in recent years. According to network data monitoring, South Korea entered the world's top 10 carbon-emitting countries in 2021. To address this issue, the Korean government has set a goal of achieving carbon neutrality by 2050 (UNCC, 2020). One of the major sources of greenhouse gas emissions in Korea is buildings, which account for about 20% of all GHG emissions (Kwak et al., 2019). The Korean government has been promoting the construction of carbon-neutral buildings. However, the high cost of constructing such buildings has made it difficult for low-income households to access them.

This paper argues that starting a housing subsidy program for low-income households can help achieve carbon neutrality in Korea by increasing the adoption of carbon-neutral buildings. The housing subsidy program could be designed to cover a portion of the construction cost of a green building or to provide low-interest loans to low-income households to help with the construction of carbon-neutral buildings.

1. Method

To conduct this analysis, a search was conducted using the following databases: Google Scholar, Web of Science, and Scopus. The keywords used in the search included "housing subsidy program," "low-income households," "carbon neutrality," and "South Korea." Filters were applied to limit the search to articles written in English and which have open access availability.

The selected sources were chosen based on their relevance, credibility, and publication date. The articles had to be published in recent years to ensure that the information was up-to-date. The relevance of the articles was determined by their title, abstract, and keywords. Only articles that highly addressed the importance of a housing subsidy program for low-income households in achieving carbon neutrality were selected. The credibility of the articles was determined by the reputation of the journals in which they were published and the credentials of the authors.

The articles which were selected were grouped into two categories: those that focused on the importance of a housing subsidy program for low-income households on achieving carbon neutrality in South Korea and those that analyzed the effectiveness of existing housing subsidy programs in other countries.

The articles that focused on the importance of a housing subsidy program for low-income households on achieving carbon neutrality in South Korea found that such a program could help reduce carbon emissions from the housing sector by promoting the adoption of energy-efficient technologies and practices. These articles also highlighted the need for targeted policies that address the unique needs of low-income households, such as access to affordable financing and technical assistance. The articles that analyzed the effectiveness of existing housing subsidy programs in other countries found that such programs can be effective in reducing energy consumption and carbon emissions from the housing sector.

However, the success of these programs depends on factors such as the design of the program, the availability of financing, and the level of public awareness and participation. Achieving carbon neutrality goals requires significant financial support and a certain amount of trial and error, so patience and perseverance are crucial.

2. Results

2.1. Challenges and opportunities

Starting a housing subsidy program for low-income households in South Korea has both challenges and opportunities in terms of achieving carbon neutrality.

One of the main challenges is the cost of implementing such a program. The government would need to allocate a significant amount of funding to subsidize housing for low-income households, which may be difficult to do given other competing priorities. Additionally, the construction and renovation of housing units to meet carbon-neutral standards can be costly, which may limit the number of households that can benefit from the program.

Another challenge is ensuring that the program is effective in reducing carbon emissions. The government would need to establish clear eligibility criteria and monitoring systems to ensure that the housing units meet the necessary carbon-neutral standards. It is also important to ensure that the program does not inadvertently lead to increased energy consumption or other negative environmental impacts.

Despite these challenges, there are also opportunities to achieve carbon neutrality through a housing subsidy program for low-income households. One opportunity is to use the program as a way to promote the adoption of renewable energy sources, such as solar panels, in low-income households. This can help to reduce carbon emissions and increase energy independence for these households.

Another opportunity is to use the program to promote sustainable urban development. By providing housing subsidies in areas with access to public transportation and other sustainable infrastructure, the program can encourage low-carbon lifestyles and reduce the need for private vehicles.

2.2. Recommendations

Based on the literature analysis, several recommendations can be made to address the gaps and challenges in starting a housing subsidy program for low-income households on achieving carbon neutrality in South Korea.

First, allocate sufficient funding for the housing subsidy program to ensure that it can reach a significant number of low-income households. This funding could come from a variety of sources, including government budgets, private sector contributions, and international aid (Yoon & Song, 2023).

Second, develop clear eligibility criteria for the program to ensure that it reaches those who need it most. This could include income thresholds, age requirements, and other factors that are relevant to low-income households.

Third, establish a monitoring and evaluation system to ensure that the upgrades made to homes are effective in reducing energy consumption and greenhouse gas emissions. This could include regular inspections of homes, surveys of participating households, and data analysis to track energy consumption and emissions.

Fourth, provide education and outreach to participating households to ensure that they understand how to use the energy-efficient upgrades effectively and maintain them over time. This could include workshops, training sessions, and informational materials that are tailored to the needs of low-income households.

In conclusion, starting a housing subsidy program for low-income households can play a crucial role in achieving carbon neutrality in South Korea. It can help address the challenges that low-income households face in accessing affordable, energy-efficient housing and can have a positive impact on reducing greenhouse gas emissions.

3. Discussion

3.1. Why is carbon reduction necessary in south korea

Asia is the world's largest carbon emitter, with China the world's largest carbon emitter and Japan consistently in the top five.

By comparison, it seems that South Korea's carbon emissions are not that big and the figure actually dropped in these years. In reality, however, as industries returned to normal in 2021 following the COVID-19 pandemic, economic growth drove up carbon emissions in South Korea (see Figure 1).

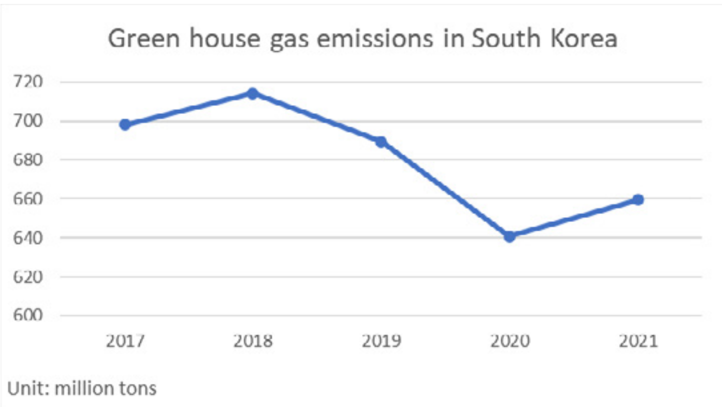

Figure 1. South Korea's Green house gas emissions from 2017 to 2021 (Data source: Ritchie, H., & Roser, M., 2022)

According to Seo Heung-won, head of the Greenhouse Gas Inventory and Research Center, there has been a rise in energy production, industrial manufacturing, and transportation fuel consumption in Korea (Im, E., 2022). It can also be seen from the figure that if South Korea does not take proactive measures to reduce carbon emissions, higher carbon emissions will be seen in the future.

3.2. What can be learned from other Housing Subsidy Programs

There are two housing subsidy programs to be discussed.

One example of a successful housing subsidy program for low-income households is the Low-Income Home Energy Assistance Program (LIHEAP) in the United States. LIHEAP provides financial assistance to low-income households to help them pay their energy bills and make energy-efficient improvements to their homes. The program has been successful in reducing energy consumption and improving the living conditions of low-income households (U.S. Department of Health and Human Services, 2019).

Another failed example is the Green Deal. It was a government scheme designed to help homeowners and businesses in England to make energy-efficient improvements to their properties. Under the Green Deal, property owners could apply for loans to fund energy-saving measures, such as insulation, heating, and lighting upgrades. The Green Deal was intended to help reduce greenhouse gas emissions by improving the energy efficiency of buildings in England, as well as to create jobs in the energy efficiency sector. However, the scheme was ultimately deemed unsuccessful due to low uptake and high interest rates on the loans. The Green Deal was officially discontinued in 2015 (Rosenow, J., & Eyre, N., 2016).

Why LIHEAP has been successful while The Green Deal has failed? Through the background analysis of the two programs, three reasons can basically be concluded here:

Firstly, LIHEAP has a clear and specific goal of providing low-income households with assistance to pay their energy bills, while The Green Deal had a more complex and ambitious goal of reducing carbon emissions and promoting energy efficiency. Secondly, LIHEAP has a well-established and efficient system for delivering benefits to eligible households, while The Green Deal faced challenges in terms of implementation and uptake. Thirdly, LIHEAP has enjoyed bipartisan support and stable funding, while The Green Deal was a more politically divisive initiative that faced opposition from some stakeholders.

Korea can draw valuable lessons from both the successes and failures of LIHEAP and The Green Deal. The targeted assistance provided by LIHEAP, which is based on clear eligibility criteria, is an effective way to ensure that low-income households receive the assistance they need. Additionally, LIHEAP's provision of a range of services, including energy assistance, weatherization, and energy education, can help to address the multifaceted needs of low-income households.

On the other hand, The Green Deal's reliance on loans that were attached to the property made it unattractive to homeowners who were concerned about the potential impact on their property values. Korea can learn from this failure by designing a program that is financially viable and attractive to homeowners. Additionally, it is important to set realistic goals and targets, and to establish effective monitoring and evaluation mechanisms to ensure that the program is achieving its intended outcomes.

3.3. Special advantages

According to a study conducted by the Korea Energy Agency in 2017, the adoption of carbon neutral buildings could reduce energy consumption by up to 40% compared to conventional buildings. If South Korea can successfully promote the construction of carbon-neutral buildings, it will become a pioneer in this field in Asia, with the ability to provide guidance to other countries and increase its international influence.

In fact, China and Japan, as carbon-emitting countries, have issued many regulations on energy-saving buildings. However, China has not given high priority to carbon-neutral buildings due to its economic development needs and large land area, which makes policy promotion difficult. Japan's building industry is highly developed, but its location in the Pacific seismic zone means it has some special requirements for building materials, making it challenging to adjust the building market.

South Korea has several advantages when it comes to promoting carbon-neutral buildings. Compared with China, South Korea has a smaller land area and higher population density, making policy implementation faster and public opinion feedback more immediate. Compared with Japan, although South Korea is also located in the Pacific seismic zone, there are fewer earthquakes, and the building structure is relatively simple, making it easier to adjust the related industry.

Furthermore, providing housing subsidies for low-income families may help alleviate internal social class conflicts in South Korea. With rapid economic growth and accelerated modernization, social class differentiation in South Korea is becoming increasingly serious. The implementation of the housing subsidy program can help low-income families rent or purchase affordable housing, reducing their economic burden and improving their quality of life. This can help alleviate internal social class conflicts in South Korea.

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Carbon Tax Development in the EU in the Context of Carbon Neutrality

Hailing LIU

Jiangsu University of Science and Technology, Zhenjiang, Jiangsu, China, 212100

E-mail: HaiLing7809@163.com

***Corresponding author**

Abstract

Facing the climate change crisis, the carbon tax is internationally recognized as one of the most effective market-based policy instruments to reduce greenhouse gas emissions. It is significant for the European Union to explore how to structure a uniform carbon tax system to achieve the objective of "carbon neutrality". Its primary function is to internalize the external environmental costs so that fossil energy consumers can consider the environmental costs in their decisions. This paper reviews the existing carbon tax policy, identifies the necessity of imposing a carbon tax based on the public goods theory and the polluter pays principle, further determines that the tax should be calculated based on fossil fuel consumption and carbon content, clarifies the rationality of imposing the tax at the consumption end, To be more equitable and to avoid a disconnect between tax capacity and tax burden, a more moderate taxation approach is proposed for progressive rates of carbon taxation. A reasonable policy proposal for the EU to achieve the objective of "carbon neutrality".

Keywords: Carbon neutrality; carbon tax; climate change; environmental costs; super progressive tax rate.

1. Carbon tax development in the EU in the context of carbon neutrality

Industrialization for more than 150 years, massive deforestation, and overconsumption of resources due to the massive use of disposable goods have produced many greenhouse gases, including carbon dioxide, and the level of greenhouse gases in the atmosphere has grown to unprecedented levels, and the growing greenhouse gases cause global warming. Global warming will trigger the melting of glaciers and permafrost and rising sea levels, jeopardizing the balance of natural ecosystems and threatening the human environment, undermining the harmony between humans and nature. The global ecological balance has been disrupted and climate change is already having a significant impact on a global scale, with frequent extreme weather conditions, increasing catastrophic floods, and exposing coastal cities and countries to extreme risks. The concept of "carbon neutrality" has been created to prevent and control the risks posed by climate change. Carbon neutrality means that the total amount of carbon dioxide or greenhouse gas emissions produced directly or indirectly by a country, company, product, activity, or individual over a certain period of time is offset by its own carbon dioxide or greenhouse gas emissions in the form of afforestation, energy saving, and emission reduction to achieve a positive or negative offset and achieve relative ‘zero emissions’. Controlling carbon dioxide emissions and achieving a balanced carbon cycle is significant for combating climate change, and is also an international obligation for the EU as a global benchmark for emissions reduction.

A market-based measure to reduce emissions has been proposed as a way of reducing emissions due to the importance and urgency of reducing emissions globally. A Carbon Tax (CT) is a tax imposed on carbon dioxide emissions. The purpose of the tax is to protect the environment and to reduce global warming by increasing the cost of emissions and curbing CO_2 emissions. The main objective is to reduce fossil fuel consumption and CO_2 emissions by taxing the carbon content of various fossil fuel products in proportion to their carbon content. A carbon tax originated in 1920 in the book The Economics of Welfare by the British economist Pigou, also known as the Pigou tax (e.g., Pigou,1920) [1], who argued that the divergence between marginal net private output and marginal net social output was due to the existence of marginal social costs and that the cost of pollution should be added to the price of the product because it made the manufacturer profitable but cost nothing. The cost of pollution should be added to the price of the product, in the shape of a tax to make up the difference between marginal net private output and marginal net social output. However, it was not until 1990 that Finland first introduced a carbon tax based on the carbon content of fossil fuels, which was then €1.12 per tonne of CO_2 equivalent(e.g. Khastar and Aslani,2020)[2]. According to the World Bank’s State and Trends of Carbon Pricing 2022 report released in May 2022, as of April 2022, more than forty countries or regions around the world have priced carbon through carbon tax policies or carbon emissions trading, and a total of 68 carbon pricing mechanisms have been implemented, accounting for approximately 23% of global greenhouse gas emissions, 37 of which are carbon tax systems, involving 27 countries. The imposition of carbon taxes varies from country to country, ranging from US$1/t to US$137/t, with significant differences in the level of taxation(The World Bank,2022)[3].

Generally speaking, European countries have higher carbon tax rates, with national carbon tax levies as shown in Table 1. However, most carbon prices are still well below the US$40-80/t needed to meet the Paris Agreement’s 1.5°C temperature control target, and a report by The High-Level Commission on Carbon Prices identified the need to set a carbon price of US$50-100/t by 2030 to keep the global temperature control target below 2°C. EU countries are also considering the introduction of a harmonized carbon tax system across their member states to compensate for the shortcomings of their carbon emissions trading system, which was implemented in January 2005.

Table 1: Status of carbon tax collection in European countries

Country	Carbon tax rate (US$/t CO_2)
Poland	0.08
Spain	17
Latvia	17
Slovenia	19
Portugal	26
Denmark	22-27
Luxembourg	28-43
Ireland	37-45
Netherlands	46
France	49
Finland	59-85
Sweden	130

In recent years, several countries around the world have introduced carbon taxes, but the EU does not have a more uniform carbon tax system, and there are still large amounts of carbon emissions outside the scope of the levy. To maximize the benefits of carbon reduction, the signaling role of carbon pricing should be strengthened to cover a wider range of emissions and achieve more emission limits. This paper will examine the current situation of carbon taxation in the EU, to provide useful policy recommendations for the development of a carbon tax in the EU and the regulation of carbon.

2. Methods

2.1. Theoretical analysis method

The theoretical analysis method is a scientific analysis method to understand the essence of things and their laws through rational thinking based on perceptual understanding. It is a method of analysis that breaks things down into components, characteristics, attributes, and relationships, and then defines and establishes them in essence, and then grasps their regularity through comprehensive analysis. In this paper, the necessity of a carbon tax is explained through the "public goods theory" and the "polluter pays principle".

Public Goods Theory defines the environment as a public good that is non-competitive and non-exclusive, from which there can be benefits at no cost. Public goods are difficult to sell and their market mechanisms are not well developed, so non-market forces, and therefore government forces, need to intervene. Carbon emissions allow fossil energy consumers to benefit economically without excessive costs but hurt the overall social environment, which makes government intervention necessary and justifiable. The government should play a corrective role in the market economy by allocating resources and regulating market demand, following the principle of 'utility-cost-taxation', whereby those who use public goods pay the appropriate price.

The Polluter Pays Principle (PPP) refers to the principle that all individuals and organizations that discharge pollutants into the environment should pay a certain amount of money to compensate for the damage caused by their polluting behavior. The principle establishes the idea that environmental resources have a 'price' and fundamentally reverses the traditional perception of 'free air'. The cost of preventing environmental pollution caused by the consumption of fossil fuels and the cost of compensating for the damage caused by pollution should ultimately be reflected in the price of the product or service, which is the internalization of external costs.

2.2. Literature analysis method

It has been over a century since the carbon tax was first proposed in 1920, and it has been an enduring topic of academic research. Based on the current urgency of carbon neutrality, a large number of scholars have conducted research on carbon taxes as a market-based means of reducing emissions in recent years.

Carbon tax, as a type of environmental protection tax, is usually levied on the production and consumption of carbon-containing fossil fuels (Poterba,1991; Lin and Li,2011)[4][5]. It is an economic policy tool for environmental protection aimed at reducing greenhouse gas emissions and is considered to be the most cost-effective means of reflecting environmental costs in the price of the final product(Hájek,2019; Jaffe,2002)[6][7]. The carbon tax has the dual attributes of environmental law and tax law, as well as the functions of both market and government mechanisms, and can achieve "double dividends". (Pearce,1991) [8]formally defines the concept of double dividend when discussing tax reform, arguing that a carbon tax can achieve two purposes for the government: the first is a "green dividend", which increases the cost of using traditional fossil energy sources and thus induces companies to use new energy sources or improve the efficiency of energy use to reduce emissions. The second is the "social dividend", in which carbon tax revenues can be used by the government to promote social equity and increase social welfare. (Wesseh,2019)[9] argues that the social dividend is driven by job creation through the input of renewable energy technologies, increasing the supply of additional labor. The use of a neutral carbon tax can achieve the goal of reducing greenhouse gas emissions and adjusting the degree of economic distortion of the existing tax system. Unlike emission reduction mechanisms such as the Emissions Trading System (ETS), which controls total emissions, a carbon tax requires only a relatively small increase in administrative costs to achieve higher emission reduction targets. At its core is price control, which does not set a cap on the total amount of emissions, but rather uses price intervention to guide emitters to optimize their behavior in producing products or providing services, thereby achieving the goal of emission reduction.

Although carbon taxes have been implemented in some countries, there is no reliable data on their actual impact(Tol,2017)[10], and therefore research in this area is necessary. The current academic consensus is that carbon taxes are effective in reducing CO_2, with optimal pricing of emissions presenting a key challenge (Kickhöfer and Agarwal,2018)[11]. Although a carbon tax can reduce energy consumption, improve energy efficiency, and promote the use of renewable energy, it will also have a negative impact on the economy, reduce the competitiveness of the industry and produce carbon leakage effects(Lin and Li,2011)[5], so a scientific and reasonable carbon tax system is of great importance to the EU.

2.3. Logical deduction method

Through the previous literature review, this paper presents an overview of carbon tax studies, analyses the theoretical basis of carbon tax formulation, clarifies its mechanism of action and, on this basis, provides a theoretical basis for the formulation of a carbon tax more in line with the EU market.

Carbon taxes are based on two main types of taxation. The first is a direct tax on emissions or carbon content, but it requires high measurement requirements and is expensive to implement, and is currently only used by a few countries such as Poland and the Czech Republic; the second is a tax based on total fuel consumption and the carbon content of the fuel to calculate carbon emissions, which is a simpler model and is used by most countries. Therefore, the second approach could be considered more often for carbon taxation.

There are three main categories of taxation segments. The first is to tax only the production side of fossil fuels, such as Iceland and Japan; the second is to tax only the consumption side of fossil fuels, such as Poland and the UK; and the third is to tax both the production and consumption sides, such as the Netherlands, where the production side, importers, distributors and consumption side of fossil fuels are all taxed. The tax on the production side is easy to administer, but it is difficult to effectively transmit price signals to consumers, which affects the regulatory effect of the carbon tax. A tax on both the production and consumption sides would result in double taxation and would be too harsh to be replicated. A tax on the consumption side is in line with the “polluter pays principle” and the “principle of fairness”, and can effectively generate price transmission and awaken awareness of energy saving and emission reduction among consumers.

The core element of a carbon tax is the tax rate. The current tax rates are broadly divided into three types: fixed rates, proportional rates, and progressive rates. A flat rate is a fixed amount of tax directly based on the unit of taxation. The fixed tax rate often disconnects the tax capacity from the tax burden but is often used in academic research on carbon taxation because it is easy to calculate. A proportional tax rate is a tax rate where the tax base varies in equal proportion to the tax amount and is not shifted by the size of the tax base.

Proportional taxes are often based on amounts and are levied in proportion to the amounts, whereas emissions are not amounts and therefore proportional tax rates do not apply to carbon taxes. A progressive tax rate is a multi-tiered tax rate that is graduated according to the number or amount of objects to be taxed. The progressive tax rate reflects the principle of energy burden. The higher the carbon emissions, the higher the applicable tax rate, which better matches the burden level of the taxpayer with the tax capacity. Progressive tax rates can be divided into two types: fully progressive tax rates and over-progressive tax rates. The full progressive tax rate is a progressive tax rate at which the entire amount of the tax object is taxed at the corresponding level, and the tax burden will increase unreasonably at the threshold of the two levels. The over-progressive tax rate, on the other hand, divides the amount of the tax object into several levels and sets the corresponding tax rate for each part of the level. The degree of progression is more moderate and no unreasonable increase in tax burden will occur at the junction of the progressive levels, therefore, it is often used when setting tax rates.

2.4. Conclusion

A carbon tax is a market-based policy instrument whereby the government imposes a charge on carbon emissions through a carbon tax to provide a policy incentive to reduce emissions, the price of carbon is determined by the government, and the market determines the level of emissions reduction under the price incentive. The implementation of a carbon tax policy can accelerate carbon neutrality. By reading and generalizing the literature, this paper concludes the specific features of a carbon tax, as shown in Table 2:

Table 2: Carbon tax features

Carbon tax		
Characteristic		A market-based tool to address climate change
Objective		Putting a price on carbon, internalizing the external costs to emitters, and reducing carbon emissions
Government level	Carbon price level	Government Decision
	Carbon emission level	Market Decision
	Scope of Implementation	The broad scope of taxation, applicable to dispersed, mobile emission sources
	Cost of implementation	Low cost of collection and easy to replicate, but dependent on national tax collection system supervision
	Implementation resistance	The increased tax burden on emitters, vulnerable to opposition
	Fairness	Relatively high transparency and fairness
	Income use effect	Carbon tax revenues can be used for energy saving and emission reduction projects, which can achieve both environmental and social welfare dividends
	International trading	Countries implementing carbon taxes risk weakening international competitiveness
Enterprise level	Emission reduction costs	Carbon abatement costs are determined to facilitate enterprises to choose the optimal abatement path on their own
	Technology Innovation Incentive	A single proportional tax rate provides little incentive for low-carbon technology innovation, while progressive tax rates are more effective in stimulating low-carbon innovative technologies

As discussed above, progressive tax rates may be more appropriate for taxing carbon emissions, but they have not been used in previous studies due to the complexity of the process of calculating progressive tax rates. The progressive tax rate is not the same as a proportional tax rate, for example, personal income tax is a progressive tax rate, the higher the income, the heavier the tax burden, and the same can be applied to the progressive carbon tax rate in this paper, the higher the carbon emissions, the heavier the tax burden should be, and according to the polluter pays principle, the tax should start from zero, as long as the consumption of fossil fuels generates carbon emissions, you will have to pay The tax should start at zero, with all fossil fuel consumption generating carbon emissions being subject to the relevant emission charges. A carbon tax would have a strong price pass-through and would result in higher emission reductions at a lower cost than total emissions control through emissions trading.

3. Discussion

Given the imperative of achieving carbon neutrality, this paper investigates carbon tax policies. The analysis is made on three aspects: the basis of carbon taxation, the taxation segment, and the setting of tax rates. The main innovation is the idea of a progressive rate of carbon taxation, which offers a theoretical basis for policy formulation. However, the final carbon tax rate to be applied in the EU will still need to be determined in light of the specific circumstances of each country and the trade-offs between different sectors, and perhaps more in-depth research is needed at this level.

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Rational Use of Spatial Panning is an Effective Means to Achieve Carbon Neutrality

Xiaoqiao LIU

Chang'an University, Xi'an, Shaanxi, China, 710064

Email: liuxqiao0616@163.com

***Corresponding author**

Abstract

Taking the carbon neutrality target of each country as a starting point, we analyzed various influencing factors that have an impact on carbon emissions, selected three representative countries, analyzed different natural and socio-economic conditions of each country, proposed strategies on how to use territorial spatial planning for carbon neutrality management, and proposed priorities for optimizing spatial patterns and planning responses to meet the carbon neutrality target in the future, hoping to provide suggestions for achieving carbon neutrality in other international places. It is expected to provide suggestions for other international places to achieve carbon neutrality.

Key words: Spatial panning; carbon neutrality; suggestion.

1. Rational use of spatial panning is an effective means to achieve carbon neutrality

Spatial planning can increase carbon sinks and reduce carbon emissions by optimizing urban spatial forms and changing land use functions, which is important to achieve the double carbon goal. The current planning practice often cuts into low-carbon planning from the perspective of ecological planning, or promotes urban reduction and quality improvement from the perspective of qualitative guidance, with a view to achieving carbon neutrality. However, the main direction and focus of planning vary from country to country, so how should we use spatial planning as a limited means to achieve global carbon neutrality?

In recent years, global high temperature, ocean acidification, sea level rise, extreme heavy precipitation and other climate problems have occurred frequently, greenhouse gas emissions are considered to be the most important factor affecting global climate change, and carrying out carbon emission reduction actions to address climate change has become a common global challenge. In order to effectively control carbon emissions and respond to global climate change, the Kyoto Protocol, the United Nations Framework Convention on Climate Change and the Paris Agreement are the three milestone international legal texts, thus forming the global climate governance pattern after 2020. In order to achieve the climate governance goal of controlling the global average temperature increase to within

2℃ higher compared to the pre-industrial period and striving to keep the temperature increase within 1.5, Europe, as a global climate governance leader, proposed a carbon neutral target in 2019 and released the European Green Deal to address climate change at the end of 2019, followed by more and more countries actively proposing carbon neutral targets. On September 22, 2020, President Xi Jinping announced at the 75th session of the United Nations General Assembly that China "will strive to peak its carbon dioxide emissions by 2030 and strive to achieve carbon neutrality by 2060". This shows that achieving carbon neutrality is an inherent requirement for the global construction of ecological civilization system and the implementation of high-quality development, an inevitable choice for striving to solve the outstanding problems of resource and environmental constraints and achieving the sustainable development of global people, as well as a solemn commitment to build a community of human destiny.

The European Spatial Development Perspective (ESDPI) has taken European spatial planning to a new level. Spatial planning" has also become a special concept. Since the 21st century, with the advancement of globalization and informationization, the urban and rural spaces of various countries, especially the dense urban areas and metropolitan belts in developed countries and regions, have undergone significant changes in spatial and human environments, and in the pursuit of sustainable development goals, human beings have begun to reflect on the nature and orientation of planning. In the process of pursuing the goal of sustainable development, human beings have begun to rethink the nature and orientation of planning. The original planning system of each country has been challenged in the new development context, and in order to maintain the coordination, integrity and strategy of spatial development, more and more countries pay attention to the integration of planning, and shift from traditional urban planning and land use planning to spatial planning and reform and improve the spatial planning system from time to time. Now spatial planning has become an effective means for countries to reasonably allocate land use structure, coordinate urban layout and promote ecological civilization construction.

Therefore, according to the different development characteristics of each country, combined with the preparation and implementation of each country's territorial spatial planning, building a pattern of territorial spatial development and protection conducive to carbon peaking and carbon neutrality, promoting green and low-carbon transformation of urban and rural construction, advocating green optimization of the pattern of territorial spatial development and protection, strengthening territorial spatial planning and use control, plays a vital role in the implementation of the carbon neutrality target.

2. Method

2.1. Materials

In this paper, we read a large amount of international well-known literature in the past three years, mainly from Peking University and CSSCI, to establish the interrelationship between land use structure and carbon emissions.

2.2. Procedure

Analyze the various influencing factors that have an impact on carbon emissions. The factors influencing carbon emissions include population, economy, technology, and construction land. Among them, population influence factors are often selected from indicators such as population size, population urbanization rate, population growth rate, etc. to analyze the relationship between carbon emission indicators and carbon emission; economic influence factors are often selected from indicators such as total GDP, the proportion of secondary and tertiary production, and the affluence of residents; technology influence factors are often selected from indicators such as the proportion of coal-based energy, energy intensity, etc.; construction land influence factors are often analyzed from the scale of land The influence of construction land is often analyzed in terms of land size, function type, material structure, etc.

Based on the regulation between influencing factors and carbon emissions and identified three representative countries, namely Germany, Denmark and China, according to the characteristics of spatial planning in different countries, and analyzed the natural and economic development of each country respectively, and proposed the use of The effective strategies to achieve carbon neutrality through spatial planning are proposed for each country.

3. Results

From the history of human civilization development, the function, scale, structure and layout of the territorial spatial pattern in different periods have influenced carbon emissions. In the period of agricultural civilization, the spatial pattern of the country with the growth of agricultural land was formed, the focus was on guaranteeing food production and survival needs, and since fossil energy was not used, the main influence on carbon emission was some human agricultural activities, and the pressure of carbon emission was not obvious; in the period of industrial civilization, the use of fossil energy promoted the priority development of urban space, and the spatial pattern of the country with the growth of construction land was formed. The scale of intensive use of construction land and the proportion of industry all affect carbon emissions and lead to a significant increase in carbon emissions and increasing ecological pressure. Under the concept of ecological civilization in the new era, countries should adhere to the concept of sustainable development and promote the optimization and coordination of the territorial spatial pattern on the basis of ecological priority. The key is to reshape the territorial spatial pattern by optimizing the industrial structure, improving energy efficiency and restraining the spatial expansion of construction land, so as to enhance the ecological carbon sink capacity on the one hand and realize carbon emission reduction and intensive transformation development on the other.

In general, the spatial pattern of land affects the carbon balance of the region through the structure and intensity of land use and its changes, as well as the way of carrying human activities. On the one hand, the pattern and characteristics of regional natural carbon balance are determined by natural processes such as photosynthesis and respiration. On the other hand, human activities greatly change the carbon balance of natural regions through industrial activities, resource development, energy consumption and land use. The impact of the change of territorial spatial pattern on regional carbon balance has two sides. For different land spaces, fossil energy consumed by industrial production, transportation and living is the main cause of carbon emission from construction land, while agricultural activities, land reclamation, ecological restoration and forest management can enhance the ecological carbon sink capacity of agricultural land and forest land.

Therefore, emission reduction/sink enhancement and regulation of regional carbon balance can be achieved by optimizing the spatial layout of national land and human activity intensity constraints. For example, from the spatial proximity and connectivity relationship, the diversified proximity layout of carbon source/sink function land can help the carbon absorption in proximity, the proximity layout of high energy-consuming industrial land and clean energy land can help to get rid of the dependence on fossil energy in the production process, and the optimization of transportation land pattern can help to improve the energy utility efficiency, all of which can help to reduce the carbon emission intensity and significantly change the regional carbon balance.

4. Discussion

In recent years, many developed countries have adopted legislation based on carbon neutrality targets, and some of them have achieved remarkable results. Based on this, this paper selects Germany, Denmark and China as representative samples to explore their methods of achieving carbon neutrality through spatial planning as an effective means.

4.1. Germany

Germany was the first country in the world to carry out spatial planning, which consists of federal planning, state planning, regional planning and local planning. German spatial planning, with its emphasis on “order”, focuses on whether regional and social development is balanced, the impact of development on the environment and whether development is sustainable.

Germany is in the cool westerly zone between the continental climates of the eastern Atlantic Ocean. Agriculture is well developed and highly mechanized. Forests cover an area of 10,766,000 hectares, accounting for about 30%

of the country's area. Territorial spatial planning can ensure that Germany's forest area does not decrease and the mechanization level of intensive agricultural land use does not decrease through reasonable land use indicators.

Germany is a relatively poor country in terms of natural resources. Apart from its rich reserves of hard coal, lignite and salt, it relies heavily on imports for raw materials and energy, and imports about 2/3 of its primary energy. The German Association for Environment and Nature Conservation and others believe that spatial order planning needs to be given more power in areas such as land protection, mining management, and spatial layout of wind energy facilities to avoid excessive power of local subjects to the detriment of public interest. Spatial planning can be used to reduce the damage to forests and the environment in the mining process as well as to do the reclamation work after mining.

Industrial development focuses on heavy industry. The automobile and machinery manufacturing, chemical and electrical sectors are the pillar industries. Spatial planning should use policies such as precise land supply and mixed industrial land supply to guide traditional industries to green and digital upgrade, develop new green industries, and promote the creation of a green, low-carbon and circular economic system.

4.2. Denmark

At present,Danish spatial planning is divided into three levels:national planning,municipal planning and local planning.The objectives of Danish spatial planning are always in line with the economic and social development and the external environment of the country.In recent years,the Danish national planning has focused more on European integration,national and regional center building,environmental protection,and so on.

In recent years,Danish national planning has focused more on the issues of European integration,national and regional center construction,and environmental protection,playing a strategic leading role in infrastructure construction,ecological protection,water conservation and energy construction.

Denmark has a temperate maritime climate with warm winters,cool summers,abundant precipitation,a mild and stable climate throughout the country,and relatively uniform annual precipitation.Therefore,sustainable reforestation and restoration of degraded forests are good measures advocated in the national plan.This measure increases carbon dioxide uptake,while increasing the resilience of forests and promoting a circular bio-economy.

Denmark is a small and open economy with a highly developed agriculture.Spatial planning can be used to increase land dedicated to science,technology and infrastructure and to create new carbon reduction technologies to improve climate change,for example,by promoting production and the use of new sources of protein,which can ease the pressure on agricultural land.

With its extensive coastline and seas where hot and cold currents meet,Denmark is rich in marine resources.It is important to use spatial planning to manage marine space more sustainably,especially to help harness the growing potential of offshore renewable energy.Action can also be taken in maritime transport,including regulating access to its ports by the most polluting vessels and forcing docked vessels to use shore-based electricity and increasing the use of vessels with low carbon emissions.

4.3. China

China's territorial spatial planning started late but developed rapidly and consists of three parts: master plan, special plan and detailed plan.

China is a vast country with a large absolute area but a small land area per capita, a complex land use type, a complex urban-rural dual structure, a high degree of intensive land use in cities and towns, and a relatively low efficiency of land use in rural areas, resulting in some land that could be of ecological value not realizing its value. Carbon emission rights and carbon quotas can be used as anchors, and land development rights can be allocated in an integrated manner according to the differences in the functions of the main body of each region , and Urbanized areas focus on emission reduction, while countryside areas focus on sink enhancement. The priority task is to reduce emissions in urbanized areas and increase sinks in rural areas. Establish a trading mechanism for carbon emission rights and carbon credits. Improve the inter-regional trading market for carbon emission rights and the financial transfer payment system to enhance the competitiveness of each region. The government will also improve the inter-regional carbon emission trading market and financial transfer payment system to enhance the consistency of incentives among regions in achieving low-carbon development transition. To improve the inter-regional carbon trading market and financial transfer payment system, and enhance the consistency of incentives among regions in achieving low-carbon development.

China is still a developing country, with a high proportion of primary and secondary industries in its industrial structure and a significantly low proportion of tertiary industries, as well as an irrational and inefficient internal structure. Spatial planning can be used for structural optimization. Based on the goal of carbon neutral development, theories such as new urbanism and new idyllic city are developed from the perspective of spatial form to study how to promote the optimization of urban form layout and build a low carbon emission land use system.

China has a large regional area with high railroad and highway coverage, and urban travel mostly uses cars as transportation. Land use layout regulation is aimed at promoting carbon emission reduction and carbon sink, improving the utilization rate of clean energy through the adjacent distribution of industrial land and clean energy land, reducing spatial and temporal distance friction through the adjacent distribution of residential land and public facilities land, and enhancing carbon sink capacity through the arrangement of rings, corridors and wedges in green areas. The plan increases the construction of public transportation road network and infrastructure, and increases the use of public transportation to reduce carbon emissions.By reasonably delineating the three zones and three lines, we can ensure that the urban area does not increase excessively and the ecological area does not decrease, increase the efficiency of ecological land use, improve the forest coverage, enhance the carbon sink capacity, and reach the goal of carbon neutrality as soon as possible.

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Low-Carbon Buildings Development and Application in Europe

Wenzheng SUN

Dalian Maritime University, Dalian, China, 116026

Email: sun_wenzheng_icnt@iie.world

***Corresponding author**

Abstract

The Earth is the home for human survival and development. With social progress and rapid economic development, global energy demand has sharply increased. The concentration of carbon dioxide is rising year by year, and the destruction of the ecological environment is becoming increasingly severe. Reducing energy consumption and lowering carbon dioxide emissions are among the important tasks humanity currently faces. For the energy-intensive and highly-polluting construction industry, achieving building decarbonization is a crucial step towards sustainable development, and the development of low-carbon buildings is the inevitable path to address the low-carbonization of the construction industry. It is pointed out that as one of the human activities with the highest energy consumption, the construction industry has a significant impact on the environment throughout the process of design, construction, use, maintenance, and demolition. By comparing and studying examples of low-carbon building construction in European countries, taking into account their respective characteristics and the low-carbon technologies used, we can summarize the advanced low-carbon concepts and technologies employed in typical low-carbon buildings in Europe. This provides a positive outlook for the future development prospects of low-carbon buildings.

Keywords: Carbon neutrality; climate change; low-carbon buildings; European cases; energy-saving technology.

1. Low-carbon buildings development and application in Europe

Currently, the building stock is rapidly increasing on a global scale. It is projected that by 2060, the increase in building area every five days will be equivalent to the size of Paris. Carbon neutrality in the construction industry is a crucial aspect in achieving climate goals. In Europe, buildings account for approximately 40% of total energy consumption and contribute to about 36% of total greenhouse gas emissions (Huseynov, 2011). In the face of the growing building area and energy consumption, decarbonization of the building sector is of paramount importance in achieving climate targets.

Currently, in Europe, there are numerous old and energy-inefficient buildings. Statistics show that approximately 35% of housing in EU member states is over 50 years old, and 75% of buildings are assessed as low-energy efficiency. Furthermore, the primary energy consumption in buildings is attributed to heating and hot water, with a relatively smaller proportion for cooling. However, with global climate warming, the potential demand for cooling will continue to rise. In EU member states, heating and hot water alone account for nearly 80% of energy consumption in households, and approximately 75% of the energy supply still relies on fossil fuels, further complicating the decarbonization of the building sector(Li, 2011).

Germany, as one of the EU member states, also faces similar challenges. Statistics indicate that in 2018 alone, existing buildings in Germany consumed 839 TW·h of final energy for heating, hot water, lighting, and air conditioning. Residential buildings accounted for about two-thirds of the energy consumption, while non-residential buildings accounted for approximately one-third (CLG, 2008). Although the carbon emissions from buildings have decreased since 1990, there has been a stagnation in the trend over the past decade, and the rate of renovation for old buildings is not optimistic (BMWi, 2021).

The Paris Agreement, which was signed at the United Nations Climate Change Conference (COP21) in December 2015 (Agreement, P, 2015) is the first legally binding comprehensive global climate protection agreement. According to the agreement, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) commit to keeping the global average temperature rise well below 2 degrees Celsius above pre-industrial levels and to making efforts to limit the temperature increase to 1.5 degrees Celsius.

Under the threat of continuously rising global temperatures, major developed countries around the world have formulated corresponding policies based on their own social backgrounds and economic strengths, with energy and climate change at their core (Fetting, 2020). These countries are transitioning towards low-carbon industries and moving towards a low-carbon society through different development models. Particularly in Europe, it has been a champion and promoter of energy efficiency, emission reduction, and low-carbon economy worldwide. Europe embraces a low-carbon lifestyle and guides people to live, learn, and produce in the right low-carbon manner. Moreover, Europe has conducted research in the field of low-carbon buildings for a long time and has prioritized achieving low-carbonization in building technologies.

Among these efforts, the construction of low-carbon and zero-carbon buildings in the UK and the construction of passive houses in Germany are successful examples. These projects have achieved significant results in energy conservation, environmental protection, and greenhouse gas emissions reduction.

Low-carbon buildings align with the trend of energy conservation and emission reduction. They not only effectively improve the comfort of living environments but also represent the inevitable path for achieving energy efficiency and emission reduction in modern cities. Low-carbon buildings will undoubtedly be the direction for future development in the construction industry and the necessary choice for countries to achieve emission reduction targets, protect the ecological environment, and reduce carbon dioxide emissions. In today's competitive international environment, carbon emissions rights are critical to a country's future development. The development of low-carbon buildings is beneficial for countries to strategically reserve carbon emissions trading resources, promote domestic economic development, and drive the development of related sectors. Achieving low-carbon buildings serves as the starting point and cornerstone for developing urban low-carbon emissions and a low-carbon economy (Anderson, 2006).

As the low-carbon and environmental-friendly concept gradually penetrates into the daily lives of ordinary people, it is crucial to explore how to utilize low-carbon technologies, combined with management, policies, and other measures, to address the potential adverse environmental impacts during the construction process. Additionally, it is important to explore future building development and construction models to achieve the goal of "building decarbonization." This is currently a pressing matter for both human development and environmental protection. The success of low-carbon buildings and technologies in Europe undeniably lays a foundation for the development of low-carbon buildings.

2. Method

The research framework begins by examining the interrelationships and interactions between people, environment, energy, and buildings. It focuses on studying the relationship between carbon dioxide emissions reduction and buildings, highlighting the crucial role of low-carbon technologies in reducing energy consumption in buildings and exploring the necessity for the construction industry to adopt a low-carbon path. Subsequently, the research delves into the theoretical foundations of low-carbon buildings and conducts a comprehensive and thorough analysis of European low-carbon building examples and the application of low-carbon technologies. By studying the development of low-carbon buildings in Europe and the application of various low-carbon building technologies under different conditions, the research aims to identify the optimal path for adopting low-carbon technologies.

The research primarily adopts a combination of literature review and case analysis methods to summarize low-carbon technologies based on different aspects of low-carbon buildings. The following guiding principles are proposed based on the summary:

(1) Literature review:

Extensive literature review is conducted, including books, papers, journals, online resources, and specialized literature, to gather information on the development process and examples of low-carbon buildings. The focus is on the technological advancements in low-carbon buildings. Through the review of literature, the research gains in-depth understanding of the development trends in low-carbon buildings, particularly focusing on the development and construction trends in European countries. The essence extracted from the literature serves as necessary references for future development of low-carbon buildings and provides guidance.

(2) Comparative analysis of case studies:

Based on the collection of relevant case study materials from various European countries, a comparative analysis is conducted both horizontally and vertically. By comparing representative cases from different European countries, the characteristics, technical approaches, development trends, and innovations of these cases are summarized, laying the foundation for improving and optimizing technical approaches.

(3) Data analysis:

Data from yearbooks, reports, literature, planning documents, and regulations are analyzed to examine the quantity, regions, timeframes, regulations, and other specific indicators of low-carbon building examples in Europe. Regularities, development trends, and existing technical approaches are derived from the analysis of data.

(4) Inductive summarization:

The basic characteristics of European low-carbon building technologies and design techniques are summarized, forming a complete theoretical framework.

(5) Typological approach and typical argumentation:

Classical cases are analyzed to provide a typological analysis and a more essential generalization from a rational cognitive perspective.

In conclusion, through the collection of theoretical materials on low-carbon buildings, the research organizes and categorizes the theories of low-carbon buildings. By conducting horizontal and vertical comparisons of significant milestones in low-carbon building cases from different countries, conclusive theoretical concepts regarding low-carbon buildings and technologies are derived.

The development of low-carbon buildings in developed countries such as Europe and the United States started early. It is considered an important strategic goal for national low-carbon development, and its growth has been rapid. These countries are at the forefront in terms of building legislation, practices, and low-carbon technologies. Due to the shared political, economic, and social development systems in European countries, they have many similarities in the ways and experiences of developing low-carbon buildings. These include promoting widespread adoption of low-carbon concepts among the public, establishing medium- to long-term low-carbon development goals, implementing comprehensive legal and regulatory frameworks, implementing tax policies and various forms of public financial support to facilitate the development of the low-carbon building market, and establishing robust systems for low-carbon building assessment standards.

Developed countries in Europe and America have already established a strong presence and expertise in low-carbon building development within the international construction industry. Therefore, their concepts and experiences in the development of low-carbon buildings and technologies are worth analyzing and studying. For this research, representative low-carbon building cases from the United Kingdom, Germany, and Spain have been selected for analysis.

3. Result

3.1. The practice of low carbon buildings in UK

With the continuous development of its economy, the United Kingdom is making practical efforts to address the challenges of climate change. It was the first country in the world to propose a reduction in carbon dioxide emissions and establish legally binding medium- to long-term targets. It is also the first country in the world to legally require buildings to achieve zero emissions and zero energy consumption.

Located in Western Europe along the eastern coast of the Atlantic Ocean, the UK has a typical temperate maritime climate. Influenced by the mid-latitude westerlies and the North Atlantic Drift, it receives abundant precipitation throughout the year, with a relatively even distribution. The lowest temperatures usually do not drop below -10°C, and the highest temperatures do not exceed 32°C. Due to the shorter daylight hours and ample rainfall during winter, the heating season in the UK is relatively long. Taking advantage of this characteristic, the BedZED community fully utilizes waste, sunlight, air, and water to engage in sustainable dialogue with modern people and buildings. Through various low-carbon technological measures, it aims to reduce building heat loss and maximize the use of solar thermal energy, ultimately achieving the goal of eliminating traditional heating methods (Dunster, 2013).

All the residences in the BedZED zero-carbon community face south, and each unit has a glass sunspace. The roof, exterior walls, and floors are insulated with 300mm thick insulation material. The windows are made of triple glazing with argon gas filling, allowing them to absorb heat as much as possible during winter. In summer, these designs minimize the conduction of outdoor high temperatures, eliminating the need for air conditioning. The window frames are made of wood with excellent thermal insulation properties, reducing heat transfer and cleverly recycling thermal energy. Another method of maintaining indoor temperature is through roof greening. A succulent plant called "sedum" covers the rooftops, greatly reducing heat loss during winter. This is a major reason why residents in BedZED save 90% of energy in heating and cooling compared to conventional homes, effectively achieving "zero heating."

The construction materials used in the houses, including timber, glass, and 95% of the steel, are recycled. Choosing wooden frames for windows alone reduces carbon dioxide emissions by over 10% (approximately 800 tons) during the manufacturing process.

A significant factor in the community's low energy consumption is the combined heat and power (CHP) plant, which plays a crucial role. It generates electricity for the community by burning wood waste and utilizes the heat produced during this process to supply hot water. Each unit is equipped with solar photovoltaic panels, which, although costly, are used for multiple purposes. The warm sunshine provides hot water and charges electric cars. On the roofs, there are rows of peculiar-looking "wind cowls" that continuously bring fresh air into the first room. These passive ventilation devices are entirely driven by wind and rotate according to the wind direction, providing fresh air to the interior and expelling stale air. Additionally, they contain heat exchangers that can recover 50% to 70% of the heat in exhaust gases, preheating the cold fresh air from outside.

Figure 1. BedZED zero carbon community

In today's world, where energy issues are of great concern, the completion of the BedZED zero-carbon community offers hope for future human living patterns. Its advanced sustainable design concepts and comprehensive utilization of environmentally friendly low-carbon technologies have made this community an exemplary zero-carbon residential neighborhood in the UK.

3.2. The practice of low carbon buildings in Germany

Germany experiences mild summers and moderate winters. Nevertheless, nearly one-third of the country's primary energy products are consumed by residential heating. In the search for energy-efficient and environmentally-friendly building technologies, a 70-year-old existing building in Germany was transformed into the country's first "3-liter house" through modern low-carbon technology. Currently, the "3-liter house" serves as a global model for energy retrofitting of existing buildings (Erhorn, 2015). The name "3-liter house" originates from the fact that after the renovation, the annual heating oil consumption per square meter does not exceed 3 liters (equivalent to approximately 4.5 kg of coal).

Figure 2. 3-liter house in Germany

During the retrofitting process, four major low-carbon energy-saving technologies were employed: enhancing the thermal insulation performance of the building envelope, utilizing phase change energy storage insulation mortar with an inner wall "air conditioning system" function, implementing a ventilation system with heat recovery, and integrating a fuel cell unit as a small-scale power station.

Following the modernization, the heating oil consumption of the "3-liter house" decreased from 20 liters to 3 liters. For a 100 m² apartment, the annual heating cost decreased, and the carbon dioxide emissions reduced by 80%. These improvements showcase significant economic and environmental benefits.

3.3. The practice of low carbon buildings in Spain

Spain, located in southern Europe, has a Mediterranean climate characterized by warm winters and hot summers. Ventilation and air conditioning systems are major energy consumption points in this region. The construction of Atika residences adopts a prefabricated modular structural system. The first sample of an Atika residence was assembled in the city of Bilbao, Spain, and there are plans to transport it by car to different countries for assembly in the future. This modular prefabricated system can save approximately one-third of construction time while ensuring a more precise architectural structure even after multiple disassemblies(Guo, 2012).

Figure 3. Atika house in Spain

In addition, other low-carbon energy-saving technologies are employed in the design. The thickness and density of the exterior walls are adjusted to provide insulation and thermal insulation. White lime boards are used as the best reflective material for sunlight. Overhangs or blinds on windows are utilized to create shading. Narrow streets and balconies are designed to ensure shaded areas and airflow. The cooling effect is achieved by utilizing flowing water.

Atika residences incorporate sloping roof technology, low-energy strategies, comprehensive solar energy systems, intelligent building management systems, and modular construction techniques. They represent a new type of energy-efficient housing in Europe and serve as a model for future residential developments in the region.

The nature of low-carbon buildings determines that low-carbon construction supported by low-carbon technologies is inevitably energy-saving, environmentally friendly, and low-emission. Achieving a harmonious building environment that aligns with the living environment is the optimal approach for energy efficiency and emission reduction through low-carbon technologies in low-carbon buildings.

European policymakers actively promote the innovation and application of low-carbon and energy-saving technologies in the construction industry, encouraging the development and implementation of new energy technologies. In terms of existing examples of low-carbon buildings in Europe, the implementation of low-carbon building technology transformation and innovation in Europe focuses on two main technical breakthroughs: energy-saving and emission reduction.

(1) Decarbonization of building structures:

European low-carbon buildings achieve energy efficiency and carbon emission reduction by designing the orientation of buildings in a rational manner. Effective insulation and thermal insulation of building envelopes can also contribute to energy savings. Furthermore, reducing the energy consumption of heating, air conditioning, and other equipment helps reduce carbon dioxide emissions.

Natural ventilation systems are installed to exchange indoor and outdoor air while recovering heat to minimize energy loss. Suitable daylighting techniques are also chosen. Proper building orientation, as seen in the three case studies, significantly contributes to energy efficiency and carbon emission reduction.

Additionally, effective insulation and thermal insulation of building envelopes can effectively reduce carbon dioxide emissions.

(2) Selection of appropriate renewable energy sources:

During the design and construction of buildings, renewable energy utilization technologies such as solar energy, wind power, and biomass energy should be fully utilized based on local environmental conditions and building usage characteristics to increase the utilization rate of renewable energy. The utilization of solar energy should consider local sunshine duration and intensity, while wind energy utilization should take into account wind speed and direction.

(3) Use of locally sourced environmentally friendly building materials:

When constructing buildings, prioritize the use of green and environmentally friendly building materials sourced locally. Additionally, maximize the utilization of recyclable materials such as wood, steel, and glass to reduce emissions. Choosing locally sourced building materials also reduces the transportation distance, thus minimizing carbon emissions generated during transportation.

(4) Increasing carbon sinks and reducing overall emissions:

In the process of decarbonizing buildings, besides reducing carbon emissions through energy-saving measures, it is essential to increase carbon sinks and reduce overall emissions. The most practical method to increase carbon sinks in buildings is through greening.

By considering the absorption of carbon dioxide, increasing carbon sinks can be achieved. To achieve carbon balance in nature, plants absorb carbon dioxide through photosynthesis. Applying carbon sequestration techniques in low-carbon buildings by utilizing plants helps increase the carbon sinks of buildings.

(5) Rainwater collection and utilization:

Low-carbon buildings should consider the collection and utilization of rainwater and domestic wastewater. Designing water reuse systems not only conserves water resources but also indirectly reduces emissions.

These measures reflect the European approach to low-carbon building technology transformation and innovation, emphasizing energy efficiency, emission reduction, and sustainable practices.

4. Discussion

The world is constantly evolving, and the destructive effects of global warming and environmental pollution are increasing. Driven by rapid urbanization, low-carbon buildings have the advantages of resource conservation and protection of the natural environment. However, low-carbon buildings also face significant development challenges, stemming not only from the speed and scale of their construction but also from the appropriate application of low-carbon technologies. Taking Europe as an example, the region has limited internal resources and a high dependency on imported energy. Faced with increasingly fierce international competition, its spatial development will inevitably expand into the field of clean energy and low-carbon technologies. However, the current global development of the construction industry is not conducive to energy saving, emission reduction, and ecological conservation. Instead, it exacerbates the contradiction between carbon dioxide emissions and environmental energy. Therefore, in the study of low-carbon buildings and the application of technologies, particularly the focus on energy saving and emission reduction, and harmonious coexistence with nature, are of great significance for energy efficiency in buildings and the sustainable development of cities. The formulation of Europe's low-carbon strategy and the development of low-carbon buildings are successful examples. In the process of their development, low-carbon building technologies play a crucial role in the utilization of new energy sources and environmental protection, serving as a technical guarantee for achieving energy-saving and emission reduction in the construction industry while balancing environmental resource capacity.

How to implement the application of low-carbon technologies in the sustainable development of buildings is of great importance for a country and a city. On the one hand, low-carbon building technologies can address conflicts with environmental protection in building planning, design, construction, use, and maintenance. On the other hand, low-carbon building technologies are resource-efficient in terms of energy, land, materials, water, etc., and they actively promote the utilization of renewable energy. Therefore, further analysis and research are needed for the application system of low-carbon building technologies. In conclusion, the development of low-carbon buildings has a strategic significance that transcends generations for countries and urban development.

The following are some of the ideas discussed in this article, presented as conclusions:

(1) Low-carbon buildings are a new concept.

Therefore, this article analyzes and studies them from the perspective of the concept of low-carbon buildings, presenting their characteristics. Low-carbon buildings focus on the efficient and resource-saving use of energy, materials, water, and other resources throughout their lifecycle, and they extensively incorporate new technologies such as renewable energy. Based on the analysis of classic cases of low-carbon buildings, new approaches for the application of low-carbon building technologies are proposed.

(2) Guiding optimized construction in urban buildings.

This mainly involves setting the goal of constructing buildings with low carbon emissions and utilizing appropriate low-carbon building technologies to minimize ecological damage and energy consumption, forming a complete system of building energy-saving and emission reduction technologies.

(3) Promoting the rapid development of low-carbon building technologies.

This primarily involves using low-carbon building technologies to achieve energy efficiency, material conservation, water conservation, carbon reduction, and fostering harmonious and orderly coexistence between buildings and the environment.

In conclusion, low-carbon building technologies are not only the focus of the construction industry but also a concern for human survival and development. Starting with the concept of low carbon, it changes the means by which humans utilize technology. It is a manifestation of human progress and serves as a medium for the harmonious development of humans, buildings, and the environment.

To envision the future of architectural development is, more precisely, to envision the future of human survival and development. Humanity should realize that the current high-energy consumption and high-pollution development could have serious consequences for future human development. The development and construction of low-carbon buildings provide broad space for the development of urban construction industry and also offer solutions to environmental pollution and energy consumption issues. How to handle the contradiction between economic development and environmental protection in construction is not only a concern for cities but also a concern for nations.

The ultimate goal of discussing the fate of low-carbon building technologies is to improve the quality of the living environment and achieve energy conservation and emission reduction. The development of low-carbon buildings is an ongoing process of innovation and the application of low-carbon technologies. With technological advancements and the continuous emergence of new low-carbon building technologies, there will be a more comprehensive system of low-carbon building technologies in the future. Establishing a global repository of low-carbon building technologies will facilitate the selection and application of appropriate low-carbon technologies in planning and constructing low-carbon buildings. This is a necessary approach to achieve building decarbonization. While relying on low-carbon technologies, buildings also need to consider factors such as economics, society, regional environment, and climate differences. Most importantly, the demands of residents should be considered, reflecting the concept of “people-oriented low-carbon building.”

With the continuous development of international low-carbon strategies, the improvement of energy-saving policies in the construction industry, and the progress of global carbon trading mechanisms, the low-carbon market is gradually forming and maturing. Low-carbon buildings will have significant development and the low-carbon building market will move towards a healthy interaction between supply and demand. Low-carbon buildings will become an important part of people’s daily lives, and the construction industry will no longer be a major consumer of energy and emitter of greenhouse gases. Instead, it will be an inevitable result that promotes global economic, social, and political development.

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Regionalization Strategy of Carbon Neutral Policy Based on Gridding

Xinjie YU

Dalian Maritime University, Dalian, China, 116026

Email: yuxinjie@dlmu.edu

***Corresponding author**

Abstract

Rasterization refers to the use of GIS technology to virtualize the actual geographic location and establish a certain model by setting certain parameters to reflect the distribution of certain types of data in a certain time and space range. The traditional spatial division method suffers from limited spatial and temporal accuracy, cumbersome data collation, and a mismatch of spatial units, which seriously restrict the practical application of social data in regional policy-making. Nowadays, the goal of achieving carbon neutrality is urgent, and policy formulation is even more important. On this basis, this study explores the use of the rasterization method to divide geographic areas within a specific administrative region to reflect the overall environmental conditions of different regions in a more detailed and accurate way, to formulate different carbon-neutral management policies according to local conditions, coordinate the development of regional environmental integration, and achieve the process of carbon neutrality faster.

Keywords: Carbon neutrality; policy recommendations; rasterization; regionalized management.

1. Regionalization strategy of carbon neutral policy based on gridding

The current era is a critical time for achieving carbon neutrality, and the key to this is the development of carbon neutral policies. How can we determine the carbon-neutral process and environmental conditions of different regions and classify them geographically? And how to formulate regional carbon neutral management policies to accelerate the process of carbon neutrality? This is the main question of this paper.

Climate change is a global problem facing mankind. The rapid increase in population, the rapid development of industry, the carbon dioxide produced by human activities, and the carbon dioxide produced by fuel combustion, far exceed the rate of conversion of carbon dioxide into organic matter, so that the heat radiated by the sun to the earth can not be dissipated to outer space, increasing the temperature of the earth's surface, resulting in the "greenhouse effect", while the poles This has led to an increase in the temperature of the Earth's surface, resulting in the "greenhouse effect," as well as melting glaciers and rising sea levels in the poles. In this context, it is important to propose the strategic goal of carbon peaking and carbon neutrality.

In the 1920s, the development of metrological geography promoted the study of regional data rasterization. Geographers investigated and explored the distribution of socio-economic data in a specific region based on qualitative methods, and tried to theoretically explore the spatial distribution law of the data in the specific space. Some studies assume that cities are ideal circular geographic spaces, and the population is distributed in a circular shape around the center of the circle, i.e., the city center, and then propose the decaying density law of urban population distribution (Clark). With the development and application of probability theory and mathematical statistics, many researchers have started to analyze and study the law of spatial distribution of socio-economic data in a deeper way. Some of these researchers proposed international population policies and strategic planning in response to the increasingly intense population problems (Helfer). As can be seen, the early research on regional data rasterized distribution mainly focused on demographic and economic data, collecting data, dividing the space of the special area into regional types based on qualitative or semi-quantitative methods, and summarizing the laws of distribution, theories for the analysis of development strategies, more lack of quantitative methods.

In the 1990s, GIS and RS were widely and deeply applied in various industries in national or global large-scale regions, and with them came the rapid development of regional rasterization research and the establishment of socio-economic data databases. Some scholars have applied the GIS surface interpolation method to regional socio-economic data rasterization (Goodchild); with the collection of spatial data in global and national dimensions, the establishment of its database, the study of quantification methods, and the formulation of regional policies and development plans, the development of regional data rasterization has received wide attention from the academic community. Some research scholars have analyzed the correlation between their city size and building and population distribution based on high-resolution remote sensing images (Ogrosk). However, most of the studies target individual cities. With the urgent need for economic globalization and social development, a research method should be established to increase the practical value and application of regional rasterized distribution studies. For the study area with complex topography, the rasterized distribution of regional socio-economic data cannot be analyzed only by a single factor, and the distribution model should be established by combining environmental-related data such as woodland and water. Some researchers have combined land use information to obtain the spatial distribution of rasterized population in Leicestershire, UK (Langford et al.)

Thus, the current study helps us to rasterize the region and tailor carbon neutral management policy development to the local context. Specifically, we collect relevant socio-economic data, divide the regions by building suitable models, and make policies for different categories of regions.

2. Method

2.1. Participants

This study takes Administrative Region A as an example, which is a geographically diverse space with different climatic environments, carbon emissions, carbon neutrality such as afforestation, and a regionalized distribution of carbon neutrality processes.

2.2. Design

The experiment was divided into three sessions, including two preparation sessions and one session to obtain conclusions. In the first two sessions, this paper first collected data from relevant administrative regions for data pre-processing; then virtualized the space, rasterized and classified the space by building a suitable mathematical model. In the final session, different carbon neutral policies are formulated for different types of rasterized areas.

2.3. Materials

The main indicators for evaluating carbon neutrality are carbon pollution intensity, carbon accumulation, carbon earth growth rate, carbon emission reduction, and carbon offset.

Carbon pollution intensity refers to the amount of carbon emitted per unit of incremental production, and is used to assess the degree of impact of carbon emissions on production activities, etc.

Carbon accumulation refers to the amount of carbon accumulated, which can indicate the degree of impact of carbon emissions on the environment in the regional space.

Carbon Earth Growth Rate is the study of the rate of increase of carbon pollution per unit of time and is used to accurately detect the degree of sharp changes in carbon pollution.

Carbon emission reduction is the reduction of the amount of carbon dioxide emissions from human activities and is intended to assess the extent to which people contribute to the mitigation of carbon pollution.

Carbon excursion is an indicator of the ability to transfer carbon molecules from one region to another and is likewise used to assess the magnitude of people's ability to contribute to the mitigation of carbon pollution.

The specific meanings of the indicators and their functions are shown in the table below:

Table 1: The Specific Meanings and Functions of Indicators

indicator	**meaning**	**function**
carbon pollution intensity	the amount of carbon emitted per unit of incremental production	assess the degree of impact of carbon emissions on production activities
carbon accumulation	the amount of carbon accumulated	indicate the degree of impact of carbon emissions on the environment in the regional space
carbon earth growth rate	the study of the rate of increase of carbon pollution per unit of time	accurately detect the degree of sharp changes in carbon pollution
carbon emission reduction	the reduction of the amount of carbon dioxide emissions from human activities	assess the extent to which people contribute to the mitigation of carbon pollution
carbon offset	an indicator of the ability to transfer carbon molecules from one region to another	assess the magnitude of people's ability to contribute to the mitigation of carbon pollution

The environmental data such as vector data and raster data used in this study can be processed by using ArcG IS for spatial data processing and SPSS, EViews, and other software for statistical data analysis.

2.4. Procedure

For this problem, we need to determine the spatial model of administrative region A first, then build several mathematical models based on the delineated spatial model to simulate the actual ecological environment, and finally solve the problem. Based on previous research on the feasibility of regional rasterization and combined with previous research in the field of rasterization, we rasterize the administrative region A before building the mathematical model.

The rasterization method is a map space modeling method that allows for the cell division of the actual physical environment. For calculation, the actual activity space of organisms in administrative region A is assumed to be rectangular, divided into rasters, and numbered. The specific numbering method is shown in equations (1) and (2):

$$M = \frac{x_{\max}}{R_s} \quad (1)$$

$$N = INT\left(\frac{x}{R_s}\right) + M \times INT\left(\frac{y}{R_s}\right) \quad (2)$$

Equation (1), X_{max} refers to the maximum length of the geospatial horizontal axis of administrative region A, which indicates the size of the raster into which the protected area is divided. In equation (2), it is the sequence number of the raster of administrative region A. This function is used to round the calculation result, and the mathematical meaning of the coordinates is any point on the geospatial space of administrative region A.

After that, assuming that the coordinates of the center point of the geospatial raster of A administrative region obtained by rasterization are (x,y) , we can get the relationship between these coordinates and the raster number, as shown in equation (3):

$$\begin{cases} x_R = (N\%M) \times R_s + R_s/2 \\ y_R = INT(N/M) \times R_s + R_s/2 \end{cases} \quad (3)$$

Subsequently, a multiple regression model was developed for the rasterized area based on carbon-neutral indicator data. The calculation equation can be referred to as equation (4).

$$I_i = \sum_{j=1}^{n} a_j \times P_{ij} + b$$
$$I_i^{'} = p \times nq + b \quad (4)$$

Where, Ii, Ii' are the data of different carbon neutral indicators in administrative region A. The constant terms' b and b' of the regression equation are set to zero.

The coefficients corrected by the modeling factors are rasterized separately using ArcG IS to obtain the raster division results within the A administrative area. The coefficient correction formula is as equation (5):

$$a_{ij} = \frac{I_i}{I_i^{'}} \times a_j \quad (5)$$

3. Results

After rasterizing the geospatial space of administrative region A, the raster consists of three types: carbon-neutral ecological corridor raster, carbon-neutral observation raster, and carbon-neutral high-quality raster. The meanings are as follows:

(1) Carbon neutral ecological corridor raster:

This raster-type area has more serious carbon emission exceedance and the environment is damaged, so residents and tourists are not allowed to enter this raster area for activities and industrial activities such as production to ensure that the environment is not affected by human interference factors, reduce the impact of negative factors and achieve carbon neutrality as early as possible.

(2) Carbon Neutral Observation Grid:

This type of grid has fewer carbon emissions and less damage to the environment, and within the grid, moderate production activities are allowed, but strict activity standards must be set; at the same time, relevant strategies are formulated to promote the carbon-neutral process.

(3) Carbon neutral high-quality raster:

This raster-type area does not exceed the carbon emission standard, the environment is not damaged, the scope and limit of human activities in this raster area are larger, and the main production activities can be carried out without affecting the environment, and they can offset their own carbon dioxide or greenhouse gas emissions by planting trees, energy saving and emission reduction, etc., to achieve positive and negative offset and actively drive the surrounding areas to achieve carbon neutrality.

Through theoretical exploration of academic predecessors, this paper finds that the ecological and human interests within the geographic space of administrative region A can be well served by developing adaptive carbon-neutral management policies in the geographic space of administrative region A.

The adaptive carbon neutral management policies and strategies in this paper aim to adapt to the needs by adjusting conservation methods and intensity. The management of geospatial spaces in the administrative region can be divided into three types: adaptive carbon neutral resource management, adaptive carbon neutral adjustment management, and adaptive carbon neutral impact management, with the following implementation policies.

(1) Carbon Neutral Ecological Corridor Grid:

Adaptive carbon-neutral resource management. It tends to protect the atmospheric environment and other natural resources in the rasterized area and reduce the impact of other negative factors, and its conservation objectives are biological conservation, ecological optimization, and carbon neutrality achievement.

The main measures are: first, to strictly limit and manage undesirable disturbances to the rasterized area of the ecological corridor and prohibit any activities other than scientific research needs and other activities; second, not to build production facilities that pollute the environment and destroy resources, and to develop relevant policies to restore the environment.

(2) Carbon Neutral Observation Grid:

Adaptive carbon neutral adjustment management. It tends to observe and study the regional characteristics based on the current carbon-neutral degree, adjust the coordination between human activities and the environment, establish and improve related measures, and promote the development of the environment and carbon-neutral activities in the geographic space of administrative region A in a good direction.

The main measures are: firstly, prohibiting destructive observations, investigations, and activities with economic benefits greater than the benefits of carbon neutrality, and at the same time, personnel from relevant departments are responsible for organizing regular regional environmental and atmospheric surveys to monitor and evaluate the extent of the process of achieving carbon neutrality.

(3) Carbon Neutral Quality Grid:

Adaptive Carbon Neutral Impact Management. Its preferred option is to carry out human activities such as major production activities without affecting the environment.

The main measures are: based on the protection of the environment and the process of achieving carbon neutrality, tourism and economic development can be developed in the area, and their own carbon dioxide or greenhouse gas emissions generated by themselves in the form of afforestation, energy saving, and emission reduction.

The following table2 shows the various policies:

Table 2: Policy of Different Rasterized Area Types

Rasterized Area Type	Management Policy Name
Carbon-neutral ecological corridor raster	Adaptive carbon neutral resource management
Carbon-neutral observation raster	Adaptive carbon neutral adjustment management
Carbon-neutral high-quality raster	Adaptive Carbon Neutral Impact Management

4. Discussion

However, due to the complex non-linear relationships of multiple types of factors such as climatic factors, environmental factors, and socio-economic factors in some regions, the rasterization method based on multiple linear regression used in this study cannot accurately judge the regional types and remains only a theoretical level study. Therefore, in the future development of carbon-neutral policies, it is necessary to combine specific data and conduct field visits and inspections to determine the specific regional rasterization types, which is the direction that this paper would like to explore in the future.

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The Role of Individual Lifestyle Change in Achieving Carbon Neutrality and Ways to Lead the Public to Participate in Carbon Neutrality

Minqi ZHANG

Taizhou University, Taizhou, Zhejiang, China, 318000

Email: zhang_minqi_icnt@iie.world

***Corresponding author**

Abstract

Based on the concept and connotation of carbon footprint, this study studies the role of individual lifestyle in achieving carbon neutrality, proposes feasible plans to change individual lifestyle and methods to guide the public to participate in carbon neutrality, so as to provide scientific reference for reasonable decomposition of emission reduction responsibility.

The epidemic and floods brought about by extreme climate change have seriously threatened human life and security. Reducing carbon emissions has become a pressing task for the construction of ecological civilization. Based on the fact that mankind is a community with a shared future, everyone should shoulder the responsibility of reducing emissions. At the same time, although various countries have introduced some relevant policies, but "it is difficult to change people's way of thinking", "residents lack of low-carbon awareness" and other problems still exist. Leading the public to participate in carbon neutrality is the only way to achieve carbon neutrality.

Keywords: Carbon emission; emission reduction; low-carbon life; public participation; individual carbon emission credit system.

1. The role of individual lifestyle change in achieving carbon neutrality and ways to lead the public to participate in carbon neutrality

In 2022, the UK Met Office issued its first-ever red alert for extreme heat. Japan and other countries reported tens of thousands of heatstroke cases, Spain and Portugal reported thousands of deaths from heat stroke, and India and Pakistan were already hit by temperatures ranging from 45°C to 50°C as early as April. The world was under extreme weather. The continuous occurrence of extreme weather is caused by global warming, which is mainly caused by human activities.

According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, the world has embarked on a dangerous path. The effects of climate change are felt all over the globe. Without significant emissions cuts, global temperatures will rise by 4 degrees Celsius above pre-industrial levels, threatening all parts of the world with rising sea levels, water shortages, ecosystem degradation and other climate impacts. There is no time to delay action.

Carbon neutrality is the solution to the global warming problem. It achieves emission reduction in various ways to offset the total amount of carbon dioxide or greenhouse gas emissions directly or indirectly produced by countries, enterprises, products, activities or individuals within a certain period of time, achieving positive and negative offset and achieving relative “zero emissions”.

The future of mankind is developing together. Everyone must assume the responsibility of reducing emissions. It has gradually become the consensus of all sectors of society to realize a low-carbon life in an all-round way. However, it is not mandatory or necessary for individuals to practice carbon neutrality, and the implementation of policies and activities related to “carbon neutrality” mostly depends on people’s personal will. Therefore, it is key to change people’s way of thinking and enhance the awareness of “low carbon”. At the same time, individual emission reduction lifestyle should be advocated to let more people participate in the efforts to achieve carbon neutrality.

Practice low-carbon concept, advocate low-carbon life, and establish personal carbon emission credit system are the direction of this paper. Firstly, carbon footprint mainly refers to the total emissions of greenhouse gases emitted by human production and consumption activities in terms of carbon dioxide emissions. Low-carbon life means to try to reduce the energy consumed during daily work and rest, so as to reduce personal carbon footprint, especially CO_2 emissions, so as to reduce air pollution. This is done mainly achieved by changing the details of life. In the process of practicing the concept of low-carbon life, individual awareness of emission reduction and correct ways to guide public participation are crucial. This requires feasible low-carbon life practices to provide reference, and the establishment of a personal carbon emission credit system to guide public participation.

This paper will analyze the role of individual lifestyle in achieving carbon neutrality, propose feasible plans to change individual lifestyle and guide the public to participate in carbon neutrality.

2. Method

2.1. Personal lifestyle -- practicing the concept of low-carbon life.

Low-carbon lifestyle should include the following aspects:

(1) Low emission consumption, that is, people in the process of life to minimize the amount of greenhouse gas emissions. Such as reducing low-cost consumption, recycling goods, green travel and so on.

(2) Economic consumption, that is, people pay attention to saving the use of resources and energy in the process of life, so that their consumption reaches the minimum and most economical. For example, avoid consumerism and practice rational consumption.

(3) Safe consumption means that the consumption results in the course of people’s life have the least impact on the living environment of the society and the least harm to the health of others. Such as supporting carbon neutral products.

(4) Sustainable consumption, that is, the consumption process of people’s life can maintain the long-term and stable development of resources, production and life.

Low-carbon lifestyle consumption model guides consumers’ consumption behavior, and provides solutions to the problem of using consumption materials around to meet the needs of their own survival, development and enjoyment. Low-carbon life is based on civilized, scientific and healthy ecological consumption mode, so that people can balance material consumption, spiritual consumption and ecological consumption, and guide human consumption behavior and consumption structure to further rationalize, scientific and rationalized.

2.2. Guide the public to participate in carbon neutrality -- make use of big data to

provide new ideas for public participation.

Establish a personal carbon emission credit system, a voluntary personal carbon budget system. Establish a personal carbon emission reduction APP by means of technology enabling such as big data, blockchain and artificial intelligence. Calculate individual daily carbon emission reduction by calculating personal activities, such as household electricity consumption, gas use, TV, mobile phone, bus, subway, airplane, green shopping or green living, and quantize abstract behaviors into considerable carbon emission data for people to query and record the low-carbon contribution in life, to provide people with the intuitive feeling of practicing the concept of low-carbon life.

Assign a value to individual carbon reduction. Specifically, low-carbon travel, energy conservation and emission reduction are calculated, registered and certified. To achieve specific quantification of individual behavior of energy saving and carbon reduction and assign certain value, further introduce welfare system and policies after achieving certain indicators, effectively guide the public to participate in the practice of low-carbon life and achieve emission reduction. By entrusting individuals with the value of carbon emission reduction and linking the credit of carbon emission reduction with everyone's consumption behavior and eating habits, the public can participate in the realization of carbon neutrality.

Support the inclusion of individual carbon account emission reduction into the national carbon trading market, and establish and develop a positive guidance mechanism that combines commercial incentives, policy encouragement and certified emission reduction trading. Mobilize the enthusiasm of the public, realize the mobilization of the whole people, give play to the role of the individual sector in carbon neutrality.

3. Result

3.1. Practice low-carbon life and make contribution to emission reduction.

Advocating low-carbon life can not only improve public awareness of environmental protection, but also change People's Daily lifestyle and consumption pattern. Raise public awareness of the global challenges posed by climate change and propose simple and easy environmental actions in daily life, such as green consumption and energy conservation; Put forward green living suggestions, such as garbage sorting, household greening, tree planting and other activities to strengthen environmental protection; Provide environmental protection ideas, actively participate in green activities, exchange low-carbon consumption experience, popularize the concept of environmental protection, and save energy in daily life, implement low-carbon life, and take joint actions to slow down the trend of global warming. Low-carbon life should be advocated in response to global climate change. Only when more people change their current high-carbon lifestyle and consciously follow the pace of development of low-carbon economy can the world have the basis for climate security and hope for the future. Therefore, we should vigorously advocate and cultivate the awareness of environmental morality of the whole nation, transform people's low-carbon life into conscious actions, give full play to the role of every citizen in practicing low-carbon civilized life, guide low-carbon production and consumption patterns in effective ways, form a social atmosphere to practice low-carbon, form the consciousness of the whole people, and guide the actions of the whole people with norms. In this way can we make our due contribution to the fight against global climate change.

3.2. Use big data to establish a personal carbon emission credit system and guide public participation.

The quantification and reduction of carbon footprint is the basis for the development of personal carbon purchase business. The development of personal carbon credit market, while incorporating carbon information, helps to standardize the standards of personal carbon footprint calculation and promote the development of personal carbon neutrality and carbon purchase business with the help of market-oriented means.

It is also conducive to the development of carbon finance business. Carbon finance refers to all financial activities that serve to limit greenhouse gas emissions, including direct investment and financing, carbon index trading and bank loans. A large amount of traceable and quantifiable personal carbon information in the personal carbon credit market, such as personal carbon footprint, carbon neutralization and carbon purchase, and personal carbon assets, can provide a series of data and information for commercial banks to innovate personal carbon finance business.

4. Discussion

Global carbon emissions comparisons for year show that household carbon emissions in 2022 reached 3.56GT CO_2, accounting for 9.85% of the total carbon emissions. Industrial and surface transport will account for nearly half of all carbon emissions in 2022, accounting for 46.8 percent. "Consumption determines production." Low-carbon lifestyle will mainly affect industrial production and transportation, which account for a large proportion of carbon emissions and are easily affected by the public. "Low-carbon life" not only includes the details of many energy-saving technology improvements in manufacturing and construction, but also includes many energy-saving details in People's Daily living habits. Thus, individual lifestyle changes have great potential in achieving carbon neutrality. The lifestyle of mass production, mass consumption and mass abandonment seriously restricts the implementation of the strategy of sustainable development and pollutes the ecological environment. It is the consumption led by this wrong idea that has caused the shortage of energy and resources in the world. The advocacy of low-carbon life can not be ignored in the realization of carbon neutrality, which is one of the important links.

Many countries have introduced active market instruments to promote emission reduction in the context of the global response to climate change. The European Emissions Trading System officially launched the world's first greenhouse gas emission quota trading market in 2005: the United States, Australia and other countries have also established carbon emission trading schemes to trade carbon in a voluntary way. At the individual level, the UK Department for Environment, Food and Rural Affairs has used a carbon emission calculator to estimate the carbon emissions produced by people's living consumption. It is found that 40% of the UK's annual carbon emissions directly come from the activities of individuals and households. The Chinese Academy of Sciences pointed out in "Some Policies and Recommendations on China's Carbon Emissions" that between 1999 and 2002, Households account for 30% of China's carbon emissions. It can be seen that there is a lot of room to reduce the carbon emissions of residential life. An effective market approach might be to set up an individual carbon trading system.

Climate change is a global problem facing mankind. Carbon dioxide emissions and greenhouse gases of all countries have soared, posing a threat to living systems. In this context, all countries in the world have put forward the goal of achieving carbon neutrality by reducing greenhouse gases by means of global agreement. As citizens of the planet, everyone should participate in the goal of becoming carbon neutral. Changing personal lifestyle, advocating low-carbon life, actively guiding public participation, and establishing personal carbon emission credit system are of great positive significance for realizing carbon neutrality, and we should actively participate in them.

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The Circular Economy in the Fashion Industry

Jiayi ZI

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

Email: zi_jiayi_icnt@iexchange.world

***Corresponding author**

Abstract

In the context of "carbon neutrality" becoming a hot topic, more and more countries are promising to complete the time for carbon neutrality. In contemporary times, the fashion industry is one of the most important reasons for climate change. This paper will introduce the application of circular economy, challenges and future development suggestions from the theme of establishing circular economy in fashion industry. For example, the establishment of a secondary market, strengthen culture and education. The author will use the data search and collation method to complete this article.

Keywords: Circular economy; sustainable strategy; carbon neutral; fashion industry.

1. Introduction

The fashion industry, as a huge business empire, has always been driving the development of social trends. However, as "carbon neutrality" has become a hot topic, the negative impact of the fashion industry is also emerged. Take the garment industry for example, during its entire life cycle, textiles produce 5-10 percent of the world's emissions of greenhouse gases, consume the world's second largest amount of water, and release polluting microplastics and chemical agents to waterways.(Zhang, L. 2023) Therefore, people's awareness of environmental protection has gradually improved, and has begun to put forward higher requirements for the sustainability of the fashion industry. As a new economic development mode with the efficient utilization of resources as the core, circular economy is being gradually applied in the fashion industry. This article will take the form of a review which mainly introduces the application, challenges and future countermeasures of circular economy in the fashion industry in the current era.

2. Methods

Find useful content from the available information. Look for keywords about "fashion" and "circular economy" in the Nature and Science journals. Search the amounts of information for articles. Through comparative analysis of the same research content as other cases, we find its limitations and make some suggestions and methods. Combined with their own understanding and analysis, we will perfect it into a review paper.

3. Results

The application of circular economy in the fashion industry is mainly reflected in the following aspects:

The first point is to reduce waste. In the traditional linear economic model, fashion products are often regarded as fast moving consumer goods and are discarded after a period of time, resulting in a large waste of resources. Fast fashion culture brings huge costs, which speeds up the generation of clothing garbage. Chile's vast Atacama desert has become a "fast fashion garbage dump", with a huge stock of waste clothes piled (ZongJuan Wallpaper, 2022). In the circular economy model, factories can make fashion products after wearing them for a period of time, repair, clean or reengineering, and they can enter the market again, thus reducing waste. The establishment of the second-hand market is a good solution. With the support of the concept of "carbon neutrality", the Internet combined with the second-hand trading mode and circular economy is becoming an industry strongly supported by the policy. At the same time, with the economic downturn cycle, the change of consumers' shopping concept and other factors, second-hand goods represent the consumption concept of environmental protection, and buying vintage and vintage products has become a fashion trend, which is becoming popular around the world. At the same time, the major head e-commerce is also increasing the attention and investment to the second-hand market.(IT Orange) "Under the Background of Global Circular Economy, 2023 Development Report on the Investment and Financing of Second-hand Transactions"

The second is to improve sustainability: Previously, large amounts of textiles ended up in landfills. In the circular economy model, designers need to consider the sustainable aspects of their products, including the life cycle, repairability, and recyclability. This will encourage designers to choose more environmentally friendly and durable materials and manufacturing methods in the design and manufacturing process, thus improving the sustainability of fashion products. For example, the technology to recycle cellulose in fabrics can make clothing more sustainable (Nature 611,2022), or take a life-cycle approach to examine technological advances to improve sustainability at each stage and suggest future directions (Zhang, L. 2023).

Creating business opportunities: As consumers' attention to environmental and sustainability issues continues to increase, their demand for circular fashion products is also increasing. This will prompt more brands and businesses to start producing and selling circular fashion products, creating new business opportunities for the fashion industry.In 2019, the scale of the global secondhand goods e-commerce transaction market reached $822.8 billion; in 2020, the global secondhand goods e-commerce transaction market scale increased to $895.6 billion (Wu,M. 2023). This shows that creating sustainable business opportunities with circular economy characteristics will continue to promote the green transformation of the economy and subtly change more people's consumption concepts.

Challenges Faced by Circular Economy in the Development of Fashion Industry:

Although circular economy has broad application prospects in the fashion industry, it still faces some challenges: The first is the quality and safety issues. Recycling fashion products often undergo multiple processes of repair, cleaning or remanufacturing, and their quality and safety issues may be more prominent compared to new products. How to ensure the quality and safety of recycled fashion products is an important problem that needs to be solved. Secondly, the establishment of an effective recycling system is the key to the successful application of circular economy in the fashion industry. At present, the recycling systems in many fashion industries are still insufficient, and further improvement of relevant facilities and policies is needed. Finally, more consumer concept shifts are needed. To promote circular fashion products, it is necessary to change the consumption concept of consumers. Consumers need to gradually accept the concept and advantages of circular fashion products, and understand their impact on the environment and the role of resource conservation.

4. Discussion

According to the above mentioned, it is a general trend to establish a circular economy in the fashion industry, but there are still limitations. All the conditions are established in an ideal state, with sufficient funds and the people's cooperation. But now some developing countries do not have the above conditions, and the productivity of some developing countries is not even enough to support their national economy. Moreover, some developing countries are suffering from the "fashion garbage" from developing countries, and fashion has become a meaningless term in some areas. Therefore, this article is limited to the circular economy that some countries with "fashion junk needs to create". For these countries, they can strengthen their policy support. For example, tax incentives and financial support measures can be provided to encourage enterprises to produce and sell circular fashion products. Or to establish industry standards. The industry association may formulate industry standards for the circular fashion industry and standardize the production, recycling, reuse and reuse processes of related products. At the same time, strengthen the industry self-discipline and supervision, to ensure product quality and safety. Then the publicity and education should be strengthened. The circular economy will be widely promoted through various channels to improve consumers' awareness of environmental protection and sustainable development issues. At the same time, the publicity and promotion of circular fashion products should be strengthened to improve consumers' awareness and acceptance of these products.

5. Conclusion

Circular economy, as a new economic development model with resource efficient utilization as its core, provides an opportunity to address the environmental challenges facing the fashion industry while meeting consumer demand for sustainable products. By implementing strategies such as reducing waste, improving product sustainability, creating business opportunities through increased demand for circular products, strengthening policy support, establishing industry standards, enhancing publicity and education efforts, and enterprises are encouraged to strengthen technological innovation. The fashion industry can promote the development of circular economy and achieve resource conservation and environmental protection.

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The Impact of Emerging Technologies Mainly on the IoT on Carbon Neutrality

Zhuoyu ZONG

Hainan University, Haikou, Hainan, China, 570228

Email: zong_zhuoyu_icnt@iexchange.world

***Corresponding author**

Abstract

Climate change is the most important issue facing humanity. In recent years, one extreme weather event after another and global warming triggered by greenhouse gas emissions from fossil energy consumption have put the world on the cusp of another energy revolution. The development and utilization of renewable and clean energy constitute the third energy revolution. In this context, it is urgent to propose "carbon neutrality". Carbon neutrality is an significant strategy and goal, through the form of afforestation, energy conservation and emission reduction, offset its own carbon dioxide emissions, to achieve carbon dioxide "zero emissions" can help mitigate the adverse effects of climate change, protect the health and diversity of the ecosystem. At the same time, carbon neutrality is also a global goal, and through collective action, countries can collectively mitigate the adverse effects of climate change on global society and economy. The Internet of Things can play an important role in achieving carbon neutrality, and IoT systems are like a "digital skin" for our planet. Using sensors to effectively monitor, analyze and manage CO_2 emissions, cloud applications to share data and improve energy efficiency, and AI modeling to predict carbon footprints are all effective ways to achieve carbon neutrality. By educating researchers about carbon-neutral policies and integrating IoT technologies, we can more effectively reduce carbon emissions and drive environmental sustainability.

Keywords: Carbon neutrality; Internet of Things; GHG emissions; climate change.

1. Introduction

Scientists have shown over decades of research that human activity is causing climate change. After the Industrial Revolution, human economic activities emitted huge quantities of greenhouse gases into the Earth's atmosphere. Rising concentrations of greenhouse gases in the atmosphere are already having a major impact on the Earth's climate system. Carbon neutrality is urgently needed. Carbon neutrality refers to offsetting the generated carbon dioxide (CO_2) through carbon capture, storage, and conversion within a certain period, to achieve "zero emission" of greenhouse gases. The Paris Agreement aims to limit global warming to 1.5 °C above the pre-industrial levels. To achieve IPCC's objective, carbon neutral target must be realized globally by the middle of the 21st century [1]. However, "Emissions Gap Report 2019" released by the United Nations Environment Programmer (UNEP) presents that there still exists a big gap between countries' targets to reduce carbon emissions and 1.5 °C goal [2][3].

In the face of the challenges of environmental governance and achieving carbon neutrality, this paper aims to explore the different forms of applications of IoT technology and how these can work together to form a comprehensive carbon neutral solution. In the process of carbon neutrality, how to make full use of IoT technologies to achieve accurate monitoring and management of carbon emissions has become a key issue.

Today, with the Internet of Everything, everything is tightly connected through the threads of the Internet of Things. The introduction of IoT technologies can not only improve the efficiency of carbon neutrality, but also reduce the cost of implementing carbon neutrality strategies. With real-time monitoring and intelligent decision-making, companies and governments can better formulate carbon management strategies, reduce unnecessary carbon emissions, and promote sustainable development.

This article will explain in the next chapter the criteria on which the convergence of IoT and carbon neutrality is based. Next, we delve into different forms of IoT applications. These are three short chapters on sensor applications, cloud applications, and AI modeling. We will explain the comparison between the research results of this article and existing literature, delve into the connotation of the recommended methods in these literatures, summarize the main findings of the research, propose the future development direction of the Internet of Things in the field of carbon neutrality, and reflect on the shortcomings of current technology. Provide scientific and practical solutions to achieve climate neutrality goal.

2. Methods

The Internet of Things (IoT, Internet of Things) is also called "sensor network", which is the general name of "sensor network" in the world; It refers to objects by loading various information sensing devices. The advent of the IoT concept has broken the previous conventional thinking. Considering the previous elements. A definition for a connected object could be: "Sensor(s) and/or actuator(s) carrying out a specific function and that are able to communicate with other equipment. It is part of an infrastructure allowing the transport, storage, processing, and access to the generated data by users or other systems." A definition for a connected object could be: "Sensor(s) and/or actuator(s) carrying out a specific function and that are able to communicate with other equipment. It is part of an infrastructure allowing the transport, storage, processing, and access to the generated data by users or other systems." Then, a definition for the IoT would be: "Group of infrastructures interconnecting connected objects and allowing their management, data mining and the access to the data they generate. [4]" IoT technology has played a huge role in tackling carbon neutrality.

This paper refers to papers from Z-library, IEEE, ScienceDirect, and other databases on the application of the Internet of Things to carbon neutrality. Greenhouse gas emissions and climate change affect carbon neutrality standards. Each module of the article considers relevance and science, and references articles published in the recent past. By comparing the existing techniques by referring to several literature, we can discover the shortcomings of the existing techniques and have more novel ideas.

The Internet of Things technology still has shortcomings in the management of carbon neutrality, and the management of carbon neutrality requires us to have a more detailed grasp of the current situation of the earth, and most of the applications of the Internet of Things are implemented in some areas, and there is no large-scale coverage. For example, remote areas, rural areas, and uninhabited areas are mostly not monitored because IoT application technology is not mature enough and the energy consumption and cost of trying to cover these areas is too high. This is just for land areas, and for the wider ocean it is difficult to keep abreast of ocean conditions with current technology. There is still more room for IoT technology to grow, and here are a few directions in which it could govern carbon neutrality.

2.1. Sensor monitoring, analysis, and management of environmental data

When it comes to the Internet of Things, many people's first thought is sensors. Sensors are a technology that people working in the IoT industry cannot do without. In agriculture-related majors at my school, many teachers and students use sensors to monitor the temperature and humidity of the environment in which fruits and vegetables are grown, and to understand the growing conditions of fruits and vegetables. The status data of the growing environment of fruits and vegetables can be seen briefly through the IoT network. Monitoring environmental data with sensors is a very good option. The sensor transmits the collected data to the data processing part or the monitoring center via wired or wireless communication. By setting thresholds or criteria for sensors, early warnings and prompts for abnormal or excessive data can alert the relevant personnel to take timely measures.

The combination of modern environmental monitoring and the Internet of Things and other technologies. Therefore, modern methods of environment monitoring are known as SEM systems, due to use of IoT, AI and wireless sensors [5]. The WSNs provide the connectivity of the data, captured by employing sensors and IoT devices, used to record, monitor, and control various environmental conditions, such as water quality, temperature, air quality, etc. A smart environment system can be easily understood [6]. For carbon-neutral governance, accurate environmental data obtained by sensors is an important reference for responding to environmental changes.

2.2. Cloud applications improve energy efficiency and reduce carbon emissions.

Cloud computing and Internet of Things (IoT) are two very different technologies that are both already part of our life. Their adoption and use are expected to be more and more pervasive, making them important components of the Future Internet. A novel paradigm where Cloud and IoT are merged together is foreseen as disruptive and as an enabler of a large number of application scenarios [7].

Green cloud computing is also one of the emerging technologies. The benefits of green cloud computing are focused mainly on energy saving and carbon-footprint reduction. However, the development of green cloud computing is closely related to the evolution of green data centers, because the data centers are the core of the cloud computing. According to Koomey [8], the energy consumed by data centers in 2010 represented 1.3% of the total consumption. Now, cloud computing environments and MapReduce [9] have evolved separately to address the need to process large data sets. Cloud computing environments leverage virtualization to increase utilization and decrease power consumption through virtual machine (VM) consolidation. The benefits of cloud computing adoption for small and medium enterprises in terms of reducing energy consumption and carbon emissions were analyzed by Williams. [10]. The results indicated that the carbon footprint of the ICT sector could be reduced by 1.7% if 80% of enterprises use cloud computing [11][12].

Cloud computing is a neoteric model that integrates existing technologies to improve resource usage efficiency. Results using these technologies vary, but cloud computing currently faces issues such as immature software design and virtual machine technology. This is also a major challenge in combining cloud applications with carbon neutrality.

AI measurement and carbon reduction

AI-based solutions have clear advantages over traditional manual measurement methods. It can more quickly, reliably, and accurately determine the full carbon footprint of any given organization, and its powerful forecasting and data analysis capabilities can help decision-makers make more correct decisions. Google, for example, has partnered with the ElectricityMap platform to use AI systems to display clean power production around the world in real time and aggregate carbon footprint data across countries. On top of that, Google has managed to significantly reduce carbon emissions by matching its energy consumption plans to the availability of low-carbon electricity from the grid.

Regarding the specific paths and action strategies for enterprises to use AI to reduce carbon emissions, the answer given in the book , 《Reduce Carbon and Costs with the answer is given in the Power of AI》 ,wrote by Charlotte Degot and her team that is “Companies can use AI-powered data engineering to automatically track emissions throughout their carbon footprint. Predictive AI can forecast future emissions across a company’s carbon footprint, in relation to current reduction efforts, new carbon reduction methodologies, and future demand. As a result, the company can set, adjust, and achieve reduction targets more accurately. By providing detailed insight into every aspect of the value chain, prescriptive AI and optimization can improve efficiency in production, transportation, and elsewhere, thereby reducing carbon emissions and cutting costs” [13].

Specific paths and action strategies for companies to use AI to reduce carbon emissions can be expanded and applied in the process of governing carbon neutrality. Leveraging AI to address climate change challenges will not only help human society successfully transition from high-carbon to low-carbon and net-zero carbon, but also drive companies to find ways to succeed in a low-carbon world and achieve a win-win situation for economic development and social benefits, he added.

3. Results

We are now facing a more serious environmental crisis. The impact of environmental damage can grow exponentially, eventually causing unacceptable disasters. In the face of such dilemmas, long-term, effective strategies are particularly important. Changing the current state of the environment through technology is certainly an excellent solution.

Sensor detection of environmental data, cloud applications and AI prediction are among the technological changes aimed at improving the efficiency of work and resource allocation. They are helpers in managing carbon neutrality, but after that, formal action is more important. The fact that technology can ease our lives does not mean we can sit back and relax. Instead, we should be more concerned about the irreversible damage to the environment that over-development may cause, or the consequences of exacerbating climate change.

Different regions have different levels of development. Developing carbon neutrality is not the highest priority option for underdeveloped and developing countries compared to developing industry and manufacturing. These countries do not have the level of education and science and technology to support them in achieving this goal. Carbon neutrality goal. Promoting the process of carbon neutrality requires the collaboration of all countries in the world. The application of IoT technologies is not only the interconnection of things, but also the interconnection of countries. Novel technologies and environmental protection concepts should be embraced by more countries.

Science and technology are advancing at a rapid pace. New history may be made every day, and human civilization will advance further.AI and cloud applications, once the stuff of science fiction movies, are gradually becoming reality. The Internet of Things (IoT) is envisioned to grow rapidly due the proliferation of communication technology, the availability of the devices, and computational systems [14]. Green and low carbon are major trends in the future development of various industries. Industrial transformation is a priority. The existing industrial system will undergo tremendous changes, and this change is an opportunity to lead to green environmental protection.

4. Discussion

The theme of the 21st century is peace and development. This is an age where people and things are connected. Compared to carbon neutral global emission reduction research, technological innovation and global emission reduction research have grown faster, indicating that technological innovation is increasingly valued. Therefore, there will be more research on technological innovation in the future, including energy technology, emission reduction technology, optimization technology and measurement technology. Moreover, individual technologies are currently far from sufficient to achieve carbon neutrality goals. From a technical point of view, future research will be diverse and interdisciplinary [15].

Comparing this paper with the existing literature, the difference is that this paper considers the impact of more non-technical factors on the governance of carbon neutrality based on IoT combined with carbon neutrality. What is lacking is more professional technical research and innovation. suggestion. At the same time, the approach of promoting carbon neutrality through IoT mentioned in this paper has been intensively studied in the existing literature. At the same time, the concept of this paper is closer to the existing literature.

In my opinion, there are several directions of development for the three technologies mentioned in this paper: sensors, cloud applications and artificial intelligence. For sensors, it is a good choice to use new materials, structures, and processes to improve the sensitivity, stability, and lifetime of the sensor, as well as to reduce the cost and difficulty of maintaining the sensor. For cloud applications, updating software design and virtual machine technology is very important. For AI technology, it is significant to have AI learn more about carbon neutrality and formulate strategies and plans. These technological advancements are a huge challenge and opportunity for IoT technology and carbon neutrality. Seizing opportunities for technological advancement can clear roadblocks for the future.

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The Path to Carbon Neutrality in the Glass Industry

Bingxi CHEN

Hainan University, Haikou, Hainan, China, 570228

Email: chen_bingxi_icnt@iexchange.world

***Corresponding author**

Abstract

This article mainly studies how to achieve carbon neutrality in the field of glass. Currently, global climate change has become a common challenge faced by countries around the world, and the construction industry is one of the main sources of global greenhouse gas emissions. As one of the widely used materials in the construction industry, the greenhouse gas emissions such as carbon dioxide generated during its production and use cannot be ignored. Therefore, how to achieve carbon neutrality in the glass industry has become an important research direction.

This article adopts a lifecycle assessment based approach to comprehensively analyze the production, transportation, use, and disposal of glass, and proposes corresponding emission reduction measures. Specifically, we will focus on the following aspects: firstly, optimizing production processes to reduce energy consumption and waste generation; Secondly, promote the concept of green buildings and improve building energy efficiency; The third is to strengthen the recycling and utilization of waste and reduce environmental pollution. Through the comprehensive application of these measures, carbon emissions during glass production and use can be effectively reduced, achieving the goal of carbon neutrality.

The focus of this study is to explore effective ways to achieve carbon neutrality in the glass industry and provide feasible emission reduction solutions for relevant enterprises. I hope this study can provide useful reference and inspiration for carbon reduction in the glass industry.

Keywords: Carbon neutrality; glass; architecture; industry.

1. Introduction

The global energy, environment, and climate change issues are becoming increasingly prominent, and countries have already or are facing serious environmental crises. Alleviating the sharp contradiction between economic growth and ecological protection has become an urgent practical problem that countries need to solve.

The carbon emissions in the glass industry mainly come from three aspects: fossil fuel combustion emissions, production process emissions, and emissions generated by purchasing and exporting electricity and heat. Among them, fossil fuel combustion emissions account for more than 60% of carbon emissions in glass production, carbon dioxide formed by raw material decomposition or carbon oxidation accounts for 25% -27%, and electricity emissions account for about 13%.

In 2020, China's flat glass carbon dioxide emissions were about 34 million tons, accounting for 0.33% of the country's carbon emissions. Although it is relatively low compared to high carbon emitting enterprises such as steel and cement, the glass industry still has overcapacity and strong demand for "energy conservation and emission reduction"

In order to accelerate the pace of carbon neutrality in the glass industry, conducting carbon emission analysis from the entire process of the glass industry chain and taking corresponding measures is an effective path to reduce carbon emissions in the glass industry.

2. Method

2.1. Explain search strategy

(1) Keyword selection: We have selected a series of keywords related to glass, carbon neutrality, and the construction field, such as "carbon neutrality glass", "sustainable glass production", etc.
(2) Literature database: We have used multiple academic databases, including Web of Science, Scopus, and Google Scholar.
(3) Retrieval strategy: We have used appropriate retrieval strategies for each database, combined with keyword searches. We have limited the time frame of the literature and usually choose literature from the past decade to ensure the freshness of the information.
(4) Literature screening: We conduct a preliminary screening of the search results based on the title and abstract to determine whether they are suitable for the topic of our research field.

2.2. Outline of source selection criteria

(1) Academic authority: We prioritize literature published in academic journals, conference proceedings, and reports published by industry authoritative organizations.
(2) Credibility and reliability: We only select literature that has undergone peer review to ensure its quality and accuracy.
(3) Accessibility: We prioritize literature that can be obtained for free or subscribed to through our institution to ensure that we can obtain complete literature content.

2.3. Describe literature analysis process

(1) Literature reading: We carefully read the selected literature and fully understand the information contained in it regarding glass in the field of carbon neutrality.
(2) Data extraction: We extracted data, viewpoints, and research methods related to our research topic from each literature.
(3) Comprehensive analysis: We conducted a comprehensive analysis of the extracted data, comparing the view points and results of different literature to obtain a comprehensive understanding.

2.4. Discuss development of recommendations

Based on literature analysis and comprehensive evaluation, we have put forward suggestions on the relevant issues of glass in the field of carbon neutrality. We will combine the viewpoints in the literature with our own analysis to provide feasible solutions and improvement measures.

3. Result

This article adopts a lifecycle assessment based approach to comprehensively analyze the production, transportation, use, and disposal of glass, and proposes corresponding emission reduction measures. Specifically, we will focus on the following aspects:

3.1. Firstly, optimizing production processes to reduce energy consumption and waste generation;

Starting from the production of raw materials,In the reaction process of glass, various carbonates, sulfates, and nitrates decompose at their respective decomposition temperatures, releasing gases and participating in solid-phase reactions. The thermal decomposition of carbonates and the oxidation of carbon powder are the main sources of CO_2, accounting for about 20% of the entire process emissions. Therefore, optimizing the raw material structure can effectively reduce CO_2 emissions in the glass production process. If nepheline silicate raw materials (intermediate products of Na [$AlSiO_4$] 4-K [$AlSiO_4$] 4 series) are used instead of carbonates, it can reduce the CO_2 emissions generated by thermal decomposition, reduce the erosion of refractory materials in kilns, and avoid the emission of toxic gases such as NO. In addition, the amount of broken glass can be increased as a carbon free raw material in the raw material. Generally speaking, for every 10% increase in broken glass usage, it will correspondingly reduce energy consumption by 2.5% to 3%.

Next is to optimize the fuel structure,Compared to raw materials, fuel has a greater impact on the quality of glass. Currently, the main fuels include heavy oil, petroleum coke, coal to gas, natural gas, coal tar, etc. Developing clean energy, reducing fossil fuel supply, and replacing high carbon fuels with clean fuels are effective ways to improve energy utilization efficiency and reduce carbon emissions before decarbonization of energy.

Finally, optimize the structural design of the glass furnace,Glass kilns are the equipment with the highest energy consumption in glass production lines. The melting of raw materials consumes more than half of the energy used in glass production. The energy used in the glass industry in Europe and the United States is mainly natural gas, which usually accounts for 75% to 85%, followed by electricity, which accounts for 10% to 15%, and the remaining 5% to 10% is composed of fossil fuels. In fact, from 1960 to 2010, energy efficiency increased by more than 50%, and since 2010, progress in energy efficiency has significantly slowed down due to perhaps the kiln structure design and insulation measures are unreasonable, and the quality grade of the refractory materials used is low. Therefore, optimizing the structure of glass kilns is one of the important measures to reduce furnace heat loss, reduce fuel consumption, and improve furnace thermal efficiency.

3.2. Secondly, promote the concept of green buildings and improve building energy efficiency.

Low E glass is coated on the surface of the glass, and the emissivity E of the glass can be reduced from 0.84 to below 0.15. Low-E glass can directly reflect far-infrared thermal radiation, with high infrared reflectivity, low surface emissivity, and low ability to absorb external energy. It can maintain relative stability of heat on both sides of the glass, and can also control the amount of solar radiation transmission as needed to adapt to different needs. Low-E glass can still allow solar radiation from the outdoor environment to enter the building, and this energy is absorbed by indoor objects and then converted into far-infrared thermal radiation, which is left indoors. In summer, the opposite is true. The insulation layer of Low-E glass not only helps to reduce heat loss, but also helps to maintain stable indoor temperature, thereby improving the thermal comfort of residents, reducing the electricity cost of air conditioning, and reducing carbon emissions. Against the backdrop of the “dual carbon” goal, green and energy-saving buildings have become the mainstream of domestic construction. The use of glass will make a huge contribution to achieving carbon neutrality.

3.3. The third is to strengthen the recycling and utilization of waste and reduce environmental pollution

The radiative forced convection heat transfer technology inside the tempering furnace has the characteristics of uniform heating and short time consumption, which can significantly improve the convective heat transfer ratio inside the furnace. The hot gas discharged from the tempering furnace can also preheat the compressed air before entering the furnace, saving 34% of electricity compared to ordinary furnaces. In addition, the waste heat recovery and utilization technology during the glass tempering process is also an important measure to improve energy utilization efficiency and reduce energy consumption. The flue gas temperature from the storage chamber and heat exchanger of the tank kiln is generally above 300 °C, and the emissions are large, which has high recovery value. The use of waste heat recovery equipment to treat flue gas can be used for steam power generation or direct drive equipment, as well as for preheating air, flame retardant air, drying heat sources, or workshop heating after the heat recovery of flue gas, all of which can achieve good energy-saving and emission reduction effects.

4. Discussion

Firstly, we need to optimize the glass production process to reduce energy consumption and waste generation, thereby reducing carbon emissions. This can be achieved through the use of efficient glass manufacturing technology, the use of renewable energy, improved raw material selection, and recycling methods. This can not only reduce carbon emissions and resource consumption, but also improve production efficiency and sustainability.

Secondly, we need to promote the concept of green buildings and improve their energy efficiency to reduce glass usage and energy consumption. The use of efficient thermal insulation glass, optimized lighting design, and automated systems in buildings can achieve this goal. This can reduce the energy demand and carbon emissions of buildings, while providing a more comfortable and sustainable indoor environment.

Thirdly, we should strengthen the recycling and utilization of waste and reduce environmental pollution to achieve carbon neutrality. Establishing a comprehensive recycling system, promoting awareness and technology of glass recycling, and promoting circular economy can achieve this goal. This can reduce the negative impact of waste glass landfill and incineration on the environment, while improving the sustainable utilization rate of resources.

The impact and suggestions for future research are that we need to further study new glass manufacturing technologies and explore more efficient and energy-saving production methods. At the same time, research and development of new glass raw materials and substitutes should also be carried out to reduce dependence on limited resources. In the field of green building, further research is needed on green building technology and materials to improve building energy efficiency and the effectiveness of glass use. In addition, efficient recycling and reuse technologies for waste glass can be studied, and new glass recycling and utilization models can be explored. At the same time, it is necessary to study the environmental impact of discarded glass and methods to reduce waste generation, in order to improve the sustainability of the glass industry.

In summary, these measures have a significant impact on achieving carbon neutrality in the glass industry. Future research should further explore and develop relevant technologies and policies to promote the sustainable development of the glass industry and the achievement of carbon neutrality goals. In addition, interdisciplinary and global cooperation will be crucial to promote knowledge sharing and experience exchange, and to advance the carbon neutrality process in the glass industry.

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The Connection Between Carbon Neutrality and Nature Conservation

Yueming SUN

Anhui University, Hefei, Anhui, China, 230039

Email: sun_yueming_icnt@iexchange.world

***Corresponding author**

Abstract

This essay examines the symbiotic relationship between carbon neutrality and nature conservation in the context of global efforts to alleviate climate change. It begins by defining carbon neutrality as the balance between emitted and absorbed carbon dioxide, emphasizing its importance in reducing the human carbon footprint. Nature conservation is presented as pivotal for maintaining earth's biodiversity and providing ecosystem services such as clean air, water, and climate regulation. The paper proposes to explore how pursuits of carbon neutrality positively influence nature conservation and vice versa.

Detailed descriptions of how to achieve carbon neutrality include reducing emissions through energy efficiency, renewable energy, and lifestyle changes, alongside carbon offsetting measures like reforestation and carbon capture technologies. Global initiatives like the Paris Agreement underscore the commitment of various countries to carbon neutrality, with an emphasis on coherence and collaborative action.

The essay discusses the essence of biodiversity and ecosystem services, highlighting the critical nature of conservation for sustaining human life. It addresses threats to conservation, primarily stemming from human activities like deforestation, pollution, and climate change.

Lastly, the interconnection of climate change mitigation and ecosystem preservation is analyzed. The role of natural ecosystems in carbon sequestration is explained, with forests, wetlands, and oceans acting as carbon sinks, and their broader role in climate change mitigation is discussed. The paper aims to show the intertwined nature of achieving carbon neutrality and conserving natural ecosystems, advocating for integrated policy approaches for a sustainable future.

Keywords: Carbon neutrality; biodiversity and ecosystem services.

1. Introduction

1.1. Definition of carbon neutrality

Carbon neutrality alludes to accomplishing a harmony between transmitting carbon and engrossing carbon from the air in carbon sinks. It is a state where the net measure of carbon dioxide (CO_2) and other carbon compounds delivered into the environment is balanced by a comparable sum being taken out or disposed of. This idea is pivotal with regards to global endeavors to battle climate change, as it means to lessen the general carbon footprint of people, associations, and countries to nothing. Accomplishing carbon neutrality normally includes a blend of decreasing existing discharges and upgrading carbon sequestration through different means.

1.2. Importance of nature conservation

Nature conservation is the act of securing, protecting, and overseeing natural conditions and untamed life to forestall the corruption of the world's biodiversity and ecosystems. It is crucial for keeping up with the wellbeing and dependability of the planet, guaranteeing the endurance of innumerable species, and giving fundamental ecosystem services like clean air and water, fertilization of harvests, and guideline of climate. Conservation endeavors likewise assume a critical part in supporting natural assets for people in the future and keeping up with the biological equilibrium fundamental for life on The planet.

1.3. Proposition explanation: exploring the connection between carbon neutrality and nature conservation

This paper means to investigate the mind boggling connection between carbon neutrality and nature conservation. It will dive into what endeavors to achieve carbon neutrality can fundamentally mean for nature conservation decidedly as well as the other way around. The relationship of these two targets is essential in the more extensive setting of ecological supportability and climate change relief. By inspecting this relationship, the paper tries to feature the importance of coordinated approaches that address both carbon neutrality and nature conservation to achieve a more reasonable and strong future for our planet.

2. Carbon neutrality

2.1. Explanation of carbon footprint

The idea of a carbon footprint is key to figuring out carbon neutrality. A carbon footprint alludes to the aggregate sum of ozone harming substances, especially carbon dioxide, radiated straightforwardly or in a roundabout way by an individual, association, occasion, or item (Phophe and Masubelele, 2021). It incorporates all carbon emanations coming about because of different exercises, including energy use, transportation, and assembling. The objective of estimating a carbon footprint is to comprehend the effect of these exercises on climate change and to distinguish regions where discharges can be decreased (Keith et al., 2021).

2.2. Methods to achieve carbon neutrality

Accomplishing carbon neutrality includes a diverse methodology. One essential technique is diminishing outflows through energy productivity, sustainable power reception, and changes in transportation and modern cycles (Dish and Sun, 2023). Another basic technique is carbon counterbalancing, which remembers effective money management for projects that eliminate or lessen carbon from the climate, for example, reforestation or carbon catch innovations (Sun et al., 2022). Moreover, way of life changes at the singular level, for example, decreasing air travel and taking on a plant-based diet, can contribute essentially to carbon neutrality (GU and Tianwei, n.d.).

2.3. Global Initiatives and commitments for carbon neutrality

Globally, various initiatives and commitments expect to achieve carbon neutrality. The Paris Understanding, for example, is a milestone worldwide accord where nations focus on carbon decrease focuses to restrict global warming (Keith et al., 2021). Numerous nations have set explicit focuses for accomplishing carbon neutrality, with differing courses of events, for example, China's obligation to arrive at carbon neutrality by 2060 (Wang et al., 2023). Moreover, global associations and collusions, like the Unified Countries and the European Association, have been instrumental in advancing and supporting carbon neutrality objectives through strategies, subsidizing, and research (Cong et al., 2023). These global endeavors highlight the importance of cooperative and composed activity in the battle against climate change.

3. Nature conservation

3.1. Definition and significance of nature conservation

Nature conservation includes the assurance, safeguarding, and economical administration of natural conditions and untamed life. Its significance lies in keeping up with the planet's biodiversity, guaranteeing the endurance of different species, and safeguarding the natural ecosystems that offer basic types of assistance to mankind (Keith et al., 2021). Conservation endeavors are fundamental for the wellbeing and dependability of the World's ecosystems, which thusly support human existence by giving clean air and water, rich soil for farming, and managing the climate.

3.2. Biodiversity and ecosystem services

Biodiversity, the range of life in the entirety of its structures and connections, is a foundation of nature conservation. It incorporates the variety inside species, between species, and of ecosystems. Biodiversity isn't just important by own doing yet in addition supports ecosystem services are pivotal for human endurance and prosperity. Ecosystem services incorporate provisioning services like food and water; managing services like controlling climate and sicknesses; supporting services like supplement cycles and harvest fertilization; and social services including sporting, otherworldly, and instructive advantages (Phophe and Masubelele, 2021). The safeguarding of biodiversity is consequently indispensable to keeping up with these ecosystem services.

3.3. Threats to nature conservation

Nature conservation faces various threats, essentially determined by human exercises. Natural surroundings obliteration, because of urbanization, farming, and deforestation, is a huge danger, prompting the deficiency of biodiversity and ecosystem services (GU and Tianwei, n.d.). Climate change further worsens these threats by adjusting environments and species circulations, influencing the wellbeing of ecosystems. Contamination, overexploitation of assets, and the presentation of intrusive species likewise present huge difficulties to conservation endeavors (Wang et al., 2023). Tending to these threats requires a deliberate exertion from legislatures, associations, and people to carry out feasible practices and strategies that safeguard and protect the natural world.

4. The Interconnection

4.1. Carbon sequestration by natural ecosystems

Natural ecosystems assume a significant part in carbon sequestration, the most common way of catching and putting away environmental carbon dioxide. Woodlands, wetlands, and seas are among the best carbon sinks. Trees and plants retain CO_2 during photosynthesis, putting away carbon in their biomass and soil, which essentially decreases the grouping of ozone depleting substances in the air (Keith et al., 2021). Wetlands, including peatlands, mangroves, and seagrasses, are additionally exceptionally effective at putting away carbon, frequently more so per unit region than earthbound timberlands (Wang et al., 2023). Seas retain about a fourth of the CO_2 radiated by human exercises, with marine ecosystems like seagrass glades, salt bogs, and kelp woodlands adding to this sequestration (Wang et al., 2023).

4.2. The Role of ecosystems in mitigating climate change

Ecosystems sequester carbon as well as assume a more extensive part in mitigating climate change. By saving and reestablishing natural ecosystems, we can improve their ability to retain CO_2, which is a basic part of global endeavors to battle climate change (GU and Tianwei, n.d.). Furthermore, ecosystems add to climate guideline through cycles, for example, evapotranspiration and the upkeep of nearby microclimates, which can relieve the effects of climate change (Phophe and Masubelele, 2021). The conservation of ecosystems is subsequently a question of biodiversity protection as well as an essential way to deal with climate change relief.

4.3. Effect of climate change on biodiversity

Climate change represents a critical danger to global biodiversity. Changes in temperature and precipitation designs, more successive and extreme climate occasions, and rising ocean levels can modify living spaces and disturb the sensitive equilibrium of ecosystems (Sun et al., 2022). Species might be compelled to move to new regions, prompting shifts in species appropriations and possibly causing the decay or termination of species that can't adjust or relocate (Keith et al., 2021). The deficiency of biodiversity because of climate change can have flowing impacts, debilitating the flexibility of ecosystems and diminishing their capacity to offer fundamental types of assistance, including carbon sequestration (GU and Tianwei, n.d.). This interconnection highlights the importance of tending to climate change and biodiversity misfortune in an all encompassing and coordinated way.

5. Case studies

5.1. Examples of carbon neutrality initiatives that promote nature conservation

Costa Rica's Public Decarbonization Plan: Costa Rica has been a forerunner in coordinating carbon neutrality with nature conservation. Their Public Decarbonization Plan incorporates reforestation and the insurance of existing timberlands, which has added to carbon sequestration as well as to the protection of biodiversity (Sun et al., 2022).

China's Waterfront Blue Carbon Task: China has been zeroing in on saving and reestablishing its beach front and marine biological systems, for example, mangroves, which are strong carbon sinks. This undertaking adds to China's carbon neutrality goals as well as safeguards waterfront biodiversity and improves strength against environmental change influences (Wang et al., 2023).

5.2. Success stories and lessons learned

New Zealand's Sans hunter 2050 Drive: While principally focused on biodiversity conservation, this drive to kill obtrusive hunter species has had positive ramifications for carbon sequestration. Reestablishing local woods and bird populaces helps in keeping up with sound environments that are more powerful at catching carbon (Phophe and Masubelele, 2021).

Lessons Learned: These contextual investigations show the significance of coordinated approaches that think about both carbon neutrality and nature conservation. They feature the requirement for cooperation across countries and areas, the significance of local area inclusion and the benefits of safeguarding and reestablishing regular environments. These drives likewise show that while challenges exist, like financing and political will, the drawn out benefits for the environment, biodiversity, and human prosperity are significant.

6. Challenges and trade-offs

6.1. Balancing carbon neutrality goals with conservation priorities

Balancing the goals of accomplishing carbon neutrality with conservation priorities can challenge. Drives pointed toward lessening carbon discharges, for example, enormous scope environmentally friendly power projects, can some of the time struggle with conservation endeavors assuming that they lead to territory annihilation or adversely influence natural life (Keith et al., 2021). For example, the improvement of sun powered or wind ranches in biologically touchy regions can disturb local environments. Additionally, afforestation projects, while perhaps not painstakingly arranged, can prompt the planting of non-local tree species that might hurt local biodiversity (GU and Tianwei, n.d.). In this way, taking on an all encompassing methodology that considers both carbon decrease and the protection of biological systems and biodiversity is vital.

6.2. Potential conflicts in land use

Land use conflicts are a huge test in adjusting carbon neutrality and nature conservation targets. The interest for land for sustainable power projects, carbon offsetting drives like tree planting, and agrarian creation can prompt rivalry for similar land assets (Phophe and Masubelele, 2021). This opposition can bring about the removal of normal biological systems or rural lands, potentially prompting food security issues or loss of biodiversity. Powerful land-use arranging and approaches that focus on multi-utilitarian landscapes can assist with moderating these conflicts.

6.3. Ensuring equitable benefits for local communities

Ensuring that carbon neutrality drives give equitable benefits to local communities is fundamental. Frequently, projects pointed toward lessening carbon discharges or monitoring nature can neglect the privileges and needs of local populaces, prompting social and financial variations (Wang et al., 2023). For instance, conservation endeavors that confine admittance to normal assets can antagonistically influence the livelihoods of native and local communities who rely upon these assets. It is essential to include local communities in the preparation and execution of such activities and guarantee that they share in the benefits, like through work creation, supportable advancement open doors, and the security of their freedoms and social legacy (Sun et al., 2022). This approach cultivates social value as well as upgrades the maintainability and adequacy of conservation and carbon neutrality drives.

7. Conclusion

The investigation of the association between carbon neutrality and nature conservation uncovers a complex yet generally interlinked relationship. Accomplishing carbon neutrality isn't just a vital stage in fighting environmental change yet additionally assumes a critical part in saving and upgrading biodiversity and biological system administrations. Alternately, compelling nature conservation techniques contribute considerably to carbon sequestration and environmental change moderation, showing the proportional benefits of these goals.

The contextual investigations and models talked about delineate successful mixes of carbon neutrality drives with conservation endeavors, featuring the potential for synergistic results. Be that as it may, the challenges and trade-offs, for example, balancing carbon decrease with conservation priorities, overseeing land use conflicts, and ensuring equitable benefits for local communities, highlight the requirement for cautious preparation and all encompassing methodologies.

As the world keeps on wrestling with the double emergencies of environmental change and biodiversity misfortune, the lessons learned from these drives are priceless. They accentuate the significance of cooperative, multi-partner moves toward that regard and consolidate local and native information and freedoms. The way ahead requires mechanical and financial arrangements as well as a profound obligation to ecological equity and manageable turn of events.

In conclusion, the quest for carbon neutrality and nature conservation, when adjusted and coordinated, offers a strong procedure for making a manageable and tough future. A way requests development, collaboration, and an unfaltering obligation to saving our planet for people in the future.

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Urban Gadern for Green City: Comparison and Inspiration—Based on Asia, Europe and South America Cases

Hua WEI

Capital University of Economics and Trade, Beijing, China, 100026

Email: wei_hua_icnt@iexchange.world

***Corresponding author**

Abstract

The design of urban gardens is of great significance for the construction of green cities. This article uses case analysis to compare the characteristics and advantages of typical green gardens in Asia (China and Japan), Europe (France), and South America (Australia) from four perspectives: culture and religion, vegetation characteristics, aesthetic elements, and funding. Based on the advantages and characteristics of green gardens in various regions, combined with current technological elements, propose some inspiring suggestions, including green roof technology application, environmentally friendly materials usage and community participation in garden maintenance. This article provides a broader perspective on the factors considered in urban garden design (green plants, garden routes, and small element planning) for different countries from the perspective of regional and cultural competitive advantages. Combined with specific cases, it provides a more detailed analysis perspective for carbon neutrality and sustainable development under the empowerment of technology in the 21st century.

Keywords: Green city; green gargen; case analysis; building design; carbon neutrality.

1. Introduction

Urban gardens play a pivotal role in the creation and sustenance of green cities (Cameron et al., 2012). It provides spaces for relaxation, recreation, and social interaction, fostering a sense of community and enhancing overall psychological well-being. Urban garden design usually aims to three keys: Climate adjustment(Tomatis et al., 2023), air quality improvement (Langemeyer et al., 2016) and psychological well-being(Velarde, M. & Tveit, M., 2007). First, urban gardern can regulate temperatures within cities by providing shade, evaporative cooling, and reducing the urban heat island effect through the presence of vegetation. Also, it alleviates extreme weather conditions by acting as natural buffers against winds, storms, and heatwaves. Second, urban garden can filter and purify the air by absorbing pollutants, such as carbon dioxide and particulate matter, while emitting oxygen, enhancing overall air quality in urban areas. Third, from perspective of pyschology, serene and aesthetically pleasing environments promote mental health and reducing stress among city dwellers. Based on these targets of urban garden designs, following factors are naturally considered. 1)Greenery. In the plant section, plant species will be considered, including native vegetation, to ensure biodiversity and adaptability to the local climate. Besides, how to Incorporate a mix of trees, shrubs, and flowers for visual appeal and ecological balance is also essential. After that, planning for sustainable maintenance practices to ensure the longevity and health of the greenery should be the last but an important part. 2)Garden Pathway Planning. Creating meandering pathways that provide scenic views and a sense of discovery within the garden. 3)Small Element Planning. Choosing and integrating elements like fountains and sculptures harmoniously with the natural surroundings and architectural features. However, different cities within different continent may exhibit unique styles influenced by local cultures, climates, and urban planning philosophies when considering greenery, gardern pathway and small element planning. The preferences and priorities in garden design can also reflect their zone advantages, from which comparison and inspiration can be especially valuable. This article will first introduce the characteristics and advantages of urban garden architecture in Asia, Europe, and South America, and then conduct a horizontal comparative analysis of them. Combining their respective advantages, inspiration for urban garden construction under the background of carbon neutrality will be proposed.

2. Description

2.1. Asia: china and japan

The nature garden landscape is the traditional style of urban gardens in China and Japan, which we can see from the Suzhou Gardens in China and the Shinjuku Gyoen National Garden in Tokyo, Japan. Typical elements of garden landscape include pavilions, stone bridges, flower walls, sculptures, plants (peach blossoms, pear blossoms, chrysanthemums, bamboos), and ponds . In terms of shape selection, China often chooses square and circular layouts (such as turrets with four sides and four corners), and likes harmony and symmetry. This is related to the traditional Chinese Taoist culture(Keswick, M., 2003). Taoist culture pays attention to "four righteousness and four corners" and "hiding the wind and gathering energy". The selection of some animals also reflects the traditional culture of China and Japan. For example, turtle stones and crane stones are commonly used, which has the meaning of longevity. Meanwhile, there are also differences between Chinese gardens and Japanese gardens. For example, Japanese gardens are deeply influenced by Zen culture(Weiss,A., 2013). Zen Buddhism advocates that practitioners pursue a spirit of asceticism and self-discipline, so static elements such as evergreen tree species, sand, and stones are often used to create a lonely and simple garden artistic conception. In particular, when it comes to choosing stones, Japan prefers natural boulders. The ancestors of the Japanese archipelago believed in animism. In this kind of nature worship, the belief and worship of huge rocks or strange-shaped stones is particularly strong. To sum up, the style of Asian urban gardens is mainly nature garden landscape, which is influenced by Taoism and Zen thoughts. It mainly focuses on the theme of returning to nature and emphasizes the "unity of man and nature".

2.2. Europe: france

Classical gardens are the style of French urban gardens. Influenced by the Renaissance, Italy, France, and England played an important role in the history of garden development from the 15th to the 19th century(Turkan, Z.& Köksaldı, E., 2021). The clever application of mathematical and geometric knowledge is mainly reflected in the design of classical symmetry and the arrangement of the main axis, such as the Palace of Versailles in France.Unlike the north-south axis of traditional palace style gardens in the East, Versailles adopted an east-west main axis, with a water sculpture with the theme of "Apollo" (as shown in the picture below) on the main axis, symbolizing that Apollo would drive his chariot to start sending light to humanity every day. In addition to the arrangement of the main axis, the most typical features include water feature canals, flower beds, tree lined roads, and magnificent decorations. These characteristics all reflect to a certain extent the ruling regime of monarchy(Weiss, A., 1995), as the Ambassador of Siam said in 1686, "Parks are the epitome of kingdoms, providing the monarch with the pleasure of perspective and perhaps even the pleasure of power through the interaction of extended paths and forests." In summary, European urban garden styles, as long as they are classical gardens, are influenced by monarchy, represented by gorgeous decorations, have a strong mythological and ornamental effect, and of course, the cost is also extremely high.

Figure 1. the Palace of Versailles

2.3. South America: australia

When it comes to urban gardens in Australia, it is inevitable to mention the Victoria State Library Garden located in Melbourne, Australia. It is the largest and oldest public library in Australia, as well as one of the earliest free public libraries in the world, with a neoclassical architectural style. It combines British and Australian local designs. The garden creates an environment where literature and nature blend through a combination of landscape, sculpture, and plants. In addition to the Victoria State Library Garden, the Royal Botanical Garden can also reflect the unique vegetation advantages of South America. Through organic layout and landscape design, it creates an ecologically rich and educational urban garden. Whether it's the Victoria State Library Garden or the Royal Botanical Garden, you can see the advantageous natural conditions and distinctive neoclassical architectural style of South America, which is also one of the advantages here.

3. Results

Based on the differential design of urban gardens in different states in terms of green plants, garden routes, and small object planning, we can see the stylistic differences brought about by the differences in climate, culture, and religion in different regions. The following table summarizes the differences from four aspects: religious culture, vegetation selection, aesthetic element composition, and funding issues. For example, from a religious perspective, the Asian region has been greatly influenced by Taoism and Buddhism, emphasizing harmonious coexistence between humans and nature. The European region has been greatly influenced by the Renaissance and Enlightenment movements, while South America has mainly been influenced by neoclassicism. These differences in religion and culture have laid the foundation for their urban gardens. From the perspective of vegetation, Asian countries prefer to use bamboo, peach, and pear trees, European countries prefer to use neatly trimmed lawns and green plants, and

South America tends to use local tropical plants. In terms of special elements, Asian countries prefer to use bridges, stones, ponds and other elements in their gardens, European countries prefer to use fountains and sculptures, and South American countries prefer to use neoclassical elements, such as columns and symmetrical structures. For funding, it needs to be analyzed based on specific circumstances, but European countries may involve some historical royal and aristocratic estates.

	Asia	Europe	South America
Religion and Culture	Buddhist principles,Taoist culture	Renaissance and Baroque styles	indigenous cultures alongside neoclassical influences
Vegetation	lush vegetation, including exotic plants and trees	manicured lawns and structured greenery	native plant species and vibrant, tropical flora
Aesthetic Elements	aesthetic elements such as water features, bridges, and rocks	statues, fountains, and architectural structures	Neoclassical elements, such as columns and symmetrical layouts
Varied Funding	come from a mix of public, private, and sometimes religious institutions, depending on the specific cultural context	often involves public or private investments, with some historically linked to royal or aristocratic estates	range from government initiatives to community-driven projects, often influenced by budget constraints and local priorities

Figure 2.The comparison amongs Asia,Europe and South America

4. Discussion

From the description and comparison in the previous statement, we can discover the characteristics and advantages of green gardens in different regions, some of which are advantages in vegetation and some are historical and cultural. With the development of modern technology, we can combine new energy, green and environmentally friendly materials, and sensor detection equipment to further transform and enhance these green gardens. For example, for the pavilions and towers preferred by Asian gardens, green roof technology can be used to improve energy efficiency; environmentally friendly materials can be used for restoration and maintenance of some ancient European classical gardens without compromising their integrity; we can encourage community participation in garden maintenance and fully utilize the characteristics of vegetation diversity in South American neoclassical urban gardens through the development of digital platforms or applications. Overall, the construction of green gardens can incorporate more technological elements for the sustainable development of green cities.

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The Role of Renewable Energy Achieving Carbon Neutrality

Zhiming LIU

Suzhou University, Suzhou, Jiangsu, China, 215009

Email: liu_zhiming_icnt@iexchange.world

***Corresponding author**

Abstract

With the increasing severity of global climate change, reducing the use of fossil fuels and switching to renewable energy has become an urgent task for us to achieve the goal of carbon neutrality. This paper will focus on the role of renewable energy in achieving carbon neutrality. First, we will introduce the background and types of renewable energy, and then explore the role of renewable energy in reducing greenhouse gas emissions, lowering carbon footprints, driving sustainable development, and promoting economic growth. Finally, we will discuss the challenges and future directions of renewable energy.

Keywords: Renewable energy; carbon neutrality.

1. Introduction

In recent years, the impact of global climate change on human society and the natural environment has become more and more obvious. Numerous scientific studies have shown that greenhouse gas emissions are one of the main causes of climate change. In order to combat climate change, the international community generally recognizes the need to take measures to reduce greenhouse gas emissions. As a clean and pollution-free form of energy, renewable energy has attracted the attention of more and more countries and regions, and has become an important means to achieve the goal of carbon neutrality.

Background and types of renewable energy Renewable energy refers to those forms of energy that can be used sustainably and are naturally renewed, such as solar, wind, hydro, biomass, etc. Compared to fossil fuels, renewable energy has the advantage of unlimited supply and reduced greenhouse gas emissions. Various renewable energy technologies are being developed and promoted, providing strong support for achieving the goal of carbon neutrality.

The role of renewable energy in reducing greenhouse gas emissions Renewable energy mainly reduces greenhouse gas emissions by reducing dependence on fossil fuels. Solar and wind are the most common forms of renewable energy, and they produce almost no greenhouse gases in the process of generating electricity. In fact, the large-scale use of solar and wind energy can replace fossil fuels for power generation, fundamentally solving the problem of carbon emissions. In addition, biomass energy and hydropower can also be used as clean energy to replace fossil fuels, and their utilization process produces less greenhouse gases, which plays an important role in reducing greenhouse gas emissions.

The role of renewable energy in reducing the carbon footprint A carbon footprint is the total amount of greenhouse gases released by an individual, company or country during production and consumption. The widespread use of renewable energy can reduce the carbon footprint. For example, replacing traditional coal-fired boilers and traditional electricity supply with solar water heaters and solar photovoltaic power generation systems can significantly reduce carbon emissions. In addition, the promotion of electric vehicles and the use of biomass as a transport fuel can also reduce the carbon footprint.

The role of renewable energy in promoting sustainable development The use of renewable energy can drive sustainable development. Traditional forms of energy are more damaging to the environment, while renewable energy is sustainable and environmentally friendly. By promoting renewable energy on a large scale, it is possible to reduce dependence on natural resources, reduce the insecurity of energy supply, and promote the green development of the economy. In addition, the development of the renewable energy industry has provided new opportunities for employment, driving innovation and technological progress in the field of sustainable development.

The role of renewable energy in promoting economic growth The development of renewable energy is not only good for the environment and sustainable development, but also plays a positive role in promoting economic growth. First, the rise of the renewable energy industry provides a good foundation for the creation of new jobs. From energy production to R&D and manufacturing, the renewable energy industry spans a wide range of sectors and provides employment opportunities for a wide range of skilled and professional talents. In addition, the widespread use of renewable energy can also reduce energy costs, improve energy efficiency, reduce energy import dependence, and further promote economic growth.

Challenges and future development directions of renewable energy While renewables have great potential to achieve carbon neutrality goals, they still face some challenges. These include the high cost of technology, energy storage issues, the sustainability of the power grid, etc. In the future, it is necessary to continuously increase investment in renewable energy R&D and innovation, and strengthen international cooperation to jointly address the challenge of climate change. At the same time, the government, enterprises and individuals should actively participate in the promotion and application of renewable energy, and accelerate the development and application of renewable energy through policy support and market mechanism guidance.

2. Result

Renewable energy plays an important role in achieving carbon neutrality. By reducing greenhouse gas emissions, lowering carbon footprints, driving sustainable development and boosting economic growth, renewable energy provides key support for our low-carbon, environmentally friendly and sustainable future. However, the challenges we face also need to be addressed together and strengthened cooperation to achieve the sustainable development of global renewable energy.

3. Discussion

The development of renewable energy can contribute to the goal of carbon neutrality to a certain extent. However, the development of renewable energy still faces many challenges. For most developing countries, the diffusion and use of renewable energy requires significant investment and technical support, and these costs may hinder the adoption and adoption of the technology. In addition, many developing countries have long relied on fossil fuels such as coal, and switching in a short period of time could lead to energy instability and risks. Therefore, while achieving the goal of carbon neutrality, energy security and the stability of the energy market need to be considered. On the other hand, while renewables can contribute less to carbon emissions, it is not a one-size-fits-all solution. For example, solar and wind power generation has a certain instability, and energy storage technology is needed to avoid temporary power outages on the supply side, and energy storage technology is more expensive. In addition, the entire supply chain, from the extraction of renewable energy to its delivery to third-party consumers, requires addressing a complex range of environmental and social issues. In other words, renewable energy technologies are only one means to achieve carbon neutrality, and all expectations should not be placed on it. In conclusion, while renewable energy can contribute to reducing carbon emissions and achieving carbon neutrality goals, we also need to be aware of the real-world challenges it faces in terms of its promotion, application and development. Therefore, we need to take a series of measures, including technological innovation, policy formulation, market mechanism building, and international cooperation, to support the wider application and more sustainable development of renewable energy in achieving carbon neutrality goals.

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RESPONSIBLE EDITOR: Liviu Carstoiu
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TYPESETTING: Qingyu KANG
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
