The 2nd
Carbon Neutrality Forum
for Doctoral Students
第二届全国碳中和
博士生论坛

成果集
Works Collection

2023年11月23~25日
November 23-25, 2023

北京·清华大学
Tsinghua University, Beijing

内部交流资料
for internal use only

- 前　言 -

本成果集是第二届全国碳中和博士生论坛在现场活动以外打造的持续性学术交流平台，旨在展现海内外青年学子的风采，促进更深入的经验交流和思想碰撞，为青年学子了解碳中和领域的跨学科动态提供便利的工具。成果集共收录了论坛的**128**个录取作品，包括**46**个口头报告（占录取口头报告总数的48%）和**82**个海报展示（占录取海报总数的75%）。这些作品相映成辉，彰显了碳中和领域的广泛性、多元性和交叉性的学科特色。

为了更加忠实地反映作品中涌现的新主题、新趋势，本成果集对作品的主题类别做了调整，由论坛原有的6个分会场主题扩充到了**11个主题**：

（1）保持了“新型能源体系与储能”、“低零碳交通”、“低零碳建筑”、“低零碳工业”、“碳汇与碳捕集、封存和利用”等5个原有的分会场主题；

（2）拆分了原有的“碳中和政策、经济与管理”分会场主题，形成了“碳中和系统规划与碳测算”、“碳中和与数字经济”、“碳金融与碳资产管理”等3个新主题；

（3）增设了“低零碳农业”、“低零碳城市”、“低碳生活方式”等3个新主题。

例如，“低零碳城市”主题凸显了跨学科特色。天津大学的杨宇灏、同济大学的蒲静等人、辽宁工程技术大学的胡晓曼分别研究了城市交通碳达峰、城市轨道交通碳排放、城市低碳物流优化等问题，新加坡国立大学的王高远等人关注城市的水碳协同治理，北京林业大学的Geng Lili等关注城市规划与碳汇问题。这些作品促使我们更加关注和认识身处的城市。

“低碳生活方式”主题则展现了终端用户侧的人群行为改变情况，这在碳中和的供给侧宏大叙事中常常被忽视。田淑英等人、刘江华等人分别研究了环境规制中的公众参与、家庭消费低碳转型等问题，陈东辉等人还关注了农村居民的住宅低碳化改造需求。人口生活方式的变化可能为我国的碳中和事业提供需求侧的重要推手。

原有的主题也呈现出了多元化的特点。例如，“新型能源体系与储能”主题覆盖了上游化石能源行业、新能源、输配电系统、电价改革、制氢和储运等各类话题。“低零碳交通”主题涉及了电动车电池回收、机场和航线碳减排等新兴话题。“碳汇与碳捕集、利用和封存”主题则吸引了化工、材料、林业、地质、经管等更多学科的参与。“碳金融与碳资产管理”主题围绕碳关税、绿证等碳金融工具，展现了政府和企业各自的处境和取舍。

在此，诚挚地感谢所有作品作者为本届论坛和成果集做出的重要贡献！碳中和是一个快速增长的新兴交叉学科领域，为年轻人闯出一片天地创造了历史性的机遇。今天我们的开放分享，将成就彼此的未来。希望本成果集见证一代创新领军人物的成长。祝大家好运！

- Foreword -

This collection is a sustained academic exchange platform created by the second National Carbon Neutrality Forum for Doctoral Students in addition to its on-site activities. It is aimed at showcasing young scholars at home and abroad, promoting deeper exchanges and inspiration, and providing convenient tools for young scholars to grasp multidisciplinary dynamics of carbon neutrality. The final collection includes a total of **128** admitted works from the Forum, including **46** oral presentations (48% of the total admitted oral presentations) and **82** poster presentations (75% of the total admitted posters). These works highlight the broad, diverse, and interdisciplinary nature of carbon neutrality.

In order to capture the emerging themes and trends in the works, this collection has adjusted the thematic categories, expanding from the original 6 subforum themes to **11 themes**:

(1) maintaining the 5 original subforum themes, including "New Energy System and Energy Storage", "Low- and Zero- Carbon Transportation", "Low- and Zero- Carbon Buildings", "Low- and Zero- Carbon Industry", and "Carbon Sink and Carbon Capture, Storage, and Utilization";

(2) Splitting the original subforum theme "Carbon Neutrality Policy, Economics and Management" to 3 new themes: "Carbon Neutrality System Planning and Carbon Measurement", "Carbon Neutrality and Digital Economy", and "Carbon Finance and Carbon Asset Management";

(3) Adding 3 new themes, including "Low- and Zero- Carbon Agriculture", "Low- and Zero- Carbon City", and "Low-Carbon Lifestyle".

For example, the theme of **"Low- and Zero- Carbon City**" highlights interdisciplinarity. YANG Yuhao from Tianjin University, PU Jing et al. from Tongji University, and HU Xiaoman from Liaoning University of Engineering and Technology respectively studied issues such as carbon peaking in urban transportation, carbon emissions from urban rail transit, and optimization of low-carbon urban logistics. WANG Gaoyuan et al. from National University of Singapore focused on coordinated water and carbon governance in cities, while GENG Lili et al. from Beijing Forestry University are concerned about urban planning and carbon sequestration. These works encourage us to observe and learn more about the cities we live in.

The theme of **"Low-Carbon Lifestyle**" illustrates changing behaviors of end-users, which is often neglected in the grand narrative of supply-side carbon neutrality. TIAN Shuying et al. and LIU Jianghua et al. respectively studied public participation in environmental regulation and low-carbon transformation of household consumption. CHEN Donghui paid attention to low-carbon transformation needs of rural residents' housing. The changes in population lifestyle may provide an important impetus for China's carbon neutrality cause.

The original themes also demonstrate vibrant diversity. For example, the theme of **"New Energy System and Energy Storage**" covers such topics as upstream fossil fuel industries, renewables, electric transmission and distribution systems, electricity price reform, and hydrogen production, storage and transportation. The theme of **"Low- and Zero- Carbon Transportation**" addresses emerging topics as battery recycling of electric vehicles, airport and airway carbon emissions reduction. The theme of **"Carbon Sinks and Carbon Capture, Utilization and Storage**" has attracted participation of more disciplines such as chemical engineering, materials, forestry, geology, and management. The theme of **"Carbon Finance and Carbon Asset Management**" presents decision-making and behaviors of governments and enterprises facing carbon finance tools such as border tariffs and green certificates.

We sincerely thank all authors for their important contributions to the Forum and the Collection! Carbon neutrality is a rapidly growing interdisciplinary field and it creates historic opportunities for young scholars to break new ground. Our open sharing today will contribute to each of our future. Hope this Collection will witness the growth of a generation of innovative leaders. Good luck, everyone!

- 声　明 -

本成果集为内部交流资料，非正式出版刊物。成果集纳入PPT、摘要和海报等作品（以下简称为“作品”）均征得了作品作者的同意，版权归作品的作者所有。如作品涉及任何侵权，由作品的作者承担一切相关责任。未经作品的作者授权，禁止复制使用作品。

- Disclaimer-

This Collection is only intended for internal communication; it is not a formal publication. The inclusion of works such as PPTs, abstracts, and posters in the Collection (hereinafter referred to as "the works") has obtained the consent of the authors of the works. The copyright belongs to the authors of the works. If the work involve any infringement of others ’ rights, the author(s) of the work shall bear all relevant responsibilities. Reproduction and use of work without authorization from the author(s) is prohibited.

- 目　录 Content -

I. 新型能源体系与储能 New Energy System and Energy Storage

II. 低零碳交通 Low- and Zero- Carbon Transportation

III. 低零碳建筑 Low- and Zero- Carbon Building

IV. 低零碳工业 Low- and Zero- Carbon Industry

V. 低零碳城市 Low- and Zero- Carbon City

VI. 低零碳农业 Low- and Zero- Carbon Agriculture

VII. 低碳生活方式 Low- and Zero- Carbon Lifestyle

VIII. 碳中和系统规划与碳测算 Carbon Neutrality System Planning and Carbon Measurement

IX. 碳中和与数字经济 Carbon Neutrality and Digital Economy

X. 碳金融与碳资产管理 Carbon Finance and Carbon Asset Management

XI.碳汇与碳捕集、利用和封存 Carbon Sinks and Carbon Capture, Utilization and Storage

新型能源体系与储能

New Energy System and Energy Storage

新型能源体系与储能 New Energy System and Energy Storage

Tandem Design of Functional Separators for Li Metal Batteries with Long-Term Stability and High-Rate Capability

Luoyi Ding (Shanghai Jiao Tong University)

The lithium (Li) dendrites growth seriously hinders the progress of increasing the long-term-cycling of lithium metal batteries (LMBs). Numerous reports have been proposed to restrict the formation of Li dendrites by employing separator modification to improve the Li-ion transference number (t_{Li}^{+}). However, ignoring the positive contribution of anions to solid electrolyte interface (SEI) will result in meager inorganic components, which casts a shadow over the development of the practical implementation of LMBs. Herein, we constructed a "tandem" separator, which could build an excellent SEI structure rich in Li-Sb alloy (Li_3Sb) and LiF in situ. Li_3Sb can significantly reduce the migration energy barrier of Li-ion (Li^+) in SEI and facilitate Li^+ transport. Therefore, the full cells with $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$ or $LiFePO_4$ cathodes show excellent cycle stability and superior rate performance.

新型能源体系与储能 New Energy System and Energy Storage

Techno-Economic Assessment and Fuel-Cycle Assessment of Hydrogen Fuel Based on High-Precision Technology Foresight

Fei Teng[1,2], Qi Zhang[1,3], Siyuan Chen[4], Lu Wang[1], Jie Jiao[1], JiangFeng Liu[1]

(1.School of Economics and Management, China University of petroleum, Beijing, 102299;2. National Science Library Chinese Academy of Sciences, Beijing, 100190; 3. Tianshan Research Institute, Xinjiang, 834000;4. Economics and Management, North China Electric Power University, Beijing, 100096)

Abstract: To comprehensively understand the potential role of Hydrogen Fuel Cell Vehicles (HFCVs) in achieving the carbon neutrality objectives of China's transportation sector, this study employed the GREET model to analyze the entire life cycle of hydrogen fuel from 2020 to 2060. By integrating various aspects such as hydrogen production, storage, transportation, and refueling, 21 different fuel pathways were constructed to evaluate their environmental and economic impacts, which are crucial for developing effective emission reduction policies. The findings indicate that, in the current phase, while renewable energy-based electrolytic hydrogen production significantly reduces air pollutants and carbon emissions, conventional hydrogen production methods using natural gas, coke oven gas, and coal exhibit superior economic performance. However, with the emergence of technological learning effects, a downward trend in pollution emissions and costs associated with hydrogen fuel is anticipated. Notably, offshore wind and biomass gasification hydrogen production play a critical role in reducing greenhouse gas emissions, and the economic feasibility of photovoltaic electrolytic hydrogen production is increasingly evident.

Keywords: High-precision; Technology foresight; Hydrogen fuel; LCA; Environmental impact; Economic evaluation

新型能源体系与储能 New Energy System and Energy Storage

Carbon-neutral Power System Transition Pathways for Coal-Dominant and Renewable Resource-abundant Regions: Inner Mongolia as a Case Study

Xiugui Wang[1,2], Zhongming Lu[3], Tianxin Li[1,2*], Peng Zhang[4]

(1. School of Energy and Environmental Engineering, University of Science and Technology Beijing, Beijing,100083, China; 2. Beijing Key Laboratory of Resource-oriented Treatment of Industrial Pollutants, Beijing,100083, China; 3. Division of Environment and Sustainability, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, 999077, China; 4. State Environmental Protection Key Laboratory of Quality Control in Environmental Monitoring, China National Environmental Monitoring Centre, Beijing, 100012, China)

Abstract

Background, Aims and Scope. Under the vision of carbon neutrality, reaching carbon peaking and neutrality targets in the power industry in coal-dominated, renewable energy-rich provinces is facing unprecedented development pressure.

Methods. This study used the optimization model to research the deeper decarburisation path with the lowest cost to the Inner Mongolian power industry. Then, three scenarios were set based on the gradual increase of carbon emission constraints and the increased renewable energy target. The electricity demand, installed capacity and generation, cost-effectiveness, and carbon emissions were evaluated under the three scenarios.

Results and Discussion. Results showed that (1) electricity demand will grow steadily in all three scenarios by 2060, to achieve carbon peak and carbon neutrality targets, with industrial electricity demand falling by an average of 41.15%, while the 'transport, storage & postal' needs to rise by 88.82%. (2) Inner Mongolia needs to fully tap the renewable energy potential, establish a renewable energy storage system, diversify its power supply mode, and achieve the 2060 carbon neutrality target. (3) Achieving a profound emission reduction at minimum cost is feasible. Compared with keeping 13.01% of coal power as a flexible power supply in the nationally determined contributions scenario, completely withdrawing coal power in the carbon neutrality scenario in 2060 will reduce carbon emissions by 148.10 million metric tons and costs by 1375.92 billion yuan.

Conclusion. This method can analyse the carbon emission pathways and emission reduction measures of the resource-based provincial power sector, including setting boundaries, scenario analysis, forecasting future emissions, analysing results, and providing policy recommendations. Providing relevant countermeasures for government departments, industry organisations, power companies, and individuals to conduct carbon neutrality-related work.

Key words: Carbon neutrality; Power system; Renewable energy; Optimization model; Scenario analysis.

新型能源体系与储能 New Energy System and Energy Storage

How do uncertain renewable energy induced risks evolve in a two-stage deregulated wholesale power market

Yining Zhang (Nanjing University of Aeronotics and Astronotics)

Integrating renewable power into power market transactions is significant in terms of achieving carbon peaking and carbon neutrality. However, the integration of intermittent renewable energy source (RES) introduces instability into power generation and brings certain risks to deregulated power market transactions. This study aims to identify the risks arising from RES power integration and analyze how these risks transmit and evolve in deregulated power markets. A Cournot game model is constructed to analyze the generation decisions of a thermal power generation company (GENCO) and a wind power GENCO in a two-stage power market. According to the results, in the mid-to-long-term power market, an increase in the uncertainty of wind power generation (WPG) would reduce wind power supply and increase the clearing price. Then, in the spot power market, the increased uncertainty related to WPG might reduce the amount of wind power traded, increase the marginal generation cost of the thermal power GENCO, raise the clearing price, and reduce the market demand for power. Finally, the uncertainty related to WPG would result in a decreasing market penetration rate of wind power and the loss of social welfare in two-stage power market transactions.

新型能源体系与储能 New Energy System and Energy Storage

碳中和背景下我国煤炭行业现状分析及优化研究

Guoqing Wu (Liaoning Technical University)

Abstract: This paper aims to deeply explore the current situation of China's coal industry in the context of carbon neutrality, and propose optimization research suggestions such as strengthening research on carbon capture and storage technology, promoting the development of clean coal technology, developing coal alternative energy, promoting structural adjustment of the coal industry, innovating coal resource management models, etc., in order to achieve sustainable development and environmental protection goals of the coal industry. As the world's largest coal producer and consumer, China's coal industry is crucial in addressing carbon emissions and environmental pollution issues. With the increasingly prominent issue of global climate change, China has clearly proposed the goal of carbon neutrality, which brings significant challenges and opportunities to the development of the coal industry.

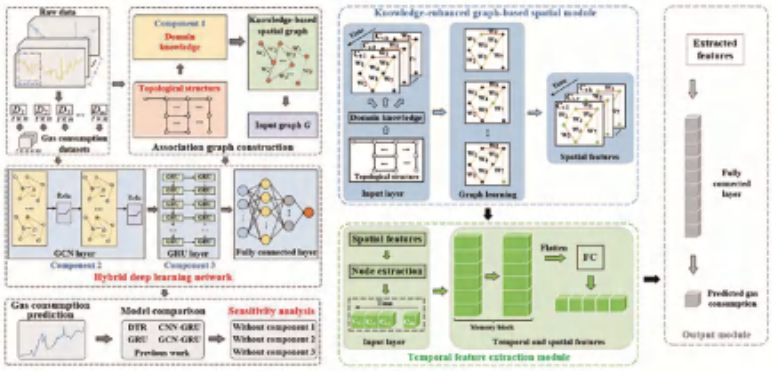
A knowledge-enhanced graph-based temporal-spatial network for natural gas consumption prediction

DU Jian[1], ZHENG Jianqin[2], LIANG Yongtu[1], XU Ning[1], LIAO Qi[1]
(1. China University of Petroleum-Beijing; 2. China Petroleum Planning and Engineering Institute)
(Tel:18810857210; Email:jiandu_cup1997@outlook.com)

Abstract

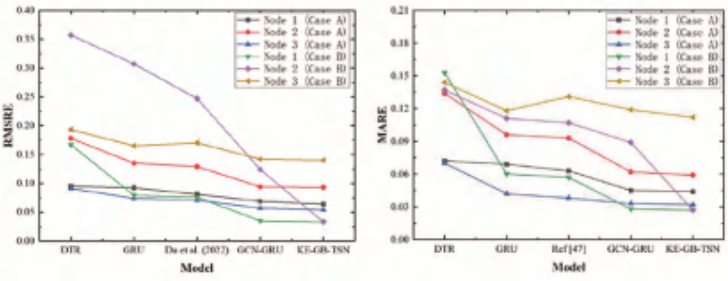
The accurate prediction of natural gas consumption plays a central role in long-distance pipeline system production and transportation planning,. The existing prediction methods for natural gas consumption barely consider spatial correlations and domain knowledge. This study proposes a novel deep learning prediction for predicting natural gas consumption. This study first applies the domain knowledge that analyses the operation technique of the natural gas pipeline network and combines the historical data to establish an association graph. Subsequently, the historical data and association graphs are input to a hybrid deep learning network to predict natural gas consumption. The comparative experiments are conducted by taking real-world cases of natural gas consumption as examples. At last, a sensitivity analysis of different components combination is carried out to exhibit the significance of each component in the proposed model. The results prove that the proposed model is capable of achieving more accurate and efficient predicted results compared to the advanced models. The Mean Absolute Relative Errors and Root Mean Squared Relative Errors gotten by the proposed model are less than 0.11 and 0.14 in all cases, indicating an improvement compared to previous works

Model

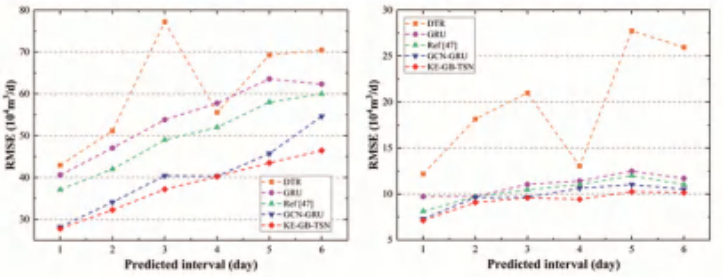


Results

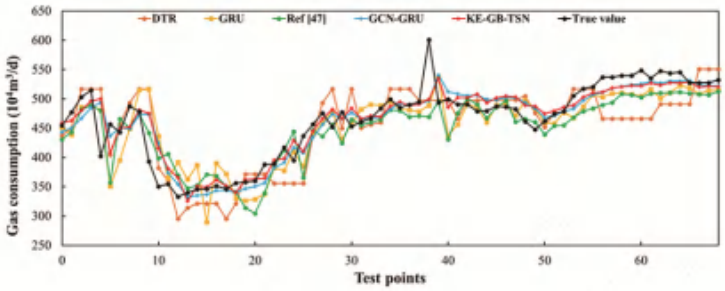
3.1 Validation and comparison of the proposed model



3.2 Robustness and stability of the proposed model



3.3 Natural gas consumption prediction



Conclusion

Natural gas has been playing an increasingly important role in people's daily life, accounting for the main consumption of heating and electricity generation. This study proposes a natural gas consumption prediction model that constructs a high-quality association graph based on domain knowledge and provides a temporal-spatial correlation extraction module for more accurate and efficient prediction. This method integrates domain knowledge in the natural gas pipeline network into an association graph for comprehensive learning of node features and topology information. Overall, this study proposes a knowledge-enhanced graph-based temporal-spatial prediction method, which addresses the drawback of only capturing nonlinear and temporal correlations for previous works. Eventually, comparative experiments of real-world natural gas pipeline cases prove that the proposed model achieves a more accurate and robust prediction performance than other advanced models, with RMSREs and MAREs less than 0.14 and 0.11 in all nodes.

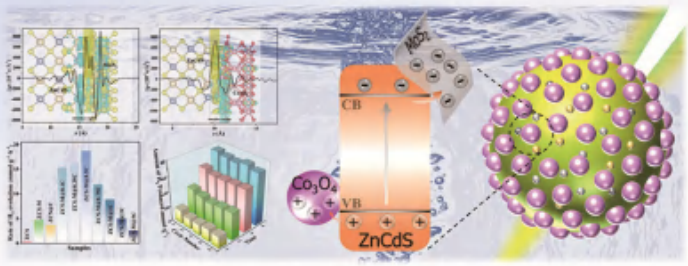
Popcorn-like ZnCdS-based nanospheres with hierarchical tandem heterojunctions synergy for efficient photocatalytic performance

Pengyu Guo, Xiaoyan Liu, Peng Zhang, Zongtao Zhang*, et al.
College of Chemistry, Jilin University, Changchun 130012, China
**Email: zzhang@jlu.edu.cn*

Abstract

Heterojunction engineering is widely recognized as one of the most effective strategies for enhancing photocatalytic performance and suppressing photocorrosion by promoting efficient carrier separation and transfer. In this work, popcorn-like nanospheres with large specific surface areas and hierarchical tandem heterojunctions were synthesized via one-pot in-situ self-assembly combined with hole-driven photodeposition. It can efficiently catalyze the photocatalytic H_2 evolution in water. Both theoretical and experimental evidence show that the incorporation of dual-internal electric fields facilitates bi-directional charge separation and rapid transfer. This work presents a novel approach to fabricating highly efficient photocatalysts with multi-heterojunctions through synergistic effects.

Scheme



Methods

Results

The morphologies of samples were carefully explored by SEM and TEM. The catalysts have a similar uniform global structure with a size of about 50 nm in diameter, which will help to significantly enhance the reduction capacity of the materials. Notably, the surface of the nanosphere is uneven, and the overall shape is like popcorn, with a more abundant surface area. STEM element mapping images of ZCSM@0.5C show that the composite contains a uniform distribution of the throughout the nanospheres.

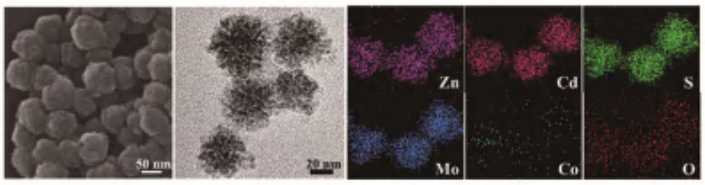


Figure 1. SEM, TEM, and EDS elemental mapping images of ZCS-M@0.5C.

The crystal structure and material phase composition of the asprepared materials were determined via XRD analysis (Fig. 2a), which confirmed that the material is a uniform solid solution. The N_2 adsorption–desorption isotherms of the photocatalysts illustrated in Fig. 2b are type IV isotherm. The curves of pore size distribution further confirm that our materials are mainly composed of rich mesopores. XPS utilized for detailed exploration of sample composition and surface valence states, and the full spectrum is shown in Fig. 2c.

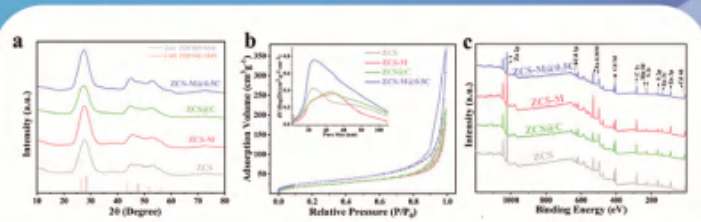


Figure 2. (a) XRD patterns, (b) N_2 adsorption–desorption isotherms with corresponding pore size distribution curves, and (c) XPS survey spectrum of specimens.

The photocatalysts have high absorptivity to the light within 500 nm, and the construction of heterojunctions has little effect on the light response range. Compared to ZnCdS, the optimized ZCS-M@0.5C exhibits a 50-fold increase in visible-light-driven hydrogen evolution efficiency, achieving 18.73 mmol·h^{-1}·g^{-1} and maintaining stability after a 20-hour cycle test. Additionally, the apparent quantum yield reaches a remarkable 10.11% at 420 nm.

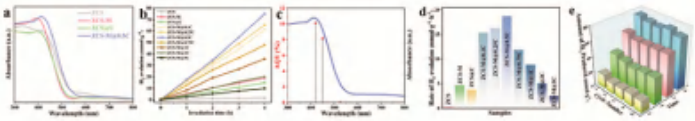


Figure 3. (a) UV–vis absorption, (b) photocatalytic H_2 evolving performance , (c) AQY, (d) average photocatalytic rates, and (e) cycling tests over the samples.

The first principles-based density functional theory (DFT) calculations were conducted to theoretically confirm the laboratorial results and elucidate the electronic frame and orientation of charges transfer in the materials. In short, ZCS-M@0.5C, through the structural design of multiple heterojunctions, electrons will eventually be transported to the electronic collector MoS_2, and then react with hydrogen ions in water to release hydrogen. Simultaneously, the holes will accumulate at the hole collector Co_3O_4, promoting an oxidation reaction that effectively suppresses carrier recombination and photocorrosion.

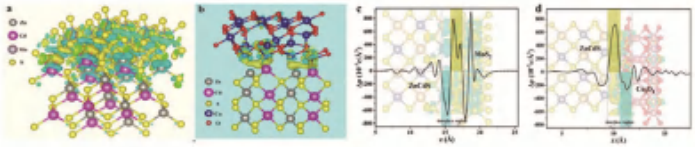


Figure 4. (a, b) The differential charge density of heterojunctions and (c, d) the planar average electron density differences △ρ(z) of heterojunctions.

Conclusions

In summary, we propose a hierarchical tandem heterojunction synergistic ZnCdS-based photocatalyst for efficient hydrogen evolution reaction performance under visible light. By integrating the in-situ one-pot solvothermal method with a facile hole-driven photodeposition method, popcorn-like mesoporous nanoballs with highly uniform dispersion were successfully synthesized. With many reactive active, the charge path is optimized by combining multiple heterojunctions through the synergistic effect of dual-internal electric fields. The utilization efficiency of carriers has been prominently enhanced, and the photocatalytic ability has been highly elevated. The optimized nanocomposite ZCS-M@0.5C photocatalyst exhibited a significantly enhanced hydrogen production rate under visible light irradiation. The photocatalyst displays exceptional photocatalytic ability and photochemical stability, rendering it a promising non-precious metal photocatalyst for clean energy applications.

References

P. Guo, X. Liu, P. Zhang, D. Zhang, W. Liu, H. Gao, M. Zhang, H. Xie, R. Wang, Z. Zhang*, S. Qiu, Popcorn-like ZnCdS-based nanospheres with hierarchical tandem heterojunctions synergy for efficient photocatalytic performance, Sep Purif Technol. 323 (2023).

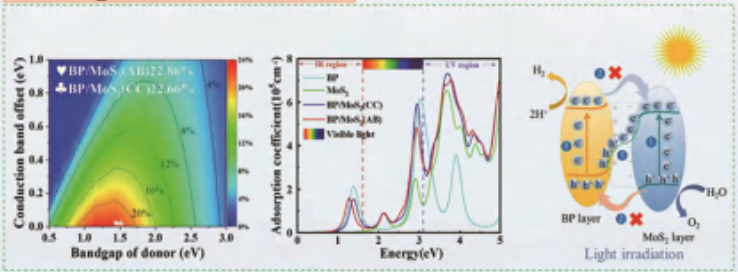
A S-scheme boron phosphide/MoS_2 heterostructure with excellent light conversion ability for solar cells and water splitting photocatalysts

Yuncai Jiang, Shuangying Lei
Key Laboratory of MEMS of Ministry of Education, School of Integrated Circuits, Southeast University
Tel:15285755546 E-mail : jiang_yc214@126.com

Abstract

Monolayer molybdenum disulfide (MoS_2) with a suitable direct band gap and strong optical absorption is very attractive for application in solar cells and photocatalytic water splitting. However, the low carrier mobility and poor infrared light response of MoS_2 hinder its further applications. To overcome these challenges, we proposed a novel S-scheme BP/MoS_2 van der Waals (vdW) heterostructure composed of MoS_2 monolayer and boron phosphide (BP) monolayer with superior carrier mobility, strong infrared, and visible light response. The study revealed that the AB and CC stacking structures exhibit remarkable PCEs of 22.86% and 22.66%, respectively, indicating their significant application prospect in solar cells. Additionally, the AB stacking exhibits a promising application prospect in photocatalytic water splitting due to its appropriate band edge positions, direct band gap, and powerful built-in electric field. Meanwhile, applying uniaxial stress is more beneficial for photocatalytic water splitting. This work paves the avenue for the exploration and application of heterostructures in solar energy conversion systems.

Graphic Abstract

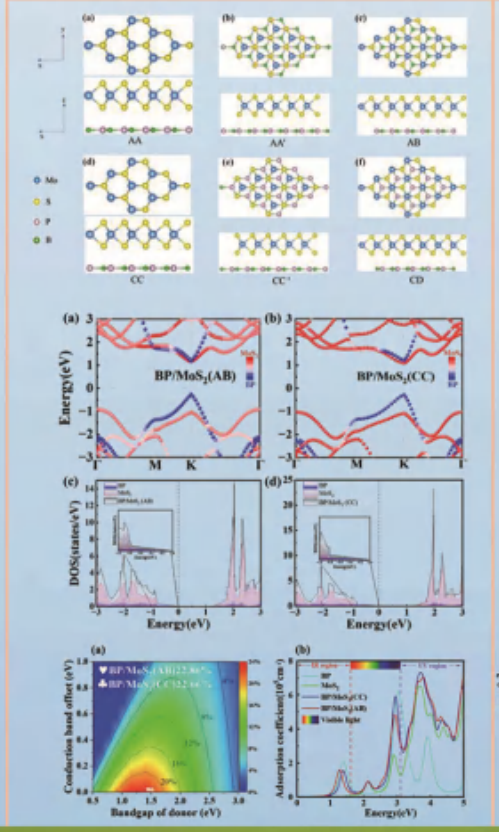


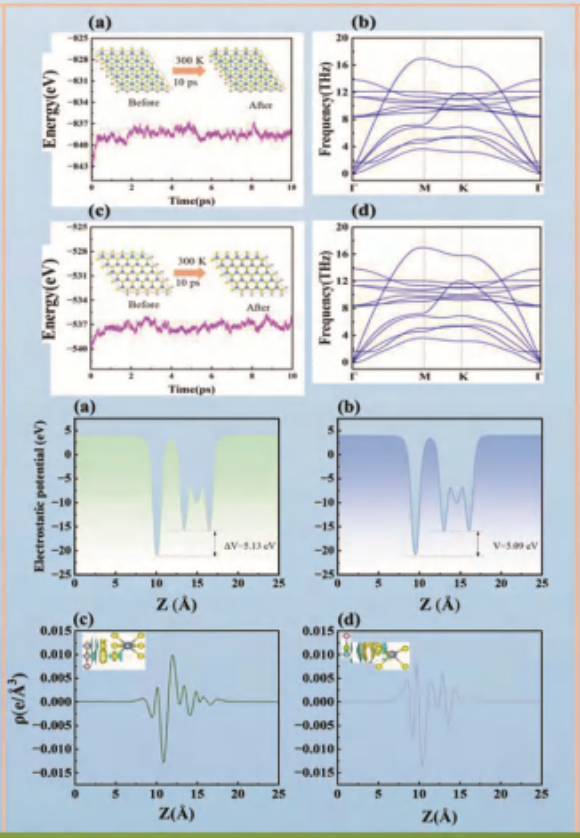
Conclusion

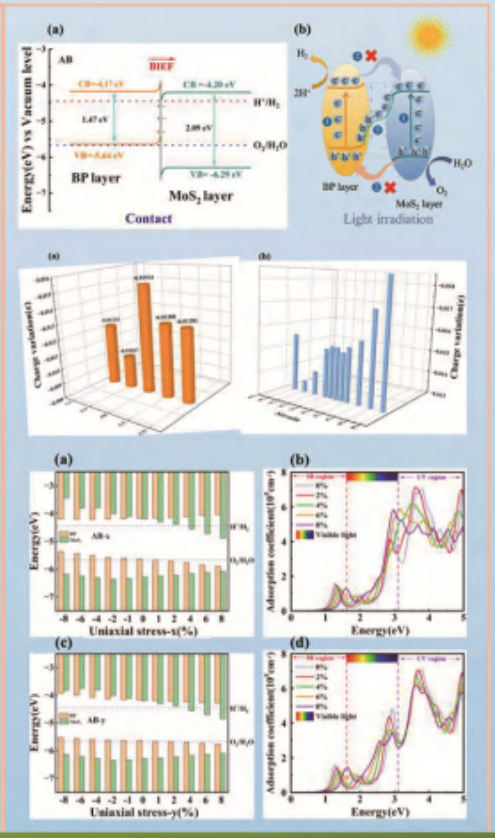
- Almost all stacking structures exhibit a S-scheme charge transfer pathway.
- The AB and CC stacking structures exhibit PCEs of 22.86% and 22.66%, respectively.
- The AB stacking structure holds significant potential for applications in solar conversion systems.

Results and discussion

- The optimized models
- Band structures and DOS
- PCE and optical adsorption
- Phonon spectra
- Molecular dynamics simulations
- Electrostatic potential and DCD
- Bader charge
- Uniaxial stress
- Charge transfer mechanism







Engineering Dense Stacking Faults in Silver Nanoparticles for Boosting the Oxygen Reduction Reaction

KANG Wen-jing, FENG Yi, LI Zhe, DU Xi-wen

School of Materials Science & Engineering, Tianjin University, Tianjin 300350, PR China

Introduction

Zinc-air batteries (ZAB) are attractive devices for energy conversion because of abundant zinc reserves and high energy density. However, oxygen reduction reaction (ORR) executed in the cathode of ZABs is really sluggish, which led to a substantial energy loss. So far, the most active ORR catalysts are platinum-based materials, but their high price seriously raises the cost of ZABs. Silver (Ag) possesses a low price (about one fiftieth of Pt), the highest electrical conductivity and superior stability, but Ag possesses an excessively weak oxygen binding energy (OBE) because of its d^{10} electronic structure, resulting in a poor activity. Defect engineering is an efficacious strategy for optimizing the activity of catalysts, but the defect density caused by traditional wet-chemical synthesis is rather low. However, it's still a big challenge to prepare catalysts with high density defects in an efficient way.

Methods

A physical process, laser ablation in liquid was used to prepare Ag nanoparticles with controllable defects due to its extremely nonequilibrium conditions. The density of defects can be facilely adjusted by changing the liquid medium Particularly, Ag catalyst produced in liquid nitrogen (LN-Ag) possesses the highest density of stacking faults.

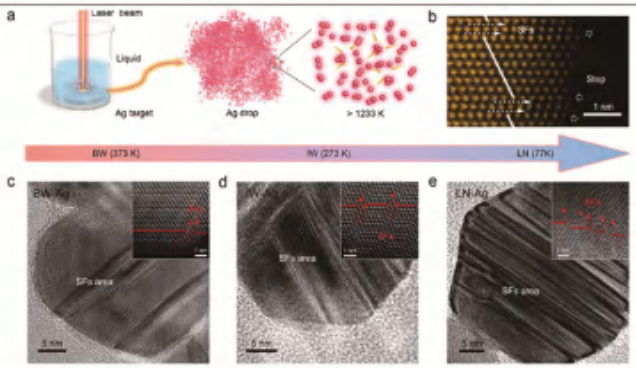


Fig 1 Preparation and characterizations of Ag NPs with different stacking faults density (SFDs).

Results and Discussion

We used X-ray absorption spectroscopy, X-ray diffraction and geometric-phase analysis to demonstrate that liquid nitrogen medium helps form abundant stacking faults which reduce the coordination number (CN) greatly and introduce high lattice tensile strain (TS). These two factors significantly improve the ORR activity of LN-Ag to an extent comparable to commercial Pt/C. According to density functional theory (DFT) calculation, the electron density between adjacent Ag atoms decreases with the reduction of CN and increase of TS, making the d-band center upshift. The upshift of the d-band center can overcome the weak adsorption of Ag catalysts and promote the ORR activity. When LN-Ag is applied in a zinc-air battery, its open circuit voltage is 1.521 V and the power density is 262.85 mW cm^{-2}, which are better than those of Pt/C and currently reported Ag-based catalysts.

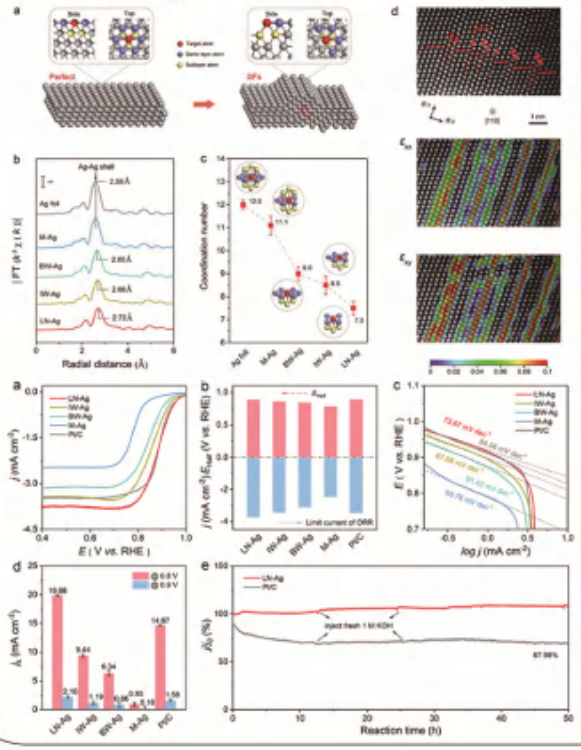


Fig 2 Characterizations of CN and TS in Ag catalysts.

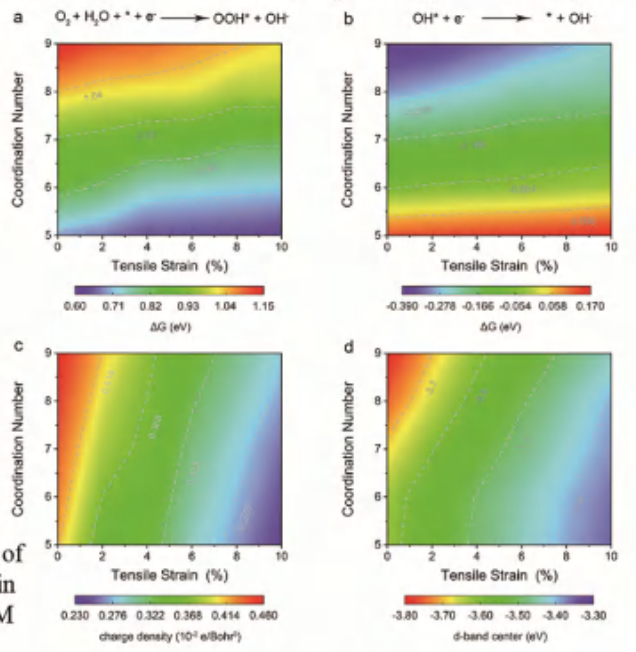


Fig 3 ORR performance of different catalysts in an O_2-saturated 1 M KOH electrolyte.

Fig 4 Theoretical calculations on the effect of CN and TS on free energy in the ORR process and the electronic structure of Ag.

Electricity productivity loss due to coal-electricity price decoupling: Evidence from Chinese thermal power industry

Xinghao Li, Chin-Hsien Yu, Jinsong Zhao, Wen-Chieh Lee, Jiafu An*
Research Institute for Digital Economy and Interdisciplinary Sciences, Southwestern University of Finance and Economics, Chengdu
E-mail address: lxh1995z@163.com

Background, Aims and Scope

China's electricity industry has long been price-controlled, and electricity prices can only oscillate within a narrow band. Meanwhile, coal prices are primarily determined by the market and cause the dilemma of coal-electricity price decoupling in China's thermal power sector. The price decoupling, thus, has been questioned as an important reason for the frequent electricity supply crises in recent years.

Methods

This study measured coal-electricity price decoupling at the regional level and empirically evaluated its impact on resource misallocation at the plant level. Based on the resource misallocation model, a counterfactual analysis was performed to estimate the productivity improvement that can be achieved by resolving coal-electricity price decoupling. In addition, we consider the effect of marketization reforms in the electricity industry, as these reforms may influence the relationship between coal and electricity price decoupling and electricity resource misallocation.

Results and Discussion

Our results show that output distortions would correlate with the coal-electricity price decoupling, which negatively impacts the industry productivity from input misallocations. According to the counterfactual analysis, reducing the extent of decoupling could lead to a productivity improvement of 8.6–11.2%. In addition, the marketization reforms of liberalizing electricity generalization rights would contribute to alleviating the resource misallocations caused by the decoupling of coal and electricity prices in the power sector.

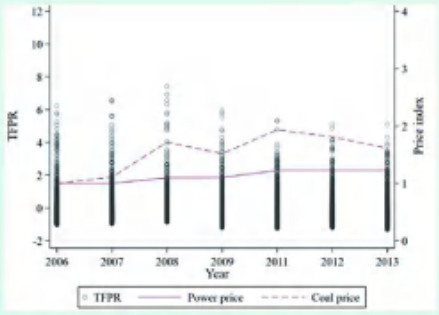


Fig 1 Coal-electricity price decoupling and the distribution of TFPR

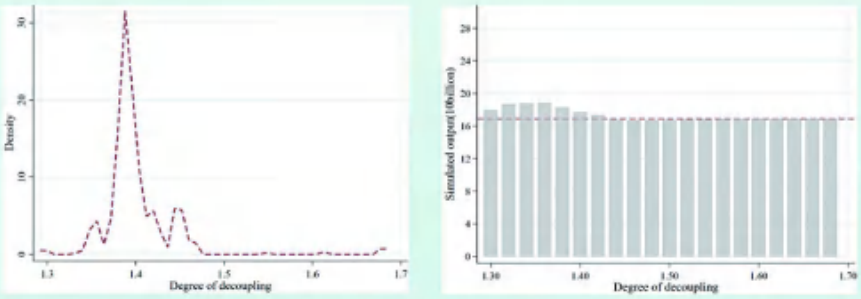


Fig 2 Counterfactual analysis based on 2008 data

VARIABLES	(1) Distortion	(2) τ_Y	(3) τ_K
Decoup	1.808***	9.216***	-2.747
	(0.413)	(2.396)	(2.228)
Constant	-1.863***	-12.254***	4.701**
	(0.431)	(2.503)	(2.327)
Firm fixed effects	Y	Y	Y
Time fixed effects	Y	Y	Y
Observations	4,332	4,332	4,332
R-squared	0.648	0.610	0.748

Table 1 Coal-electricity price decoupling and plant-level distortion

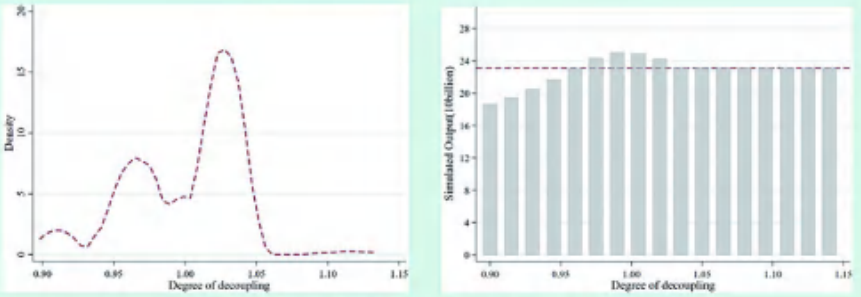


Fig 3 Counterfactual analysis based on 2011 data

Conclusion

The current results shed light on policy improvements for energy security during the energy transition in China's energy industry.

Acknowledgment

Nitrogen-coordinated Cobalt Atoms as Highly Active and Durable ORR/OER Catalysts for Rechargeable Zn-Air Batteries

Sixiang Liu[1], Gaixia Zhang[2,*] (gaixia.zhang@etsmtl.ca), Shuhui Sun[1,*] (shuhui.sun@inrs.ca)
[1]Institut National de la Recherche Scientifique (INRS)-Centre Énergie Matériaux Télécommunications, Varennes, QC, Canada
[2]École de technologie supérieure (ÉTS), University of Québec, Montréal, QC, Canada

Introduction

Nitrogen-coordinated Co single-atoms on carbon materials (Co-NC) have been regarded as promising ORR and OER catalysts for promoting the reaction efficiency of Rechargeable Zn–air batteries due to the high atom utilization and low-cost characteristic, but are suffering from the poor electrocatalytic activities and stability [1-3]. Herein, we proposed a facile ammonium salt etching strategy to construct the ZIF-derived Co-NC catalysts (CoAC-35), which exhibit superior ORR/OER activity (E_{gap} = 0.757 V *vs.* RHE) and stability (almost zero loss after 100 h) in electrochemical setups, and high activity (P_{max} = 0.566 W cm^{-2}) as well as ultralong cycling stability (cycling life of >2500 h) in rechargeable Zn-air flow batteries. This work provides a promising strategy for the synthesis of next-generation highly active and durable Pt-free ORR catalysts for Zn-air batteries and beyond.

Illustrating Scheme of CoAC-35 Catalyst Synthesis

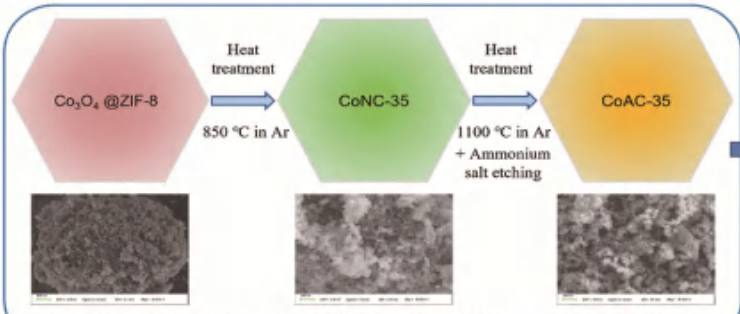
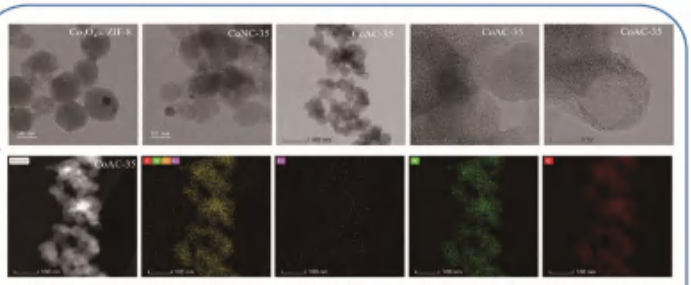


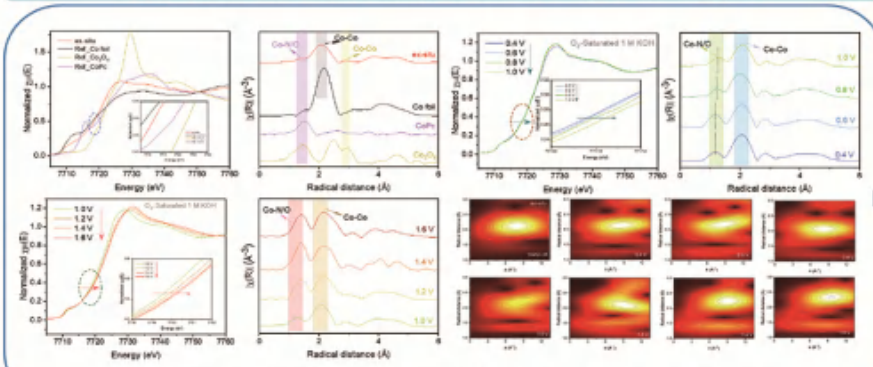
Illustration of the preparation steps of CoAC-35 catalysts and their corresponding SEM images.

TEM Characterizations of CoAC-35 Catalysts



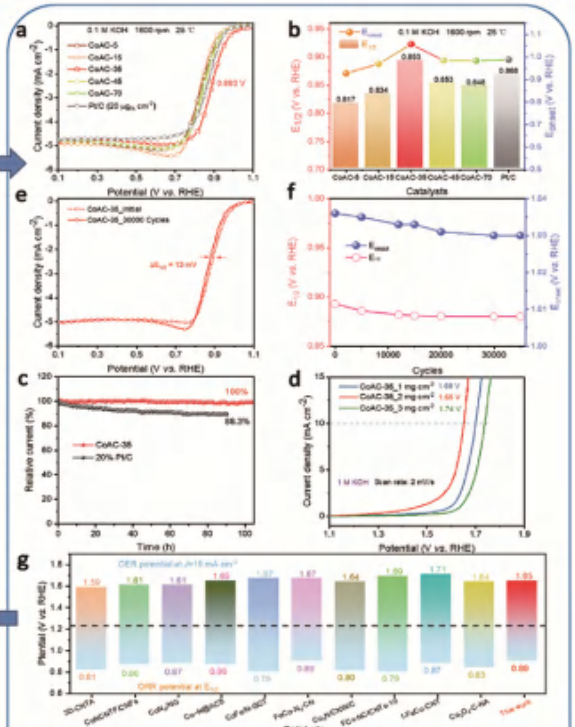
(a) TEM images of Co_3O_4@ZIF-8, CoNC-35 and CoAC-35 catalyst, and **(b)** element mapping for CoAC-35 catalysts.

Ex-situ and *in-situ* XAS Characterizations of CoAC-35 Catalysts



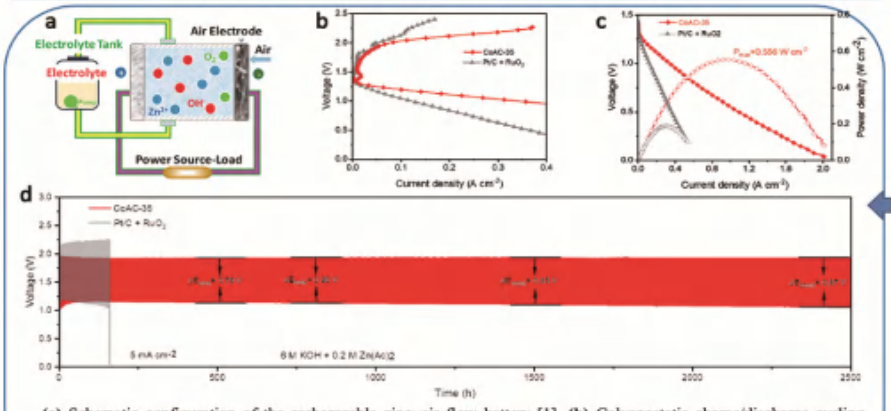
Ex-situ and *in-situ* XANES and EXAFS spectra, and k^3-weighted wavelet transformed spectra.

The ORR/OER Activity and Stability of CoAC-35 Catalysts in Alkaline Media



(a) ORR polarization curves and **(b)** corresponding half-wave potential ($E_{1/2}$) and onset potential (E_{onset}) of different amounts of Co_3O_4 doped CoAC catalysts and commercial Pt/C catalyst tested in 0.1 M KOH solution. **(c, d)** ORR polarization curves of CoAC-35 catalysts before and after CV durability test in 0.1 M KOH solution. **(e)** The current-time chronoamperometric curve. **(f)** OER polarization curves of CoAC-35 catalysts at different catalysts loading. **(g)** The CoAC-35 catalysts shows a superior ORR/OER performance compared with other reported Co-based catalyst.

Rechargeable Zn-air Batteries (ZABs) Performance



(a) Schematic configuration of the rechargeable zinc−air flow battery [1]. **(b)** Galvanostatic charge/discharge cycling performance of CoAC-35 and Pt/C+RuO_2 catalysts. **(c)** Discharge polarization and power density curves of CoAC-35 and Pt/C+RuO_2 catalysts. **(d)** Cycling stability test of a rechargeable flow ZABs at 5 mA cm^{-2}.

Conclusion

- We report a facile ammonium salt etching strategy to construct an electrocatalyst with atomically dispersed Co sites embedded on N-doped porous carbon. It demonstrates excellent bifunctional catalytic performance for ORR and OER in alkaline electrolyte.
- Most importantly, the CoAC-35 catalyst exhibits superior ORR/OER activity (E_{gap} = 0.757 V *vs.* RHE) and stability (almost zero loss after 100 h) in electrochemical setups, and also shows a high activity (P_{max} = 0.566 W cm^{-2}) and ultralong cycling stability (cycling life of >2500 h) in rechargeable Zn-air flow batteries.

References

[1] Wu, M.; Zhang, G.; Sun, S. *et al*, *ACS Energy Lett.* **2021**, 6 (4), 1153-1161.
[2] Chen, D.; Zhang, L. *et al*, *Nano Research* **2022**, 15 (6), 5038-5063.
[3] Wu, M.; Zhang, G.; Sun, S. *et al*, *Adv. Energy Mater.* **2018**, 8 (30), 1801836.

建筑节能材料河南省协同创新中心
Collaborative Innovation Center of Henan Province for Energy-Saving Building Materials
中国石油大学（北京）
China University of Petroleum - Beijing

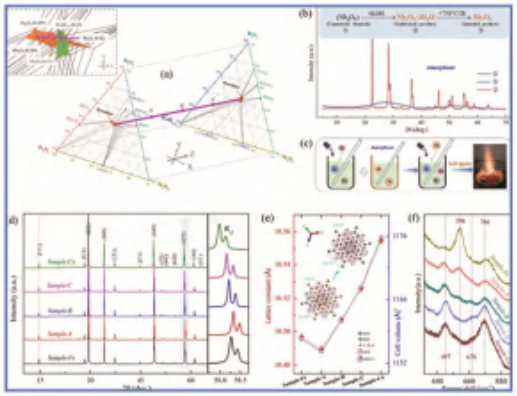
Bismuth pyrochlores with varying Fe/Co ratio for efficient Multi-functional Catalysis: Structure evolution versus Photo- and Electro-catalytic activities

Shujie Sun[a]*, Yingshan Xue[a], Dongxiao Yang[a], Xiaofeng Yin[a]*
[a]Henan Collaborative Innovation Center of Energy-Saving Building Materials, Xinyang Normal University, Xinyang 464000, China
*Email: *sjsun@xynu.edu.cn (Shujie Sun)* , *1304149816@qq.com (Yingshan Xue)*

Introduction:

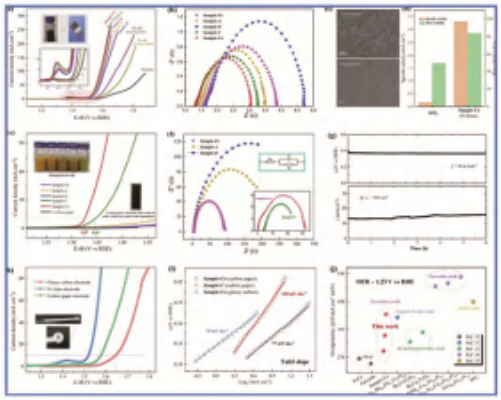
The utilization of clean energy requires the energy conversion of different processes [1], and the key to achieving any kind of efficient conversion process is to find a high-performance catalyst that can improve the rate and selectivity of redox reactions. Previous reports have demonstrated that chemical mutation is more effective than elemental doping or alloying to produce derivatives with smaller bandgaps and lower defect densities. In oxide perovskites, cation extraction at the A position or partial substitution of some low-valent metal ions at the A position is an effective strategy to improve the covalence of metal-oxygen. This is because this strategy can generate additional oxygen vacancies and shift most of the B-site transition metal ions with unstable oxidation states, thereby enhancing the mobility and kinetics of oxygen, thereby increasing electrocatalytic activity [2]. The crystal structure of bismuth pyrochlorite can withstand low positional dislocation and high vacancy concentrations, exhibiting unique stereochemical activity, therefore, the manipulation of this property through structural engineering has driven important research activities intending to realize its transformational functional potential.

Phase diagram design and characterization testing:



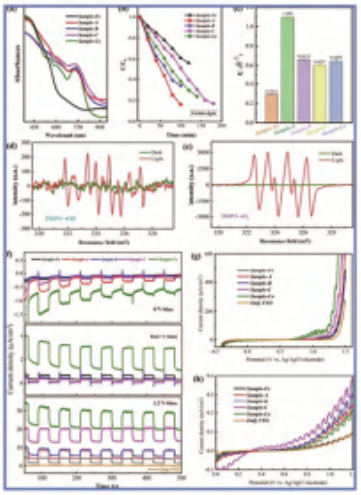
Continuous Co-level from 0 to 100% was ingeniously designed on the basis of special phase diagrams and pryocholore-type pure samples were successfully fabricated by a modified sol–gel auto-combustion method. Significantly, two opposing strucutral shifts were observed with increasing the Co-level, ascribled to the competition between displacive disorders on the Bi sites and strucutral distortions in the octahedral network.

Electrochemical OER performance:



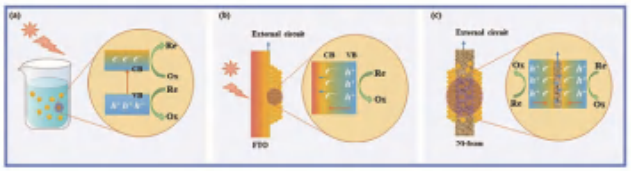
For electrocatalysis, the sample that maintains its structure with the coexistence of massive oxygen vacancies and low-spinstate Co^{2+} present a superior oxygen evolution reaction (OER) activity, with a lower OER overpotential (~300 mV at 10 mA/cm^2) and a smaller Tafel slope (~70mV/dec), and maintain the long-term stability of the current and voltage for 6h. Moreover, the underlying mechanism of the improved performances was analyzed in detail and the new insights were provied for constructing single-phase multi-functioning catalysts.

Visible-light photocatalytic performance:



For photocatalysis, the low-level Co showed a best visible-light-responsive photocatalytic activity by means of the RhB-dye decomposition, while the high-level Co exhibited a higher photoinduced current density.

Conclusion:



1. By changing the Fe/Co ratio (Co levels from 0 to 100%), the compositional engineering structural evolution of the pure-phase Bi-Nb-based pyrochlorite can be clearly observed. This cobalt-induced structural regulation is divided into three types: 1) the ranked ordered type, 2) the octahedral that replaces the Fe^{3+} and Nb^{5+} sites with Co^{2+} ions, and 3) the ranked ordered type is influenced by smaller Co ions at the Bi site.
2. For the first time, it was found that the bifocal green salt catalyst had excellent photocatalytic activity and OER activity at the same time.
3. The electric modulus spectrum shows a tunable dielectric relaxation, and an additional hidden relaxation process shows that the variable oxidation state of the Fe^{3+}/Co^{2+} ion produces a prominent thermal motion when the ionized oxygen vacancy becomes weaker.

References:

[1] W.-J. Yin, B. Weng, J. Ge, Q. Sun, Z. Li, Y. Yan, Oxide perovskites, double perovskites and derivatives for electrocatalysis, photocatalysis, and photovoltaics, Energy Environ. Sci. 12 (2) (2019) 442–462.
[2] X. Li, H. Zhao, J. Liang, Y. Luo, G. Chen, X. Shi, S. Lu, S. Gao, J. Hu, Q. Liu, X. Sun, A-site perovskite oxides: an emerging functional material for electrocatalysis and photocatalysis, J. Mater. Chem. A 9 (2021) 6650–6670.

Phase regulation enabling dense polymer-based composite electrolytes for solid-state lithium metal batteries

Qian Wu[1,2], Yingying Lu[1,2*]

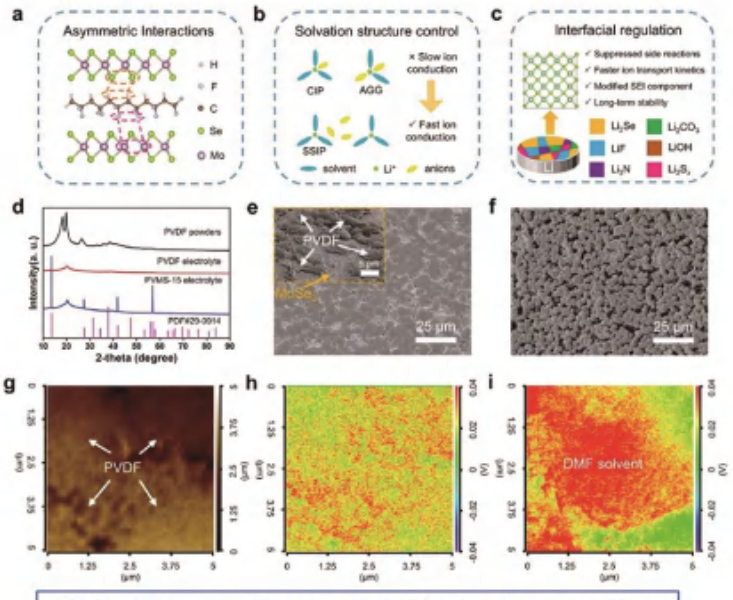
[1]State Key Laboratory of Chemical Engineering, College of Chemical and Biological Engineering, Zhejiang University, Hangzhou 310027, China

[2]ZJU-Hangzhou Global Scientific and Technological Innovation Center, Hangzhou 311200, China

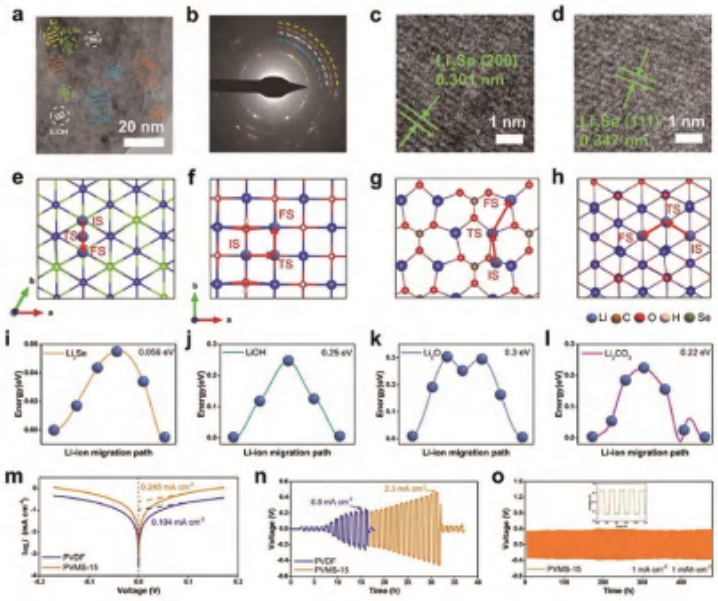
Abstract

Solid polymer electrolytes with large-scale processability and interfacial compatibility are promising candidates for solid-state lithium metal batteries. Among various systems, poly(vinylidene fluoride)-based polymer electrolytes with residual solvent are appealing for room-temperature battery operations. However, their porous structure and limited ionic conductivity hinder practical application. Herein, we propose a phase regulation strategy to disrupt the symmetry of poly(vinylidene fluoride) chains and obtain the dense composite electrolyte through the incorporation of $MoSe_2$ sheets. The electrolyte with high dielectric constant can optimize the solvation structures to achieve high ionic conductivity and low activation energy. The in-situ reactions between $MoSe_2$ and Li metal generate Li_2Se fast conductor in solid electrolyte interphase, which improves the Coulombic efficiency and interfacial kinetics. The solid-state Li||Li cells achieve robust cycling at 1 mA cm^{-2}, and the Li||$LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$ full cells show practical performance at high rate (3C), high loading (2.6 mAh cm^{-2}) and in pouch cell.

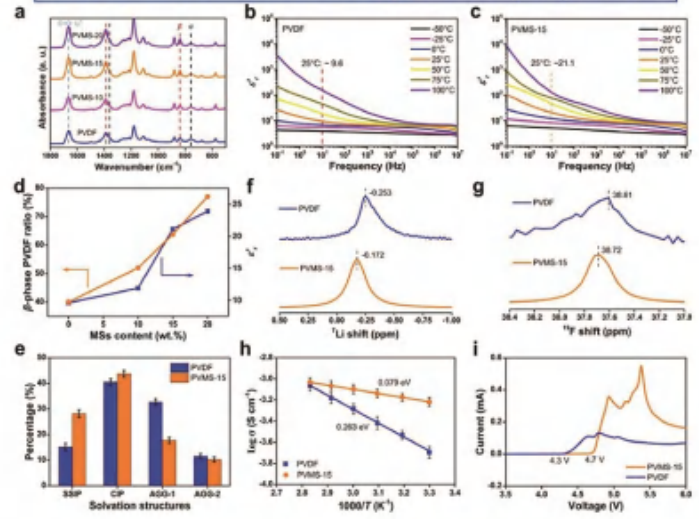
Design principles of the solid electrolyte



Interfacial analysis and characterizations



Solvation structure analysis and properties



Conclusion

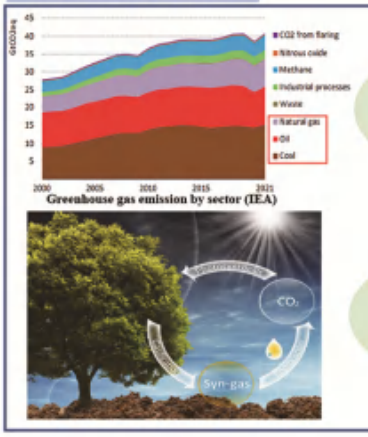
This work not only addresses several key issues of PVDF-based electrolytes through an ingenious design, but also provides an encouraging strategy that contributes to low-cost and large-scale production toward their practical applications.

Wu, Q., Fang, M., Jiao, S. *et al.* Phase regulation enabling dense polymer-based composite electrolytes for solid-state lithium metal batteries. *Nat Commun* **14**, 6296 (2023).

A biomass–solar hybrid gasification system by solar thermochemical and PV–PEM electrolysis for sustainable fuel production

XIN Yu[1,2], ZHANG Wan-lin[1,2], CHEN Fu-jie[2,3], HONG Hui[1,2*]
Institute of Engineering Thermophysics, Chinese Academy of Sciences, Beijing 100190, China

1. Introduction

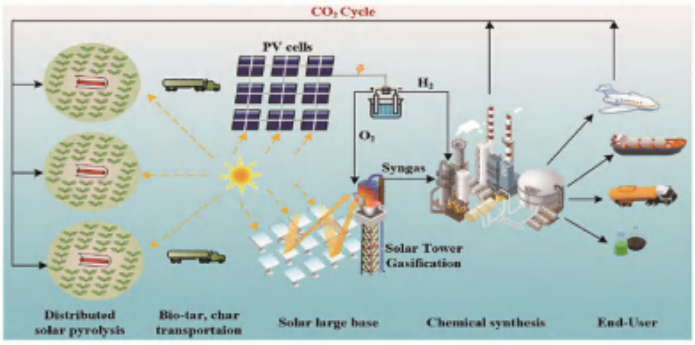


Problem
Fossil fuel consumption accounts for 99.3% of global CO_2 emissions

Solution
Utilize clean energy and green biomass carbon to produce **sustainable fuel**

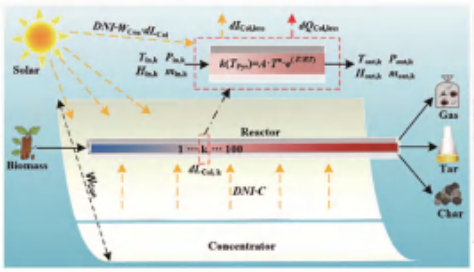
2. System design

A biomass-solar hybrid system was originally proposed through **solar thermochemical** and **PV–PEM electrolysis** for sustainable fuel production.

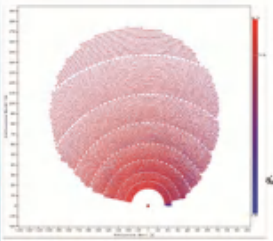


3. Simulation methodologies

Solar heat driven biomass pyrolysis

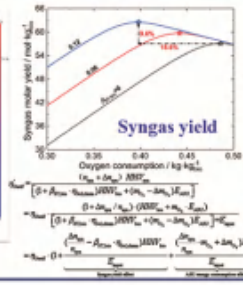


Tower concentrator

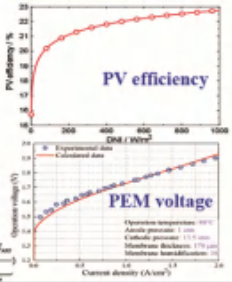


Optical efficiency: 66.54%

Gasification



PV-PEM



evaluate criteria

Index 1:
Total energy efficiency

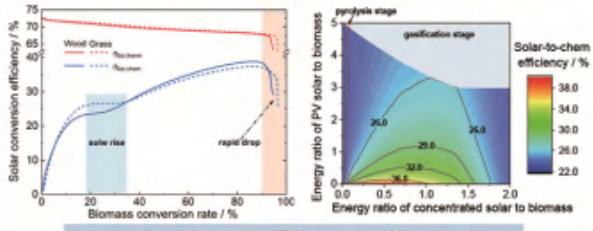
$$\eta_{En} = \frac{m_{Fuel} \cdot HHV_{Fuel}}{m_{bio} \cdot HHV_{bio} + Q_{Sol} + P_{PV} + \sum E_{equip,i}}$$

Index 2:
system carbon efficiency

$$\eta_C = \frac{m_{Fuel} \cdot x_{C,Fuel}}{m_{bio} \cdot x_{C,bio}}$$

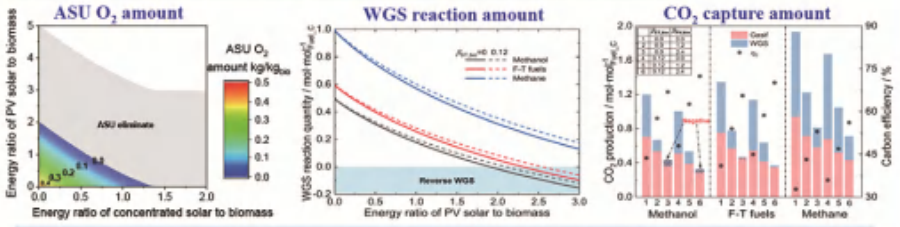
4. Results

1. Solar to chemical energy conversion efficiency



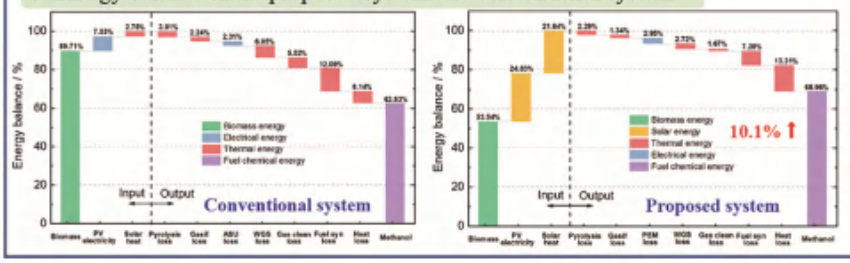
Solar to chemical energy efficiency can achieve 39.5%.

2. Advantages in system energy consumption and carbon utilization

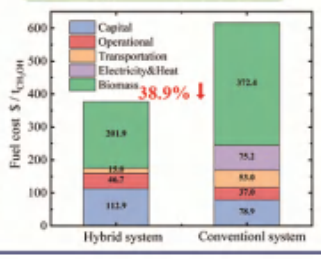


The air separation, WGS, and carbon capture units can be eliminated; Carbon efficiency improved by 85.27%.

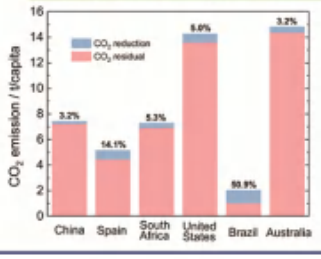
3. Energy balance of the proposed system and conventional system



4. Fuel production cost



5. CO2 reduction potential



5. Conclusions

- A hybrid system coupling biomass gasification and solar energy is proposed for sustainable fuel production.
- The energy conversion and carbon utilization efficiencies improved by 10.11% and 85.27%, respectively.
- Providing a new approach for high-efficiency, low-carbon, and cost-effective fuel production.

Contact us

Any interests can contact:
xinyu@iet.cn
honghui@iet.cn

Analyzing 3D-printed periodic structure by machine learning and its applications in high-mass loading energy storage electrodes

Yang Hao, Hu Han*, Wu Mingbo*

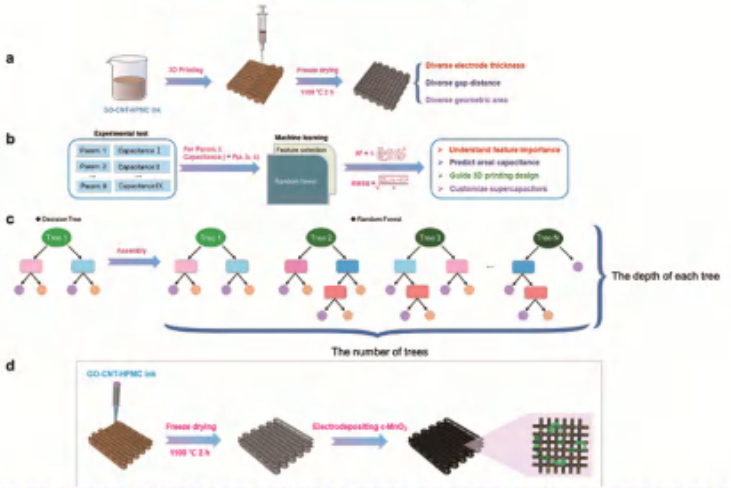
State Key Laboratory of Heavy Oil Processing, Institute of New Energy, College of Chemistry and Chemical Engineering, China University of Petroleum (East China), Qingdao 266580, China

Email: hhu@upc.edu.cn; wumb@upc.edu.cn

Abstract

Commencing with a machine learning approach, we conducted a comprehensive analysis and optimization of the structural parameters of periodic electrodes. Subsequently, a porous integrated electrode was constructed based on this optimized periodic structure. This electrode design features multi-dimensional carrier transmission channels and a profusion of accessible electrochemical active sites. The incorporation of such a structure enhances the internal mass transfer processes within the high-capacity electrode. Consequently, this breakthrough facilitates the complete unleashing of the excellent intrinsic electrochemical properties of the active material, addressing the limitations associated with traditional high-loading electrodes and paving the way for enhanced electrochemical energy storage device performance.

Methods



Result and discussion

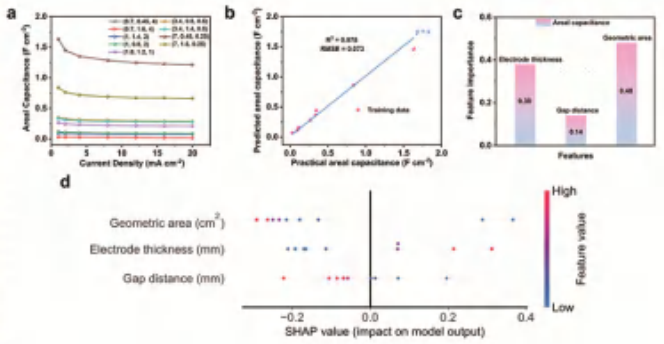


Figure 1. The machine learning models predict outcomes

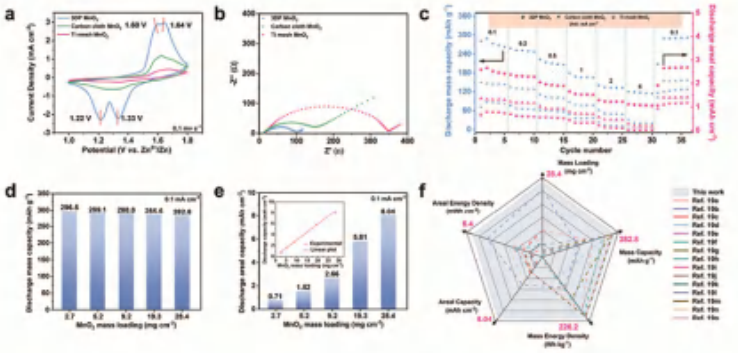


Figure 2. High-mass loading energy storage electrode applications

Conclusion

1. Machine learning model can be established based on 9 carefully selected original experimental data and showed high fitting accuracy with R^2 of 0.978 and RMSE of 0.073.

2. A remarkable loading mass of 28.4 mg cm^{-2} is achieved without compromising the gravimetric performance, leading to an extremely high areal capacity of 8.04 mAh cm^{-2} at 0.1 mA cm^{-2} based on 3D-printed carbon structure

Acknowledgements

中国石油大学（华东）
CHINA UNIVERSITY OF PETROLEUM
NSFC
山东省科学技术厅
Department of Science & Technology of Shandong Province
山东能源集团
SHANDONG ENERGY GROUP

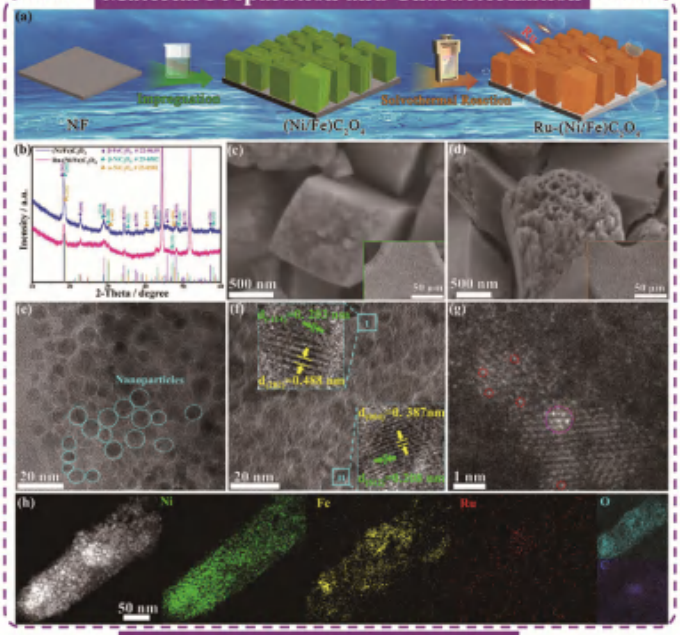
Trace Ru Atoms Implanted into a Ni/Fe-Based Oxalate Solid-Solution-like with High-Indexed Facets for Energy-Saving Overall Seawater Electrolysis Assisted by Hydrazine

Jiayang Zhao[1], Yuhao Wu[2]
[1]Department of Chemical Engineering, Tsinghua University, Beijing 100084, China
[2]Institute of Chemistry, Chinese Academy of Sciences, Beijing, 100190 China

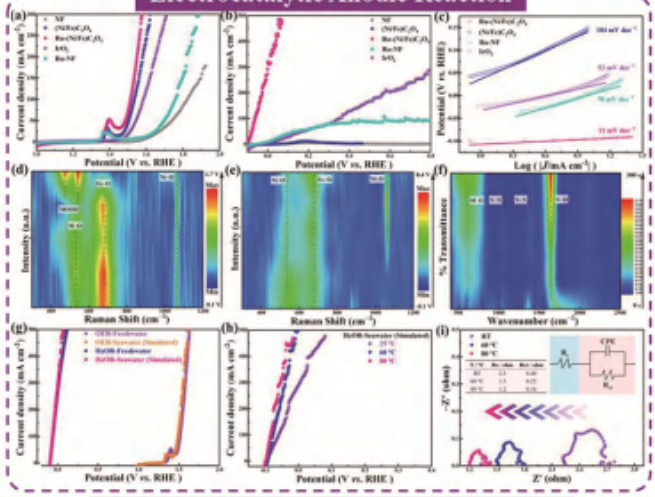
Abstract

Seawater splitting is considered as an economically appealing yet technically challenging approach to generate hydrogen fuel. Hampered by the sluggish oxygen evolution reaction (OER) and the detrimental effects of chlorine electrochemistry, designing robust and highly efficient electrocatalysts for the hydrogen evolution reaction (HER) in parallel with the hydrazine oxidation reaction (HzOR) is extremely imperative for hydrogen production in seawater mediums. Herein, we present a protocol that implants Ru nanospecies into a Ni/Fe-oxalate solid-solution-like with high-indexed facets to engineer an effective and novel-structured catalyst (Ru-(Ni/Fe)C_2O_4). Systematic experiment alongside the theoretical calculations reveal that the synergistic effect of Ru nanospecies and high-index facets from (Ni/Fe)C_2O_4 endows Ru-(Ni/Fe)C_2O_4 with extraordinary activities of HER, OER and HzOR. When assembled into an electrolyzer, the cell voltage reduces to 0.01 V at 10 mA cm^{-2} for HER-HzOR coupling seawater splitting. Moreover, the system remains stable under 500 mA cm^{-2} at 80 ° C for 50 h, almost meeting the requirements for quasi-industrial electrolysis. This work proposes a guideline for preparing multifunctional electrocatalysts and provides an effective strategy for developing seawater electrolysis to achieve a hydrogen economy society.

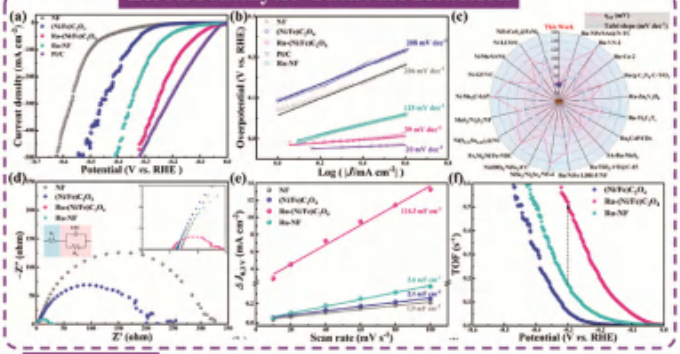
Material Preparation and Characterization



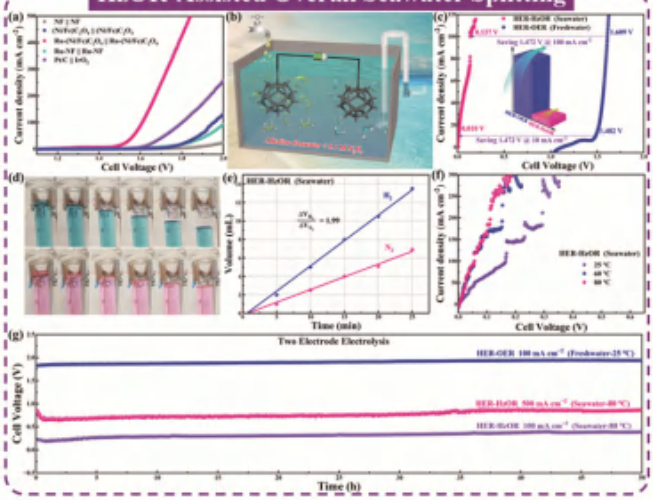
Electrocatalytic Anodic Reaction



Electrocatalytic Cathodic Reaction



HzOR-Assisted Overall Seawater Splitting



Conclusion

In summary, we have elaborately synthesized a new electrocatalyst by implanting trace Ru nanospecies into a Ni/Fe-based oxalate solid-solution-like through facile and easy-scale procedures. The (Ni/Fe)C_2O_4 is applied to disperse Ru nanospecies; and meanwhile, the Ru nanospecies are implanted into the HIFs to regulate the electronic structure of Ni/Fe and stabilize the structure of (Ni/Fe)C_2O_4 by forming Ru–M bonds. Impressively, the as-obtained Ru-(Ni/Fe)C_2O_4 exhibits extraordinary trifunctional activity toward the HER, OER and HzOR in alkaline seawater. Notably, the electrolyzer assembled by Ru-(Ni/Fe)C_2O_4 only requires an ultralow voltage of 0.01 V to reach 10 mA cm^{-2} for overall alkaline seawater splitting assisted by HzOR. Besides, the cell remains stable at a large current density of 500 mA cm^{-2} at 80 ° C for 50 h, almost meeting the requirements for quasi-industrial electrolysis. This work provides a new perspective for designing multifunctional electrocatalysts and develops a promising pathway for overall seawater splitting to achieve a hydrogen economy.

基于全产业链技术进步预见的中国绿氢供应网络布局优化研究

(焦婕, jiaojie_122@163.com, 中国石油大学（北京）经济管理学院;
张奇*, zhangqi56@tsinghua.org.cn,中国石油大学（北京）经济管理学院;
王歌, 华北电力大学 经济与管理学院;
刘江枫, 中国石油大学（北京）经济管理学院;
杨珂欣, 中国石油大学（北京）经济管理学院;
潘勋章,中国石油大学（北京）经济管理学院)

要点

- 到2060年，中国绿氢总需求将超过370亿吨。工业领域绿氢需求将达30亿吨，并且主要集中于河北、江苏、山东、辽宁、山西等省；交通领域绿氢需求将达340亿吨，且集中分布在河北、河南、安徽、浙江、江苏等省。
- 到2060年，不同制氢技术（碱性、质子交换膜、固体氧化物）与氢储运技术加速升级进步，推动绿氢生产成本显著下降，西部地区的新疆、西藏、四川、云南等省绿氢成本降至13.1元/kg，而在东北三省绿氢成本能够下降至12.1元/kg以下；
- 随着绿氢技术的快速进步，绿氢生产已推广至全国各省，在全国范围内形成规模化生产，并将在七大区域形成多个氢气生产中心，逐步构建起多种输氢方式的“绿氢全国一张网”输氢网络。

引言

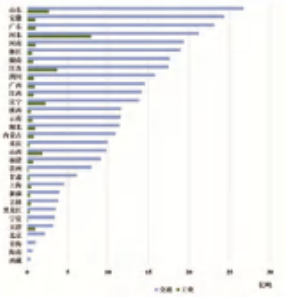
- 双碳目标下，氢能在中国能源系统绿色低碳转型中起到重要作用，基于可再生能源的电解水制氢被视为最佳绿氢生产技术；
- 中国可再生能源和氢需求的区域分布不均衡将导致区域间绿氢供需不平衡；
- 绿氢制取和储运技术尚未成熟，较高成本严重阻碍绿氢规模化发展；
- 随着氢能全产业链技术的进步，如何优化绿氢供应网络布局方案是亟待解决的问题。

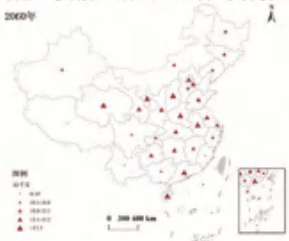
方法

- 构建绿氢需求预测模块，预测未来各省工业、交通领域用氢需求。
- 建立绿氢生产潜力评估模块，评估各省绿氢制取潜力。
- 基于学习曲线构建绿氢技术预见模块，利用绿氢制取技术和管道输氢技术的学习率预测未来制氢及输氢成本变化趋势。
- 以上述三个模块作为数据输入，构建绿氢供应网络布局优化模型，探究未来各省绿氢生产及运输最优布局方案。

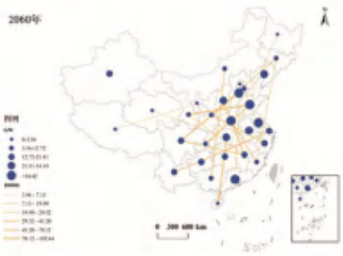
结果与讨论

- 为实现碳中和目标，中国各省需要在工业、交通领域加快绿氢对传统化石能源的替代使用。到2060年，中国绿氢总需求将超过370亿吨，其中，工业领域的绿氢需求将达30亿吨，主要分布在河北、江苏、山东、辽宁、山西等工业生产大省；交通领域绿氢需求将达340亿吨，主要分布在河北、河南、安徽、浙江、江苏等省份。





- 制氢及氢储运技术的快速进步带来全国产氢成本快速下降，且可再生资源集中地区成本下降更加显著。在技术进步的背景下，可再生能源资源分布是导致各省单位制氢成本差异的重要因素，呈现出东北和西部地区最低，其次是东部沿海地区，中部地区最高的分布特征。
- 随着制氢和储运技术的进步及成本下降，中国氢气生产逐步由部分地区试点项目的小规模生产，转变为各省布局制氢设备的全国范围大规模生产。中国将在七大区域形成多个氢气生产中心，东北地区以辽宁省为制氢中心；华北地区以河北、内蒙古为制氢中心；华东地区以山东、江苏、安徽等省份为制氢中心；华中地区则是湖北省拥有更大产氢规模；华南地区则以广东为生产中心；在西北和西南地区，以新疆、四川和云南三省为最大制氢中心。



结论

本文以中国各省为单位，基于各省绿氢需求、制氢潜力和技术进步数据，构建了绿氢供应网络布局优化模型，求解和分析了碳中和目标下，制氢输氢成本变动趋势以及中国绿氢生产和运输的最优空间布局。研究结论如下：

- 区域绿氢需求、绿氢供应潜力及绿氢制取、储运技术进步所带来的成本变动是决定中国未来绿氢供应网络布局的重要因素；
- 到2060年，中国各地区工业、交通领域将产生大规模绿氢需求，工业用氢将占较大比重；
- 绿氢制取和储运技术的进步将带来绿氢成本下降约60%，促进各区域形成制氢优化布局；
- 中国将分别在七大区域形成七大制氢中心，并逐步构建起“全国一张网”输氢网络。

综上所述，想要实现中国氢能体系的规模化发展，要加快绿氢制取、储运技术的突破与升级，并依据各区域绿氢需求及供应潜力实施最优布局方案，优化配置绿氢资源。

致谢

作者感谢国家社科基金重大项目（21ZDA030），国家自然科学基金面上项目(No. 42271305),新疆自治区自然科学基金杰出青年科学基金项目（2022D01E56），天山研究院开放基金项目(No. TSKF20220010)的支持。

焦婕，中国石油大学（北京）经济管理学院博士生。主要研究方向为：绿氢供应布局优化，区域协同发展下的电氢耦合。

通过配置优化和电力管理实现可再生能源-储能发电系统稳定并网

孔福林[1]，刘禹锌[1]，童莉葛[1,*](tonglige@me.ustb.eud.cn)，王立[1]，丁玉龙[2]
[1] 能源与环境工程学院，北京科技大学，中国北京　[2] 伯明翰储能中心与化学工程学院，伯明翰大学，英国伯明翰

一、引言

为应对全球能源危机、实现碳中和气候目标，可再生能源将成为能源生产和消费革命的主流方向。2022年，新增的发电装机容量中有83%都来自可再生能源，其中太阳能和风能贡献了90%。

不稳定性和间歇性是阻碍可再生能源高效稳定并网的主要原因，而储能技术的发展有效缓解了该问题。研究发现，储能技术可实现70%发电量由可再生能源供给的目标。然而，通过文献调研发现，仅靠储能并不能解决与可再生能源并网相关的众多挑战。而，将储能与需求响应结合使用可以进一步提高其利用率与并网稳定性。

目前的研究主要关注微电网或离线电网，而忽略了可再生能源并网场景下的优化需求。因此，为了提高可再生能源在电网中的渗透率，本研究提出了一种基于混合整数二次规划的可再生能源—储能发电系统优化模型，确定了可再生能源及储能系统最佳配置，实现了电力的高效分配。

二、物理模型

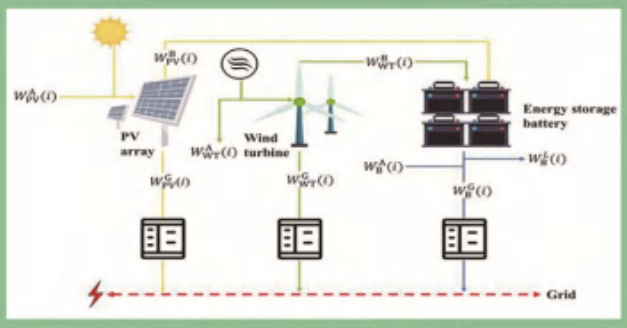
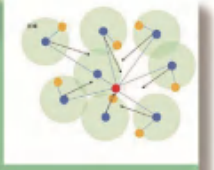


图1 可再生能源并网系统

三、方法论



1. 目标函数：

- 调度期间内总并网电力最大

$$Y = \max \sum_{i=1}^{n} (W^{G}(t))$$

$$W^{G}(t) = W_{PV}^{G}(t) + W_{WT}^{G}(t) + W_{B}^{G}(t)$$

2. 等式与约束：

(1) 光伏/风力发电模型
(2)光伏/风力/储能电力平衡
(3)可再生能源最小装机约束
(4)储能电池系统容量约束
(5)储/释能最短运行时间约束

3. 决策变量：

(1) 储能电池的电力分配
(2) 光伏/风力的装机容量、实时发电量
(3) 光伏和风力的电力分配
(4) 可再生能源系统实时总并网电量
(5) 储能电池的设计容量
(6) 储能电池的实时容量
(7) 储能与释能过程的开关状态

四、案例分析与讨论

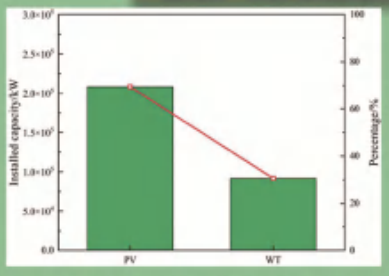


图2 光伏/风力机组的装机容量和比例

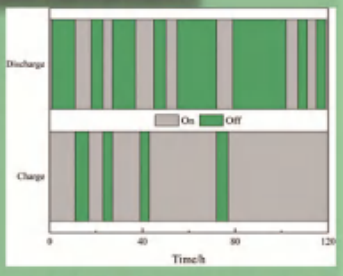


图3 储能电池充放电过程甘特图

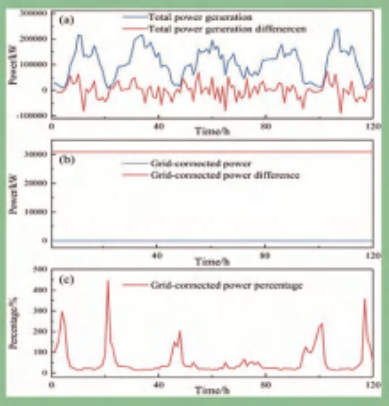


图4 能源系统并网结果

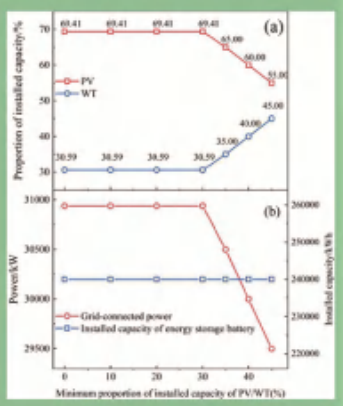


图5 光伏/风力装机容量最小比例影响

五、结论与展望

- 该模型满足全部设备操作要求与工艺约束，确定了光伏面板、风力涡轮以及储能电池的最佳装置容量。
- 相邻时刻实时总发电量差在-89.37 MW~75.32 MW范围内波动。优化后，总电网并网电量稳定在30.94 MW，没有波动。
- 敏感性分析表明，PV/WT装机容量占比增加不影响储能电池装机容量，但会降低稳定并网电量。

具有废热回收与介质再利用功能的新型液氮储能空分

A novel cryogenic air separation unit with energy storage: Recovering waste heat and reusing storage media

刘禹锌[1] 孔福林[1] 童莉葛[1,*] 贺秀芬[1] 郭伟[1] 左忠琪[1] 王立[1] 丁玉龙[2]

(1. 北京科技大学 能源与环境工程学院 冶金工业节能减排北京市重点实验室 北京 中国;2. 伯明翰大学 伯明翰 英国)

(Email：tonglige@me.ustb.eud.cn)

摘要：低温储能技术（CES）是一种重要的规模储能技术，但独立CES工艺的低往返效率（RTE）较低、投资回收期较长，将空分装置（ASU）与CES结合能够提高了系统的能效，但系统的不可逆损失仍然较大。本文讨论了ASU与CES深度集成的可能性，提出了一种新型的具有废热回收与介质再利用功能的新型液氮储能空分工艺（AS-LNES-WHSM）。AS-LNES-WHSM将传统的独立储能压缩操作和多级直接膨胀发电操作改进为共享压缩操作和混合发电操作。AS-LNES-WHSM将能量传输过程从“冷能到电”转变为“冷能到直接电、间接电和产品”。以某实际的ASU为研究对象，利用Aspen Plus软件对集成系统进行了仿真。分析结果表明，AS-LNES-WHSM减少了系统的不可逆转损失，降低了初始资本成本和运行成本。

1. AS-LNES-WHSM工艺

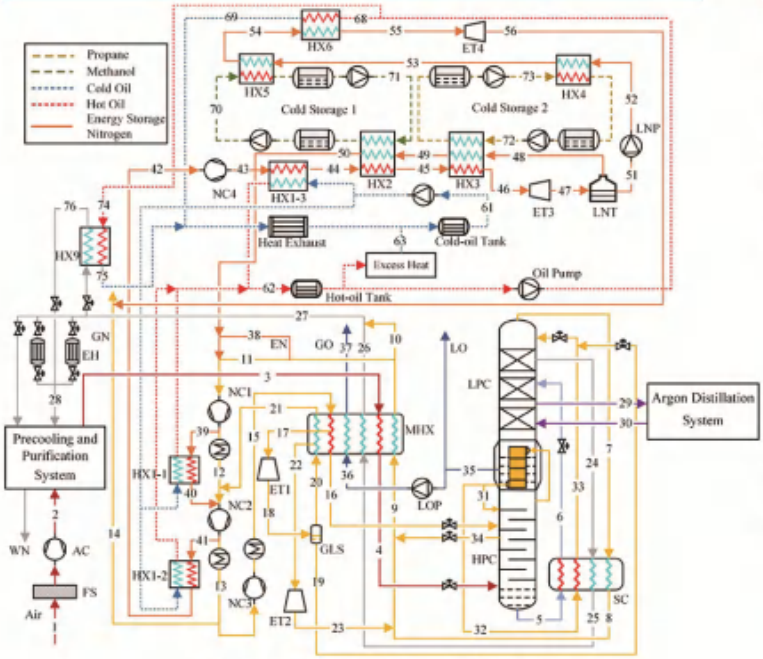


图1 AS-LNES-WHSM工艺流程图

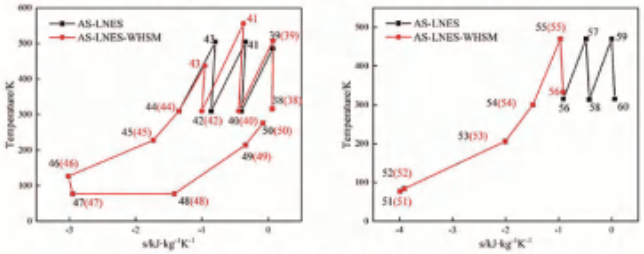


图2 AS-LNES-WHSM工艺的T-S图

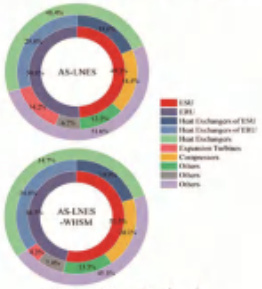


图3 烟损失分布

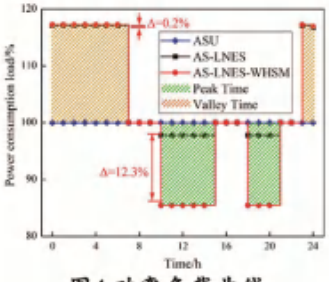


图4 功率负载曲线

2.能效分析

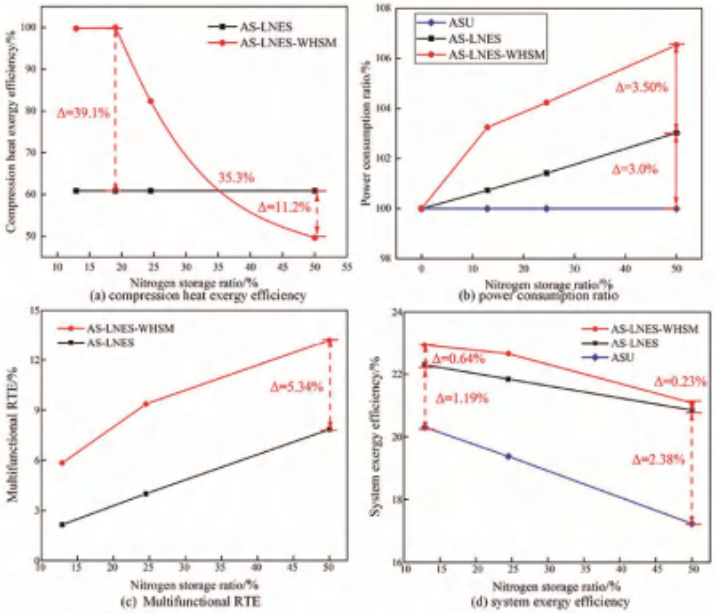


图5 （a）压缩余热㶲效率；（b）功耗比；（c）系统RTE；（b）系统㶲效率

表1 性能参数比较

Parameters	AS-LNES	AS-LNES-WHSM
$\eta_{RTE,\ baseline}$	0.506	0.537
$\eta_{ex,\ ESU}$	0.843	0.839
$\eta_{ex,\ ERU}$	0.788	0.913
$\eta_{ex,\ baseline}$	0.597	0.722

3.结论

本研究探讨了ASU与CES深度融合的可能性，这一工艺可以为未来储能技术的发展提供理论和数据基础。

1. AS-LNES-WHSM的基准RTE和㶲效率分别为0.537和0.722，分别比常规ASU-CES工艺高6.2%和20.9%。
2. AS-LNES-WHSM的简化投资回收期仅为1年左右，比常规ASU-CES工艺缩短了8.3年。

基于第一性原理的铁基载氧体还原动力学研究

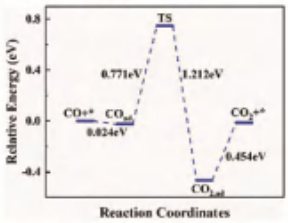
王洋，李振山*
清华大学能源与动力工程系，热科学与动力工程教育部重点实验室，北京，100084

摘 要

在化学链燃烧技术中，载氧体的反应动力学是材料制备、反应器设计以及系统运行的关键。如何从微观尺度出发，建立描述载氧体宏观尺度反应特性的动力学模型是当前的一大挑战。本研究以Fe_2O_3的还原为对象，建立了基于第一性原理的微观动力学速率方程理论。首先，基于密度泛函理论搜寻反应路径求解能垒等信息；第二，利用过渡态理论计算反应速率常数；第三，使用Langmuir吸附模型描述反应表面并基于质量作用定律建立表面反应速率方程；最终，通过考虑体相扩散描述载氧体整体转化率与表面反应速率的关系，得到基于第一性原理的微观动力学速率方程理论。将实验结果对该模型进行验证，结果表明数据吻合较好，说明该模型不依赖实验数据拟合即可对载氧体的反应动力学进行预测，这将为载氧体的制备与筛选提供一强有力的理论工具。

模 型

DFT计算



三步反应机理

R.1: $CO_{(g)} + Fe_2O_3 \rightarrow CO_{(ad)} + Fe_2O_3$

R.2: $CO_{(ad)} + Fe_2O_3 \rightarrow CO_{2(ad)} + Fe_3O_4$

R.3: $CO_{2(ad)} + Fe_3O_4 \rightarrow CO_{2(g)} + Fe_3O_4$

总反应：$CO + Fe_2O_3 \rightarrow CO_2 + Fe_3O_4$

过渡态理论

吸附速率常数： $k_{a,gas} = A_{st}(2\pi m_{gas} k_B T)^{-1/2}$

L-H表面反应速率常数： $k_{fwd} = \frac{Q_{vib}^{TS}}{Q_{Fe_2O_3}^3 Q_{vib}^{CO_{ad}}} \frac{k_B T}{h} \exp\left(-\frac{E_{fwd,2}}{k_B T}\right)$

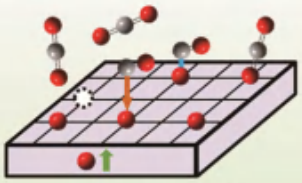
表面反应速率方程

$$\theta_{O^*} + \theta_{CO_{ad}} + \theta_{CO_{2,ad}} + \theta_V = 1$$

$$r_1 = k_{a,CO} p_{CO} \theta_{O^*} - k_{d,CO} \theta_{CO_{ad}}$$

$$r_2 = k_{fwd} \theta_{CO_{ad}} - k_{rev} \theta_{CO_{2,ad}}$$

$$r_3 = k_{d,CO_2} \theta_{CO_{2,ad}} - k_{a,CO_2} p_{CO_2} \theta_{O^*}$$



Langmuir吸附模型

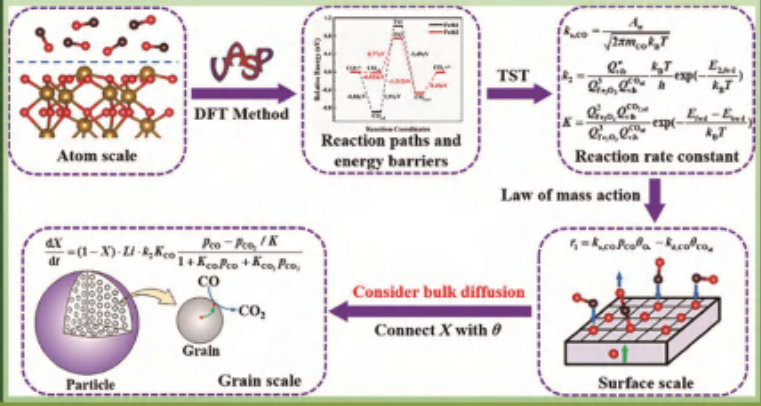
基于第一性原理的微观动力学速率方程理论

联系转化率X与表面份额θ： $X = 1 - C_{O_*}/C_{O_*}^0 = 1 - (1-\theta_V) = \theta_V$

考虑体相扩散： $dX/dt = r_2 - J_{O_*}/\Lambda_{O_*}$

模型表达式： $$\frac{dX}{dt} = k_{fwd} K_{CO} \frac{(1-X)}{1 + \frac{\rho_{OC} R_{OC} r_0}{3 M_O \Lambda_{O^*}}} \frac{p_{CO} - p_{CO_2}/K}{1 + K_{CO} p_{CO} + K_{CO_2} p_{CO_2}}$$

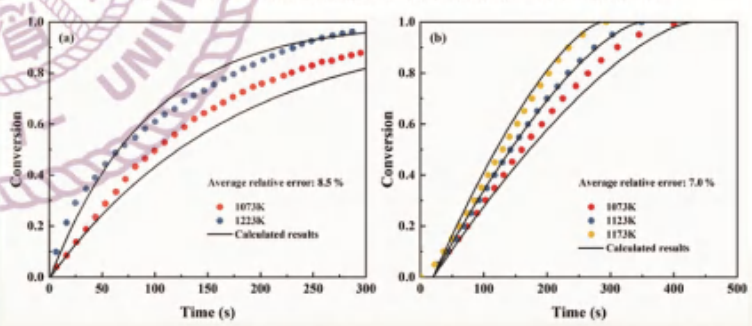
模型框架



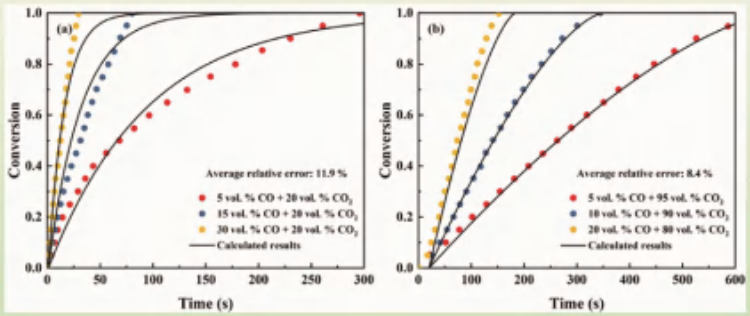
结果与讨论

模型验证

➢ 温度的影响：下图展示了两种Fe_2O_3在不同温度下与CO反应的动力学特性，结果表明实验结果与模型结果一致性良好，该模型能够较好地描述温度对载氧体反应特性的影响。



➢ 浓度的影响：下图展示了不同CO浓度下两种Fe_2O_3的反应动力学特性，结果表明实验结果与模型结果具有良好的一致性，该模型能够较好地描述浓度对载氧体反应特性的影响。



结 论

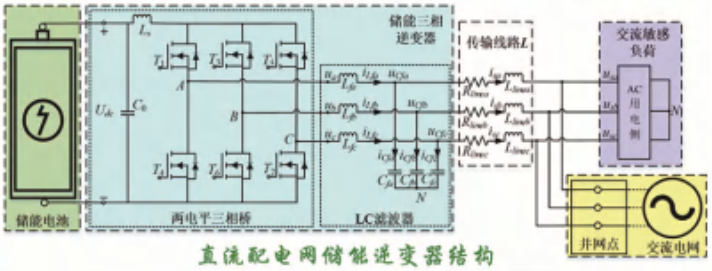
本研究基于第一性原理，从微观尺度出发，成功建立了不依赖实验数据拟合即可对载氧体反应动力学特性进行描述的动力学模型。首先，利用密度泛函理论搜寻反应路径求解能垒等信息；其次，利用过渡态理论计算反应速率常数；而后，基于Langmuir吸附理论，利用质量作用定理建立表面反应速率方程；最终，通过考虑体相扩散，联系载氧体转化率与表面反应速率的关系，得到上述模型。利用实验结果对模型进行验证，实验结果与模型预测结果具有良好的一致性，表明此模型成功将载氧体的反应微观反应特性与宏观动力学行为建立了联系，为载氧体的筛选与化学链技术的推进提供了一强有力的理论工具。

直流配电网储能逆变器负载侧电压-功率自适应均衡控制系统设计

张伟琦 王艳敏 宋凯 张涵清
(哈尔滨工业大学 电气工程及自动化学院 黑龙江 哈尔滨 150001)
(Tel:18895239266 Email:zwq1191678801@163.com)

文章背景与目标

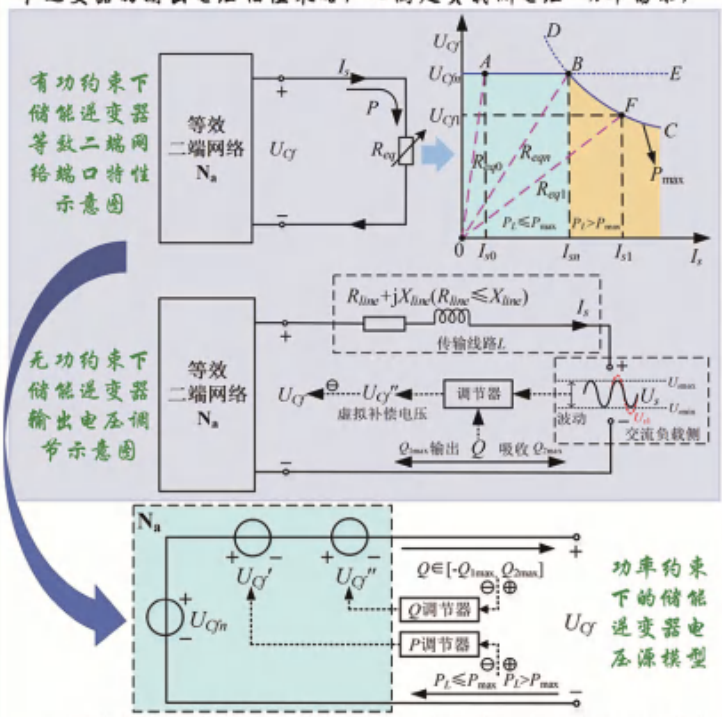
新能源配电网逆变侧运行方式的不断变化伴随着负载侧功率需求的多样化，这对储能逆变器输出电压与功率能力提出新的挑战。为增强储能逆变器负载侧电压-功率的自适应性能，降低新能源入网后对负载的影响，简化多类控制器并用的复杂性，本文基于滑模策略(SMC)设计了一种电压-功率自适应均衡控制系统。



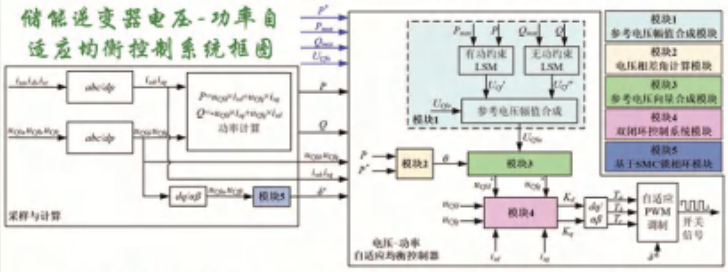
直流配电网储能逆变器结构

系统设计过程

(1)建立储能逆变器功率传输模型，以此分析有功/无功约束下逆变器的输出电压特性，并提出利用虚拟补偿电压自适应调节逆变器的输出电压幅值策略，以满足负载侧电压-功率需求；



(2)基于所提出策略按照控制功能分模块化构建电压-功率自适应均衡控制系统，引入滑模策略分别设计系统各模块控制器，并结合滑模控制律特性给出系统额的稳定性证明；

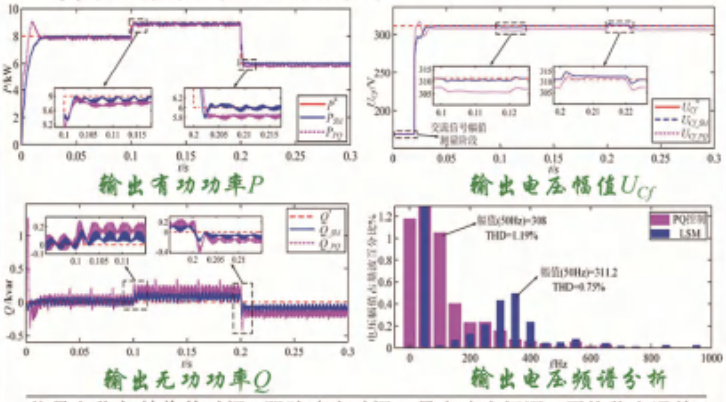


(3)设计不同实验分析并验证所设计控制系统的合理性。

实验设计与结果

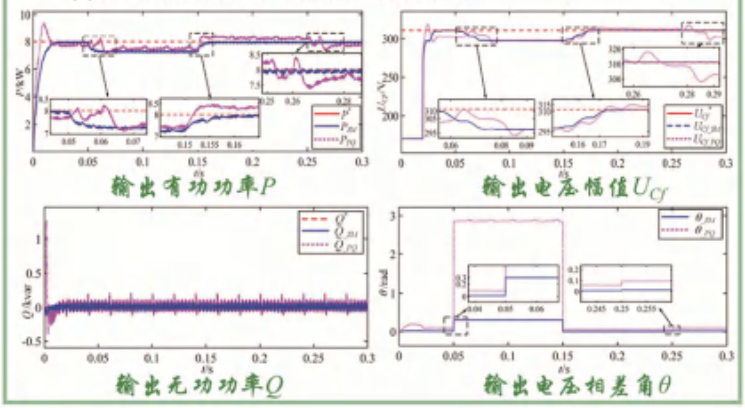
引入传统恒功率控制方法(PI控制器)作对比，通过设计多工况下的实验来验证本文所提出的自适应均衡控制系统的应用性能。

(1)系统负载功率跟踪实验分析



信号名称	初始收敛时间/s	跟踪响应时间/s	最大响应超调	平均稳态误差
P_{PQ}	0.040	0.012	1.095kW	0.228kW
P_{SM}	0.025	0.008	0.205kW	0.142kW
U_{Cf_PQ}	0.027	0.030	6.400V	5.200V
U_{Cf_SM}	0.022	0.023	3.400V	1.050V
Q_{PQ}	0.029	0.014	1.268kvar	0.170kvar
Q_{SM}	0.018	0.007	0.147kvar	0.077kvar
θ_{PQ}	0.020	0.021	3.990×10^{-3}rad	0.243rad
θ_{SM}	0.002	0.003	1.575×10^{-4}rad	0.016rad

(2)系统输出状态自适应转换实验分析



方法分析与总结

通过实验分析，得出本文所设计控制系统具有如下突出优势：

(1)所设计的电压-功率自适应均衡控制系统使得储能逆变器对负载侧功率的跟随能力显著提升。相比于传统控制策略，系统的输出电压与功率的响应时间平均提升了28.3%，输出稳态误差平均降低了58.7%，输出电压谐波频率平均降低了36.9%。

(2)所设计的电压-功率自适应均衡控制系统，由于引入滑模策略综合性地考虑并设计了储能逆变器控制环中的各功能模块，显著提升了逆变器在应对传输线路与负载侧故障时的自适应稳定。当传输线路参数与负载侧电压波动时，逆变器系统能够自动完成P/V模式至V/θ模式的状态转换，以此保证系统的输出电压与功率的快速稳定，有效提升了系统鲁棒性。

(3)虚拟电压的引入有效保护了储能逆变器的安全稳定运行。当负载侧功率需求激增时，电压-功率自适应均衡系统通过虚拟电压补偿降低输出电压幅值以保证逆变器以最大限制功率输出，在最大限度满足负载侧需求的同时，避免了储能逆变器的过载。

含储能配电网对光伏最大消纳能力分析技术研究

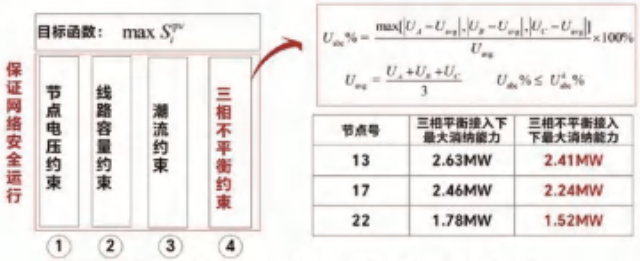
赵晨旭[1]、张磊[2]
1.天津大学电气自动化与信息工程学院，邮箱：248349577@QQ.com
2.天津大学机械工程学院，邮箱：86070576@QQ.com

文字摘要：

当前，我国正着力构建清洁低碳安全高效的能源体系，构建以新能源为主体的新型电力系统。随着以分布式光伏为代表的分布式电源规模化接入，配电网正在从传统的单向逐级辐射网络向双向多元交互系统转变，配电网的一对主要矛盾在于分布式资源开发潜力测算需求与配电网消纳边界难以刻画。因此，本文一方面从多要素建立开发模型，并对光伏接入进行精准测算；另一方面，立足电力系统层面，计及储能的时序搬移特性，引导网侧储能等可调节资源合理配置，开展提升配电网安全灵活运行水平，切实保障分布式电源消纳。

At present, our country is to construct clean low-carbon safe efficient energy system, construct a new energy as the main body of the new type of power system. With the large-scale access of distributed power supply represented by distributed photovoltaic, the distribution network is transforming from the traditional one-way step by step radiation network to a bidirectional multiple interactive system. A pair of contradictions in the distribution network lies in the difficulty of describing the demand for estimating the development potential of distributed resources and the absorption boundary of the distribution network. Therefore, on the one hand, this project considers multiple factors to calculate the development potential; on the other hand, based on the system level, taking into account the timing and movement characteristics of energy storage, it guides the rational allocation of adjustable resources such as energy storage on the grid side, improves the safe and flexible operation level of the distribution network, and effectively guarantees the consumption of distributed power.

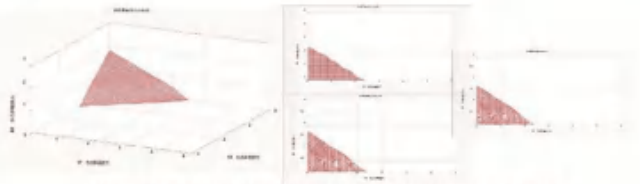
考虑分布式光伏单相接入的情况，为避免三相不平衡程度过高，引入三相不平衡程度约束：



节点号	三相平衡接入下最大消纳能力	三相不平衡接入下最大消纳能力
13	2.63MW	2.41MW
17	2.46MW	2.24MW
22	1.78MW	1.52MW

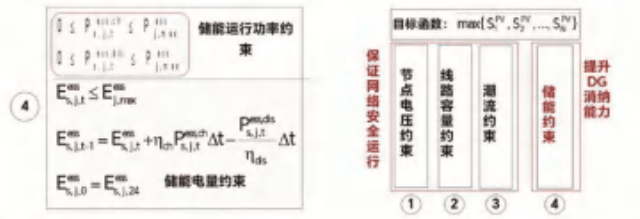
三相平衡接入时，才能达到单点接入下分布式光伏最大消纳能力边界

选取13、17、22节点作为分布式光伏接入位置，测算三点接入场景下分布式光伏最大消纳能力边界。

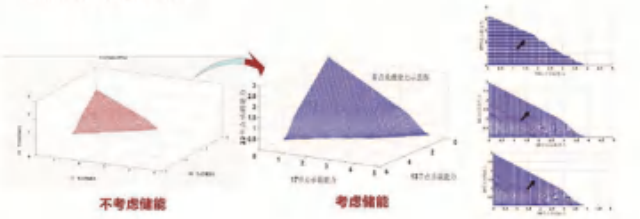


分布式光伏多点接入下，不同节点间的最大消纳能力存在制约关系，更适合用多维空间建模的方式进行描述

储能设备具有能量转移功能，能够有效提高分布式光伏的消纳比例，扩大分布式光伏最大消纳边界。



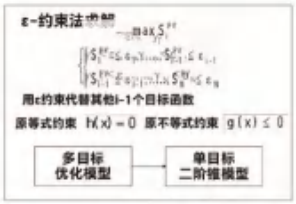
考虑储能影响后，17节点最大光伏消纳能力由2.46MW增长为3.57MW，13节点最大光伏消纳能力由2.63MW增长为3.91MW，22节点最大光伏消纳能力由1.78增长为2.94MW。配电网最大消纳能力边界得到明显扩大。



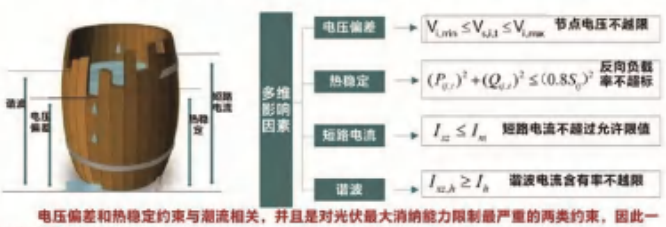
求解方法优缺点对比		
求解方法名称	优点	缺点
加权和方法	程序设计简单求解效率高	需要足够的先验知识，加权值分配主观性强
ε-约束法	简单易于实现适用性强	准确性依赖于对的合理取值
多目标遗传算法	算法精度高，可以找到多样性较好的解	计算时间长，可能无法得到稳定的最优解等问题

结合项目求解简单适用性强的需求，选择ε-约束法进行多目标求解

ε-约束法的原理是先对多个目标中最重要的一个进行优化，其他的目标作为约束条件考虑



分布式光伏的最大消纳能力受到多维因素的影响，每一种限制因素类似于木桶的木板，木桶中的最多能装载的水就是光伏的最大消纳能力，木板越短，则分布式光伏的最大消纳能力就越小。



电压偏差和热稳定约束与潮流相关，并且是对光伏最大消纳能力限制最严重的两类约束，因此一般重点考虑此两类约束。

本项目主要在分布式光伏开发潜力测算、分布式光伏最大消纳能力与最优接入分析、储能优化配置等方面进行研究，通过理论研究及算例验证得到的主要创新点如下：

- 提出了配电网分布式光伏最大消纳能力边界刻画方法，通过多维空间建模的方法，实现了不多点接入下不同节点间消纳能力制约关系的形象描述；
- 提出了考虑低碳效益的网侧储能优化配置方法，将碳排放成本纳入度量，避免了常规优化配置方法难以计及储能装置在低碳环保方面贡献的局限性；
- 开发了含储能配电网对光伏消纳能力辅助分析软件系统，将时序仿真、光伏消纳能力计算、光伏储能最优配置的流程及结果可视化展示，有效指导了配电网光储规划的相关决策。

低零碳交通

Low- and Zero- Carbon Transportation

低零碳交通 Low- and Zero- Carbon Transportation

The driving factors and mitigation strategy of CO_2 emissions from China's passenger vehicle sector towards carbon neutrality

Zhihui Gao[1,2], Qi Zhang [1,2,3 *], Boyu Liu[1,2], Jiangfeng Liu[1,2], Ruiyan Ni[1,2], Kexin Yang[1,2]
（1 School of Economics and Management, China University of Petroleum (Beijing), Beijing 102249, China;
2 School of Business Administration, China University of Petroleum-Beijing at Karamay, Xinjiang 834000, China;
3. Tianshan Research Institute, Xinjiang, 834000, China;）

Abstract

Background, Aims and Scope. Passenger vehicles have significant environmental concerns due to CO_2 emissions from well to wheel process. In 2019, road transport accounted for 86.8% of the total emissions in the transport sector. The present study aimed to identify the key emission driving factors and propose carbon abatement strategy.

Methods. An integrated analytical framework is developed, consisted of the vehicle fleet-based fuel cycle carbon emissions accounting model, Logarithmic Mean Divisia Index method (LMDI) and scenario-based prediction method.

Results and Discussion. i) The annual CO_2 emissions of passenger vehicles, which increases from 228.4 Mt in 2012 to 461.6 Mt in 2020, was primarily driven by the income per capita and passenger vehicle ownership effect. ii)The vehicle fuel intensity and market structure contributed 41.6 and 1.8 Mt respectively on CO_2 emission reduction, and the emission coefficient effect has more significant impacts on emission reduction in new energy vehicles (NEVs). iii) By optimizing the market structure, 3425.8 Mt CO_2 emissions could be mitigated, yielding the lowest aggregate emissions among all emission reduction strategies. iv) The battery technology progress will continue to contribute in carbon reduction till 2045. The effectiveness of the emission coefficient reduction strategy has been strengthened after 2045 and will bring the lowest annual carbon emissions of 26.0Mt/year by 2060.

Conclusion. The development paths of different emission reduction strategies are different, it is essential to provide corresponding policy support at different stages of passenger vehicle development. During phases of rapid growth in the number of passenger vehicles, policies should focus on promoting technological innovation and improving fuel efficiency. As NEVs dominate the market, and the marginal benefits of technological innovation begin to weaken, policies should provide more support for the use of clean energy and further optimization of transportation structures.

Key words: Passenger vehicles; LMDI model; Carbon accounting model; Driving factor analysis; Emission reduction strategies

低零碳交通 Low- and Zero- Carbon Transportation

Configuration of Airspace Corridors in China's Civil Airspace and Analysis of Carbon Emissions

Ruiling Han[1,2,3], Xinyue Ran[1]
(1. School of Geographical Sciences, Hebei Normal University, Shijiazhaung, 050024, China;
2. Hebei Key Laboratory of Environmental Change and Ecological Construction, 050024, China;
3. Hebei Technology Innovation Center for Remote Sensing Identification of Environmental Change, 050024, China)

Abstract
Background, Given the inclusivity of airspace corridors with respect to routes and aircraft, the delineation of airspace corridors can be employed to identify nationally significant air channels based on route traffic. By investigating the carbon emissions associated with airspace corridors, this research not only contributes to refining the study of aviation carbon emissions from the perspectives of route traffic and route length but also facilitates an effective assessment of the impact of carbon emissions within airspace corridors.
Aims and Scope, This paper explores carbon emissions in airspace corridors and flight routes, departing from the traditional focus on point and area-based studies of aviation carbon emissions. It offers a dynamic and comprehensive portrayal of the linear developmental trends of aviation carbon emissions on a macroscopic scale. Firstly, utilizing surveyed route data, similar airborne routes were clustered, and clusters with their central lines were extracted. Subsequently, airspace corridors were delineated based on these central lines. Secondly, an additional flight distance threshold was set, and route participants were selected to identify high-traffic airspace channels within China. The existing route network structure was analyzed accordingly. Thirdly, carbon emissions for each corridor were calculated, considering factors such as flight volume, aircraft type, and aircraft cruise time, to assess the specific spatial impact and its extent on carbon emissions.
Methods, K-means clustering method, airspace corridor delineation method, aircraft carbon emissions calculation method, super-efficiency SBM model based on non-desired outputs
Results and Discussion, Seven airspace corridors were defined, primarily situated in the central and eastern regions of China, presenting a distinctive "diamond-shaped three-dimensional structure" anchored by the four major airport clusters in China. These corridors exhibited variations in operational scale. The Harbin–Haikou corridor boasted the highest participation and flight volume, whereas the Chongqing–Zhuhai corridor had the fewest participants and the smallest flight volume. Collectively, these seven airspace corridors emitted a total of 619,431 tons of carbon. Notably, the Harbin–Haikou corridor registered the highest carbon emissions, while the Chongqing–Zhuhai corridor recorded the lowest. This paper surpasses the typical confines of aviation carbon emission research centered on airports. It actively investigates the linear dimensions of aviation carbon emissions, moving beyond the traditional emphasis on point-based studies. The paper delves into the challenges related to linear carbon emissions in aviation.
Conclusion, (1) Seven airspace corridors were identified, primarily situated in the central and eastern regions of China, forming a "diamond-shaped three-dimensional structure" with the four major airport clusters in China serving as its vertices. The core city network structure plays a pivotal role in shaping the development of the aviation network structure.
(2) Over the study period, the cumulative carbon emissions for the seven airspace corridors totaled 619,431 tons. Corridor carbon emissions and emission efficiency exhibited a positive correlation with their operational scale.
(3) Factors such as aircraft type, cruise time, and flight distance significantly impact both carbon emissions and emission efficiency within the airspace corridors.
Key words
Route Clustering, Air Corridor, Network Features, Aviation Carbon Emissions

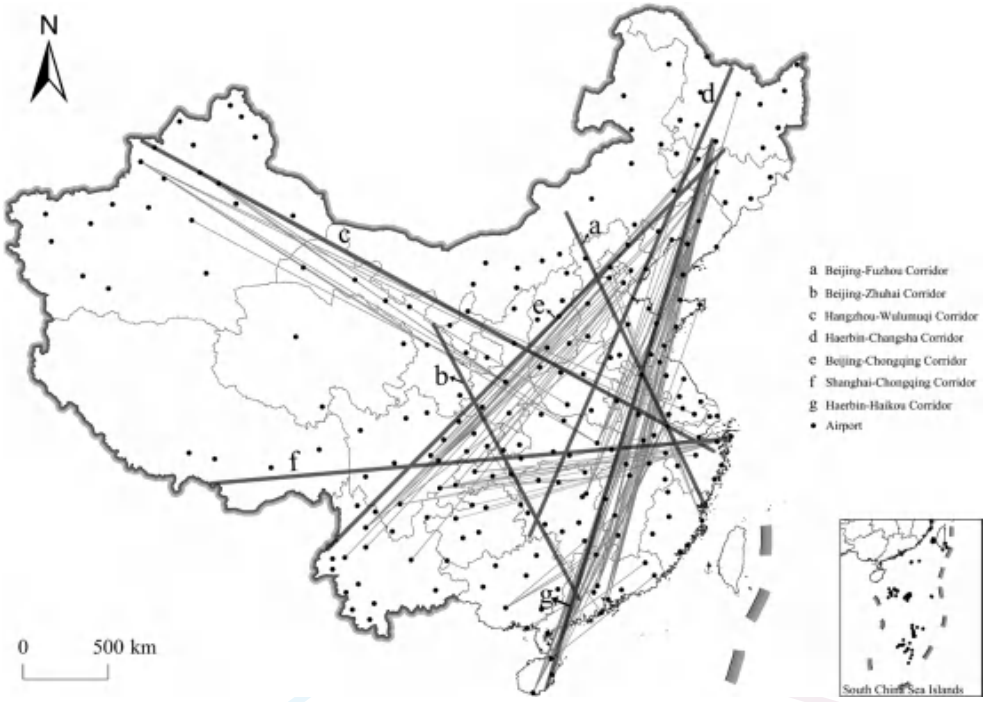


Fig1 Air Corridor Location

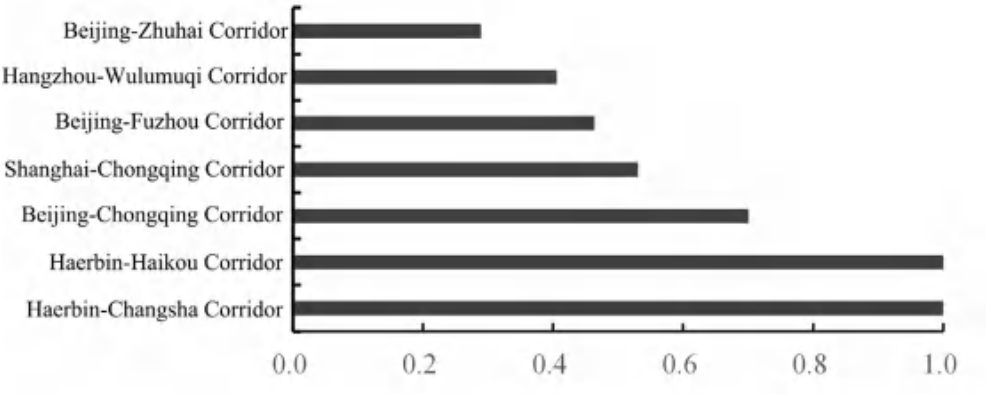


Fig 2 Air Corridor Carbon Emission Efficiency

低零碳交通 Low- and Zero- Carbon Transportation

Path planning of intelligent logistics vehicles for fresh materials in the context of carbon neutrality

Yaqin Li[1]
（1.Liaoning Technical University, Huludao 125000, China）

Abstract:
Background, Aims and Scope. With the proposal of carbon neutrality, reducing the carbon emissions of logistics vehicles has become an important task. In order to solve this problem, this paper proposes an improved ant colony algorithm to optimize the path planning of logistics vehicles
Methods. In this paper, a path planning model of intelligent logistics vehicles for fresh materials is established, and the capacity limitations, time window limitations, and carbon emission limits of logistics vehicles are considered. Then, by improving the ant colony algorithm, the carbon emission factor was introduced, and the fitness function was designed to evaluate the advantages and disadvantages of the path. In each iteration, the colony selects the next node based on the pheromone concentration and heuristic information, and updates the pheromone concentration. At the same time, in order to increase the diversity of the algorithm and avoid falling into the local optimal solution, the stochastic perturbation operation is introduced.
Results and Discussion. Through comparative experiments, the improved ant colony algorithm proposed in this paper is compared with the traditional ant colony algorithm. Experimental results show that the improved ant colony algorithm has obvious advantages in reducing carbon emissions and optimizing path planning. Compared to traditional algorithms, the improved algorithm reduces path length and carbon emissions by 10% and 15%, respectively.
Conclusion. Based on the improved ant colony algorithm, this paper proposes a path planning method for intelligent logistics vehicles suitable for fresh materials in the context of carbon neutrality. This method has significant effects in reducing carbon emissions and optimizing path planning, and provides an effective solution for the path planning of intelligent logistics vehicles for fresh materials.
Keywords: carbon neutrality; improved ant colony algorithm; Intelligent logistics vehicles

低零碳交通 Low- and Zero- Carbon Transportation

A Critical Review on Recycling Potential and Risk Analysis of Critical Metals for Traction Batteries

MA Tian[12], ZHANG Qi[123], LIU Boyu[12], TANG Yanyan[4]
(1. School of Economics and Management, China University of Petroleum (Beijing), Beijing 102249, China；2. Tianshan Research Institute, Karamay, 834000, Xinjiang, China; 3. School of Business Administration, China University of Petroleum (Beijing) at Karamay, Karamay, 834000, Xinjiang, China; 4. School of Economics and Management, China University of Geosciences (Beijing), Beijing, 100083, China)

Abstract
Background, Aims and Scope. The spent traction batteries are expected to rise explosively due to the massive adoption of EVs (electric vehicles). The critical metals, such as Lithium (Li), Cobalt (Co), and Nickel (Ni), contained in spent traction batteries will be an important material source for manufacturers of batteries. There is extensive attention and concern for metal recycling of traction batteries around the world. However, most articles reviewed technology details of the recycling processes, and the quantitative scale of critical metal recovery in the future remains unclear. Furthermore, various risks and uncertainties of metal recycling have not yet been addressed clearly, such as poor economy, safety accidents, and environmental impacts.
Methods. This paper provides an overview of recovery potential influencing factors, as well as reviews the predicted results of recovery potential in the existing literature. On this basis, the associated risks of economic, environmental, safety, and political were analyzed.
Results and Discussion. The results show that: (1) Li recycled will reach current global mine production around 2036 as Co recycled in China will be lower than the current mine import during 2025-2040. The recycling of Ni is very low relative to current world production or imports in China and the US. (2) The key factors that affect the metal recovery potential include the type of cathode material, lifetime of batteries, sales of EVs, collection rate of batteries, lifetime of cascade use, cascade use rate, and recovery rate of metals. (3) Furthermore, the reason why battery recycling is so difficult to make a profit. Different recycling processes have different environmental impacts, and the environmental problems of collection, sorting, and transportation are scarcely considered. The safety risks of battery recycling are attributed to three aspects: management, technology, and the ambient environment. Additionally, the incomplete regulation framework also creates a critical conundrum.
Conclusion. The present study makes the recycling potential of spent traction batteries clearer and summarizes the risks of battery recycling, as well as points out the further potential research direction, followed by policy implications and recommendations.
Key words: critical metal; recycling potential; risk analysis

低零碳交通 Low- and Zero- Carbon Transportation

The Development Status of the Fuel Cell for the Shipping Industry and the Prospect of the Solid Oxide Fuel Cell for the Maritime Application

WANG Xiao-yu, ZHU Jian-zhong, HAN Min-fang
(Department of Energy and Power Engineering, Tsinghua University, Beijing 100084, China)

Abstract

Background, Aims and Scope. In the context of the increasingly strict pollutant emission regulations and carbon emission reduction targets proposed by the International Maritime Organization (IMO), the shipping industry is seeking new types of marine power plants with the advantages of high efficiency and low emissions. Among the possible alternatives, the fuel cell is the most practical technology, as it provides an efficient means to generate electricity with low pollutant emissions and carbon emissions. At present, very few comprehensive researches focus on the maritime applications of the fuel cell.

Methods. News reports and literature on the maritime applications of the fuel cell in the past sixty years were collected, and the industrial development status and prospects of the marine fuel cell were summarized.

Results and Discussion. Some countries in Europe, North America and Asia have invested heavily in researching and developing the marine fuel cell, and a series of research projects have achieved concrete results, such as the industrialized marine fuel cell system or practical demonstration applications. At present, the worldwide research of the marine fuel cell focuses more on the proton exchange membrane fuel cell (PEMFC). However, the power demand of the marine fuel cell in the future will show steady growth, and thus the solid oxide fuel cell (SOFC), with the advantages of higher power, greater efficiency, long life span and fuel diversity, will be the mainstream in the next research stage. Nowadays, there have been some successful applications of the SOFC in the shipping industry for supplying the auxiliary power or the propulsion power.

Conclusion. Although some challenges exist, with the rising global fossil fuel prices and increasingly stringent environmental protection requirements, applying the fuel cell, especially the SOFC to ships on a large scale, which will lead the upgrading and updating of the marine power system to achieve energy conservation and emission reduction of the shipping industry, can be expected with a global concerted effort.

Key words: Fuel cell; Electric propulsion; Marine clean energy; Energy conservation; Emission reduction; Marine electrical equipment

Table 1 Parameters of five typical types of fuel cells.

Type	Operating Temperature	Fuel	Efficiency	Life Span
AFC	50–200 °C	H_2	50–55%	3000–10,000 h
PAFC	100–200 °C	H_2	40–45%	15,000–40,000 h
MCFC	650–700 °C	H_2, CO, CH_4, etc.	50–55%	10,000–20,000 h
PEMFC	25–100 °C	H_2	40–50%	5000–10,000 h
SOFC	600–1000 °C	H_2, CO, CH_4, etc.	50–65%	8000–100,000 h

Figure 1 Timeline of candidate short-, mid- and long-term GHG reduction measures.

Table 2 Maritime application status of the main types of fuel cell and their challenges.

Type	Maritime Application Status	Main Challenges
AFC	Very few applications	Relatively low output power High requirements for pure hydrogen and oxygen Relatively low lifespan Single fuel type Requirement for expensive platinum catalyst
PAFC	No application	Low output power Low durability Requirement for expensive platinum catalyst
PEMFC	Wider applications	Relatively low output power High requirements for pure hydrogen Complex system for water management Relatively low lifespan Single fuel type Requirement for expensive platinum catalyst
MCFC	Fewer applications	Relatively high cost Oversized volume Relatively low lifespan Existence of liquid molten carbonate Slow dynamic response
SOFC	Increasing applications	Relatively high cost Slow dynamic response

低零碳交通 Low- and Zero- Carbon Transportation

Actions and Policies of Airport Carbon Reduction in Economically Developed Countries

ZHANG Hong-ru[1] LIU Huan[1]
1.State Key Joint Laboratory of ESPC, State Environmental Protection Key Laboratory of Sources and Control of Air Pollution Complex, School of Environment, Tsinghua University, Beijing 100084, China

Abstract
Background, Aims and Scope. With the rapid growth of the aviation industry and immature emission reduction management, aviation industry have become a critical battleground for carbon emission reduction. Managers and participants of the aviation industry, including international organizations, countries, airlines, airports, aircraft manufacturers, aviation service providers, fuel suppliers and so on, are facing complex and onerous pressure to reduce emissions. The study is expected to find out the position and potential of the airport in the carbon emission reduction of the whole aviation industry. And the study covers more economically developed countries, and sorts out and horizontally compares the policies, plans and actions of these developed countries or regions.

Methods. Research methods are mainly case study and literature review, supplemented by empirical research.

Results and Discussion. Economically developed countries have implemented a series of policies and complementary measures to encourage carbon reduction in the airport sector. At the planning level, these countries have set timelines for organizing zero-emission flights; however, there is a divergence in perspectives on achieving zero carbon emissions in planning. For instance, the European Union believes in taking responsibility for the external uneconomical aspects of flights to achieve zero carbon emissions. At the operational level, economically developed countries have established low-carbon airports, but carbon reduction actions are primarily limited to scheduling and optimization at airports, resulting in limited emission reduction efforts. Few measures effectively control aircraft carbon emissions. The fundamental technical measures for carbon reduction lie in improving fuel efficiency and low carbon fuels.

Conclusion. Most of the carbon emissions in the airport area are contributed by aircraft, less by the airport itself. Therefore, airport carbon emission reduction depends on aircraft emission reduction, and aircraft emission reduction essentially depends on technological breakthroughs, then making zero-carbon green fuel the main force of emission reduction. With the improvement of fuel efficiency and the optimization of airport scheduling and operation in the future, there are marginal benefits and a limit of emission reduction potential. The key challenge is how airports can cooperate to implement these basic technical measures without affecting aviation safety and travel experience. This represents the future direction of the airport in solving the problem of reducing carbon emissions.
Key words: carbon emission reduction; aviation industry; green airport; emission reduction potential

低零碳交通 Low- and Zero- Carbon Transportation

New Energy Vehicle Charging Facility Industry and Technology Forecast in China

Ruibo Zhao [Harbin Institute of Technology (Shenzhen)]

Abstract: As a significant role in global energy transition, China has made encouraging performance in clean energy and new energy vehicles (NEV). The domestic NEV production has increased by 2500 times in the last ten years and accounts for over 65% of the global sales. However, the unbalanced development between NEV and EV charging facility put new challenge to the future of Chinese EV industry. This essay thus explores the domestic EV charging facility industry, analyzes the effects of NEV industry and charging facility on carbon emission and finally predicts the technology trends in the future by collecting and analyzing the relative data from 2011 to September 2023. The results shows that the development of NEV and EV charging facility have made obvious progress in declining the carbon emission. The article also analyzes the current problems of EV charging and battery changing, providing suggestions and guidelines for the future development of this industry.

Keywords: energy transition, new energy vehicles, charging facilities, low-carbon economy

Comparison Assessment of Carbon Footprint and Environmental Impacts of Power Lithium-ion Batteries for Electric Vehicles

CHEN Quanwei[1], LAI Xin[1,*] CHEN Junjie[1], HAN Xuebing[2], LU Languang[2], ZHEGN Yuejiu[1]

[1]*School of Mechanical Engineering, University of Shanghai for Science and Technology, Shanghai 200093, China*

[2]*School of Vehicle and Mobility, Tsinghua, Beijing 100084, China*

**E-mail address: laixin@usst.edu.cn (X. Lai)*

Highlights

- A technology-resource-environment coupling method for the sustainable evaluation of battery life-cycle is proposed.
- Key processes and materials contributing to environmental burdens and high carbon emissions during the battery production are identified.
- Multi-indicator analysis based on battery performance and geographic differences compares the applicability of different calculation methods in use-phase.
- Environmental impacts of three hydrometallurgy, direct material recycling, and multi-recycling of NCM and LFP battery are investigated.

Introduction

Under the major strategic drive of China's "Dual Carbon" initiative, lithium-ion batteries have ushered in significant development opportunities, while the tracking of their full-lifecycle carbon footprint and environmental indicators have become a hot research topic. However, there are challenges in calculating carbon emissions and implementing emission reduction measures.

Methodology

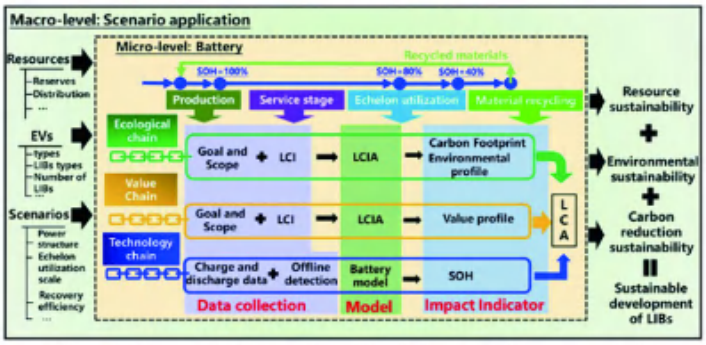


Fig. 1. Scenario-based methodological framework for sustainable evaluation.

Results and Discussion

Energy consumption in the battery production has a significant environmental impact. There are large differences between batteries with different chemical systems.

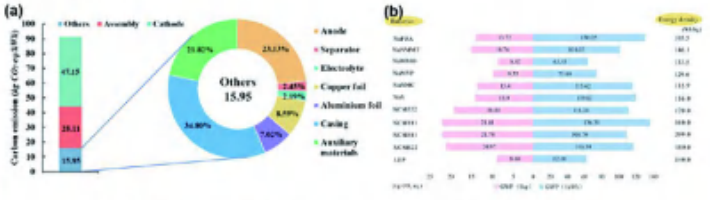


Fig. 2. Carbon emission and environmental impacts of battery production.

Results and Discussion

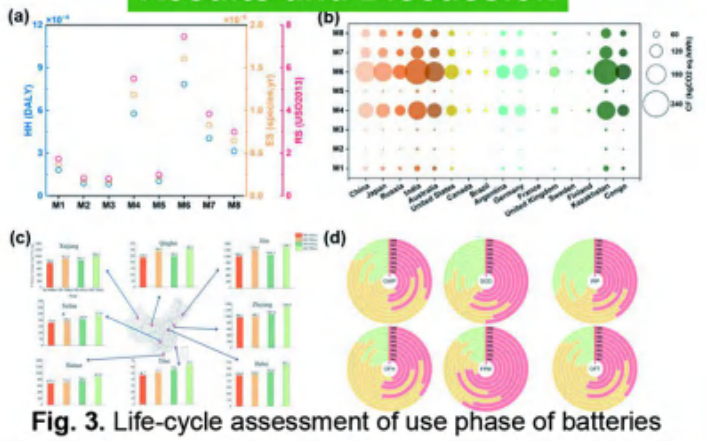


Fig. 3. Life-cycle assessment of use phase of batteries considering geographical changes and multiple indicators.

The environmental impacts significantly depending on the methodologies used to calculate energy consumption during usage-phase, as well as the process routes employed in recycling phase.

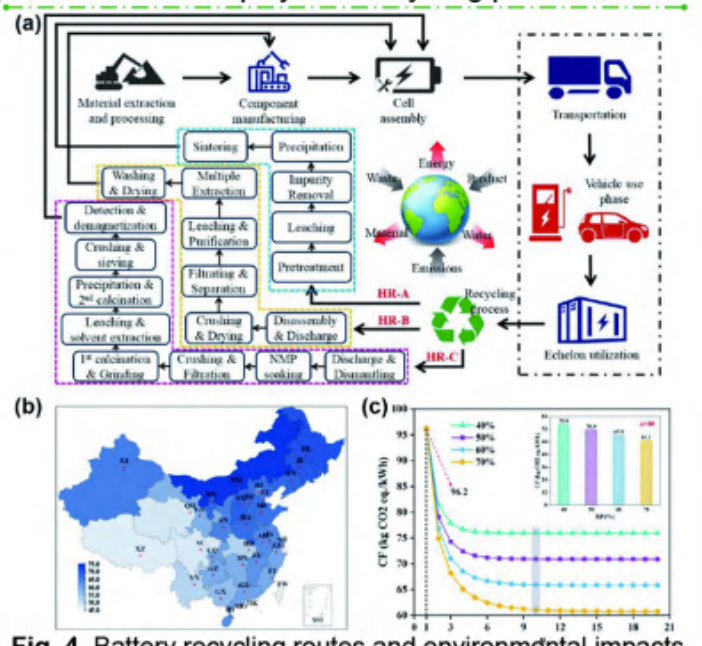


Fig. 4. Battery recycling routes and environmental impacts.

Synergistic Control Effects and Cost-Benefit Analysis of Pollution Reduction and Carbon Mitigation in China's Transportation Sector under the Dual Carbon Targets

Name: Zhang Tongtong Affiliation:China University of Petroleum (Beijing) Email: tongtong10212021@163.com

Introduction

Concerted efforts to reduce pollution and carbon emissions in the transportation sector are crucial for China to achieve the dual carbon targets. At present, there is still a lack of comprehensive research on the synergistic effects of pollution reduction and carbon mitigation in China's transportation sector over a long time scale and the cost control thereof, based on the dual carbon targets. Based on this, this study has constructed a comprehensive assessment model for pollution reduction and carbon mitigation in China's transportation sector, which is of reference significance for China and other countries facing the dilemma of pollution reduction and carbon mitigation.

Method

This study builds upon the LEAP model framework to construct a comprehensive assessment model for pollution reduction and carbon mitigation within China's transportation sector. It forecasts the energy consumption and emissions of CO_2 and six major air pollutants (CO, SO_2, NO_X, $PM_{2.5}$, PM_{10}, and HC) from 2021 to 2060 under eight emission reduction measures. Furthermore, it analyzes the synergistic control effects and costs of CO_2 and air pollutants under various emission reduction strategies.

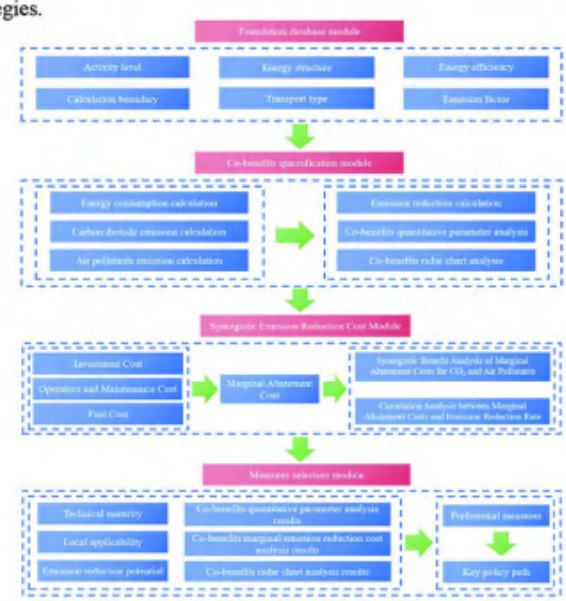


Fig 1 Structure of comprehensive assessment model for pollution reduction and carbon mitigation in China.

Results and discussion

In terms of synergistic control effects, adjusting the mode of transport (AMT) and energy efficiency improvement (EEI) have significant synergistic benefits across the entire Chinese transportation sector, but the extent of emission reduction is relatively small. Vigorously developing electricity (VDE) yields significant synergistic benefits in intercity passenger transport and urban passenger sectors, with noticeable pollution reduction and carbon reduction effects in freight and urban passenger sectors. Vigorously developing biofuels (VDB) and vigorously developing hydrogen (VDH) offers the best synergistic benefits in the intercity passenger transport sector, along with a significant contribution to emission reduction. However, vigorously developing liquefied natural gas (VDL) has a negative synergistic effect in the freight and intercity passenger transport sectors.

In terms of synergistic emission reduction costs, at the initial stage of emission reduction, it is crucial to promote measures that have a negative cost, such as adjusting the mode of transport (AMT), energy efficiency improvement (EEI), reducing the travel frequency of private cars (RFC), and regulating the number of private cars (RNC). Vigorously developing electricity (VDE) and vigorously developing hydrogen (VDH) are associated with high emission reduction costs. These measures have considerable potential for emission reduction but do not have a cost advantage in the initial stages. Over time, the marginal cost of emission reduction for all measures is expected to decrease.

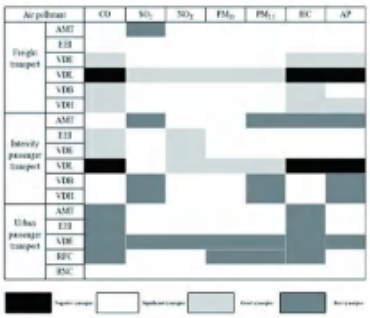


Fig 2 Distribution of synergistic effects of carbon and pollution reduction.

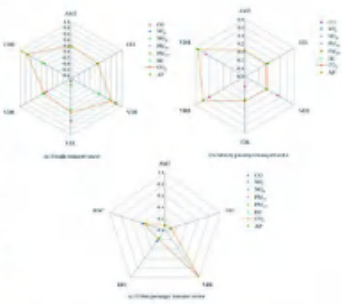


Fig 3 Radar analysis of synergies in 2060.

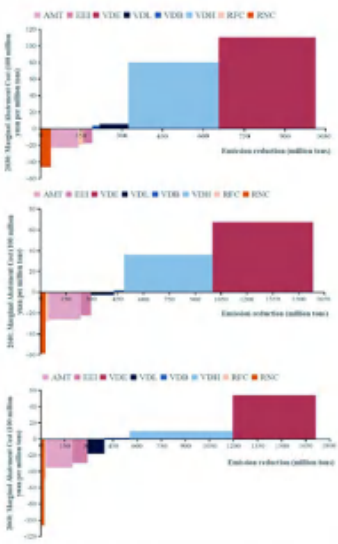


Fig 4 CO_2 and air pollutants coordinately control marginal abatement cost curve.

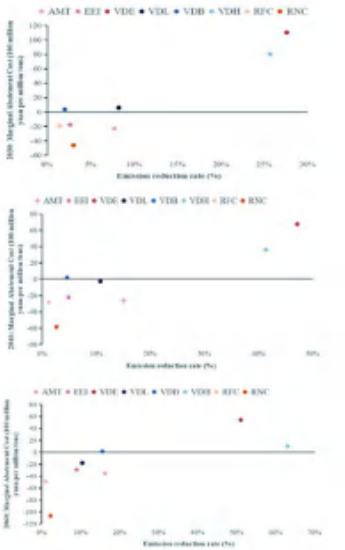


Fig 5 Scatter plot of emission reduction rate and marginal abatement costs for synergistic control of CO_2 and air pollutants.

Conclusion

To achieve the dual carbon targets at an early date, China should expedite the cleansing and decarbonization of its transportation energy system. It is prudent to cautiously advance the large-scale application of liquefied natural gas in the transportation field, and accelerate the reduction of transportation emissions through the diversification of energy structures. At the same time, it is necessary to consider synergistic benefits to attain a win-win effect. For measures with high emission reduction costs, the government can adopt certain subsidies or incentive policies to ensure the stability of the returns on emission reduction investments and to reduce the risks associated with these investments.

中国省际交通碳排放特征及其类型化低碳规划策略探索

杨宇灏（天津大学建筑学院，天津，300072）

基金支持：国自然基金重点项目（52338002），国家重点研发计划（2018YFC0704700）

yangyuhao@tju.edu.cn

Introduction

- 践行低碳发展以应对日益严峻的全球气候变化已成为重要的国际共识。交通领域是全球碳排放的主要来源之一，也是中国实现“双碳目标”的重点管控行业；
- 由于中国地域辽阔，区域发展不均衡，导致了各省交通部门的碳排放水平存在较大的差异；
- 中国的省级行政单位作为实现国家低碳目标的次级执行单位，具有统筹兼顾和协调平衡的顶层制度作用；
- 挖掘交通部门的省际差异，揭示省际交通碳排放的特征，进而制定适合于不同地区的差异化交通碳减排策略，是有效实现国家交通低碳发展目标的基本前提和重要保障。

Methods and Results

一、省际交通碳排放特征指标集的构建

基于Kaya公式的扩展，推导出省际交通碳排放在经济发展、人口密度、能源结构、运输效率、技术研发、基础设施建设、交通运行状态、居民交通行为等方面的影响因素指标。

Kaya公式

$$C = \frac{C}{PE} \times \frac{PE}{GDP} \times \frac{GDP}{P} \times P$$

影响因素扩展

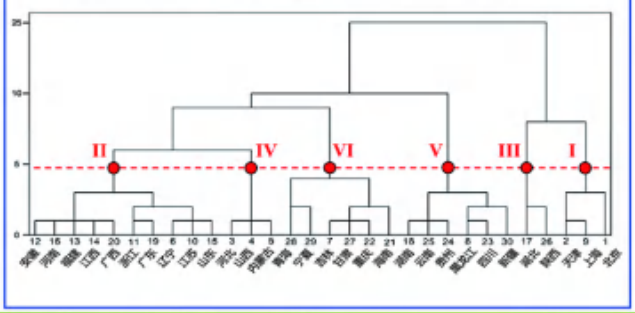
$$C_i = \sum_{k=1}^{n} \frac{C_{ik}}{E_{ik}} \times \frac{E_{ik}}{E_i} \times \frac{E_i}{GDP_i} \times \frac{GDP_i}{TS_i} \times \frac{TS_i}{SB_i} \times \frac{SB_i}{W_i} \times \frac{W_i}{P_i} \times P_i$$

省际交通碳排放特征指标集

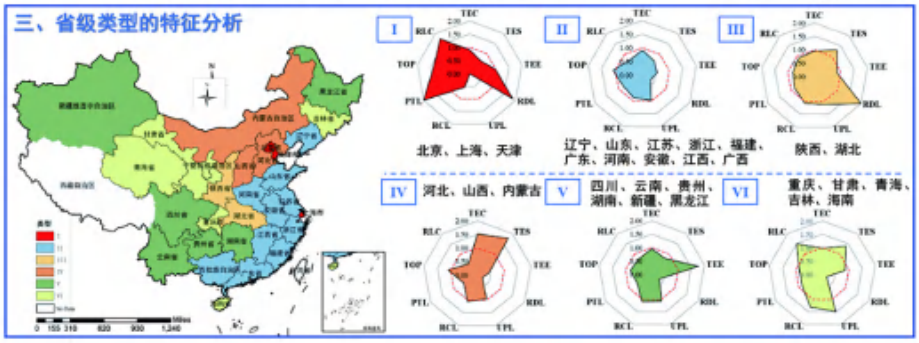
影响因素	指标名称	指标含义
经济发展	交通经济结构（TEC）	反映各省交通部门经济的结构占比在省际中的水平（即该指标与各省平均值之比，下同）。
能源结构	交通能源结构（TES）	反映各省交通部门的能源消耗中清洁能源的结构占比在省际中的水平
能源强度	交通运输能耗效率（TEE）	反映各省交通运输周转量（含客运和货运）的能源消耗在省际中的水平
	交通技术研发水平（RDL）	反映各省交通部门的技术研发能力在省际中的水平
人口因素	城市人口密度水平（UPL）	反映各省城市和县城的人口密度的比值差距在省际中的水平。
基础设施	道路建设水平（RCL）	反映各省城市道路和公路的建设强度在省际中的水平
	公共交通建设水平（PTL）	反映各省城市公共交通（公共汽电车、轨道交通和出租车）的建设强度在省际中的水平
污染强度	交通运行压力（TOP）	反映各省的道路交通运行的潜在压力（私家车）和现状压力（拥挤度）在省际中的水平
居民行为	居民生活消费水平（RLC）	反映各省居民生活的消费水平和旅行频率在省际中的水平

二、数据标准化和聚类分析

- 基于省际平均值的相对指标构建法；
- 最大值“归二法”限定的数据标准化手段；
- 特征指标的数值区间为[0, 2]；
- Ward法进行层次聚类分析；
- 将2019年中国30个省份划分为I~VI种特征类型。



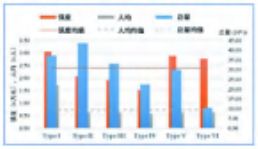
三、省级类型的特征分析

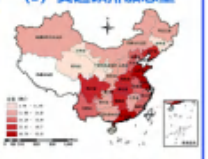


四、省际交通碳排放的核算

根据“排放因子法”对各省交通部门碳排放的“总量”、“强度”和“人均”进行了核算：

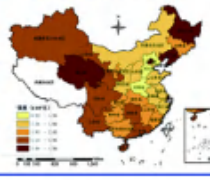
- 总量较高主要为东部沿海及其邻接省份；
- 强度较高主要呈现集中在西部、东北部省份；
- 人均较高呈现出分散分布的空间特征。

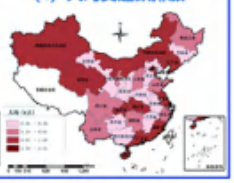




- 以三者与各自省际平均值的相对关系，识别出各类型在交通碳减排上的优先控制方向。

I IV → 人均控制型
II III → 总量控制型
V VI → 强度控制型





五、交通碳排放与特征指标的相关性分析

- 城市人口密度水平（UPL）、交通技术研发水平（RDL）和公共交通建设水平（PTL）对人均交通碳排放具有非线性作用和阈值效应；
- 验证了PTL对交通碳排放的阈值效应和负面影响；
- 人均交通碳排放的优先控制指标是RDL、PTL、UPL、RLC和TOP；
- 交通碳排放强度的优先控制指标是TEE、RLC、TEC和PTL。

六、省际交通低碳发展的碳减排策略及机制建设

- 为类型I~VI的省份提供了相匹配的差异化碳减排策略和控碳绩效考核指标KPIs；
- 提出了类型的区域能源-经济的合作发展战略、区域先进技术的共享推进计划和区域协同治理的机制建设；
- 在城市化水平较高省份的城市地区，需要重视城市人口规模的过度密集和公共交通的过度配置问题；
- 突破交通技术发展对碳排放影响的缓慢前期阶段，需要坚持长期的研究投入支撑或引进先进的节能减排技术。

类型的控碳绩效考核指标（KPIs）

	TEC	TES	TEE	RDL	UPL	RCL	PTL	TOP	RLC
Type I									
Type II									
Type III									
Type IV									
Type V									
Type VI									

增加　大幅增加　降低　大幅降低　保持

Conclusion

- 通过Kaya公式的有效扩展，推导出了省际交通碳排放的多元影响因素，并以此构建了基于9个评价指标的联合特征描述法；
- 通过对特征指标的ward法聚类分析，将2019年中国30个省份划分为I~VI种类型，并以此进行了类型的特征分析，挖掘其特征形成的原因；
- 在交通碳排放核算的基础上，通过与省际平均值的相对关系和相关性分析，识别出各类型在交通碳减排上的优先控制方向和优先控制指标；
- 为各类型省份提供了相匹配的差异化碳减排策略和KPIs，以及区域协同发展和合作共赢的低碳发展战略及机制建设；
- 能够推动区域之间在交通碳减排上的合作发展和协同治理，促进中国“双碳目标” 行动部署的统一实施。

低零碳建筑

Low- and Zero- Carbon Building

低零碳建筑 Low- and Zero- Carbon Building

Research on Life-cycle Carbon Emission Characteristics and Reduction Strategies of Polar Architecture: A Case study of Antarctic Stations

TU Shao-tsu[1], ZHUANG Wei-min[1,2]
(1. School of Architecture, Tsinghua University, Beijing 100084, China; 2. Architectural Design & Research Institute of Tsinghua University (THAD), Beijing 100084, China)

Abstract

Background, Aims and Scope. Climate change poses an increasing environmental threat to the polar regions. The construction and operation of polar architecture is one of the greatest potential threats directly affecting the polar environment, which is responsible for most polar carbon emissions. Previous studies most focus only on energy saving strategies and renewable energy use technologies during their operational phase, but a life cycle perspective is missing. This study introduces a low-carbon and life cycle research perspective, to reveal the carbon emission characteristics of polar architecture throughout their life cycle, then proposes carbon reduction strategies focuses on key aspects. Aiming to provide a basis for polar architecture to control carbon emissions and achieve sustainable development in the early design stage.

Methods. Combining literature review, comparative study and inductive method, this paper proposes a model and a variable matrix for calculating the life-cycle carbon emission of polar architecture, taking Antarctic research station as an example. Comparing the proportion of carbon emissions at each stage of the full life cycle of polar architecture with those of typical buildings in general urban environments, and analyzing the characteristics at various stages. Nine cases of Antarctic research stations constructed after 2000 are selected, to summarize 9 carbon reduction strategies and 22 sub-strategies, which further reveal the key links to improve the carbon reduction efficiency of polar architecture.

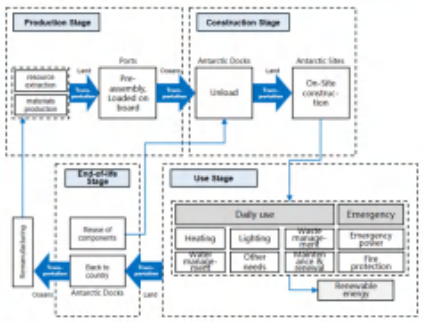


Figure 1 Calculation model of carbon emissions over the full life of an Antarctic research station

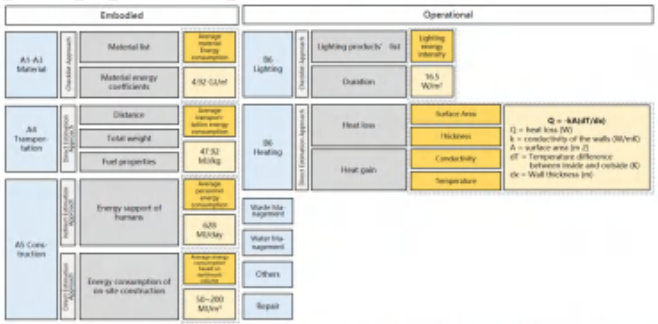
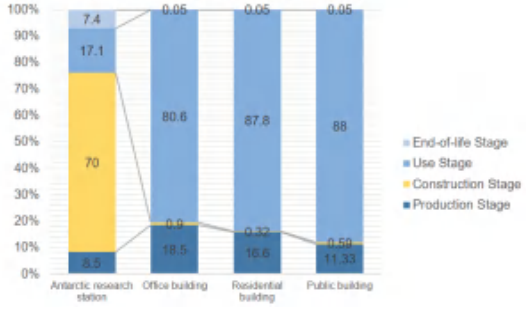


Figure 2 Methodology and variable matrix for quantifying whole-life carbon emission of polar architecture (analyzed and plotted based on the information provided in Ref [1])

Table 1 A polar building's energy consumption at various stages of the full life cycle (example of Scott base warm house, New Zealand)

		Total Energy Consumption (GJ)	Average (GJ/m²)	Proportion of life-cycle (%)
Production Stage		8862	4.9	8.5
Construction Stage	Building materials transportation	62300	70099	38.9	70.0
	Labor requirements	7534			
	On-site construction	265			
Use Stage		690*26 (years)	17940	10.0	17.1
End-of-life Stage			7799	4.3	7.4
Total			104700	58.2	100

Table 2 Carbon emissions at various stages of a polar building's whole life compared to other types of buildings



Results and Discussion. (a) Carbon emissions of polar architecture mainly come from the **transportation of building materials during the construction phase** (including transportation of construction personnel and fuel),

accounting for **70.0%** of the whole life cycle. It's different from the carbon emission composition of general urban buildings, where most of them come from the **operation phase**. (b) The next largest share of carbon emissions is in the operation and maintenance phase, which accounts for **17.1%** of the total lifespan. (c) Compared to general urban buildings, polar buildings have a **relatively average** share of carbon emissions in every life-cycle phases. (d) It was found that the key link to improve the carbon reduction efficiency of polar buildings lies in the **optimization of spatial organization and the construction process**. The optimization of interior functions, scale, spatial patterns and construction process should be further studied in conjunction with **architectural programming theory and methods**.

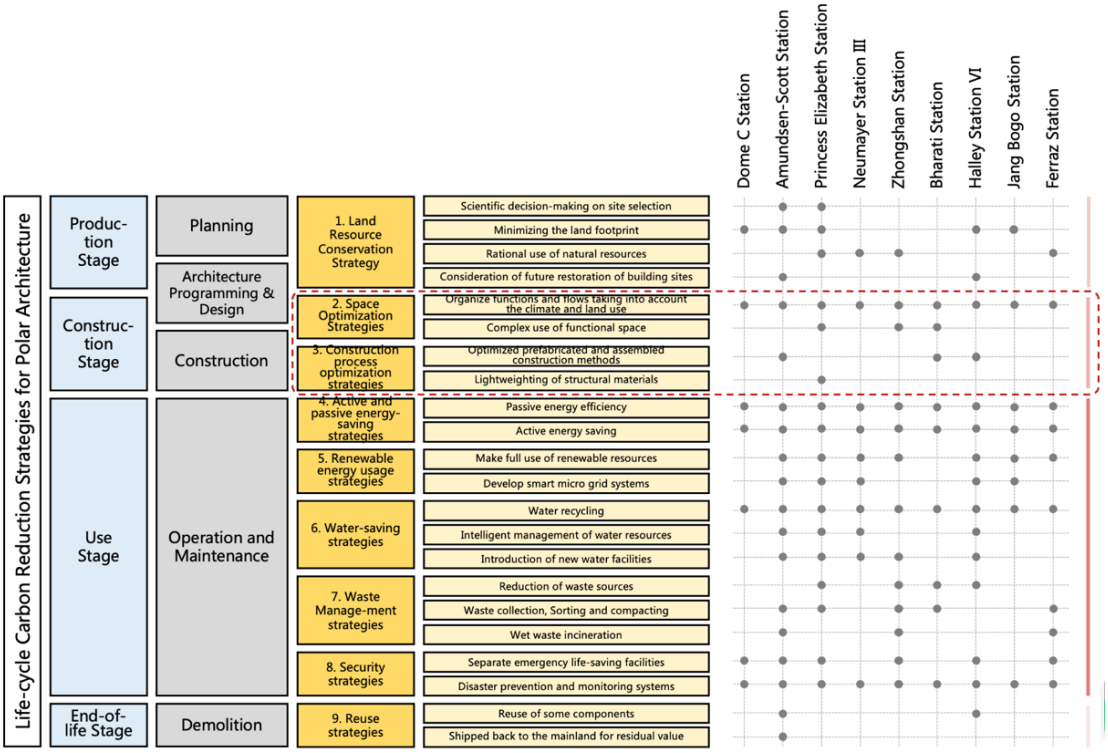


Figure 3 Carbon Reduction Strategies in the full life cycle of Antarctic research stations

Conclusion. This paper proposes life-cycle carbon emission calculation model of polar architecture, reveals its life-cycle carbon emission characteristics for the first time, and points out the key aspects of carbon reduction strategies for them. It aims to minimize the impact of buildings on the polar environment and play the role of architects in carbon neutrality. The results of this study also provide reference for the low-carbon sustainable construction of other similar buildings in extremely cold, isolated, or areas far from urban infrastructure (such as remote villages, islands, or borders).

Key words: polar architecture; antarctic research station; life cycle perspective; carbon emission characteristics; carbon reduction strategy

低零碳建筑 Low- and Zero- Carbon Building

Research on low-carbon building design from the perspective of building operation

YANG Yang[1], Gao Feng[1]
(1. School of Architecture, Tianjin University, Tianjin 300072, China)

Abstract

Background, Aims and Scope.

Background: The global imperative to address climate change has intensified efforts towards sustainable practices, with the building sector being a significant contributor to greenhouse gas emissions. In this context, the concept of low-carbon buildings has emerged as a crucial strategy to mitigate environmental impact while meeting the increasing demand for urban infrastructure. The built environment, including residential, commercial, and institutional structures, plays a pivotal role in achieving carbon neutrality and fostering sustainable living.

Aims: This paper aims to comprehensively explore and analyze the operational dimensions of low-carbon buildings. It focuses on the impact of different behavioral patterns on energy consumption in building operations. By doing so, the paper aspires to provide valuable insights for policymakers, urban planners, architects, and researchers involved in the pursuit of sustainable and environmentally conscious building practices.

Scope: The research object is the international student dormitory of Tianjin University. The scope of the study includes the analysis of carbon emissions caused by energy consumption caused by student activities within the dormitory throughout the year.

Methods.

Data Collection: Data Collection: The study employed a mixed methods approach, combining qualitative and quantitative analyses. Data collection involves the collection of existing energy consumption data of low-carbon buildings (including electricity, gas, domestic water, domestic hot water, etc.). This part of the data is provided through the logistics support department. Collection of students' daily behavior data (including time spent in the dormitory every day, energy usage time in the dormitory, energy usage behavior, etc.). This data was collected through interviews and surveys with students.

Analysis: (1) Use statistical tools (Matlab) to analyze quantitative data to determine trends and correlations; (2) Analyze carbon emissions caused by annual energy consumption in DEST software based on statistical energy consumption behavior to identify key issues. Compliant parts; (3) Provide targeted opinions on behaviors that consume excessive energy.

Results and Discussion.

Results: According to the output data of the total building load of the DEST software, all energy consumption (electricity, gas, domestic hot water, etc.) is converted into electricity consumption. The annual energy consumption of the dormitory building is 351,000 Kwh, of which air conditioning: 228,500 Kwh. , Lighting: 60,300 Kwh, other equipment: 62,200 Kwh. Since there are thermal bridges in the building and the polyline space cannot be drawn, the original data was corrected and multiplied by 1.1. The final calculated and simulated total energy consumption of the international student dormitory building was 386,100 Kwh. Subsequently, based on the 2019 energy consumption data of the international student dormitory provided by the Energy Section of the Logistics Support Department of Tianjin University Weijin Road Campus, the conversion calculation was carried out, and the total was 547,540 Kwh (including 247,540 Kwh for electricity and 100,000 Kwh for other energy sources). The comparison can be It was found that electricity remains the largest component of energy and the largest component of building carbon emissions.

Discussion: On the basis of original data, we optimized the design of the inherent building properties, building operation modes and human behavior of the international student dormitories, which can significantly reduce carbon emissions caused by energy consumption. Among them, optimizing the inherent attributes of the building can

reduce power consumption by 38.12%, updating the building operation mode can reduce power consumption by 47.26%, and rationally guiding people's behavior can reduce power consumption by 47.8%. Comprehensive consideration can reduce power consumption by 44.39%. of carbon emissions.

Conclusion.
Properly controlling the usage patterns during the building operation phase and consciously guiding people's behavior can reduce the electricity consumption of Tianjin University's international student dormitories by 30~50%. According to the North China carbon emission factor (0.8100tCO2/MWh) (2019), it can be reduced by approximately 44.39% of carbon emissions. Among them: (1) The operating mode can reduce carbon emissions by 47.26%. International student dormitories and classrooms should be used alternately (intermittently) to effectively reduce energy consumption. School administrators should encourage students not to stay in one place for a long time. (2) Properly optimizing the design of building physical characteristics can reduce carbon emissions by 38.12%. When adding thermal insulation treatment between the partition walls and floors that separate the heating and non-heating spaces of the building, external insulation should be used. Taking into account the energy consumption of heating and air conditioning, the renovation of international student dormitories reduces the north-facing window-to-wall ratio while meeting the requirements of ventilation conditions. (3) Properly guiding users' behavior can reduce carbon emissions by 47.8%.
Key words: low carbon building; building operation; Simulation analysis

低零碳建筑 Low- and Zero- Carbon Building

Bamboo as a Sustainable Construction Material for Residential Buildings in the Cold and Severe Cold Regions of China

Bolun Zhao[1,2], Yang Yu[1,2], Yitong Xu[1,2], Haibo Guo[1,2,*]
(1. School of Architecture, Harbin Institute of Technology, Harbin 150001, China; 2. Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin 150001, China)

Abstract

Background, Aims and Scope. Bamboo is a construction material with excellent mechanical and thermal properties. It also has excellent carbon storage capacity and is already widely recognized as a sustainable construction material (Fig. 1). To achieve carbon neutrality, the construction industry is carefully examining the use of bio-based materials such as bamboo as a means to realize the sustainable development. This study quantifies the bamboo's potential for energy efficiency and carbon emission reduction throughout the building life cycle in the cold and severe cold regions of China.

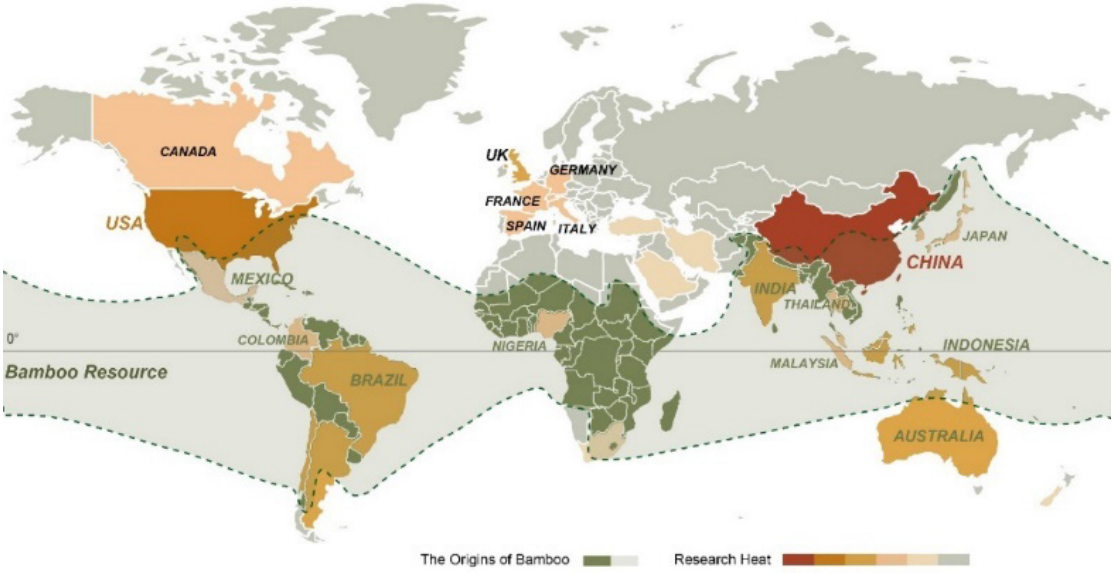


Fig. 1 The Main Locations for Research and Application of Bamboo as a Construction Material

Methods. This study applies a process-based LCA approach. As shown in Fig. 2, this study consolidates and simplifies the building life cycle into three stages: the materialization stage (M0-M3), the operation stage (M4), and the end-of-life (EoL) stage (M5). For the operation stage, the basic demands of heating, cooling, lighting, and equipment are simulated over fifty years using software (IES-VE). In order to carry out a comparison of energy efficiency and carbon reduction, a case study building using both reinforced concrete (RC) and bamboo for the building envelope, is simulated in five different cities.

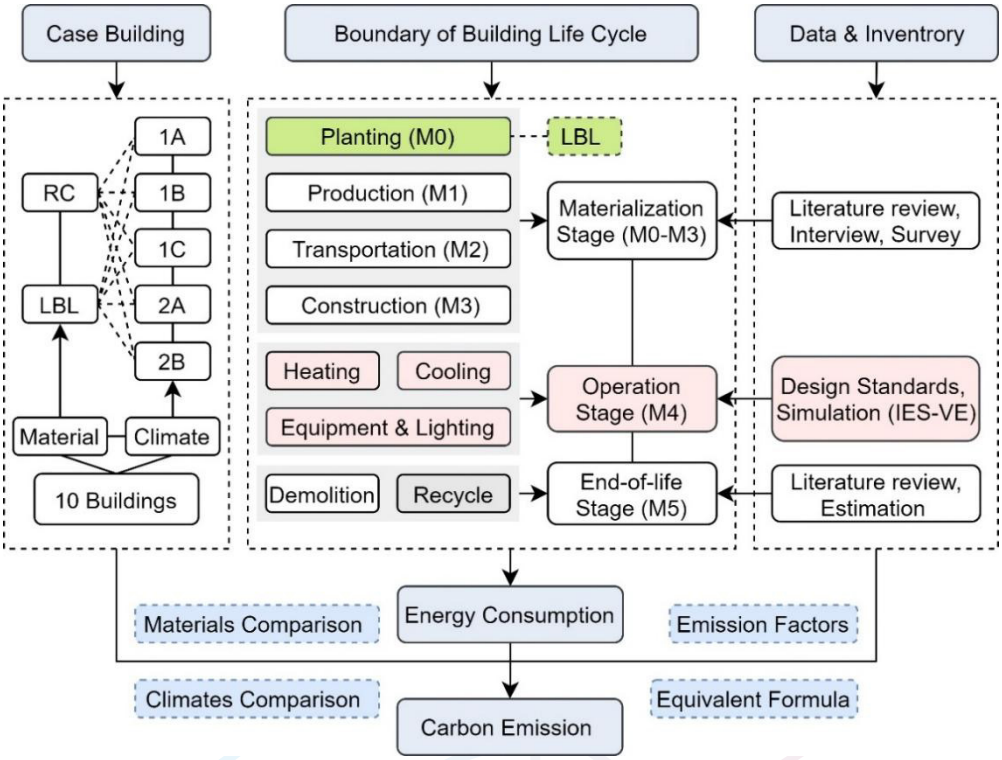


Fig. 2 Research Framework

Results and Discussion.

(1) The energy annual consumption of bamboo buildings during the operation stage is 167.20 *kWh*/m^2, 148.58 *kWh*/m^2, 123.96 *kWh*/m^2, 98.62 *kWh*/m^2, and 93.58 *kWh*/m^2 respectively for the case study cities, which is 3 to 5% more energy efficient than RC buildings (Fig. 3).

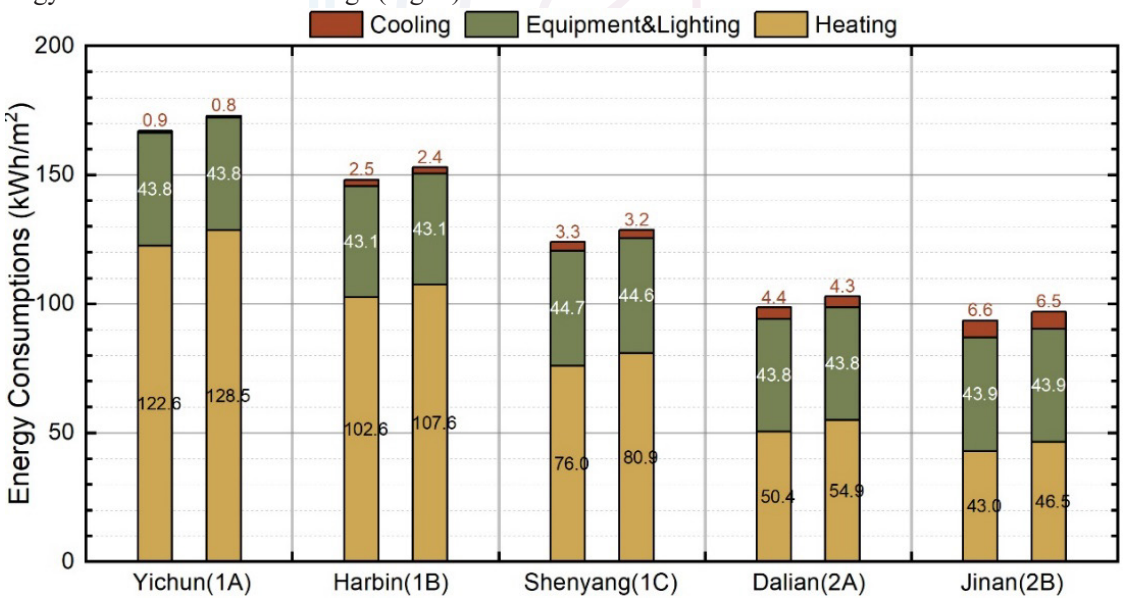


Fig. 3 Energy Annual Consumption of Study Buildings in the Operation Stage

(2) The CO_2 emissions during the bamboo building life cycle are 5724 *kg*/m^2, 5167 *kg*/m^2, 4436 *kg*/m^2, 3803 *kg*/m^2, and 3724 *kg*/m^2 respectively for the case study cities, a reduction of 7 to 20% over the RC buildings (Fig. 4).

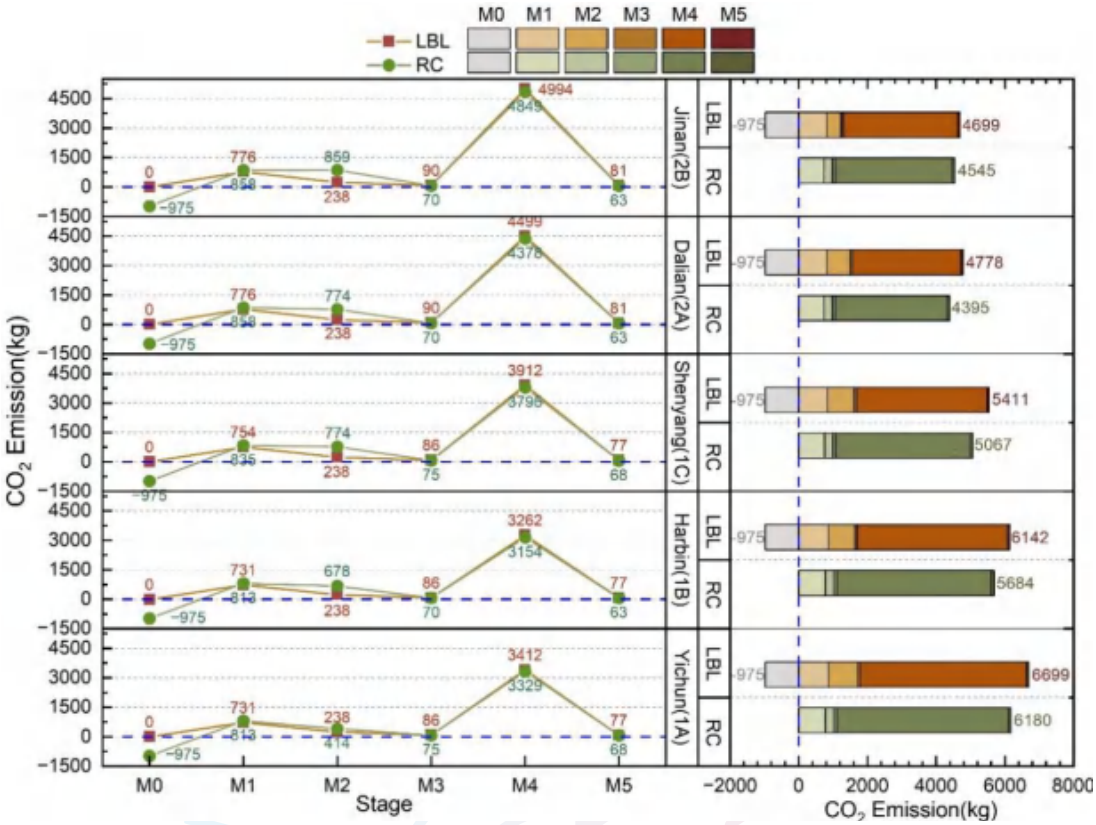


Fig. 4 Life Cycle CO2 Emissions of Study Buildings in Five Cities

(3) Bamboo buildings can have significant reduction in CO_2 emissions when compared with RC buildings. Nevertheless, there is still potential for optimizing carbon emissions during certain stages and processes of the bamboo building life cycle. The trends for CO_2 emission reduction in the bamboo building life cycle in different cities are represented in Fig. 5.

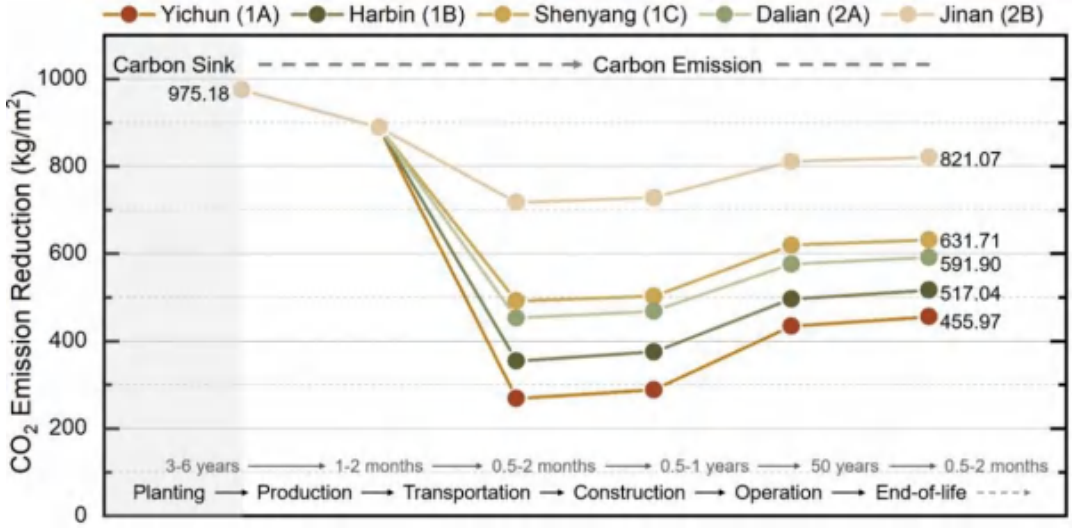


Fig. 5 The Trend of CO2 Emission Reduction in Bamboo Building Life Cycle

Conclusion.

(1) For the operation stage, heating demand reduction is the main contributor to energy saving in bamboo buildings. Since the performance of the bamboo construction material will also be affected over time, the problem of durability that needs to be addressed.

(2) The materialization stage has a significant influence on emissions during the bamboo building life cycle. On one hand, bamboo planting sequesters vast amounts of carbon but on the other, transportation emissions are an important factor due to the distance between the source of the materials and the building locations (Table 1).

Table 1 CO2 Emission Reduction of Bamboo Buildings in Five Cities

Bamboo Buildings	Net (kg/m^2)		M1 (kg/m^2)		M2 (kg/m^2)		M3 (kg/m^2)		M4 (kg/m^2)		M5 (kg/m^2)	
	Value	Ratio	Value	Ratio	Value	Ratio	Value	Ratio	Value	Ratio	Value	Ratio
Yichun	456.0	100%	-81.6	-18%	-620.8	-136%	20.0	4%	145.2	32%	22.0	5%
Harbin	517.0	100%	-81.6	-16%	-535.4	-104%	20.0	4%	120.9	23%	21.0	4%
Shenyang	631.7	100%	-81.6	-13%	-399.7	-63%	11.0	2%	117.0	19%	11.9	2%
Dalian	591.9	100%	-81.6	-14%	-439.9	-74%	16.0	3%	107.9	18%	15.4	3%
Jinan	821.1	100%	-81.6	-10%	-176.2	-21%	11.0	1%	82.8	10%	9.9	1%

Notes: positive values represent the reduction in emissions, while negative values represent the increase.

(3) Bamboo is an energy-efficient construction material that can be used as a suitable alternative to traditional materials. It is not only suitable for construction in the areas suited for bamboo cultivation but also has potential applications in the cold and severe cold regions of China.

Key words: bamboo construction materials; residential building; carbon emissions; energy saving; life cycle assessment

低零碳建筑 Low- and Zero- Carbon Building

An Intelligent Platform for Carbon Emission Monitoring in Modular Integrated Construction Projects

Jason Xin ZHOU[1], Xiaohan WU[1], Yue TENG[1], Hengqin WU[1], Geoffrey Qiping SHEN[1]

([1]Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China)

Abstract:

Background, Aims and Scope. The escalating concern over climate change necessitates a more efficient monitoring of carbon emissions across various sectors, particularly in the construction industry, which is known for its substantial environmental footprint. This innovative Modular Integrated Construction (MiC), a method that involves off-site fabrication and on-site installation, has been recognized for its potential to reduce construction waste and enhance productivity. However, the carbon emissions throughout the life cycle of buildings, from production to demolition, still pose a significant environmental challenge, so it is important to clearly monitor and track carbon emissions from the whole construction process to lay the groundwork for reducing carbon emissions and moving towards carbon neutrality. This study aims to address this challenge by integrating BIM and IoT technologies to establish a comprehensive monitoring system in the production, transportation and installation stages.

Methods. This paper proposes an innovative approach to carbon emission monitoring in MiC projects by developing an intelligent platform that leverages Building Information Modelling (BIM) and Internet of Things (IoT) technologies. In this system, Radio Frequency Identification (RFID) sensors are employed to identify the module ID and corresponding material usage data are extracted from a pre-set database. Vibration sensors are placed in the module production line and on-site installation line to measure equipment running time, enabling real-time calculation of energy usage. Accelerometer sensors are installed in transportation vehicles. Furthermore, a data service platform has been developed to facilitate wireless data transmission from the production line to the computing platform, where monitoring results are visually presented.

Results and discussion. The proposed platform can empower stakeholders to observe and comprehend the real-time carbon footprint of their projects, aiding informed decision-making for more sustainable practices. Additionally, it offers predictive analytics, enabling proactive measures to reduce carbon emissions. This research is anticipated to make a significant contribution to the understanding of sustainable construction practices and provide valuable insights for industry practitioners, policymakers, and other stakeholders, assisting them in achieving sustainability goals and meeting regulatory requirements.

Conclusion. In summary, the incorporation of BIM and IoT technologies offers a promising approach to monitoring carbon emissions in MiC projects. It provides project practitioners with the ability to observe and manage irregular emissions promptly, recognize potential emission risks, and investigate potential strategies to mitigate carbon emissions in the construction sector.

Key words: carbon emission monitoring; sensors; internet of things; modular integrated construction

Carbon emission analysis of two novel slab systems in China through life cycle assessment and BIM technology

Xierong Gu [a], Zhonghao Chen [a], Yao Sun [b*]

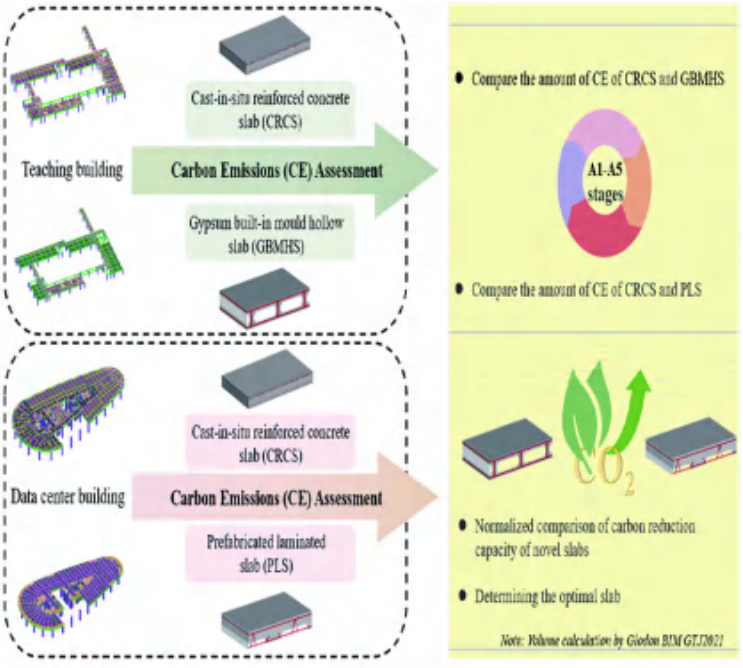
a. School of Civil Engineering, Xi'an JiaotongLiverpool University, Suzhou 215028, China;
b. School of Civil Engineering, Hunan University, Changsha 410082, China)

Background/Aims

With the increasing severity of global climate change, the issue of carbon emissions has received widespread attention [1]. As one of the primary sources of global carbon emissions, the construction industry accounts for one-third of all energy-related carbon emissions [2]. To cope with this challenge, the Chinese government has actively taken measures and issued several policy documents to promote the development of China's construction industry in a low-carbon direction. Given the high carbon emissions generated during the construction process of traditional cast-in-situ reinforced concrete slabs (CRCS), this study aims to explore and evaluate two new floor slab systems: Gypsum built-in moulded hollow slab (GBMHS) and precast stacked slabs. Prefabricated laminated slab (PLS). Both floor systems are more environmentally friendly and sustainable low-carbon building solutions.

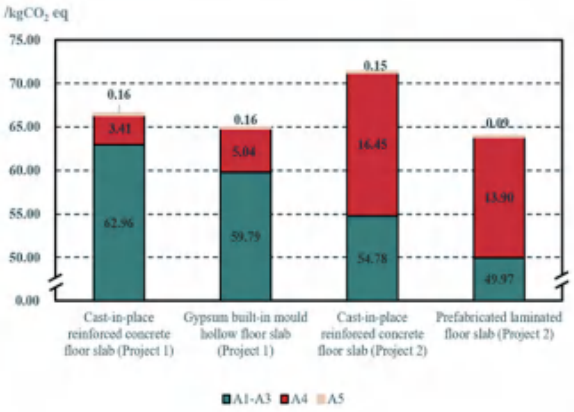
Methods

To comprehensively understand the carbon emission performance of these two new floor systems, we used building information modelling (BIM) and life cycle assessment (LCA) methods to conduct quantitative research. BIM allows us to simulate the actual application of the floor slabs more accurately, while LCA provides carbon emissions data from raw material extraction to building demolition.



Results

After in-depth research, we found that the total carbon emissions of GBMHS were only reduced by 2.37% compared with traditional CRCS, which is a relatively small reduction. The total carbon emissions of PLS were decreased by 11.6%, showing a more apparent low-carbon advantage. These data provide us with the environmental performance of two new floor systems in real-world applications.



	Project 1		Project 2	
	Scheme A (CRCS)	Scheme B (GBMHS)	Scheme A (CRCS)	Scheme B (PLS)
Stages	A1-A5	A1-A5	A1-A5	A1-A5
Unit	kgCO2 eq			
Total	149095.33	145638.29	165284.01	150107.84

Conclusion

This study evaluates the environmental impact of two new slab systems in China. It provides valuable reference information for decision-makers in the construction industry to help them choose the best low-carbon solution among numerous slab systems

References

1. Teng Y., Li K., Pan W., and Ng T.: Reducing building life cycle carbon emissions through prefabrication: Evidence from and gaps in empirical studies, Building and Environment. 132. 125-136. 2018

2 Tang F., Ma T., Zhang J., Guan Y., and Chen L.: Integrating three-dimensional road design and pavement structure analysis based on BIM, Automation in Construction. 113. 103152. 2020

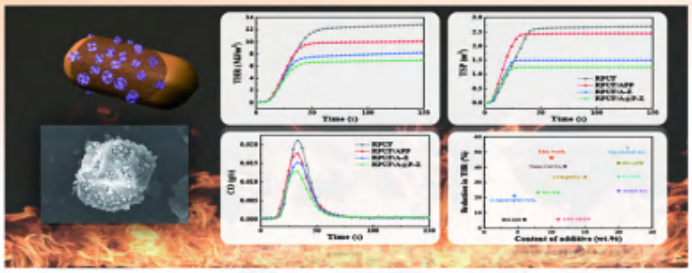
A novel ternary inorganic–organic hybrid flame retardant containing biomass and MOFs for high-performance rigid polyurethane foam

Xiaoyan Liu, Pengyu Guo, Borong Zhang, Jianxin Mu*
College of Chemistry, Jilin University, Changchun 130012, China
**Email: jianxin_mu@jlu.edu.cn*

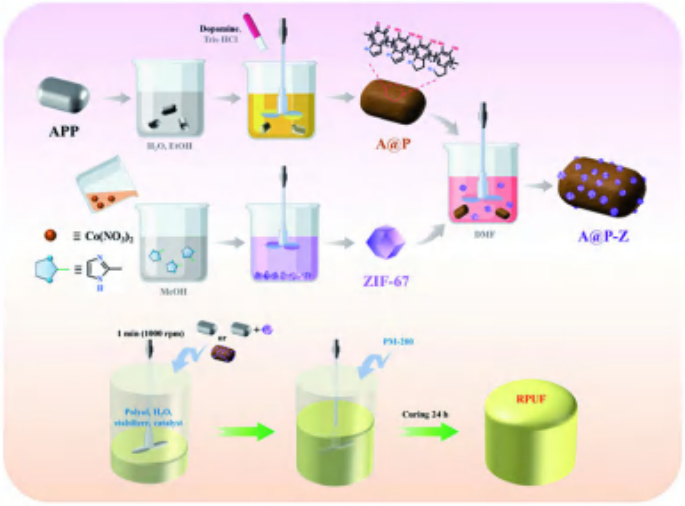
Abstract

In this work, using biomass PDA as an intermediate interface, APP, PDA, and ZIF-67 were combined into a ternary inorganic–organic hybrid flame retardant (A@P-Z). The hybrid flame retardant not only strengthened the mechanical properties of RPUF composites owing to its good compatibility but also emerged with low total heat release, low total smoke production, and low peak CO production rate in cone calorimetry tests. The hybrid flame retardant also produced an impressive flame inhibition effect in the gas phase, inhibiting the production of organic fragments and releasing phosphorus-containing and nitrogen-containing gaseous compounds with free radical quenching and diluting effects. This work provides a new and efficient way to prepare high-performance RPUF composites using inorganic–organic hybrid flame retardants.

Scheme



Methods



Results

The phase composition and structure of the prepared samples were characterized by FTIR, XRD, TGA, etc. This confirmed the successful synthesis of the material, and then further analyzed its composition and structure.

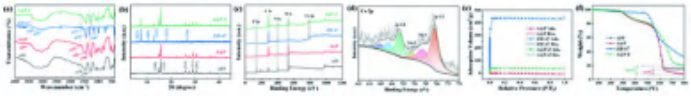


Figure 1. FTIR (a); XRD (b); XPS (c); HR-XPS (d); N_2 isotherms (e); TGA curves (f).

The micromorphologies of samples were observed by SEM and TEM. ZIF-67 is uniformly embedded on the surface of A@P, which significantly increases the specific surface area of the filler. Through the EDS result of A@P-Z, it can be observed that the elements are evenly distributed, confirming the successful synthesis of the A@P-Z assembly.

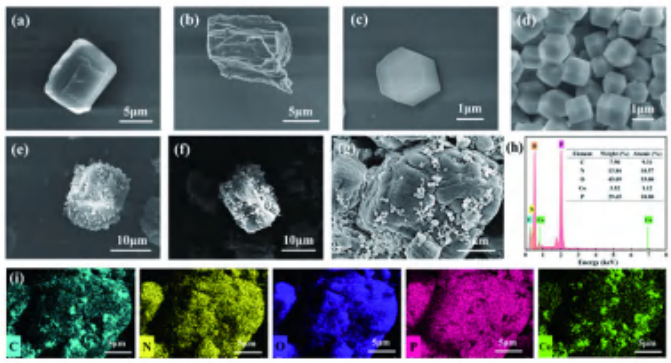


Figure 2. SEM images of APP (a), A@P (b), and ZIF-67 (c-d); SEM images (e-g), EDS (h), and elemental mapping (i) of A@P-Z.

Combustion data of pure RPUF and its composites.

Samples	TTI (s)	pHRR (kW/m²)	THR (MJ/m²)	pSPR (m²/s)	TSP (m²)	pCOP (g/s)	av-EHC (MJ/kg)	LOI (%)	UL-94
RPUF	6 ± 1	373.6 ± 8.9	12.84 ± 0.39	0.0982 ± 0.0031	2.686 ± 0.081	0.021 ± 0.006	22.4 ± 0.5	19.7 ± 0.2	NR
RPUF/APP	6 ± 1	361.7 ± 5.8	10.65 ± 0.27	0.1354 ± 0.0035	2.441 ± 0.078	0.018 ± 0.004	16.6 ± 0.4	23.8 ± 0.3	V-2
RPUF/A-Z	6 ± 0	282.3 ± 6.1	8.19 ± 0.19	0.0957 ± 0.0026	1.495 ± 0.037	0.015 ± 0.003	18.0 ± 0.4	24.8 ± 0.3	V-2
RPUF/A@P-Z	6 ± 0	229.4 ± 5.2	6.98 ± 0.13	0.0793 ± 0.0019	1.253 ± 0.022	0.013 ± 0.001	15.8 ± 0.2	25.6 ± 0.2	V-0

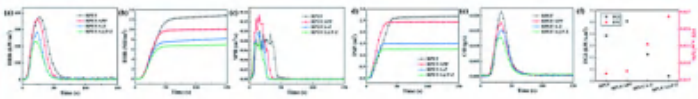


Figure 3. HRR (a), THR (b), SPR (c), TSP (d), CO production rate (e) versus time curves of RPUF and its composites; FGI and FPI (f) of RPUF and its composites.

LOI and UL-94 are often used to evaluate the flame retardancy of materials in industrial applications. At such a low amount of flame retardant, the LOI of RPUF/A@P-Z even reaches 25.6 %, reflecting the outstanding flame retardancy of A@P-Z. The UL-94 tests present an intuitive improvement in the flame retardancy of the composites.

Figure 4. The digital photos of samples during UL-94 test.

Conclusions

Taking advantage of the excellent adhesion of PDA, ZIF-67 was uniformly distributed on the surface of APP modified by PDA; therefore, the A@P-Z inorganic–organic hybrid flame retardant was prepared in this work. The interaction between the flame retardant and matrix was strengthened, and the mechanical properties of the composites were improved, benefiting from the unique functional groups and rough surface of A@P-Z. A@P-Z promoted the formation of compact and highly graphitized char residues in RPUF composites in the condensed phase, enhancing the charring and barrier effects. A@P-Z also presented a good flame inhibition effect in the gas phase. By comparing with the flame retardant system of simple physical blending of APP and ZIF-67, this work revealed the advantages of A@P-Z inorganic–organic hybrid integrated flame retardant in improving the comprehensive properties of RPUF and provides a promising scheme for the preparation of flame retardant RPUF composites with practical value.

References

Liu, X.; Guo, P.; Zhang, B.; Mu, J.*, A novel ternary inorganic–organic hybrid flame retardant containing biomass and MOFs for high-performance rigid polyurethane foam. *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 2023, 671, 131625.

低零碳工业

Low- and Zero- Carbon Industry

Selective Photooxidation of Methane to Formaldehyde via TiO_2 Crystal Phase Engineering in flow reactor at room temperature

JIANG Yu-heng[1,2], TANG Zhi-yong[1]

(1. Chinese Academy of Science (CAS) Key Laboratory of Nanosystem and Hierarchy Fabrication, CAS Center for Excellence in Nanoscience, National Center for Nanoscience and Technology, Beijing 100190, P. R. China; 2. Center for Nanoscale Science and Technology, Academy for Advanced Interdisciplinary Studies, Peking University, Beijing 100871, P. R. China)

Abstract

Background, Aims and Scope. As the main component of natural gas, CH_4 is an abundant but potent greenhouse gas whose impact on global warming is 25 times greater than that of CO_2. To innovate the conventional strategy of burning CH_4 into CO_2 in oil fields, the direct conversion of CH_4 into value-added liquid commodity holds great promise to efficiently utilize fossil feedstocks and reduce greenhouse gas emission. Formaldehyde is is widely used as feedstocks in over 50 industrial processes. Actually, 40% of industrial methanol nowadays is employed to synthesize formaldehyde. Photocatalytic conversion of methane to formaldehyde under mild conditions, which represents a long-sought-after goal for industrial sustainable production, remains extremely challenging to afford high production and selectivity using cheap catalysts.

Methods. Herein, we present the crystal phase engineering of commercially available anatase TiO_2 via simple thermal annealing to obtain the TiO_2 phase junction nanomaterials. Based on the fact that the pipeline transportation pressure of natural gas is up to 200 bar, high-pressure reaction mode is conducive to making full use of the original energy. Moreover, a high-pressure atmosphere increases the solubility of methane in water, which could boost the efficiency of methane conversion. Thus, all the photocatalytic methane oxidation experiments have been carried out in a pressured reactor at room temperature. We also notice that beyond the catalyst construction, the adopted reactor is equally important. At present, all works about the photocatalytic methane conversion have been carried out in a batch reactor, which is merely suitable for small-scale catalyst screening rather than continuous production. Herein, a new type of “pause-flowing” reactor is manufactured for scale-up production of formaldehyde.

Results and Discussion. Biphase catalyst of anatase (90%) and rutile (10%) TiO_2 with the optimal phase interface concentration exhibits the exceptional performance in the oxidation of methane to formaldehyde under the reaction condition of water solvent, oxygen atmosphere and full-spectrum light irradiation. An unprecedented production of 24.27 mmol g_{cat}^{-1} with an excellent selectivity of 97.4% towards formaldehyde is acquired at room temperature after a 3 h reaction. Both experimental results and theoretical calculation disclose that the crystal phase engineering of TiO_2 lengthens the lifetime of photogenerated carriers and favors the formation of intermediate methanol species, thus maximizing the efficiency and selectivity in aerobic oxidation of methane to formaldehyde. More importantly, the feasibility of scale-up production of formaldehyde is demonstrated by inventing the “pause-flowing” reactor.

Conclusion. In this work, we realize the efficient, selective, continuous and stable production of formaldehyde via photocatalytic methane oxidation under mild condition. This work offers a paradigm to approach the industrial photocatalytic transformation of low carbon feedstocks including but not limited to methane via rational design of both catalysts and reactors.

Key words: Methane; TiO_2; Photo; Mild condition

References:

[1] Fan, Y.; Zhou, W.; Qiu, X.; Li, H.; Jiang, Y.; Sun, Z.; Han, D.; Niu, L.; Tang, Z., Selective photocatalytic oxidation of methane by quantum-sized bismuth vanadate. *Nature Sustainability* **2021, 4 (6),** 509.

[2] Jiang, Y. H.; Zhao, W. S.; Li, S. Y.; Wang, S. K.; Fan, Y. Y.; Wang, F.; Qiu, X. Y.; Zhu, Y. F.; Zhang, Y.; Long, C.; Tang, Z. Y., Elevating Photooxidation of Methane to Formaldehyde via TiO_2 Crystal Phase Engineering. *J Am*

Chem Soc **2022, 144 (35)**, 15977.
[3] Jiang, Y.; Li, S.; Wang, S.; Zhang, Y.; Long, C.; Xie, J.; Fan, X.; Zhao, W.; Xu, P.; Fan, Y.; Cui, C.; Tang, Z., Enabling Specific Photocatalytic Methane Oxidation by Controlling Free Radical Type. *J Am Chem Soc* **2023, 145 (4)**, 2698.
[4] Jiang, Y.; Fan, Y.; Li, S.; Tang, Z., Photocatalytic Methane Conversion: Insight into the Mechanism of C(sp^3)–H Bond Activation. *CCS Chemistry* **2023, 5 (1)**, 30.

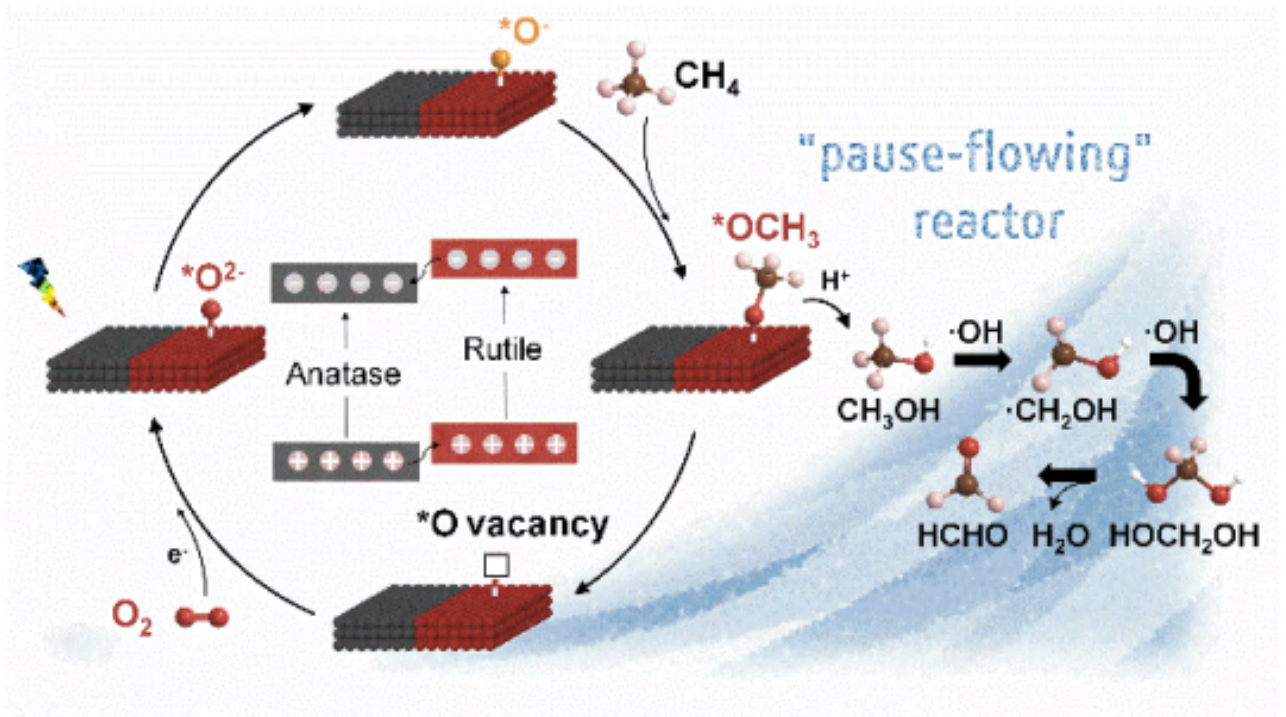


Fig 1 Selective Photooxidation of Methane to Formaldehyde via TiO_2 Crystal Phase Engineering in flow reactor at room temperature.

低零碳工业 Low- and Zero- Carbon Industry

Technical path design of polygeneration system based on iron and steel industry: A multi-objective optimization approach

Mao Xu[a], Zongguo Wen[a]

a. State Key Joint Laboratory of Environment Simulation and Pollution Control (SKLESPC), School of Environment, Tsinghua University, Beijing, 100084, China

Abstract

Polygeneration system has great potential for energy conservation and pollutant emission reductions. However, its application faces the difficulty in technology selection under multiple objectives simultaneously. This study investigated a case polygeneration system where the iron and steel plant is the core with four paths and 20 technologies. A multi-objective optimization model is developed to select the optimal technology combination of each polygeneration path under energy conservation, emission reduction, and cost control objectives, which is solved by the non-dominated sorting genetic algorithm-II (NSGA-II). The optimal results can reach significant energy conservation and emission reduction effects while obtain economic benefits. However, synergistic and conflicting relationships among the objectives exist in both scales of iron and steel plants. The final decision scheme can achieve the mitigations equivalent to 15.9-27.1% and 16.3-42.6% of the energy consumption and air pollutant emissions of the steel enterprises with annual production of 3 Mt/a and 9 Mt/a, respectively. There are 13 and 12 technologies that are selected as the final decision scheme in the polygeneration system in these two case enterprises. These findings demonstrate the significant roles the polygeneration system play and provide critical insights and methodology in the technical selection of the polygeneration system.

Keywords: Polygeneration system; Multi-objective optimization; Energy conservation; Pollutant reduction; Iron and steel industry

Effects of defective structure originating from N incorporation-evaporation of Co-based biomass carbon catalysts on methane dry reforming

ZHANG Xiaodi[1], ZHANG Guojie[1]
(1. State Key Laboratory of Clean and Efficient Coal Utilization, College of Chemical Engineering and Technology, Taiyuan University of Technology, Taiyuan, 030024, Shanxi, P. R. China)

Abstract
Background, Aims and Scope. The development of inexpensive, readily available, and highly sinter and coke resistant catalysts for methane dry reforming (DRM) is indeed an important and urgent requirement. Utilization of defective structures to limit the aggregation of reactive metals. Meanwhile, the unpaired electrons of defective structures not only enhanced the basicity of the support to promote the adsorption and activation of CO_2, but also improved the electronic environment of the anchored metals sites. The active metal exerts its catalytic effect on the support, so the nature of the support determines the catalytic performance of the catalyst to a certain extent. Carbon materials serve as excellent metal catalyst supports due to several advantageous properties, including low cost, wide availability, and good electrical conductivity. In addition, the used catalyst can be recycled by recovering the active metal through simple calcination, realizing the recycling of metal. Based on this, in this study, novel methane dry reforming catalysts with defect structure-limited domains were prepared by introducing defective structures in biomass carbon materials through the introduction-evaporation of N atoms, and further loading Co with biomass carbon materials rich in defect structures as supports. Thanks to the defective structure, the prepared metal-based defect-rich biomass carbon catalysts exhibited excellent catalytic activity and stability.
Methods. Herein, defect-rich biomass carbon materials are obtained in a simple way. Under the combined effect of high temperature and defect inducers, the evaporation of N atoms introduced to the carbon skeleton and intrinsic N atoms in the biomass leads in the production of defective structures. The amount of defect inducer (KOH) added during the preparation process was varied to obtain a series of biomass carbon materials with different numbers of defective structures. Further, defect-confined Co catalysts (Y-NC(Z)-20Co) for DRM were reasonably designed and developed using defective biomass carbon as support. As a comparison, BC(X)-20Co was prepared without the introduction of external nitrogen atoms in the preparation process. Here, X, Z represent different amounts of KOH.
Results and Discussion. The defective structures were introduced in biomass carbon materials by the incorporation-evaporation process of external N atoms. The defective structure enhanced the utilization of Co in the metal precursor and limited the growth of Co particles while effectively prevented the aggregation of Co particles during the DRM reaction. CO_2-TPD showed that the increase in the number of defective sites could enhance the basicity of the carbon materials, which promoted the adsorption and activation of CO_2. Reactive oxygen species generated by the CO_2 activation process effectively inhibited the coke development. According to the XPS results, the defective structure affects the chemical environment of Co, which is manifested by the increased electron cloud density around Co. This boosted the activation of CH_4. Due to these two aspects, Co-based defect-rich biomass carbon catalysts exhibited an outstanding catalytic performance in DRM reaction. In the 24 h long-term stability evaluation, the CH_4 and CO_2 conversions of Y-NC(3)-20Co remained stable at 75% and 86%, respectively. Compared with other metal-carbon material catalysts, the catalysts in this study showed good competitiveness.
Conclusion. Biomass material was used as carbon precursor and melamine was used as an external nitrogen source. Defect structures were successfully introduced in the biomass carbon material by incorporating the introduction-evaporation of external N atoms. Novel dry reforming catalysts with small particle size and high dispersibility were prepared by using defect-rich biomass carbon material as a support and further loading active metal Co. The synthesized defect structures act as active centers for activating gas molecules and as “traps” for anchoring active metals. At the same time, the defective structures also enhance the exposure of catalytically active species (Co^{2+}) on the catalyst surface. Thanks to the synergistic effect of defect structures, the prepared Co-based/defect-rich biomass carbon material catalysts exhibited excellent catalytic performance. This study provides a new strategy for the construction of metal-based carbon material catalysts with multiple active catalytic centers.
Key words: DRM reaction; Biomass carbon materials; Nitrogen; Defective structures, Co-based catalysts

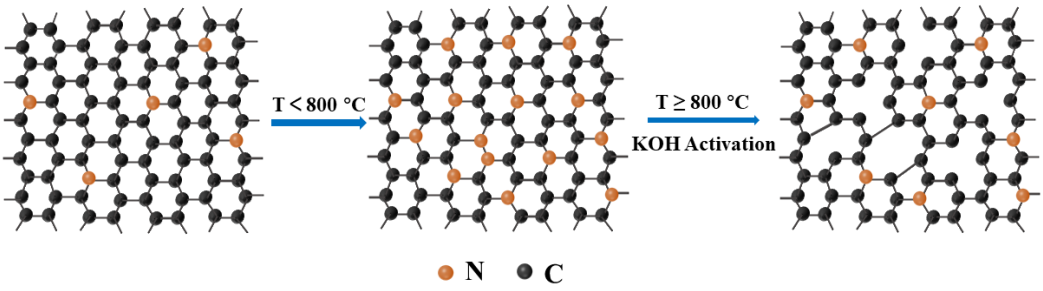


Fig 1 Schematic diagram of the defects formation.

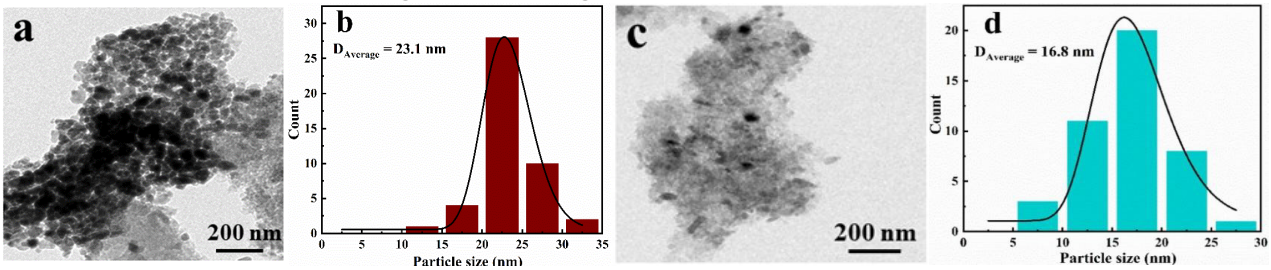


Fig 2 (a) TEM image and (b) Co particle size distribution of BC(3)-20Co; (c) TEM image and (d) Co particle size distribution of Y-NC(3)-20Co

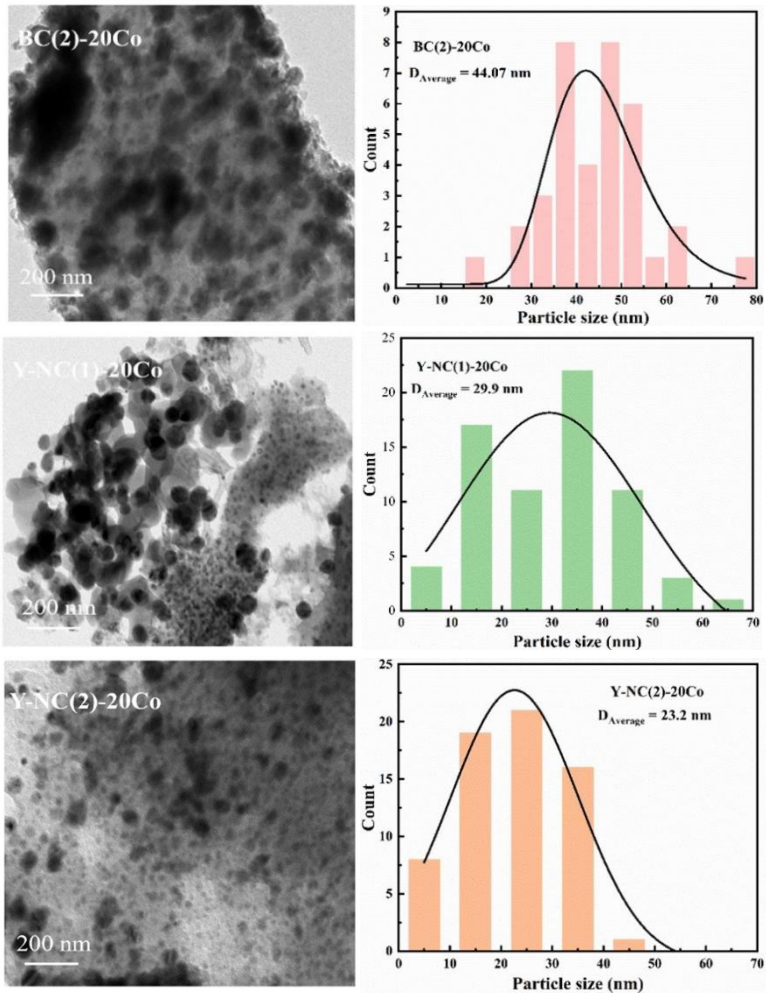


Fig 3 TEM images and particle size distribution of BC(2)-20Co, Y-NC(1)-20Co and Y-NC(2)-20Co

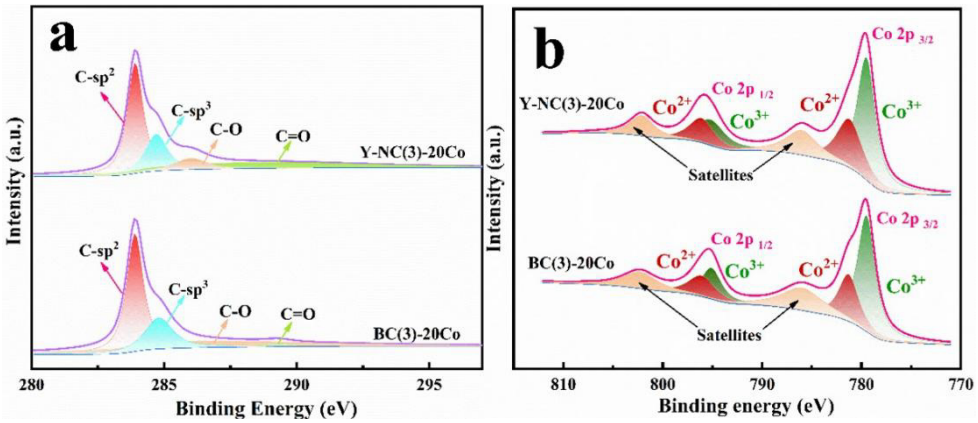


Fig 4 High resolution XPS spectra of (a) C1s and (b) Co2p in BC(3)-20Co and Y-NC(3)-20Co

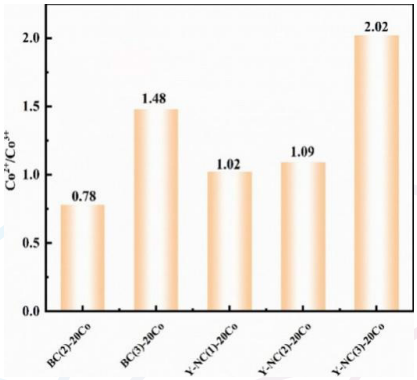


Fig 5 Co^{2+}/Co^{3+} value of all Co-based catalysts

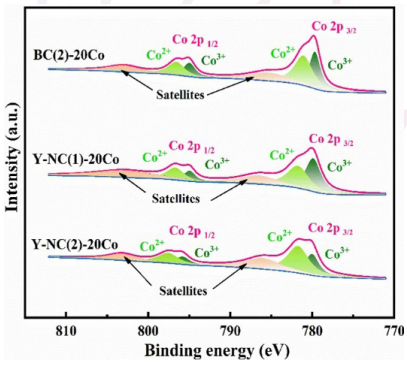


Fig 6 XPS spectra of Co 2p in BC(2)-20Co, Y-NC(1)-20Co and Y-NC(2)-20Co

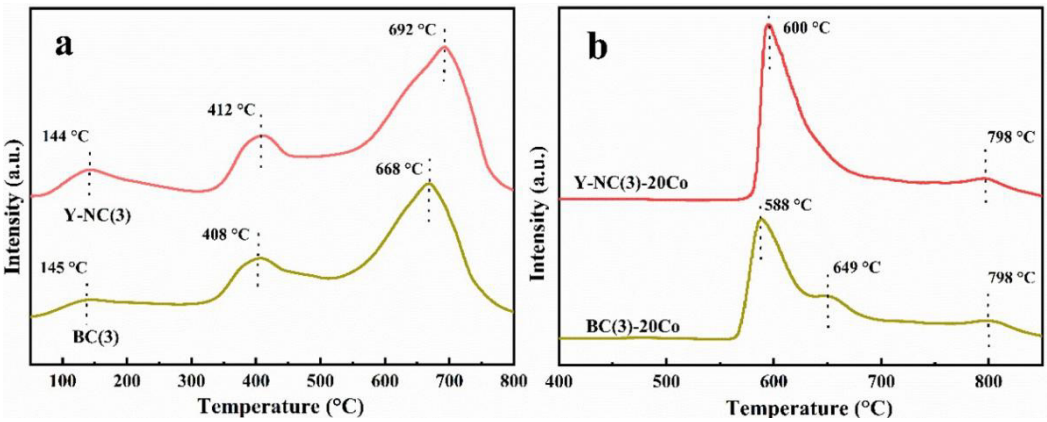


Fig 7 (a) CO_2-TPD on metal-free BC(3) and Y-NC(3) and (b) CH_4-TPD on BC(3)-20Co and Y-NC(3)-20Co

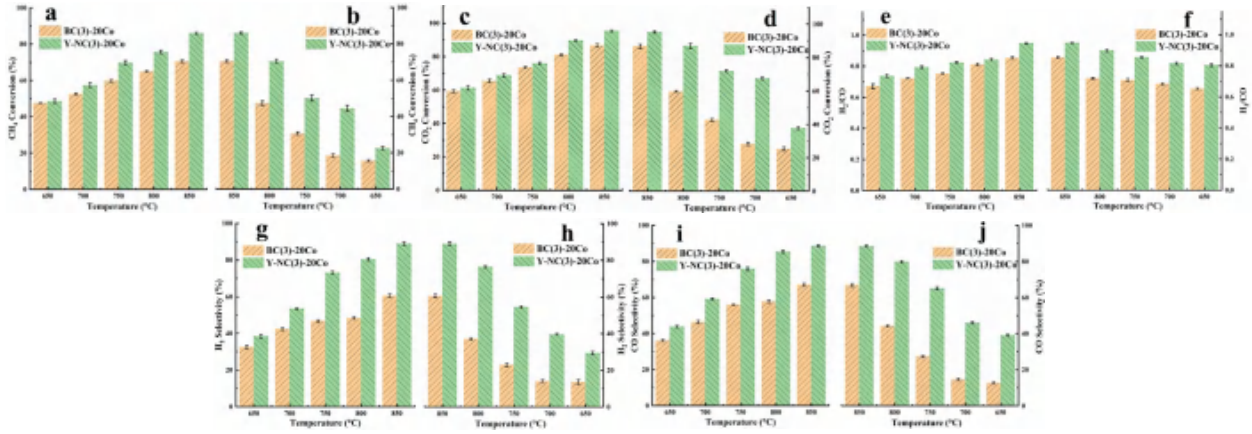


Fig 8 CH_4 (a, b) and CO_2 conversion (c, d), H_2/CO (e, f), H_2 Selectivity (g, h) and CO Selectivity (i, j) of BC(3)-20Co, Y-NC(3)-20Co at different reaction temperature

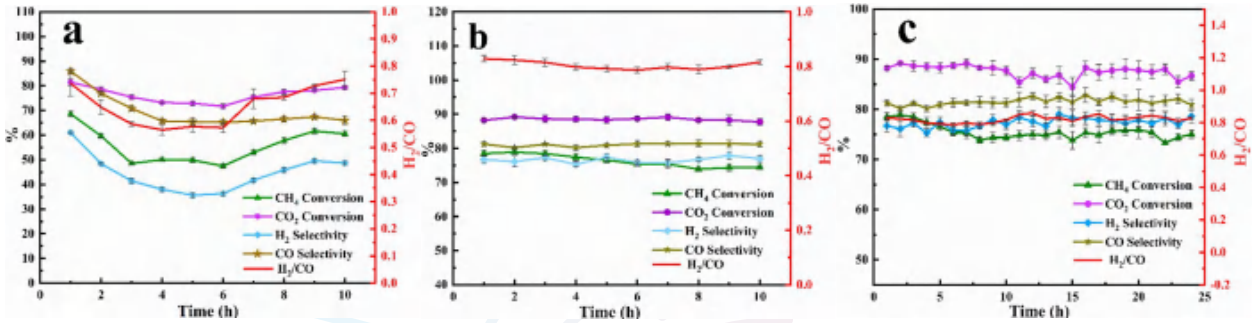


Fig 9 (a) CH_4 conversion, CO_2 conversion, H_2/CO, H_2 Selectivity and CO Selectivity of BC(3)-20Co and (b) Y-NC(3)-20Co variation with reaction time (10 h); (c) CH_4 conversion, CO_2 conversion, H_2/CO, H_2 Selectivity and CO Selectivity of Y-NC(3)-20Co variation with reaction time (24 h)

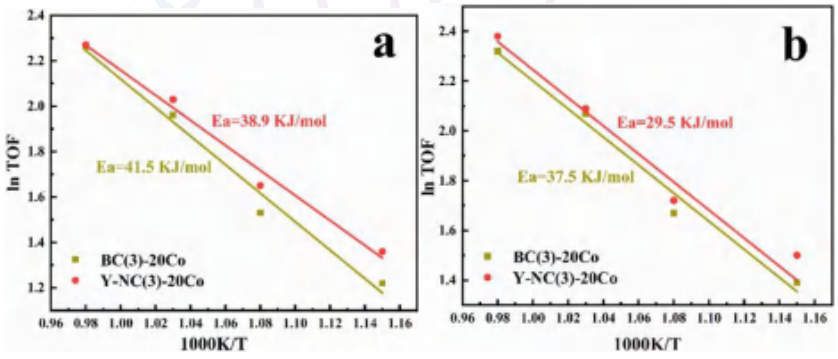


Fig 10 Arrhenius plots for the methane dry reforming over BC(3)-20Co and Y-NC(3)-20Co: (a) CH_4; (b) CO_2

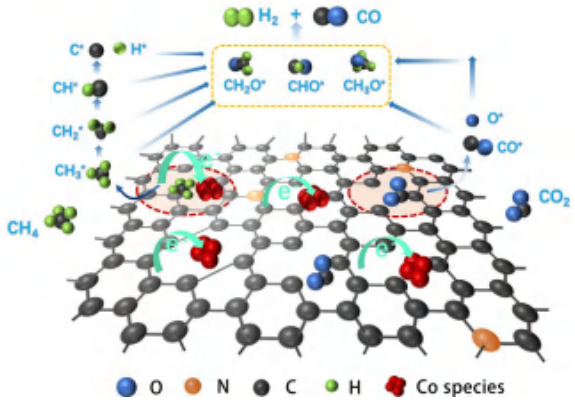


Fig 11 Possible reaction mechanism over Y-N(Z)-20Co catalyst

Hydrothermally synthesized smectite as a thickener with favorable rheological and tribological properties over a wide temperature range

Lei Hao [a], Xinrui Zhao [a], Chengcheng Zhang [a], Lei Wang [a], Hong Xu [a], Jinxiang Dong a,
a College of Chemical Engineering and Technology, Shanxi Key Laboratory of Chemical Product Engineering, Taiyuan University of Technology, Taiyuan 030024, China

Introduction

At present, the world is facing serious problems of resources, environment and sustainable development. The reduction of resources and energy have become the bottleneck to achieve economic and sustainable development. Lubrication is extremely important for today's industrial production, which can reduce the loss of energy and avoid the wear of industrial equipment. With carbon peaking and carbon neutrality targets proposed, the lubricating grease has been faced with new challenge. It is not only necessary to reform from the aspects of raw materials, production process and application, but also to strengthen the in-depth research on base oils, thickeners and additives. As an important component of grease, thickener has become the focus of research. Among them, smectite grease is an environmentally friendly lubricating grease.

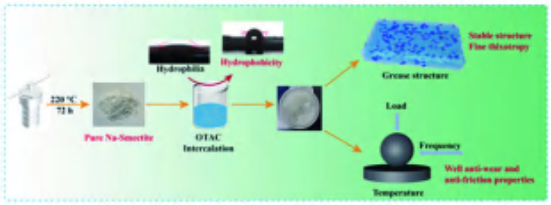


Fig. 1. Schematic diagram of synthetic smectite as a thickener.

Experiment

Smectite was synthesized in this system: NH_4F-$MgAc_2$-$Al(NO_3)_3$-TEOS-NaOH. The reactor was placed at 220 °C for 5 days. After cooling to room temperature, the samples was washed with deionized water. Pure smectite was obtained by drying at 100 °C for 12 h.

Results

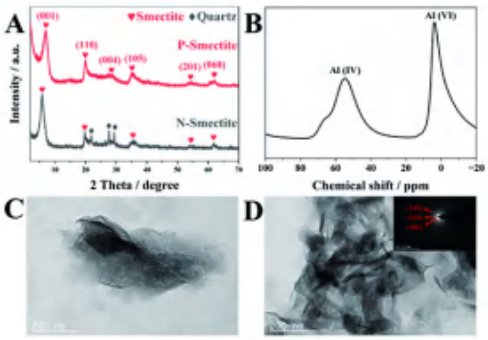


Fig. 2. (A) XRD patterns of natural smectite and synthetic smectite; (B) ^{27}Al NMR spectrum of synthetic smectite: TEM images: (C) natural smectite, (D) synthetic smectite (local electron diffraction image at upper right).

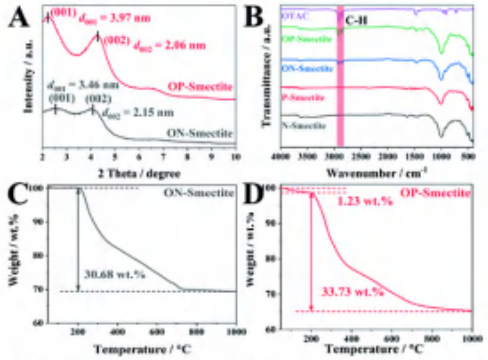


Fig. 3. Organic intercalated natural smectite (ON-smectite) and synthetic smectite (OP-smectite): (A) XRD patterns, (B) FT-IR spectra, and thermogravimetric traces (C: ON-smectite; D: OP-smectite).

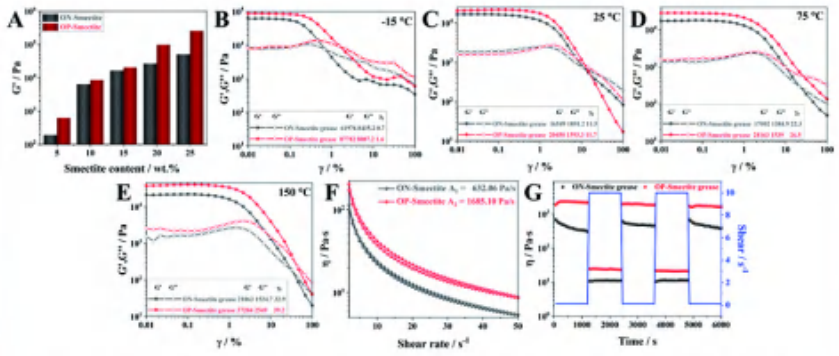


Fig. 4. Rheological properties of ON-smectite grease and OP-smectite grease: (A) storage modulus (G') corresponding to different thickening agent contents; (B) viscoelastic plots for smectite grease at −15 °C; (C) viscoelastic plot of smectite grease at 25 °C; (D) viscoelastic plot of smectite grease at 75 °C; (E) viscoelastic plot of smectite grease at 150 °C; (F) the thixotropic ring of smectite grease and (G) plots of apparent viscosity of smectite grease versus shear rate.

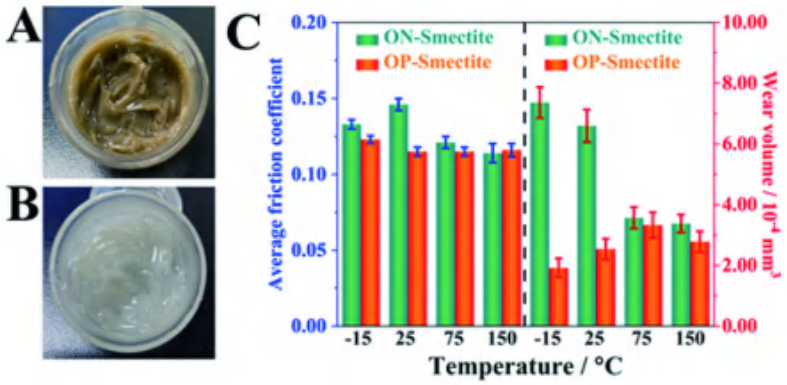


Fig. 5. Photographs of base oil and smectite grease: (A) ON-smectite grease, (B) OP-smectite grease;(C) average friction coefficient and wear volume.

ON-Smectite greases appeared edblack, while OP-Smectite grease appeared white, which may be caused by the presence of iron in natural smectite. In addition, OP-Smectite grease had better anti-wear and anti-friction properties at different temperatures.

Conclusion

(1) The pure smectite was synthesisized by a one-step hydrothermal process;
(2) The intercalated synthetic smectite with larger cation exchange capacity had better hydrophobicity and higher organic content than that of natural smectite;
(3) Compared with natural smectite grease, synthetic smectite grease had stronger thickening ability and exhibited excellent and more stable tribological properties at -15, 25, 75 and 150 °C.

Acknowledgement

We are thankful for the financial support provided from the National Natural Science Foundation of China (21978186, U21A20315, 21436008) and the Fund for Shanxi "1331" Project (1331) .

太原理工大学
TAIYUAN UNIVERSITY OF TECHNOLOGY

Heterogeneity and Influence Factors of Carbon Productivity: Evidence from Chinese Manufacturing Enterprises

Name: Xinzi Wang **Email: wangxinzi07@163.com**
Supervisor: Xiujin Li **Affiliation: School of Ecology and Environment, Beijing Technology and Business University**

Abstract

Understanding influence factors and heterogeneity of carbon productivity in manufacturing enterprises can provide important guidance for designing carbon reduction policies. In this study, the heterogeneity of carbon productivity of Chinese manufacturing enterprises was measured by employing enterprise-level data from 2001 to 2011. The empirical findings demonstrated that carbon productivity did not show a decreasing trend over time, but the changing pattern varied across industries. Based on a panel regression model, the result also found that both enterprise features and external factors significantly affected carbon productivity. Asset size, enterprise age, management level, export intensity, marketization level and etc. significantly increased carbon productivity, while enterprise financing and government subsidies decreased the productivity. In addition, effects of factors on carbon productivity differed by enterprise types, so governments should formulate differentiated environmental policies for various enterprises.

Result

➢ Carbon productivity heterogeneity

Table 1: Carbon Productivity Statistics

Descriptions	China											USA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2007
Panel A. Industry-Wide Statistics												
Mean	7.54	7.56	7.63	7.7	7.85	8.03	8.09	8.27	8.32	8.36	8.51	8.42
SD	1.94	1.93	1.94	1.96	1.97	2.01	2.03	2.03	2.02	2.05	2.06	1.16
Panel B. Within-Industry 90-10 Productivity Differences												
Mean	4.08	4.07	4.07	4.15	4.15	4.29	4.42	4.37	4.32	4.43	4.36	2.27
SD	1.08	1.12	1.04	1.12	1.13	1.19	1.16	1.05	1.07	1.19	1.04	0.57
p90-10	2.77	2.86	2.66	2.88	2.9	3.05	2.97	2.7	2.75	3.05	2.65	1.46
Panel C. Within-Industry Standard Deviation of Productivity												
Mean	1.59	1.59	1.59	1.62	1.62	1.67	1.72	1.7	1.68	1.73	1.7	0.89
SD	0.42	0.43	0.4	0.44	0.44	0.46	0.45	0.41	0.42	0.46	0.40	0.22
p90-10	1.11	1.11	0.99	1.05	1.08	1.1	1.09	1.01	1.04	1.13	0.96	0.49

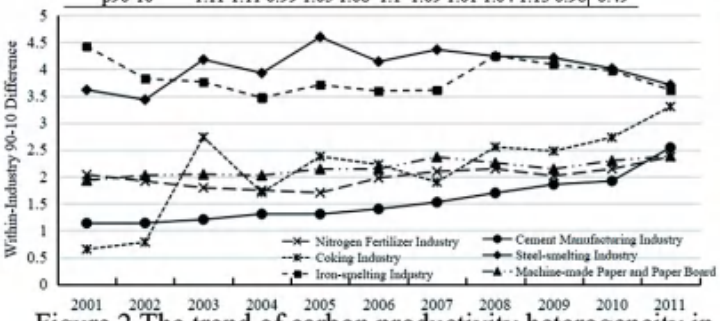


Figure 2 The trend of carbon productivity heterogeneity in China's major high-polluting industries

➢ Influence factors of carbon productivity

Table 3 Heterogeneity results

lnproductivity	state	foreign	private	high	low	capital	labor	tech
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
size	0.1150***	0.2349***	0.2233***	0.1530***	0.3028***	0.3689***	0.1601***	0.2149***
	(4.79)	(10.70)	(10.45)	(5.61)	(10.38)	(13.03)	(5.73)	(7.56)
age	-0.0051***	0.0091***	0.0084**	0.0054***	0.0056***	0.0073**	0.0017	0.0037**
	(-2.65)	(2.80)	(2.46)	(2.70)	(3.05)	(2.02)	(0.79)	(2.09)
age_sq	0.0000	-0.0001**	-0.0001*	-0.0002***	-0.0001***	-0.0002***	-0.0001*	-0.0001***
	(0.54)	(-2.05)	(-1.65)	(-3.79)	(-3.82)	(-3.26)	(-1.97)	(-3.78)
export	0.2287*	0.4315***	0.3629***	0.4495***	0.4206***	0.3720**	0.2143**	0.3454***
	(1.69)	(6.04)	(5.01)	(3.58)	(6.67)	(2.39)	(2.54)	(3.94)
manage	0.1745***	0.0259***	0.0243***	0.0209***	0.0403***	0.0344**	0.0248***	0.0335***
	(8.17)	(4.81)	(4.57)	(2.65)	(5.21)	(2.25)	(2.89)	(4.15)
finance	-2.3257***	-4.3129***	-3.7728***	-2.9641***	-5.8001***	-7.0265***	-4.0965***	-5.4334***
	(-2.79)	(-7.56)	(-6.44)	(-5.52)	(-11.58)	(-10.85)	(-6.51)	(-11.11)
gdp	-0.1583	-0.0630	0.1753	-0.4241**	-0.2857	0.1357	-0.2864**	-0.1610
	(-0.50)	(-0.19)	(0.50)	(-2.50)	(-1.51)	(0.37)	(-2.04)	(-1.02)
middle	-1.5372***	-0.9002***	-0.6211**	-0.5326**	-1.0367***	-1.1625***	-1.1342***	-1.1905***
	(-5.64)	(-3.37)	(-2.10)	(-2.62)	(-6.75)	(-3.45)	(-6.31)	(-7.46)
west	-1.5242	-1.0488	-0.3514	-1.5902***	-1.0421**	-0.2439	-1.5075***	-1.2171**
	(-1.65)	(-1.21)	(-0.38)	(-2.92)	(-2.06)	(-0.25)	(-2.83)	(-2.40)
market	0.0400	-0.0048	-0.0060	0.1127***	0.0689***	0.0186	0.0807***	0.0594**
	(0.93)	(-0.15)	(-0.18)	(3.90)	(2.72)	(0.37)	(2.75)	(2.29)
subsidy	-1.8234*	1.2563*	1.4327**	0.2193	-1.6457*	-3.1610**	0.0915	-0.5570
	(-1.85)	(1.96)	(2.16)	(0.37)	(-1.90)	(-2.40)	(0.12)	(-0.79)
ownership				-0.1272**	-0.2124***	-0.2409***	-0.2346***	-0.2513***
				(-2.44)	(-6.97)	(-5.81)	(-4.75)	(-6.71)
pollution	-1.1843***	-0.7434***	-0.7110***				-2.0074***	-0.9981***
	(-4.28)	(-17.88)	(-17.10)				(-28.06)	(-23.14)
_cons	10.0038***	7.6545**	5.3408*	9.6366***	8.3595***	3.8802	11.2863***	8.6693***
	(3.55)	(2.56)	(1.67)	(6.55)	(4.90)	(1.20)	(8.42)	(5.95)

Conclusion

The relationship between economic growth and carbon emission reduction is complex. Finding ways to balance the dual objectives is a problem faced by China and other countries, especially developing countries. Improving carbon productivity can effectively solve the problem and is the best way to achieve economic growth under the pressure of carbon controlling. In this context, using enterprise-level micro data, this paper firstly tried to analyze the heterogeneous characteristics of China's carbon productivity across manufacturing industries and enterprises. And then, based on enterprises level data from 2001 to 2011, this paper examined the impact of various factors on carbon productivity by using a panel regression method.

The results show that the average level of carbon productivity of Chinese manufacturing enterprises is constantly improving, but the huge gap between enterprise carbon productivity has not gradually decreased over time. From 2001 to 2011, the log of output per ton carbon dioxide emitted increased from $1881.8 to $4964.2, while the mean of within-industry 90-10 productivity differences increased from 5815 percent to 7726 percent. Compared with America, the differences in carbon productivity between industries and enterprises appear to be large. In terms of influencing factors, both micro environment (features of enterprises) and macro environment have impacts on the enterprises' carbon productivity. And impacts of some factors may vary across sub-samples, which were obtained by grouping the full sample by ownership, energy consuming intensity, or dependence on production factor.

Policy implications

- In order to further control carbon emission, enterprises with low carbon productivity must be paid attention and treated strictly. Taxing or penalizing enterprises with low carbon productivity is an effective way to encourage them to reduce energy consumption or increase investment in green technologies.
- The realization of economies of scale is conducive to improving the carbon productivity of manufacturing industry.
- Governments should implement differentiated subsidy policies. Providing financial subsidies to enterprises is one of the government's industrial policy tools, but its impact on carbon productivity is heterogeneous.
- The location factor cannot be ignored in formulating energy-saving policies. The energy-saving targets setting in government plan are allocated to regions according to the target responsibility system.

Digitization and Traceability of Comfort Performance and Environmental Footprints of Textiles

University of Manchester · Department of Materials · Textiles and Apparel
Xiaonan Xu
Supervised by: Dr. Henry Yi Li, Dr. Jo Colon, Dr. Yao Yao

1 What is Digital Product Passport?

A DPP is a combination of i) a unique product identifier, and ii) data collected by different value chain actors related to this unique identifier. This data may include the characteristics of the product and information about its value chain and life.

- Product information, traceability and supply chain visibility.
- Full-lifecycle tracking.

2 Why do textiles need DPP?

- **Fashion Big Data Business Model (FBD_Bmodel):** To create a digital passport for each stage textile products and traceable advanced approach to tracing and managing carbon footprints based on the Fashion Big Data Business Model (FBD_Bmodel) digital technology platform.
- **Carbon Footprint Tracing:** i) Establish a robust carbon footprint tracing system to quantify the environmental impact at each stage of the textile product's journey. ii) Utilize data analytics to identify key contributors to carbon emissions and formulate strategies for reducing the carbon footprint.
- **Businesses and Consumers:**

Businesses

will innovate by crafting sustainable, circular materials, fostering environmental responsibility.

Consumers

will benefit from informed choices based on sustainability criteria, contributing to a growing demand for eco-friendly products.

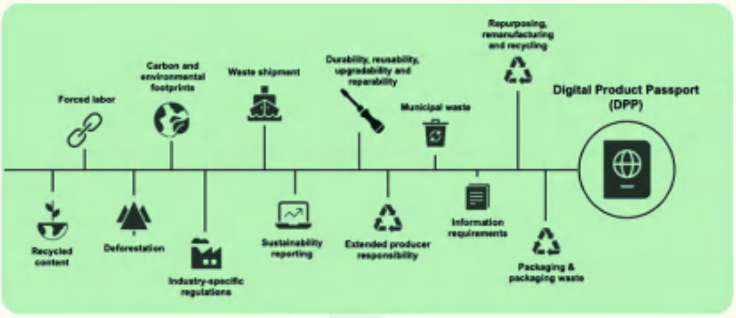
- **Digital Passport Implementation:** Develop a digital passport system that uniquely identifies each stage of a textile product's lifecycle.
- **Comprehensive Lifecycle Coverage:** Include information about the origin of raw materials, production processes, transportation methods, and end-of-life disposal options.

References

Brun, A., et al.(2020) 'Supply Chain collaboration for transparency', *Sustainability*, 12(11), p. 4429.
FBD_BModel. Available at: https://www.fbd-bmodel.eu/objectives/ (Accessed: 18 Nov. 2023).
Saari, L. et al. (2022). ' Digital Product Passport Promotes Sustainable Manufacturing'.
Zhang, L. et al. (2022) 'Advancing life cycle sustainability of textiles through technological innovations', *Nature Sustainability*, 6(3), pp. 243–253.

3 What is FBD-Bmodel?

- FBD_BModel, sponsored by the European Union, aims to establish a digital technology platform for delivering innovative functional garment products within a local EU-based textile supply chain.
- An extended virtual space allows the display and evaluation of fashion and functional performances, considering factors like thermal comfort and skin touch comfort.



Fashion Big Data Business Model Platform Interface

4 What is the influence?

- **Green and Digital 'Twin' Transition**
- **Traceable Carbon Footprint Model**
- **Energy and Resource Efficiency**
- **Holistic Sustainability Approach**

Contact

xiaonan.xu-2@postgrad.Manchester.ac.uk
Textile and Apparel
Department of materials,
School of Nature Science,
Faculty of Science & Engineering

The Impact of Chipmakers Building Factories on the Development of New Energy Power ——The Case of German Industry

ZHANG Yiwen, SHANG Ruochen, GAO Chuchen
School of Management, Harbin Institute of Technology, Harbin 150001, China
Tel:18811578289 E-mail:yiwenzhang0809@qq.com

Introduction

Under the promotion of the European chip Act, chip manufacturers have built factories in Europe, Germany has become the first choice for many large factories in Europe, there are three main reasons: first, the German government plans to allocate huge funds from the "climate and transformation fund" to promote the development of German chip manufacturing industry; Second, as a traditional auto manufacturing power, Germany has a large demand for chips in its new energy transition; Third, Germany has a leading position in the European semiconductor industry, with the largest semiconductor industry center in Europe. One of the key issues in the development of the chip industry in Germany is the supply of electricity, as chip manufacturing is extremely sensitive to the cost of electricity and requires extremely high stability of power.

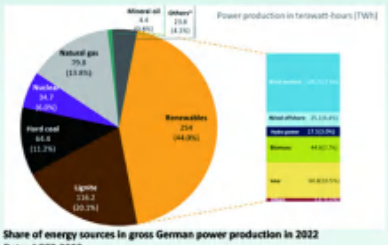
Methods

In the case of TSMC, a single TSMC company consumed 8 percent of Taiwan's entire electricity consumption in 2022, consuming more than 20 billion kilowatt-hours. In 2022, Germany's total electricity consumption is 484.2 billion KWH, with industrial consumption accounting for about 47 percent, or about 2,275 KWH. In 2022, land-based and offshore wind power accounted for 17.4 percent and 4.4 percent of Germany's electricity generation, respectively, for a total of 21.8 percent, while solar power accounted for 10.5 percent, biomass for 7.7 percent, hydropower for 3 percent and other sources for 1 percent. Renewable energy generation accounted for approximately 44 percent of total electricity generation. Power grid fluctuations caused by Germany's power shortage and high proportion of renewable energy generation have become a key constraint on the chip industry's development.

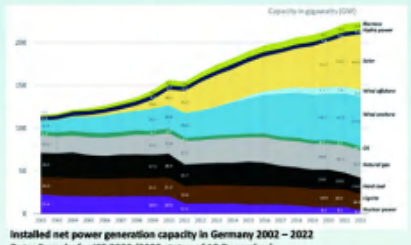
Discussion

A survey conducted by the Association of the German Automotive Industry (VDA) on auto parts companies and small and medium-sized car companies in February 2023 showed that the international competitiveness of the German automotive industry has been declining, industrial policy has performed poorly, and about 90% of the companies surveyed believe that Germany is not internationally competitive in terms of energy costs, labor, and tax burdens, and that the biggest problem is the high price of electricity and natural gas.

Most of the carbon emissions from modern mobile devices and data center equipment come from hardware manufacturing and infrastructure, and chip manufacturing is a major source of carbon emissions, the major challenge for the electronics industry in the future is whether it can withstand the pressure of carbon emissions and power consumption.



Share of energy sources in gross German power production in 2022
Data: AGEB 2023



Installed net power generation capacity in Germany 2002 – 2022
Data: Fraunhofer ISE 2022 (2022 status of 19 December)

Gross power production in Germany 1990 - 2022, by source.
Data: BDEW 2022, data preliminary

German power export balance 1990 - 2022.
Data: BDEW 2022 (2022 data preliminary)

Conclusion

With the iterative upgrading of industries and the development of high-end manufacturing such as chips, a large and stable supply of electricity is particularly important, but the huge amount of power consumption required for industrial development contradicts the current goal of energy saving and carbon reduction. Reducing carbon emissions through new energy power generation is currently characterized by high fluctuations and high costs.

It is of great significance to summarize the energy transformation process and the problems in developed countries such as Germany to promote the energy transformation and realize the goal of "double carbon" while improving our scientific and technological strength.

A novel economic benefit calculation modeling applying to coal mining

Zhicheng Zhang, Yanyu Guo, Guorui Feng, Tingye Qi
College of Mining Engineering, Taiyuan University of Technology, Taiyuan, 030024
Tel : 15695251797 E-mail : zhangzhicheng0514@163.com

Abstract and background of the study

Coal is one of the primary energy sources in China. Due to different mining processes, the environmental impact of each mining method varies. Traditional mining methods have relatively low costs but a **substantial ecological impact**. For example, backfilling mining is environmentally friendly but raises mining costs for surface settlement, Coal gangue solid waste pollution, etc. Therefore, to meet the **current sustainable development** concept, based on the principles of coal mining, a novel economic benefit calculation modelling applied to coal mining is presented to analyze the economy's differential benefits under different mining methods and their **impact on the environment**.

Main research content

First, a model was established to investigate the economic benefits of coal mining.
Secondly, the differential benefits under three mining methods, collapse mining, cemented backfill mining and material-improved cemented backfill mining, were calculated for a mining site in China as an example.
Finally, four crucial factors affecting coal mine efficiency were identified using hierarchical analysis, the intersection of the differential benefits of the three mining methods under the four essential factors was derived, and the degree of influence of the vital factors on the economic efficiency of coal mines was analyzed using the univariate method.

The main formulas of the model

$$m_{0c}=\rho_c \cdot S \cdot r_0$$

The mass of raw coal mined at this workface using CM can be expressed

$$m_c = m_h + m_g + m_t \qquad \alpha=\frac{m_h}{m_c}=\frac{m_{0h}}{m_{0c}}=\frac{m_{1h}}{m_{1c}}$$

The expression for the residual rate of high-quality coal left after the coal processing plant

$$Q_{gf}=q_{gf}\cdot m_{0g} \qquad \begin{aligned} W_w &= Q_0 - Q_p - Q_{tr} - Q_{gf} \\ &= m_{0h}\cdot q_h - Q_p - Q_0\cdot\varepsilon - q_{gf}\cdot m_{0g} \end{aligned}$$

the independent using of traditional mining methods

$$m_w = S\cdot r_1\cdot b_w\cdot\rho_w \qquad m_{ce} = S\cdot r_1\cdot b_{ce}\cdot\rho_{ce} \qquad m_a = S\cdot r_1\cdot b_a\cdot\rho_a \qquad m'_{1g} = S\cdot r_1\cdot b_g\cdot\rho_g$$

Quality of cement, gangue, fly ash and water used in mining areas

$$Q_w = m_w\cdot q_w \qquad Q_a = m_a\cdot q_a \qquad Q_g = m'_{1g}\cdot q_g \qquad Q_{ce} = m_{ce}\cdot q_{ce} \qquad Q_{mix}=\lambda\cdot(Q_w+Q_a+Q_g+Q_{ce})$$

Cost of cement, gangue, fly ash and water used in mining areas

$$\rho_{mix}=\frac{\rho_{bo}\cdot\rho_{ce}}{\theta\cdot\rho_{ce}+(1-\theta)\cdot\rho_{bo}}$$

Combined density of materials after mixing

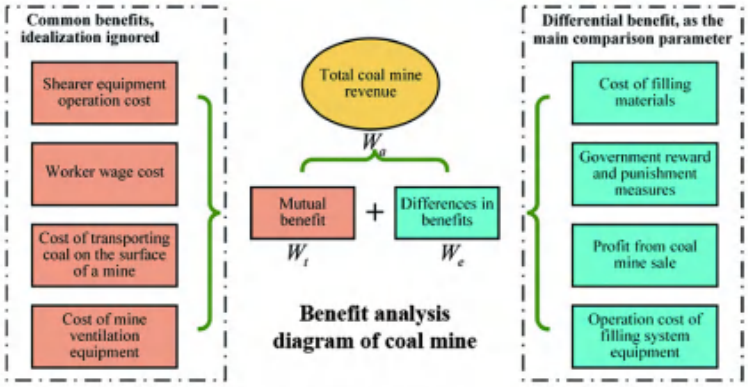
$$b'_w=\frac{m_w/\rho_w}{m_w/\rho_w+m_a/\rho_a+m'_{1g}/\rho_g+m_{ce}/\rho_{mix}}$$

Volume share after mixing

Conclusion

(1) The differential benefits of the three mining methods were calculated by establishing an EBCM model.
(2) Taking a mining area as an example, four important factors, namely coal reserves, national coal tax rate, national coal tax reduction rate, and cement market price, which affect the differential benefits of coal, are calculated by hierarchical analysis.
(3) They are analyzed to obtain that coal reserves, national coal tax reduction rate and differential benefits of coal mines show a positive relationship. National coal tax rate and cement market price are negatively associated with the differential benefits of coal mines.
(4) Through the derivation of the EBCM model, the intersection of the differential benefits of three mining methods under four important factors is calculated, which can be used for the selection of coal mining methods. When the differential benefits are similar or the same, the MCBM with higher safety and better environmental benefits can be prioritized to ensure good social benefits, contribute to the rational exploitation and sustainable development of energy.

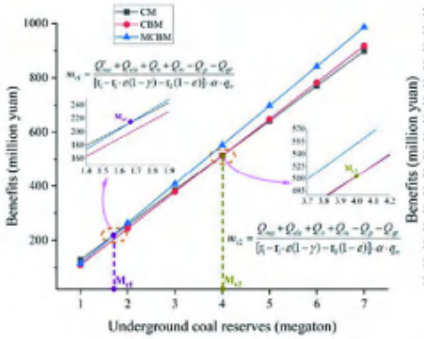
Analysis and discussion of the model



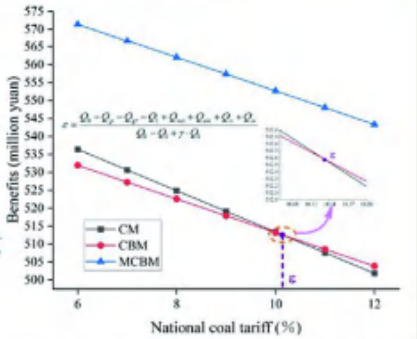
Benefit analysis diagram of coal mine

The model applies to all types of coal mines and can be used to select low-consumption, low-cost and high-yield mining methods according to the actual situation of coal mines and local policies, guiding the formulation of government policies and the selection of mining methods for coal mining enterprises, which is of great significance to the sustainable development of the environment and the rational exploitation of energy.

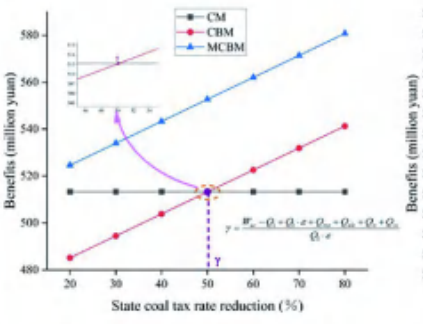
Plotting of calculation results



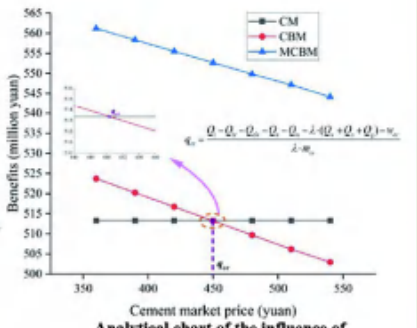
Coal reserves impact analysis chart



Analysis chart of the influence of the national coal tax rate



Analysis chart of the influence of the national coal tax rate



Analytical chart of the influence of the market price of cement

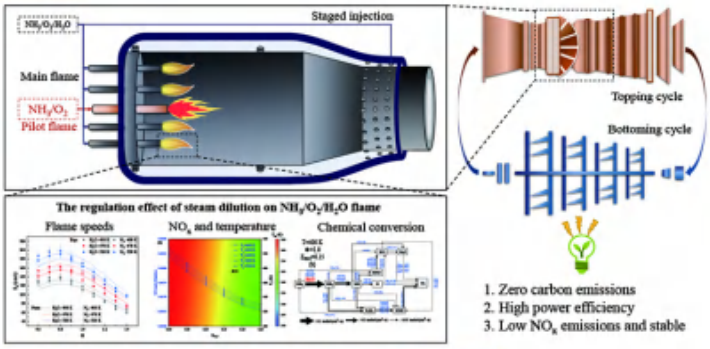
Insight into the regulation effect of steam dilution on oxygen-enriched ammonia combustion characteristics

张屿，韩博，李欣成，张文达，张林瑶，赵义军*，孙绍增
（哈尔滨工业大学 能源科学与工程学院 燃煤污染物减排国家工程实验室，黑龙江 哈尔滨，150001）
(Tel:13060172736, Email: zhangyuflame@163.com)

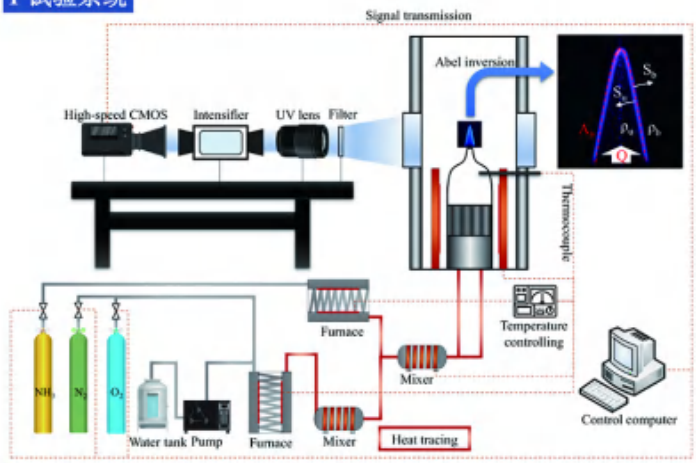
文字摘要：

富氧燃烧是强化氨燃烧的有效手段，但其会造成高温和NO_x排放问题，增加燃烧室和脱硝设备负荷。H_2O作为氨燃烧主要产物，是控制温度和NO_x排放的潜在稀释剂，$NH_3/O_2/H_2O$燃烧系统能达到与天然气CES循环相近的效率。本工作探究了常压下$NH_3/O_2/H_2O$火焰速度、火焰温度和NO排放特性，构建了$NH_3/O_2/H_2O$动力学模型并关联了关键组分/反应与层流燃烧速度/NO/温度。从化学反应角度解释了蒸汽对氮转化、热释放和火焰传播的作用机理，提出了蒸汽稀释调控富氧燃烧的规律和机制。

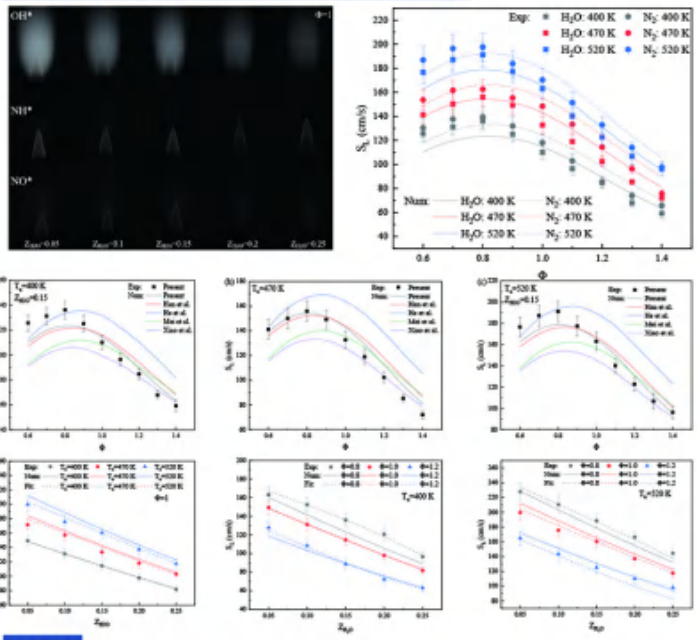
图摘要



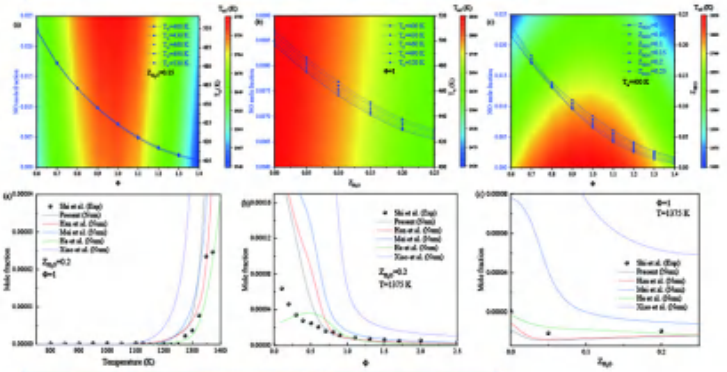
1 试验系统



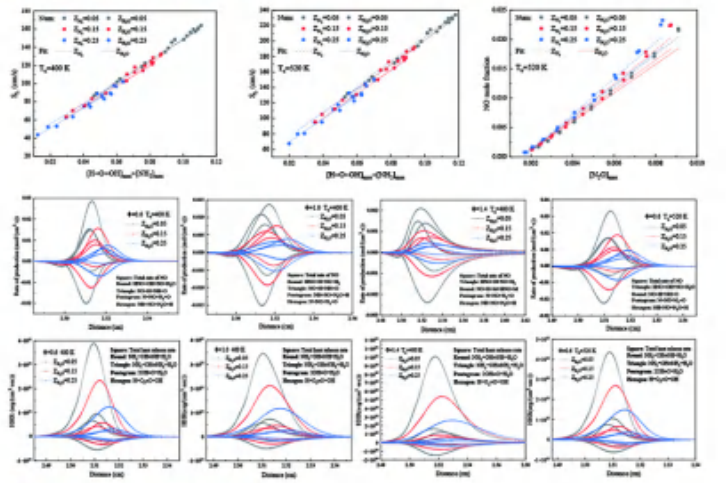
2.1 层流火焰速度特性和机理准确性验证



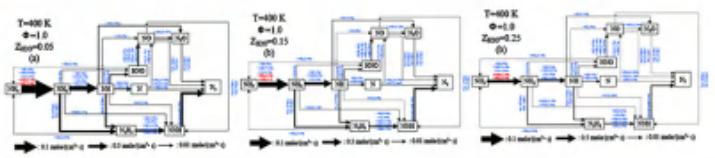
2.2 火焰温度/NO排放特性和机理准确性验证



2.3 关键组分/反应与火焰特性的关联规律



2.4 氮转化路径分析



3 结论

(1) 氨的一次分解和H/O自由基池是决定$NH_3/O_2/H_2O$层流火焰速度和氮转化的关键，蒸气稀释会抑制氨的初级分解并减少H/O自由基池。
(2) NO主要通过NH/HNO的转化生成，并主要通过N_2O-NNH机制消耗。蒸气稀释有效降低了火焰温度和NO排放，但在极贫燃条件下也可能会略微促进NO排放。
(3) 蒸汽稀释在贫燃或富燃条件下对NO排放和温度的抑制作用加剧，因此优化燃烧组织方式（如RQL技术）是调控燃烧效率、温度和排放的必要手段。

低零碳农业

Low- and Zero- Carbon Agriculture

Seggiani渣层流动模型中熔渣粘度的处理方式

白孟龙，赵义军*，张林瑶
（哈尔滨工业大学 能源科学与工程学院，黑龙江 哈尔滨，150001）
(Tel:17863107960, Email: 22B902032@stu.hit.edu.cn)

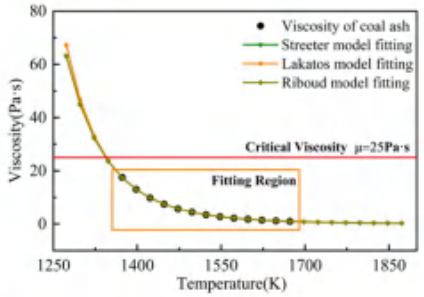
文字摘要

在碳中和战略目标下，煤气化技术将会是我国未来煤炭领域的一条重要发展路线。在煤气化技术推广应用中，液态排渣过程的稳定性日益凸显，如何有效提升Seggiani渣层流动预测模型的计算精度问题亟待解决。本研究侧重探索了熔渣粘度处理方式对模型计算精度的影响，主要包含了温度-粘度的拟合形式和粘度-厚度的近似简化两方面。通过熔渣层的厚度、温度、粘度、流动速度以及炉壁处的热流密度等参数进行解析，以实现兼顾熔渣流动特性求解的简易化和高精度这一目标。

1 煤灰成分

化合物	SiO_2	CaO	Al_2O_3	MgO	K_2O	Na_2O	Fe_2O_3	FeO	Other
质量分数	32.156	27.298	24.320	4.237	1.579	1.559	3.453	3.226	2.172

2 煤灰粘度



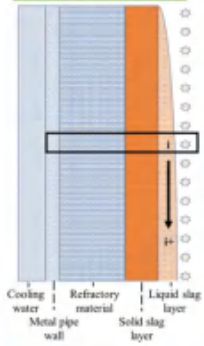
$$\mu_s = A\cdot\exp(B/T)$$

$$\mu_l = A\cdot\exp(B/(T-C))$$

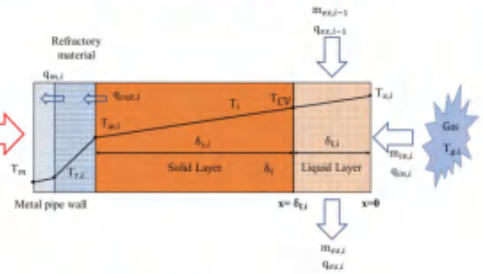
$$\mu_r = A\cdot T\cdot\exp(B/T)$$

3 Seggiani渣层流动模型

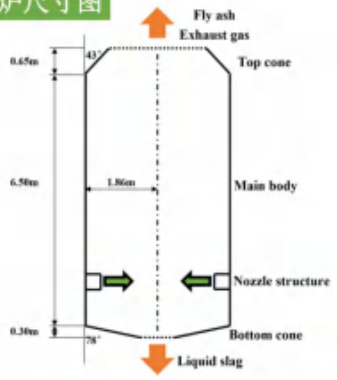
计算单元划分



流动参数示意



气化炉尺寸图



质量守恒方程

$$\rho\frac{d\delta_i}{dt} = \frac{m_{in,i} + m_{ex,i-1} - m_{ex,i}}{A_i}$$

动量守恒方程

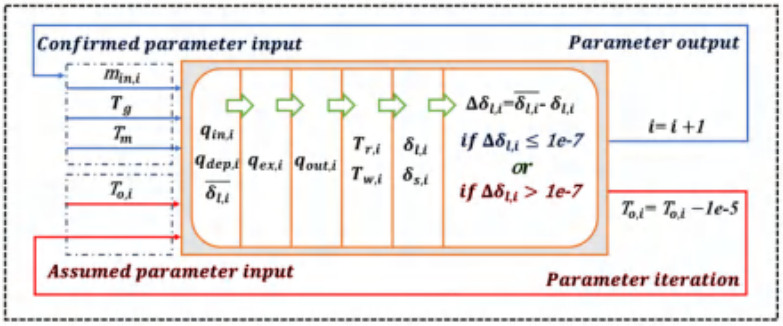
$$\frac{d}{dx_i}\left(\mu_i\frac{dv_i}{dx_i}\right) = -\rho g\cos\beta_i$$

能量守恒方程

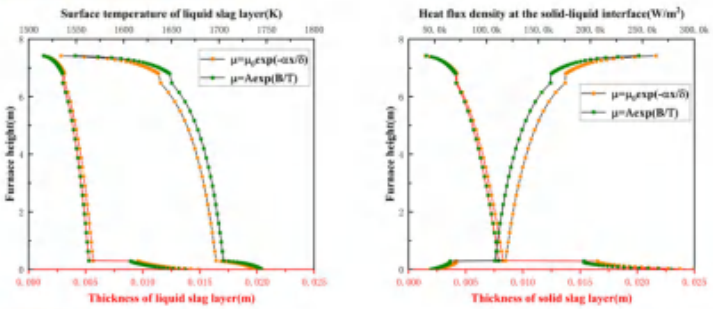
$$\rho c\frac{d\left(T_{avg,i}\delta_{all,i}\right)}{dt} - \rho\frac{d\delta_{s,i}}{dt}q_f = q_{in,i} - q_{out,i} + \frac{m_{in,i}cT_{in,i} + q_{ex,i-1} - q_{ex,i}}{A_i}$$

计算流程示意

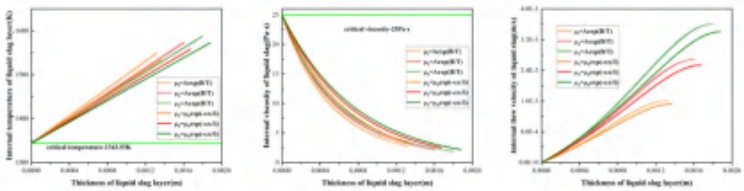
Calculation process under stable flow conditions of slag



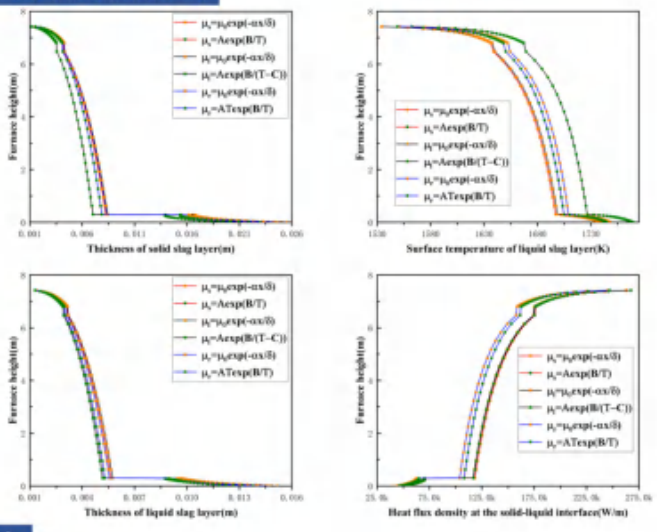
4.1 流动参数轴向变化



4.2 粘度-厚度近似处理



4.3 温度-粘度拟合形式



5 结论

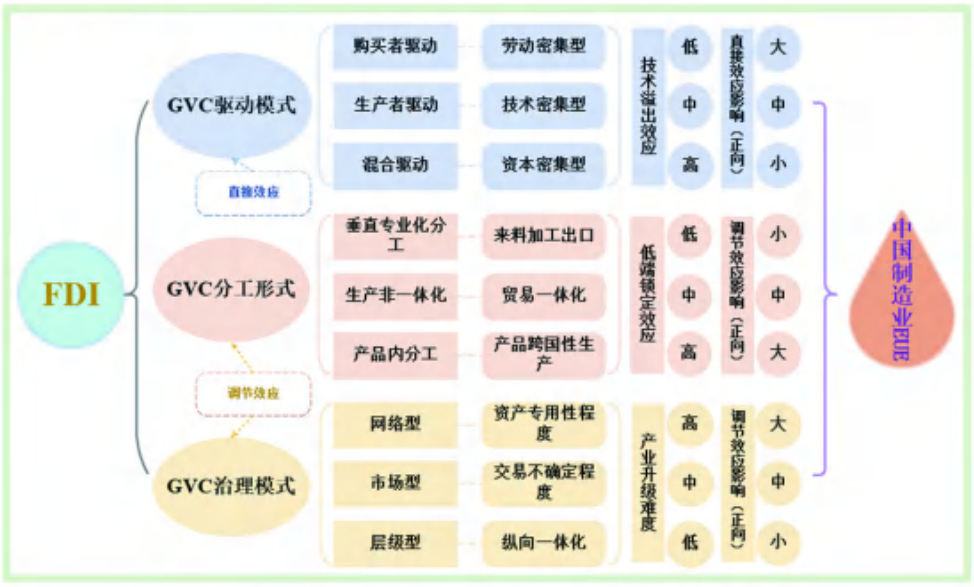
(1) 熔渣沿炉膛轴线方向流动过程中，流动参数的变化幅度逐渐减弱；
(2) 炉壁处倾角和流动面积发生变化时，流动参数的变化幅度将出现阶跃变动；
(3) 针对粘度-厚度关联采用近似处理方式所产生的偏差将沿着流动方向持续发散；
(4) 通过$\mu_r = A\cdot T\cdot\exp(B/T)$进行粘度拟合可兼顾熔渣流动特性求解的简易化和高精度。

外商直接投资、GVC演进模式与中国制造业生态不平等交换

龚梦琪，阮榕鹏
(武汉工程大学 法商学院，湖北 武汉 430205)

摘要：外商直接投资（FDI）影响东道国生态不平等交换(EUE)的研究方兴未艾，而基于GVC（全球价值链）演进模式视角将为此问题的研究提供新的思路。这篇论文的创新点如下：首先，将FDI对环境污染的影响机制扩展到对EUE的影响机制，填补了现有研究中的空白。其次，在经验分析方面，本文采用多区域投入产出方法计算EUE，考虑了不同国家和地区之间的经济联系和资源流动。不仅研究了GVC驱动模型下FDI对中国制造业EUE的直接影响，还分析了GVC分工模型和GVC治理模型的调节效应。第三，对EUE进行分解，检验了FDI对EUE不同方面的影响。本文基于2000-2014年中国制造业12个细分行业数据，利用面板数据回归模型，实证分析GVC驱动模式下FDI对中国制造业EUE影响的直接效应以及GVC分工模式和GVC治理模式对二者影响机制的调节效应。结果表明：不同GVC驱动模式下，FDI对中国制造业EUE均具有显著的加强关系，且存在明显的异质性，其中购买者驱动下的制造业EUE水平受FDI的加强作用最大；就GVC分工模式而言，产品内分工对FDI影响制造业EUE的正向调节效应最大；就GVC治理模式而言，网络型治理模式对二者影响机制的正向调节效应最大。将EUE进一步分解后发现：就生产侧而言，其基于GVC演进模式下的回归结果与EUE基本一致，然而消费侧的回归结果与前面二者存在差异，据此进行比较分析，发现就样本期整体而言，若想缓解FDI对中国制造业EUE水平的正向影响，目前最适合中国的GVC演进模式分别是混合驱动模式、垂直专业化分工、层级型治理模式。本文的启示在于当前我国制造业在引进外资时应重点引入技术密集型产业，利用其“技术溢出”效应助力行业转型升级，鼓励行业内企业自主进行技术突破以突破行业价值链封锁壁垒，在融入GVC时尽可能地采取垂直专业化分工形式和层级型治理模式，最终改善我国制造业EUE。鉴于中国是最大的发展中国家，本文通过研究FDI对中国融入GVC过程中对EUE的影响，为广大发展中国家提供有关结论和建议，为更协调可持续的世界发展做出一些贡献。

关键词：外商直接投资（FDI）；全球价值链(GVC)；中国制造业；生态不平等交换(EUE)



GVC演进模式下外商直接投资对中国制造业生态不平等交换影响机制图

实证结果：

- 不同的GVC演进模式下回归结果显示：就GVC驱动模式而言，不同驱动模式下FDI对EUE均有显著正向影响，加剧了中国制造业EUE，且购买者驱动下FDI对EUE的正向影响程度最大。就GVC分工形式而言，生产非一体化和产品内分工对FDI影响EUE具有正向调节作用，且产品内分工的调节效应更大。就GVC演进模式而言，市场型和网络型对FDI影响EUE具有正向调节作用，且网络型的调节效应更大。
- 将EUE进一步分解为PEUE和CEUE后发现：就PEUE而言，其基于GVC演进模式下的回归结果与EUE基本一致，然而CEUE的回归结果与前面二者存在差异，据此进行比较分析，发现就样本期整体而言，若想缓解FDI对中国制造业EUE水平的正向影响，目前最适合中国的GVC演进模式分别是混合驱动模式、垂直专业化分工、层级型治理模式。
- 将FDI分解为HFDI和VFDI后发现：就GVC驱动模式而言，购买者驱动下HFDI和VFDI对EUE影响均显著为正，而生产者驱动下VFDI对EUE的正向影响甚至大于购买者驱动。就GVC分工形式而言，VFDI在垂直专业化分工的调节下对EUE的正向影响较HFDI更为显著。就GVC治理模式而言，二者对EUE的影响关系与FDI保持一致。

本文建议：

- 就GVC驱动模式而言：①在我国制造业引进FDI时，为缓解FDI对EUE和PEUE的负面影响，应尽量避免引入购买者驱动产业。②为强化FDI对CEUE的正面影响，则应加大生产驱动产业的引进。③为缓解VFDI对EUE的负面影响，应优先筛选混合驱动产业进入，主要原因在于VFDI以垂直专业化分工为基础，在融入全球价值链生产体系初期，资本密集型产业的进入不仅能够帮助我国建立基础的制造业生产条件，而且为日后发展进口替代贸易打下了良好的基础，这也为其他正处于制造业发展初期且位于GVC生产体系中的发展中国家提供了经验。
- 就GVC分工形式而言，为缓解FDI对制造业EUE的负面影响，在参与GVC分工时我国应尽量采用垂直专业化分工形式。生产非一体化和产品内分工均加剧了FDI对我国制造业整体EUE水平的影响，这些从侧面反映了我国制造业在全球价值链中尚处于劣势地位，说明我国制造业在发展过程中亟需进行产业升级并增加产品的附加值以突破低端锁定实现GVC的产业跃迁，这一过程的核心是技术的迭代进步和创新突破。
- 就GVC治理模式而言，为缓解FDI对制造业EUE的负面影响，我国应争取采用层级型治理模式。该治理模式下，发达国家采用FDI方式于我国开设子公司或合资公司之后，由于技术溢出效应的存在，我国的部分企业可以通过模仿创新活动提升我国制造业产业发展水平，缩小我国制造业与发达国家的差距，以期在发展过程中实现某些技术的“弯道超车”。

碳减排责任与贸易竞争力何以兼得？——来自工业隐含碳配额的中观证据

胡剑波（贵州财经大学 经济学院，贵阳 550025），麦骏南（贵州财经大学 大数据应用与经济学院，贵阳 550025）
(Tel：13629637592 Email：mjn0213@163.com)

引言背景

全球应对气候变化的挑战愈加严峻，继续实施碎片化的单边减排政策将会不可避免地导致“碳泄露”的问题频发，进而引起世界各国碳减排责任归属与维系贸易竞争力之间的纠纷和摩擦。

出口导向型的工业化发展中国家面临着不对称的碳减排压力，即额外负担的环境成本逆差将会削弱具有比较优势的工业产品在海外市场的综合实力和竞争优势。

近年来，利用市场手段应对工业贸易的碳泄露风险和加速工业经济的绿色转型是中国一项卓有成效的制度创新。故在此背景下，研究如何借助隐含碳配额机制来实现 “履行碳减排责任”与“巩固贸易竞争力”的合理兼顾，对持续提升中国在国际气候谈判中的制度性话语权极具理论价值和现实意义。

模型方法

1.本文构建的低碳贸易竞争力指数（LCTC），既衡量了产业部门的国际竞争力处于何种水平，又反映了产业部门的碳减排成效是否显著。

①贸易隐含碳排放量：

$$C_{ex} = F_c^d T_{ex} + F_c^d A^m \left(I - A^d\right)^{-1} T_{ex}$$

$$C_{im} = F_c^d A^m \left(I - A^d\right)^{-1} T_d + F_c^d T_m + F_c^d A^m \left(I - A^d\right)^{-1} T_{ex}$$

②低碳贸易竞争力指数：

$$LCTC = \frac{\frac{T_{ex}}{C_{ex}} - \frac{T_{im}}{C_{im}}}{\frac{T_{ex}}{C_{ex}} + \frac{T_{im}}{C_{im}}} = 1 - \frac{2\frac{T_{im}}{C_{im}}}{\frac{T_{ex}}{C_{ex}} + \frac{T_{im}}{C_{im}}} = 1 - \frac{2T_{im}}{C_{im}\frac{T_{ex}}{C_{ex}} + T_{im}}$$

④基于扩展的Kaya恒等式的LMDI指数分解模型

$$LCTC = \sum_{i=1}^{n} \frac{LCTC_i}{L_i} \times \frac{L_i}{K_i} \times \frac{K_i}{E_i} \times \frac{E_i}{C_i} \times C_i = \sum_{i=1}^{n} H_i \times S_i \times U_i \times O_i \times C_i$$

2.本文采用三阶段ZSG-SBM模型对隐含碳排放配额进行优化：

③三阶段ZSG-SBM模型：

$$\min\varphi = \frac{1 - \frac{1}{m}\sum_{p=1}^{m}\frac{s_p^-}{x_{ip}}}{1 + \frac{1}{s_1+s_2}\left(\sum_{r=1}^{s_1}\frac{s_r^g}{y_{ir}^g} + \sum_{r=1}^{s_2}\frac{s_r^b}{y_{ir}^b}\right)}$$

$$s.t.\begin{cases} K_i = \sum_{i=1}^{n}\lambda_i k_i + S^k,\ L_i = \sum_{i=1}^{n}\lambda_i l_i + S^l,\ E_i = \sum_{i=1}^{n}\lambda_i e_i + S^e \\ Y_i = \sum_{i=1}^{n}\lambda_i y_i - S^y \\ \varphi C_i = \sum_{i=1}^{n} c_i \left[1 + \frac{c_j(1-\varphi)}{\sum_{i=1, i\neq j}^{n} c_i}\right] \\ \sum_{i=1}^{n}\lambda_i = 1, S^k \geq 0, S^l \geq 0, S^e \geq 0, S^y \geq 0 \end{cases}$$

研究结论

（1）从调整额度来看，电子信息制造业和轻工纺织业的增量最高，原材料工业的削减程度最大；从最终配额来看，电子信息制造业和机械设备制造业获得的碳配额最多，而能源供应业和资源采掘业获得的碳配额最少。

（2）从指数变动来看，原材料工业和能源供应业上升趋势显著，初始效率值较高的电子信息制造业和轻工纺织业略有下滑，但零和博弈后上述部门出现的额外福利损失在可接受的范围之内。从比较优势来看，原材料工业和能源供应业实现了向高比较优势的跃升，但资源采掘业始终存在较高比较劣势的问题需要引起重视。

（3）中国工业低碳贸易竞争力的增长来源以及各影响因素的贡献大小表现出显著的部门异质性，共通之处在于人才质量的提高、禀赋结构的调整、资本能效的改进、能源消费的变革和配额分派的优化是强化中国工业低碳贸易竞争力的重要途径。

实证分析

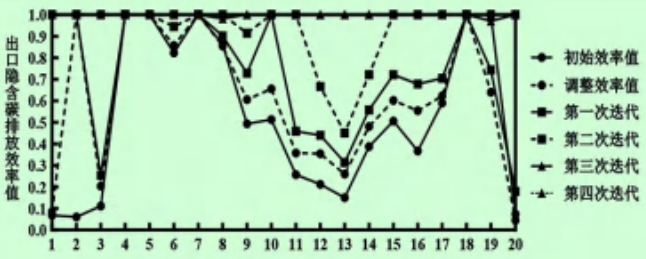


图 1 三阶段ZSG-SBM模型的效率优化过程

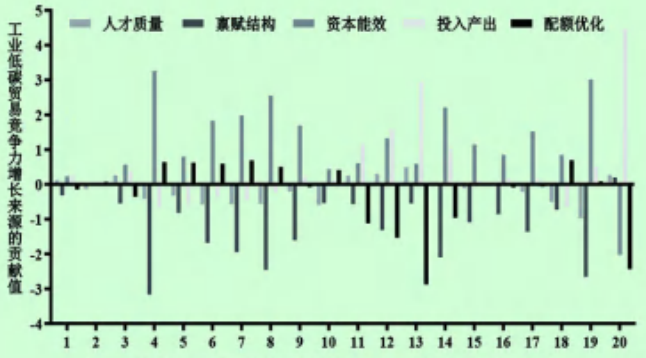


图 2 中国工业各部门低碳贸易竞争力指数的增长来源分解

表 1 中国工业各部门出口隐含碳排放配额的分配结果和低碳贸易竞争力的指数对比

编号	产业部门	初始配额（Mt）	最终配额（Mt）	配额优化前的工业低碳贸易竞争力	配额优化后的工业低碳贸易竞争力
1	煤炭开采和洗选业	434.94	290.94	-0.690	-0.570
2	石油天然气开采业	3674.57	6885.93	-0.851	-0.918
3	金属采矿选采业	3736.26	1209.69	-0.811	-0.512
4	非金属矿及其他矿采选业	359.83	674.30	0.179	-0.132
5	食品制造及烟草加工业	2159.31	4046.43	0.156	-0.155
6	纺织业	7673.17	12161.21	0.394	0.184
7	服装皮革羽绒及其制造业	7462.37	13984.07	0.255	-0.054
8	木材加工及家具制造业	3935.22	5960.62	0.310	0.113
9	造纸印刷及文教体育用品制造业	8341.33	7893.47	0.328	0.352
10	石油加工、炼焦及核燃料加工业	1977.96	2802.30	0.261	0.092
11	化学工业	32641.38	14898.02	0.274	0.587
12	非金属矿物制造业	7910.19	2869.84	0.338	0.695
13	金属冶炼及压延加工业	22410.90	3358.04	0.238	0.831
14	金属制品业	12831.79	6674.57	0.345	0.596
15	通用、专用设备制造业	20411.66	19959.05	0.218	0.229
16	交通运输设备制造业	6917.79	6455.72	0.200	0.233
17	电气机械及器材制造业	26734.98	25563.30	0.319	0.339
18	通信设备、计算机及其他电子设备制造业	39507.47	74034.79	0.262	-0.046
19	仪器仪表制造业	2629.29	2820.66	0.224	0.190
20	电力、热力生产和供应业	1005.83	213.28	0.349	0.814

摘要
Abstract

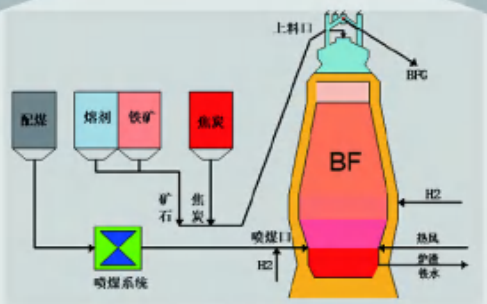
以传统高炉为研究对象，对其运行过程简化，建立了高炉理论能耗模型，并从热力学角度分析了不同富氢方式对高炉运行过程的影响。研究结果表明：与基准工况相比，在考虑富氧和注入富氢气煤的情况下，高炉理论极限能耗相对降低了33.5kgce/t，碳排放相对降低了60kg/t；在此基础上向风口注入50Nm³的H_2，能耗和碳排放分别再降低0.99kgce/t和40kg/t；在此基础上将富氧率从2.78%提高到6.7%，能耗再降低2.9kgce/t,但碳排保持不变；将喷氢位置改为炉身，能耗和碳排基本不变，但风口理燃温度骤升至2270℃；通过控制风口理燃温度至原水平，可使能耗和碳排再降低19.8kgce/t和180kg/t

研究背景
Research Background

在碳中和背景下，作为碳排主要设备，光提升高炉能效已经不能满足钢铁行业的降碳需求，需从高炉能源结构着手，降低高炉对碳还原剂的依赖，从而实现降碳目的。氢能作为绿色无污染还原剂，已经成为高炉替代碳还原剂的首选原料。因此，进行高炉富氢喷吹方式研究对开展高炉富氢喷吹试验有重要意义

研究方法
Research Method

本文通过简化高炉运行机理，将高炉内部运行区间依据传热规律和还原过程划分为风口区、高温区和低温区，应用物质流能量流方法构建了高炉的理论能耗模型。由于喷吹方式改变对风口区影响较大，本文将风口理燃温度作为运行约束加以限制，并分析了不同富氢喷吹方式对风口理燃温度的影响，并得到了相应工况下的工序能耗和碳排结果。



东北大学
Northeastern University

高炉富氢喷吹方式的理论分析

Theoretical analysis of hydrogen rich injection method in blast furnace

钟再锡[1,2]，张琦[1,2]，籍杨梅[1,2]
1 东北大学（冶金学院）；2 国家环境保护生态工业重点实验室

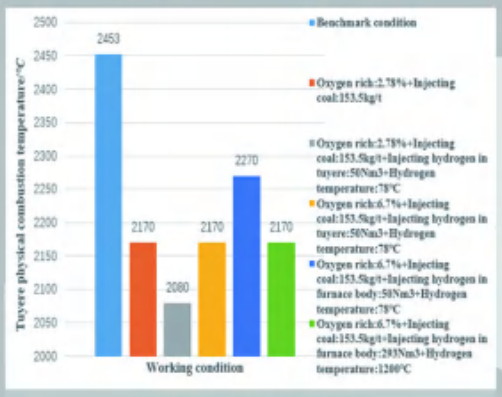


图1 不同富氧喷吹方式下的风口理燃温度

Fig. 1. the theoretical temperature at the tuyere under different hydrogen rich injection methods

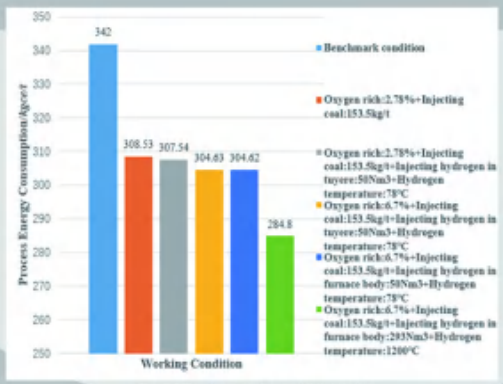


图2 不同富氢喷吹方式下的高炉理论极限能耗

Fig.2. the theoretical ultimate energy consumption of BF ironmaking process under different hydrogen rich injection methods

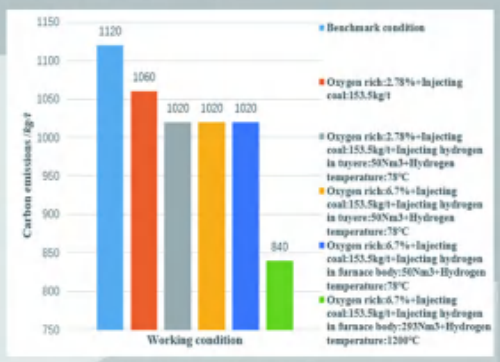


图3 不同富氢喷吹方式下的高炉理论碳排放量

Fig.3. the theoretical carbon emission of BF ironmaking process under different hydrogen rich injection methods

分析一
Analysis

图1反映了不同富氧喷吹方式对风口区域理论燃烧温度的影响。从图中可知，不考虑任何富氧喷煤和喷氢情况下，高炉有最高的风口理论燃烧温度，为2453℃；当考虑2.78%的富氧和153.5kg/t的喷煤时，风口理燃温度相对降低了293℃；在此基础上，向风口区域喷入50Nm³的H_2，风口理燃温度再降低90℃；将富氧率提高至6.7%，可使风口理燃温度恢复至2170℃；在此基础上，将喷氢位置改为炉身，风口理燃温度骤升至2270 ℃；通过增加喷氢量可使风口理燃温度恢复至2170 ℃。

分析二
Analysis

图2和图3反映了不同富氢喷吹方式对高炉工序理论极限能耗和碳排的影响。从图中可知，在基准工况下的能耗和碳排分别为342kgce/t和1120kg/t；当考虑富氧喷煤时，能耗和碳排分别相对降低了33.5kgce/t和60kg/t；当向风口喷入H_2后，能耗和碳排分别再降低0.99kgce/t和40kg/t；提高富氧率后，能耗降低了2.91kgce/t，但碳排保持不变；将喷氢位置改为炉身后，能耗和碳排均保持不变；提高喷氢量后，能耗和碳排分别降低了19.8kgce/和180kg/t，节能降碳效果显著。

结论
Conclusion

- 不考虑任何富氧喷煤和富氢喷吹工况下的风口理燃温度最高，通过喷煤和喷氢可使得风口理燃温度降低，提高富氧率可以增加风口理燃温度；
- 喷氢位置的改变对工序能耗和碳排影响较小，但对风口理燃温度影响较大；
- 通过提高富氧率和改变喷氢位置增加风口理燃温度，再通过喷入富氢气煤和H_2将风口理燃温度降低至合理水平(本文假定为2170℃)，可使工序理论极限能耗和碳排降低至284.8kgce/t和840kg/t，相较基准工况，可获得57.2kgce/t和280kg/t的节能降碳空间。

低零碳城市

Low- and Zero- Carbon City

低零碳城市 Low- and Zero- Carbon City

Response of Urban Ecosystem Carbon Storage to Land Use/Cover Change and Its Vulnerability Based on Major Function-Oriented Zone Planning

Lili Geng, Yuanyuan Zhang *, Huixian Hui, Yuhan Wang and Yongji Xue *

School of Economics & Management, Beijing Forestry University, Beijing 100107, China;
lilygeng@bjfu.edu.cn (L.G.); hhxbjfu@bjfu.edu.cn (H.H.); wyh1014@bjfu.edu.cn (Y.W.)
*Correspondence: zhangyy_1998@bjfu.edu.cn (Y.Z.); xyjbjfu@bjfu.edu.cn (Y.X.); Tel.: +86-010-6233-8447 (Y.X.)

Abstract: Vigorous emphasis has been placed on optimizing land spatial planning to protect carbon storage and enhance ecosystem resilience. What is the effectiveness of the Major Function-Oriented Zone (MFOZ) planning implemented to achieve this goal in China? Especially in urbanized areas where there are more pronounced conflicts between humans and land. Taking the Beijing-Tianjin-Hebei (BTH) urban agglomeration as the target area, this study explored the response of carbon storage to land use/cover change (LUCC) and its vulnerability to ecological service functions under MFOZ planning. The 30 m × 30 m spatially resolved Landsat TM/ETM remote sensing images from 2000 to 2020 were used. The data preprocessing was performed mainly through radiometric calibration, clipping, and reclassification through the ArcGIS 10.7 software. Applying the InVEST model, which uses the LUCC map and carbon storage density of the four carbon pools, including above-ground carbon density, below-ground carbon density, dead organic carbon density, and soil organic carbon density, to evaluate the carbon storage under the current landscape or in the future, the results show that: (1) The BTH ecosystem experienced a carbon storage reduction of about 7.25 × 10 Mg from 2000 to 2020 due to the expansion of construction land, which crowded out cropland. Carbon storage in the BTH showed a high concentration in the "northeast-southwest" direction and a tiny distribution in the "middle-east" direction. (2) From 2015, the initial effects of the MFOZ planning were seen, with the ecological land in the Central Core Zone and Eastern Coastal Development Zone decreasing while the proportion of high-carbon storage areas in the Eastern Coastal Development Zone increasing. (3) Over the two decades, the land use intensity index improved by 4.65 overall, and vulnerability worsened from 2000 to 2015 and was alleviated from 2015 to 2020. This study will provide a scientific reference for optimizing urban spatial land use planning and promoting carbon sequestration in ecosystems.

Keywords: land use/cover change; carbon storage; InVEST model; Major Function-Oriented Zone Planning; vulnerability; Moran's I index

Urban low-carbon logistics distribution route optimization based on improved genetic algorithm

Hu Xiaoman
(School of Business Administration, Liaoning Technical University, Huludao 125105, China)

Abstract

Background, Aims and Scope. With the acceleration of urbanization and the increasingly serious environmental problems, low-carbon logistics distribution has become an important part of urban sustainable development. Aiming at the realistic problems of high cost and large carbon emission of urban logistics distribution in China, this paper constructed an urban logistics distribution route optimization model considering demand uncertainty and carbon emission constraints, and proposed an improved adaptive genetic algorithm suitable for multi-vehicle models.

Methods. By using urban logistics distribution data and Matlab R2014a software to conduct simulation tests, the optimal urban logistics distribution route scheme under the constraint of demand uncertainty and carbon emission is obtained.

Results and Discussion. The simulation results show that the improved adaptive genetic algorithm has good effectiveness and applicability in solving the problem of urban logistics distribution route optimization. Under the constraint of demand uncertainty and carbon emission, the improved adaptive genetic algorithm can effectively reduce the cost of urban logistics distribution. Compared with the single-vehicle distribution scheme, the multi-vehicle distribution scheme is more advantageous in urban logistics distribution.

Conclusion. By constructing an urban logistics distribution path optimization model considering demand uncertainty and carbon emission constraints, and using an improved adaptive genetic algorithm, this study obtained the optimal urban logistics distribution path scheme under demand uncertainty and carbon emission constraints. This scheme can effectively reduce the cost of urban logistics distribution, and the multi-vehicle distribution scheme is more advantageous in urban logistics distribution, which provides an effective reference for solving the problems of high cost and large carbon emission of urban logistics distribution in China.

Key words: Improved adaptive genetic algorithm; Urban logistics; Path optimization; Demand is uncertain; Carbon emission constraint

Table 1 Simulation results of target parameters by traditional genetic algorithm and improved multi-objective genetic algorithm

Algorithm	Distribution cost		Delivery vehicle	
	Simulation value	Range of change	Simulation value	Range of change
Traditional genetic algorithm	7436.52	-	7	-
Improved multi-objective genetic algorithm	7214.25	-2.98	5	-28.57

Note: The change amplitude refers to the change of the simulation value of the target parameters of the improved multi-objective algorithm compared with the traditional genetic algorithm.

Table 2 Influences of single-vehicle and multi-vehicle distribution schemes on the value of objective function

Distribution scheme	Vehicle type	Distribution costs
Single vehicle type	A	7629.42
	B	7968.31
	C	8503.13
multi-vehicle		7214.25

Note: A, B and C represent 3 different types of delivery vehicles.

The Relevance Between Residential Block Forms and Building Carbon Emissions Under the Guidance of a Carbon Neutrality Goal: A Case Study of Wuhan, China

LI Gao-mei[1,2],WANG Si-yao[1]
(1. School of Architecture & Urban Planning, Huazhong University of Science and Technology; 2. Hubei Engineering and Technology Research Center of Urbanization, Wuhan 430074, China)

Abstract: Controlling building carbon emissions (CE) is the key link to achieving the goal of carbon neutrality, and residential blocks are the main positions for realizing a building's carbon neutrality. This work aimed to evaluate the building carbon emissions intensity (CEI) levels of residential blocks using Rhino and Grasshopper and to quantify the relevance between the block form parameters and a building's carbon emissions (CE). Firstly, 48 cases were selected by stratified sampling, and they were classified by architectural typology. Secondly, the residential block morphological parameters and building carbon emissions were calculated. Thirdly, the relevance between the block form parameters and the building's CE was quantified using statistical methods. Lastly, low-carbon planning strategies for residential blocks under a target of carbon neutrality were proposed. The findings showed that the influence of the block form parameters on a building's CE was 31.66%. A building's shape factor has a positive influence on its CE, and the floor area ratio, building volume–site area ratio, and building height have negative influences on its CE. A building's shape factor, cover ratio, and surface–site area ratio synergistically impact its CE. The weight of a building's shape factor on its carbon emissions was 3.84 times that of its cover ratio and 4.46 times that of its surface–site area ratio. The technology workflow proposed in this study can provide data in support of carbon emissions assessments and low-carbon planning strategies for urban blocks in other cities in China and worldwide.

Key words: carbon neutral; residential blocks; block form; building carbon emissions; low-carbon planning

低零碳城市 Low- and Zero- Carbon City

Carbon emissions of urban rail transit in Chinese cities: A comprehensive analysis

PU Jing[1,2,3], CAI Chen[1,3], GUO Ru[1,3], LIN Rui-min[1], LIU Lia[1,2,3], PENG Kai-ming[1,3], HUANG Xiang-feng[1,2,3]

(1. College of Environmental Science and Engineering, Tongji University, Shanghai 200092, China; 2. Shanghai Research Institute for Intelligent Autonomous Systems, Tongji University, Shanghai 200092, China; 3. China Institute of Carbon Neutrality, Tongji University, Shanghai 200092, China)

Abstract

Background, Aims and Scope. A considerable proportion of the greenhouse gases emitted into the atmosphere is attributable to the transportation sector. Urban rail transit (URT) distinguishes itself from various public transportation modes due to its significant carrying capacity and independent right-of-way. Existing literature predominantly focused on carbon emissions within the broader transportation sector, leaving a notable gap in our understanding of the carbon emissions to URT systems across China. The patterns, decoupling status, and drivers of carbon emissions from URT in China remain unclear despite the ongoing development of URT. This study is the first to conduct a comprehensive analysis of URT carbon emissions in all Chinese subway cities, and classified host cities into four categories.

Methods. The study analyzed the URT carbon emissions in all Chinese subway cities using spatial analysis models, the Tapio decoupling model, and the LMDI decomposition approach.

Results and Discussion. Results showed that the Chinese URT has experienced a notable surge in development in the past eight years, characterized by an annual carbon emissions growth rate ranging between 5% and 34% from 2015 to 2022. Spatiotemporal variations in Chinese URT carbon emissions revealed faster growth in southwestern China compared to the northeastern region. Significant differences existed in carbon emissions between the four types of cities. From 2015 to 2022, the most developed Type I cities consistently had the highest emissions, although the share of emissions showed a declining trend. The emission intensity of the Type IV cities was up to four times higher than Type I cities.

Conclusion. Only 12% of cities accomplished weak decoupling between carbon emissions and economy; these cities were mainly highly developed Type I cities. The URT development of carbon emissions was influenced by the increment of energy intensity and economic activity. These results implied that carbon emissions from Chinese URT will continue to rise in the foreseeable future.

Key words: urban rail transit; carbon emissions; carbon emission intensity; spatiotemporal analysis; decoupling analysis; LMDI decomposition

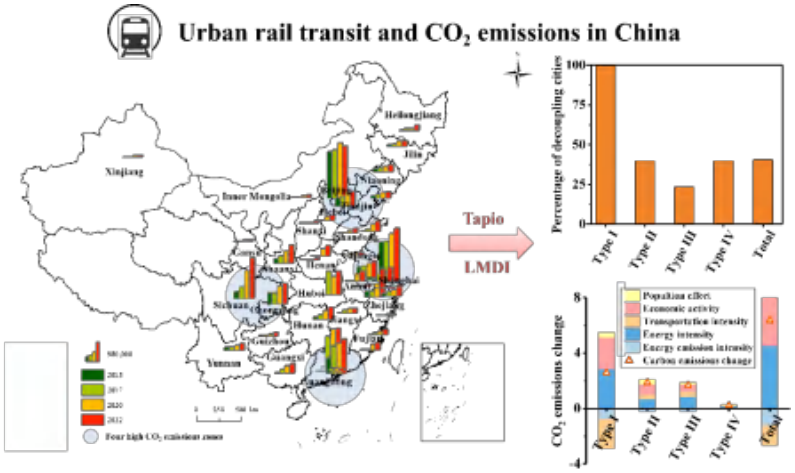


Fig 1 Urban rail transit and CO_2 emissions in China.

低零碳城市 Low- and Zero- Carbon City

The Correlation between water-carbon and urban spatial form in built-up areas: evidence from Shenzhen

Gaoyuan Wang [a, b], Muhan Li [a], Yangli Li [a,c, *]
a. School of Architecture, Tianjin University, Tianjin 300072, China
b. Department of Architecture, College of Design and Engineering, National University of Singapore, 4 Architecture Drive, 117566 Singapore
c. School of Civil Engineering and Architecture, Southwest University of Science and Technology, Mianyang 621010, China

Abstract
The synergy of water and carbon management holds profound significance for the sustainable development of urban spaces. Methods that involve scientific simulation of the spatial distribution of water usage and carbon emissions within cities await exploration, with relatively scant research delving further into the potential implications of the association between water consumption and carbon emission spatial patterns. This study integrates diverse spatial datasets, statistical yearbook data, sectorial affiliations, and geographical entities, along with time-series estimation techniques, to model the spatial distribution of water usage and carbon emissions in Shenzhen at a 1 km² grid scale. Subsequently, spatial correlations between the two are explored using GeoDa, and a carbon emissions per unit of water consumption (CEWC) model is constructed, drawing from performance metrics. Employing Geodetector and Spearman's correlation analysis, the study further investigates the impact of spatial form on water usage and carbon emissions. This methodological approach unveils the spatial distribution of water consumption and carbon emissions in Shenzhen at a finer resolution. The results elucidate that high-value concentrations are situated within the functionally developed urban core, with a subtle positive spatial correlation between the two parameters. The distribution of CEWC underscores a more profligate water utilization in traditional industrial zones and secondary central areas. It is evident that BD, ISP, BSD, and BSI stand as the primary drivers of the spatial distribution of water consumption and carbon emissions, with a notable enhancement in explanatory power resulting from their interplay with urban morphology. Furthermore, BSD, BSI, BH, and CEWC exhibit substantial correlations, with parameters describing building height exerting a significant negative influence on CEWC. In light of the outcomes, the study puts forth recommendations for top-tier coordinated management, flexible spatial growth, and the guidance of block spatial intensity. The research contributes empirical evidence regarding the spatial interrelation between water consumption and carbon emissions, thereby providing a robust foundation for policy decisions pertaining to the coalescence of water and carbon in the spatial development of mega-cities.

低零碳城市 Low- and Zero- Carbon City

Can the transportation sector in Beijing reach its carbon peak? A multi-scenario analysis based on the extended STIRPAT model

YANG Yu-hao
(School of Architecture, Tianjin University, Tianjin 300072, China)

Abstract

Background, Aims and Scope. The transportation sector plays a pivotal role in China's efforts to achieve CO_2 reduction targets. As the capital of China, Beijing has the responsibility to lead the era's demand for low-carbon development and provide replicable and scalable low-carbon transportation development experience and wisdom for other cities in China. This study calculates the CO_2 emissions of the transportation sector in Beijing from 1999 to 2019, constructs the extended STIRPAT model (population, affluence, technology, and efficiency) to reveal the effects of different influencing factors, and predicts the development trends, peak times, and quantities of transportation CO_2 emissions in 9 scenarios for Beijing from 2021 to 2035.

Methods. (1) Extended STIRPAT Model (Table 1). (2) Ridge Regression Analysis. (3) Scenario Forecast Analysis: setting growth rates of influencing factors in different scenarios (Table 2) and scenario design for transportation CO_2 Emission Prediction (Table 3).

Results and Discussion. (1) The total amount of CO_2 emissions from Beijing's transportation sector exhibits a trend of gradually stabilizing in terms of growth, with a corresponding gradual deceleration in the rate of increase. Kerosene, gasoline, and diesel are the main sources of transportation CO_2 emissions in Beijing, with an annual average proportion of 95.78% (Figure 1 and Figure 2). (2) The degree of influence of the indicators on transportation CO_2 emissions, in descending order, is: energy in-tensity, per capita GDP, population size, GDP by transportation sector, total transportation turnover, public transportation efficiency, possession of private vehicles, and clean energy structure. Among them, the proportion of clean energy structure and public transportation efficiency are negatively correlated with transportation CO_2 emissions, while the remaining indicators are positively correlated. (3) In the 9 predicted scenarios, all scenarios, except scenario 2 and scenario 4, can achieve CO_2 emission peaks by 2030, while scenarios 7 and 9 can reach the peak as early as 2025 (Table4 and Figure 3). (4) The significant advancement and application of green carbon reduction technologies have profound implications, as they can effectively offset the impacts of population, economy, and efficiency indicators under extensive development. Effective population control, sustainable economic development, and transportation efficiency improvement are viable means to help achieve carbon peaking and peak value in the transportation sector.

Conclusion. Firstly, as calculated in this study, the CO_2 emissions of the transportation sector in Beijing from 1999 to 2019, increased from 5.43 million tons in 1999 to 37.84 million tons in 2019, with an annual average growth rate of 10.42%. Kerosene, gasoline, and diesel are the primary sources of CO_2 emissions in Beijing's transportation sector. Secondly, the STIRPAT model was extended to include four aspects—population, affluence, technology, and efficiency—and ridge regression was used to establish the impact relationships between the eight evaluation indicators and CO_2 emissions. From highest to lowest impact, these indicators are EI > PG > P > TG > TT > PTE > PV > CES. Finally, based on the extended STIRPAT model, the development trends and peak scenarios of transportation CO_2 emissions in Beijing during 2021 to 2035 were predicted under nine scenarios. The prediction results show that the probability of the transportation sector in Beijing reaching peak CO_2 emissions before 2030 is high if the city steadily promotes the transition of economic and population development from extensive growth focused on speed and scale to intensive growth emphasizing quality and efficiency. The progress and application of green carbon reduction technologies are of great significance, as they can effectively offset the impacts of population, economy, and efficiency indicators under extensive development. Effective population control, sustainable economic development, and transportation efficiency improvement are viable means to help achieve carbon peaking and peak value in the transportation sector.

Key words: transportation sector; CO_2 emissions; carbon peak; STIRPAT model; scenario forecast; Beijing

Table 1. Description of the extended STIRPAT model variables

Influencing factors	Related indicators	Explanation and calculation of the indicator	Unite
Population	population size (P)	Permanent population in Beijing refers to persons actually living for more than half a year	ten thousand people
Affluence	Per capita GDP (PG)	Gross Regional Product / Permanent population	Yuan / person
	GDP by transportation sector (TG)	-	10^8 Yuan
	Possession of private Vehicles (PV)	-	ten thousand vehicles
technology	Energy intensity (EI)	energy consumption per unit of transportation GDP	tons / ten thousand Yuan
	Clean energy structure (CES)	clean energy consumption (electricity and natural gas) / total energy consumption	%
Efficiency	Total transportation turnover (TT)	The sum of total passenger turnover and total freight turnover	ten thousand tons · km
	Public transportation efficiency (PTE)	Passengers traffic of public transport / number of operating public transport vehicles in operation	ten thousand person-times / vehicle
The extended STIRPAT regression equation	Where represents CO2 emissions from the transportation sector, , , , , , , , and are the abbreviations for the eight indicators listed in Table 1. 0.39, 0.44, 0.331, 0.09, 0.849, -0.043, 0.15 and -0.107 are the regression coefficients of the respective variables, reflecting the elasticity relationship between each indicator and transportation CO2 emissions. -5.01 denotes the random error term.		

Table 2. Setting of the indicator change rates

Rate mode	Period	P	PG	TG	PV	EI	CES	TT	PTE
Low	2021-2025	-0.13%	6.50%	8.00%	2.50%	-2.50%	5.00%	7.00%	1.50%
	2026-2030	-0.18%	4.50%	6.50%	2.00%	-3.50%	7.00%	5.00%	0.50%
	2031-2035	-0.23%	2.50%	5.00%	1.50%	-4.50%	9.00%	3.00%	0.00%
BAU	2021-2025	-0.08%	8.50%	9.00%	3.00%	-3.50%	7.00%	9.00%	2.50%
	2026-2030	-0.03%	6.50%	7.50%	2.50%	-4.50%	9.00%	7.00%	1.50%
	2031-2035	0.02%	4.50%	6.00%	2.00%	-5.50%	11.00%	5.00%	0.50%
High	2021-2025	-0.03%	10.50%	10.00%	3.50%	-4.50%	9.00%	11.00%	3.50%
	2026-2030	0.02%	8.50%	8.50%	3.00%	-5.50%	11.00%	9.00%	2.50%
	2031-2035	0.07%	6.50%	7.00%	2.50%	-6.50%	13.00%	7.00%	1.50%

Table 3. Types of the scenarios

Scenarios				P	PG	TG	PV	EI	CES	TT	PTE
Scenario 1	BAU										
Scenario 2	Technical stability	High efficiency	High growth	H	H	H	H	BAU	BAU	H	H
Scenario 3			Low growth	L	L	L	L	BAU	BAU	H	H
Scenario 4		Low efficiency	High growth	H	H	H	H	BAU	BAU	L	L
Scenario 5			Low growth	L	L	L	L	BAU	BAU	L	L
Scenario 6	Technical breakthrough	High efficiency	High growth	H	H	H	H	H	H	H	H
Scenario 7			Low growth	L	L	L	L	H	H	H	H
Scenario 8		Low efficiency	High growth	H	H	H	H	H	H	L	L
Scenario 9			Low growth	L	L	L	L	H	H	L	L

Table 4. Forecast of Transportation CO_2 Emissions in Beijing from 2021 to 2035 (10^4 t)

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
2021	4605.63	4627.38	4599.36	4611.60	4583.67	4539.02	4511.53	4523.53	4496.14
2022	4812.30	4900.15	4757.07	4866.77	4724.67	4760.47	4621.46	4728.04	4589.99
2023	4828.56	4936.19	4737.67	4919.35	4721.51	4749.47	4558.46	4733.27	4542.91
2024	5045.23	5227.17	4900.12	5191.56	4866.75	4981.19	4669.54	4947.26	4637.73
2025	5271.63	5535.29	5068.15	5478.83	5016.45	5224.21	4783.32	5170.92	4734.53
2026	5375.49	5721.71	5112.84	5643.57	5043.01	5347.92	4778.82	5274.89	4713.56
2027	5481.41	5914.41	5157.92	5813.26	5069.70	5474.57	4774.34	5380.94	4692.68
2028	5589.40	6113.60	5203.40	5988.05	5096.54	5604.22	4769.85	5489.12	4671.89
2029	5699.53	6319.50	5249.29	6168.09	5123.52	5736.93	4765.37	5599.48	4651.20
2030	5811.83	6532.34	5295.57	6353.55	5150.64	5872.79	4760.90	5712.06	4630.60
2031	5781.59	6589.01	5208.89	6382.32	5045.49	5865.98	4637.30	5681.96	4491.83
2032	5751.51	6646.18	5123.63	6411.21	4942.49	5859.17	4516.92	5652.03	4357.22
2033	5721.59	6703.85	5039.77	6440.24	4841.59	5852.38	4399.65	5622.25	4226.65
2034	5691.82	6762.02	4957.28	6469.40	4742.76	5845.59	4285.44	5592.63	4099.99
2035	5662.21	6820.69	4876.13	6498.69	4645.94	5838.81	4174.18	5563.16	3977.12

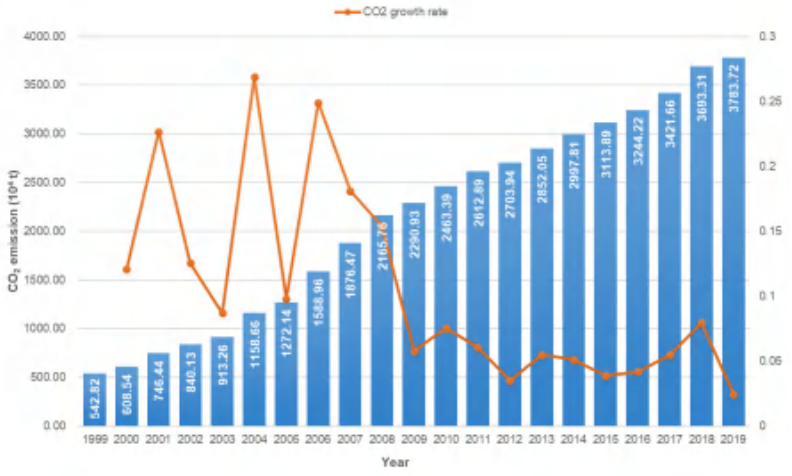


Figure 1. Total CO_2 emissions and annual growth rate of transportation sector in Beijing from 1999 to 2019

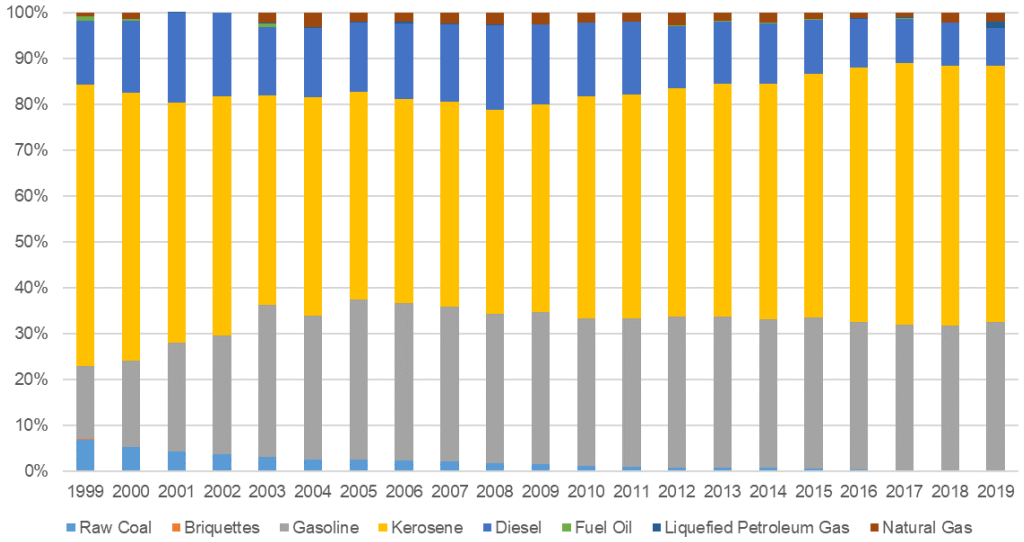


Figure 2. Contribution of Beijing's transportation energy consumption types to CO_2 emissions

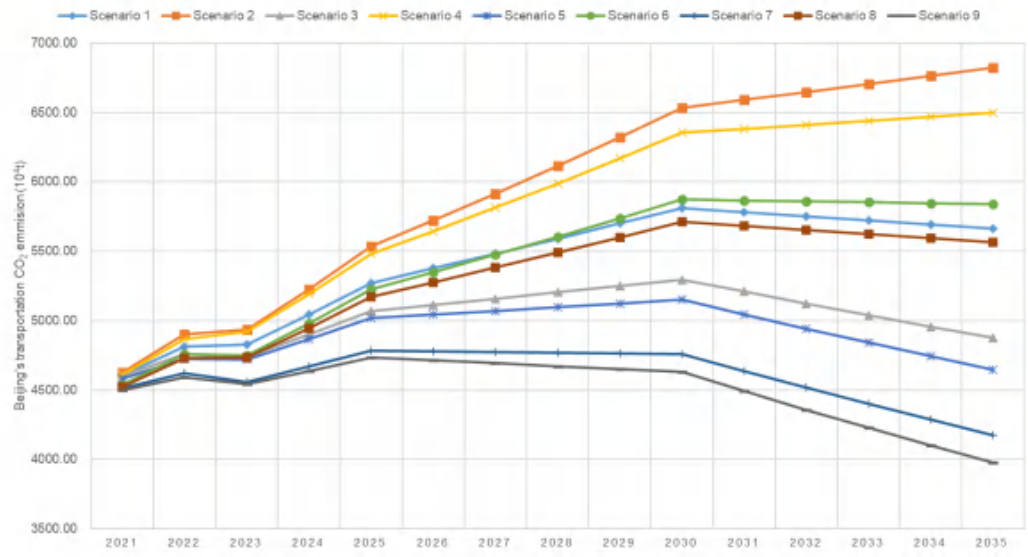


Figure 3. Scenario forecast of Beijing's transportation CO_2 emissions from 2021 to 2035

Study on Low-Carbon and Industrial Development of Lake Taihu Tourist Resort in Suzhou

ZHANG HONG-RU[1], LIU HAN[2], WANG QIAN-LI[3]
1. Shenzhen International Graduate School, Tsinghua University, Shenzhen 518055, China
2.School of Environment, Tsinghua University, Shenzhen 100084, China
3.School of Civil Engineering, Tsinghua University, Shenzhen 100084, China
Email address: zhr21@mails.tsinghua.edu.cn

1.Background and significance

Suzhou Taihu Lake National tourist Resort is one of the 12 **National Tourist Resorts** established with the approval of the State Council in 1992, and it is also the first batch of pioneering areas to join the WTO tourism industry opening to the outside world.

The present situation is faced with the problem of mismatch between "**demand of current social and economic development**" and "**National Tourism Resort**".The situation that the main characteristics are not prominent caused by piecemeal tourism resources, and the incoordination between "**eco-environmental protection**" and "**industrial development**".

Fig. 1 Satellite image of Taihu Lake tourist Resort

In the highly developed Taihu Lake area, facing the pressure of resources, environmental protection and cost, tap the development potential of the region; explore the low-carbon development path of tourism in the resort area, integrate tourism resources and highlight characteristics; with the comprehensive advantages of nature, humanities and location, study the future industry around Taihu Lake.

2.Research content and analysis with key methods

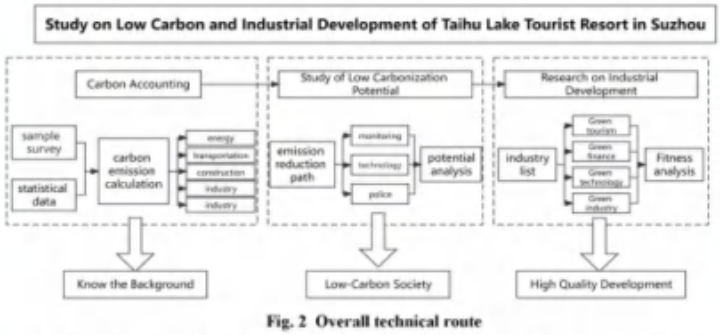


Fig. 2 Overall technical route

Regional Carbon Accounting: The accounting will refer to the Urban greenhouse Gas Accounting tool Guide issued by the World Resources Institute, the Provincial greenhouse Gas inventory compilation Guide (trial) issued by the National Development and Reform Commission and the IPCC national greenhouse gas inventory guide and other domestic and foreign certified accounting methods, combined with important factors such as **energy activities** and **forest coverage** of Suzhou Holiday Resort, adopt the concept of **emission scope** to define the carbon emissions of the resort.

Table 1 Urban greenhouse gas emission inventory (provincial inventory reporting mode)

pes of emission sources and absorption sinks	CO_2 (kt)	CH_4 (kt)	GHG (kt CO_2e)
Total emissions (net emissions)	808.0	0.10	821.9
Total energy activity	1072.8	0.000	1072.8
Total industrial production process	0.00		0.00
Total agriculture		0.2	7.4
Land use change and forestry totals	-264.8	-00.6	-274.7
Total waste disposal	0.00	0.50	16.40

Low-carbon path research: Combined with **regional carbon accounting research**, the comprehensive solution of low-carbon park is a solution for the key point of low-carbon transformation of the park in the energy field. As an integrated operation guide, it cooperates directly with each other to solve the obstacles that may be encountered **in the zero-carbon development of the park from different dimensions**, and systematically help the park to achieve the low-carbon goal in the energy system.

Industrial development research: According to the goal of "**achieving results in five years and forming a system in ten years**", it will promote the development of green and low-carbon industries. By 2025, the scale and innovation capability of the city's low-carbon green industry will be significantly improved, the agglomeration effect will initially appear. By 2030, the scale of green low-carbon industry will continue to grow and become an important engine of the city's economic development, **building a relatively complete ecological chain of green and low-carbon industry**.

3.Research results, conclusions and innovations

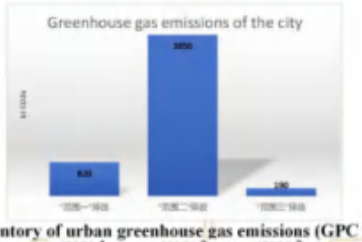


Fig. 3 Inventory of urban greenhouse gas emissions (GPC reporting mode)

- **Regional carbon Accounting (2019).**
- Urban forest carbon sinks **offset about 10% of urban carbon emission**
- The per capita emission of the resort is 4.26 tCO_2/ years, which is **much lower** than that of China (9.21 tCO_2/ years).
- The GDP emission per unit of resort is 0.69t CO_2 / 10,000 yuan, which **much lower** than the average level of China (1.02 tCO_2 / 10,000 yuan).
- **Low carbon potential analysis.**
- Innovate the **financing mode of energy construction** and achieve the goal of energy sharing.
- It will comprehensively promote low-carbon innovation technology collaboration
- **Research on industrial development.**
- Focus on green industry and lead regional development.
- Exploration on optimization of **"Ancient + Legacy + New"** industry.
- Enhance the tourism diversity of resorts and increase the feasibility of **"science and technology tourism"**

Evolving water, energy and carbon footprints in China's food supply chain

Qilin Cao [1,2], Junnian Song [1,2,3,*], Chaoshuo Liu [1,2], Wei Yang [1,2,3,*]
[1] Key Laboratory of Groundwater Resources and Environment, Ministry of Education, Jilin University, 130021 Changchun, China.
[2] College of New Energy and Environment, Jilin University, 130012 Changchun, China.
[3] Jilin Provincial Key Laboratory of Water Resources and Environment, Jilin University, 130021 Changchun, China.
***Corresponding author:** Junnian Song, songjunnian@jlu.edu.cn; Wei Yang, yangwea@jlu.edu.cn. 2699 Qianjin Street, Jilin University, 130012 Changchun, China.

INTRODUCTION

- Food-supply related activities are depleting water resources, wasting energy and aggravating climate change to feed the swelling population. How the water, energy and carbon footprints (WECFs) transfer in the entire food supply chain (FSC) and evolve driven by socioeconomic effects remains elusive.
- Herein, we propose adapted models of structural path analysis (SPA) and structural decomposition analysis (SDA) specifically for the FSC based on input-output analysis. Beyond evaluating the WECFs in China's FSC induced by household consumption during 2007–2017, we track their transfer through the supply chain, and unravel their key evolutionary characteristics and socioeconomic drivers.
- Our findings inform policies required for synergetic control of WECFs along FSC and optimized decision-making on FSC management.

Fig1. Graphical abstract

METHODS

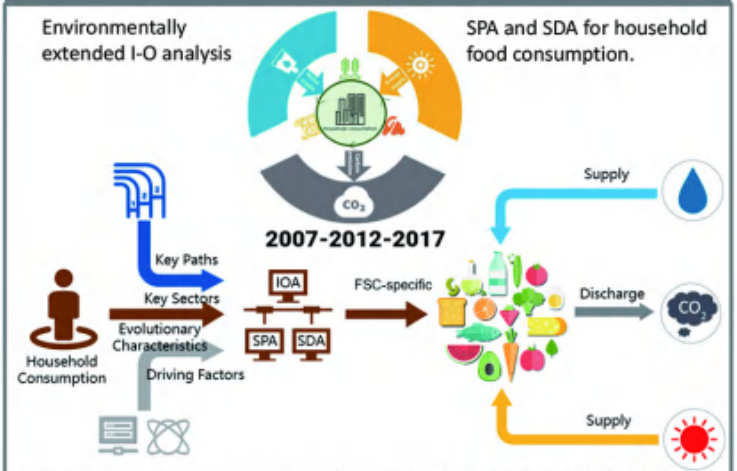


Fig2. Schematic representation of WECFs in the FSC induced by household consumption, and Technology Roadmap

CONCLUSION

(1) Agriculture, Food processing, Chemicals, and PSEH are the key sectors for WECFs in the FSC.
(2) TSP and Services show surging contribution to the WECFs (by about 130%–170% over the decade), in contrast to the declining dominance of Chemicals and PSEH.
(3) Alongside the expanding capacity of food supply, the growth rate of the WFs (from 15% to 10%) and CFs (from 34% to 15%) is gradually slowing down, with an overall transition towards environmentally friendly.
(4) From a supply-side perspective, the path length for WECFs has been lengthening over time, with a general 5%–8% increase in the share of paths associated with PL2.
(5) Per capita consumption effect and intensity effect are most influential in driving the WECFs, positively and negatively, respectively. The increased consumption of premium foods imposes pressures on the WECFs along the supply chain, which is a non-negligible effect in driving growth of WECFs.

Original Article: https://doi.org/10.1016/j.jclepro.2023.138716
Contact Information: caoql23@mails.jlu.edu.cn;

RESULTS

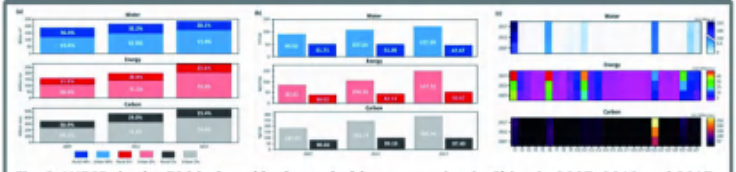


Fig. 3. WECFs in the FSC induced by household consumption in China in 2007, 2012 and 2017. (a) Total WECFs and contributions of urban and rural household consumption. (b) Per capita WECFs. (c) WECFs contributed by sectors in the FSC.

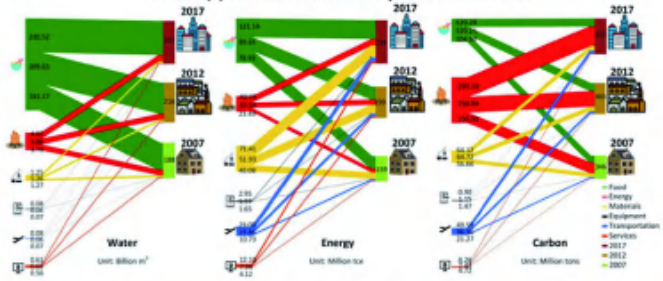


Fig. 4. WECFs in six categories in the FSC induced by household consumption in China in 2007, 2012 and 2017.

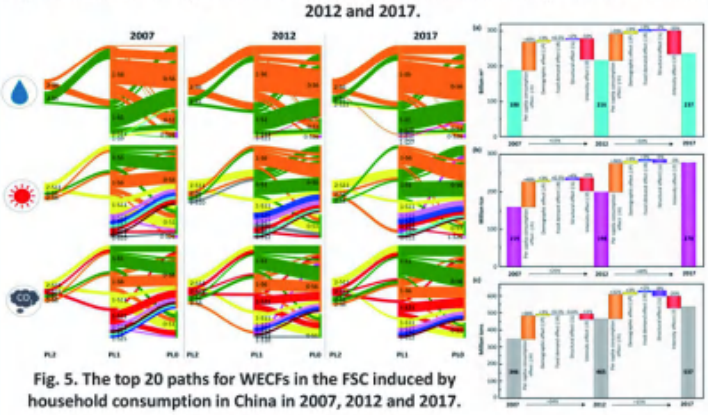


Fig. 5. The top 20 paths for WECFs in the FSC induced by household consumption in China in 2007, 2012 and 2017.

Fig. 6. Contributions of five socioeconomic effects to changes in total WECFs in the FSC induced by household consumption during 2007–2017 in China. (a) Changes in WFs and contribution of five effects; (b) Changes in EFs and contribution of five effects; (c) Changes in CFs and contribution of five effects.

Study on spatial and temporal characteristics of agricultural carbon emissions, carbon peaking prediction and decoupling efforts in western region

DING Ning, WANG Gui-Rong ,XIA Yong
School of Economics and Management , Xinjiang Agricultural University

• Background, Aims and Scope

Agriculture is both a major contributor to *carbon emissions* and an important *carbon sink system*, and the benefits of reducing emissions and carbon are higher than those of *other industries*. Therefore, studying the influencing factors of *agricultural carbon emissions* in the western region and carrying out the prediction of agricultural *carbon peaks* will help promote the development of agricultural emission reduction *in the western region*.

Methods

The IPCC method was used to measure the total amount of agricultural carbon emissions in the western region; on the basis of the carbon emissions measurement, the factors affecting carbon emissions in the western region were decomposed and decoupled using the LMDI factor decomposition model and the TAPIO decoupling model, etc., and the carbon emissions were predicted.

• Results and Discussion

The results of the study show that: (1) There are obvious *spatial differences* in the total amount of *agricultural carbon emissions*, the intensity of *agricultural carbon emissions*, and the structure *of agricultural carbon emissions* in the western region; (2) The facilitating effect of *the internal structural factors* of agriculture is expected to be greater than that of the factors of *population size*, The factors of agricultural production efficiency, and the factors of the internal structure of agriculture in that order; (3) If the influencing factors of *the agricultural carbon emissions* of the western region keep the same rate of growth as in the original one, the agricultural carbon emissions will not *reach the peak value in 2050.*

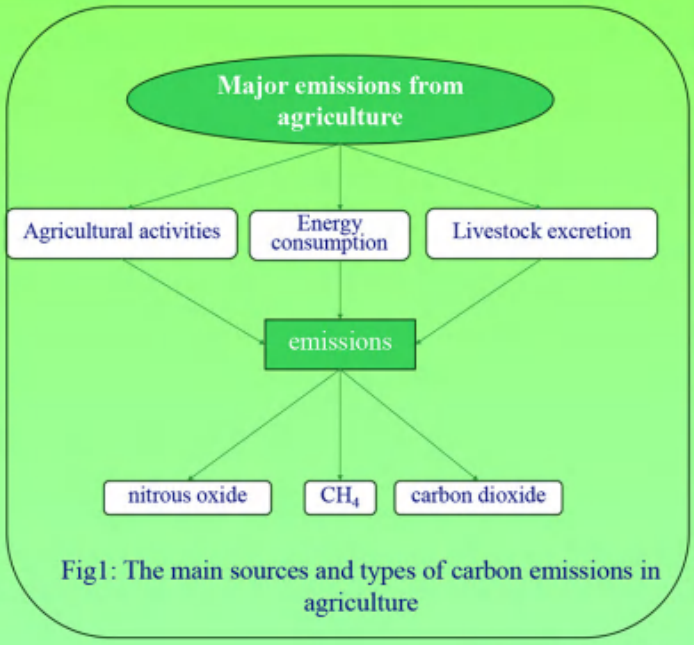


Fig1: The main sources and types of carbon emissions in agriculture

Conclusion

(1) The total agricultural carbon emissions in the western region show a growing trend, and there are obvious spatial differences in the total agricultural carbon emissions, the intensity of agricultural carbon emissions, and the structure of agricultural carbon emissions; (2) the level of agricultural economic development will be the only factor contributing to the agricultural carbon emissions in the administrative regions and most of the provinces; and (3) the decoupling of the agricultural carbon emissions and the growth of the agricultural economy in the western region shows gradual improvement from the state of expanding linkage to a weak and then to a strong decoupling.

Integrating production, ecology and livelihood confers a sustainable farmland system under wheat-maize cropping

Yanshu YIN, Changbin Yin, Thomas Dogot

Affiliation: Economics and Rural Development Laboratory, Gembloux Agro-Bio Tech, University of Liège, Belgium *Email: Yanshu.Yin@doct.uliege.be*

Introduction

To achieve the United Nations Sustainable Development Goals (SDGs), positive actions are being taken to improve the global agricultural system. Maintaining lower carbon emission and a sustainable development in agricultural production play an important role in meeting multi-objective demands in the farmland system such as guaranteeing food security, promoting eco-friendly agriculture and increasing farmers' income. Recently, a sustainable farmland system was proposed by integrating production, ecology and livelihood in China, but without comparison and evaluation with other farmland systems, and the interaction of elements in farmland systems is not well characterized.

Generally, the most prevalent three farmland systems include conventional farmland-small holder farming mode (CF-SFM), high-standard farmland- intensive farming mode (HSF-IFM), and sustainable farmland-intelligent farming mode (SF-ITFM). In this study, the system boundary of farmland construction is identified, revealing that how different inter-matching forms of farmland infrastructure development and field management practices affect the environmental-economic efficiency.

Materials and Methods

The study was conducted in Yanggu, Ningyang, and Yuncheng counties, Shandong province of China, which is a major grain-producing region located in the North China Plain. The data collection was conducted by randomly visiting households and face-to-face interviewing from Sep to Dec 2021 to ensure the collected information accuracy. All data of both input and output including economic parameters of the cropping management were recorded in detail, and some data reflecting the martials input of farmland construction such as design plan, feasibility report and engineering project estimation, were supplied by the local agricultural administration departments.

The integrated benefits in the farmland systems were evaluated by life cycle assessment (LCA), life cycle cost (LCC), cost-benefit analysis (CBA) and net ecosystem economic benefit (NEEB) under wheat-maize cropping. Furthermore, the development potential in a farmland system with the best integration benefits and regional contribution magnitude were simulated.

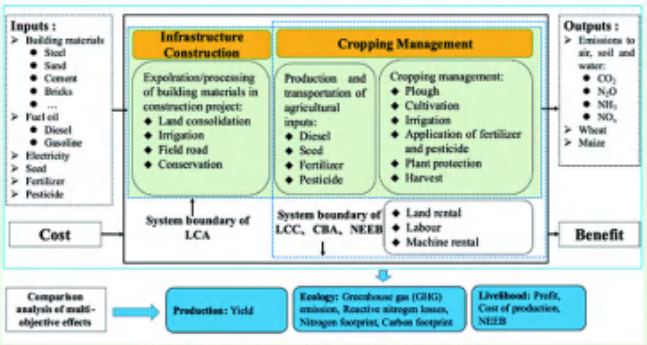


Fig 1 Framework and system for assessment

As presented in Fig 1, system boundary, relevant inputs boundary and outputs of farmland systems were characterized. At present, the farmland construction is a behavior of the government-mediated, while the cropping management is performed by agricultural producers, thereby causing inconsistent investment partners at the two stages. Consequent economic analysis on the farmland systems (LCC, CBA, NEEB) is focused on the farmland utilization, while the construction costs are investigated by comparing the different farmlands. In this study, an assessment framework of multi-objective effects was developed to understand the integrative effects of farmland systems on the production, ecology and livelihood.

Results

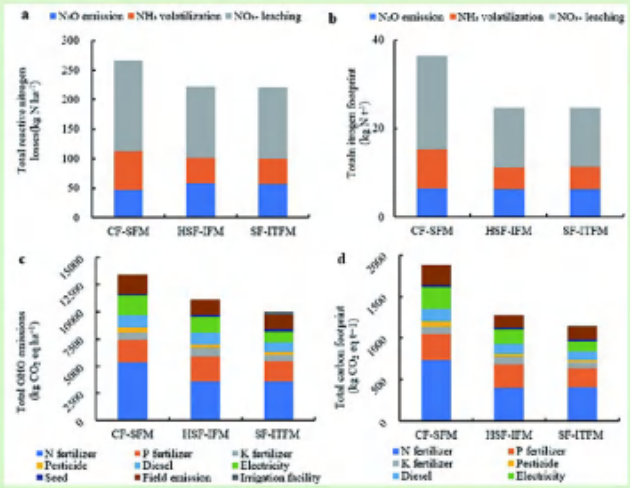


Fig 2 Reactive nitrogen losses (a), nitrogen footprint (b), greenhouse gas emissions (c), and carbon footprint (d) under wheat-maize rotation in three systems

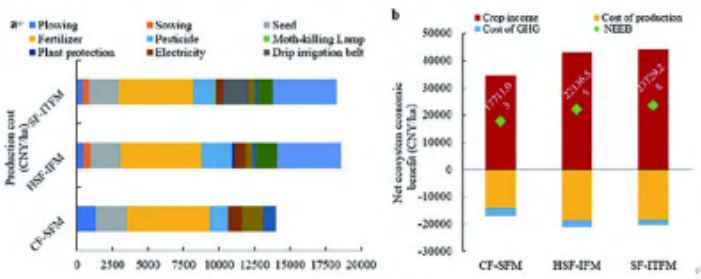


Fig 3 Cost of wheat-maize cropping under three systems (a); NEEB of three systems (b)

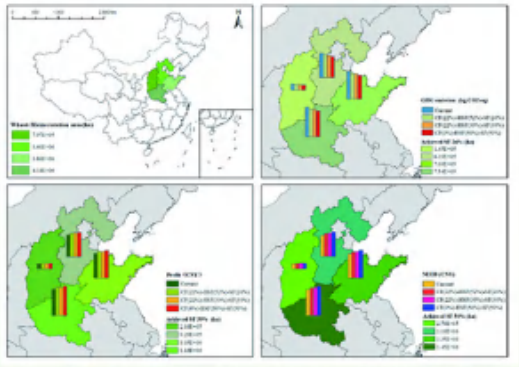


Fig 4 Benefits potential promoting the SF-ITFM in the North China Plain

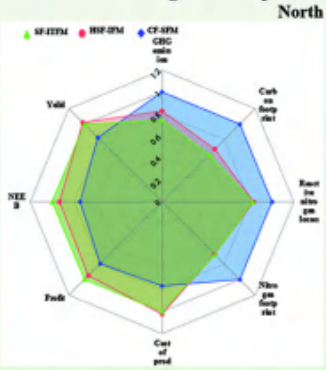
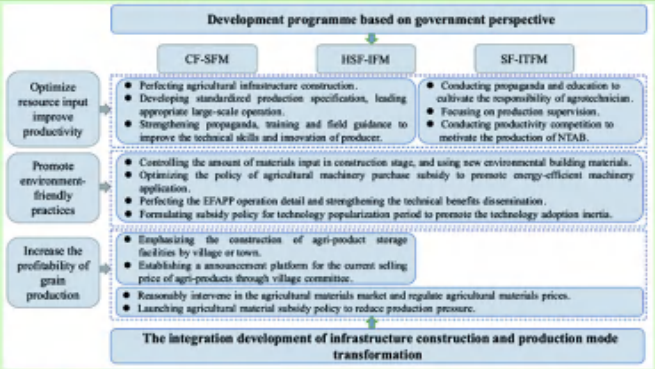


Fig 5 Comprehensive multiple-objective comparison under wheat-maize cropping in three systems

The results demonstrate that sustainable farmland-intelligent farming (SF-ITFM) mode not only lowered resource input, but also improved the productivity, and also plays a positive role in regulating the reactive nitrogen losses, nitrogen and carbon footprint and greenhouse gas emission. Additionally, the sustainable farmland-intelligent farming mode is an optimum economic practice, and totally decreases CO_2 emission of 9.01E+07 t, and increases the net ecosystem economic benefit of 101 billion Chinese yuan and the grain yields of 1,278 t in the North Plain of China.

Implication and Conclusion



This study suggests that both scientifically improving field management practices and effectively ascertaining the policy requirement in different farmland systems are of great importance for promoting the sustainable farmland system.

Acknowledgment

LIÈGE université
中国农业科学院 CHINESE ACADEMY OF AGRICULTURAL SCIENCES

Research on the temporal and spatial characteristics and evolution trend of green development efficiency of China's grain industry

Jie Zhou[1], Haipeng Chen[1] and Yue Chen[1]

[1]College of Economics, Sichuan Agricultural University, 611130 Chengdu, China

Introduction

The green and sustainable development of the grain industry is a prerequisite for maintaining basic human life and production activities. It plays an essential role in ensuring the steady growth of the economy and society. Since 2020, the impact of major public health events and geopolitical conflicts have had a great impact on food trade. With the transformation of China's economic and social development from the pursuit of scale expansion to higher quality development, regional characteristics, and different development stages need to be fully considered to realize the grain industry's green development. Systematically combing and analyzing the temporal and spatial distribution characteristics and evolution trend of green development efficiency of China's grain industry is of great significance for in-depth analysis of the path of China's grain industry's green development.

Methods

Green Total Factor Productivity (GTFP)

This paper adopts the SFA approach to measure China's green total factor productivity of grain to portray the efficiency of green development of the grain industry.

Kernel Density Estimation

The Gaussian kernel function with high accuracy is used to estimate the dynamic distribution and evolutionary trend of the green development efficiency of China's grain industry. The kernel density distribution map can reflect the location, shape, and extensibility of the distribution of variables and more intuitively portray the distribution state of variables in time and space.

Space Markov Chain

The methodology not only reflects the state of China's each region, but also portrays its upward and downward shifting mobility issues. Comparing the magnitude of the corresponding values of the traditional Markov and spatial Markov transfer matrices, it is possible to analyze whether the neighboring regions have an impact on the local transfer of the efficiency of the green development of the food industry.

Results

The SFA model is employed to measure the green development efficiency of the grain industry in 31 provinces of China from 2003 to 2022, and the boxplot (Fig. 1) demonstrates that the green development efficiency of China's grain industry has improved dramatically during the past 20 years and differences between regions are narrowing.

As of 2022, the spatial distribution of the green development efficiency of China's grain industry is relatively balanced, but it is relatively high in the east and west and relatively low in the center (Fig.2).

Figure 3 indicates that the regional differences in China's grain industry's green development efficiency are gradually narrowing and gradually developing from unipolar to bipolar polarization.

Table 1 shows that the green development efficiency of China's grain industry will gradually improve in the future, showing a rising trend from low efficiency to high efficiency. In addition, all types of adjacent spaces show a shift from low to high, where polarization within regions can be mitigated, and there is a graded development trend between areas.

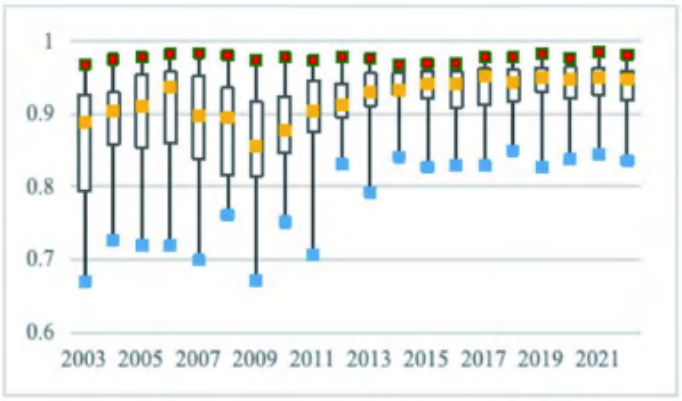


Fig 1. The boxplot of green development efficiency of China's grain industry

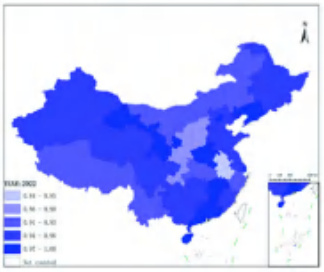


Fig 2. Spatial distribution

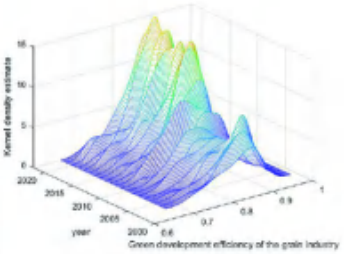


Fig 3. Kernel density map

State Type			1	2	3	4
Excluding spatial lag	Initial state		0.4839	0.3226	0.1290	0.0645
	Equilibrium		0.1869	0.2285	0.2791	0.3054
Spatial lag	Equilibrium	1	0.2737	0.2676	0.2015	0.2572
		2	0.1557	0.1970	0.3732	0.2741
		3	0.1337	0.2468	0.2056	0.4138
		4	0.0000	0.3093	0.5567	0.1340

Table 1. Forecasting the evolutionary trend of green development efficiency in China's grain industry

Conclusion

At present, China's grain industry's green development should fully account for the problem of interregional differences. The contradiction between food security and environmental pollution shall be harmonized. Moreover, it is necessary to give full play to the spatial spillover effect and strengthen interregional synergy and cooperation. Meanwhile, government intervention in areas of inefficient agglomeration needs to be strengthened.

Acknowledgment

The Sichuan Provincial Social Science Planning Key Project in 2022 entitled "Study on the Synergistic Path of Carbon Reduction, Pollution Reduction, Green Expansion and Growth in Sichuan" (Grant No. SC22ZD005)

References

[1] Gong S, et al. Does seed industry innovation in developing countries contribute to sustainable development of grain green production? Evidence from China[J]. Journal of Cleaner Production, 2023,406:137029.
[2] Robaina-Alves M, et al. A new frontier approach to model the eco-efficiency in European countries[J]. Journal of Cleaner Production, 2015,103:562-573.

我国农业实现碳中和的法制保障研究

中国农业大学人文与发展学院 雷锦锋

一、问题的提出

- 当前，全球变暖，将引发严重的自然灾害，严重威胁人类生存。中国主动提出“3060”双碳目标。
- 农业碳排放是中国碳排放的第二大来源。
- 但与主要通过节能减排来减少碳排放的工业、电力等行业相比，农业在这一问题上具有特殊性（碳源与碳汇）。
- 农业碳减排具有成本低、潜力大的优势，应在农业碳减排和增汇方面先行先试，开展示范性工作。

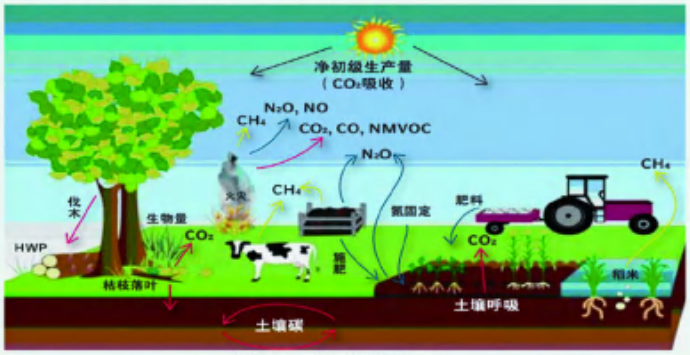


图1 农业系统碳排放示意图

二、文献回顾

当前，学界研究更多关注工业碳排放问题，对农业碳排放问题重视尚且不足，而针对农业碳中和问题的专门性研究则更少。现有研究成果主要涉及：

- 农业碳排放特征与减排潜力的研究
- 农地利用与农业碳排放关系研究
- 低碳农业的政策支持研究

总体而言，我国已有研究倾向于农业碳排放现状和减排路径，缺乏对农业碳中和政策法律支撑的研究。农业碳中和问题亟须从农业碳中和的制度需求、主体定位及国际经验三个方面开展研究。

据此，要保证农业碳中和目标顺利实现，有必要梳理审视我国农业碳中和现状及相关立法，提出农业碳中和的实现路径与制度保障。

三、农业碳中和的现状及特殊性

1.我国农业碳排放的现状

- 农业碳排放区域差异性（东中部>西部）
- 达到碳排放量峰值时间不同

根据胡婉玲等学者2020年计算出的数据（表1），我国农业已经实现碳达峰，当前农业碳排放处于下降状态。据此，当前相关研究重点应当聚焦于进一步推动减少农业碳排放，以实现农业碳中和。

2.农业碳中和的特殊性

- 农业具有碳源和碳汇的双重属性。
- 其中，农业碳汇具有正外部性，如何将农业碳汇的正外部性内部化，对激励农业碳汇的可持续供给至关重要。由于农业碳汇的无形性、非竞争性、非排他性及受益者不特定性，其价值难以像普通商品那样通过自发市场得以实现，也难以通过政府补贴或行政命令方式得到补偿，故需要国家适度干预。

表1 中国东中西部区域农业碳排放的峰值

地区	农业碳排放量（万吨）最大值	
	数值	年份
东部	3733.64	2005
中部	3601.61	2015
西部	2064.55	2016
全国	9141.63	2015

注：不包含我国港澳台地区的数据。

四、现行政策法律面临的挑战

农业碳中和急需当前政策法律的保障，这对现行政策法律带来了挑战。由于双碳目标提出的时间较短，我国目前尚未出台关于农业碳中和的专门法律法规，也并未就农业领域制定具体的温室气体减排目标。

因此，当前农业碳中和对现行政策法律提出了挑战。具体表现在：

- 部分关键领域缺乏政策法律支持
- 缺乏有效的监督与反馈机制
- 激励措施尚显乏力

五、多元共治：农业碳中和制度构建

根据多元共治理论，提出完善农业碳中和的法制保障，要科学把握制度构建中政府、市场和社会的关系。

政府主导

通过界定与分配产权、设定义务等方式矫正市场失灵或为市场和社会机制发挥作用提供制度条件。

市场化运作

通过供求、价格和竞争机制高效配置资源。

社会参与

通过公众参与和志愿活动实现多中心或网络化治理。

本研究建议将这一模式纳入农业碳中和法律体系构建之中，以明确三方主体的定位、目标与责任，为开展农业碳中和工作提供法律指引。

六、我国农业实现碳中和的制度体系建设

1 完善关键领域的法律制度

将农业碳减排行动视为整体，从其双重属性出发制定涉及农业碳减排和增汇的目标和政策法律体系。

2 建立多元共治下的监督与反馈机制

注重从政策法律制定到效果评估全过程的广泛性与开放性，以此保证政策工具的有效性。

3 完善适宜多元主体激励制度

针对农业产业链内不同主体，采取不同的激励制度。

七、结语

我国当前正面临减少农业碳排放以实现农业碳中和的迫切需要，但也存在实现途径不明确、政策法律保障不足的问题。

对此，我们应当进一步明确农业碳中和的制度需求，结合我国农业碳排放现状，借鉴外国农业碳中和领域先进经验，采用多元共治模式，政府、社会、市场共同参与农业碳中和实践，完善相关法律制度保障，助推我国顺利实现农业领域碳中和，进而推动全领域碳中和目标的达成。

利用碳交易推动农业减排的理论与路径分析：国际经验及其对中国的启示

罗崇佳[1] 陈敏鹏[2*]

1. 清华大学 能源环境经济研究所；2. 中国人民大学 农业与农村发展学院

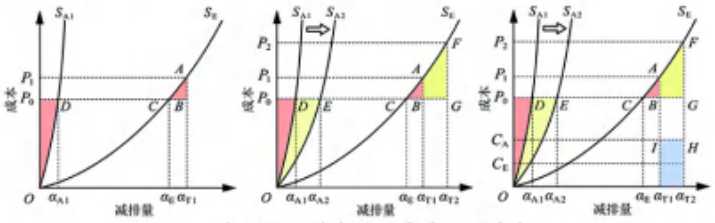
摘 要

如何利用碳交易推动农业深度减排亟待讨论。本文回顾了利用碳交易促进农业减排的理论，梳理了相关国际实践、经验和障碍，并识别了利用碳交易推动中国农业减排的路径。理论上，在交易成本低于节约的减排成本的情况下，利用碳交易促进农业深度减排具备经济可行性，但在实践中面临排放不确定性大、技术标准体系匮乏、减排效果不稳定以及监测、报告和核查成本过高等障碍。农业纳入自愿碳市场在创新组织方式、构建风险分担机制和开发核算标准等方面取得较大进展，但目前全球尚未将农业纳入强制碳市场。为积累经验并降低交易成本，农业可先参与自愿碳市场后逐步向强制碳市场过渡。中国核证自愿减排量的农业项目是农业和自愿碳市场结合的重要实践，可在政策、方法学、运行机制等条件成熟的情况下逐渐扩大农业自愿减排项目的数量和规模。由于农业对粮食安全和国民经济发展的重要作用，是否将农业纳入强制碳市场必须非常谨慎。

1 背景概述

- 农业是温室气体的重要排放源。作为农业大国，2014年中国农业温室气体排放总量为830 Mt CO2-eq，占碳排放总量的7.42%。同时，农业减排面临着威胁粮食安全、缺乏颠覆性技术、技术扩散难度大等挑战，创新政策工具成为促进农业减排效率的重要手段。
- 2021年7月，中国全国碳排放权交易市场正式启动，但目前仅纳入或计划纳入能源和工业部门。2022年中央一号文件首次提出“研发应用减碳增汇型农业技术，探索建立碳汇产品价值实现机制”，能否以及如何利用碳交易推动农业深度减排脱碳成为重要问题。

2 理论框架



农业纳入碳交易的成本收益分析

(A) 农业纳入碳交易的效益分析；(B) 农业由自愿碳市场向强制碳市场过渡的效益分析；(C) 农业由自愿碳市场向强制碳市场过渡的成本效益分析

- 在不考虑交易成本的情况下，在碳交易中纳入农业能够以更低成本实现相同的减排量，节约减排量为 ODP_0 与 ABC 面积之和 (图 A)。
- 假定存在农业减排技术进步促进了碳市场对农业覆盖率的提高，均衡情况下农业减排量由α_{A1}增加为α_{A2}，而其他部门减排量仍为α_E。此时，利用碳交易节约的农业减排成本增加为OEP_0和FGC，节约成本更大 (图 B)。
- 假定农业和非农业部门的单位减排交易成本分别为C_A和C_E，则$HI\alpha_{T1}\alpha_{T2}$呈现了农业纳入强制碳市场相比纳入自愿碳市场增加的交易成本 (图 C)。
- **因此，农业应当循序渐进，先参与难度更低的自愿碳市场，通过“干中学”的方式逐步降低交易成本。当强制碳市场的交易成本低于节约的减排成本时，才可以考虑将农业纳入强制碳市场。**

3 国际经验

- **农业纳入自愿碳市场**在创新组织方式、构建风险分担机制和开发核算标准等方面取得进展，但仍存在农业温室气体排放不确定性大、农业技术标准体系构建困难和减排效果不稳定等障碍。

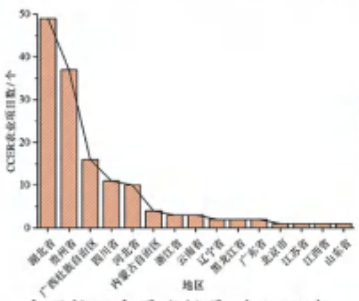
自愿碳交易项目信息

减排机制	发起者	涵盖的农业活动	中国是否参与	项目规模	交易形式
清洁发展机制（CDM）	联合国	牲畜粪便管理、生物质油生产、接种豆科作物、水稻种植用水管理、氮管理、乳业饲料补充、土地覆盖、造林和再造林等	曾经参与	发展中国家的项目级活动	通过联合国碳抵消平台交易，也在环境大宗商品交易所旗下拍卖平台（CBL）、碳资产交易平台（CTX）、区块链碳信用交易平台（ACX）上市交易
核证碳标准（VCS）	非盈利组织	土地利用，包括造林、再造林和恢复、农林用地管理、改善森林管理、减少森林砍伐和退化排放、避免草地和灌木林转变、退地恢复和保护等	是	项目级活动	在核证碳标准的注册登记系统交易，也在 CTX 上市交易
黄金标准（GS）	非盈利组织	土地利用，包括作物管理、牧场管理、牲畜管理、植树造林等	是	项目级活动	在黄金标准的注册登记系统交易，也在 CTX 上市交易
美国碳登记（ACR）	非盈利组织	退化土地再造林、避免草地和灌木林转变为作物生产地、改善森林管理、沼泽或湿地恢复等	否	项目级活动	在美国碳登记注册登记系统交易，或者与 CBL 关联交易
气候行动储备（CAR）	非盈利组织	森林和草原碳汇营、氮管理、水稻种植、土壤富集、城市森林管理、城市植树、畜牧业养猪沼气利用、有机废弃物消化和堆肥等	否	项目级活动	在气候行动储备的注册登记系统划转，也在 CBL、ACX 上市交易
REDD+交易框架（ART）	非盈利组织	林业碳汇项目	否	国家级和下一级或府司法管辖区	在 Emergent（非营利组织名称）森林金融加速器平台购买
全球碳委员会（GCC）	非盈利组织	支持 CDM 所有农业方法学的活动	是	项目级活动	在埃信华迈（IHS Markit）注册登记系统交易

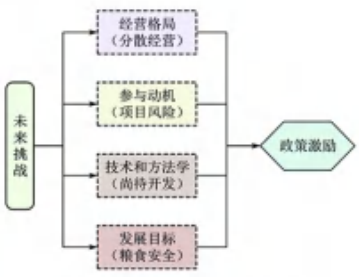
- **农业纳入强制碳市场**尚无成功实践。农业分散经营的特征和强制碳市场的统一监管之间存在巨大矛盾，众多的农业经营主体增加了市场交易和政府监管的难度，并引致了更高的监测、报告和核查成本。

4 中国行动

- 从区域上看，15个省份开设农业减排项目，集中于南方和东部地区。
- 从类型上看，农业户用沼气项目和林业碳汇项目是CCER农业项目的主要来源，分别占据总数的85.31%和9.09%



中国核证自愿减排量（CCER）农业备案项目区域分布



农业纳入碳交易的未来挑战

低碳生活方式

Low-Carbon Lifestyle

数字素养、低碳知识与农村居民住宅低碳化改造需求

（Impact of Digital Literacy on Rural Residential Low-Carbon Transformation）

陈东辉，徐涛，乔丹*
邮箱：13871958083 cdhui1998@163.com，xutao_2013@outlook.com，qiaodan1124@126.com
（海南大学 国际商学院，海口 570228）

1.摘要

实行农村住宅低碳化改造，不仅能够提高农村居民生活品质，还能提高农村居民福祉。本文以农村住宅低碳化改造为例，在应用机器学习的Lasso回归选取控制变量基础上，利用Oprobit模型分析数字素养对农村居民住宅低碳化改造需求的影响。结果表明：第一，数字素养对于农村住宅低碳化改造需求具有正向影响。除节能门窗改造需求外，数字素养对于墙壁屋顶改造需求、太阳能改造需求和低耗能家电需求均具有正向促进作用。第二，机制分析表明，低碳行为知识、低碳住宅知识和低碳政策知识在数字素养影响农村住宅低碳化改造需求发挥了中介作用。第三，异质性分析显示，自建房面积小、距离物流点近和住宅需求满意度低的农村居民更倾向于住宅低碳化改造。因此，依据不同群体制定差异化住宅低碳化改造策略，促进农村居民进行住宅低碳化改造，有助于实现和美乡村建设和乡村生态宜居。

第一，与以往研究相比，本研究重点关注了农村地区住宅低碳化改造的需求，提出低碳住宅外立面改造（墙壁与屋顶改造）和低碳住宅设备改造（太阳能热水器、太阳能照明和低能耗设备）等方面，丰富了农村住宅低碳化改造需求的内涵。第二，本研究构建农村居民“数字素养——低碳知识——住宅低碳化改造需求”的逻辑框架，深入阐释数字素养对住宅低碳化改造需求的影响机理及低碳知识中介作用机理，拓展了农村居民住宅低碳化改造理论的研究边界。第三，农村低碳住宅研究是低碳经济和低碳乡村建设理论体系的重要组成部分，本研究有益于丰富农村地区低碳化改造需求的理论体系，弥补农村地区住宅低碳化改造方面研究空白。

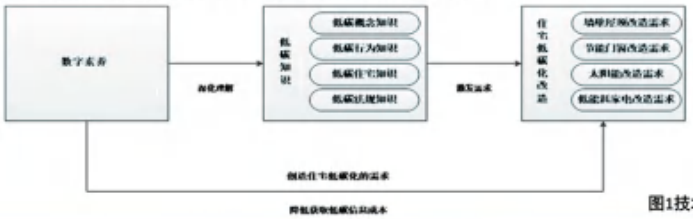


图1技术路线图

2.现状分析

图2住宅低碳化改造需求现状

3.主要变量描述性统计

表1 数字素养衡量指标

维度	变量说明	回答选项的分布（%）				
		1	2	3	4	5
数字通用素养	会使用智能手机的一般功能	8.02	6.10	13.22	24.29	48.36
	会使用微信的一般功能	11.64	4.75	9.49	25.54	48.59
	会使用网络搜索信息	37.74	5.99	7.68	19.21	29.38
数字社交素养	经常使用微信、QQ等的朋友圈功能	23.39	8.25	7.46	19.44	41.47
	能够熟练参与线上聊天互动	14.80	6.10	8.25	24.29	46.55
	能够熟练进行线上信息分享	21.92	8.36	7.68	20.90	41.13
数字创意素养	会制作并分布生活相关的短视频	44.52	5.65	7.57	14.24	28.02
	会制作并发布工作/职业相关的短视频	57.40	7.46	7.01	9.15	18.98
	会利用线上平台进行直播	88.25	4.41	2.49	2.26	2.60

表3 控制变量筛选的调节参数估计

调节参数	参数	变量个数
第一次调节参数	0.138	0
最优调节参数前一次调节参数	0.004	14
最优调节参数	0.004	14
最优调节参数后一次调节参数	0.004	14
最后一次调节参数	0.000	14

表4控制变量的lasso回归系数

变量名称	系数	变量名称	系数
自沙	0.109	保亭	0.073
空间布局	-0.103	邻居互帮互助	0.069
受访者上学	0.096	邻里关系	-0.044
社会网络	0.094	建造时间	0.042
参加知识学习	0.090	距离	0.041
生态感知	0.085	受访者年龄	-0.024
收入	0.084	五指山	-0.009

表2 主要变量描述性统计

	变量	变量说明	最小值	最大值	均值
因变量	住宅低碳改造需求	您是否有墙壁屋顶改造、节能门窗改造、太阳能热水器和疏散照明改造和选用低耗能家电需求？	0	4	1.462
	墙壁屋顶改造需求	是否具有墙壁改造和屋顶改造需求0=没有；1=有	0	1	0.318
	节能门窗改造需求	是否具有节能门窗改造需求0=没有；1=有	0	1	0.334
	太阳能改造需求	是否具有太阳热水器和太阳能照明改造需求0=没有；1=有	0	1	0.336
	低耗能家电需求	是否具有低耗能家电需求改造需求0=没有；1=有	0	1	0.475
自变量	数字素养	因子分析法得出	0.921	4.866	3.490
中介变量	低碳概念知识	您理解“碳排放”的含义？1=完全不了解；2=不够清楚；3=一般；4=比较清楚；5=非常清楚	1	5	1.511
	低碳行为知识	您理解“低碳生活”“低碳生产”的含义？1=完全不了解；2=不够清楚；3=一般；4=比较清楚；5=非常清楚	1	5	1.506
	低碳住宅知识	您理解“低碳住宅”的含义？1=完全不了解；2=不够清楚；3=一般；4=比较清楚；5=非常清楚	1	5	1.183
	低碳政策知识	您了解低碳住宅相关的政策和法规吗？1=完全不了解；2=不够清楚；3=一般；4=比较清楚；5=非常清楚	1	5	1.371
控制变量	受访者性别	受访者的性别0=女1=男	0	1	0.580
	受访者年龄	受访者实际年龄	17	73	47.133
	教育年限	受访者实际受教育年限	0	16	7.864
	受访者收入	受访者收入（万元）	0	324	5.998
	社会网络	人情礼品支出（万元）	0	5	0.275
	距离	家距离物流点距离	0	50	2.617
	参与知识学习	受访者是否参与村庄组织的学习活动	0	1	0.233
	空间布局	您对目前您家的房屋空间布局满意吗？1~5	0	5	3.365
	邻里关系	您与周围邻居间互帮互助的情况多吗？1~5	1	5	4.071
	生态感知	您感觉周围野生动植物数量比以前减少了吗？1~5	1	5	2.218
	地区虚拟变量	五指山=1，其余地区=0	0	1	0.220
		自沙=1，其余地区=0	0	1	0.271
		保亭=1，其余地区=0	0	1	0.245

4.基准回归

表5数字素养与农村住宅改造需求基准回归

	住宅低碳改造需求	墙壁屋顶改造需求	节能门窗改造需求	太阳能改造需求	低能耗家电改造需求
	回归(1)	回归(2)	回归(3)	回归(4)	回归(5)
数字素养	0.101**	0.092*	0.039	0.118**	0.111**
	0.04	0.05	0.05	0.05	0.05
受访者性别	-0.058	-0.087	-0.166*	0.143	-0.086
	0.08	0.09	0.09	0.09	0.09
受访者年龄	0.003	0.007	0.005	0.003	-0.002
	0	0	0	0	0
受访者上学	0.015	0.013	0.012	0.008	0.019
	0.01	0.01	0.01	0.01	0.01
收入万元	0.006**	0.005*	0.004	0.006	0.003
	0	0	0	0	0
社会网络	0.176	0.259**	0.167	0.071	0.065
	0.11	0.11	0.11	0.1	0.11
距离	0.006	0.017*	0.020**	-0.01	-0.004
	0.01	0.01	0.01	0.01	0.01
建造时间	0.102	0.226	0.18	-0.027	-0.013
	0.12	0.15	0.15	0.14	0.14
参与组织学习	0.164*	0.198*	0.084	0.018	0.254**
	0.09	0.11	0.11	0.11	0.11
空间布局	-0.064**	-0.072**	-0.094***	-0.042	-0.014
	0.03	0.03	0.03	0.03	0.03
邻里关系	0.034	0.015	0.039	0.022	0.032
	0.03	0.04	0.04	0.04	0.04
生态感知	0.047*	-0.02	0.026	0.075***	0.071**
	0.03	0.03	0.03	0.03	0.03
五指山	-0.055	-0.173	0.19	-0.141	-0.087
	0.11	0.13	0.13	0.13	0.13
自沙	0.189*	0.145	0.183	0.067	0.233*
	0.1	0.12	0.12	0.12	0.12
保亭	0.121	0.038	0.112	0.022	0.256**
	0.11	0.13	0.13	0.13	0.12
N	885	885	885	885	885
r2_p	0.021	0.036	0.026	0.026	0.043

表6处理过内生性之后数字素养与农村居民住宅低碳化改造需求的估计结果

	第一阶段	第二阶段
数字素养		0.241**
		(0.09)
考虑信息安全问题	0.345***	
	(0.02)	
控制变量	已控制	已控制
Constants	2.863***	-0.251
	(0.33)	(0.57)
Cragg-Donald Wald F statistic	297.595***	
Kleibergen-Paaprk LM statistic	192.393***	
观测值	885.000	885.000
r2	0.582	0.560

5.进一步机制分析

表7数字素养、低碳知识与农村住宅改造需求基准回归

	回归(1)	回归(2)	回归(3)	回归(4)	回归(5)	回归(6)	回归(7)	回归(8)
数字素养		0.097**		0.088**		0.095**		0.087**
		0.04		0.04		0.04		0.04
低碳概念知识	0.036	0.022						
	0.03	0.03						
低碳行为知识			0.086***	0.073**				
			0.03	0.03				
低碳住宅知识					0.093**	0.079*		
					0.04	0.04		
低碳法规知识							0.155***	0. 143***
							0.04	0.04
Bootstrap（1000）次置信区间	(-0.005,0.023)		(0.004,0.033)		(0.001,0.019)		(0.005,0.031)	
间接效应占比	-----		13.59%		6.39%		13.18%	
N	885	885	885	885	885	885	885	885
r2_p	0.019	0.021	0.021	0.023	0.020	0.022	0.023	0.025

6.异质性分析

表8 数字素养、低碳知识与农村住宅改造需求分组回归

	自建房面积小组	自建房面积大组	距离物流点近组	距离物流点远组	住宅需求低满足组	住宅需求高满足组
数字素养	0.098**	0.124	0.134**	0.038	0.282***	0.060
	0.05	0.08	0.05	0.06	0.09	0.05
控制变量	已控制	已控制	已控制	已控制	已控制	已控制
样本量	613	272	513	372	207	678
拟合优度	0.024	0.040	0.034	0.027	0.051	0.020

7.结论与讨论

第一，数字素养对于农村住宅低碳化改造需求具有正向影响。除节能门窗改造需求外，数字素养对于墙壁屋顶改造需求、太阳能改造需求和低耗能家电需求均具有正向促进作用。
第二，机制分析表明，低碳行为知识、低碳住宅知识和低碳政策知识在数字素养影响农村住宅低碳化改造需求发挥了中介作用。
第三，异质性分析显示，自建房面积小、距离物流点近和住宅需求满意度低的农村居民更倾向于住宅低碳化改造。
因此，依据不同群体制定差异化住宅低碳化改造策略，促进农村居民进行住宅低碳化改造，有助于实现和美乡村建设和乡村生态宜居。

家庭收入对居民家庭食物浪费碳足迹的影响研究——来自中国营养与健康调查的证据

刘江华 谢梦圆 王雯琳
（上海财经大学财经研究所，上海 200433）
（Tel：15927160703, Email: xmy4080@163.sufe.edu.cn）

研究背景：全球正在面临严重的食物浪费，大量的食物浪费会对大气、水、土地和生物多样性造成环境影响。中国家庭的食物浪费现象日益严峻，全年产生了1.1亿吨与居民家庭食物浪费有关的碳足迹。在中国居民收入不断提高的背景下，科学评估家庭收入对居民家庭食品浪费行为及其碳足迹的影响，并理清其作用机理，对于实现“双碳”气候目标和粮食安全具有重要的现实意义。

研究内容及方法：本文基于2004、2006年和2009年中国健康与营养调查（CHNS）数据，分别建立Logit模型与Tobit模型，实证研究家庭收入对居民家庭食物浪费行为及其产生碳足迹的影响，并探讨其作用机制。

主要结果：（1）家庭人均收入增长10%，家庭发生食物浪费的概率以及食物浪费带来的碳足迹将分别增加6%和0.94%，且家庭收入增长对农村家庭和低教育水平家庭居民家庭食物浪费产生碳足迹的作用更强。（2）机制检验的结果表明，家庭收入通过规模、结构与技术效应影响食物浪费产生的碳足迹。其中，规模效应表现为收入增长提高了各类食物的浪费量，结构效应表现为收入增长提升了肉蛋奶等碳密集型食物的浪费比例，技术效应表现为收入增长改善了家庭的食物储存和烹饪条件。（3）异质性研究在高膳食得分家庭中发现了家庭收入与居民家庭食物浪费碳足迹的“倒U型”关系，表明膳食知识的普及是减少食物浪费碳足迹的重要手段。这意味着，家庭收入提高会带来食品浪费和碳足迹增加的风险，因此有必要加强对居民膳食行为的教育和引导，以促进资源节约型低碳社会的建设。

变量	家庭是否有浪费行为（是=1）			
	（1）	（2）	（3）	（4）
	pooled logit	Random-effects logit	conditional logit	边际效应
家庭人均收入的对数	0.120***	0.120***	0.108**	0.006
	(3.51)	(3.50)	(2.14)	(1.30)
家庭规模	0.090***	0.090***	0.055	0.003
	(3.92)	(3.86)	(1.34)	(0.97)
是否饲养家禽家畜	0.185**	0.185**	0.141	0.008
	(2.48)	(2.43)	(1.19)	(0.87)
家庭平均受教育年限	-0.030***	-0.030***	-0.007	-0.000
	(-2.86)	(-2.87)	(-0.30)	(-0.28)
未成年人数占比	0.269	0.269	0.314	0.018
	(1.43)	(1.45)	(1.07)	(0.84)
膳食认知得分	-0.037***	-0.037***	-0.023	-0.001
	(-2.75)	(-2.81)	(-1.22)	(-0.82)
食物偏好	-0.075***	-0.075***	-0.099***	-0.006
	(-3.65)	(-3.65)	(-3.59)	(-1.17)
人均活动强度	-0.011	-0.011	0.009	0.001
	(-0.33)	(-0.33)	(0.17)	(0.18)
户主性别（男=1）	-0.003	-0.003	-0.059	-0.003
	(-0.03)	(-0.03)	(-0.29)	(-0.27)
户主年龄	-0.005*	-0.005*	-0.001	-0.000
	(-1.79)	(-1.78)	(-0.20)	(-0.19)
户主是否工作（是=1）	0.025	0.025	-0.089	-0.005
	(0.34)	(0.34)	(-0.80)	(-0.65)
社区有无超市（有=1）	-0.614***	-0.614***	-0.298**	-0.017
	(-8.36)	(-7.87)	(-2.11)	(-1.06)
社区有无铺过的道路（有=1）	-0.119*	-0.119*	-0.048	-0.003
	(-1.71)	(-1.68)	(-0.39)	(-0.38)
社区城市化与发展指数	0.016***	0.016***	0.022***	0.001
	(6.47)	(6.38)	(3.33)	(1.33)
社区各类食品价格	是	是	是	是
省份固定效应	是	是	是	是
年份固定效应	是	是	是	是
样本量	9055	9055	3509	3509
Hausman Test (Chi2)	-	-	299.72***	

变量	家庭人均食物浪费碳足迹			
	（1）	（2）	（3）	（4）
	OLS	混合 Tobit	随机效应 Tobit	边际效应
家庭人均收入的对数	0.131***	0.194***	0.187***	0.094***
	(4.98)	(4.74)	(4.54)	(4.54)
家庭规模	0.013	0.051*	0.047*	0.024*
	(0.77)	(1.93)	(1.73)	(1.73)
是否饲养家禽家畜	0.215***	0.294***	0.294***	0.147***
	(3.84)	(3.31)	(3.28)	(3.28)
家庭平均受教育年限	-0.017**	-0.033***	-0.030**	-0.015**
	(-2.06)	(-2.68)	(-2.39)	(-2.39)
未成年人数占比	-0.124	-0.066	-0.007	-0.003
	(-0.87)	(-0.30)	(-0.03)	(-0.03)
膳食认知得分	-0.023**	-0.044***	-0.039**	-0.019**
	(-2.22)	(-2.72)	(-2.43)	(-2.43)
食物偏好	-0.031**	-0.061**	-0.069***	-0.034***
	(-1.97)	(-2.47)	(-2.84)	(-2.84)
人均活动强度	-0.007	-0.012	-0.007	-0.003
	(-0.25)	(-0.30)	(-0.16)	(-0.16)
户主性别（男=1）	-0.071	-0.083	-0.062	-0.031
	(-1.11)	(-0.87)	(-0.61)	(-0.61)
户主年龄	-0.008***	-0.011***	-0.010***	-0.005***
	(-3.58)	(-3.33)	(-2.99)	(-2.99)
户主是否工作（是=1）	0.069	0.098	0.062	0.031
	(1.20)	(1.10)	(0.70)	(0.70)
社区有无超市（有=1）	-0.518***	-0.822***	-0.756***	-0.377***
	(-9.04)	(-9.17)	(-8.20)	(-8.19)
社区有无铺过的道路（有=1）	-0.060	-0.125	-0.082	-0.041
	(-1.07)	(-1.52)	(-0.97)	(-0.97)
社区城市化与发展指数	0.014***	0.022***	0.020***	0.010***
	(7.21)	(7.83)	(6.86)	(6.86)
_cons	2.504***	2.007***	1.690***	
	(6.42)	(3.34)	(2.75)	
社区各类食品价格	是	是	是	是
省份固定效应	是	是	是	是
年份固定效应	是	是	是	是
LR test			176.51***	
样本量	9055	9055	9055	9055

公众参与型环境规制与家庭消费低碳转型
——基于中国家庭追踪调查的经验证据

田淑英，李雨涵*，孙 磊
(安徽大学经济学院，合肥 230601)
*E-mail：h823957247@163.com

摘要： 气候变暖形势严峻，家庭消费产生的碳排放不可忽视。基于中国家庭追踪调查（CFPS）微观数据库，实证检验公众参与型环境规制对家庭消费低碳转型的影响，探索其中可能存在的作用机制。研究结果表明，公众参与型环境规制显著推动了家庭消费低碳转型，在经历一系列稳健性检验后，结论依然成立；公众参与型环境规制可以在消费端驱动公众低碳消费选择和在生产端优化用能结构进而推动家庭消费低碳转型；此外，家庭抚养负担比重、地区资源禀赋差异以及政府环境执法力度会对规制效果产生差异化影响；进一步研究发现，公众参与型环境规制并不会造成居民消费结构降级。最后，从拓宽环境治理的公众参与渠道、坚持消费端与生产端双向发力以及确保政策实施精准化等方面提出政策建议，以期为如期实现“双碳”目标、健全多元共治的现代环境治理体系提供更多经验证据。

环境规制作为一种以保护环境为目的约束性力量，是解决环境污染问题的重要工具。公众参与型环境规制是通过政府引导，社会公众出于自身环保意识对环境提出诉求，影响着政府及相关部门公共政策的制定与执行，能有效缓解企业与政府间的信息不对称问题、填补政府污染监督盲区，迫使政府加强环境管控或企业降低污染排放，在最大程度上弥补“政府失灵”、避免“市场失灵”。

理论分析与研究假说

消费端：公众行为驱动效应

根据计划行为理论，消费者的行为表现会受到其行为意愿的影响，密切关注环境问题的消费者，倾向以较为环保的方式进行消费。微观主体所形成的“个人层面”的环保意识，会促使其本身承担起一定的环境责任，积极参与绿色低碳消费。通过环境规制政策的引导，环保意识逐渐深入人心，进而社会公众的消费观念和需求偏好会发生改变，在消费时倾向选择更具有绿色低碳特质的产品，伴随大众环保意识的觉醒，公众对美好生活的向往也愈发强烈，“低碳”需求不断扩张，主动削减高碳消费、崇尚低碳消费，有效推动家庭消费低碳转型。

生产端：用能结构优化效应

中国长期以来粗放型经济发展方式，导致了能源的大量消耗，解决这一问题亟需实现用能结构的低碳化转型。一方面，公众参与型环境规制通过社会公众监督企业违法排污行为，迫使乱排乱放企业进行污染治理和低碳转型；另一方面，公众参与型环境规制对政府层面的环保监管及督察成效施加压力，提高政府环境执法力度，迫使政府层面有效处理所反映的环境问题。对于此，企业会更加注重环境效益，加强对清洁能源的开发与利用，优化用能结构。用能结构的变革优化进一步推动企业向社会公众提供更加低碳、节能的产品，在生产端为公众践行低碳消费奠定丰富物质基础，促进社会公众消费低碳产品，推动家庭消费低碳转型。

进一步分析：对家庭消费结构的影响

严厉的正式环境规制容易导致企业生产成本升高、生产规模降低，企业在短期可能会通过减产、降低员工薪资水平甚至减少岗位人数来转嫁生产成本，尤其是对低技能劳动者来说形势更为严峻，进而会对社会就业规模和人民生活水平产生负向冲击。最终环境规制对就业的负向冲击效应会反映到家庭收入水平上，根据生命周期假说，消费行为是由其生命周期内预期收入决定，因此公众会因为收入水平的下降和对未来收入的不确定性而减少消费支出和预算。考虑到基本生活需要，公众会倾向于优先降低非基础性支出，从而造成家庭消费降级。

实验设计与结果分析

公众行为驱动效应： 参考wang等（2023）选取成人个人问卷中“您认为中国环境问题严重程度”问题经过处理后来表示居民环保意识水平（envaware），该问题答案为10分制，分值越高代表该问题的回答人认为中国的环境问题越严重。

用能结构优化效应： 借鉴付凌晖（2010）与柳亚琴等（2022）构建能源消费结构低碳化指数来表征能源消费结构变量（cenergy）。

变量	(1)	(2)
	envaware	*cenergy*
PER	0.065***	0.005***
	(0.005)	(0.000)
Constant	-0.218	1.421***
	(0.190)	(0.024)
Observations	95,839	39,737
R-squared	0.758	0.914
控制变量	是	是
家庭固定效应	是	是
时间固定效应	是	是

结果如上表第（1）列所示，公众参与型环境规制变量的回归系数为0.065，在1%的置信水平上显著，表明公众参与型环境规制可以通过提高居民环保意识在消费端引导公众购买低碳产品、崇尚低碳消费，推动家庭消费低碳转型。如上表第（2）列所示，公众参与型环境规制变量的回归系数为0.005，在1%的置信水平上显著，表明公众参与型环境规制能够通过优化用能结构推动企业从生产端向社会公众提供更加低碳的产品，为公众践行低碳消费提供充分物质基础，推动家庭消费低碳转型。

对家庭消费结构的影响： 将家庭问卷中食品、衣着和居住支出定义为生存型消费支出；文教娱乐支出定义为发展型消费支出；家庭设备、医疗保健和交通通讯支出定义为享受型消费支出，分别以发展型消费支出和享受型消费支出之和与生存型消费支出的比值（dconsume1）、发展型消费支出和享受型消费支出占总消费支出的比重（dconsume2）同时指代家庭消费结构变量。

变量	(1)	(2)
	dconsume1	*dconsume2*
PER	-0.112	-0.003
	(0.080)	(0.003)
Constant	-6.906**	-0.228**
	(3.317)	(0.115)
Observations	39,707	39,737
R-squared	0.281	0.442
控制变量	是	是
家庭固定效应	是	是
时间固定效应	是	是

结果如左表所示，公众参与型环境规制变量的回归系数分别为-0.112、-0.003，表明公众参与型环境规制可以通过推动居民消费降级来降低家庭消费间接碳排放，但回归系数并不显著，说明其并不会对居民消费结构产生显著消极影响。

结论与政策建议

本文以中国家庭追踪调查微观数据库为基础，探究公众参与型环境规制对家庭消费低碳转型的影响作用。结果发现，公众参与型环境规制能有效推动家庭消费低碳转型，这一结论在经历工具变量、安慰剂等一系列稳健性检验后仍然成立；机制检验得到公众参与型环境规制可以从消费端和生产端两方面实现对家庭消费低碳转型推动作用；同时，这一作用的发挥效果受到家庭抚养负担比重、地区资源禀赋差异以及政府环境执法力度的差异化影响，家庭抚养负担较低、资源型地区以及环境执法力度较高样本中推动作用更加显著；进一步分析发现，公众参与型环境规制并不会从内需方面导致家庭消费降级以此实现家庭消费低碳转型。基于此，本文提出以下政策建议以供决策参考：第一，拓宽环境治理的公众参与渠道，加快构建环境多元共治格局。第二，坚持消费端与生产端双向发力，推动形成绿色低碳的消费方式。第三，立足不同地区和家庭差异化情况，把准方向、精准施策。

安徽大学 Anhui University

碳中和系统规划与碳测算

Carbon Neutrality System Planning and Carbon Measurement

Evolution of Distribution Networks for China's 'Mega' Renewable Energy Centers

Ye Fan, PetroChina Planning & Engineering Institute, Beijing, Fanyecup@foxmail.com
Li Lin, School of Vehicle and Mobility, Tsinghua University, Beijing, linli19@mails.tsinghua.edu.cn
Ziqi Zhang, School of Public Policy and Management, Tsinghua University, Beijing, zhang-zq17@tsinghua.org.cn

Background, Aims and Scope

China is steadfast in its commitment to achieving the 'dual carbon' target by 2060, with an increasing emphasis on expanding the share of green power supply (Zhang et al., 2020), making the construction of large-scale solar and wind 'Mega' Energy Centers a pivotal focus during the '14th Five-Year Plan' (Fig. 1). China has established several green electricity and certificate markets national wide to promote the realization of environmental values in power production enterprises and meet the demand for green electricity from market. Nevertheless, the distributional networks of national 'Mega' Energy Centers have not been thoroughly examined and exhibit various limitations in facilitating the expansion of renewable energy development. Therefore, we devised a distribution model based on different renewable energy production scenarios, revealing optimal routes for China's 'Mega' Renewable Energy Centers on Chinese green electricity and certificate markets.

Fig. 1 Distribution of China's 'Mega' Renewable Energy Centers

keywords: 'Mega' Renewable Energy Centers, Green Certificate, Green Electricity, Heuristic Search, Genetic algorithm model

Methods

We have developed an optimization model considering the fixed and variable costs of the green electricity supply chain, regional demand constraints, the proportion of regional renewable energy consumption, and certificate pricing. We simulate the maximized profit output from different allocation strategies. We utilize heuristic searching methods (Edelkamp & Schrödl, 2011) (Fig. 2) and Genetic Algorithm model (Mirjalili & Mirjalili, 2019) to achieve optimal results. The model also encompasses typical scenarios that energy suppliers might encounter to ensure the practical applicability of the output distribution strategy.

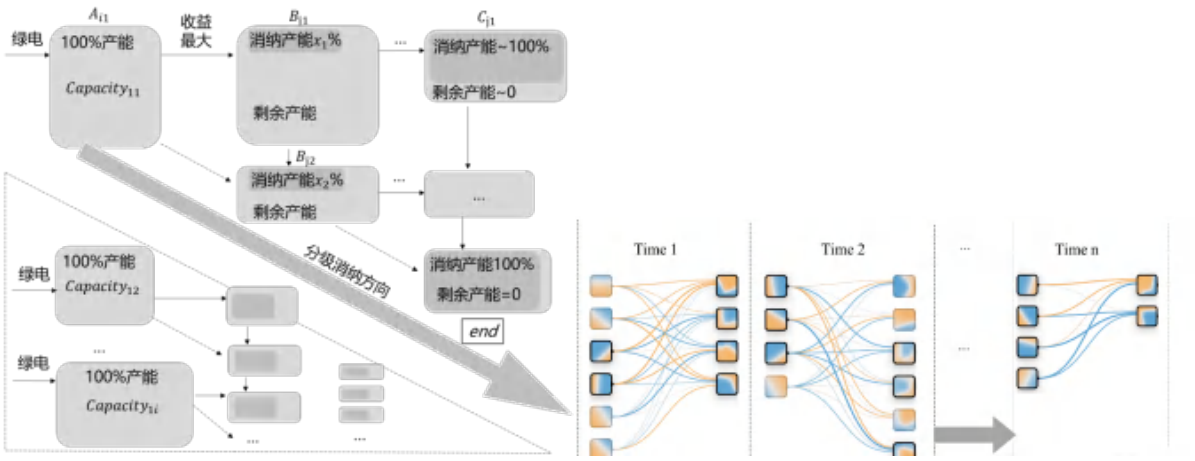


Fig.2 Heuristic search method

Results and Discussion

We incorporated reliable data sources, encompassing mandatory green electricity consumption rates at the provincial level, market share predictions, and authoritative forecasts of green electricity and certificate prices/costs per kWh in various regions. Additionally, we found limitations on energy transportation paths due to national grid constraints and conducted sensitivity analysis thereafter. The model's results indicate that collaboration among several adjacent provincial centers, market supply separation, and pre-lockdown long-term contracts yield the most benefits. However, these findings also underscore the importance of removing trade barriers to unleash the demand for green energy consumption.

Conclusion

This study develops a data-driven optimization model for China's 'Mega' Renewable Energy Centers' green electricity distribution, finding that inter-provincial collaboration, market separation, and long-term contracts can maximize economic profits and environmental benefits. However, realizing the full potential of optimal distribution strategies requires increased regional cooperation and removing trade barriers to unlock suppressed demand. Future research should focus on assessing implementation challenges and comprehensive mechanisms from economic, environmental, and social factors of China's 'Mega' Renewable Energy Centers.

Reference

Edelkamp, S., & Schrödl, S. (2011). *Heuristic search: theory and applications*. Elsevier.

Mirjalili, S., & Mirjalili, S. (2019). Genetic algorithm. *Evolutionary Algorithms and Neural Networks: Theory and Applications*, 43-55.

Zhang, H., Zhang, X., & Yuan, J. (2020). Transition of China's power sector consistent with Paris Agreement into 2050: Pathways and challenges. *Renewable and Sustainable Energy Reviews*, *132*, 110102.

Analysis of algal blooms and study of microalgae harvesting and carbon emissions in eastern China's water blooms

Hao Wen [1,*], WU Meili [1]
(1. School of Earth Science and Environmental Engineering, Anhui university of Science and technology, Huainan, 232001, China)
*Email:2019059@aust.edu.cn

Abstract
Background, Aims and Scope. Water blooms caused by eutrophication of water bodies have a great impact on the watershed environment and residents' life. In this study, sampling points were set up in the waters of Chaohu Lake and Huaihe River tributaries where water blooms erupted, and the water quality indexes of the water samples and the dominant algal species causing blooms were analyzed, and microalgae harvesting research was carried out on the basis of a new type of flotation material. Commonly used microalgae harvesting techniques include centrifugation, filtration, sedimentation and air flotation. The flotation material used in this study is made from compound frying oil, which is easy to obtain and can be reused compared with other harvesting methods. The harvesting process saves energy and reduces carbon emissions, thus realizing the goal of reducing emissions.
Methods. To assess the environmental impact and economic energy consumption of this harvesting process through life cycle assessment. Explore the mechanism of interaction between Chlorella and floating beads according to XDLVO theory. Typical water samples were selected for single-factor flotation harvesting experiments to analyze the range of values of influencing factors. Some water samples were analyzed by response surface method to explore the key factors and optimal harvesting conditions affecting the experiment.
Results and Discussion. According to the results of response surface experiments, pH, dilution ratio and aluminum sulfate concentration were mostly significant influencing factors in the recovery rate and enrichment ratio of water samples. Combining the results of single-factor and response surface experiments, the recovery ratio of each water sample was more than 70%, and the method used in this study was effective for natural water bodies. Among them, water sample ② had the highest recovery rate (97.21%) and enrichment ratio (1.68%). According to the analysis of BBD experiment, the optimal harvesting conditions of water sample ⑤ were pH: 8, dilution ratio: 2, stirring rate: 180 rpm, with a recovery rate of 93.45% and an enrichment ratio of 1.47%; and the optimal harvesting conditions of water sample ⑨ were pH: 6, concentration of aluminum sulfate: 50 mg/L, and addition of floating beads: 20 ml/L, with a recovery rate of 92.11% and an enrichment ratio of 1.74%. The economic cost of harvesting 1 m3 of microalgae was $15.96, the energy consumption was 0.075 kW-h/m3, and the CO2 emission was 0.07 kg/m3.
Conclusion. Field understanding of the waters of Chaohu Lake and Huaihe River tributaries is of practical significance for the realistic management of Shuihua. The compound frying oil emulsion is selected as floating beads, and the compound frying oil is reused, which is harmless to the environment. In the subsequent process of microalgae oil production, it saves the cost and time of separation and recycling, and puts forward feasible suggestions for the restoration of rural waters and the management of water bloom.
Key words: water bloom; harvesting;buoy-bead flotation method; response surface method; life-cycle assessment

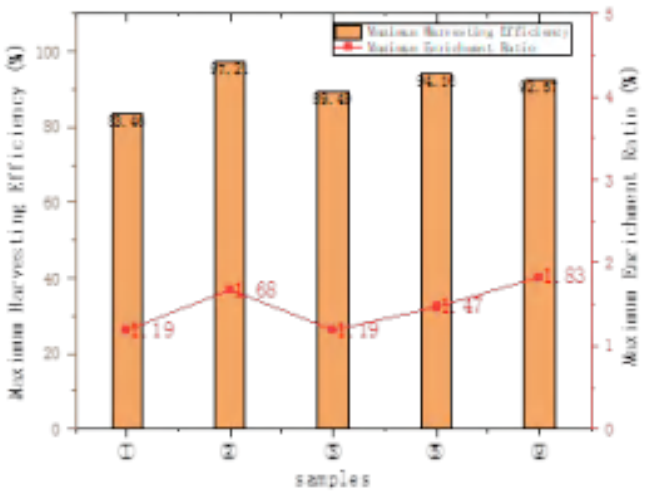


Fig 1 Maximum harvesting and enrichment ratio of water samples.The data of water samples ⑤⑨ and ①②③ were obtained from response surface experiment and single factor experiment respectively.

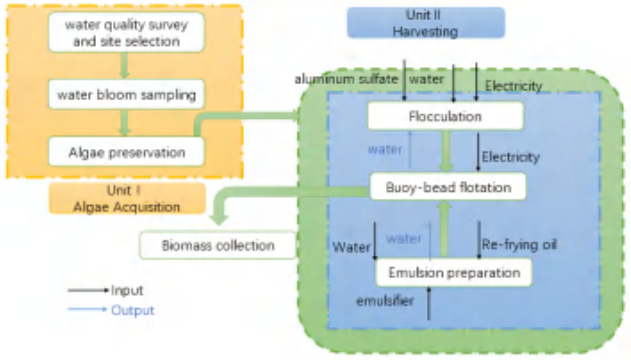


Fig 2 The boundary of microalgae treatment system

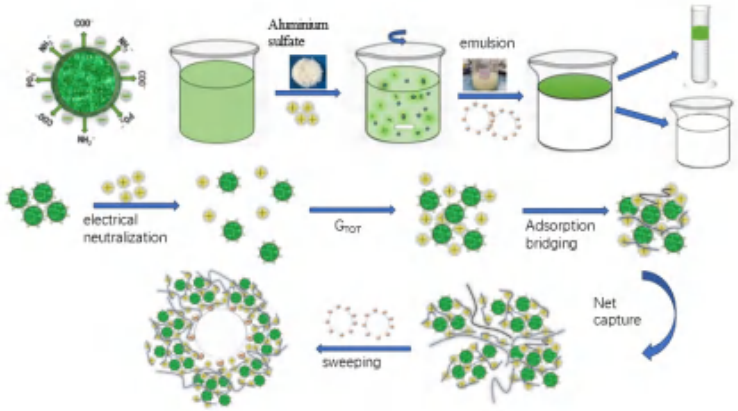


Fig 3 Microalgae harvest mechanism diagram of emulsion as buoy-bead

Table 1 Inventory analysis for microalgal acquisition and harvesting.

Unit			Values[a]	
Flocculation	Input			
		Water	1.000	m^3
		aluminum sulfate	0.100	Kg
		Electricity	0.003	KW h
Emulsion preparation	Input			
		emulsifier	0.8	L
		Re-frying oil	39.2	L
		Electricity	0.047	KW h
		Water	0.092	m^3
	Output			
		water	0.080	m^3
Microalgae flotation	input	Electricity	0.025	KW h
	output	Water	1.6	$^m3$

Table 2 Energy consumption and CO2 emissions of different harvesting methods

Harvesting method	Energy consumption [kW h/ m^3]	CO_2 emission kg/m^3	Harvesting efficiency (HE)	
DIAF	0.46	0.43	>95%	
Settling with flocculant	0.10	0.09	>95%	
Dissolved air flotation(DAF)	1.50	1.40	>90%	
Direct centrifugation	1.43	1.33	>90%	
Buoy-bead flotation	0.075	0.07	>90%	this study

Based on PLUS modeling analyzing impacts and predicting rural carbon emissions from land use type changes

Mingjie He[1]
([1] School of Architecture, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, Harbin 150000, China)

Abstract:

Background, Aims and Scope. Traditional agriculture's crude operation and production mode, especially the random transformation of land use type and operation mode, have become the important way to influence the carbon emission of agriculture. In order to reduce carbon emissions from agriculture and rural areas, predicting and planning for future changes in land use types is extremely important for mitigating global warming and extreme weather.

Methods. The article takes Harbin as an example (figure 1). Firstly, the PLUS model is used to obtain the conversion contribution of each land type and to analyze the root causes of land type changes using the random forest method. Secondly, analyzing the factors affecting the carbon emission effects of rural land use and classifying land use types and management practices, which leads to the construction of a reference table of carbon emission intensity for land-type shifts (table 1). Finally, using the PLUS model, the temporal and spatial changes in carbon emissions in 2035 under the three scenarios of cropland protection, natural development and woodland protection were projected to provide advice and recommendations for rural emission reduction.

Results and Discussion. The results of the study show that: The conversion of woodland and grassland to other land use types is shown as a carbon sink, while the conversion of built-up land to other land use types is shown as a carbon source. Agricultural production methods such as fertilizers and pesticides increase rural carbon emissions, with agricultural films contributing most significantly to the increase in carbon emission factors (5.18 kg/kg). Carbon intensity of rural land under woodland conservation scenarios has a strong contribution to agricultural emission reductions. Based on the conclusions of the above study, suggestions and recommendations for energy conservation and emission reduction in response to changes in rural land use types are proposed.

Conclusion. The methodology is based on the example of rural areas and provides constructive suggestions and recommendations for rural energy conservation and emission reduction, which can be implemented in other rural areas, especially in developing countries. At the same time methods to achieve the goal of reducing carbon emissions are important for achieving carbon neutrality.

key words: PLUS modeling; Carbon neutral policy; Rural; Land use type changes

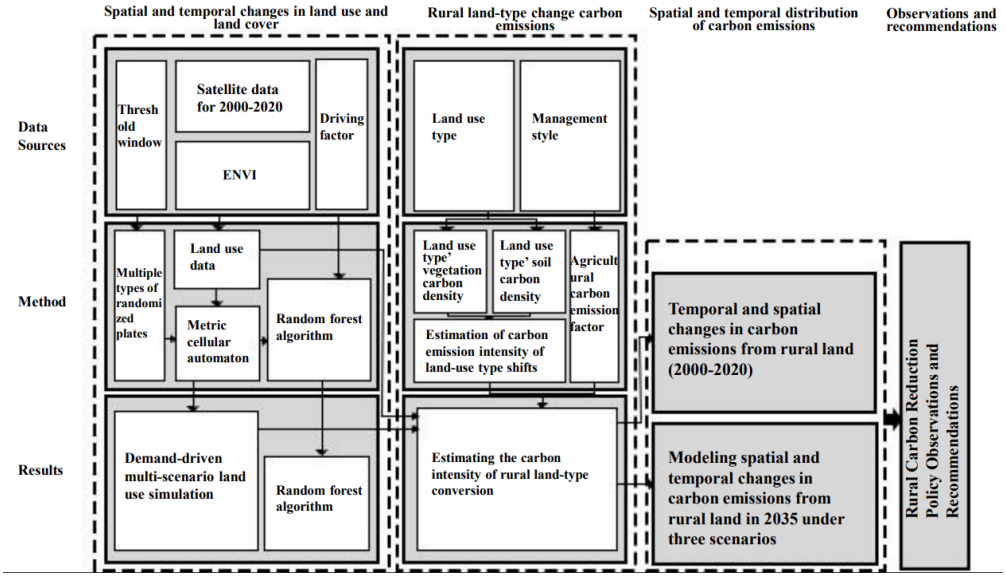


Fig 1 Research Framework.

Table 1 Table of carbon emission intensity for land-type shifts

	Agricultural production methods	Vegetation carbon density	Soil carbon density	Agricultural production methods	Total（t/hm²）
Forest		24.6	187.8		212.4
Grasslands		9.8	151.9		161.7
Building land		6.8	128.5		135.3
Unutilized land		13.5	165.5		179
Cropland	Fertilizers	7.6	154.2	0.11	161.90
	Agrochemical	7.6	154.2	0.0089	161.81
	Diesel fuel	7.6	154.2	0.18	161.98
	Turn the soil	7.6	154.2	0.003	161.80
	Irrigation	7.6	154.2	0.15	161.95
	Agrofilm	7.6	154.2	0.02	161.82

Visual Analysis of "Double Carbon" Theme Research in Key High Energy Consumption Industries Based on Knowledge Graph

HOU Xiaopeng,ZU Binghui,CAO Yue
（College of Business Administration，Liaoning Technical University，Huludao 125105，China）

Abstract:

Background, Aims and Scope. Achieving the "double-carbon" goal is the most prominent global environmental protection issue in the field of ESG governance and sustainable development at home and abroad. As a highly consistent "double-carbon" concept, realizing the low-carbon transformation and development of high-energy-consuming industries such as coal and electric power is a key link for China to realize the goal of "double-carbon".

Methods. In order to clarify the development status and evolution trend of "double-carbon" theme field in key high energy consuming industries in China, CiteSpace and COOC were used to visually interpret the journal literature on "double-carbon" theme in key high energy consuming industries in CNKI database from 2001 to now.

Results and Discussion. In order to objectively reflect the overall commonness and the characteristics and differences of various industries in this field, the present situation and future development trend of this field are analyzed from three aspects: literature publication characteristics, research topics and evolution trends, and author and institution characteristics based on the two dimensions of the whole and industry perspectives.

Conclusion. Finally, some suggestions are put forward according to the current development situation in this field. It provides a reference for future scholars in this field to study the theme of "double-carbon" in the industry.

Keywords: Key high-energy-consuming industries; Double carbon; COOC; Citespace; Bibliometric method

Incorporating Health Co-benefits into Province-Driven Climate Policy: A case of banning new internal combustion engine vehicle sales in China

Jianxiang SHEN (Tsinghua University

Abstract

Incorporating health co-benefits from co-abated air pollution into carbon mitigation policy making is particularly important for developing countries to boost policy efficiency. For sectors that highly depend on electrification for decarbonization, it remains unclear how the increased electricity demand and consequent health impacts from sectoral mitigation policy in one province would change the scale, regional and sectoral distribution of the overall health impacts in the whole country. This study chooses banning new sales of internal combustion engine vehicles in the private vehicle sector in China as a case. The results show that without carbon neutrality and air pollution control goals in electricity generation, 53% of CO2 reduction and 65% of health benefits from private vehicle sector would be offset by increased electricity demand. The regional distributions of CO2 reduction and health benefits due to a province-driven ban policy are greatly uneven, as the top five provinces take up over one-third of the total impact in China. Health benefits per ton of carbon reduction (H/C) may vary by up to 8 times across provinces. Finally, the provinces in southeast China and the Sichuan Basin, with their stably high H/C values, are suggested to enact the province-driven ban policy first.

Key words: carbon mitigation, health co-benefits, private vehicle, province-driven policy, policy implementation order

Optimization and Management of Urban Water Supply Systems for Carbon Neutrality: A Perspective on the Water-Energy-Carbon Nexus

Tan Shiqi[1], Yao Liming[1,2]
(1. Business School, Sichuan University, Chengdu 610065, China; 2. State Key Laboratory of Hydraulics and Mountain River Engineering, Sichuan University, Chengdu 610065, China)

Abstract

Background, Aims and Scope. The United Nations Sustainable Development Goals (SDGs) necessitate achieving sustainable development in both socioeconomic and ecological aspects in a more balanced and integrated manner. Urban water resource systems (UWSS) in China are currently facing the severe threats of climate change and water resource scarcity, and these challenges intersect with the objectives of sustainable development and the "Dual Carbon" goals. These new requirements extend to various facets of urban water supply systems, such as water resources, energy, and carbon emissions reduction. Clarifying the relationships among water, energy, and carbon emissions, known as the "Water-Energy-Carbon Nexus (WEC-Nexus)," is pivotal for a city's sustainability and low-carbon development.

Methods. This paper establishes a framework and methodology for carbon emission accounting throughout the entire lifecycle of UWSS, grounded in the intricate nexus between water, energy, and carbon. The study utilizes emission factors to examine the carbon emission characteristics of Beijing's UWSS from 2011 to 2020. Furthermore, a multi-objective optimization model is developed to synergistically optimize both socioeconomic and environmental benefits within Beijing's UWSS. This optimization balances economic costs, carbon emissions mitigation, and reductions in water environment pollution. In addition, a multi-factor System Dynamics model for UWSS is constructed, simulating the interplay among subsystems, such as socioeconomic and ecological environments, and the evolving dynamics of the water-energy-carbon nexus. To address specific sub-indicators related to SDGs, five future scenarios are defined, and scenario analysis is employed to forecast the developmental trends of water resource shortages, water environmental impacts, carbon emissions, and economic costs within Beijing's UWSS.

Results and Discussion. (1) The UWSS in Beijing has a large potential for carbon emission reduction, and there are significant differences in carbon emissions at different stages. (2) There is a need for further synergy and optimization between the "pollution and carbon reduction" as well as the socio-economic and ecological benefits of Beijing's UWSS. (3) The rapid economic growth development model no longer applies to the future planning of Beijing's UWSS, but should be fully coordinated with technological innovation and ecological protection. (4) Optimized allocation of urban water resources under the WEC-Nexus can help Beijing conserve water consumption and provide water supply in a more economical, environmentally friendly, and sustainable way.

Conclusion. Beijing UWSS is currently facing a severe water shortage, which will threaten the water security of residents and socio-economic development in the long run. The urban planning goal of pursuing rapid economic development must be traded off with the ecological and environmental goals, especially under extreme climate conditions. The optimization model proposed in this paper considers the multi-objective decisions of economy, water environment, and carbon emission faced by UWSS and has obtained good operation results in Beijing. Improved water reuse and wastewater treatment technologies will effectively help to improve water quality and reduce carbon emissions while increasing water efficiency for agricultural irrigation and ecological protection can also contribute to sustainable urban development. Human activities remain a crucial aspect of carbon reduction in UWSS, as end-users are the most significant contributors to energy consumption and carbon emissions. Optimizing the urban water system for carbon reduction and water pollution from the entire life cycle and adopting more energy-efficient water supply strategies and technologies can contribute to the synergistic optimization of WEC-Nexus. In the simulation model of this paper, technological advancement and ecological conservation do not imply a compromise between cost and economic development but rather a transfer of payments that favor economic costs.

Key words: urban water supply system; water-energy-carbon nexus; sustainable development; water consumption; carbon emission mitigation; scenario analysis

Effects of land use change on carbon emission and its driving factors in Shaanxi Province from 2000 to 2020

Chenxu Zhao[1], Yuling Liu[1,1*], Zixuan Yan[1,2]

(1 State Key Laboratory of Eco-Hydraulics in Northwest Arid Region of China, Xi'an University of Technology, Xi'an, Shaanxi 710048, China

2 State Key Laboratory of National Forestry Administration on Ecological Hydrology and Disaster Prevention in Arid Regions, Xi'an University of Technology, Xi'an, Shaanxi 710048, China)

**Corresponding author. Yuling Liu, Xi'an University of Technology, No.5, South Jinhua Road, Xi'an, Shaanxi 710048, China.*

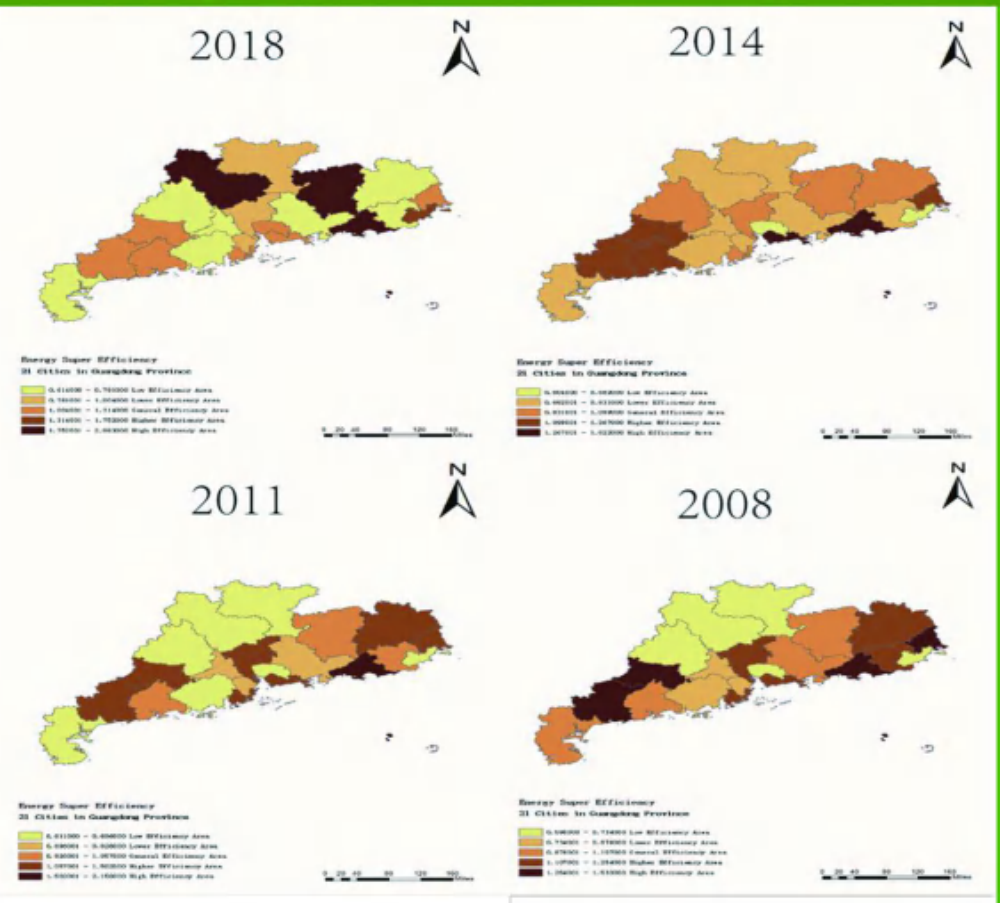
Email address: lyl29992359@163.com.

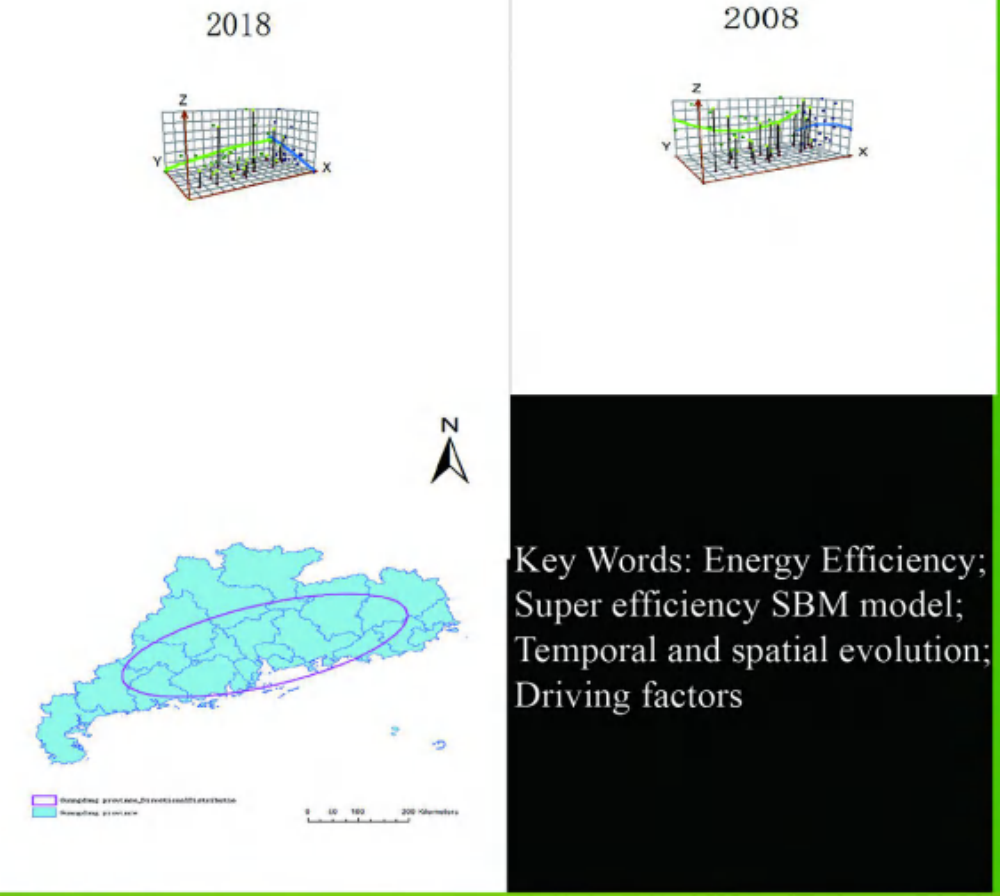
Abstract: Exploring the process of carbon emissions under the "carbon peaking and carbon neutrality goals" can contribute to sustainable economic development. This research takes Shaanxi Province as an example. We elaborated the spatial and temporal characteristics of land use change from 2000 to 2020, and adopted the carbon emission model method to calculate land use carbon emissions, also used urban morphological indicators to reveal the main factors of carbon emission changes. The results show that from 2000 to 2020, the land use change in Shaanxi Province is mainly reflected in the increase of construction land area and the decrease of agricultural land area. Among them, the construction land area increased by 2192km^2, and the agricultural land area decreased by 5006km^2. Land use carbon emissions increased by 1.28×10^{11} kg during this period. Construction land is a major contributor to carbon emissions. The forestland is the main carbon sink. Carbon emissions showed a spatial pattern of "high in the north, low in the south, and concentrated in the middle". Urban form change is the driving factor affecting land use carbon emissions in Shaanxi Province. The results of the research contribute to the understanding of regional carbon emission mechanisms and provide a scientific basis for reducing carbon emissions.

Keywords: Land use carbon emissions; Spatial-temporal pattern; Driving factors; Urban form; Shaanxi Province

1 * Corresponding authors. Xi' an University of Technology, Xi' an, Shaanxi 710048, China. Tel.: +86 29 82312658; fax: +86 29 82312658.

E-mail addresses: lyl29992359@163.com.





Research on the spatiotemporal evolution characteristics and driving factors of energy use efficiency from the perspective of the green economy – Taking 21 cities in Guangdong Province as examples

Name: Deng Gang

The Institute for Sustainable Development, Macau University of Science and Technology

Exploring the spatial differences and driving factors of energy efficiency is beneficial for regional sustainable development. In order to achieve the goal of a dual carbon policy, measures to reduce energy consumption and achieve low-carbon green transformation are essential. This study used relevant data from 21 prefecture-level cities in Guangdong Province ,and used the SBM model of unexpected output, the natural discontinuity method of ArcGIS, spatial trend surface analysis, standard deviation ellipse analysis, center of gravity transfer trajectory model, geographic detector model to analyze the spatial differences and driving factors of energy efficiency in 21 cities in Guangdong Province. The study found that there were significant spatial differences in energy utilization efficiency in 21 cities in Guangdong Province, finally, based on the impact of five driving factors, including urbanization level, regional financial development level, government intervention level, economic development level, and digital economy development level, on energy efficiency, relevant suggestions and measures ought to be explored to achieve green and low-carbon transformation and sustainable development.

Key Words: Energy Efficiency; Super efficiency SBM model; Temporal and spatial evolution; Driving factors

Research on Smart Shrinkage Strategies of County-level Cities in Liaoning Province under Low-Carbon Orientation

Author : Huang Shan [1] , Lu Xu [2] , Yi Haoming [3]

1.PhD student, Architecture and Urban Planning School of Shenyang Jianzhu University , No.9 Hunnan East Road, Hunnan District, Shenyang , China, 110168 , huangmeimeiheiha@163.com.

2.Professor and PhD Supervisor, Architecture and Urban Planning School of Shenyang Jianzhu University , No.9 Hunnan East Road, Hunnan District, Shenyang , China, 110168 , luxupku@163.com

3.Urban Planner, Shenyang Urban Planning & Design Institute Co.,Ltd. , Xinshijie Building, No.1 South Sanhao Street , Heping District , Shenyang , China , 110004, 852185312@qq.com.

Abstract : 【**Background**】 At this stage, Liaoning Province is in a state of heavy shortage of carbon emission allowance, and is facing an extremely serious carbon deficit problem. In Liaoning Province, 64% of the 44 county-level administrative units are in the state of contraction, and the carbon emission problem of the shrinking cities occupies a dominant position. 【**Aims and Scope**】 Achieving low-carbon development of cities in the context of shrinking is a must for the revitalization of Northeastern China. 【**Methods**】This paper makes judgments in two dimensions. One is the vertical time pulse and the other is the horizontal spatial agglomeration characteristics. The temporal trend and spatial coordination relationship between Carbon-Emissions & Urban-Shrinkage are presented by this method. By establishing the index system of "Carbon-Emissions & Urban-Shrinkage" in Liaoning Province, we utilized the coupling coordination method and spatial autocorrelation model to comprehensively evaluate the relevant relationship and then determined the contraction factors that hinder low-carbon development. 【 **Conclusion** 】 On this basis, the coupled spatial pattern of "Carbon-Emissions & Urban-Shrinkage" in Liaoning is characterized. A smart shrinkage strategy for low-carbon development is proposed.

Keywords : Smart shrinkage; Low-carbon; Coupling coordination; Liaoning Province

低碳导向下的辽宁省县级城市精明收缩策略研究

作者： 黄山（沈阳建筑大学博士研究生）、路旭（沈阳建筑大学教授、博士生导师）、衣浩铭（沈阳市规划设计研究院规划师）

摘要： 【背景】现阶段辽宁省碳排放权额处于重度欠缺状态，面临极为严重的碳排放赤字问题。在辽宁省 44 个县级行政单元中 64%的县市处于收缩状态当中，收缩城市的碳排放问题占据主体地位。【目的】在收缩语境下实现城市的低碳发展是东北振兴的必由之路。【方法】本文从纵向时间脉络和横向地理空间集聚特征两个维度判断碳排放与城市收缩的时间发展趋势和空间协调关系。通过建立辽宁省“碳排放强度与收缩程度”指标体系，利用耦合协调度和空间自相关模型综合评价相关关系，判断阻碍低碳发展的收缩因子。【结论】在此基础上识别辽宁整体“碳排放强度与收缩程度”耦合空间格局特征，提出适应低碳发展的精明收缩策略。

关键词： 精明收缩；低碳；耦合协调；辽宁省

Analyzing and Forecasting the Demand and Carbon Emission of China's Energy System Based on the LEAP Model

LIN Dan [a]
[a] School of Energy and Mining, China University of Mining and Technology (Beijing), Beijing 100083 , China
(Email: lindan8678@163.com)

Introduction

Energy runs through the entire process of economic and social development. Energy is the main battlefield for the achievement of the carbon peaking and carbon neutrality. It is essential to analyze China's energy demand and carbon emissions under the constraints of the carbon peaking and carbon neutrality targets. It is the premise and basis for the design of energy transition pathways, and can also provide strong support for policy formulation. The present study aimed to analyze China's total energy, as well as energy demand by sector and carbon emissions by 2030 and 2060 under the carbon peaking and carbon neutrality targets.

Methods

- By using the scenario analysis method and comparative analysis method, three scenario analysis models were constructed, namely the baseline scenario, the policy scenario, and the enhanced policy scenario.
- The LEAP (Long-range Energy Alternatives Planning System) model was also used to predict China's energy demand and carbon emissions under different scenarios.

Results

The results show that under the policy scenario, China's carbon peaking target is not achieved in 2030. Under the enhanced policy scenario, China can achieve its carbon peaking target in 2030, and carbon emissions will decrease gradually after peaking in 2029.

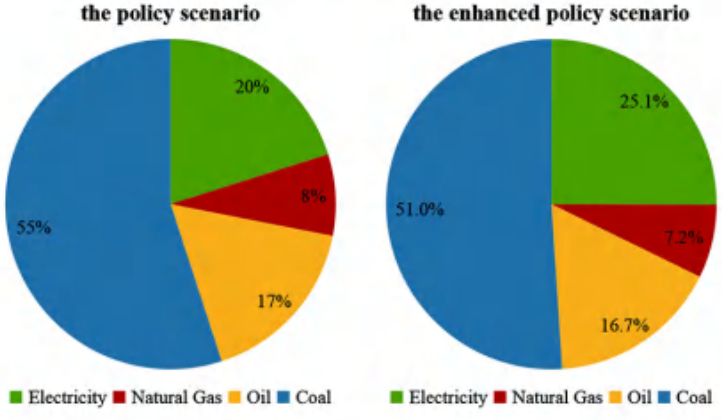
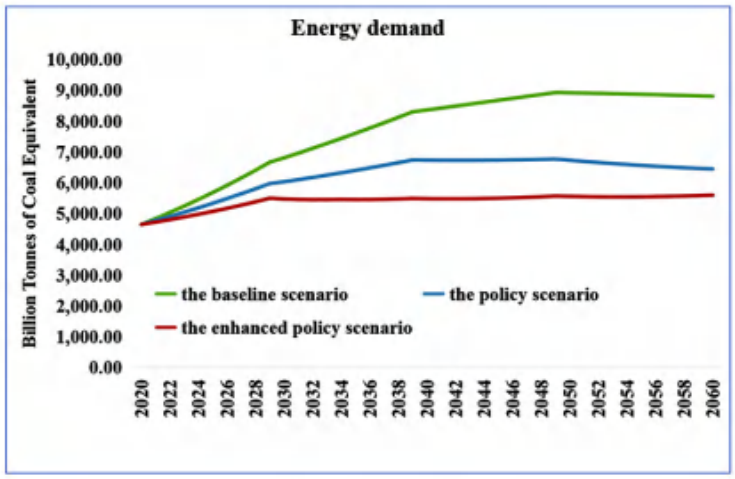


Fig 1 Share of non-fossil energy in primary energy consumption, 2030



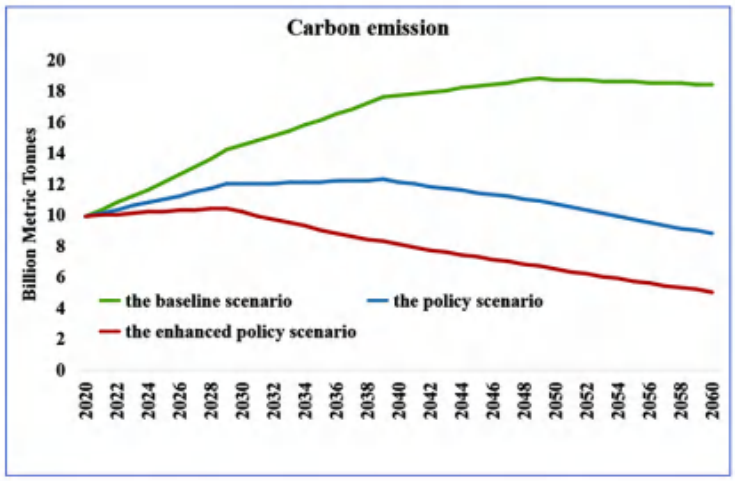


Fig 2 Energy consumption and carbon emissions

Results and Conclusion

Under China's existing macro-development planning and policy intensity in China, there are still certain pressures to achieve the carbon peaking and carbon neutrality targets.

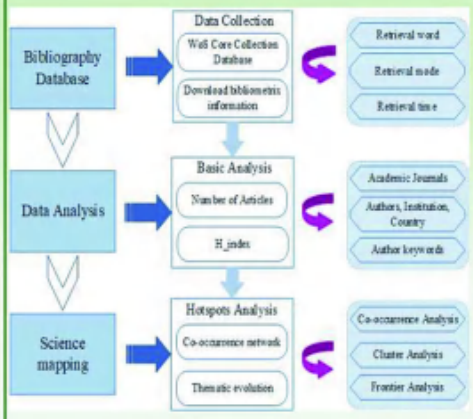
Progress and hotspots of research on land-use carbon emissions: A global perspective

Liu Min, Chen Yinrong*
(College of Public Administration, Huazhong Agricultural University, Wuhan 430700, China)
17853112030 lm_hzau.edu.cn@webmail.hzau.edu.cn

1 Abstract

Carbon emissions from land-use change are the leading causes of the greenhouse effect. Exploration of the progress and hotspots of research on land-use carbon emissions (LUCEs) is crucial for mitigating global climate warming. However, a comprehensive and systematic review of LUCEs research from a global perspective is still lacking. We used the WoS Core Collection Database to analyze the current status of research on LUCEs from a global perspective with the aid of the bibliometrix tool, aiming to reveal research hotspots and future development trends.

2 Methods



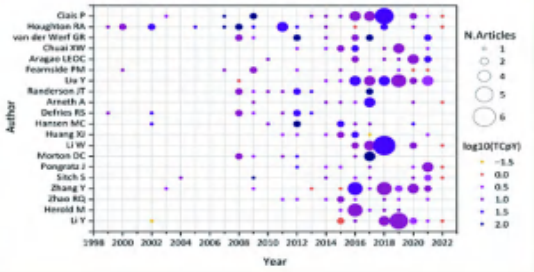
The search method was retrieval subject as TS= ("land use*" AND "carbon emission*"), the time span is set to "1992-2022", and obtained a total of 1092 literature data finally.

3 Results

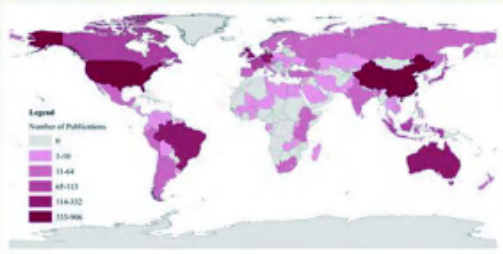
3.1 The trend in the number of publications and citations on LUCEs research

3.2 The growth trends of the top 10 most related journals

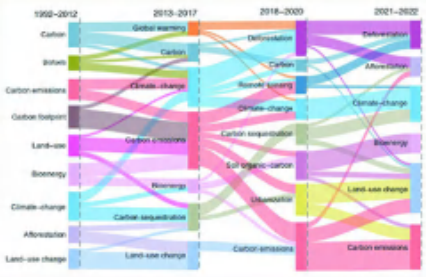
3.3 Authors' production over time



3.4 Country's scientific production



3.6 Thematic evolution path of LUCEs research



3.5 Keyword co-occurrence map, keyword cluster map, and heat maps of the annual keyword

4 Conclusions

Generally, research on LUCEs is becoming increasingly abundant. A multi-disciplinary cross-fertilization of integrated environmental science, earth ecology, and sustainable development has replaced single disciplines like geography or ecology in LUCEs research. Research topics include carbon emissions from land use, agriculture, and forests. Research emphasis has steadily switched from quantitative measurement to investigating the impact mechanism in LUCEs, combated remote sensing satellite technologies to track and predict the future trend of LUCEs worldwide.

5 Acknowledgment

HUAZHONG AGRICULTURAL UNIVERSITY 1898
NSFC National Natural Science Foundation of China

"Mask" does not survive, why low carbon: Waste mask treatment status and application program investigation -- Qingdao waste mask treatment as an example

LIU Zhao-chun
(School of Economics and Management, China University of Petroleum, Beijing 102249, China)

中国石油大学 CHINA UNIVERSITY OF PETROLEUM BEIJING

Background, Aims and Scope

Masks play a personal protection, isolation of the virus at the same time, with a large number of waste masks processing work should not be underestimated. If the method of incineration continues to be used, it will continue to increase CO_2 emissions, cause air pollution in the short term, and may become one of the man-made causes of the "greenhouse effect" in the long run. Therefore, it is urgent to optimize the mask material from the root and change its treatment.

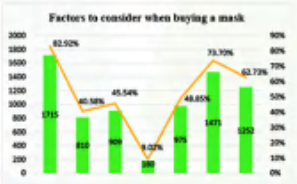
Methods

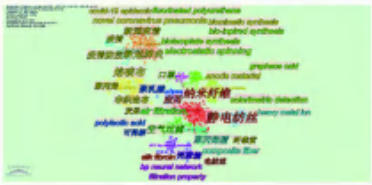
prefecture	Population (10,000)	Sampling percentage	Sample size (person)	Effective field investigation (copy)
Shinan District	486643	6.65%	135	132
Shibei District	1096879	10.89%	221	214
West coast new District	1903595	14.41%	293	289
Laoshan District	502370	7.54%	154	150
Licang District	737281	8.65%	176	169
Chengyang District	1109606	11.31%	230	222
Jimo District	1336077	12.20%	248	246
Jiaozhou City	907820	9.59%	194	192
Pingdu City	1191348	10.42%	212	211
Laixi City	720103	8.43%	171	171
headcount	10071722	100%	2046	1996

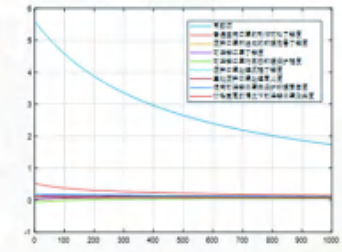
We conducted a specific investigation among citizens, community garbage sorting, environmental protection volunteers and some staff of Qingdao Ecological Environment Bureau in 10 districts of Qingdao.Through CiteSpace literature analysis, multiple responses, ridge regression prediction, K-Means clustering and other methods, This paper analyzes and summarizes the public's understanding and handling opinions on waste masks.

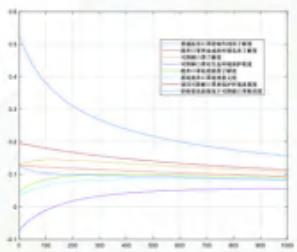
Results and Discussion

This paper analyzes and summarizes the public's opinions on the treatment of waste masks, and puts forward targeted suggestions, calling on the whole society to adopt reasonable and effective treatment methods of waste masks by improving the publicity of the dangers of waste masks, and exploring the rationality of the application of new masks such as degradable masks.









Conclusion

By increasing the publicity efforts on the harmfulness of discarded masks, we call on the whole society to adopt reasonable and effective disposal methods for discarded masks. At the same time, we explore the rationality of the application of new types of masks, such as biodegradable masks, and implement "emission reduction" into practical actions, promoting the construction of a resource saving and environmentally friendly society, and achieving sustainable development.

Decarbonisation Research Characteristics, Hotspots and Prospects: A Systematic Review Based on Scientometric Analysis

NING Xuanwei, HU Longying, ZHOU Mengting
School of Economics and Management, Beijing Forestry University

Background&Objectives

Background

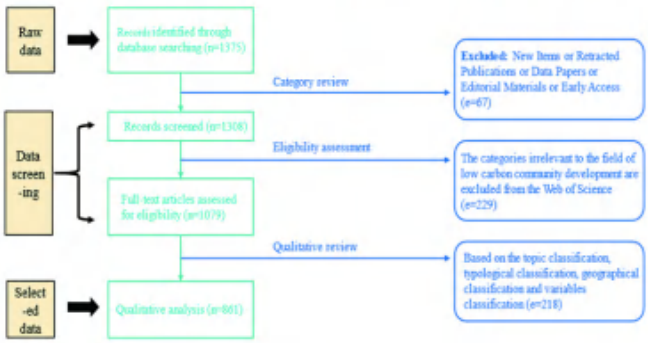
- Global climate change has become the greatest non-traditional security challenge to human development, and low-carbon development is the best solution to climate change.
- Cities account for 75%-80% of global carbon emissions and 71-76% of global carbon emissions from energy activities, making them the main battleground for global energy conservation and emission reduction.
- As a meso-scale research object, low-carbon communities are more implementable and operational than macro-scale low-carbon cities.
- The existing review articles mainly present a thematic and national focus and lack comprehensive research on community-based low carbon construction.
- Also, there is a lack of use of intuitive visualisation tools to reveal the characteristics of the literature in order to visually and effectively understand current research trends.

Objectives

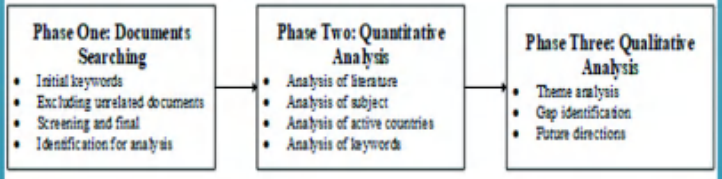
- Quantitatively assess the community low carbon research literature and its different bibliometric parameters.
- Develop a scientific map of the bibliometric parameters of the community low carbon research literature.
- Identify gaps in the existing community low carbon research literature.
- Provide future research directions for community low carbon research.

Methods

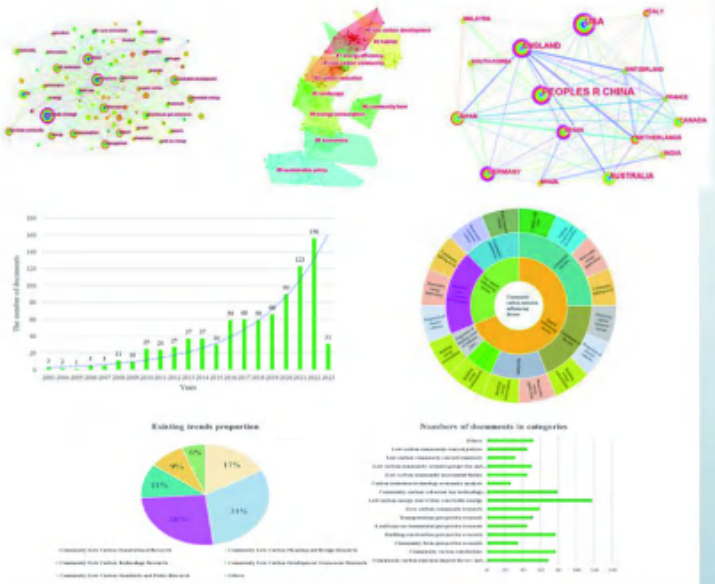
Bibliometric analysis is universally used to measure scientific progress in various disciplines of science and engineering and is a valid research tool for systematic analysis, and it identifies global research trends from multiple perspectives and provides potential guidance for future research. Through bibliometric analysis, this paper revealed the characteristics and hotspots of community low carbon research.



Based on reading the titles, abstracts, keywords and full texts of 861 articles, and referring to the results of the clustering diagrams from the previous quantitative analysis phase, relevant research themes were summarised in the qualitative analysis phase. We conducted a detailed literature review of each theme in the qualitative analysis phase, and finally conducted a trend analysis of the research themes based on the results of the qualitative and quantitative analysis, and also pointed out relevant research gaps and future prospects.

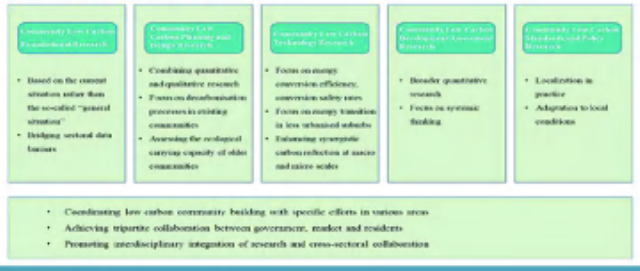


Results



Conclusion

- Key disciplines included environmental science, energy fuels, environmental studies, green and sustainable science and technology, engineering environment and meteorology and atmospheric science.
- China, the USA and the UK contribute the most number of publications in community low carbon research.
- Low carbon community planning and design research (31%), community low carbon technology approach research (26%) and community low carbon building fundamentals research (17%) were the hot themes in this paper's research, closely followed by community low carbon assessment research (11%).
- Community low-carbon research is a comprehensive subject, and in addition to the need for comprehensive research and extension in a single direction for each trend, there is also a need to study the cooperation and coupling between the various themes, and to promote interdisciplinary integration research and cross-sectoral collaborative research.



Acknowledgements

This study is supported by the General Program of the National Nature Science Foundation of China (71873009).

Response of Ecosystem Service Value to Landscape Pattern Changes under Low Carbon Scenario: A Case Study of Fujian Coastal Areas

福建師範大學 FUJIAN NORMAL UNIVERSITY

WEN Linsheng [1], CAI Guo[1], LIN Yuying [1 *], LI Baoyin [1, *]

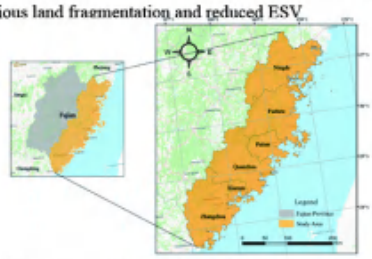
(1. State Key Laboratory for Subtropical Mountain Ecology of the Ministry of Science and Technology and Fujian Province, School of Geographical Sciences, school of carbon neutrality future technology, Fujian Normal University, Fuzhou, 350117, China)

1. Introduction

Ecosystem services are important for achieving the goal of sustainable development. The Ecosystem Value Equivalent Factor (EEFF) per unit area method proposed by Costanza et al (1997) has the advantage of being easy to operate and the input data are easily accessible.

Carbon emissions affect the ecosystem by influencing climate change, thus affecting the ESV. However, under our dual-carbon goal, few studies have incorporated low-carbon scenarios into scenario analyses of ecosystem services to predict future linkages between ecosystem service values and landscape patterns.

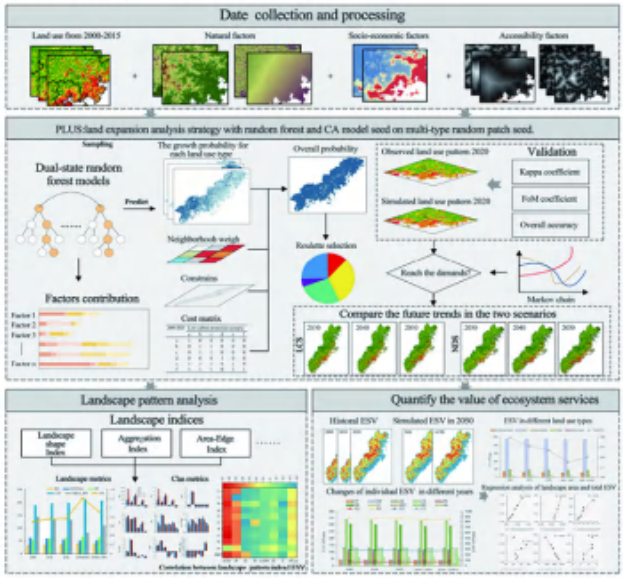
The Fujian coastal areas where the topography is undulating and fragmented. There are difficulties such as environmental pollution, water and soil loss, and natural catastrophes like as typhoons and floods occur year-round. Consequently, the natural environment is quite delicate. In addition, it is located in the hub of mountain and sea areas, facing problems such as intensified land use, serious land fragmentation and reduced ESV.



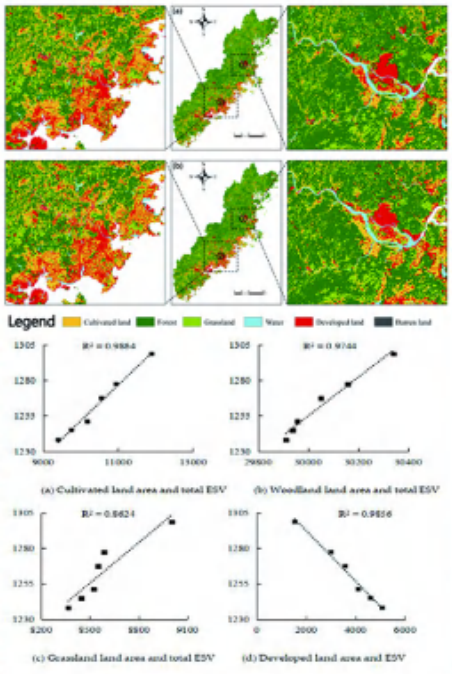
The objectives of this study are: (1) to analyse the spatial and temporal evolution of the landscape pattern in Fujian coastal areas in the past 20 years, and to simulate the landscape pattern in 2050; (2) to describe the change characteristics of 12 landscape indices and use the correlation between the index and individual ESV to reflect the impact of landscape pattern index on individual ESV; (3) to quantify the temporal and spatial changes of the total ESV in the study area on the grid scale; (4) to analyse ESV changes of different landscape types, so as to explore the response and future trend of ESV to landscape pattern changes.

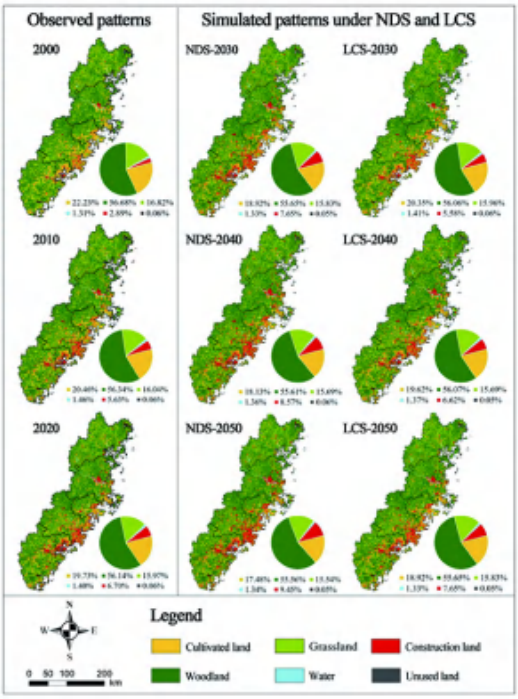
2. Materials and Methods

The flow chart of this study mainly included four parts (Figure 2). First, the collected social and economic data was processed. Secondly, Markov chain was used to predict LUCC demand, and the PLUS model was used to distribute the demand. Thirdly, the landscape index was used to describe landscape pattern changes. Fourthly, ESV was quantified and the response of ESV to landscape pattern changes was analysed.



3. Results





1.The historical and simulated landscape types are similar in spatial distribution, and the woodland landscape type has the largest area, followed by Cultivated land and grassland. From 2030 to 2050, the construction land area under LCS will account for 5.58%, 6.62% to 7.67%, while that under NDS will account for 7.65%, 8.57% to 9.45%.

2.At the landscape scale, the ED, LSI, PD and IJI indices are increasing, the CONTAG and AREA_MN indices have been decreasing,; at the landscape type scale, the PD, NP and ED indices of each landscape type showed a rising trend, while the CLUMPY and AI indices decreased. The changes of these indices indicate that the landscape shape in Fujian coastal areas tends to be complex and fragmented, the continuity of landscape types becomes low, and the aggregation of patches becomes weak.

3.The total value of ESV in coastal Fujian decreased by 3.134 billion from 2000 to 2020, and the LCS resulted in higher ESV in 2050 than the NDS 1.294 billion, indicating that the optimized LUCC structure is consistent with low carbon conservation objectives.

4.During the past 20 years, the total ESV decreased by 3.134 billion yuan. Except for the slightly higher ESV in the water, the ESV of other land types decreased. Urban expansion came at the cost of cultivated land loss, with a decline in ESV of -11.39% for cultivated land in the nature conservation scenario and - 4.10% in the LCS. Total ESV values were significantly and positively correlated with PLAND, LPI and AI indices, and significantly and negatively correlated with ED and NP.

4. Conclusions

Assessing the influence of landscape pattern changes on ecosystem service value (ESV) is critical for developing land use policy and increasing ESs. This study uses the PLUS model to simulate the dynamic changes of landscape pattern and ESV in 2050 under LCS. By exploring the correlation between different types of landscape areas and landscape pattern indices and ESV, an attempt is made to find the intrinsic link between them, with the following conclusions: (1) the most noticeable changes are the reduced cultivated land area and the rapid expansion of construction land area from 2000 to 2020. By 2050, construction land will account for 7.67% of the total land area under LCS, where NDS will account for 9.45%, and changes in the landscape pattern indices all indicate there will be greater variety and fragmentation, with the NDS being more serious than the LCS; (2) From 2000–2020, the total ESV value showed a decreasing trend. In 2050, the ESV under the LCS will be 122.387 billion yuan, which is higher than the NDS; and (3) The correlations between ESV and landscape indices indicate that landscape pattern changes significantly impact ESV. Simulating ESV in LCS can provide guidance for optimising landscape patterns, promoting the benign operation of the regional ecosystem, and achieving sustainable ecological development.

绿色发展研究中心
Green Development Research Center

Towards Carbon Neutrality

How can China's resource-based regions mitigate carbon emissions and control pollution?

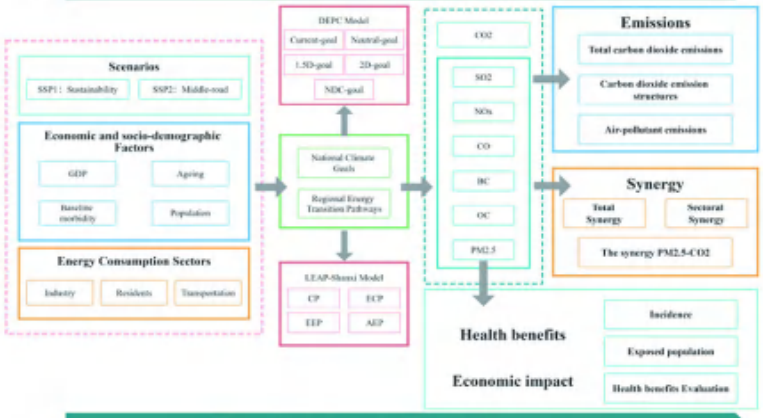
Author:Zhang Rentao (rentao_z@163.com) [1, 2] **Tutor:Cong Jianhui** [1, 2] 1,Shanxi University 2,School of Economics and Management, Shanxi University

Keywords: Synergy; Health Benefits; Carbon Neutrality; Carbon Reduction; Pollution Reduction

Background & Introduction

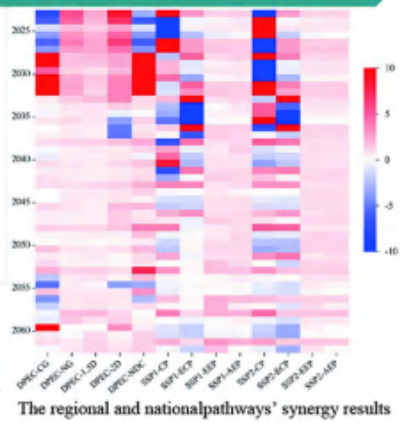
China's ambitious carbon neutrality needs coherent regional actions as foundation, promoting effective and sustainable carbon emission and air pollutants reductions in resource-based regions enhances possibility of achieving national climate goals. We constructed an integrated framework with multiple models to examine the gaps between regional climate actions and national climate goals. Further, we quantified the synergies between carbon and pollutants in multiple pathways and goals, and evaluated the population health and economic impacts of different climate actions regionally. We found that Shanxi Province's current actions are at least 85% away from China's carbon neutrality with carbon reduction potential yet to be tapped, electrification upgrading can significantly narrow the emission reductions gap between regional actions and national goals, with more positive and sustainable synergistic trends for carbon and pollutants reductions. Meanwhile, the improvement of current actions and electrification across all sectors will bring about more than 90% health benefits and reduce the economic impact of air pollution by about 90%. In particular, we found paradoxical results of synergies at aggregate level but not at sectoral level. we proposed alternative pathways and implications to achieve the synergy. We provided suggestions to regions on alternative pathways to choose climate actions with synergies and health, motivating regions to positively contribute towards national climate goals.

Models & Methods

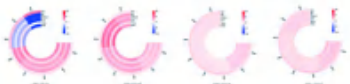


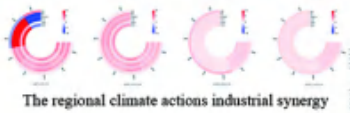
Results & Findings

The regional climate actions and national climate goals carbon dioxide emissions (billion tons)

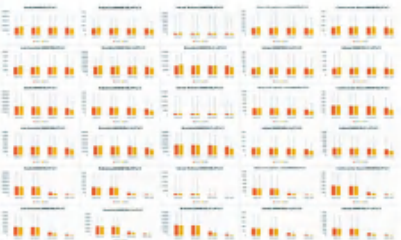


The regional and nationalpathways' synergy results

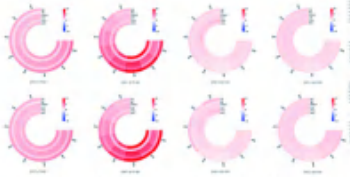




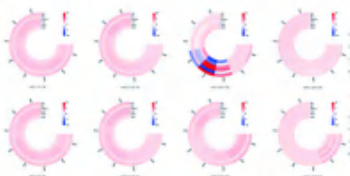
The regional climate actions industrial synergy



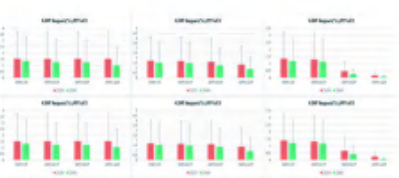
The some health benefits of regional climate actions



The regional climate actions residential synergy



The regional climate actions transportation synergy



The economic impacts of regional climate actions

Conclusions & Discussion

Our study found that:
(1) Shanxi's current climate actions' carbon emission reductions still have a large gap with the regional requirements of national climate goals, and electrification can effectively narrow the gap between regional actions and national goals, achieving China's carbon neutrality emission reductions requirements for Shanxi;
(2) insufficient and fluctuating synergies between carbon and pollutant reductions may be a major reason for Shanxi's current climate actions failing to perform well in reducing carbon emissions; and the higher the regional emission reduction requirements in the national climate goals, the higher synergies in the corresponding goal pathways;
(3) synergistic effect of the aggregate is uncertain in the sectoral dimensions, the synergistic effects between carbon and pollutants need to be studied in a multi-dimensional and comprehensive manner in order to effectively support the need for collaborative management.

We provide some suggestions for regions with high pressure on carbon emissions reduction:to fully evaluate the differences between regional climate actions and national goals, and design actions pathways according to regional resource conditions; combining electrification with less coal resources and lowering fossil energy share can contribute towards regional emission reduction requirements for the region to meet the national climate goals.

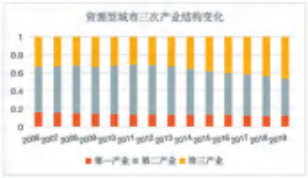
Meanwhile, not only China's carbon neutrality efforts, but most countries' climate goals do not require all regions of the country to act in unison. But there cannot be a large gap between regional actions and the regional emission reduction requirements of national climate goals unless it will create a long-term climate cost-raising obstacle to national goal achievement.

环境规制下的产业转型正导致污染转移
——资源型城市与非资源型城市对比研究

曹小楠
（重庆大学经济与工商管理学院，重庆，400000）
(Email:20220201008@stu.cqu.edu.cn)

1. 研究背景

2013年国务院印发了《全国资源型城市可持续发展规划（2013-2020）》，首次在全国提出资源型城市概念。但长期以来，中国资源型城市以第二产业为支柱产业，其高耗能、高污染的产业模式，给当地带来经济快速增长的同时也带来了严峻的生态问题。



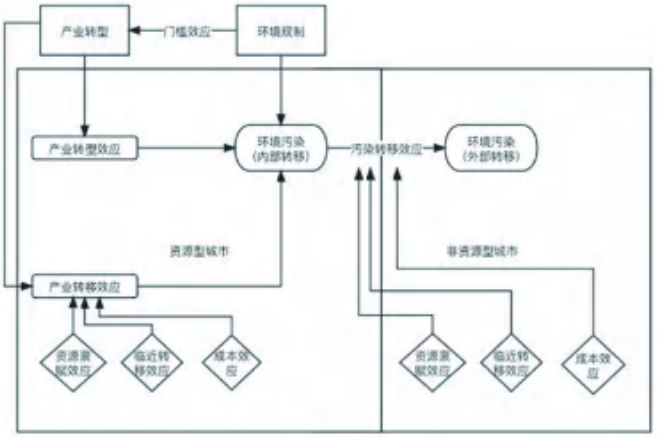
为摆脱长期资源依赖导致的资源诅咒困境，资源型城市开始转型。环境规制下的产业转型存在产业转移和产业转型效应。产业转移效应，即转移高污染的第二产业，发展第三产业。同时资源型城市污染指数先升后降。

2. 数据与模型

本文使用中国城市面板数据，并将数据划分为资源型城市与非资源型城市，构建产业转型综合指数作为产业转移效应和产业转型效应的代理指标。

通过空间自回归固定效应模型探究环境规制下产业转移效应引发的污染转移路径。检验不同阈值下污染转移的空间特征。通过门槛效应模型检验不同环境规制强度的作用结果是否存在异质性。进一步检验污染转移是否存在资源禀赋效应和成本效应。

3. 机制路径



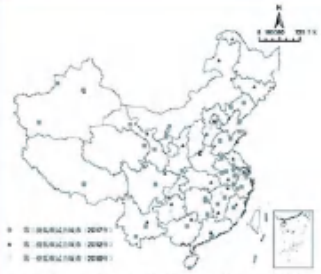
4. 结论

产业转型具有显著的产业转移效应，即资源型城市产业结构综合指数与工业污染排放指数显著负相关，且资源型城市环境规制会加强这种污染转移效应，但环境规制的加强作用存在门槛值；进一步检验资源型城市环境规制下的产业污染转移路径发现，污染的转移具有临近效应、资源禀赋效应和要素成本效应，即污染转移既存在于资源型城市内部，又存在于资源型城市与非资源型城市之间。研究结论表明，资源型城市环境规制要因地制宜，强度适宜，且产业转型方式应向着提升技术创新的方向使劲，而不是追求短期的环境改善。

低碳城市试点政策对企业就业规模及结构的影响
——兼论数字赋能的驱动作用

韩洪芳*，曾雪婷
（首都经济贸易大学 劳动经济学院，北京 100070）

引言



2010、2012与2017年三批低碳城市试点（图源：钟昌标等, 2020）

导致

社会经济各领域全面变革

图源：石化行业低碳发展白皮书（2022）

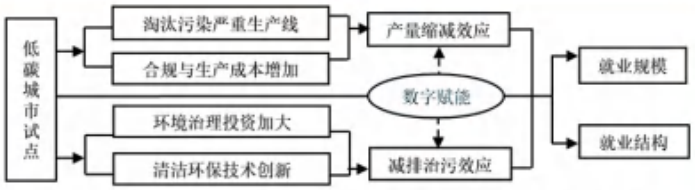
提振绿色相关职业市场需求

新兴数字技术蓬勃发展

图源：派可数据网

- 低碳城市试点政策能否有效推动就业稳规模优结构？
- 数字赋能能否协调并推进低碳转型与就业优化同步发展同样值得深究。

理论分析



产量缩减效应：企业通过压缩产量规避降碳合规成本压力，使得就业规模减少，同步造成高技能劳动力需求下降。

减排治污效应：企业开展清洁技术研发、环保投资等治理活动，导致减排治污环节对不同技能劳动力的相对需求发生改变，进而改变了企业的雇员数量及结构。

数字赋能能够强化低碳经济转型对就业规模扩大以及就业结构升级的驱动作用。

研究方法

从就业规模与就业结构**双重视角**考察低碳转型对企业就业的影响

检验试点政策的产量缩减与减排治污效应的内在机制，进一步打开低碳转型引致中国劳动力市场调整的作用黑箱

区分企业要素密集度、产权性质与规模属性并区分命令型、市场型、自愿型政策工具类型的执行效果以**识别试点政策稳就业效应的企业主体与政策来源**

剖析低碳转型的就业效应在**数字赋能驱动**下的效果及其机制变化

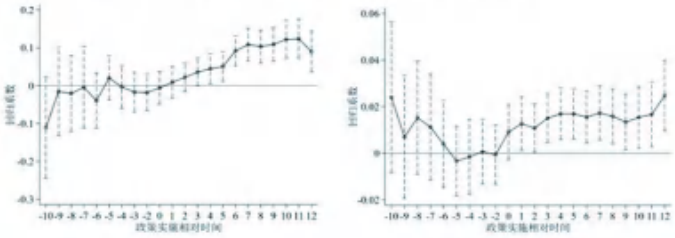
结果

基准分析与异质性检验结果

低碳城市试点政策促进企业就业规模增长，特别是推动高技能劳动力就业，促使就业结构向高级化转变

	labor	labor_s	生产岗	技术岗		labor	labor_s
Policy	0.029**	0.013***	-0.071***	0.129***	命令型	-0.061	0.072*
	(0.012)	(0.003)	(0.011)	(0.011)		(0.149)	(0.039)
Controls	Yes	Yes	Yes	Yes	市场型	0.358***	-0.027
id	Yes	Yes	Yes	Yes		(0.132)	(0.035)
year	Yes	Yes	Yes	Yes	自愿型	-0.465**	-0.078
N	34551	34551	26381	29063		(0.207)	(0.061)
R^2	0.905	0.815	0.627	0.525	R^2	0.905	0.815

通过平行趋势检验，满足双重差分前定条件



a 就业规模　　b 就业技能结构

机制检验与数字赋能驱动分析结果

低碳城市试点政策通过产量缩减效应抑制企业就业规模增长以及就业技能结构升级。

低碳城市试点政策通过减排治污效应进而扩大企业就业规模以及促进就业技能结构升级。

数字赋能能够强化低碳经济转型对就业规模扩大以及就业结构升级的驱动作用。

	产量缩减效应			减排治污效应			数字赋能调节效应	
	output	labor	labor_s	greinvest	labor	labor_s		labor	labor_s
policy	-0.022*	0.039***	0.013***	0.136*	0.031***	0.012***	policy×dig	0.030***	0.007***
	(0.012)	(0.010)	(0.003)	(0.076)	(0.012)	(0.003)		(0.006)	(0.002)
output		0.471***	0.011***				lcp	-0.007	0.006
		(0.008)	(0.002)					(0.013)	(0.005)
greinvest					0.006***	0.001***	dig	0.026***	0.042***
					(0.001)	(0.000)		(0.005)	(0.002)
R^2	0.925	0.928	0.815	0.689	0.909	0.817	R^2	0.906	0.297

注：括号内为企业-年份层面的聚类稳健性标准误；*表示 p<0.10，**代表 p<0.05，***代表 p<0.01；controls, id, year 均已控制

结论

- 低碳城市试点显著促进企业就业规模提升及技能结构升级
- 产量缩减效应低于减排治污效应是试点促使企业就业规模增长与技能结构升级的内在机制。
- 数字赋能强化试点对就业规模扩大及结构升级的驱动作用。
- 试点对资本密集、国有及大规模企业就业促进作用更大，市场型与命令型政策工具分别发挥的促就业与优结构作用更强。

参考文献：Berman,E.,and L.T.M.Bui,2001. J Public Econ,2001,79(2),265-295.

致谢：云南省哲社科规划项目(YN2023014)

hhf@cueb.edu.cn

碳中和目标下的长期能源-环境-经济规划：中国区域能源转型路径与二氧化碳减排战略研究

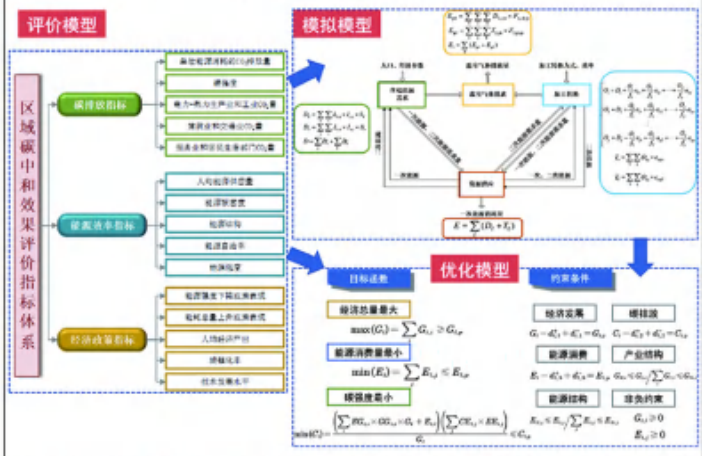
柳梦琳 吴江涛* 郎智凯 孟现阳
西安交通大学教育部热流体科学与工程重点实验室， 陕西 西安， 710049
Tel：15940849687 E-mail：menglinliu@stu.xjtu.edu.cn

研究背景

中国于2020年制定了国家碳达峰和碳中和排放目标，并在全国低碳试点开展了一系列应对气候变化的政策行动。研究区域CO_2排放达峰和中和情况，制定基于地方特点的减排路线图，是实现国家目标的基础。在日益严峻的环境约束下，如何优化能源系统，满足经济发展的要求，对决策者来说仍是巨大的挑战。因此，考虑能源-经济-环境各子系统之间的权衡，建立可用于碳中和目标下全国各地区的长期综合规划模型具有重要的现实意义。

本研究旨在建立可应用于全国各省（市）的区域发展长期规划模型，通过地区历史和当前发展数据确定区域能源-环境-经济优化权重，同时模拟区域内不同时期、不同技术与政策组合下的碳排放和能源需求，对比分析各政策和技术的碳减排潜力，预测区域达峰与中和情况；进一步以模拟结果为基础，结合实际经济发展目标，规划区域的节能减排和产业升级路径。选取中国中西部地区的典型省份——陕西省作为区域研究案例，应用并验证所提出的区域长期综合规划方法，得到2030-2060能源与产业发展的最优目标方案。

模型方法



基于指标评价、模拟预测和最优化等方法理论，构建集评价-模拟-优化为一体的区域能源-环境-经济发展长期规划模型。该模型首先综合区域的碳排放、能源效率和经济政策的历史与现实表现，构建碳中和效果评价模型；其次，以评价结果作为情景设置的依据，建立模拟预测模型，模拟分析区域的CO_2排放量和能源需求情况；最后，建立最优化模型，基于模拟预测结果设定输入参数，且根据评价模型结果确定优化权重，最终得到区域能源消费和产业结构发展的优化方案。

案例研究

陕西省
- 低碳试点省份：十三五 能源强度下降15%
- 西部能源型省份：原煤17.41% 原油13.83%
- 经济转型发展期：新能源电力装机32.21%

能源需求旺盛 煤炭占比高 CO_2快速增长

研究区域：
将模型应用于陕西省2020~2060年能源-环境-经济协同发展研究，验证了模型的可靠性和计算结果的准确性。

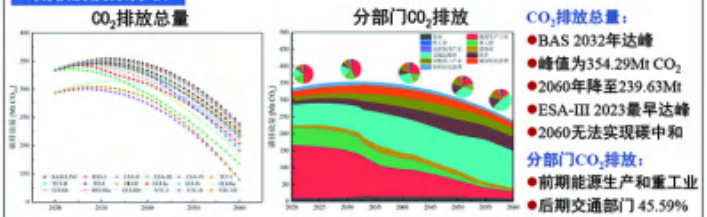
情景设定：
ESA： 低碳能源和可再生能源转型的可行性、发展速度对碳中和的影响
TE： 终端部门用电量占比对减排的影响
EEI： 提高能源传输与转换效率、调整产业结构和提高终端能源利用效率
NTC： 碳捕集利用与封存技术发展水平

情景设定与说明

情景	编号	子情景
基准情景（Baseline Scenario, BAS）		维持基期现行的节能减排行动和政策
能源结构调整情景（Energy Structure Adjustment Scenario, ESA）	ESA-I	天然气导能源替情景
	ESA-II	可再生能源导能发展情景
	ESA-III	早期发展天然气-后期发展可再生能源
	ESA-IV	早期发展可再生能源-后期发展天然气
终端电气化情景（Terminal Electrification Scenario, TE）	TE-I	工业部门电气化率60%（算数平均）
	TE-II	工业部门电气化率60%（几何平均）
	TET-I	交通部门电气化率60%（算数平均）
	TET-II	交通部门电气化率60%（几何平均）
能源效率提升情景（Energy Efficiency Improvement Scenario, EEI）	EEI-I	能源传输效率提升情景
	EEI-II	发电效率提升情景
	EEI-III	终端转换情景
	EEI-IV	工业结构调整情景
	EEI-V	工业终端能源利用效率提升情景
	EEI-VI	交通业终端能源利用效率提升情景
负碳技术情景（Negative Carbon Technology, NTC）	NTC-I	基础发展水平情景
	NTC-II	均衡发展情景
	NTC-III	快速发展情景

结果讨论

碳排放模拟分析



CO_2排放总量：
- BAS 2032年达峰
- 峰值为354.29Mt CO_2
- 2060年降至239.63Mt
- ESA-III 2023最早达峰
- 2060无法实现碳中和

分部门CO_2排放：
- 前期能源生产和重工业
- 后期交通部门 45.59%

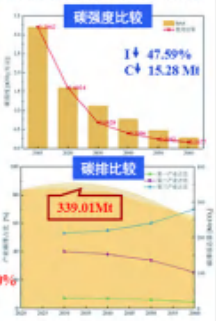
节能减排关键行动

中短期（2035年）：
- 天然气替代减排效果最佳 (27.4%)
- 经济转型能源节约率最大 (41.9%)

长　期（2060年）：
- 可再生能源替代减排最大(34.9%)
- 经济转型能源节约率最高 (45.2%)

优化结果分析

	GDP	能源消费量	CO_2强度	各产业GDP占比（亿元，%）			各类能源消费量占比（万标煤，%）			
	亿元	万标煤	万吨CO_2/亿元	第一产业	第二产业	第三产业	煤炭	石油	天然气	电力及其他
2030	49124	32417.09	0.6828	3638.68 /7.80	19659.60 /40.00	26015.72 /53.00	6208.79 /50.00	1811.70 /14.59	2161.67 /17.41	2245.13 /18.00
2040	82426	33514.02	0.3995	5884.97 /6.80	31466.73 /38.20	45334.30 /55.00	3355.06 /25.50	1331.40 /10.09	2529.08 /19.00	6097.68 /45.59
2050	122418	31487.04	0.2102	7197.32 /6.00	41536.63 /33.94	73524.23 /60.06	1521.77 /13.25	861.38 /7.50	3067.90 /16.00	7035.99 /65.25
2060	154979	9568.59	0.1677	7132.57 /4.59	39579.33 /25.41	108486.50 /70.00	119.98 /1.25	479.93 /5.00	959.86 /10.00	8018.82 /83.75



- 到2060年煤炭和石油占比将降为6.25%，第二产业将下降到25.40%
- 不影响经济增长下，2030年陕西省碳强度将降到0.6828吨/万元

结论

构建了集评价-模拟-优化为一体的区域发展长期综合规划模型，为研究区域的长期能源-环境-经济协同发展提供理论支撑。该模型将定性分析与定量研究相结合，通过主观和客观的历史与当前条件确定3E系统不同目标之间的权重；同时，结合模拟预测模型量化区域中长期发展过程中的多种不确定因素，并利用多目标优化模型进行3E系统中长期规划，提高规划策略的可靠性。

利用模型研究陕西省CO_2排放情况和减排路径，为陕西省节能减排提供政策建议，促进其“能源-环境-经济”（3E）的协调发展。通过加速能源转型，调整产业结构，辅以负碳技术等手段，陕西省将于2025年实现碳达峰，于2057年实现碳中和，能源消费将于2040年达峰；为实现经济发展目标，陕西省2030年碳强度需降低到0.6828吨/万元以下；2060年陕西省煤炭和石油消费占比需下降至6.25%，第二产业比重下降到25.40%

参考文献

1. Barrett, J., S. Pye, S. Betts-Davies, O. Broad, J. Price, N. Eyre, J. Anable, C. Brand, G. Bennett, R. Carr-Whitworth, et al. 2022. Energy demand reduction options for meeting national zero-emission targets in the United Kingdom. Nat. Energy 7(8), 726-735.
2. BP., 2021. Statistical Review of World Energy 70th edition. British Petroleum, British.
3. Cai L., J. Luo, M. Wang, J. Guo, J. Duan, J. Li, S. Li, Liting Liu a, and D. Ren. 2023. Pathways for municipalities to achieve carbon emission peak and carbon neutrality: A study based on the LEAP model. Energy 262, 125435.

碳中和愿景下中国能源政策文本量化研究——基于“结构—工具—效力”三维框架

任云燕， 王志强
(a. 新疆农业大学,新疆 乌鲁木齐 830052; b. 新疆农业大学,新疆 乌鲁木齐 830052)
(Tel:15261358601; ,Email:3384826627@qq.com)

一、研究背景

实现碳达峰碳中和目标，是贯彻新发展理念、构建新发展格局、推动高质量发展的内在要求。为此，中国制定了碳达峰十大行动，陆续出台并不断完善碳达峰碳中和“1+N”政策体系。

能源是碳达峰碳中和的重要领域，在“十四五”期间我国将推进能源革命，建设清洁低碳、安全高效的能源体系。《关于完善能源绿色低碳转型体制机制和政策措施的意见》《“十四五”现代能源体系规划等系列中央政策文件的连续出台，表明了国家对加快能源绿色低碳转型工作的鲜明态度。

二、能源政策三维分析框架构建

文章基于能源政策的具体特征，从政策结构、政策工具和政策效力3个维度，构建能源政策三维分析框架（见图1）。

图1 能源政策三维分析框架

（一）政策结构

X轴是政策结构维度。包括政策词云、政策形式、政策层级和政策语义。政策形式和政策层级可以反映政府的重视程度以及政策文本的权威性。政策语义特征分析能够较好揭示近年来我国能源政策的关注领域和发展趋势。

（二）政策工具

Y轴是政策工具维度。按照Howlett & Ramesh的政策工具分类方法，本文将能源政策工具分为强制型、自愿型和混合型三种。

（三）政策效力

Z轴是政策效力维度，由PMC模型和政策力度构成。第一，运用PMC一致性指数模型，通过构建政策指标体系测量单项政策PMC指数，建立可视化3×3矩阵，绘制PMC曲面图，以直观衡量政策的不完美程度；第二，借鉴张国兴等的政策力度量化思路，通过对政策发布单位、政策类型进行评分，计算单项政策的政策力度分值，弥补PMC效力评价的主观性误差。

三、政策文本分析与研究发现

（一）政策结构分析

1.政策样本词云分析

对110项关于低碳能源的政策文本进行词频分析，在筛选和去除例如“推进”“推动”“提升”“加强”“加快”等动词、助词及其他无意义的单字和数字后形成能源政策词云图（图2）及能源政策高频词社会网络图（图3）。

其中，创新、绿色、技术、安全、再生等与能源领域高度相关的词汇占据了较大比重，说明在双碳背景下，各政府尤其重视加快推动低碳核心技术应用，构建清洁低碳、安全高效的能源体系。

其次，从规划、体系、机制等次级高频词可看出，相关领域体制机制的创新、政策体系的完善、治理方式的优化是大力推动能源领域节能减排以及加快构建现代能源体系的重要抓手。

图3 能源政策词云图

图4 能源政策高频词社会网络图

2.政策文本的数量结构特征

第一，自2021年1月至2023年8月期间，共有61份中央及部委就能源工作发布相关政策文件，目前已有11个省份出台省级能源领域碳达峰实施方案，22个省印发32份能源领域“十四五”发展规划及节能减排相关政策文件。第二，2022年，相关政策的发文数量增速较快，与2021年相比，增长率达到130%。

3.政策文本的层级和发布主体特征

通过对收集的政策文本进行分析可以发现：第一，政策主体层级较高。研究期内中央层级的发文占到55.45%，省级政策文本占比44.55%。第二，中央层面能源政策以单主体发文为主，涉及主体较为广泛，参与能源政策发布的中央机构数为25个。国家能源局和发展改革委是主要的政策发布主体。第三，发文方式以独立发文为主，同时也涉及政府不同机构之间的联合发文，但是省级层面多部门之间的联动有待进一步提升。

图5 全部政策样本政策主体社会网络

为了进一步探究我国能源政策发布主体的社会结构网络，将整理的政策文本中涉及联合发文的政策主体数据导入Gephi软件，对政策发布主体进行社会网络分析，绘制政策主体社会网络，并选择中央、北京、河南、新疆等代表性政策主体绘制社会网络图（图6），以更直观的方式呈现不同区域间政策主体的合作情况。

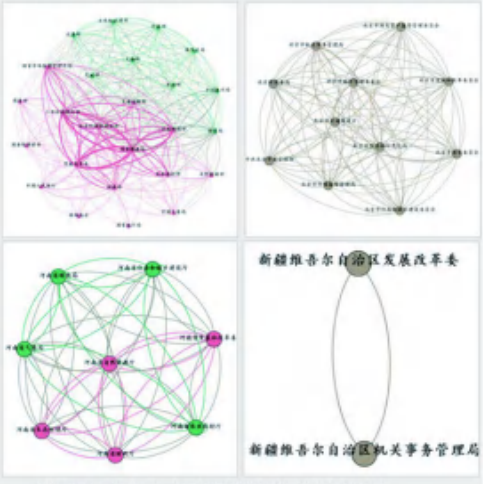


图6 中央、北京、河南及新疆政策主体网络合作关系图

（二）政策工具分析

1.各政策工具偏好分析

研究以政策文件中的段落为最小编码单元，若遇到一个段落可能涉及多个政策工具，则对该段落进行进一步细分。借助Nvivo软件，构建节点并对政策条文进行内容分析。通过统计，110份能源政策文件中共有3080条政策编码。各类政策工具统计情况如图7所示。

图7 各类政策工具频数图

借助Nvivo软件，对三种类型政策工具进行词云分析，以此直观感受碳达峰碳中和背景下中国政府对于能源政策的关注重点及发力方向。

(a)强制型 (b)混合型 (c)自愿型

图8 三种不同政策工具的词云图

（三）政策效力分析

在政策效力分析方面，第一，基于PMC指数模型，通过变量选取与指标识别、建立多投入产出表、PMC指数计算，得到各项政策得分分布情况，如图9所示；第二，借鉴张国兴等学者的政策力度量化思路，计算110份政策文本的政策力度，结果如图10所示。

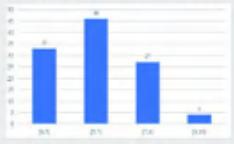


图9 各项政策得分分布情况

图10 各年度政策力度得分情况

四、结论与建议

（一）研究结论

第一，中央层面上，已形成以国家能源局等为主体的协调型合作网络，且国家能源局及住建部发挥着战略性作用；地方层面上，除北京省和河南省外，其他省份仍处于府际协同探索阶段；央地层面上，虽然当前央地政策网络规模可观，网络结构连通性较好但是研究期内央地间暂未出现合作关系，现有合作有待增强。

第二，政策工具运用多元，集中在强制型（1944条，占比63.12%），其次是混合型（756条，占比24.55%），自愿型政策工具仅380条，占比12.34%，“一强双弱”特征明显；且强制型政策工具与混合型政策工具内部存在明显结构失衡。

第三，中国能源政策整体处于良好发展状态（PMC得分均值为5.89，70%政策隶属良好及以上等级），但是政策样本个体之间差异明显（PMC得分极差为6.52），部分政策仍存在提升空间。

（二）研究建议

第一，丰富政策形式，强化府际协同。持续完善政策组合，统筹政府注意力的合理配置。央地及各部门之间进一步耦合，寻求中央、地方之间的相对均衡和良性互动。

第二，促进政策工具平衡使用，发挥互补性作用。强化政策激励力度，适度提升混合型、自愿型政策工具的使用比例，不断丰富和创新能源政策工具箱、构建体系合力。

第三，加大执行资源投入力度，保障政策目标实现。从着力提升人才培养措施入手，为能源领域双碳目标实现提供要素支撑。

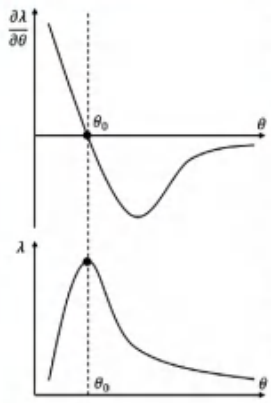
中国式环境分权与企业漂绿行为

张冬洋[1]，王晋立[2]✉
（[1]首都经济贸易大学经济学院，北京 100070；[2]中国人民大学应用经济学院，北京 100872）

1 摘要

在绿色经济转型的背景下，如何深入推进中国式环境分权体制改革，有效预防企业漂绿等伪社会责任行为成为当下亟需探究的重大理论问题和现实问题。本文利用2011—2021年中国省份层面和企业层面数据，对环境分权如何影响企业漂绿进行了研究。理论分析和实证检验结果表明：（1）环境分权对企业漂绿具有非线性的影响，二者呈现出“倒U型”关系。（2）财政分权能够发挥调节效应，缓解地方政府环境治理投入的财政约束，强化了环境分权的作用强度，使“倒U型”曲线更加陡峭。（3）机制检验结果显示，环境规制和融资约束是主要的影响路径，在环境分权对企业漂绿的影响中起到了部分中介效应。（4）环境分权对企业漂绿的影响效果具有异质性，非国有企业、重污染企业和高新技术企业的漂绿程度对环境分权的敏感程度较高，分权发挥的作用效果更强，“倒U型”曲线陡峭，其他类型企业则与之相反。以上结论在消除潜在的内生性问题，进行一系列稳健性检验后仍然成立。本研究为提高我国政府现代化环境治理能力、加快企业绿色转型提供了理论依据和政策指引。

2 理论基础



结合宏观层面的分权理论以及微观层面的异质企业模型，构建起中国式环境分权与企业漂绿行为的经济理论模型。以此为基础，对政府行为、消费者行为和企业漂绿进行系统性地分析。

3 实证策略

加入调节效应的计量模型设定(TWFE)：

$$GW_{ijt} = \beta_0 + \beta_1 ED_{it} + \beta_2 ED_{it}^2 + \delta Z_{ijt} + \mu_i + \lambda_t + \delta_k + \varepsilon_{it} \quad (1)$$

$$GW_{ijt} = \beta_0 + \beta_1 ED_{it} + \beta_2 ED_{it}^2 + \beta_3 ED_{it} \times FD_{it} + \beta_4 ED_{it}^2 \times FD_{it} + \beta_5 FD_{it} + \delta Z_{ijt} + \mu_i + \lambda_t + \delta_k + \varepsilon_{it} \quad (2)$$

企业漂绿强度指标构建：

$$GW_{jt} = \left(\frac{ESG_{jt}^{dis} - \overline{ESG_{jt}^{dis}}}{\sigma_{dis}}\right) - \left(\frac{ESG_{jt}^{real} - \overline{ESG_{jt}^{real}}}{\sigma_{per}}\right)$$

环境分权指标构建：

$$ED_{it} = \left[\frac{Env_{it}/POP_{it}}{Env_t/POP_t}\right] \times \left[1 - \frac{GDP_{it}}{GDP_t}\right]$$

4 研究结论

研究结论如下：（1）环境分权对企业漂绿具有显著的非线性影响，二者呈现出“倒U型”关系。当位于曲线左半支时，环境分权表现出促进效应，当位于曲线右半支时，则能够表现出抑制效应。（2）财政分权能够发挥调节效应，缓解了地方政府对于环保支出的财政约束，强化了环境分权的影响效果，使“倒U型”曲线变得更加陡峭。（3）机制检验结果表明，环境规制和融资约束是两个主要的影响路径，发挥了部分中介效应。（4）环境分权对不同类型企业的影响具有异质性，环境分权对非国有企业、重污染企业和高新技术企业的作用强度更强，“倒U型”曲线更为陡峭，非线性特征明显。而其他类型企业则与之相反，企业漂绿行为对环境分权变动的敏感程度较低。

5 主要贡献

首先，我们对企业漂绿程度进行精准衡量，探究了环境分权对它的非线性影响，解释了已有文献研究结果相反的悖论。第二，理论机制方面，本文将环境分权对企业漂绿的作用效果分解为融资约束和环境规制两个维度，揭示了传导机制。第三，将研究对象聚焦到更加微观的企业层面，从多个角度检验了异质性效果，为政策制定提供了理论依据。

6 致谢

首都经济贸易大学 CAPITAL UNIVERSITY OF ECONOMICS AND BUSINESS
中国人民大学 RENMIN UNIVERSITY OF CHINA
NSFC National Natural Science Foundation of China

碳中和与数字经济

Carbon Neutrality and Digital Economy

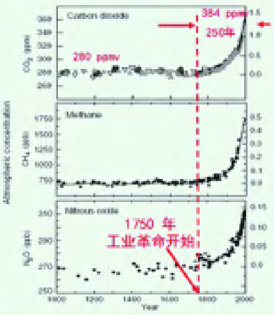
The digital economy, industrial structure upgrading, and carbon emission intensity —— empirical evidence from China's provinces

侯娜[1] 赵婉争[1]，苏妮[1]，刘雯雯[1]
[1]北京林业大学，北京，100083

Introduction

The impact of global climate change is bringing more and more severe challenges to human survival and development. The conclusion of the Paris Agreement in 2015 has become the political and legal basis for all countries to work together to tackle climate change.

Trends in global concentrations of major greenhouse gases

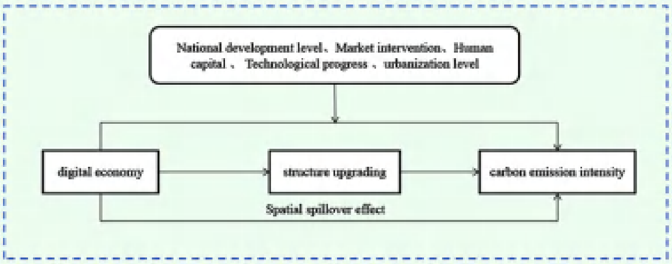


"China will increase its level of nationally determined contributions, adopt more robust policies and measures, ***and strive to peak carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060.*** All countries should foster a new vision of innovative, coordinated, green, open and shared development, seize the historic opportunity presented by the new round of scientific and ***technological revolution and industrial transformation, promote a"Green recovery"*** of the world economy after the pandemic, and create a strong synergy for sustainable development."

——习近平在第七十五届联合国大会一般性辩论上的讲话

Research framework

Based on this, this study proposes a research model of digital economy, industrial structure upgrading and carbon emission intensity based on the theory of new structural economics. According to the operating principle of new structural economics, the relationship between digital economy and carbon dioxide emissions depends on whether the digital economy is compatible with the endowment factors and the industrial structure endogenously determined by the structure at a specific stage of development. In the process of promoting industrial structure upgrading, digital economy can effectively reduce energy consumption, improve energy efficiency, and thereby reduce carbon emission intensity.



Results and discussion

The main objective of this paper is to explore the mechanism of the digital economy's impact on carbon emission .intensity Empirical investigations were implemented through the fixed-effect model, intermediary effect model, analyzing provincial panel data from 2010-2019.

Benchmark regression results

	(1)	(2)	(3)	(4)
	CI	CI	CI	CI
DEI	-4.700***	-2.575***	-1.395***	-1.042***
	(0.3297)	(0.3582)	(0.3476)	(0.3527)
cons	3.343***	8.971***	4.156***	1.874
	(0.2239)	(1.2760)	(1.3302)	(2.2822)
Control variables	No control	control	control	control
Individual fixed effects	No	No	No	Yes
Time fixed effects	No	No	Yes	Yes
Sample size	300	296	296	296

Mediating effect test

	(1)	(2)	(3)	(4)	(5)
	CI	indu	theil	CI	CI
DEI	-1.303***	0.590**	0.324***	-1.042***	-1.102***
	(0.3585)	(0.2317)	(0.0788)	(0.3527)	(0.3680)
indu				-0.377***	
				(0.0944)	
theil					-0.503*
					(0.2872)
cons	-1.334	9.041***	4.762***	1.874	0.860
	(2.1791)	(1.4207)	(0.4788)	(2.2822)	(2.3652)
Control variables	Control	Control	Control	Control	Control
Individual fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Sample size	296	299	299	296	296

Endogenous tests

	(1)	(2)	(3)	(4)	(5)	(6)
	[illegible] the digital economy			[illegible] Internet penetration rate		
	CI	indu	CI	CI	indu	CI
DEI	-3.500***	1.160***	-3.110***	-3.330***	3.310***	-3.540**
	(0.4034)	(0.1060)	(0.6073)	(1.3409)	(0.4418)	(1.2884)
indu			-0.104***			-0.114***
			(0.0318)			(0.1089)
cons	-0.043	18.118***	2.888	-1.272	7.874***	1.107
	(2.4064)	(1.4090)	(2.5399)	(1.3550)	(1.3450)	(2.2855)
			[illegible]			
IDEI	0.122***	0.122***	0.100***	0.006***	0.006***	0.004***
	(0.0314)	(0.0314)	(0.0315)	(0.0008)	(0.0008)	(0.0005)
Weak tool variable identification	Pass	Pass	Pass	Pass	Pass	Pass
Control variables	control	control	control	control	control	control
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	266	266	266	294	294	266

Robustness test

	(1)	(2)	(3)	(4)	(5)	(6)
	[illegible]			[illegible]		
	CI	indu	CI	CI	indu	CI
DEI	-1.887***	1.080***	-1.581***	-2.144***	0.839***	-2.140***
	(0.4232)	(0.4911)	(0.4110)	(0.2912)	(0.4141)	(0.2845)
indu			-0.270***			-0.271***
			(0.0833)			(0.0946)
cons	-1.338	10.180***	1.368	0.315	9.682***	1.942
	(2.3136)	(1.4711)	(2.3180)	(1.5786)	(1.0618)	(1.6308)
			[illegible]			
IDEI	0.388***	0.123***	0.482***	0.300***	0.303***	0.480***
	(0.0314)	(0.0524)	(0.0159)	(0.0068)	(0.0068)	(0.0057)
Weak tool variable identification	Pass	Pass	Pass	Pass	Pass	Pass
Control variables	control	control	control	control	control	control
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	254	254	254	266	266	266

Heterogeneity analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Eastern		Mid and west		High		Low	
	CI	indu	CI	indu	CI	indu	CI	indu
DEI	-0.418*	-0.021	-0.129	0.423**	-0.358**	0.072	-0.484	0.712**
	(0.2594)	(0.4582)	(0.7876)	(0.2832)	(0.2576)	(0.4588)	(0.6759)	(0.2975)
cons	-1.418	13.917***	5.230	0.902	-0.760	18.911***	4.718	1.197
	(1.2644)	(2.8970)	(3.9942)	(1.4348)	(1.3277)	(2.2784)	(4.1911)	(1.4234)
Control variables	control	control	control	control	control	control	control	control
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	109	109	187	187	110	110	186	186

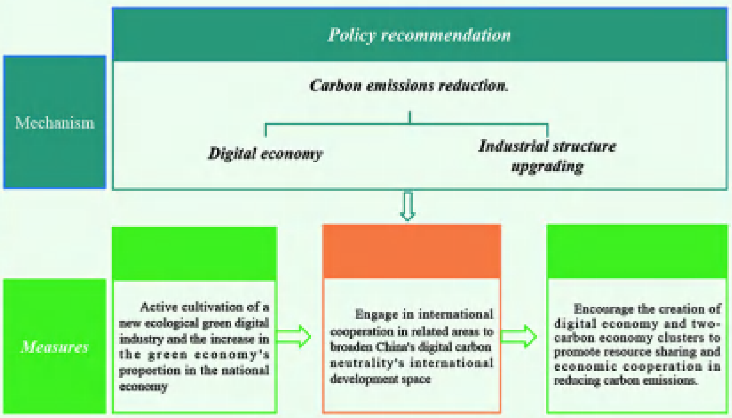
Test of moderating effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Level of economic development		Degree of market intervention		Level of human capital		Advances in technology		Urbanization	
	Low	High	Low	High	Low	High	Low	High	Low	High
DEI	0.410	-0.378**	-1.079***	-0.261	0.708	-0.382*	0.130	-0.702**	0.214	-0.784*
	(0.7808)	(0.1888)	(0.2121)	(1.2796)	(0.8490)	(0.2448)	(0.4018)	(0.3079)	(0.4094)	(0.3821)
cons	11.880**	-0.118	-1.118	1.898	9.181*	1.802	4.588	-1.515	14.884***	0.884
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Controlled variable	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Individual fixation effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	189	107	182	114	137	134	223	83	166	138

Spatial spillover effect test

	(1)	(2)	(3)	(4)	(5)
	0-1matrix	Geographical distance matrix	Economic distance matrix	Economic geographic matrix	Gravity matrix
	CI	CI	CI	CI	CI
	-2.003***	-0.635	-0.650	-0.504	-1.030**
	(0.5678)	(0.4824)	(0.5978)	(0.5255)	(0.5081)
Direct effect DEI	-2.319***	-3.108***	-2.222***	-3.060***	-2.893***
	(0.3289)	(0.3219)	(0.3288)	(0.3184)	(0.3197)
The indirect effect DEI	-3.250***	-1.465***	-2.708***	-1.547***	-1.944***
	(0.5584)	(0.4510)	(0.7551)	(0.5017)	(0.4775)
The total effect DEI	-5.569***	-4.570***	-4.930***	-4.606***	-4.836***
	(0.5325)	(0.4684)	(0.7702)	(0.5063)	(0.4797)
ρ	0.268***	0.202***	0.440***	0.2455***	0.214***
	(1.0697)	(0.0592)	(0.0802)	(0.0645)	(0.0603)
Control variables	Control	Control	Control	Control	Control
Individual fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Sample size	300	300	300	300	300

Digital economy significantly diminishes carbon emissions intensity; secondly, it confirms the significant mediating role of industrial structure upgrading; thirdly, increased levels of economic development, market openness, human capital, technological advancement, and urbanization all have constructive moderating effects on the carbon emission reduction facilitated by the digital economy; fourthly, the influence of the digital economy on carbon emission intensity has spatial spill-overs.



主办单位：清华大学、中国学位与研究生教育学会

中央财经大学

The Impact of Digital Currency on Green Consumption: A DSGE Model Approach

LI Hang-da1
(1. Institute of Finance and Economics, Central University of Finance and Economics, Beijing 100081, China)

Abstract

Background, Aims and Scope. In the context of escalating climate change concerns, green consumption has emerged as a critical strategy for sustainable development. This research examines the potential of digital currency to incentivize green consumption behaviors and its implications for the carbon finance sector. By leveraging the features of digital currency, such as traceability and programmability, this study aims to understand how monetary policy and digital currency design can align with environmental objectives.

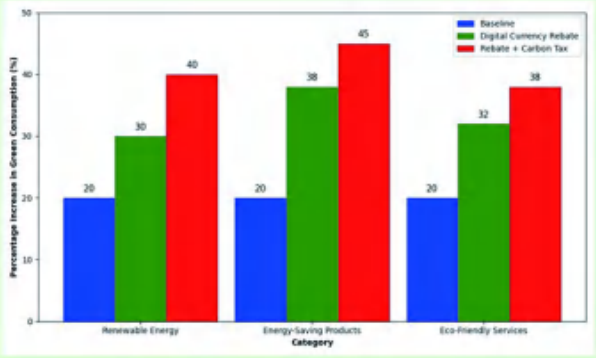
Methods. A dynamic stochastic general equilibrium (DSGE) model is employed to simulate the economy's response to the introduction of a digital currency that incentivizes green consumption. The model incorporates sectors for carbon finance, traditional and green goods, and policy instruments that influence consumer behavior through digital currency mechanisms. Various scenarios are tested to assess the robustness of digital currency incentives in different economic conditions.

Results and Discussion. The DSGE simulation reveals that digital currency, when designed with green incentives, can effectively shift consumption patterns towards environmentally friendly goods and services. The results indicate a substantial reduction in carbon emissions and an increase in investment within the green sector. Furthermore, the model suggests that the effectiveness of digital currency as a tool for promoting green consumption is significantly enhanced by supportive regulatory frameworks and carbon pricing policies.

Conclusion. The study concludes that digital currency has the potential to play a transformative role in promoting green consumption and supporting carbon finance mechanisms. Policymakers and financial institutions can leverage digital currency to align financial flows with environmental sustainability, fostering a transition towards a low-carbon economy.

Key words: Digital Currency, Green Consumption, DSGE Model, Carbon Finance, Monetary Policy

Fig 1 impact of Digital Currency Policy on Green Consumption



The Impact of Digital Technology Innovation on Urban Carbon Emissions

MIAO Jichao[1], ZHAI Ningning[2]
E-mail: 17852151006@163.com; zhainingning1998@163.com

Background, Aims and Scope

The present study aimed to explore the carbon emission reduction effect of digital technology innovation under the new era of ecological civilization construction of China. Employing panel data encompassing 253 Chinese cities over the period from 2006 to 2020, the current study conducts a random effects regression analysis to examine the nonlinear effects of digital technology innovation on carbon emissions and elucidate the underlying mechanisms.

Results and Discussion

Our findings reveal a substantial inverted U-shaped correlation between digital technology innovation and both per capita and total urban carbon emissions. In other words, as the level of digital technology innovation surpasses a critical inflection point, its influence on carbon emissions changes from a positive promotion effect to a negative inhibitory effect.

Heterogeneity Analysis

In the low resource endowment subgroup, the carbon emission reduction effect of digital technology innovation is better. In the subgroup with low environmental governance pressure, digital technological innovation always promotes carbon emissions and shows "pro-carbon" characteristics, while in areas with high environmental governance pressure, digital technological innovation has an inverted U-shaped effect on carbon emissions. In terms of digital infrastructure, the inhibitory effect of digital technology innovation on carbon emissions is first seen in the high-group samples, but as the level of digital technology innovation continues to improve, digital technology innovation in the low-group samples shows greater potential for emission reduction.

Mechanistic Analysis

The current study reveals that digital technological innovation primarily fosters the reduction of urban carbon emissions through the attraction of economic agglomeration, the advancement of cleaner industrial structure upgrades, and the progression of green technology.

Table 1 Benchmark Regression Results

Variable	Carbon	
	(1)	(2)
Dti	17.383*** (3.35)	15.841*** (3.10)
Dti2	-72.020*** (-2.68)	-66.595** (-2.52)
control variable	YES	YES
fixed effect	YES	YES
R-squared	0.976	0.977

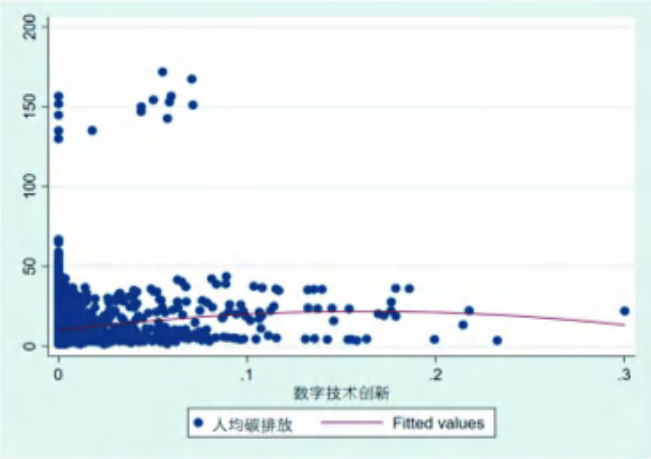


Table 2 Heterogeneity Analysis

variable	Resource Endowment		Environmental Governance Pressures		Digital Infrastructure	
	Low	High	Low	High	Low	High
dti	26.599*** (3.22)	13.251** (2.37)	17.525* (1.92)	20.134*** (3.06)	36.192*** (3.24)	2.628 (0.89)
dti2	-116.627*** (-2.60)	-50.109* (-1.84)	-64.221 (-1.21)	-74.884*** (-2.59)	-158.529** (-1.98)	-35.853*** (-2.64)
control variable	YES	YES	YES	YES	YES	YES
fixed effect	YES	YES	YES	YES	YES	YES
R-squared	0.986	0.968	0.975	0.983	0.976	0.985

Policy Recommendations

- Optimize the innovation environment and focus on achieving key digital technology breakthroughs.
- Promoting synergistic optimization of digital development and carbon neutral policies.
- Promoting inclusive development of digital technology innovations.

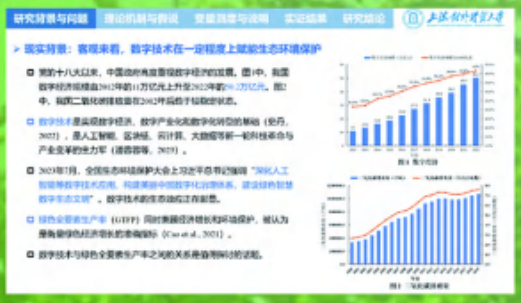
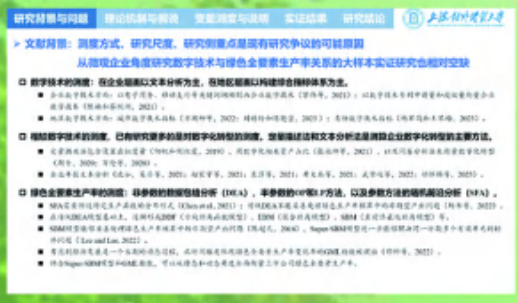
数字技术具有绿色生产率效应吗？
——基于上市公司的实证检验

闫海洲[1] 曾维琴[2]

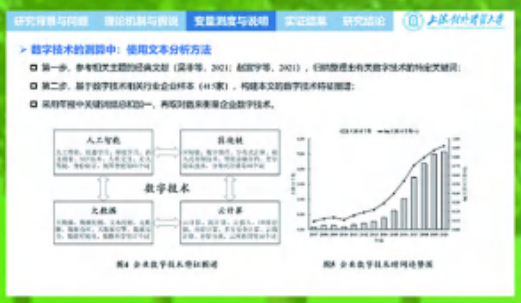
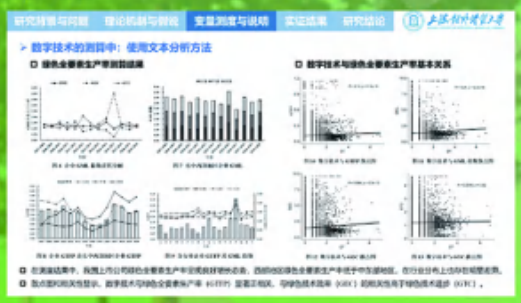
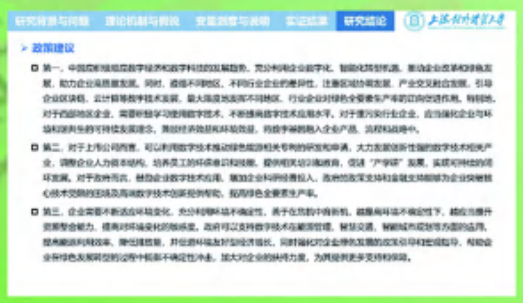
1.闫海洲，上海对外经贸大学，博士生导师，教授，Email：cyberhai@126.com。
2.曾维琴，上海对外经贸大学，硕士研究生，Email：z3097297593@163.com。

摘要：数字技术已经开始渗透到企业发展的各个层面，是否会对企业绿色经济行为产生影响还没有足够的证据。**本文使用2007~2020年沪深两市A股上市公司数据，使用文本分析刻画企业数字技术强度，利用非期望产出Super-SBM模型测算企业绿色全要素生产率，探讨企业数字技术对绿色全要素生产率增长的作用。研究发现：**数字技术显著正向影响绿色全要素生产率增长，且该作用存在“结构性”驱动效果，主要靠拉动绿色技术效率进而提升绿色全要素生产率。**机制分析表明，**数字技术通过提升企业绿色创新水平、绿色创新效率、人力资本技能结构、人力资本教育结构来促进企业绿色全要素生产率提升。**进一步分析发现，**我国碳排放权交易试点政策、低碳城市试点政策能够有效促进数字技术的绿色生产率效应发挥。**异质性检验表明，**在东部地区、非重污染行业、低环境不确定性的企业中，数字技术对绿色全要素生产率提升作用更显著。本文的研究结论为企业绿色转型提供启示与参考。

关键词：绿色全要素生产率；数字技术；绿色创新；人力资本结构；绿色低碳发展

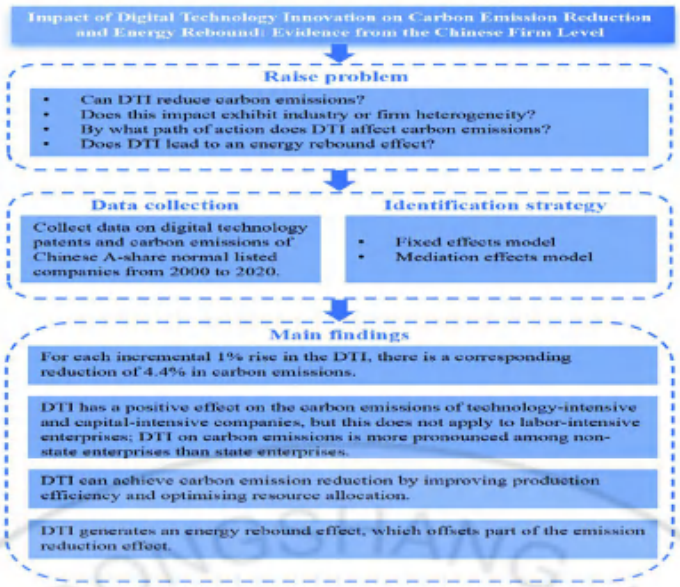


Impact of Digital Technology Innovation on Carbon Emission Reduction and Energy Rebound: Evidence from the Chinese Firm Level

Nengyu Liu[a, *], Yue Liu[a], Chang Gao[a]
[a] School of Economics, Zhejiang Gongshang University, Hangzhou, China
Co-author of e-mail：liunengyu@sina.com

Abstract
Digital technologies are increasingly acknowledged as a critical means to achieve cleaner production, carrying profound implications for meeting the "dual carbon" target of carbon peaking and carbon neutrality. Examining the influence of digital technology innovation (DTI) on carbon reduction and energy rebound, the study presented intriguing findings by analyzing data from listed Chinese companies between 2001 and 2021. Firstly, for every 1% increase in technological innovation, carbon emissions are reduced by 4.4%. Secondly, DTI can significantly reduce carbon emissions for companies that are heavily involved in technology and capital-intensive industries. Thirdly, the study identifies production efficiency and resource allocation as the pathways through which DTI impacts the reduction of carbon emissions. Finally, DTI can generate an energy rebound effect, which can partially offset the emission reduction impact. These insights offer invaluable lessons and references not only for China but also for other developing nations in their pursuit of dual-carbon goals.



Introduction
On one hand, population growth and the rapid pace of urbanization are driving an increased demand for energy and consumption, particularly in modern societies with energy-intensive lifestyles (Sun and Dong 2022; Yi et al. 2022). On the other hand, advancements in science and technology have fueled rapid economic growth, yet they have simultaneously heightened the demand for energy sources like electricity, coal, and oil (Sheng et al. 2020), which resulted in a significant increase in carbon emissions. Being one of the largest economies, China grapples with the challenge of balancing economic growth with carbon emission reduction. Hence, delving into viable carbon emission reduction pathways is not only vital for China to attain its carbon neutrality goal but also offers a practical reference for developing countries.

Results

- The baseline analysis's results are presented in the table 1. Column (1) shows that the estimated coefficient on DTI is -0.024 and is statistically significant at the 1 per cent level after the inclusion of a range of control variables. This suggests that DTI can significantly reduce carbon emissions. In columns (2) and (3) we add time and firm fixed effects respectively and the results didn't change noticeably . Specifically, for every 1% increase in technological innovation, carbon emissions are reduced by 4.4%.

- We evaluate the energy rebound effect of DTI, and the results are shown in column (1) of Table 2. The regression coefficient of is 0.039 and significantly positive. This suggests that the rebound effect in energy from DTI partially counteracts the carbon reduction efforts. Furthermore, we performed a 2SLS regression analysis in column (2) of Table 2, to verify the robustness of the results, and the estimates did not change.

Table 1
The impact of DTI on carbon emissions.

Variables	(1)	(2)	(3)
ditein	-0.024***	-0.029***	-0.044***
	(0.006)	(0.006)	(0.007)
Constant	-15.346***	-14.975***	-14.552***
	(0.224)	(0.230)	(0.323)
Control	YES	YES	YES
Firm FE	NO	YES	YES
Year FE	NO	NO	YES
N	34,284	34,284	34,284
R^2	0.623	0.635	0.635

Note: Standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table 2
Estimation on the energy rebound effect of DTI

Variables	(1) FE	(2) 2SLS
ditein	-0.164***	-0.125***
	(0.010)	(0.018)
ditein×energy	0.039***	0.038***
	(0.002)	(0.002)
Constant	-13.990***	14.586***
	(0.310)	(0.132)
Control	YES	YES
Firm FE	YES	YES
Year FE	YES	YES
N	34,284	34,284
R^2	0.647	0.680

Note: Standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Conclusions
The rapid emergence and evolution of digital technology in China has created new opportunities for various industries. Against this backdrop, we explore the impact of DTI on carbon emission reduction as well as energy rebound using data from listed companies in China from 2000-2021. The main conclusions are as follows:

- DTI can dramatically reduce carbon emissions. Precisely, for each incremental 1% rise in the DTI, there is a corresponding reduction of 4.4% in carbon emissions.
- DTI generates an energy rebound effect, which offsets part of the emission reduction effect.

碳金融与碳资产管理

Carbon Finance and Carbon Asset Management

Capital Drives "Stickiness", Intertemporal Transfer of Embodied Carbon, and Dynamic Consumption Carbon Footprint

Ding Chenxin[1,2], Sun Hui[1,2]

(1. Center for Innovation Management Research of Xinjiang, Xinjiang University, Urumqi 830046, China;

2. School of Economics and Management, Xinjiang University, Urumqi 830046, China)

Abstract

Background, Aims and Scope. China's economic development has long relied on fixed capital input, and the diversity of fixed capital composition and the long-term nature of its use determines the complexity of its embodied carbon transfer. While previous studies have focused on the spatial separation of production and consumption, with trade as the primary focus, there has been a lack of research on the intertemporal transfer of hidden carbon. This can be studied by analyzing the dynamics of capital formation and utilization.

Methods. In this paper, the capital flow matrix from 2003 to 2020 is used to internalize capital in input-output analysis, and the capital depreciation matrix is used to track the intertemporal transfer of implied carbon in the process of capital use, which is defined as the dynamic consumption carbon footprint.

Results and Discussion. The findings indicate that China has accumulated a significant amount of fixed capital that can be used for future production. The carbon footprint of dynamic consumption is approximately 58% to 72% of that of traditional consumption, with the reduced portion being reflected in future consumption. The sector distribution of the carbon footprint of dynamic consumption is more balanced, with a significant increase in the carbon footprint of the tertiary industry sector, closely aligned with its value added. The key sectors for emission reduction are electric heating production and supply, as well as the equipment and instruments sectors.

Conclusion. When considering the carbon emissions caused by the depreciation of fixed capital, the size of the carbon footprint of consumption depends not only on the carbon intensity of current production but also on the extent to which current production relies on past-formed fixed capital and the carbon intensity of previous production. Therefore, policies that modify the service life of fixed assets can partially reduce the dynamic carbon footprint of consumption. This study provides a reference for relevant policymakers.

Key words: Capital embodied carbon; Intertemporal transfer; Dynamic Carbon Footprint; Input-Output Analysis

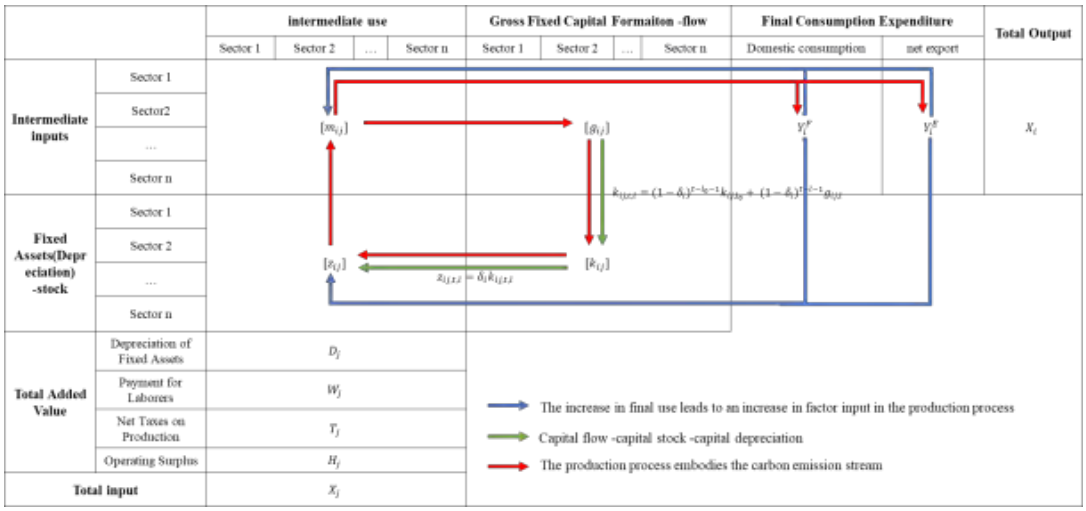


Fig 1 Input-output process-based factor flows and carbon footprint flows

Research on Multidimensional Relationship Network and Carbon Emission Reduction Effect of Manufacturing Enterprises--Based on the Mediating and Moderating Role of Autonomous Innovation

LUO Xiao-juan[1], LV Li[2]
(1. Jiangxi Institute of Economic Development, Jiangxi Normal University, Nanchang 330013, China; 2. Jiangxi Institute of Economic Development, Jiangxi Normal University, Nanchang 330013, China)

Abstract
Background, Aims and Scope. Under the guidance of the strategic goal of "carbon peak and carbon neutrality", the emission reduction effect of manufacturing industry plays a pivotal role, and industrial upgrading and transformation is the key to realize carbon peak and carbon neutrality, which is related to the overall situation of China's economic and social development. As an important main body to achieve the industrial carbon emission reduction target and promote industrial modernization, how to enhance the carbon emission reduction ability of industrial enterprises has become a key issue that needs to be solved by the theoretical and practical circles. In order to explore how the relationship network affects corporate carbon emissions, this study empirically examines the impact of multidimensional relationship network on corporate carbon emissions and its path of action from the perspective of microenterprises based on the research data of 1,226 industrial enterprises collected in 2022.
Methods. In this study, by constructing full samples and subsamples with multidimensional relational networks, econometric models such as mixed regression, mediation effect and moderating effect are applied to determine the effects and mechanisms of multidimensional relational networks on carbon emission reduction of enterprises.
Results and Discussion. The main findings are: (1) the existence of multidimensional relationship networks has a significant inhibitory effect on corporate carbon intensity, and the higher the richness of the relationship networks, the more obvious the inhibitory effect; (2) quantile regression shows that, overall, with the increase of the quantile point, the absolute value of the regression coefficient of the multidimensional relationship networks on the intensity of corporate carbon emissions is constantly getting bigger, and the stronger is the inhibitory effect of the multidimensional relationship networks on the carbon intensity of corporations; (3) the Heterogeneity analysis indicates that compared with the low digital level and end-product production enterprises, the carbon emission reduction effect of the multidimensional relationship network on the high digital level and intermediate goods enterprises is more significant; (4) From the viewpoint of the mechanism of action, independent innovation is not only an important mediator of the multidimensional relationship network affecting the carbon intensity of enterprises, but also has the moderating effect of strengthening the inhibitory effect of the multidimensional relationship network on the enterprise's carbon emission.
Conclusion. The policy suggestions on strengthening the embeddedness of multidimensional relationship network, enhancing the level of digital empowerment and guiding enterprises' independent innovation are of great reference value for enhancing the comprehensive emission reduction ability of industrial enterprises and promoting the high-quality development of industry.
Key words: municipal solid waste; incineration; greenhouse gas; emission process

Empirical study on the impact assessment of the EU carbon border adjustment mechanism on product export costs

Lanxin Zhang (Tsinghua University)

Abstract: On May 17, 2023, the EU Carbon Border Adjustment Mechanism (CBAM) Act came into force, which will impose a CBAM charge on the carbon emissions of some imported goods. However, embedded emissions, free allowances and other key el-ements related to the accounting of the CBAM charge are not clearly defined in the CBAM provisions, leading to high uncertainty about the impact of the CBAM on export costs. This study analyzes the rules of CBAM regulations in depth, examines the accounting scope and rules of the above key elements, proposes a methodological framework for assessing the CBAM impact of export costs, and carries out empirical research using crude steel products as an example. Results show that within the system boundary and emission accounting scope of CBAM, the embedded carbon emission of 1t of converter crude steel in China is 1.73tCO2eq. The in-cremental cost of China's crude steel export to the EU is 37.26 euros/t. Based on the above assessment results and taking into account the differences in climate policy systems between China and the EU, this study proposes a number of policy recommendations to deal with CBAM, including negotiating the implicit carbon price, reducing the carbon intensity of products and adjusting the export structure. This study aims to provide methodological support for China's export enterprises to quantitatively assess the economic impacts of CBAM, and to provide a reference basis for the Ministry of Commerce and other governmental departments to participate in envi-ronmental trade negotiations and formulate policy measures to deal with CBAM.

绿色金融有助于减污降碳吗？——兼论绿色财政的门槛效应

摘要：绿色金融作为重要的减排工具，在合理的绿色财政引导下，有助于放大资源配置效能，强化减污降碳效应。本文以2007—2020年中国大陆30个省市区（不含西藏）的省级面板数据为样本，采取双向固定效应和门槛效应模型，探索绿色金融的减污降碳效应及绿色财政的门槛效应。研究发现：（1）绿色金融存在显著的减污降碳效应，且减污效应大于降碳效应。（2）绿色金融可通过优化产业结构抑制污染物和二氧化碳排放。（3）绿色税收和绿色财政支出对绿色金融具有门槛效应。当绿色税收规模处于0.12%—2.41%之间时，有助于增强绿色金融的减污效应，同时确保其降碳效应。当绿色财政支出规模处于4.16%—4.21%，有助于提高绿色金融的减污效应。研究结论为完善绿色金融制度、优化绿色税收和绿色财政支出提供政策启示，有助于进一步推进减污降碳。

关键词：绿色金融；绿色财政；减污降碳；绿色税收；绿色财政支出

本摘要来源：胡剑波,陈行.绿色财政会增强绿色金融的减排效果吗？——基于减污降碳视角.财经论丛，2023，10：25-35.

Realistic Dilemma, Constraints and Model Innovation of Forestry Carbon Sink Credit Financing

QIN Tao, WANG Shan, DENG Shuwen, ZHU Ran
(School of Economics and Management, Beijing Forestry University, Beijing 100083, China)

Abstract: As the main path for realizing the value of forestry carbon sinks, forestry carbon sink credit financing is of great value in revitalizing forestry carbon sink resources, enhancing the value of carbon sink assets, and alleviating the financing constraints of carbon sink operating enterprises. At present, some regions in China have explored the pilot forestry carbon sinks pledge financing business, but face the realistic dilemma that it is difficult to replicate and promote the existing model. The article analyzes the financing mode and existing deficiencies of typical cases, in-depth analysis of forestry carbon sinks credit financing the current reality of the problem, and explore the fundamental reasons affecting the forestry carbon sinks to play the role of pledge. The study found that: ① the legal attributes of forestry carbon sinks are not clear, and there is a lack of legal basis for the change of relevant rights and interests involved in the process of pledge establishment. ② The lack of standards for assessing the value of forestry carbon sinks makes it difficult for banks to recognize the results of the assessment of the value of the pledge. (iii) It is difficult to dispose of the forestry carbon sinks assets and realize the pledge right, and the banks cannot effectively control the risk of credit defaults due to the lack of realization paths of the pledge right. Therefore, this study innovatively proposes “forest right mortgage with forestry carbon sink pledge + carbon sink value insurance + forest right (carbon sink) storage guarantee” by introducing the policy pledge, value recognition and financial credit enhancement functions of forestry carbon sink insurance and the guarantee credit enhancement role of carbon sink storage mechanism in the realization of the pledge right, It innovatively puts forward three forestry carbon credit financing models, namely, “forestry carbon sink (expected return right) value insurance policy pledge + carbon sink storage guarantee” and “forestry carbon sink asset pledge + carbon sink price index insurance”, which provide feasible paths for the widespread development of forestry carbon sink pledge financing. Finally, in view of the constraints of forestry carbon credit financing, specific strategies are proposed to promote the effective development of forestry carbon credit financing in five aspects: improving the institutional framework of forestry carbon sinks, unifying the standard of carbon sinks assessment and accounting, optimizing and innovating the carbon insurance products, establishing the guarantee system for the storage of carbon sinks, and constructing the financial support system for forestry carbon sinks.
Key words: forestry carbon sinks; credit; pledge guarantee; insurance; financing

Whether the combined policy of carbon tax and carbon trading is effective--an experimental study based on the current status of China's carbon pricing policy

*Hanting Wang, Guoqin Bu**
International business school, Jinan University, Guangdong,China
E-mail:hantingwangjnu@foxmail.com;buguoqin@163.com

Abstract

China is planning to introduce carbon tax policy to control the carbon emissions of country better and achieve the "3060 goals", but there is still widespread discussion about how to introduce it and how to combine it with cap and trade. China has already established a national carbon emission trading market, however, there is also disagreement on whether to impose the carbon tax on companies and projects that have been included in scope of cap and trade. This paper adopts the research method of experimental economics to study the effect on social economy and social emission reduction under cap and trade, carbon tax, carbon tax-carbon trading policies, and analyzes average prices of carbon market under cap and trade and carbon tax-carbon trading policies. The study finds that: under the carbon tax-carbon trading policy, carbon emissions cannot be reduced significantly; but the profits of manufacturers will be reduced significantly, meanwhile, this reduction effect is even more severe for high consumption manufacturers; and it will be resulting in a lower average carbon market price under the carbon tax-carbon trading policies than under the cap and trade policy. This paper will provide theoretical suggestions for introducing carbon tax policy into China in the future, and make policy recommendations for the better development of China's carbon market. The 3060 goals refer to the Chinese government's proposal that China will strive to achieve its carbon peak by 2030 and its carbon neutrailty by 2060.

Experiment

- We constructed a simulation experimental platform for carbon pricing policy within the Economics Laboratory.
- A total of 720 subjects were recruited and participated in the carbon market trading experiment.
- We conducted semi-structured interviews with experimental subjects at the end of the experiment

Result and discussion

Table 1 Design of experiments

Group	Carbon reduction policy	Experimental design
Control Group		There is no carbon reduction policy, and manufacturers are free to produce within the allowed range
Experimental Group I	Cap-and-trade	Manufacturers must have carbon allowances to produce, and they can trade carbon allowances in the carbon market
Experimental Group II	Carbon tax	Manufacturers are free to produce within their means, but pay carbon tax on the carbon generated by the products they produce
Experimental Group III	Carbon trading and carbon tax	Manufacturers must have carbon allowances to produce, and they can trade carbon allowances in the carbon market and pay carbon tax on the carbon generated by producing their products.

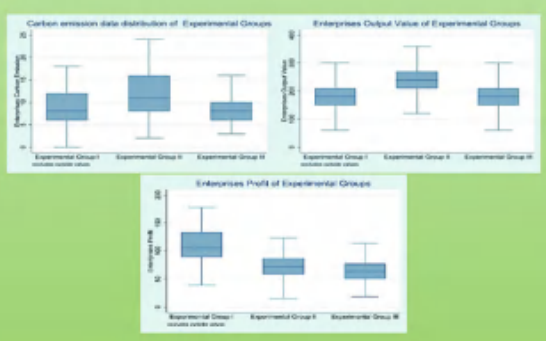


Fig 1,2,3 Production Value, Profit and Carbon Emission Data Distribution of Manufacturers under Production Markets

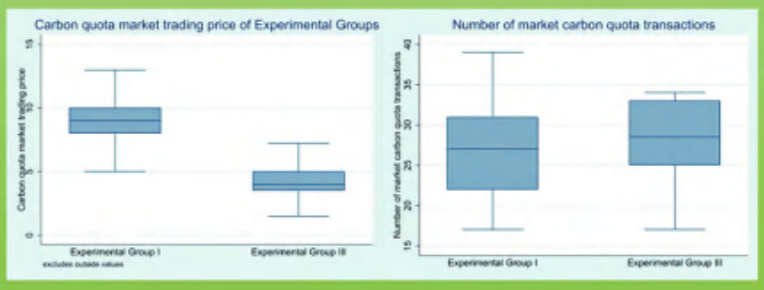


Fig 4,5 Volume and price effects of transactions on the trading market

- Carbon taxes and carbon trading policies imposed on emission control entities at the same time can significantly reduce their production margins to the point of lowering the price they expect to pay for carbon market allowances
- Our experiments show that the introduction of a carbon tax still has a dampening effect on the production of manufacturers, which also corresponds to carbon emissions.
- After the introduction of the carbon tax, the trading price of allowances in the carbon market was significantly reduced; at the same time, in our experimental group, we did not find a reduction in the frequency of trading, which may be a result of the market's unchanged demand for the optimal allocation of resources

Policy recommendations

- Carbon tax and carbon trading policy can not be implemented on the same emission control subjects
- Carbon trading policies should progressively move from intensity to total emissions control
- Reasonably set the starting point of carbon tax and adjust the carbon tax rate at an appropriate time
- Implementation of a carbon tax on exports to countries with carbon tariffs, such as the European Union, and on emission subjects that cannot be included in the scope of carbon trading

Recognition of achievement

✓This paper has published in Environmental Science and Pollution Research(SCI Q1,IF:5.8)
✓The project was funded by the Guangdong Provincial Science and Technology Innovation Strategy Special Funds ("Climbing Plan")
✓The project was awarded the national innovation and entrepreneurship training program for college students.
✓The project won the third prize of the 18th Challenge Cup Extracurricular Academic and Technological Works Competition in China and the Grand Prize of Guangdong Province.

Low-Carbon Innovation in China: Does Position Matter?

Li Xia, Shuo Gao, Qianwen Shao, Jiuchang Wei & Zhi Li
lixia_nov18@mail.ustc.edu.cn
University of Science and Technology of China
中国科学技术大学 University of Science and Technology of China

Abstract

Through combining the resource dependence and social network theories, this study sheds light on how two major kinds of interlocking network positions — central network position and structural holes position — drive corporate low-carbon innovation. We consider the mediating effect of information asymmetry and knowledge absorptive capacity to reap benefits from occupying the two advantageous network positions. We have empirically investigated a sample of 3365 listed firms over the period of 2009–2018 drawn from China, the largest emerging market economy as well as the biggest carbon dioxide emitter. Our main results show that either holding a central network position or spanning a structural holes position plays a significant role in stimulating low-carbon technologies, and the promotion effect can be partially channeled through downward information asymmetry and upward knowledge absorptive capacity. Our findings differ from earlier work because of our emphasis on network position, and our specific focus on corporate low-carbon innovation and China's unique setting, rather than network size, greenhouse gas emissions, and developed economies. This study also provides significant implications for executives striving to improve firms' low-carbon innovation performance, and for policymakers seeking ways to fulfill the mission of carbon dioxide abatement.

Introduction & Research Gaps

SINCE the mid-20th century, climate change has been widely recognized as a growing threat to society and the economy, owing largely to the surging greenhouse gases of human activities. As an effective response to climate challenges under ever-increasing environmental pressures, low-carbon innovation (LCI) has been in the spotlight for decades, primarily for its great potential to achieve carbon abatement and gain competitive advantages for firms. In comparison with conventional innovation, LCI is featured by a so-called double externality issue, that is, technological spillover at the research and development (R&D) stage and ecological spillover at the implementation and diffusion stage.

Despite some previous studies that have explored the association between board interlocks and general innovation behaviors, such as investment efficiency, conventional innovation, and general R&D expenditure, it still remains unclear about the influence of board interlock networks on environmental innovation behaviors like LCI. Several prior studies have explored the effect of the network size of board interlocks on corporate environmental behaviors, however, to a large extent, another important property of board interlock networks - network position - has been neglected. Indeed, there are several studies that have stressed the value of network positions to new product introduction, organization innovative capabilities, and new product development, whereas there is little empirical evidence on if and how specific positions embedded within board interlock networks affect LCI.

Considering specific network positions that mirror the discrepancies of established board social capital as well as China's institutional setting, it seems intuitive to take into account information asymmetry (ASY) and knowledge absorptive capacity (KAC) as potential mediators in the relationship between board network positions and LCI to further examine latent mechanisms by which occupying such focal network positions drive firm-level LCI. Surprisingly, in the extant literature, the effect of board interlock networks on LCI has mostly been directly explored while the factor of KAC has only been studied occasionally. The few studies that cover such a factor normally treated KAC as a boundary condition while ignored the role of ASY.

Research Framework & Stylish Facts

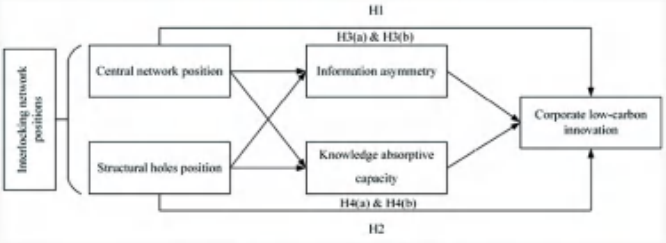


Fig. 1: Conceptual framework and hypotheses.

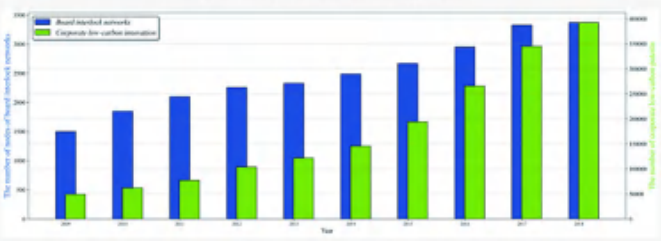


Fig. 2: Board Interlock Networks and Corporate Low-carbon Innovation

Illustration of board interlock networks

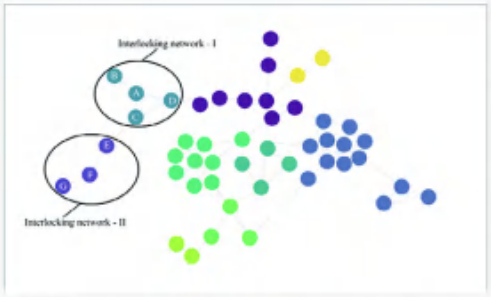


Fig. 3: The Largest Connected Component of the Board Interlock Network in 2009

In Fig.3: Each node denotes an individual firm. The size of a node is proportional to the number of its connections with other nodes. The color of nodes refers to the clustering results based on the community detection algorithm, and the corresponding weighted modularity score is 0.669. Nodes (i.e. firms) belonging to the same cluster are painted with the same color. Thus, Firm A is occupying a network position with the highest centrality within its own cluster. While Firm A and C have no direct connections, it is Firm B that bridges these two firms. So, Firm B is spanning a structural holes position.

Fig. 4: The Largest Connected Component of the Board Interlock Network in 2018

In Fig.4: Each node denotes an individual firm. The size of a node is proportional to the number of its connections with other nodes. The color of nodes refers to the clustering results based on the community detection algorithm, and the corresponding weighted modularity score is 0.737. Nodes (i.e. firms) belonging to the same cluster are painted with the same color.

Contributions

This study is of great significance in several ways. First, by fusing insights from resource dependence theory and social network theory, we contribute to a growing body of general literature on board social capital and corporate environmental behaviors by demonstrating the top-down effect of board interlock networks on LCI, an issue that has been so far neglected in the literature. By doing so, we contribute to the ongoing discussion on the question of why some firms have the superior performance of LCI to others from a relatively novel perspective of network position. Second, to our knowledge, we are the first to introduce ASY and KAC as two potential mediators in the relationship between interlocking network positions and LCI. Our findings imply that advantageous network positions can turn into improved LCI performance through downward ASY and upward KAC, which helps to further explain why some firms are of competitiveness in the field of low-carbon technologies and others are not. Third, this study contributes to the area of LCI by addressing recent calls for more attention to both the antecedents of LCI and the influence of board interlocks on multifaceted aspects of firm performance. Finally, this study investigated the association between board interlocks and LCI in the research setting of China, a quintessential emerging economy that is striving for sustainable industrial development, for studying. In this sense, although this study is situated in the context of board interlock networks and low-carbon technologies in China, our key insights are likely to still hold in other settings. It has been evidenced that firms worldwide are embracing the value of sharing members of boards under ever-increasing pressure of fulfilling low-carbon targets, indicating that our main findings have the potential to be extrapolated from China to other regions.

Conclusion While current literature has recognized that social capital is responsible for catalyzing innovative capabilities, far less attention has been devoted to exploring whether and how advantageous network positions in the sense of embedded board social capital drive corporate low-carbon innovation. To this end, we take a first step towards identifying the latent mechanisms by which occupying advantageous network positions can bring about the improvement of LCI outputs, which is based on 3365 China's A-listed firms over the research period from 2009 to 2018. Specifically, our results implied that either holding a central network position or spanning a structural holes position serves as a significant contributor to firm-level LCI in the sense that board social capital and corporate low-carbon technologies go hand in hand. And we identified ASY and KAC as two mediators that channel the effect of central network position and structural holes position on LCI. These findings add substantially to our current understanding of how firms' output of low-carbon technologies benefits from interlocking network positions in terms of information-based and knowledge-based competitive advantages.

Impact of Emission Fee to Environmental Protection Tax on Environmental Protection Performance of High Pollution Listed Enterprises

Yannan ZHOU, Jie GAO, Ziang ZHAO, Pengfei HAO

香港科大(广州)
HKUST(GZ)

Introduction

The transition from an emission fee policy to an environmental protection tax exerts notable social influence on businesses. This research predominantly studies how environmental protection tax (EPT) initiatives influence the 'E' metric within corporate Environmental, Social, and Governance (ESG) frameworks, with specific emphasis on high-polluting, listed firms in China. Utilizing the Difference in Differences (DID) model, the study aims to empirically substantiate the efficacy of these policy interventions in bolstering environmental protection and progressing corporate sustainability. In particular, the research quantifies the policy effects on alterations to the 'E' metric and discerns the disparate impacts among various polluting entities. Additionally, the investigation integrates controlling variables such as the enterprise's size, social contributions, and governance integrity, to provide an all-encompassing understanding of environmental protection accomplishments. Projected outcomes of this study include empirical policy-making and investor guidance in crafting and executing proficient strategies that resonate with ESG objectives. The research results are anticipated to enlighten policy conversations and practices concerning environmental protection and sustainability, playing an instrumental role in encouraging responsible and sustainable business practices.

Emission Fee to Environmental Protection Tax → **Influence** → Environmental Protection Performance of High Pollution Listed Enterprises

How to measure?

E grade in ESG system

Indicators

Methods

The study's methodology involves applying the Difference-in-Differences model to generate empirical evidence demonstrating the effectiveness of transitioning from emission fees to Environmental Protection Tax policies in bolstering environmental preservation and corporate sustainability. By comparing the average changes in ESG performance across these two groups over time, the DID model allows us to unravel the causal impact of the transition from emission fees to environmental protection tax, thereby quantifying the policy-induced environmental preservation and corporate sustainability.

Expected Results

The outcome of this research is to provide evidence-based guidance for policymakers and investors on designing and implementing effective policies that align with ESG goals. The findings of this study will inform policy debates and practices related to environmental protection and sustainability and contribute to promoting responsible and sustainable corporate behavior. Overall, this research gives valuable insights into the effectiveness of ETP policies in achieving ESG objectives and highlights the importance of incorporating ESG considerations into policy-making and corporate decision-making.

Conclusions

The research determined that transitioning from an environmental protection fee to an environmental protection tax markedly enhanced the ESG performance of high-polluting companies, especially the E indicator in the ESG system. Besides, this green tax model had additional beneficial effects, leading to a notable rise in green innovation, enhancing corporate social responsibility, fostering the development of green corporate governance, and propelling high-polluting firms towards green, low-carbon operations. This aligns with the nation's strategic "double carbon" objectives.

环境权益交易如何实现减污降碳协同增效：理论与经验证据

陈 梁
（华中科技大学 经济学院，湖北 武汉 430074）
（E-mail: liangchen2021@163.com）

研究动机

当前中国同时面临环境质量持续改善与“双碳”目标的双重约束，协同推进减污降碳是统筹美丽中国建设与碳达峰碳中和目标的必然选择。从污染治理与碳排放控制的实践来看，中国最早开始治理二氧化硫污染，并在2007年开始试点SO_2排污权交易，在规制SO_2污染的过程中并未强化碳排放控制，基于SO_2排污权交易可以更好地识别二氧化硫污染治理的协同降碳效应。

本文将排污权交易约束纳入异质性企业模型，以二氧化硫排污权交易试点作为环境权益交易的准自然实验，并采用中国工业企业环境统计数据库、中国工业企业数据库与企业专利数据库匹配后的数据，基于减源效应和创新效应视角，从理论与实证两个角度分析与检验二氧化硫排污权交易制度影响企业减污降碳协同的微观机理与政策效果。

主要边际贡献：第一，系统准确识别市场型环境规制的协同降碳效应，为利用市场机制推动减污降碳协同增效提供重要经验证据；第二，通过引入排污权交易约束拓展异质性企业模型，构建排污权交易通过减源效应和创新效应影响企业减污降碳协同的理论框架；第三，评估排污权交易通过减污降碳协同产生的经济社会效益，并探究相关碳市场的协同规制问题。

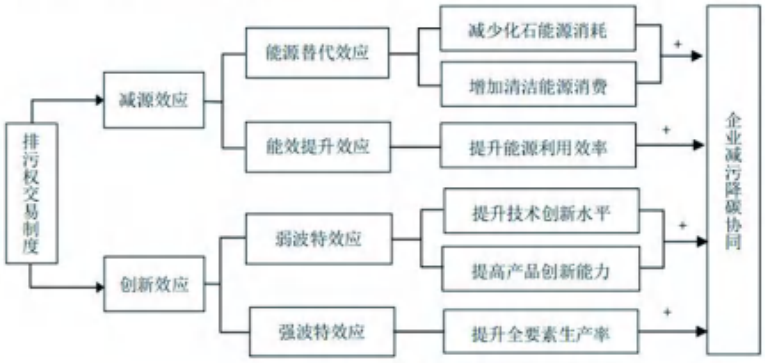


图1 理论机制分析框架

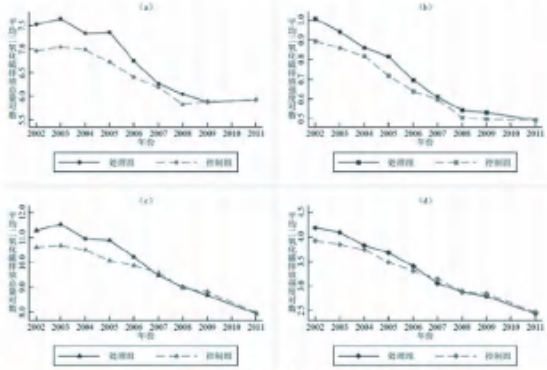


图2 试点与非试点地区企业二氧化硫和二氧化碳排放均值变化

效益估算

运用收益分析法估算减污降碳协同效应带来的经济社会效益。一方面，估算排污权交易制度实施期间的工业SO_2减排量和相关效益，2007-2011年工业SO_2减排总量约2235.58万吨，使呼吸系统疾病及肺癌相关医疗费用支出减少3822.84亿元；另一方面，估算排污权交易制度实施期间的工业CO_2减排量和碳社会成本，2007-2011年碳社会成本为646.07亿美元，以2011年平均汇率6.46折算即4173.61亿元。排污权交易的经济社会总效益约7996.45亿元，约占2011年GDP总量的1.69%。

表1 工业SO_2减排量

年份	工业SO_2排放实际值/万吨	企业SO_2排放的估计系数	平均减排效应	工业SO_2排放反事实值/万吨	工业SO_2减排量/万吨
2007	2139.98	-0.204	-0.185	2624.25	484.27
2008	1991.37	-0.204	-0.185	2442.01	450.64
2009	1865.94	-0.204	-0.185	2288.20	422.26
2010	1864.42	-0.204	-0.185	2286.33	421.91
2011	2017.23	-0.204	-0.185	2473.73	456.50
总量					2235.58

表2 工业CO_2减排量与碳社会成本

年份	工业CO_2排放实际值/亿吨	企业CO_2排放的估计系数	平均降碳效应	工业CO_2排放反事实值/亿吨	工业CO_2减排量/亿吨	碳社会成本（美元/吨）	每年碳社会成本/亿美元
2007	57.36	-0.293	-0.254	76.88	19.53	5.22	101.95
2008	59.51	-0.293	-0.254	79.77	20.26	5.37	108.80
2009	68.12	-0.293	-0.254	91.31	23.19	5.54	128.47
2010	73.67	-0.293	-0.254	98.75	25.08	5.70	142.96
2011	82.02	-0.293	-0.254	109.94	27.92	5.87	163.89
总社会成本							646.07

主要结论

本文通过理论推演与实证检验，探究环境权益交易能否以及如何实现减污降碳协同增效。研究发现，排污权交易显著降低了企业二氧化硫、二氧化碳排放总量与强度，产生减污降碳协同效应，该效应在成熟期或衰退期企业、国有企业、大气污染行业及经济发展水平较低地区中更强。机制检验表明，排污权交易通过清洁生产和末端治理促进污染减排；排污权交易激励企业能源消费替代和提升能源效率，通过减源效应实现减污降碳协同；基于创新效应的协同路径主要来自弱波特和强波特效应，不仅提高企业技术创新和产品创新能力，还通过提升企业全要素生产率协同推进减污降碳。进一步分析发现，排污权交易主要通过降低能源消费强度有效提升减污与降碳系统协同程度，在推动减污降碳的同时带来经济社会效益，从而实现减污降碳协同增效。此外，排污权交易产生的协同降碳效应会导致碳配额超发，碳市场需要对碳配额分配实施协同规制。

企业发行绿色债券的碳减排效应研究

杜东英
（南京农业大学金融学院，江苏 南京，210095）
E-mail :2020218003@stu.njau.edu.cn

摘要：
企业如何通过发行绿色债券助力企业碳减排一直是学术界关注的议题，然而鲜有研究关注绿色债券对公司碳减排的影响。因此，本文利用我国沪深A股上市公司数据，以首次发行绿色债券事件作为准自然实验研究场景，以此构建交叠双重差分模型检验企业发行绿色债券的碳减排效应。研究发现：绿色债券能够显著地降低企业碳排放量。此外，机制分析表明，研发创新和融资约束的缓解是绿色债券发行企业进行碳减排的主要驱动因素。异质性分析表明，绿色债券的碳减排效应在非国有企业、高科技企业、非重污染行业、较高代理成本、较高环境规制以及募集资金中用于补充绿色营运资金金额占比高的情形下更明显。但是，绿色债券的第三方认证并不会对绿色债券的碳减排效应产生异质性影响。总体上，本文的研究结论为通过完善绿色债券市场体系建设助力企业碳减排提供了有益政策启示。

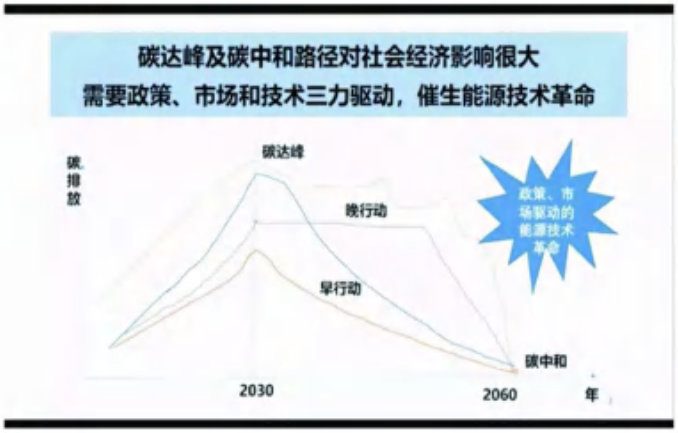


图 1 绿色债券发行交错DID

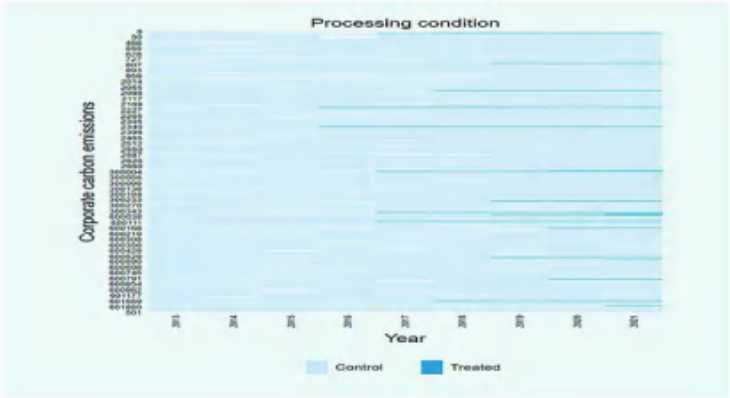


图 2 平行趋势检验结果

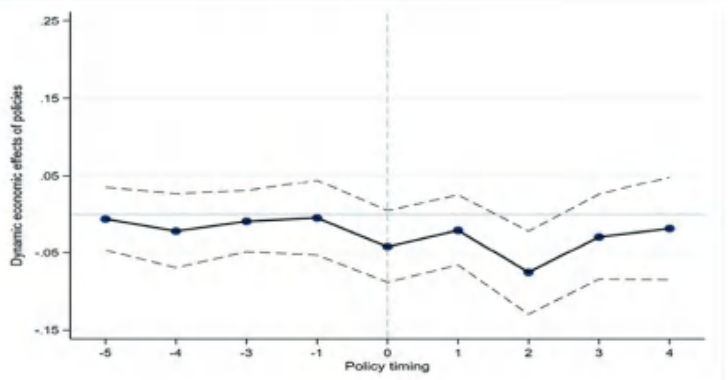


图 3 TWFE 估计偏误权重分布

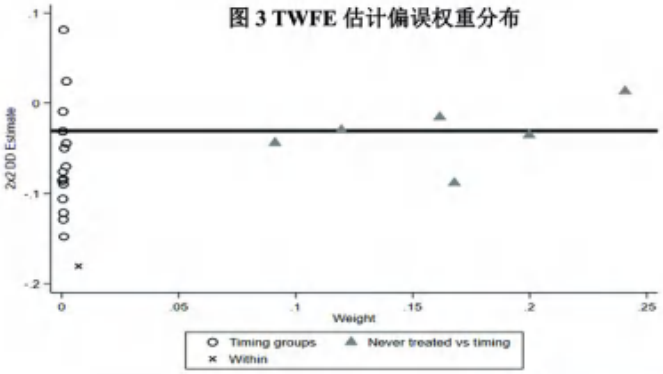
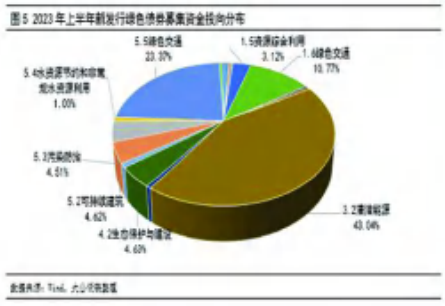
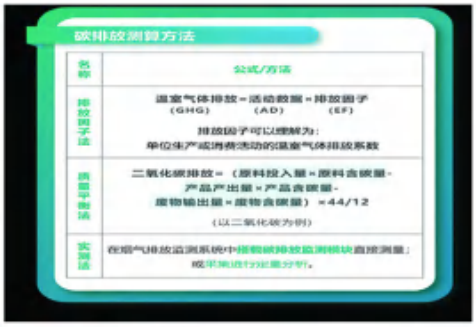


表4 绿色债券与碳减排关系基准回归结果

变量	被解释变量：*ICO*			
	高维固定效应模型		双向固定效应模型	
	(1)	(2)	(3)	(4)
GreenBond	-0.025***	-0.026***	-0.025***	-0.026***
	(-2.61)	(-2.78)	(-2.61)	(-2.78)
_cons	0.603***	0.582***	0.583***	0.548***
	(2.96)	(2.99)	(2.95)	(2.86)
控制变量	Yes	Yes	Yes	Yes
公司固定效应	Yes	Yes	Yes	Yes
年度固定效应	Yes	Yes	Yes	Yes
行业固定效应	No	Yes	No	Yes
Adjusted-R²	0.502	0.503	0.360	0.361
N	14293	14293	14293	14293





基于区块链的中国碳排放权交易

郝仪佳[1] 夏咏[1] 曹守峰[2] Email：1147328085@qq.com
1.新疆农业大学 乌鲁木齐 830052 2.The University of Queensland Brisbane，Australia

摘要

基于区块链的碳排放权交易应用，是我国利用数字化科技实现"双碳"目标的重要实践探索。目前，我国的碳排放权交易经历了三个发展阶段，正处于全国碳排放权交易市场配额现货交易大力发展阶段。区块链具有高透明度、可追溯性、安全可靠性、去中心化等特点，能够有效解决传统的碳交易市场中面临的交易效率低、信息透明度低等相关问题。但作为新兴事物，区块链+碳排放权交易仍面临许多新的挑战，如何更好的推动区块链技术在碳排放权交易市场中的运用，需要我国探索相关的实践经验。要完善相关信息披露制度，创新监管手段，避免出现监管盲区；进一步提升从业人员的专业化水平，防范技术错误风险。未来应探索更多的实践经验，从而推动碳排放权交易与区块链技术深度结合，为我国实现"双碳"目标创造出更大的动力。

背景

目前，中国作为世界上最大的碳排放国家之一，积极参与全球气候治理，中国将节能减排、推行低碳经济作为国家发展的重要任务。2020年9月，在第七十五届联合国大会一般性辩论上，习近平总书记首次明确我国要采取更加有力的政策和措施，争取二氧化碳排放量在2030年前达到峰值，2060年前实现碳中和目标。目前，我国已开设9家可交易碳资产的交易所，其中允许个人进行开户的碳交易所有5家。截至2023年10月20日，全国碳市场碳排放配额累计成交量达到3.518亿吨，累计成交额为183.86亿元，碳配额二级市场现货交易规模位居同时期国际市场首位。

中国碳排放权交易情况

1.国际CDM项目阶段（2005-2012年）

我国碳排放交易权在此阶段较为单一化，仅实施国际CDM（Clean Development Mechanism）项目，交易对手以欧盟为主。CDM项目本质上是一种权力的交换，通过合作使得碳交换的出售方与购买方达到"双赢"的一种机制。我国的CDM项目类型主要集中在可再生资源和新能源领域，积极开展CDM项目可以为采用清洁生产技术的企业获得融资渠道，并获得清洁技术支持。2013年之后，欧盟碳交易机制（EU-ETS）不再接受来自中国的新注册CDM项目，我国国际CDM项目开发基本彻底结束。

2.区域碳排放权交易试点阶段（2013-2020年）

此阶段我国尝试碳排放权交易试点工作，2013-2020年我国碳交易总量累计达到23718万吨，2017年为该阶段的交易峰值，达到4900.31万吨。碳交易额呈现增长趋势，累计成交约57.47亿元，2020年达到该阶段的最高点，交易额约为12.67亿元。除此之外，我国开展国家核证自愿减排机制。（China Certified Emission Reduction，CCER）

表1区域碳排放权交易试点阶段各省市初期发展概括

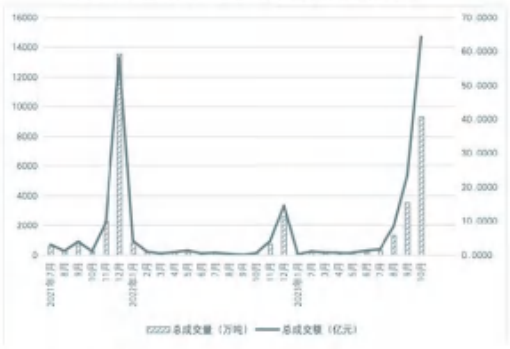
地区	启动时间	主要交易产品	门槛	配额分配方法	市场调节机制
深圳	2013.6.18	SZEA、CCER	工业3000吨煤，政府机关及大型公建1万平方米	免费分配+拍卖，电力行业历史强度法	需求端：采用可调控的总量设置机制；供给侧：采用配额储备、配额供给、拍卖配额等方式调控供应
上海	2013.11.26	SHEA、CCER	工业2万吨煤，非工业1万吨煤	免费分配+不定期拍卖，电力行业标杆法	公开透明市场化运作
北京	2013.11.28	BJEA、BCER、CCER	控排单位5000吨煤	免费分配+不定期拍卖，电力行业标杆法	配额预留拍卖，配额回购
广东	2013.12.19	GDEA、PHCER、CCER	2万吨煤	免费分配+拍卖，电力行业标杆法	采取"控制和预留"方式进行配额总量管理，政府预留一部分配额调节市场
天津	2013.12.26	TJEA、CCER	2万吨煤以上	免费分配+拍卖，电力行业历史强度法	市发改委有启动调控机制的权限，通过投放或回购配额的方式稳定交易价格
湖北	2014.4.12	HBEA、CCER	6万吨煤	免费分配，部分采用历史排放法，部分采用标杆法	配额管理机制，价格涨跌幅限制
重庆	2014.6.9	CQEA、CCER	2万吨煤	免费分配+历史法	涨跌幅限制
福建	2016.12.12	FJEA、FFCER、CCER	5万吨煤	免费分配+拍卖，电力、水泥、铝等行业标杆法，其他行业历史排放法	政府预留10%，配额进行市场干预

数据来源：根据《中国碳金融市场研究2021》、《中国碳金融市场研究分析报告》等相关资料整理。

3.全国碳排放权交易市场配额现货交易阶段（2021-至今）

经过试点项目的实践，2021年2月1日《全国碳排放权交易管理办法（试行）》的正式发布，标志着我国碳排放权交易正式进入全国实施阶段。2021年7月16日，中国ETS交易系统正式上线交易，截至到2021年12月31日，全国碳排放权交易市场第一个履约周期顺利结束。在第一个履约周期内，全国碳市场碳排放配额累计成交量为1.79亿吨，累计成交额76.61亿元，共有1833家重点排放单位按时完成配额清缴，全国碳排放权市场总体配额履约率约为99.5%。

图1 全国碳排放配额（CEA）成交量及成交额



数据来源：根据上海环境能源交易所数据整理。

区块链应用于碳排放权交易

2021年1月27日，国家电网、国家能源集团等8家中央企业共同合作发起并创立"区块链+碳交易"生态网络场景，利用区块链的先进技术性，促进碳交易市场发挥活力，推动碳重点排放主体升级产业结构。2023年3月3日，全球首个"区块链+碳交易"国际标准《基于区块链的碳交易应用标准》正式发布，该标准填补了碳交易领域区块链国际标准空白。

区块链+碳交易的特点

1.透明度高：区块链的不可变分类账本通过记录与碳配额相关的所有交易来提高透明度。这有助于监管机构和市场参与者确保市场的完整性。

2.可追溯性：区块链允许碳配额从发放到报废的可追溯性。这种可追溯性确保配额不会被重复计算并用于其预期目的。

3.安全性：区块链的加密功能增强了碳配额交易的安全性，降低了欺诈和未经授权的访问风险。

4.去中心化：碳交易相关数据的储存和处理均分布在不同的网络节点，在一段时间内，如果交易等信息有任何数据变化，任何人均可采用相同的技术标准加入自己的信息进行记账，延伸区块链。

5.智能合约机制：智能合约可预先设置好碳交易过程中的预期金额和数量，当参与碳交易的企业报出相应的数据并满足预期值时，交易便自动达成，大大降低了碳交易过程的交易成本。

挑战与思考

1.交易存在隐形风险，智能合约存在监管盲区：基于区块链的碳排放权交易作为一种创新型减排制度，在发展初期阶段，相关的监管政策与监管机构的监管范围无法全面覆盖，易出现利益输送、数据造假等违规行为。另外智能合约的预设规则自动达成交易与执行，使得交易双方可通过私下达成共识，趁市场活跃度较低时，提交明显高于或低于市场行情的价格进行买卖一定数量的碳排放权交易申报，在此过程中没有人工监督。因此需要创新监管手段，可通过"以技术规制技术"的思路，利用区块链自身的特性，将区块链技术应用于监管方面。在碳排放权交易的区块链分布式网络中设置一定数量的、由监督管理部门所掌握的"超级节点"，仅由监管部门和机构享有该"超级节点"的监督管理权限。

2.市场相关建设不足，存在一定技术风险：目前我国碳核查发展处于初级阶段，存在碳核查标准欠统一、碳核查指南不完善等问题，市场上的碳核查机构的资质参差不齐，对企业的碳排放数据的准确性可能会造成影响。若出现企业的生产或消费碳排放数据恶意篡改或计算错误等现象，导致错误的碳排放数据存储到区块链中，将会强化错误数据的负面影响。区块链本身无法校对数据存储前的真实性，并且由于其本身作为"信任机器"的基本属性，不可篡改的特性使得容易导致数据主义及数据固化现象，即人们形成忽略其他信息源，盲目信任区块链中信息的"自动化偏见"。如果碳交易区块链中出现技术错误，可能会导致交易市场的混乱，不能及时触发交易或触发错误交易，最终导致碳交易双方利益受损。应加强对区块链技术人员普及碳金融、碳交易市场的知识，提升区块链技术人员的专业化水平，防范技术错误风险。

碳排放权交易试点政策对能源转型的影响

唐月，李世祥
（中国地质大学（武汉） 公共管理学院，湖北 武汉 430074）

文字摘要

随着应对气候危机、保障能源安全、保护生态环境等问题日益受到重视，世界各国都在加快推进低碳转型的步伐。中国在2013年实施了碳排放权交易试点政策，通过降低二氧化碳排放量来实现中国的低碳和可持续发展，因此评估该政策对环境和经济带来的影响具有必要性和现实意义。本文利用中国大陆30个省市的面板数据，探讨了碳排放权交易试点政策对能源转型的影响，并运用调节效应模型与分位数回归模型进行异质性分析，以期为中国和其他发展中国家加快能源转型进程、探索绿色发展道路提供参考。

1.引言

气候危机是当今最严峻的全球性挑战之一，国际社会正积极开展合作以共同应对气候变化。

能源部门的碳排放已经成为人类排放的主要来源。中国的碳排放量与能源消费量巨大。

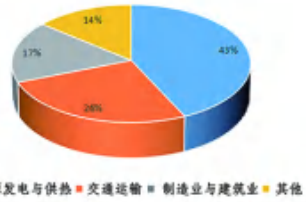


图1 2020年全球碳排放主要来源构成

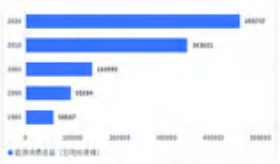


图2 1980年-2020年中国能源消费总量

2.方法

本文运用DID模型探讨了中国的碳交易试点政策对能源转型的影响。

3.结果

由表2可见，第（2）列双重差分项的系数在1%的水平上显著为负，表明与非试点省份相比，试点省份的单位GDP能耗可降低8.55%，即碳排放权交易试点政策在一定程度上促进了试点地区能源转型。

为了减少样本选择偏差，使用倾向得分匹配DID（PSM-DID）进行重新检验，对照组分别按照1:2和1:5的比例通过最近邻匹配获得，结果如表3所示。由表3可以看出，控制外生变量后，核心解释变量的系数均为负值，且在1%的水平上显著，表明基线回归结果是稳健的。

表4的第（1）列为能源禀赋的调节效应结果，核心解释变量与能源禀赋的交互项系数显著为负，表明能源禀赋对碳交易政策促进能源转型有正向调节作用。第（2）列为经济发展水平的调节作用结果。经济发展水平与核心解释变量的交互项系数显著为正，表明经济发展水平对碳交易政策促进能源转型有负向调节作用。

Table 2 DID model regression results.

Variable	ET	
	(1)	(2)
Pilot	0.0230	-0.0855***
	(0.0255)	(0.0199)
eco		-0.886***
		(0.174)
ep		0.0224
		(0.0184)
inv		0.0352*
		(0.0191)
urb		-1.916***
		(0.434)
fin		0.348**
		(0.143)
edu		-0.293
		(0.208)
is		0.218
		(0.211)
Constant	0.821***	8.769***
	(0.00635)	(1.176)
Province FE	YES	YES
Year FE	YES	YES
Observations	360	360
R-squared	0.955	0.975

Notes: Robust t-statistics are in parentheses. *** $p<0.01$, ** $p<0.05$, and * $p<0.1$.

Table 3 PSM-DID estimation.

Variable	(PSM) 1:2	(PSM) 1:5
	ET	ET
Pilot	-0.161***	-0.148***
	(0.0400)	(0.0253)
eco	-0.766***	-0.815***
	(0.272)	(0.205)
ep	0.0242	0.0503**
	(0.0295)	(0.0250)
inv	0.0495	-0.0543
	(0.0704)	(0.0343)
urb	2.048*	1.726*
	(1.191)	(0.924)
fin	0.394	0.229
	(0.241)	(0.154)
edu	-0.555*	-0.481
	(0.314)	(0.298)
is	0.00743	0.467**
	(0.309)	(0.195)
Constant	3.396	3.266**
	(2.498)	(1.539)
Province FE	YES	YES
Year FE	YES	YES
Observations	61	93
R-squared	0.989	0.982

Notes: Robust t-statistics are in parentheses. *** $p<0.01$, ** $p<0.05$, and * $p<0.1$.

Table 4 Results of moderating effects.

Variable	ET	
	(1)	(2)
Pilot	0.254***	-2.879**
	(0.0617)	(1.286)
ep	0.140***	
	(0.0108)	
Pilot×*ep*	-0.135***	
	(0.0250)	
eco		-0.847***
		(0.148)
Pilot×*eco*		0.596**
		(0.264)
Control	YES	YES
Province FE	YES	YES
Year FE	YES	YES
Observations	360	360
R-squared	0.768	0.752

Notes: Robust t-statistics are in parentheses. *** $p<0.01$, ** $p<0.05$, and * $p<0.1$.

本文以5%、25%、50%、75%、90%为分位点，进行面板数据分位数回归。表5是分位数回归输出结果。

Table 5 Results of the quantile regression.

Variable	ET				
	5%	25%	50%	75%	90%
Pilot	-0.151***	-0.205***	-0.325***	-0.590***	-1.013***
	(0.0335)	(0.0288)	(0.0393)	(0.0658)	(0.0617)
Constant	0.398***	0.545***	0.745***	1.077***	1.597***
	(0.0115)	(0.0161)	(0.0540)	(0.0589)	(0.0533)
Observations	360	360	360	360	360

Notes: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

4.结论

第一，碳排放权交易试点政策可以促进能源转型。

第二，随着煤炭能源禀赋的提高和经济发展水平的下降，碳排放权交易试点政策能更有效地促进能源转型。

第三，碳排放权交易试点政策对能源转型的促进作用在高分位数点更为明显。

致谢

本研究得到教育部人文社会科学基金(2YJA790030)和中国地质大学(武汉)中央高校基本科研业务费(CUG2642022006)的资助。

奖励还是惩罚？企业策略性 ESG 披露的市场后果

王文娇[1]，孙自愿[1]
（1.中国矿业大学 经济管理学院，江苏徐州，221116)
wenjiaowang@cumt.edu.cn

研究背景

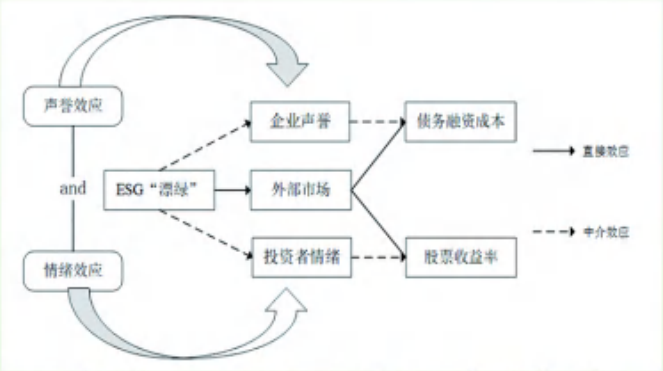
- ESG信息披露标准不统一
- ESG信息披露要求差异大
- ESG评价体系的构建尚待完善

ESG披露可能无法准确反映企业的实际ESG绩效，存在“口惠而实不至”、“报喜不报忧”的现象。这种策略性披露也叫做ESG“漂绿”

ESG被视为企业的“第二张财报”。作为信息劣势方的外部市场难以甄别企业、披露的真实性和有效性，甚至产生过度的积极反应，破坏了外部市场稳定性。

上述ESG披露带来的积极效应究竟是由于企业策略性的ESG“漂绿”还是真实的ESG实践，仍有待进一步检验。

研究假设与设计



- 假设1：ESG“漂绿”会在短期内降低企业债务融资成本。
- 假设2：ESG“漂绿”会在短期内提高企业股票收益率。

研究样本

本文选择2012-2021年沪深A股上市公司作为初始样本，并进行如下筛选：（1）剔除金融类、保险类、ST类和*ST类上市企业；（2）剔除主要变量缺失的企业；（3）为消除极端值影响，本文对所有连续变量进行1%的缩尾处理。最终共得到664家企业1818个观测值。关于ESG披露和ESG绩效的数据分别来自彭博ESG数据库和汤森路透的Asset4数据库(目前称为Refnitiv Eikon)。其他样本数据主要来源于CSMAR数据库以及CNRDS数据库。

研究结论

（1）外部市场并没有识别出企业ESG“漂绿”的策略性行为，ESG“漂绿”在短期内降低了企业债务融资成本提高了股票收益率， 然而这种误导效应并不持久。

（2）基于“声誉效应”和“情绪效应”的机制分析表明，ESG“漂绿”通过提升企业声誉来降低债务融资成本，通过提振投资者情绪来提高股票收益率。

（3）基于“GONE”舞弊理论的企业ESG“漂绿”成因分析表明，管理层短视主义、管理层权力过大、财务困境压力和信息不对称会导致企业采取不负责任的ESG实践，进行策略性的ESG披露。

（4）基于内外部治理的异质性分析表明，在独立董事监督高、四大审计、存在投资者实地考察和行业竞争程度高的情况下企业ESG“漂绿”的误导效应得到了一定程度的抑制。

“双碳”目标下数字金融赋能新型能源体系建设研究

韦金洪
中南财经政法大学金融学院

研究背景

新型能源体系建设是碳达峰碳中和目标实现的主战场，是实现经济高质量发展的重要保障。二十大报告着重强调“深入推进能源革命，加快规划建设新型能源体系”。据统计，2023年前三季度全国分布式光伏新增装机6714万千瓦，分步式能源体系已初现雏形。但由于新能源产业存在地理界线，传统的金融无法满足众多小型分散化新型能源体系投融资的需求，而具有打破地理空间壁垒、服务效率高、边际成本趋于零的数字金融为破解新型能源体系建设过程中投融资难题带来了新思路。

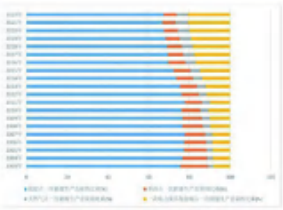


图1 我国一次能源接续替代情况

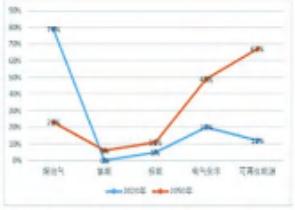


图2 2020年与2050年的能源格局占比变化

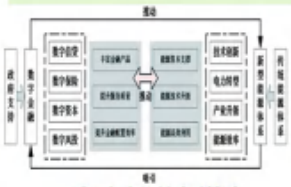


图3 耦合协调关联模型

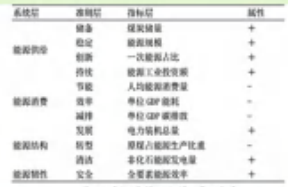


图4 新型能源体系测度

图5 基于计算机系统架构设计数字金融赋能新型能源体系

研究方法

- 基于2011-2021年中国地市级面板数据，使用熵值法，从能源供给、能源消费、能源结构、能源韧性四个维度构建了新型能源体系指标体系，运用城市、时间、个体固定模型、调节效应模型等实证检验了数字金融对新型能源体系建设的影响效应、机制和异质性。
- 运用计算机系统架构的思想，设计数字金融赋能新型能源体系建设的“互惠-共生-循环”系统架构。
- 采用模糊ISM-MICMAC模型解决路径优化问题。

赋能机制和路径

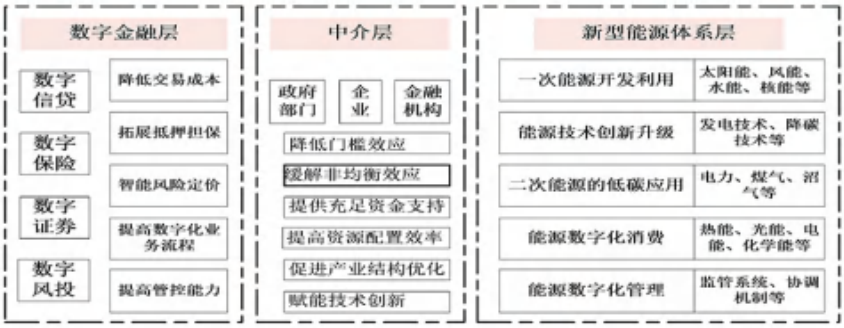


图6 数字金融赋能新型能源体系建设路径

- **数字银行赋能新型能源体系建设。**基于金融共生系统理论，构建“政府+新能源企业+数字金融机构”组成新型能源体系金融共生模式，形成政府合理补贴、数字金融机构积极放贷、新能源企业在数字金融赋能下推进新型能源体系的互惠共生系统。
- **数字保险赋能新型能源体系建设。**基于ESG理念，构建新型绿色低碳保险赋能架构，探索数字金融嵌入水电、风电、光伏等清洁能源保险、绿色建筑性能保险、森林生态碳汇保险、碳排放权交易相关保险等的赋能路径，革新新型能源体系建设保险机理。
- **数字资本赋能新型能源体系建设。**基于演化动力学理论，探索资本市场与能源产业的相互深化与依赖路径，探索低碳转型相关绿色基金产品、绿色债券产品的创新、清洁低碳能源行业供应链金融以及市场化投融资机理。
- **数字风投赋能新型能源体系建设。**基于创新驱动理论，构建风险投资资金在新型能源体系技术研发阶段的引进和退出机制，评价新型能源体系建设中技术吸收和溢出效应；基于学习曲线的投资成本演化理论，优化新型能源体系初创企业实现资本在生产经营、研发创新活动中的最大效用路径。

应用价值：运用数字金融赋能新型能源体系在一次能源开发利用、能源技术创新升级、二级能源低碳应用、能源数字化消费、能源数字化管理等环节上的优化。提出数字金融渗透到新型能源体系建设的互动协调规律，从数字金融赋能新型能源体系建设的源头和技术创新入手，优化数字金融赋能新型能源体系建设的路径，推进实施数字金融赋能理论的政策建议、制度保障体系以及优化调控对策。

研究结论

- **推动数字金融赋能新型能源体系的产能溢出效应。**融入ESG投理念、碳中和贡献度指标，促进数字金融赋能高碳企业转型、数字金融赋能新能源产业链发展。
- **打造新型能源体系建设与“双碳”目标充分结合的投融资平台。**配套数字技术赋能新型能源体系建设的系统化政策、推进数字技术赋能能源产业整合优化、完善数字技术赋能新型电力系统建设。
- **优化数字金融赋能新型能源体系建设的互动循环机理。**将数字金融嵌入到全国统一能源大市场建设中，运用顶层设计的思维，增强能源企业与金融机构之间建立价值转换机制，有效调剂能源与资金的余缺，提高能源生产端与消费端的互动，促进金融资本在生产企业中的有效循环。

中南财经政法大学 ZHONGNAN UNIVERSITY OF ECONOMICS AND LAW
作者简介：
韦金洪，中南财经政法大学博士生，研究方向为数字金融与新型能源体系，E-mail：weijinhong@stu.zuel.edu.cn。
该论文是国家社科一般项目（23BJY098）阶段性成果。，Phone:18077766916

农村居民清洁能源转型补贴机制设计

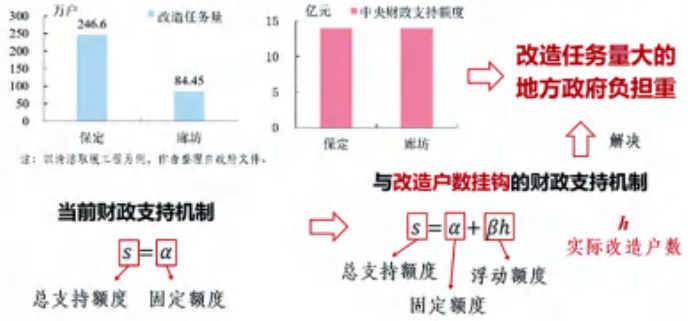
张睿宁 李慧
北京理工大学管理与经济学院 能源与环境政策研究中心

文字摘要：

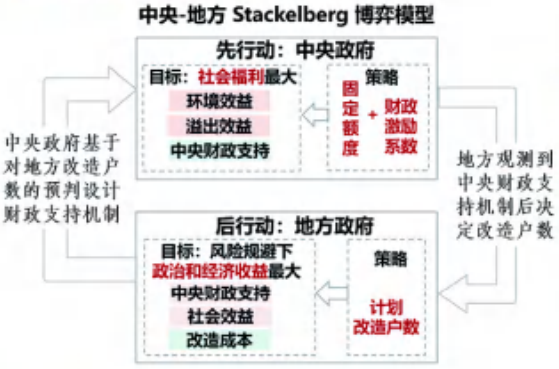
为促进农村家庭清洁能源可持续消费，设计科学、有效的农村居民清洁能源转型补贴十分关键，而中央财政投入机制在其中发挥重要作用。本文以农村居民“煤改气”工程为例，从央地关系出发，针对目前清洁取暖中央财政奖补资金标准根据试点城市规模分档确定、造成部分改造量大的城市负担重的现实问题，基于Stackelberg博弈方法，设计了一套“固定额度+绩效激励系数”的中央财政支持机制。中央政府作为先行动者，以社会福利最大为目标，设计最优的财政支持机制；地方政府作为后行动者，以地方政府经济和政治利益最大为目标，选择最优的计划改造户数。数理推导得出以下结论：改造成本高、环境效益大、风险规避程度高的地区，应设计更高的财政激励系数；对于改造成本小、环境效益大、风险规避程度低的地区，应设计更低的固定额度。中央政府财政支持预算上限越高，应设计更高财政激励系数和更低固定额度。以新一批清洁取暖试点城市呼和浩特为例进行分析，得出此时中央政府需支持的财政总额度为5.53亿元，相比于当前7亿元的中央财政支持额度可每年节约1.47亿元，三年累计节约4.41亿元。研究结果旨在为设计引导农村居民清洁能源转型的中央财政投入机制提供参考。

现实问题：

- 当前中央财政支持机制仅挂钩**城市行政级别**，未充分考虑实际改造户数。



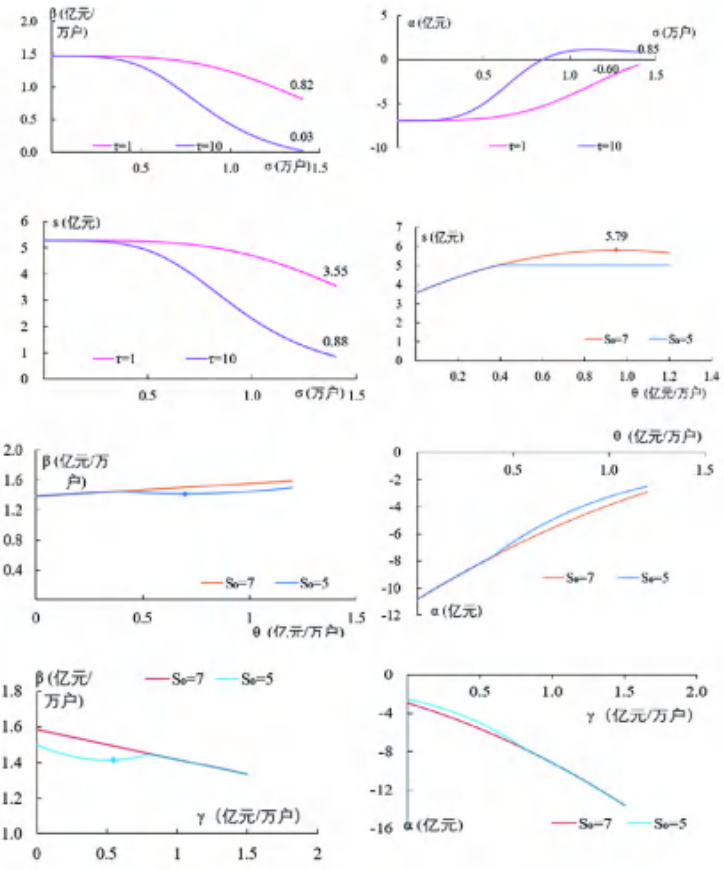
研究框架：



拟回答

- 中央政府**如何设计**财政支持机制调动地方改造积极性？
- **改造风险、改造成本、社会效益**等如何影响中央财政支持机制？

模拟结果：



结论与政策建议：

- 地方政府越**风险规避**，设计**越小**的财政激励系数和**越高**的固定额度
- 地方政府**补贴成本越高**，设计**越大**的财政激励系数和**越高**的固定额度
- 中央政府**预算上限越高**，设计**越大**的财政激励系数和**越低**的固定额度

以新一批清洁取暖试点城市呼和浩特为例：
在不减少改造量的情况下，本研究提出的财政支持机制可每年节约中央政府1.47 亿元。

- 可对“煤改气”推行有序的地区，通过典型**选树宣传、荣誉表彰**等手段给予激励。以降低中央政府补贴经济成本，有序促进农村清洁能源建设。
- **建议推行地区差异化的中央财政支持机制。**对改造不可控因素多(如降水多推迟工期)、地方政策保守的地区给予更高的“固定补贴”和更小的财政激励系数。

碳汇与碳捕集、利用和封存

Carbon Sinks and Carbon Capture, Utilization and Storage

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Artificial humic acid regulates the impact of fungal community on soil macroaggregates formation

AI Shuang[1], MENG Xiang-hui[1], ZHANG Zhou-xiong[1], LI Ronghui[2], TENG Wen-hao[2], CHENG Kui[1], YANG Fan[2]

1. College of Engineering, Northeast Agricultural University, Harbin 150030, China; 2. School of Water Conservancy and Civil Engineering, Northeast Agricultural University, Harbin 150030, China

Abstract

Background, Aims and Scope. Artificial humic acid (A-HA), which is synthesized from agricultural wastes with high similarity to natural humic substance (HS) extracted from soil, has been proven with potential for biological carbon sequestration in black soils by our group. However, the mechanism involved in A-HA application on soil aggregation process resulting from stimulation of microbial activities and changes in microbial communities remains unclear.

Methods. This study investigated the correlation between the formation and stability of soil aggregate and fungal communities with various amounts of A-HA addition in the rhizosphere and non-rhizosphere soil.

Results and Discussion. A-HA can increase TOC and DOC concentrations in soil, promoting macroaggregate formation and increasing mean weight diameter (MWD). In addition, soil aggregates binding agents such as polysaccharide, protein, extracellular polymeric substances (EPS), and glomalin-related soil protein (GRSP) were significantly increased by adding A-HA. A-HA can drive microaggregate to assemble to macroaggregate by increasing the abundance of beneficial fungi (*e.g.*, *Talaromyces* and *Mortierella*). The co-occurrence network supported that A-HA shifted the key species and increased interactions of fungal taxa.

Conclusion. A theoretical basis was provided that A-HA can drive microaggregate to assemble to macroaggregate through increasing the abundance of beneficial fungi (*e.g.*, *Talaromyces* and *Mortierella*) in the rhizosphere 509and non-rhizosphere soil. The results provide a possibility for the wide application of A-HA to soil fertility restoration in the future.

Keywords: Artificial humic acid (A-HA); Soil organic carbon; Aggregate formation; Carbon stability; Fungal community

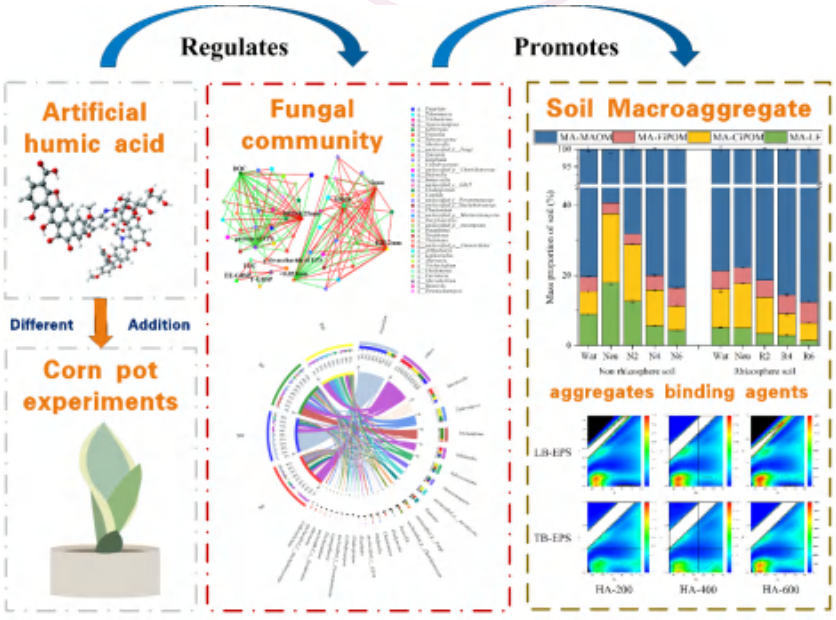


Fig 1 Artificial humic acid drives the formation of soil macroaggregates

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Cu-Cu atomic spacing effect enhancement strategy for efficient CO_2 utilization

BI Xin-ze[1], WANG Hong-zhi[2], WU Ming-bo[1]
(1. State Key Laboratory of Heavy Oil Processing, China University of Petroleum (East China), Qingdao 266580, China; 2. College of Chemistry and Chemical Engineering, Ocean University of China, Qingdao 266100, China)

Abstract
In the process of electrocatalytic CO_2 reduction for the preparation of high-value C2+ products, the relatively high thermodynamic barrier of C-C coupling hinders the coupling step, resulting in poor selectivity of the target products. C-C coupling often involves the cooperative adsorption of carbon-containing intermediates by two Cu atoms and subsequent coupling. Precise control of the distance between adjacent Cu active sites is crucial for promoting the C-C coupling process and improving the selectivity of C2+ products. The existing spacing enhancement effects are generally limited to single-atom catalyst systems. The loading of single-atom catalyst is generally low and it is difficult to provide multiple metal-metal atomic active sites, which often implies disadvantages against the C-C coupling step as well as the C2+ products. Moreover, due to current experimental techniques, it is challenging to precisely regulate the Cu-Cu distance between two Cu atoms on bulk catalysts. Density functional theory (DFT), as a quantum mechanical method for studying the electronic structure of multi-atomic systems, not only is used to verify experimental results but also provide theoretical basis for material design or reaction mechanisms. In this work, DFT as a research tool is used to help screen for the optimal Cu-Cu atomic distance and explore experimental strategies for precise control of atomic distances. Guided by DFT calculations, a strategy of regulation the Cu-Cu atomic spacing based on vacancy defect engineering is proposed to promote the C-C coupling process, thereby enhancing the catalytic activity of the catalyst and the selectivity of ethanol. Accordingly, ultrathin two-dimensional vanadium selenide-copper selenide nanosheets (V_{Se}-$Cu_{2-x}Se$) with abundant Se vacancies were prepared. Under the lattice strain caused by the abundant Se vacancies, the spatial distance between Cu-Cu atoms is effectively shortened. The charge distribution at the active site is altered by the shortened Cu-Cu atomic distance. Besides, the shortening of the Cu-Cu atoms distance also reduces the oxidation state of Cu and increases the electron donating ability of the active sites. Importantly, the shortened Cu-Cu atomic distance significantly reduces the thermodynamic barrier of the *CO-*CHO asymmetric coupling process, promoting the C-C coupling process. Combining experimental observations and DFT calculations, it is found that the Cu-Cu atomic distance of 2.51 Å selectively produce ethanol in the voltage range of -0.4 to -1.6 V (vs. RHE), with an faradaic efficiency of ethanol as high as 68.1% at -0.8 V potential. The V_{Se}-$Cu_{2-x}Se$ prepared based on this strategy effectively improved the selectivity of ethanol by utilizing the spacing effect of dual-active sites, achieving efficient electroreduction of CO_2 to ethanol, and providing new ideas for the regulation and preparation of catalysts for other reactions involving multi-electron-coupled protons.

Key words: spacing effect; CO_2ER; C-C coupling; defect engineering

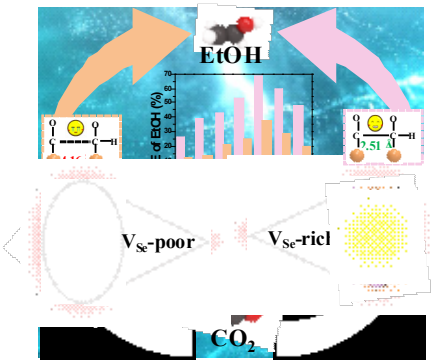


Fig 1 Efficient electrocatalytic reduction of CO_2 to ethanol enhanced by spacing effect of Cu-Cu in $Cu_{2-x}Se$ nanosheets.

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Feasibility analysis of long-term CO_2 sequestration as hydrates in subsea sediments

Gu Yuhang[1], Yin Zhenyuan[1,*], Liu Xuejian[1], Huang Hailin[1], Li Shuaijun[1]
(1. Institute for Ocean Engineering, Tsinghua Shenzhen International Graduate School, Tsinghua University, Shenzhen 518055, China)

Abstract

Background, Aims and Scope. Hydrate-based CO_2 sequestration in subsea sediments is a promising way to reduce carbon emissions. However, current studies mainly focus on lab experiments and lack field-scale feasibility analysis. Therefore, we aim to verify the feasibility of this sequestration method at field-scale and quantitatively analyze effects of permeability, salinity, thermal conductivity and CO_2 injection rate on sequestration performance.

Methods. Hydrate-based CO_2 sequestration in subsea sediments is a complex multiphysics process, involving multiphase flow, heat transfer and hydrate formation and dissociation. To accurately characterize this process, we develop a novel thermo-hydro-mechanical multi-field coupled simulator CO2_HYD based on the state-of-art TOUGH + HYDRATE code. The framework of TOUGH + HYDRATE is maintained while we modify the primary variable switch method (PVSM) for possible phase changes in liquid CO_2 - CO_2 hydrate system during sequestration (Fig. 1). We adopt Peng-Robinson equation to calculate the density of liquid CO_2 at varying pressure and temperature. We introduce calculation method of Spycher et al. (2003) to consider the solubility of liquid CO_2 in H_2O and incorporate the friction theory (Quiñones et al., 2000) for viscosity modeling of liquid CO_2. As for thermophysical properties of CO_2 hydrate, we replace the original methane hydrate phase equilibrium with the CO_2 hydrate phase equilibrium curve derived from CSMGem, and consider the effect of NaCl on phase equilibrium using the equation of Dickens and Quinby-Hunt (1997). In addition, we modify a series of properties associated with CO_2 hydrate, including enthalpy of formation, density, thermal conductivity, and heat capacity.

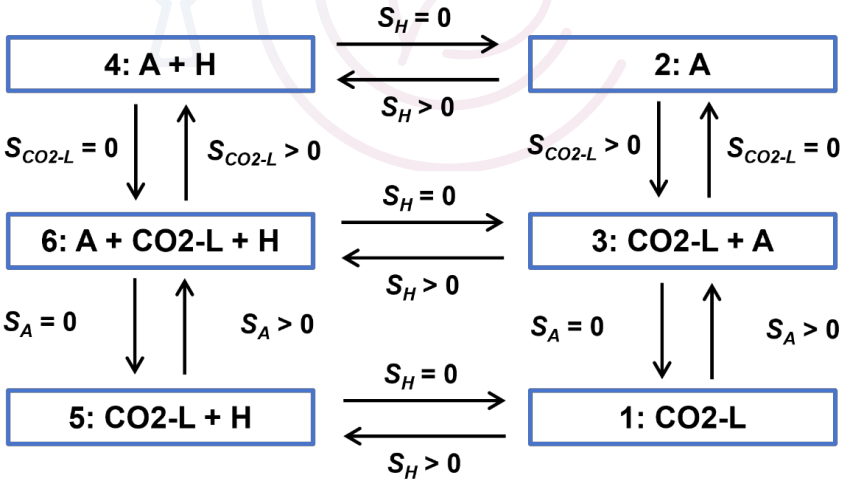


Fig. 1. Possible phase combinations in the liquid CO_2-CO_2 hydrate system (The designations of three single phase are CO2-L – liquid CO_2, A – aqueous, H – CO_2 hydrate).

Results and Discussion. The simulation results reveal that CO_2 component exists mainly as liquid and dissolved phases during CO_2 injection, with very little hydrate formed above the injection interval due to the high-temperature area around the well. At the end of injection (t = 5 y), the mass fraction of liquid CO_2 is ~70%, dissolved CO_2 is ~29%, and CO_2 in hydrate phase only accounts for ~1%. After the end of injection (t > 5 y), the temperature around the well decreases rapidly, and a large amount of hydrate forms and gradually expands to form a low-permeability cap. At t = 100 y, the mass fraction of liquid CO_2 is ~17%, dissolved CO_2 is ~41%, and CO_2 in hydrate phase is ~42%. The phenomenon of massive hydrate formation during sequestration which greatly restricted upward CO_2 migration verifies the long-term stability of hydrate-based CO_2 sequestration at field-scale. In addition,

permeability, salinity, thermal conductivity and CO_2 injection rate all have significant impacts on the sequestration performance. The conversion of liquid CO_2 to CO_2 hydrate decreases with increasing permeability, salinity and injection rate, and increases with increasing thermal conductivity (Figs. 2 and 3).

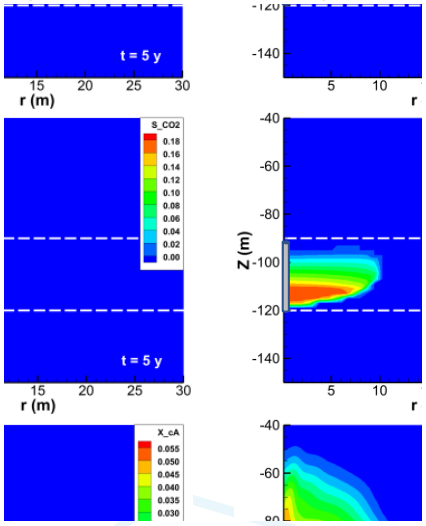


Fig. 2. Distributions of typical properties (S_H, $S_{CO2\text{-}L}$ and X_{CO2}) of the formation at t = 5 y and t = 100 y.

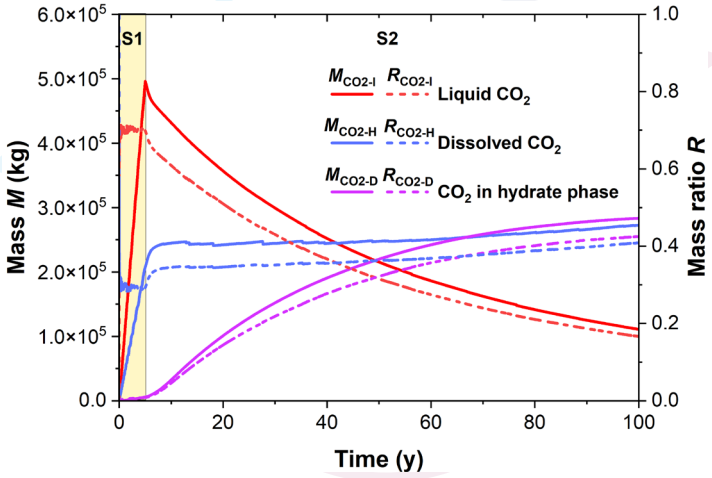


Fig. 4. Evolutions of mass M and mass ratio R of CO_2 component in different phases (S1: 0-5 y; S2: 5-100 y).

Conclusion. The present work builds a novel multi-field coupled simulator and numerically investigates the feasibility of carbon sequestration in subsea sediments by hydrate method at field scale for the first time. The results show that CO_2 hydrate massively forms after the end of injection and gradually expands into low-permeability cap that can stably exists for 100 years. The hydrate cap greatly restricts upward migration of liquid CO_2, forcing it to gradually transform into dissolved phase and hydrate phase, which makes hydrate-based CO_2 sequestration feasible. Permeability, salinity, thermal conductivity of the formation and CO_2 injection rate all have significant impacts on the sequestration performance, which provides guidance for site selection and optimization of injection scheme.

Key words: CO_2 sequestration; CO_2 hydrate; feasibility analysis; long-term stability; numerical code; CCUS

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Embedded Mo/Mn Atomic regulation for Durable Acidity-reinforced HZSM-5 Catalyst toward Energy-efficient Amine Regeneration

Mingyue Li[1]
(1. MOE Key Laboratory of Resources and Environmental Systems Optimization, College of Environmental Science and Engineering, North China Electric Power University, Beijing, 102206, PR China)

Abstract

Background, Aims and Scope. Metal–molecular sieve composites with high acidity are promising solid acid catalysts (SACs) for accelerating sluggish CO_2 desorption processes and reducing the energy consumption of CO_2 chemisorption systems. However, the production of such SACs through conventional approaches such as loading or ion-change methods often leads to uncontrolled and unstable metal distribution on the catalysts, which limits their pore structure regulation and catalytic performance.

Research methods. In this study, we demonstrated a feasible strategy for improving the durability, surface chemical activity, and pore structure of metal-doped HZSM-5 through bimetallic Mo/Mn modification. The excellent activity of the catalyst has been proved by many experiments.

Results and Discussion. This strategy involves the immobilization of Mo–O–Mn species confined in a MFI structure by regulating MoO_4^{2-} anions and Mn^{2+} cations. The embedded Mn/Mo species of low valence can strongly induce electron transfer and increase the density of compensatory H^+ on the MoMn@H catalyst, thereby reducing the CO_2 desorption temperature by 8.27 °C and energy consumption by 37% than blank.

Conclusion. The durability enhancement and activity regulation method used in this study is expected to advance the rational synthesis of metal–molecular sieve composites for energy-efficient CO_2 capture using amine regeneration technology.

Key words: CO_2 capture; amine scrubbing; catalytic CO_2 desorption; metal–molecular sieve composites; structure regulation

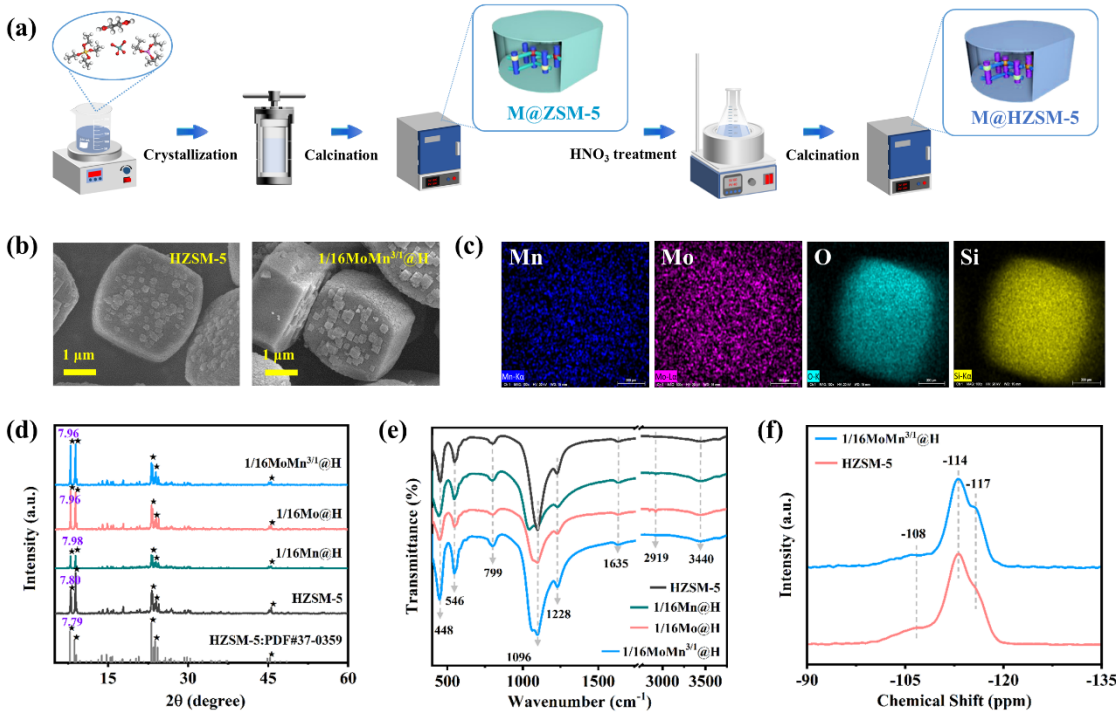


Fig 1 (a) Schematic diagram of synthesis process of catalysts; (b) SEM of HZSM-5 and 1/16MoMn$^{3/1}$@H; (c) Elemental mapping of 1/16MoMn$^{3/1}$@H; (d) XRD patterns of the 1/16MoMn$^{3/1}$@H, 1/16Mo@H, 1/16Mn@H and HZSM-5; (e) FTIR spectra of various catalysts; (f) ^{29}Si NMR spectra of the 1/16MoMn$^{3/1}$@H and pristine HZSM-5.

Fig 2 (a) Mn 2p and Mo 3d XPS spectra of 1/16MoMn$^{3/1}$@H; (b) O1s XPS spectra of various catalysts; (c) Mn K-edge XANES spectra of MoMn@H, MnO_2, and Mn foil; (d) Fourier transform of k^3-weighted EXAFS spectra; (e) N_2 adsorption-desorption isotherms of various catalysts; (f) Pore-size distribution curve of the 1/16MoMn$^{3/1}$@H, 1/16Mo@H, 1/16Mn@H and HZSM-5; (g) EIS curves of different catalysts. (h) NH_3-TPD profiles of various catalysts; (i) Py-IR profiles of various catalysts.

Fig 3 Comparison of CO_2 capacity and desorption rate catalyzed by various catalysts: (a) monometallic M@H; (b) Mo@H with different Mo dosage; (c) MoMn@H with various Mo/Mn ratios (inset: CO_2 capacity at 30 min, sample 1 to 6 is assigned to blank, 1/16Mn@H, 1/16MoMn$^{1/3}$@H, 1/16MoMn$^{2/2}$@H, 1/16MoMn$^{3/1}$@H and 1/16Mo@H, respectively); (d) Comparison of activation energy (E_a) of CO_2 desorption reaction under blank and catalytic conditions; (e) Arrhenius Plot under catalytic and blank conditions at different temperatures; (f) Comparison of energy consumption; (g) Long life cycle curves for 10h; (h-i) Comparisons of catalytic rich MEA solution regeneration performances with different reported catalysts.

Fig 4 (a) Possible catalytic mechanism for MoMn@H to promote CO_2 desorption in MEA solutions; (b-c) Relative energies of key reaction paths under different catalytic conditions.

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Hydrology and primary production affect dissolved organic matter composition and contribute to its stability throughout the Aquatic Continuum of Semiarid region of China

SHAO Ming-yu[1,2], LIU Zai-hua[1]
(1. State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550081, China; 2. University of Chinese Academy of Sciences, Beijing 100049, China)

Abstract
Dissolved organic matter (DOM) plays crucial role in carbon cycling within inland surface waters. However, there is limited research on the effects of primary production and hydrology on the composition of DOM across the river-reservoir-wetland aquatic continuum and the stability of the resulting autochthonous DOM (Auto-DOM). We combined measurements of water chemistry, optical spectroscopy, Fourier transform ion cyclotron resonance mass spectrometry, and stable isotopic measurements ($\delta^{2}H$, $\delta^{18}O$ and $\delta^{13}C_{DIC}$) to elucidate the link between in-stream hydrological and primary production processes and DOM composition throughout the Aquatic Continuum of Bahe River in Northwest China. We found that significant evaporation and aquatic primary production co-occurred in this watershed, with a large amount of water loss and DIC assimilation in the water column. With enrichment of the stable water isotope $\delta^{2}H$, the relative abundances of the humic-like compounds decreased and the relative abundances of the protein-like substances increased, suggesting that humification degree and terrestrial signal of riverine DOM decreased while autochthonous production increased along the flow pathway. In addition, we chose the summer with high primary production to further investigate the stability of Auto-DOM and observed that the stability ratio (Fmax(C2/(C2+C4))) of Auto-DOM to the ratio of carboxylic-rich alicyclic molecules in different water bodies had a consistent trend, suggesting that the phytoplankton-derived and biomineralized C2 compound is a potentially recalcitrant DOM in inland waters. We conclude that hydrology and primary production affect DOM quality and may be potential sources of recalcitrant DOM compounds in a wide range of inland waters, which has important implications for understanding the role of inland waters in the global carbon cycle.
Keywords: Aquatic photosynthesis, Autochthonous dissolved organic matter, Stable water isotope, Stability, Carboxylic-rich alicyclic molecules

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Investigating competitive adsorption of CO_2 and H_2O in direct air carbon capture

SHEN Minghai[1,2], KONG Fulin[1], GUO Wei[1], ZUO Zhongqi[1], TONG Lige[1], ZHANG Peikun[1], WANG Li[1], KAWI Sibudjing[2], CHU Paul K[3], DING Yulong[4]

(1. School of Energy and Environmental Engineering, University of Science and Technology Beijing, Beijing 100083, China; 2. Department of Chemical and Biomolecular Engineering, National University of Singapore, 4 Engineering Drive 4, Singapore 119260, Singapore; 3. Department of Physics, Department of Materials Science and Engineering, and Department of Biomedical Engineering, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, China; 4. Birmingham Centre for Energy Storage & School of Chemical Engineering, University of Birmingham, B15 2TT, UK)

Abstract

Direct air carbon capture (DAC) techniques enable the capture of carbon dioxide from the atmosphere to mitigate carbon emissions and reduce the concentration of carbon dioxide in the atmosphere. Since the adsorption capacity of the adsorbent for H_2O is lower than that of CO_2, direct capture of CO_2 in the air will reduce the adsorption capacity and adsorption efficiency due to the competitive adsorption of H_2O and CO_2. The traditional capture method is chemical absorption or drying the air first to capture CO_2 separately. Green and environmentally friendly physical adsorption technology that captures CO_2 and H_2O together can reduce equipment space, system complexity and energy consumption. The competitive adsorption of CO_2 and H_2O has an important impact on direct air carbon capture and carbon capture from wet flue gases. I will demonstrate our discovery and control methods of the competitive adsorption rules of CO_2 and H_2O in direct air carbon capture. Through molecular dynamics and various characterization methods, we compared and analyzed the pore size changes, CO_2 and H_2O adsorption energies, and CO_2 separation effects of NaX zeolite under the temperature effect and electric field. The reasonable optimization of pore size structure and the distribution of Na^+ ions have an important impact on the competitive adsorption of CO_2 and H_2O. We believe that the Na^+ sites can be fixed through the rational design of the O-T-O (T = Al, Si) framework. Owing to the E-field formed by the plasma and exposure to CO_2, it morphs into a stable low-energy structure that can accommodate more CO_2. By increasing the surface area and adsorption sites for CO_2, the NaX zeolite after the dual plasma treatment and CO_2 exposure for 60 minutes shows the highest adsorption capacity of 5.49 mmol·g^{-1}. By increasing the desorption energy consumption of the NaX zeolite by 5.88%, more efficient and larger-capacity low-concentration carbon dioxide capture can be accomplished. By inhibiting the adsorption of H_2O or separating adsorption sites, high-capacity co-adsorption of CO_2 and H_2O can be achieved. In the co-recovery process of CO_2 and H_2O, separation and recovery of high-purity CO_2 and H_2O can be achieved according to the desorption law of CO_2 and H_2O. Our results disclose that by proper design of the materials and separation technology, joint capture and recovery of CO_2 and H_2O by a direct air carbon capture system can be accomplished.

Key words: carbon dioxide; water; adsorption; carbon capture; direct air carbon capture

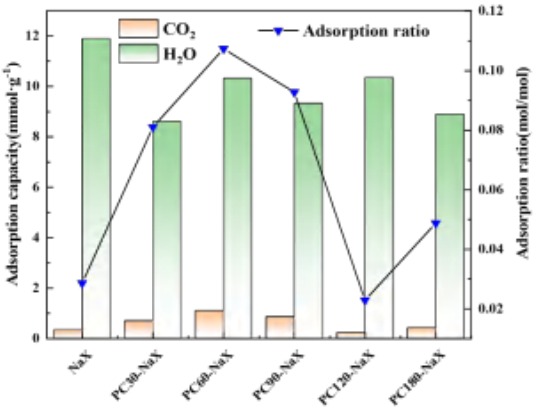


Fig 1 Adsorption capacity and separation ratio of CO_2 and H_2O in an atmosphere of 400ppmCO_2 and RH40%.

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Biological mechanisms affecting the release of greenhouse gases from microbial fuel cell - constructed wetland by simultaneously altering structure and electron shuttles

WANG Qing-hua[1], LIANG Ya-yi[1], TANG Jiang-kang[1], PU Zhen-bin[1], HUANG Lei[1, 2, 3]
(1. College of Resources and Environment, Southwest University, Chongqing 400715, China; 2. Chongqing Key Laboratory of Agricultural Resources and Environment, Chongqing 400716, China, 3. Chongqing Engineering Research Center of Rural Cleaner Production, Chongqing, 400716, China)

Abstract

Background, Aims and Scope. The objectives of this study were (1) to assess the role of different structures and electron shuttles in influencing pollutant removal and greenhouse gas emissions from the system; (2) to study the microbial communities and functional genetic changes in different systems; and (3) to reveal the interaction between greenhouse gas emission reduction, electron transfer and microorganisms.

Methods. Four groups of wetlands were constructed, those in which the anaerobic and aerobic zones were separated (named SC), those in which the anaerobic and aerobic zones were not separated (named IC), and those in which iron and carbon materials were added separately were named SFC and IFC, respectively. The static chamber method was used to collect gas samples, and the concentration of greenhouse gas was measured via gas chromatography (7890D, Agilent, USA). High-throughput sequencing and functional gene results were obtained by sending sludge samples to Shanghai Meiji Biomedical Technology Company. SPSS 23.0 was used for one-way ANOVA and Pearson correlation analysis. Origin 2021, R software (version 4.3.0) and Gephi interactive platform were used for graphical analyses.

Results and Discussion. Changing the structure increased the removal effect of NH_4^+-N, and the NH_4^+-N removal rate was about 100% in the split system. The addition of iron carbon in the split system decreases the removal of pollutants, while the opposite phenomenon occurs in the integrated system, which may be due to the fact that the electron transfer generated by the ferrocarbon microelectrolysis may be limited to the filler that is in contact with the ferrocarbon material. The cumulative release of N_2O and CH_4 in SC was reduced by 51.83% and 89.33%, respectively, compared to IC. And by changing the structure 42.66% of N_2O was increased and 64.96% of CH_4 was decreased in the iron-carbon system. Altering the structure and adding iron-carbon electron shuttles affected nitrogen removal efficiency and GHG emissions by altering the relative abundance of nitrifying, denitrifying, and electrochemically active bacteria, such as *Nitrospira*, *Azospira*, *Thauera*, norank__f__norank__o___*Saccharimonadales*, *Dechloromonas*, *Denitratisoma*, norank__f__*Saprospiraceae* and norank_f_*Bacteroidetes_vadinHA17*. In addition, two changes occurring in MFC-CW affected functional genes related to the production of greenhouse gases.

Conclusion. (1) Greenhouse gas emission reduction and pollutant removal were further enhanced by adding iron carbon or changing the system structure based on the incorporation of microbial fuel cells into constructed wetlands. (2) Changing the structure and adding iron carbon had an interactive effect that could affect functional gene abundance by enhancing the interaction of functional bacteria with electrochemically active bacteria, which in turn enhanced pollutant removal and reduced greenhouse gas release. (3) Changing the structure may be more appropriate in systems without added iron-carbon, otherwise the benefits of adding iron-carbon electron shuttles are offset by separating the aerobic and anaerobic zones of the iron-carbon system.

Key words: MFC-CW; greenhouse gas emission; microbial communities; functional gene

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Amine-functionalized disordered hierarchical porous silica derived from blast furnace slag with high adsorption capability and cyclic stability for CO2 adsorption

Huangyu Yan (Taiyuan University of Technology)

This study proposes a novel solution to the challenge of achieving high cycle stability in CO2 adsorbents prepared through impregnation with organic amines. Specifically, industrial waste blast furnace slag was used to prepare a support material called BHF, which possesses three pore structures: micropores, mesopores, and macropores. This unique structure facilitates high loading of organic amines and improves CO2 adsorption effectiveness. To counteract agglomeration effects caused by loading large amounts of organic amines, the morphology and skeleton of the carrier material were analyzed in detail. The results showed that the rough “hive” morphology, disordered cell-like skeleton structure and abundant pores of BHF allows for uniform dispersion of pentaethylenehexamine (PEHA), an organic amine, and provides advantageous transportation of CO2 molecules within the adsorbent. Based on the study of kinetics, activation energy, and isosteric heat of adsorption, the adsorption mechanism of 70PEHA-BHF was determined to be a chemical-physical binding adsorption. The adsorption diffusion mechanism suggests that the rate-limiting step is film diffusion. Furthermore, the 70PEHA-BHF adsorbent achieves a balance between CO2 adsorption capacity and cycle stability. At 80 ◦C and 15 vol. % CO2, the CO2 adsorption capacity of 70PEHA-BHF is 6.27 mmol/g, with only a 1.43 % CO2 loss after 10 cycles of testing. It anticipates that this newly developed 70PEHA-BHF adsorbent will provide additional possibilities for the application of hierarchical porous materials in CO2 adsorption research.

碳汇与碳捕集、利用和封存 Carbon Sinks and CCUS

Research on multi-site synergetic carbon capture characteristics of Cu-based ionic metal organic frameworks (I-MOFs) constructed by *in-situ* immobilization of ionic liquids

ZHANG Yuke[1], WANG Jiancheng[1], YI Qun[2], SHI Lijuan[2]
(1. State Key Laboratory of Clean and Efficient Coal Utilization, Taiyuan University of Technology, Taiyuan 030024, China; 2. School of Chemical Engineering and Pharmacy, Wuhan Institute of Technology, Wuhan 430205, China;)

Abstract

Background, Aims and Scope. As an important emission reduction technology, high-efficiency capture and separation of CO_2 is highly desirable to implement low-carbon development strategy. Ionic liquids (ILs), with low volatility, is proposed to solve the corrosion problem of equipment in the traditional ammonia solution absorption process, which, yet faces with the challenge regards of high viscosity and unsatisfactory regeneration performance.
Methods. Immobilization of ILs has diversified the field of porous solid adsorbents. Ionic-metal organic frameworks (I-MOFs), which combines the functions of ILs and rich pores of framework structure, are extensively applied for gas adsorption and separation. Conventional methods such as covalent grafting, ship-in-a-bottle, or impregnation have been developed to immobilize ILs on the surface or channels of MOFs. For the narrow microporous environment, the strategies aforementioned inevitably cause channel blockage (tricky to retain the ultramicropores structure), fussy steps, and endowed with uneven distributed of functional sites. Herein, serving as competitive ligands candidates in the formation of I-MOFs, ionic functional groups (represented by ILs) are introduced as part of the I-MOFs skeleton, which can improve the active sites distribution and retain pore micro-environment.
Results and Discussion. In this work, microporous I-MOFs (Cu-AFIL-M) were constructed in one step by using 1-aminoethyl-3-methylimidazolium phenoxylate (AFIL) and BTC as mixed organic ligand. The oxyl group exhibits high affinity with CO_2 as the Lewis basic center bringing about superior CO_2 adsorption capacity of 149 cm^3 g^{-1} (150% higher than that of Cu-BTC) and high IAST predicted selectivity with CH_4 of 22 under atmospheric condition.
Conclusion. The isosteric adsorption heat, CO_2-TPD and density functional theory reveal that the adsorption mechanism is the ion basic center and unsaturated metal active sites, and there is electrostatic attraction and hydroxyl bonding between CO_2 and modified functional groups. This work provides a feasible strategy for the rational design of I-MOF and lays useful insights for structural tuning to promote their applications.
Key words: Carbon dioxide capture; solid adsorbent; ionic liquids; Immobilization

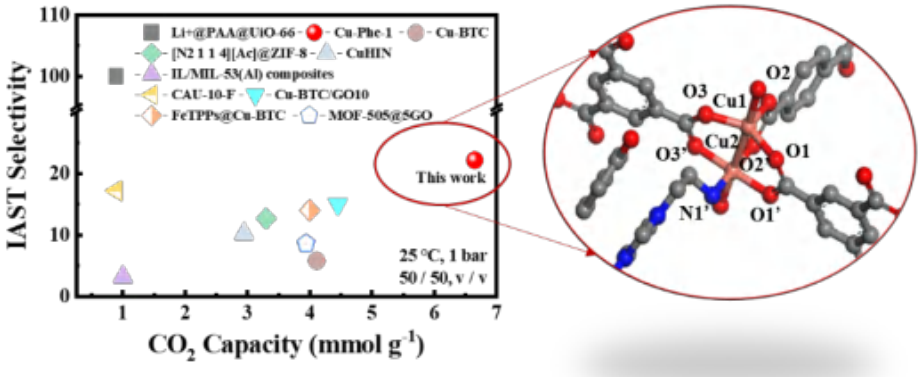


Fig 1 Comprehensive performance comparison of the IAST selectivity and CO_2 adsorption performance

A Study on the Price of Carbon Sinks in China's Marine Fisheries

Yuan Chai, Xiaoli Zhang
College of Marine Culture and law, Shanghai Ocean University, Shanghai 201306, China
Institute of Marine Science, Shanghai Ocean University, Shanghai 201306, China
E-mail address: chaixianrun@163.com

Background, Aim and Scope

The carbon sink function of cultured shellfish and algae is an important aspect of marine ecosystem. Their significant carbon sequestration potential provides a valuable means to enhance ecological sequestration. Studying the price mechanism for ecological sequestration of shellfish and algae will facilitate the participation of marine fishery carbon sink in domestic voluntary emission reduction market trading and international carbon emission rights trading. This will enable the realization of the ecological value of China's marine fisheries. Currently, there is a dearth of research on the pricing of carbon sinks in marine fisheries. The pricing of carbon sinks in marine fisheries is constrained by the imperfect measurement and accounting methods used for carbon sinks. Based on a review of relevant literature, this study proposes the intrinsic value of China's fishery carbon sink.

Method

Specifically, it aims to determine the shadow price of China's marine fishery carbon sink by analyzing the data on shellfish and algae culture in marine fisheries from 1979 to 2022. The study establishes a model that goes beyond logarithmic production and utilizes ridge regression estimation and testing, and then find out the price of carbon sinks in marine fisheries according to the formula:

$$P(c_t) = \frac{Y_t}{c_t}(\beta_c + \beta_{lc}\ln l_t + \beta_{kc}\ln k_t + 2\beta_{cc}\ln c_t)$$

Figure1 ridge plot of each variable in model

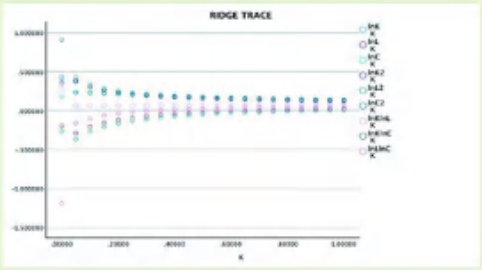


Figure2 Goodness of fit plots of models under different ridge trace values

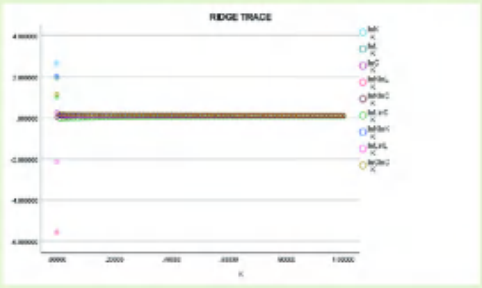
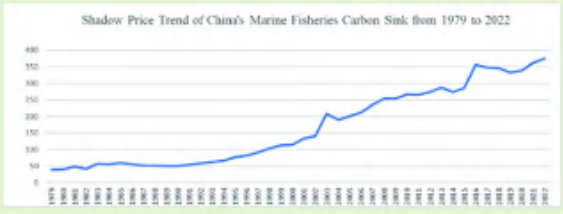


Figure3 shadow price trend of China's Marine Fisheries Carbon sink from 1979-2022



Results and discussion

Finally, the shadow price of China's marine fishery carbon sink is calculated for the period from 1979 to 2022. The table below show that the value of parametric of formula

Table1 the estimated values of β_c 、β_{lc}、β_{kc}、β_{cc}

参数	β_c	β_{lc}	β_{kc}	β_{cc}
估计值	0.3540	-0.0040	0.0106	0.0138

Conclusion

- This study primarily focuses on the trading price of carbon sequestration in marine fisheries.
- The present study aim to find out the price mechanism of methodology of marine fishery carbon sequestration promptly.
- This will accelerate the realization of the ecological and economic value of marine fishery carbon sequestration.

CO_2 Photoreduction to C_2H_4 on Conjugated Microporous Polymer with Cu SAs

LI Jing[1], WANG Jin[1, 2, *]

1. School of Environment, Beijing Key Laboratory of Aqueous Typical Pollutants Control and Water Quality Safeguard, Beijing Jiaotong University, Beijing 100044, China;
2. Tangshan Research Institute, Beijing Jiaotong University, Tangshan 063000, China.

Background and Aims

Selective conversion of CO_2 to fuels and chemicals has been considered one of the key challenges in the photocatalytic CO_2 reduction reaction. The present study aimed to design and synthesize photocatalysts that can adsorb CO_2 and transfer electrons.

Methods

We choose hexachlorocyclophosphazene (HCPP) and 1,3,5-triethynylbenzene as the monomers of CMP, where HCPP is rich in N and P elements and has good CO_2 adsorption capacity, while the ethyl in 1,3,5-triethynylbenzene has electron transfer capacity. Cu single atoms loaded CMPs with a series Cu contents (Cu_n@CMP, n = 0.006, 0.012, 0.024, 0.030, and 0.048 mmol) were constructed for catalyzing CO_2 reduction into CH_4 and C_2H_4 under visible light (300 W Xe lamp with a 420 nm cut-off filter).

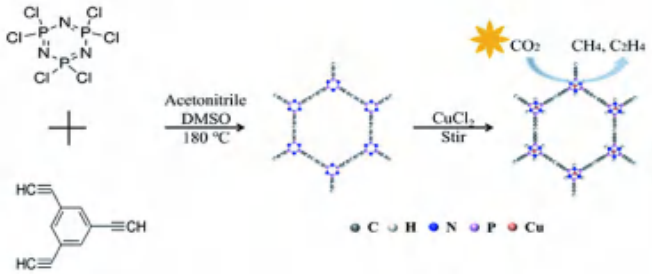


Fig 1. Synthesis and structural characterizations of $Cu_{0.012}$@CMP.

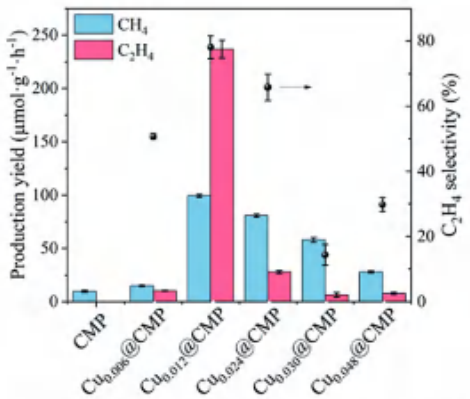


Fig 2. Photocatalytic performance and C_2H_4 selectivity for CO_2 reduction of CMP with different Cu catalysts.

Results

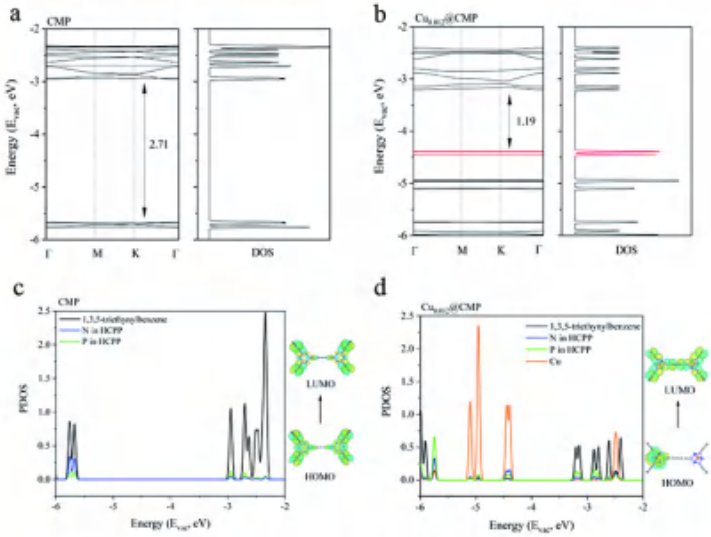


Fig. 3. Band structures and DOS of (a) CMP and (b) $Cu_{0.012}$@CMP. For the purpose of comparison, the contribution of Cu SAs in the band structures was distinguished by red coloring. PDOS and HOMO-LUMO transitions of (c) CMP and (d) $Cu_{0.012}$@CMP.

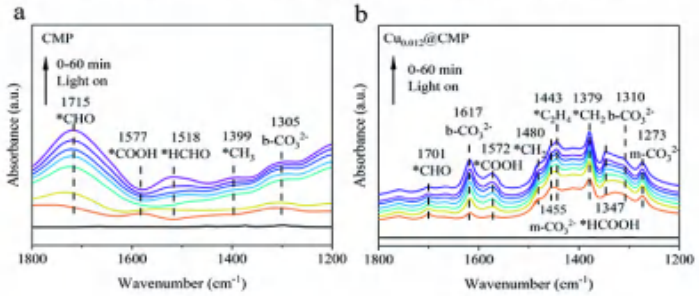


Fig 4. *In situ* DRIFTS measurement using (a) CMP and (b) $Cu_{0.012}$@CMP as a catalyst under the dark and visible light irradiation, respectively.

Conclusions

The synergistic effect in the $Cu_{0.012}$@CMP leaded to a high total yield (236.81 μmol·g^{-1}·h^{-1}) for the conversion of CO_2 to C_2H_4 with high selectivity (78.2%). The *in situ* DRIFTS spectra further confirmed the C-C coupling and possible reaction pathway by discussing the surface species formed during the photocatalysis. The synergistic function of Cu SAs and CMP could lower the overall activation energy barriers for CH_4 and C_2H_4 formation processes, which was the key factor to enhance the production of CH_4 and C_2H_4.

Keywords: conjugated microporous polymer; Cu single atoms; synergistic effect; CO_2 photoreduction; highly selective ethylene production.

Acknowledgments: Fundamental Research Funds for the Central Universities [No. 2021YJS130].

Wildfire evidence in the Jurassic coal from Xinjiang and its paleoclimate effect

LU Qing-feng[1,2,*], SANG Shu-xun[1,2], WANG Wen-feng [1,2]

[1]Jiangsu Key Laboratory of Coal-based Greenhouse Gas Control and Utilization, Carbon Neutrality Institute, China University of Mining & Technology, Xuzhou 221008, China; [2]Key Laboratory of Coalbed Methane Resources & Reservoir Formation Process, Ministry of Education, School of Resources and Geosciences, China University of Mining & Technology, Xuzhou 221116, China. (*corresponding E-mail: luqingfeng@cumt.edu.cn)

1. Introduction

Wildfires are important events in geological history. Wildfires emit large amounts of carbon monoxide, carbon dioxide and heat, causing temperature increases, climate change, and affecting the growth of plant and animal. Charcoal, the product of incomplete combustion of wildfire, is equivalent to fusain and inertinite. Because of its stable aromatic structure and inoxidizability, charcoal can be preserved in sedimentary strata for a long time. The Jurassic is the primary coal-forming period in Xinjiang, with abundant coal resources. The Jurassic coal are characterized by enrichment of inertinite, providing a possibility for studying Jurassic wildfires and its paleoclimatic effects.

2. Sampling and methods

A total of 36 fresh stratified samples were collected from a strip mine in the B1 coal seam of the Yihua mine, Wucaiwan mining area, eastern Junggar coalfield. The research methods include the macroscopic petrology observation, quantitative of maceral, determination of inertinite reflectance, the homogenization degree of cell wall, and identification of polycyclic aromatic hydrocarbons (PAHs).

3. Results and discussion

3.1 Macroscopic coal petrology and maceral

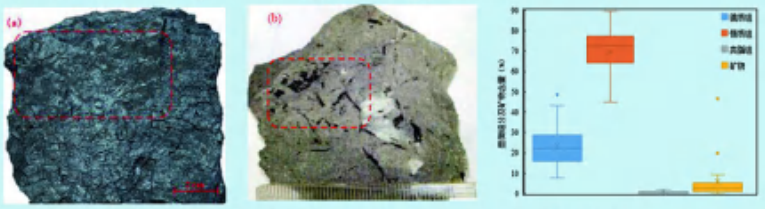


Fig. 1 Charcoal in the coal and rock samples, and maceral contents.

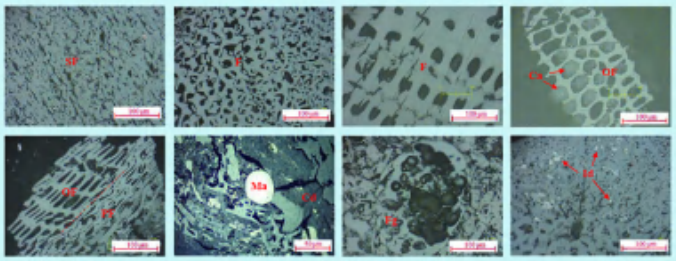


Fig. 2 Inertinite in coals under the reflected white light, immersion oil (SF, semifusinite; PF, Pyrofusinite; OF, Oxyfusinite; Ma, macrinite; Fg, funginite; Id, inertodetrinite; Ca, calcite).

3.2 Composition and sources of PAHs in coals

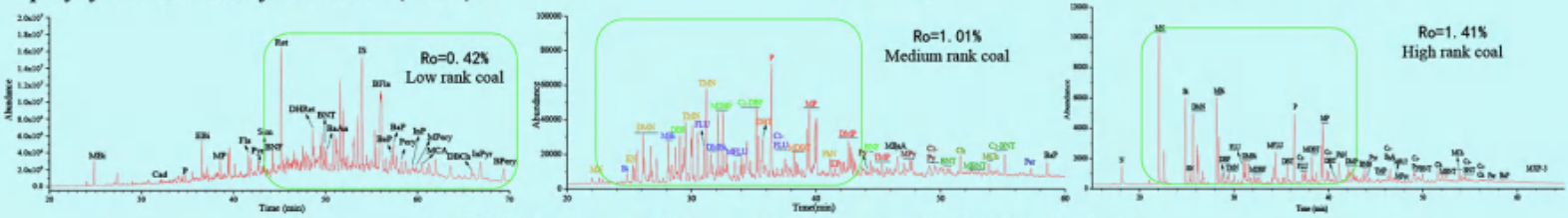


Fig. 3 GC-MS chromatograms of the aromatic fraction compositions in coals of different coal rank .

Table 1 PAHs source indicators and their respective diagnostic ratios

ratios	Petrogenic	Petroleum burning	Coal combustion	Softwood combustion
Ret/(Ret+Chi)	nd	0.15~0.50	0.30~0.45	>0.80
BaAn/(BaAn+Chi)	<0.20	>0.35	>0.35	>0.35
Fla/(Fla+Pyr)	<0.40	0.40~0.50	>0.50	>0.50
456-PAH/TPAH	<0.40	>0.50	>0.50	>0.50
1,7-DMP/(1,7+2,6-DMP)	nd	0.40	0.65~0.68	0.90

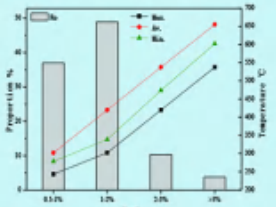


Fig. 4 Relationship between Ro and temperature.

3.3 Wildfire type and paleoclimate response

The Jurassic wildfires in the Junggar Basin were mainly medium-low-temperature surface fire and ground fire, and the frequency of high temperature fires was low according to the reflectance of inertinite and homogenization degree of cell wall.

The combustion of wildfire release huge amount of carbon into the atmosphere. Only the CO_2 released in the Junggar Basin accounted for 4.08% of the CO_2 in present atmosphere, which is one of the important factors of global warming in the Jurassic period.

4. Conclusions

The wildfire are widespread occurred in the Junngar coalfield during the Jurassic period according to the characteristics of petrology and PAHs. The wildfire types in the Junggar Basin are mainly medium-low-temperature surface fire and ground fire, and the frequency of high temperature fires is low. The carbon emission from the wildfire is one of the important factors contributing to climate warming during the Jurassic period.

References

[1] Lu QF, (2023) CUMT; [2] Lu et al. (2023) Appl. Geochem. 150, 95–101. [3] Lu et al. (2021) ACS Omega 6, 32. [4] Xu et al. (2020) Palaeobiodiv. Palaeoenviron., 559,109819. [5] Liu et al. (2022) Int. J. Coal Geol., 250, 103924.

Study on the Mobilization Rules of CO_2 Huff and Puff Development in Horizontal Wells for Heavy Oil Reservoirs

Yuhan Wang[1], Zhenhua Xu[1], Xiaokun Zhang[2], Pengcheng Liu[1], Qianhui Zhao[1]

[1] School of Energy Resources, China University of Geosciences, Beijing 100083, China.
[2] Research Institute of Petroleum Exploration and Development, PetroChina, Beijing, 100083, China.

Introduction

- Ways to conduct effective carbon capture, utilization and storage (CCUS) have become a widely held con-cern among scholars in recent years .
- CO_2 huff-n-puff is one of the main technologies for oilfield development, which is widely used in the development of low-permeability, tight-oil, and heavy-oil reservoirs..

Geological burial mechanism of carbon dioxide

- Construction sealing
- Binding gas storage
- Dissolve and seal
- Mineralized storage
- Hydrodynamic storage

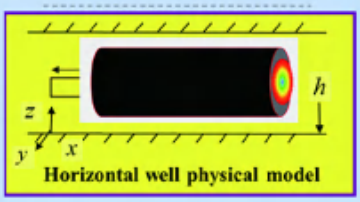
Mechanism of Carbon Dioxide Improving Crude Oil Recovery

- The Role of Carbon Dioxide in Reservoir Fluids
- The properties of carbon dioxide and its effects on reservoirs

- Resourcing carbon dioxide to generate economic benefits is more practical and practical

Mathematical model

- Assuming an infinite reservoir with horizontal, equal thickness, and upper and lower sealing, the fluid is weakly compressible, and the horizontal well is located in a homogeneous porous medium, considering the two-dimensional anisotropy of a homogeneous formation



Horizontal well physical model

Reservoir model

$$k_h\frac{\partial^2 p}{\partial x^2}+k_h\frac{\partial^2 p}{\partial y^2}+k_v\frac{\partial^2 p}{\partial z^2}=\varphi u c_t\frac{\partial p}{\partial t}$$

Initial conditions

$$p(x,y,z,0)=p_i(-\infty<x,y<+\infty,0<z<h)$$

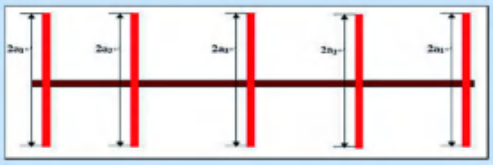
boundary conditions

$$\lim_{|x,y|\to\infty}p=p_i(0<z<h)$$

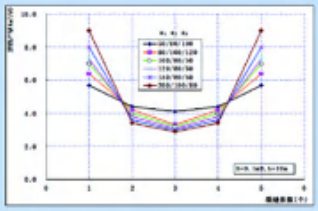
$$\frac{\partial p}{\partial z}\Big|_{z=0}=\frac{\partial p}{\partial z}\Big|_{z=h}=0(-\infty<x,y<+\infty)$$

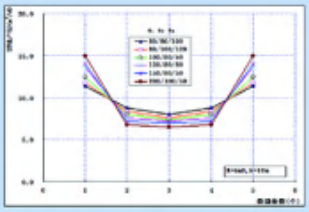
$$\lim_{r\to 0}\left(\int_0^L r\frac{\partial p}{\partial r}dx\right)=-\frac{qu}{2\pi k}$$

Analysis of Reservoir Production Law



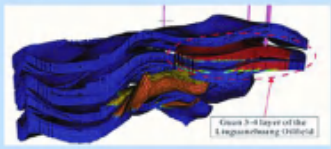
Analysis of utilization patterns

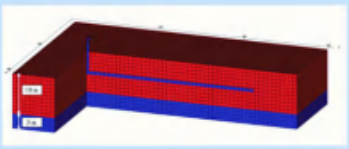


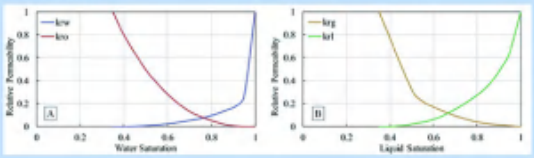


- The lower the permeability, the more obvious the advantages that both ends have. As the permeability increases, although both ends have advantages, the advantages become less and less obvious. There should be differences in fracturing and acidification for ultra-low permeability and medium to high permeability reservoirs.

Establishment of numerical simulation model



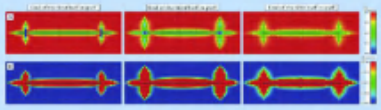


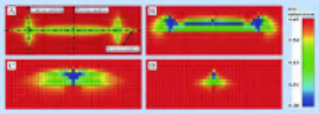


gas water relative permeability curve and oil water relative permeability curve

Fluid	Component	CO_2	C_1	C_2~C_5	C_6~C_{10}	C_{11}~C_{20}	C_{21}~C_{30}	C_{30+}
composition	Mole fraction	0.001	0.085	0.114	0.15	0.22	0.25	0.18

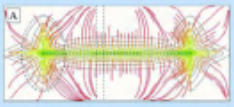
Results





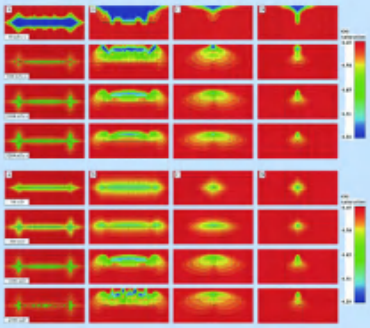
Remaining oil saturation and crude oil viscosity field: (A) remaining oil saturation change; (B) vis-cosity change in crude oil.

Schematic diagram of oil saturation in production area of horizontal well at end of five cycles of CO_2 huff-n-puff

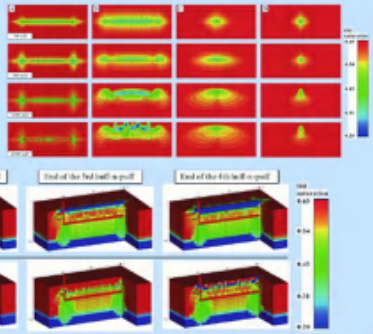


Streamline of horizontal well for CO_2 huff-n-puff: (A) top view; (B) parallel horizontal well section.

Schematic diagram of oil saturation change in different crude oil viscosities affecting production area of horizontal wells:



Oil saturation change diagram of influence of different reservoir permeability on production area of horizontal wells:



Conclusions

- The huff-n-puff CO_2 is enriched in the upper part of the horizontal well, unlocking the upper crude oil, and the oil recovery is high.
- All horizontal wells have different degrees of bottom water coning, producing lower crude oil.
- The horizontal well mainly produces crude oil in the heel and toe areas, and the production area around the middle of the horizontal well is smaller. The producing radius of the horizontal well in depletion development is about 30 m, and the radius of the production area can be expanded to about 60 m in huff-n-puff development.

Acknowledgements

The authors would like to thank the research team members for their contributions to this work. This research was funded by the National Natural Science Foundation of China (51774256).

Regional Energy System Optimization Model Coupled with Geological Storage Potential

XIANG Wen-xing[1], SANG Shu-xun[2*], HAN Si-jie[2]

1 School of Resources and Geosciences, China University of Mining and Technology, Xuzhou 221116, China

2 Carbon Neutrality Institute, China University of Mining and Technology, Xuzhou 221008, China

Background: CCUS（Carbon Capture, Utilization and Storage) technology is the key to achieve carbon neutrality in China in the future. However, the specific role of CCUS technology in the future regional energy system is still lack of detailed characterization, and there are few systematic geological storage modules in the existing energy system models.

Aims : Accurately depict the synergistic relationship between geological sequestration potential and energy resources under different scenarios.

Methods : The model predicts the total carbon emissions of the regional energy system under a given scenario strategy, coupled with the negative carbon effect of CCUS technology and the evaluation of regional CO_2 geological storage potential, sets the constraints of the lowest total economic cost and the lowest total carbon emissions, establishes a multi-objective nonlinear programming function, and simulates the optimal solution of carbon emissions of the regional energy system under different scenarios.

Practice : The paper takes Jiangsu Province as an example to verify the model. Based on the energy structure and energy consumption characteristics of Jiangsu Province over the years, combined with the storage potential of geological bodies such as Subei Basin, South Yellow Sea Basin and Fengpei coal field, the optimal solution of energy system carbon emissions in Jiangsu Province under different scenarios was simulated. The results show that CCUS technology contributes 15%-30% of carbon emission reduction in Jiangsu Province under different scenarios. Among the various geological bodies, the carbon seal stock is the largest in Subei Basin, followed by the South Yellow Sea Basin, and the abundant coal fields are less.

Core : Synergistic relationship between geological storage potential and energy resources. On the one hand, water resources and land resources limit the implementation of CCUS technology; on the other hand, the implementation of CCUS technology will affect the proportion of new energy and fossil energy in the region, and then affect the total carbon dioxide emission.

Fig.1 Conceptual model of energy system based on synergism between CCUS and new energy

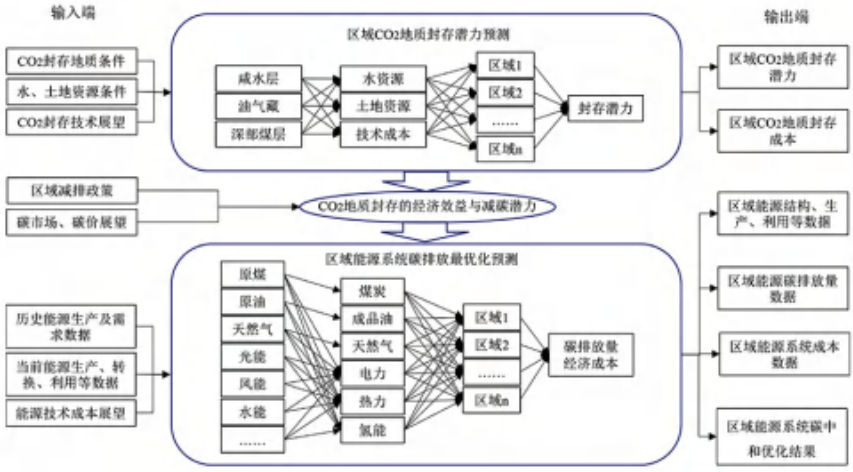


Fig 2 Regional energy system optimization model coupled with geological storage potential.

Reference

[1] SANG Shuxun, HUA Kaimin, TU Kunkun, GUO Zhenkun, Wei Fu, GUO Yuliang. Development direction and research progress of coupling technology system of biomass energy efficient utilization and carbon dioxide capture, utilization and Storage (BECCS) [J]. Journal of China University of Mining and Technology, 2023, 52 (05): 845-867.

[2] SANG Shuxun, LIU Shiqi, ZHU Qianlin, Han Sijie, Zhang Shouren, Tan Kelong, Zhou Xiaozhi, ZHENG Sijian, WANG Xu, LIU Tong. Research progress on CO_2 geological storage potential and energy resource synergy [J]. Journal of China Coal Society, 2023, 48 (07): 2700-2716.

[3] SANG Shuxun, LIU Shiqi, LU Shijian, Zhu Qianlin, Wang Meng, Han Sijie, LIU Tong, ZHENG Sijian. Technology and progress of engineered CCUS process [J]. Reservoir Evaluation and Development, 2022, 12 (05): 711-725+733.

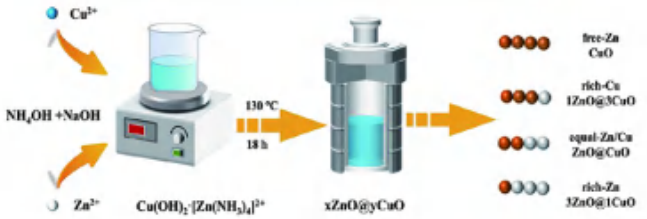
*CO spillover induced by bimetallic xZnO@yCuO active centers for enhancing C-C coupling over ECR

Zhixiu Yang, Guomin Xiao
(School of Chemistry and Chemical Engineering, Southeast University, Nanjing 211189, China)
(Tel: 15536605679, E-mail address: 230228823@seu.edu.cn)

Abstract

Cu-based catalysts attaining high catalytic activity and selectivity towards C_{2+} product remains a major obstacle, which has garnered significant attention. *CO plays a key role as an intermediate in the next process of C-C dimerization. In this study, we devise a novel approach for generating *CO in situ and facilitating its spillover to neighboring dandelion-liked CuO active sites, utilizing flower-shaped ZnO as a source of *CO intermediate. In-situ ATR-SEIRAS also unveils that *CO spillover increases the surface coverage of *CO on the catalyst, ultimately improving the selectivity for C-C coupling and C_2H_4 production. The relationship between structure and performance will offer guidance for the design of Cu-based catalysts with superior efficiency in CO_2 reduction.

Experiment



Result and discussion

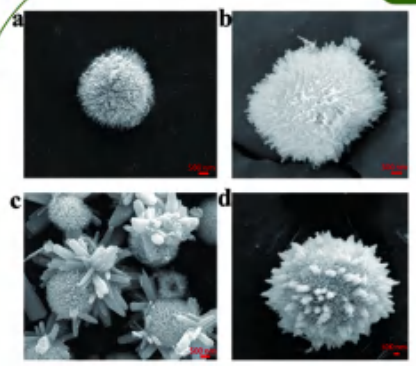


Fig. 1 SEM of (a) CuO, (b) 1ZnO@3CuO, (c) ZnO@CuO, and (d) 3ZnO@1CuO.

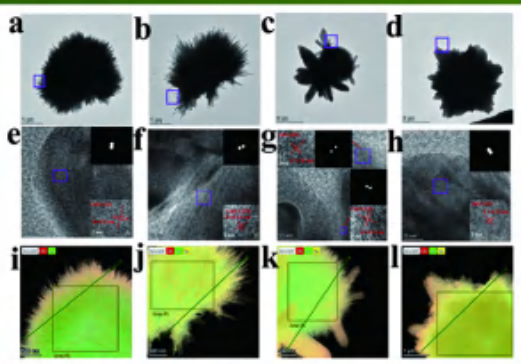


Fig. 2 TEM of(a) CuO, (b) 1ZnO@3CuO, (c) ZnO@CuO, and (d) 3ZnO@1CuO; The HR-TEM of (e) CuO, (f) 1ZnO@3CuO, (g) ZnO@CuO, and (h) 3ZnO@1CuO; The EDS of (i) CuO, (j) 1ZnO@3CuO, (k) ZnO@CuO, and (l) 3ZnO@1CuO; The elemental mapping images of ZnO@CuO, of which (m) HADDF, (n)Cu, (o) O, and (p) Zn.

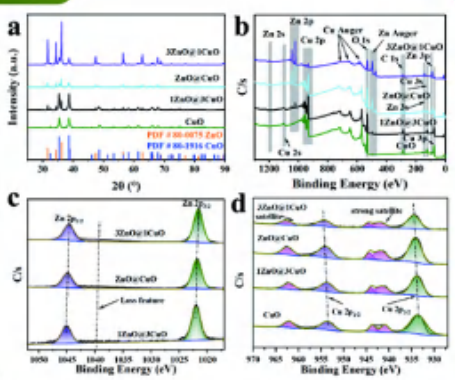


Fig. 3 (a)The XRD pattern of catalyst; The XPS spectra of catalysts (b) The survey spectrum, (c) Zn 2p spectrum, and (d) Cu 2p spectra.

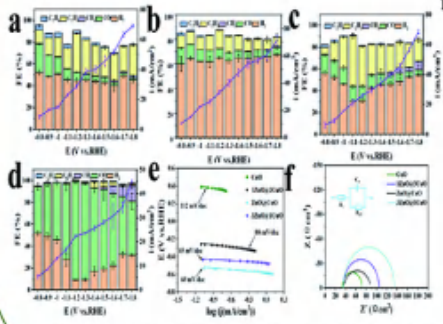


Fig. 4 The FE of (a) CuO, (b) 1ZnO@3CuO, (c) ZnO@CuO, and (d) 3ZnO@1CuO; (e) Tafel curve of all the samples; and (f) The Nyquist plates of the prepared catalyst.

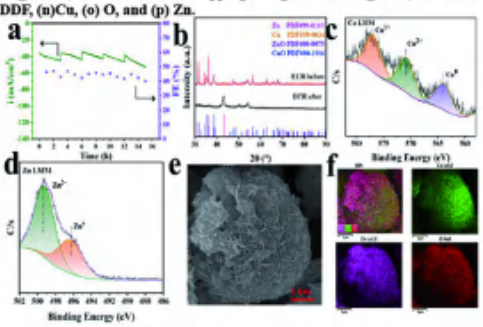


Fig. 5 (a) The stability test at -1.2 V vs. RHE of ZnO@CuO; (b) XRD pattern, (c) Cu LMM spectrum, (d) Zn LMM, (e) SEM, and (f) SEM-EDS image of ZnO@CuO after 15 h of ECR.

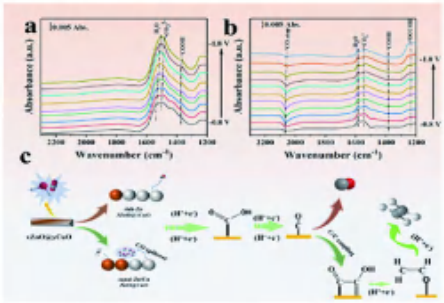


Fig. 6 In-situ electrochemical ATR-SEIRAS spectra of catalysts towards CO2 electroreduction at -0.8 V~-1.8 V: (a) 3ZnO@1CuO, (b) ZnO@CuO; and (c) the mechanism pathway diagram of xZnO@yCuO.

Conclusion

- *CO spillover induced by bimetallic xZnO@yCuO active centers.
- *CO spillover to neighboring dandelion-liked CuO active sites, utilizing flower-shaped ZnO as a source of *CO intermediate.
- In-situ ATR-SEIRAS also unveils that *CO spillover increases the surface coverage of *CO on the catalyst.

Acknowledgment

SOUTHEAST UNIVERSITY
東南大學
NSFC
National Natural Science Foundation of China

Laboratory Visualization of Supercritical CO_2 Fracturing in Tight Sandstone Using Digital Image Correlation Method

Yuxi Zang[1], Haizhu Wang[1], Bin Wang[1], Tianyu Wang[1], Shouceng Tian[1,2*]

1. State Key Laboratory of Petroleum Resources and Prospecting, China University of Petroleum (Beijing), Beijing ;
2. College of Petroleum, China University of Petroleum-Beijing at Karamay, Karamay

BACKGROUND

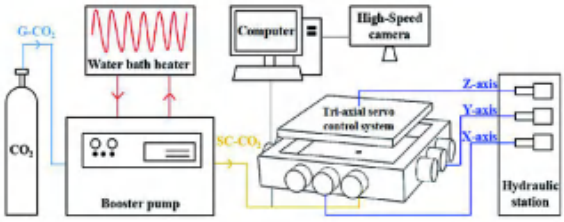
In the evolving landscape of lower-carbon energy, SC-CO_2 fracturing technology shows great potential for unconventional oilfield production. However, there is still an incomplete understanding of the fundamental mechanisms driving fracture initiation and propagation.

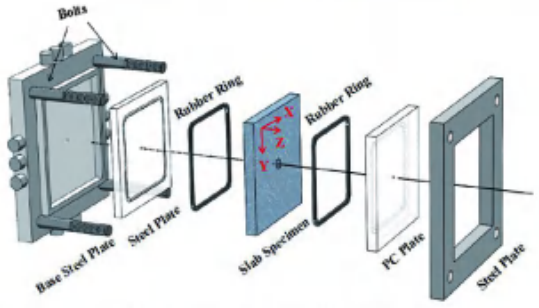
This study innovates by creating a visualization device capable of conducting experiments under tri-axial conditions. The characteristics of fracture propagation and strain field are quantitatively evaluated by DIC. This study aims to give theoretical foundation for parameter design in unconventional reservoir development.

METHODS

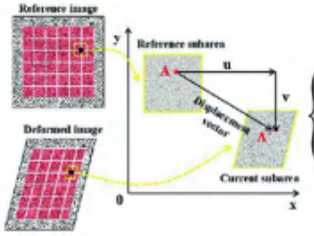
❖ Experimental apparatus

Mainly include liquid supply, pressurization control, constant temperature water bath, tri-axial servo control, data acquisition.





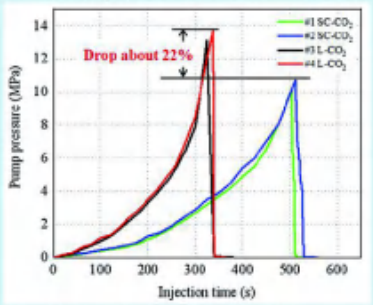
❖ DIC post-processing method



$$\begin{cases} u(x,y) = u_0 + \dfrac{\partial u}{\partial x}\Delta x + \dfrac{\partial u}{\partial x}\Delta y \\ v(x,y) = v_0 + \dfrac{\partial v}{\partial x}\Delta x + \dfrac{\partial v}{\partial x}\Delta y \end{cases}$$

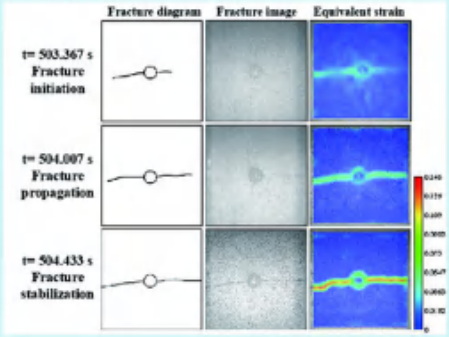
RESULTS

❖ Pump pressure-time curves

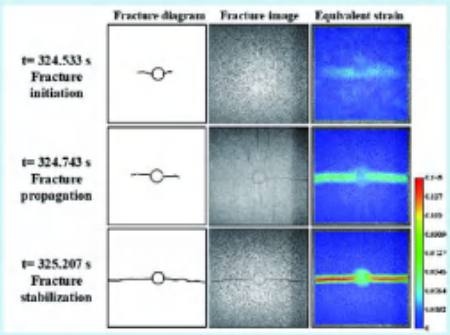


- Three stages: i) pressure rise stage; ii) pressure drop stage; iii) fracture propagation and stability stage;
- Under identical stress conditions, SC-CO_2 fracturing demonstrates a breakdown pressure 22% lower than that of L-CO_2.

❖ Spatial strain variation



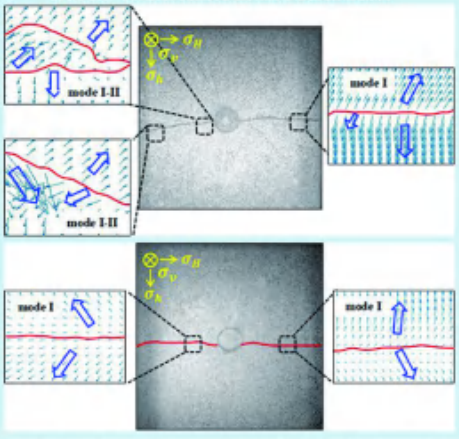
$$\begin{cases} E_{xx} = \dfrac{1}{2}\left(2\dfrac{\partial u}{\partial x} + \left(\dfrac{\partial u}{\partial x}\right)^2 + \left(\dfrac{\partial v}{\partial x}\right)^2\right) \\ E_{xy} = \dfrac{1}{2}\left(\dfrac{\partial u}{\partial y} + \dfrac{\partial v}{\partial x} + \dfrac{\partial u}{\partial x}\dfrac{\partial u}{\partial y} + \dfrac{\partial v}{\partial x}\dfrac{\partial v}{\partial y}\right) \\ E_{yy} = \dfrac{1}{2}\left(2\dfrac{\partial v}{\partial y} + \left(\dfrac{\partial u}{\partial y}\right)^2 + \left(\dfrac{\partial v}{\partial y}\right)^2\right) \end{cases}$$



$$E_{VM} = \sqrt{\frac{2}{3}\left(E_{xx}^2 + E_{yy}^2 + 2\cdot E_{xy}^2\right)}$$

E_{xx}-horizontal strain;
E_{yy}-vertical strain;
E_{xy}-shear strain tensor;
E_{VM}-Von-Mises equivalent strain

❖ Meso-mechanical mechanism



- L-CO_2 fracturing mainly forms Mode I type tensile fractures;
- SC-CO_2 fracturing mainly forms Mode I-II type tension-shear mixed fractures.

References:
[1] Blaber J, Adair B. Ncorr: open-source 2D digital image correlation matlab software[J]. Experimental Mechanics, 2015, 55(6): 1105-1122.
[2] Mises L. Theorie des Geldes und der Umlaufsmittel[M]. Duncker und Humblot, 2016.

基于生物炭处理的有机污染土治理与土壤固碳研究进展

郭玉良[1,2]，桑树勋[1,2,3]

(1. 中国矿业大学 碳中和研究院，江苏 徐州 221008；2. 中国矿业大学 江苏省煤基温室气体减排与资源化利用重点实验室，江苏 徐州 221008；3. 中国矿业大学 资源与地球科学学院，江苏 徐州 221116)

引言

- 双碳战略背景下，有机污染土的治理与固碳协同作用具有重要现实意义；
- 生物炭用于有机污染土治理能够吸附固定土体中有机污染质，防止其迁移转化；
- 将生物炭中稳定的碳埋存在土壤中，减轻由于有机质降解产生的温室气体排放及土体强度弱化，在污染土修复与固碳减排方面具有突出价值；
- 同时，将治理的污染土场地改造成为林地、农田、建筑用地等，可实现碳的循环利用，可看作生物质能-碳捕集与封存（BECCS）的一种特殊表现形式。

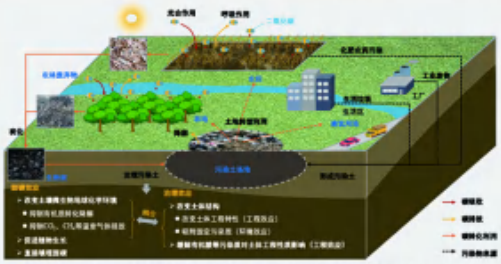


图1 土壤生物炭固碳与污染土治理耦合过程示意图

生物炭的关键特性

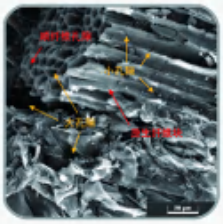


图2 生物炭微观形貌

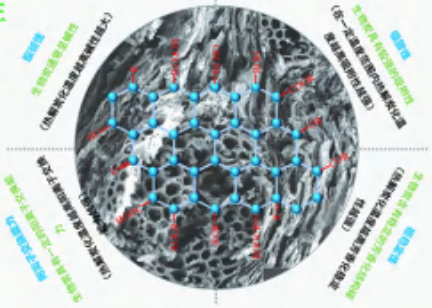


图3 生物炭基本性质特征

✓ 通常显碱性　✓ 吸附性强　✓ 碳稳定性强　✓ 具有一定的阳离子交换能力

土壤生物炭固碳效应

✓ 土壤生物炭固碳机理

- 土壤埋碳
- 吸附有机质及温室气体
- 促进植物生长

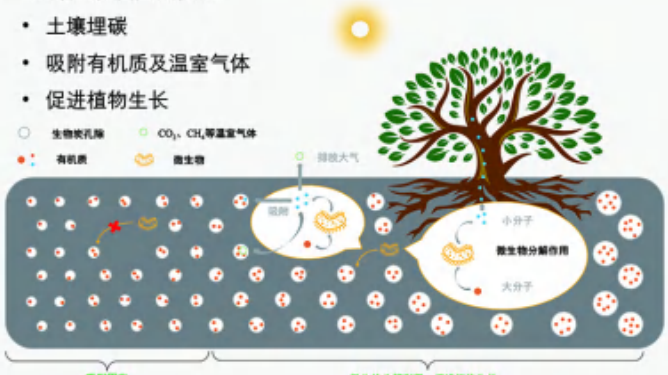


图8 生物炭孔隙结构对土壤有机质迁移行为的影响机制

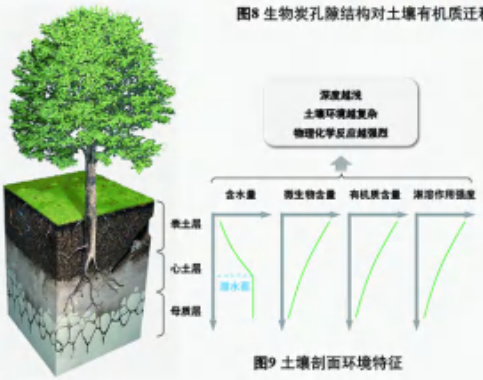


图9 土壤剖面环境特征

✓ 土壤生物炭固碳效果影响因素

- 生物炭性质
  - ① 孔隙结构
  - ② 碳结合形态
- 土壤赋存环境

土壤生物炭的污染土体治理效应

1. 生物炭对有机污染土的环境治理效应

✓ 生物炭对土壤有机污染质的稳固机理

- 化学吸附作用
- 物理吸附作用

✓ 影响因素

- 生物炭理化性质
- 有机污染质性质
- 土壤环境条件

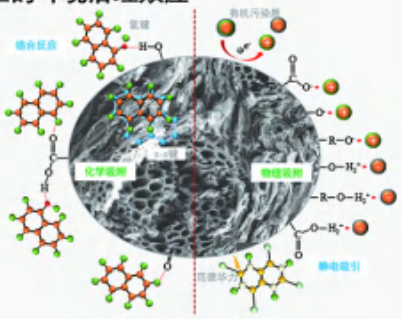


图4 生物炭对有机污染质作用机理

2. 生物炭对有机污染土的工程治理效应

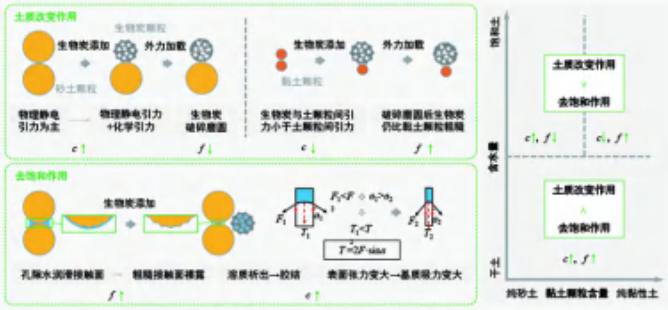


图5 生物炭对土体抗剪强度影响机理示意图

✓ 生物炭颗粒性质介于砂颗粒和黏土颗粒间　✓ 生物炭更易吸附土孔隙水

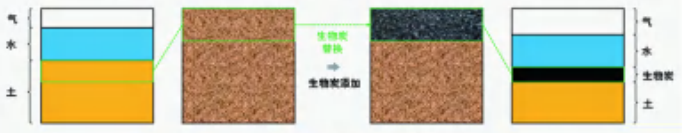


图6 生物炭添加土的三相图

✓ 生物炭使土体压缩性增强　✓ 生物炭可缓解膨胀土的胀缩性

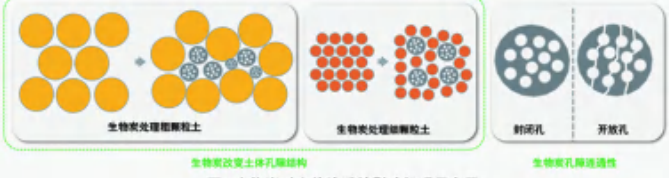


图7 生物炭对土体渗透性影响机理示意图

✓ 生物炭降低粗颗粒土体的渗透性　✓ 生物炭增加细颗粒土体的渗透性

结论

1. 目前在土壤生物炭固碳或有机污染土治理单方面的研究比较系统全面。
2. 关于生物炭对生活源有机污染土治理与固碳的协同作用规律及机理还需进一步深入研究。

作者简介：郭玉良，男，中国矿业大学，博士后（合作导师：桑树勋教授），研究方向为污染土治理与土壤固碳、生态碳汇。
电子邮箱：guoyuliang@cumt.edu.cn

植物衰老揭秘：环境和发育因素的作用

季舒平[1]，任世龙[1*]，……，王桥[1*]
1 山东大学环境研究院，山东省青岛，266237
Email: jishuping@mail.sdu.edu.cn

引言

了解植物衰老的驱动因素对于准确预测气候变化对全球碳循环的影响至关重要。 然而，春季和夏季植物发育和光合作用在多大程度上决定秋季衰老时间相对于环境因素的影响仍不清楚，尤其是草本植物。

秋季衰老对内外部因素的反应

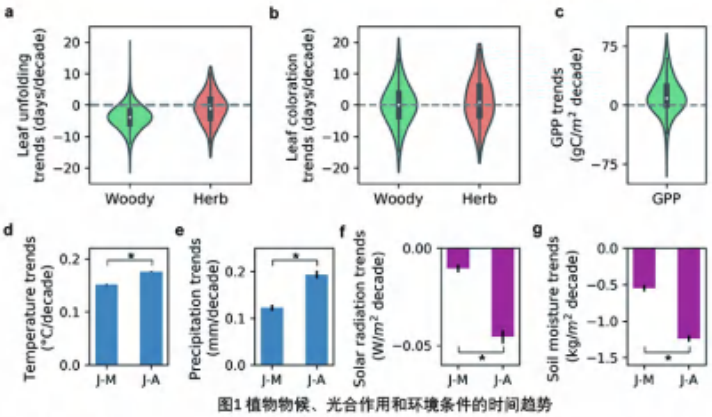


图1 植物物候、光合作用和环境条件的时间趋势

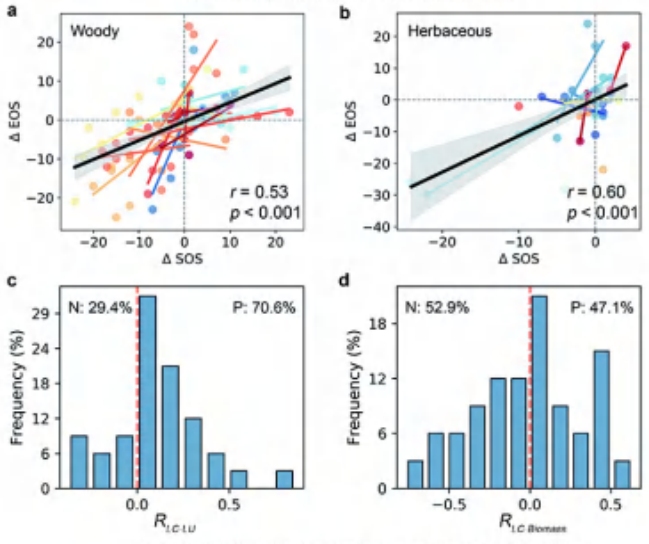


图2 在实验和牧场数据中观察到生长开始对衰老终止的促进作用

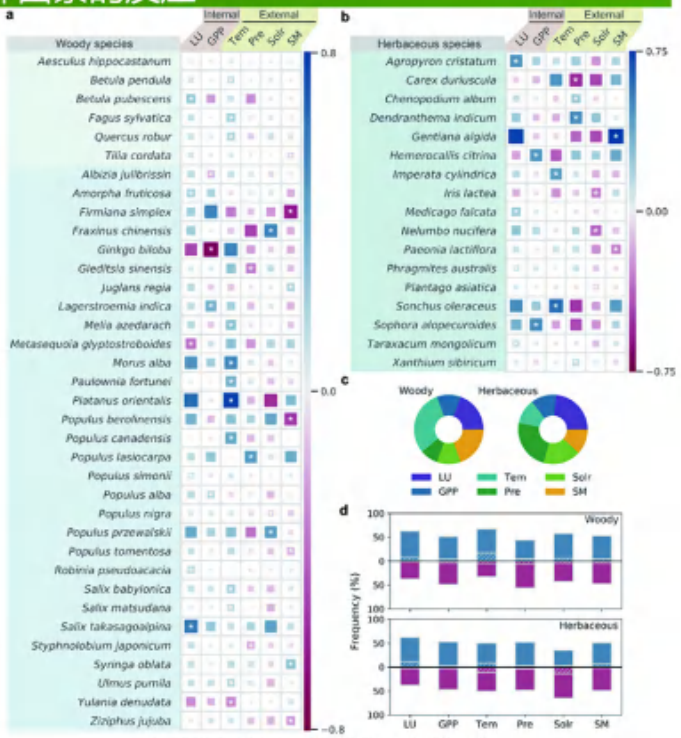


图3 生长发育和环境因素对物种水平衰老的影响

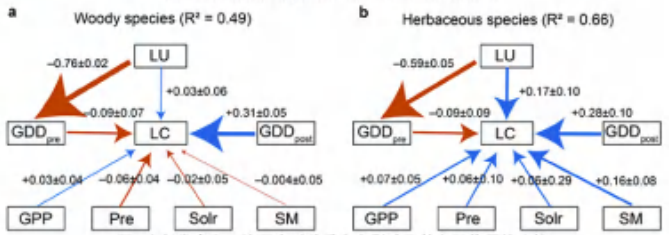


图4 生长发育和环境因素对秋季衰老影响及其交互作用的比较

较早的生长开始通过发育效应直接导致草本植物较早衰老终止，但在木本植物中则通过加速早季发育间接导致较早的衰老终止。 令人惊讶的是，光合作用活动并没有显著影响衰老终止。

秋季衰老对温度变化的敏感性降低

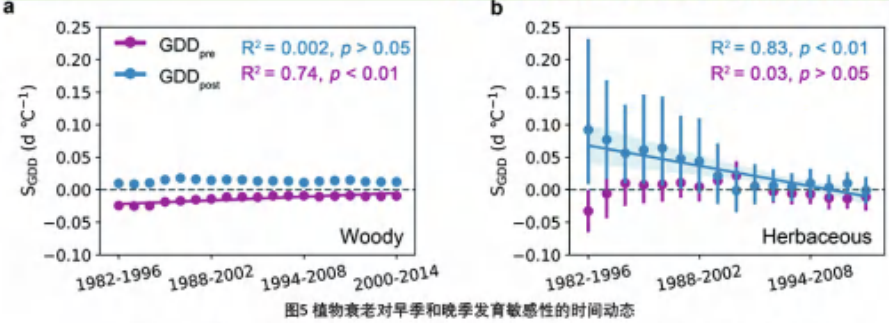


图5 植物衰老对早季和晚季发育敏感性的时间动态

无论木本还是草本物种，生长季节温度对衰老终止时间的影响都显著下降，这表明未来气候变暖对植物衰老的影响可能较弱。

本研究对内部和外部因素对温带植物衰老时间影响的全面量化提高了预测陆地碳吸收的能力。

基于微型流化床热重分析的石灰石加氢分解动力学

李丹，王邑维，王洋，李振山*
清华大学能源与动力工程系，热科学与动力工程教育部重点实验室，北京，100084

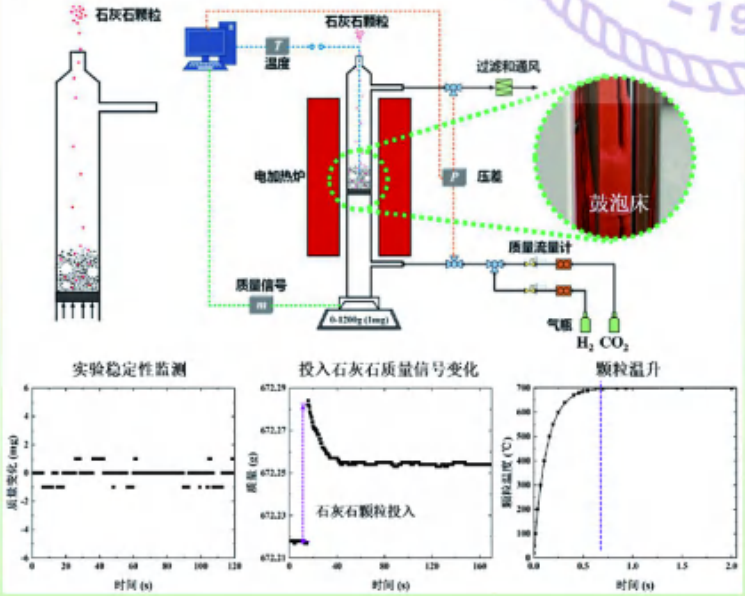
摘 要

钙循环技术是一种基于CaO碳酸化和$CaCO_3$分解的CO_2捕集技术。在该技术中，向再生反应器中掺氢可以有效解决CO_2浓度较高带来的碳酸钙煅烧温度升高、能耗增加以及吸附剂失活等问题。目前，对于碳酸钙加氢分解特性的研究并不充分，如何实现在等温条件下、流化状态中加氢分解动力学的测量是制约该研究的核心问题。

本研究开发了一种通过向微型流化床热重分析(MFB-TGA)中投入石灰石以获得碳酸钙加氢分解动力学的新方法。利用此法研究了石灰石颗粒在不同温度(610-760℃)和H_2浓度(0-50vol.%)下的加氢分解动力学，并建立了描述碳酸钙加氢分解的动力学模型。结果表明，相较常规TGA的测量结果，利用MFB-TGA测得石灰石加氢分解动力学更快；在H_2气氛中石灰石颗粒表现出明显增强的分解活性；所建模型可以很好地描述不同工况条件下的石灰石的分解特性。

实验与模型

实验方法



动力学模型

➢颗粒转化率： $X=(r_0^3-r_1^3)/r_0^3$

➢煅烧反应速率： $\dot{r}=k\cdot(\frac{P_{H_2}}{P^{\ominus}})^n(1-\frac{P_{CO_2}}{P_{CO_2,eq}})$

➢颗粒体积变化率： $\frac{dV_{CaCO_3}}{dt}=4\pi r_1^2\frac{dr_1}{dt}=-4\pi r_1^2\cdot\dot{r}$

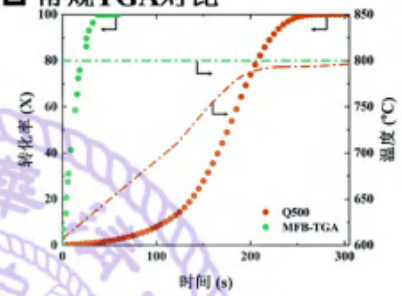
➢反应速率常数： $k_{H_2}=A_{H_2}\cdot\exp(-\frac{E_{H_2}}{RT})$ $k_{Inert}=A_{Inert}\cdot\exp(-\frac{E_{Inert}}{RT})$

➢颗粒转化率： $\frac{dX}{dt}=\frac{3A_{Inert}}{r_0}\cdot\exp(-\frac{E_{Inert}}{RT})\cdot(1-X)^{2/3}$

$$\frac{dX}{dt}=\frac{3A_{H_2}}{r_0}\cdot\exp(-\frac{E_{H_2}}{RT})\cdot(1-X)^{2/3}\cdot(\frac{P_{H_2}}{P^{\ominus}})^n$$

结果与讨论

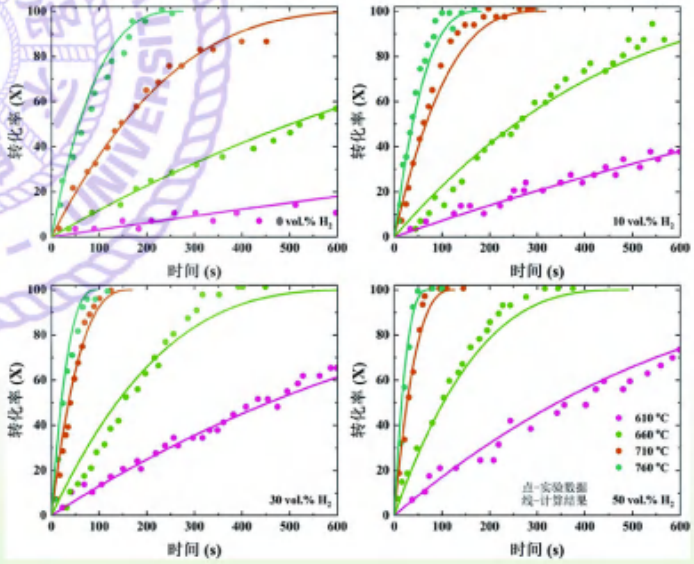
常规TGA对比



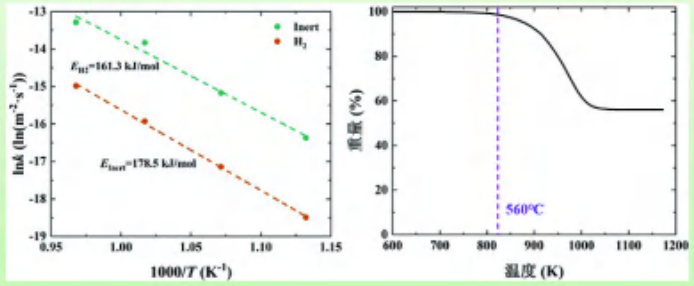
➢ 常规TGA颗粒在加热过程中发生分解，难以获得等温动力学；

➢ MFB-TGA 在流态化下测量反应动力学，更接近于实际情况。

温度与H_2浓度的影响



反应活化能



结 论

➢ 提出了一种新的将石灰石颗粒投入MFB-TGA的测量方法，可以获得流态化条件下快速升温的等温分解动力学；

➢ 研究了不同温度（610-760℃）、不同H_2浓度（0-50vol.%）下石灰石颗粒的加氢分解特性，建立了表观模型分析了MFB-TGA中获得的实验数据；

➢ 结果表明与惰性气氛相比，石灰石颗粒在50vol.%H_2气氛下的分解速率提高了5倍，在H_2存在气氛下，表观活化能值降低为161.3kJ/mol；

➢ 实验结果和等温分解模型可以为CaL技术的应用提供理论指导。

Solar-powered AnMBR-BES combined with AOM-MEC wastewater treatment technology and carbon reduction strategies

项目类别：碳汇与CCUS技术　　项目组负责人：王佳懿 指导教师：甄广印、陆雪琴

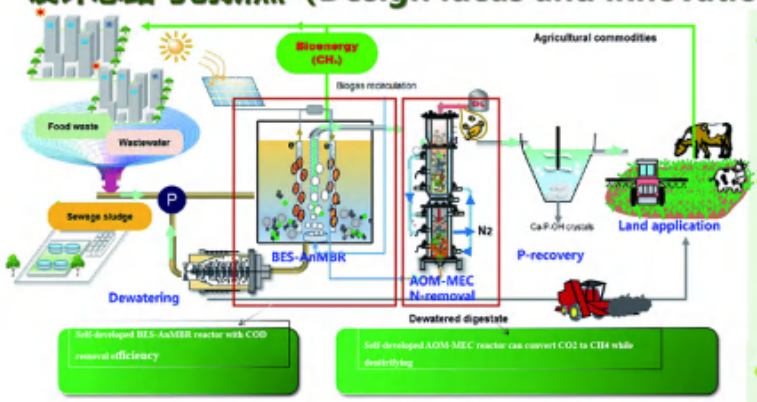
项目名称："一碳究净"——太阳能驱动下的AnMBR-BES联合AOM-MEC污水处理与减碳策略

背景（Project Background）

- 2021年全球能源相关的总CO_2排放量达到31.5 Gt，中国是世界上最大的CO_2排放国，2021年排放总量达到7500万吨。
- 污水处理行业是我国的耗能大户，2021年全行业耗电约189亿kW·h。

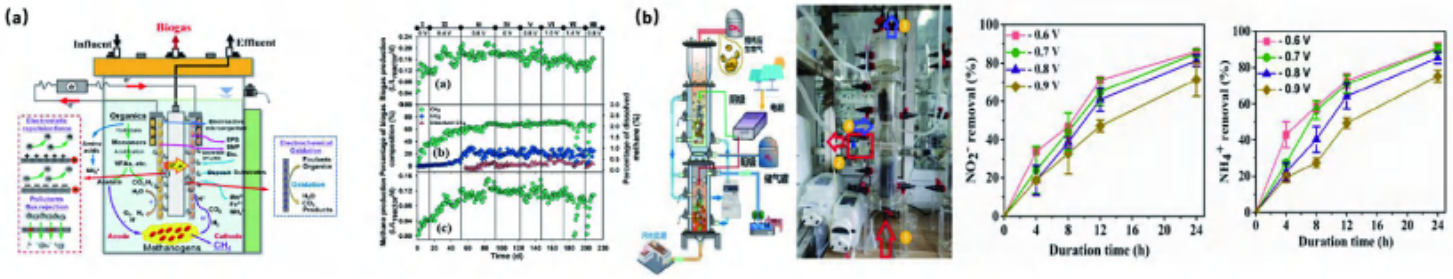
在"碳中和"的大背景下，如何将革新污水处理技术，并提高CO_2收集与资源化利用率成为关键问题。

设计思路与创新点（Design ideas and innovations）



- 设计新型"高导电性碳毡+钛网"组合电极，构建AnMBR-BES组合反应器，实现废水的深度处理及CO_2捕获和生物气原位升级提纯；构建AOM-MEC反应器，实现高氨氮废水的深度处理。
- 由太阳能驱动的生物电化学系统BES-AnMBR去除COD，之后污水进入厌氧氨氧化联合电产甲烷（AOM-MEC）系统脱除氨氮并进一步对沼气气提纯，污水再进入生化磷沉淀装置还原硝酸盐，净化后的水可以直接进行农业灌溉。
- 实现"太阳能驱动-电催化调控-厌氧膜生物处理-膜洁净分离-CO_2生物气提纯-附加产生回收"阶梯能源转化集成研究技术。

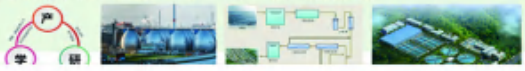
前期工作与技术经验（Preliminary work and technical experience）



- BES-AnMBR反应器中（图a），COD、PN 和 PS 去除率都高于96%，对应的平均出水浓度分别为 286.7 ± 81.7 mg/L、42.5 ± 7.5 mg/L 和 13.1 ± 5.0 mg/L。甲烷产量最高可以达到 0.18 ± 0.12 L/Lreactor/d，甲烷产量的急剧增加可归因于微生物电化学作用，其促进了氧化还原环境的形成和强化了电活性厌氧微生物的富集。说明此反应器运行稳定，且有较好的可控制性。
- AOM-MEC反应器中（图b），NO_2^--N 和 NH_4^+-N、TN 去除率高达90.0%。只需给电路提供一个很小的电压（-0.6～-0.8 V vs. Ag/AgCl）就能够克服热力学壁垒产生甲烷，且甲烷产量可达80 mL/Lreactor/d。

项目预期及前景（Project expectations and prospects）

- 小范围试点上海老港城市污水厂，预计配备两台150个Kubota板膜（每个0.8 m²）的AnMBR反应器，用于乳制品加工废水，每个AnMBR的有效体积为100m³，总处理能力可达到30t/d，同时产生880 m³/d的CH_4。
- 实验室模拟测试-污水处理厂中试-反应器批量化生产试运行-在实践中优化体系-坚持"产-学-研"融合。
- 可有效降低污水处理耗电量20%；提高污水处理及整体利用效率。



典型煤制氢CCUS改造规划碳足迹与经济性分析

轩昂，沈欣炜*
清华大学 深圳国际研究生院，广东省，深圳市，518055
ang.xuan@sz.tsinghua.edu.cn, sxw.tbsi@sz.tsinghua.edu.cn

摘要

氢能作为清洁、高效、安全的新型载体，广泛应用于工业、建筑、交通、电力行业，是世界能源转型的重要方向之一。中国作为全球最大的氢气生产国和主要的消费国，约2/3的氢气通过煤制氢生产。然而，这种通过化石燃料产生的“灰氢”，在生产过程中产生大量二氧化碳排放，极大制约了“双碳目标”的实现。碳捕集、利用与封存（Carbon Capture, Utilization and Storage, CCUS）技术作为未来实现高效快速减碳的有效途径，被国际能源署指出是实现碳中和的兜底技术。本研究首先结合传统煤制氢工艺化工过程，分析其全流程碳足迹，探究改造路线的关键部门；其次以最小化平准化制氢成本为优化目标，提出煤制氢CCUS改造规划模型；最后，针对改造规划中的关键不确定因素进行敏感度分析，讨论模型的有效边界。仿真结果表明，本文所提改造规划模型的平准化制氢成本为9.65 ￥/kg，与未改造方案相比增加36.5%，但是全流程碳足迹降低幅度达到79.7%；当单位碳收益达到170 ￥/t及以上时，煤制氢CCUS改造规划具有经济上的更优性。

模拟煤制氢CCUS改造的Aspen Plus流程图

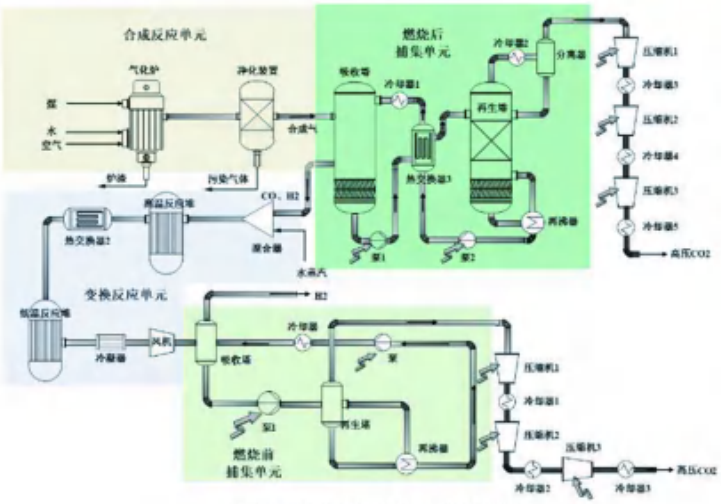


表1 不同情景下煤制氢CCUS改造规划结果

规划结果		①	②	③	④
投资容量（MW）	燃烧前捕集系统	-	4.83	4.83	4.83
	燃烧后捕集系统	-	3.18	3.18	3.18
	HFC	-	32.81	32.81	98.45
投资成本(×10⁴￥)	燃烧前捕集系统		47.89	47.89	47.89
	燃烧后捕集系统		35.66	35.66	35.66
	HFC		853.9	853.9	2561
运维成本(×10⁴￥)	燃烧前捕集系统	-	70.99	70.99	70.99
	燃烧后捕集系统	-	31.23	31.23	31.23
	CO_2运输成本	-	1219	1219	1219
	碳收益	-	-	1829	1829
	电收益	-	-	-	13455
LCOH(￥/kg)		7	11.32	9.65	-0.93

仿真结果

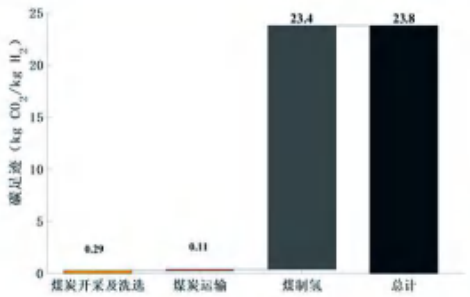


图1 煤制氢全流程碳足迹及结构图

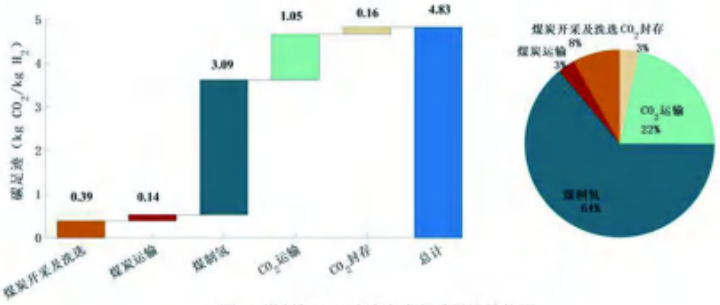


图2 煤制氢CCUS改造全流程碳足迹结构图

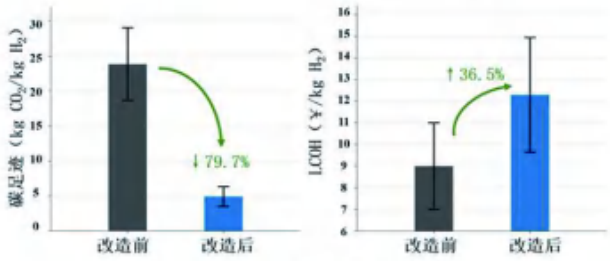
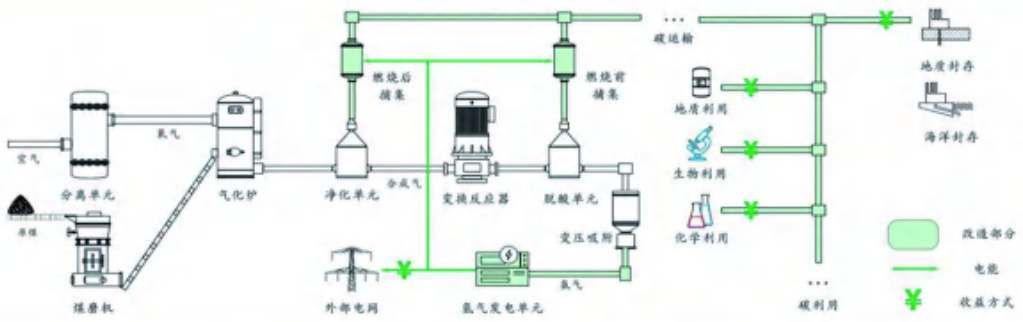


图3 煤制氢CCUS改造碳足迹与经济性对比图

煤制氢CCUS改造框架



结论

- 相较于改造前，改造后全流程碳足迹仅为原先20.29%，改造后计及碳收益的平准化制氢成本增加约36.5%；若进一步考虑氢气发电收益，可以实现制氢成本为负。
- 当煤制氢效率高于55%时，改造后全流程碳足迹低于“蓝氢”标准（4.9 kg CO_2 /kg H_2），可以实现“灰氢”变“蓝氢”。
- CO_2运输距离每增加1 km，改造后全流程碳足迹增加约0.014 kg CO_2/kg H_2，LCOH增加约0.022 ￥/kg H_2；每吨CO_2收益超过170元时，改造具有经济上的更优性。

主办单位：清华大学、中国学位与研究生教育学会

承办单位：清华大学碳中和研究院、中国学位与研究生教育学会工科工作委员会

清华大学环境学院

协办单位：清华大学学生碳中和研究协会

清华大学学生创业协会清华大学探臻科技评论社

清华大学环境学院研究生会

清华大学能源与动力工程系研究生分会