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Research on the Market-Oriented Construction of China's Blue Carbon Value Realisation: Mechanisms, Obstacles, and Pathway Innovations

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Abstract: In recent years, blue carbon has opened up a new frontier for global efforts to address climate change, protect biodiversity, and achieve sustainable development. It is regarded as a strategic resource supporting the implementation of the Paris Agreement and provides an important option for 'Nature-based Solutions'. China possesses abundant blue carbon resources, and the national 'Dual Carbon' strategy has provided significant policy drivers for blue carbon development. However, the development of China's blue carbon market remains in its early stages, characterised by project-based and pilot initiatives, and the market-based realisation of blue carbon value still faces institutional barriers. This study argues that the realisation of blue carbon value is no longer a conceptual idea. Blue carbon possesses comprehensive service value, and its value can be most effectively realised through marketisation. Contemporary technological advancements have created the conditions for blue carbon transactions. The marketisation of blue carbon value requires systematic institutional design, particularly focusing on mechanisms for defining blue carbon property rights, standard certification, transaction operations, and market supervision. Addressing the primary obstacles to the marketisation of blue carbon value in China, this study proposes four pathways: first, strengthening systematic legislation to establish a solid institutional foundation; second, developing a multi-tiered blue carbon market to stimulate market dynamics; third, promoting diversified blue carbon financial innovations to activate blue carbon assets; and fourth, strengthening international technical cooperation to advance the integration of blue carbon production and research. It is hoped that this research will contribute to realising the value of China's blue carbon, while providing more diverse references and recommendations for global climate change mitigation and the achievement of sustainable development goals.

Keywords: Blue Carbon Value; Market-Oriented Construction; Pathway Innovation

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1.Introduction

The realisation of blue carbon value and innovation in market-based pathways represent critical issues in the current efforts to address climate change, achieve biodiversity conservation, and promote sustainable development. Blue carbon, or ocean carbon sinks, refers to the processes, activities, and mechanisms whereby marine activities and marine organisms absorb carbon dioxide from the atmosphere and sequester it within marine ecosystems (Nellemann et al., 2009; IPCC, 2019)[3][14].

The formal signing of the Paris Agreement in December 2015 marked a milestone in controlling global greenhouse gas emissions. Notably, the Paris Agreement's introduction of Nationally Determined Contributions (NDCs) to replace the Kyoto Protocol's mandatory emissions reduction mechanism has pioneered new compliance pathways for voluntary emissions reductions. Against this backdrop, the value of blue carbon has become increasingly prominent.

According to the 2009 joint report Blue Carbon: The Role of Healthy Oceans in Binding Carbon–A Rapid Response Assessment by UNEP and FAO, marine ecosystems sequester 55% of the world's biological carbon annually. The ocean carbon reservoir holds 20 times more carbon than terrestrial reservoirs and 50 times more than the atmospheric reservoir. Additionally, marine biological carbon capture efficiency is high, with seagrass carbon capture efficiency being approximately 35 times that of tropical rainforests. Blue carbon storage has a long lifespan, potentially lasting thousands of years. Compared to terrestrial green carbon, blue carbon offers greater development advantages and potential. The process of realising blue carbon value provides 'Nature-based Solutions' (NbS) for addressing climate change, achieving biodiversity conservation, and promoting sustainable development. (UNEP, 2021)[15]. Marketisation is the primary pathway for realising the value of blue carbon. Transforming the intrinsic ecological value of blue carbon into measurable and tradable economic value, and allocating it through market-based mechanisms, not only aligns with global carbon emission reductions but also provides additional funding sources for the protection and restoration of global marine ecosystems, while encouraging a broader range of stakeholders to engage in global sustainable development initiatives.

As a signatory to the Paris Agreement, China pledged to the world in 2020 that it would reach peak carbon emissions by 2030 and strive to achieve carbon neutrality by 2060. As the world's largest emitter of carbon dioxide, China faces immense pressure and challenges in meeting these dual carbon reduction targets within the shortest possible timeframe. Implementing stringent emission reduction measures and continuously expanding carbon sink increments are strategic choices that cannot be delayed. China has nearly 300 square kilometres of marine territory and approximately 18,000 kilometres of continental coastline. It is one of the few countries in the world that simultaneously possesses the three major blue carbon ecosystems of mangroves, salt marshes, and seagrass meadows. Its scale of marine aquaculture ranks among the world's leading nations, endowing it with abundant blue carbon resources. Realising the value of blue carbon is a key means for China to secure a proactive position in its future development. Since 2021, the national government has introduced a series of macro policies aimed at achieving carbon peaking and carbon neutrality, and has formulated the 'Implementation Plan for Consolidating and Enhancing Ecosystem Carbon Sink Capacity', placing the enhancement of ecosystem carbon sink capacity within the context of the 'Dual Carbon' strategic needs.

Although China's blue carbon value potential is enormous, the blue carbon market is underdeveloped, the policy and legal framework is incomplete, calculation standards are not unified, and the inability to integrate compliance markets with voluntary markets creates institutional barriers, resulting in blue carbon value being underutilised or even undervalued. Additionally, the marketisation of blue carbon value involves multiple stakeholders and is constrained by various uncertainties and risks related to society, governance, finance, and technology, all of which similarly impact the development of China's blue carbon market. This study summarises the theoretical foundations for realising blue carbon value, establishes a core mechanism framework for blue carbon marketisation, and develops an analytical perspective for marketising blue carbon value. Based on this, it examines the current state of China's blue carbon marketisation and institutional barriers, and proposes targeted optimisation pathways for marketising China's blue carbon value.

2.Theoretical Basis and Market Mechanisms for Blue Carbon Value Realisation

2.1 Theoretical Basis for Blue Carbon Value Realisation

Blue carbon value realisation is not merely a conceptual idea but is grounded in a solid theoretical foundation and scientific support.

2.1.1 Theory of Ecosystem Services Value Based on Ecological Economics

Blue carbon ecosystems inherently provide integrated services such as carbon sequestration, shoreline protection, biodiversity conservation, and the provision of high-quality food sources for humans. This forms the foundation for their value conversion and realisation. The theory of ecosystem services value emphasises that humans directly or indirectly obtain

indispensable material and non-material benefits from ecosystems, which can be converted into quantifiable value through scientific assessment. In 1997, a multidisciplinary team led by Robert Costanza made the first systematic attempt to estimate the economic value of 17 ecosystem services provided by 16 biomes worldwide, with the total value far exceeding the global gross national product (GNP) at the time (Costanza et al., 1997)[1]. This study strongly demonstrated the significant contributions of ecosystems to human well-being, emphasising the necessity and urgency of incorporating the value of ecosystem services into global pricing systems and decision-making processes. The MEA defined ecosystem services as the various benefits humans derive from ecosystems, including provisioning services, regulating services, cultural services, and supporting services (MEA, 2005)[11].

2.1.2 Marketisation and Trading Theory Based on Environmental Economics

From the perspectives of public goods theory and property rights economics, blue carbon exhibits typical characteristics of a 'quasi-public good'. On the one hand, the climate regulation benefits generated by mangroves and seagrass meadows absorb carbon dioxide radiate to the surrounding and even global regions. No enterprise or individual can be excluded from the scope of benefits derived from 'mitigating global warming', fulfilling the criterion of 'non-excludability'. On the other hand, when blue carbon sequestration capacity reaches ecological carrying capacity limits, additional carbon removal services acquired by new emitters displace existing beneficiaries' shares. Human activities—particularly corporate pollution—thus generate negative externalities. This quasi-public good nature leads to insufficient spontaneous market supply. Relying solely on voluntary corporate or individual protection of blue carbon ecosystems invites free-riding, representing a classic manifestation of market failure under public goods attributes. Property rights economics theory offers a 'pathway to rights clarification' for resolving blue carbon market failure. Environmental economics posits that the externalities of ecological resources fundamentally stem from ambiguous property rights demarcation. When blue carbon's 'carbon sink property rights' lack clear attribution, protectors cannot secure commensurate benefits, while polluters bear only partial costs of carbon emissions. This results in excessive negative externalities (pollution) and insufficient positive externalities (blue carbon sequestration). The Coase Theorem posits that under ideal conditions where property rights (such as carbon emission rights) are clearly defined and transaction costs are absent, markets can self-regulate and achieve optimal resource allocation at equilibrium. This implies that establishing clear property rights for blue carbon would enable marketisation through trading mechanisms. Such a system could internalise the positive external environmental benefits generated by blue carbon ecosystems, allowing producers and protectors to receive economic compensation or returns. This, in turn, would incentivise greater conservation and restoration efforts. Consequently, from the perspective of value realisation and efficient trading, environmental economics provides theoretical support for the market-based operation of blue carbon and the reduction of transaction costs.

2.1.3 Blue Carbon Value Assessment Model Based on Environmental Science and Ecology

The development of blue carbon methodologies and value assessment models provides a comprehensive, standardised, and scientific framework for carbon sink measurement and pricing. Blue carbon methodologies are comprehensive technical specifications, standards, and processes for defining, quantifying, monitoring, reporting, and verifying the carbon removal or reduction quantities generated by blue carbon projects. They aim to ensure the authenticity of blue carbon projects and provide a scientific basis for carbon credits and market transactions. The established consensus on blue carbon methodologies includes the applicability conditions for blue carbon (geospatial scope, ecosystem types, project activity methods such as conservation or restoration), project boundaries (geographical boundaries and accounting boundaries of carbon pools and greenhouse gas sources), baseline scenarios (natural trends in carbon storage under no-intervention conditions), additionality (scenarios where project implementation exceeds usual conditions), quantification of removals (carbon increments relative to the baseline scenario), monitoring plans (standards for monitoring carbon sink changes), leakage (the possibility of increased greenhouse gas emissions due to the project), and permanence (measures to ensure the long-term stable storage of carbon sinks). Blue carbon value assessment models extend the methodological outcomes, with the core function of pricing and evaluating the economic and social value of projects. The internationally recognised assessment model is primarily InVEST (Integrated Valuation of Environmental Services and Tradeoffs). The InVEST blue carbon module establishes a basic carbon pool by summing the carbon stocks of above-ground biomass carbon pools, below-ground biomass carbon pools, soil organic

carbon pools, and dead organic matter carbon pools to derive the total carbon stock and calculates its net present value (NPV). However, assessing the value of blue carbon is an extremely complex issue, as marine biodiversity is diverse, and carbon capture capacity and carbon sequestration efficiency vary. As a result, institutions in different countries have developed diverse blue carbon accounting methods tailored to specific regional ecosystems, further complicating efforts to establish uniform standards.

2.2 Market-Oriented Mechanism Framework for Blue Carbon Value Realisation

According to the definition of the blue carbon concept, the core of realising blue carbon value lies in converting the inherent ecological value of blue carbon ecosystems into economic returns through market transactions or ecological compensation mechanisms, thereby establishing an incentive structure where protectors benefit, users pay, and destroyers compensate. Realising blue carbon value through market-based pathways offers significant advantages. The carbon market itself has an incentive effect in terms of value discovery. Through market transactions, it maximises the economic benefits of carbon sinks, incentivises social capital to focus on and invest in blue carbon projects, and drives the allocation of social resources toward directions more conducive to ecological protection and greenhouse gas emission control, thereby maximising both social and ecological benefits. Based on existing research (Zhu Hui & Zhao Jiaqi, 2025)[18] and carbon trading practices, this study proposes that the institutional framework for realising blue carbon value through market-based mechanisms primarily encompasses four aspects.

2.2.1 Clear Property Rights Definition Mechanism

Clear property rights are a prerequisite for market transactions. Blue carbon is legally recognised as a tradable 'commodity' and a special type of usufructuary right. The realisation of blue carbon value is also an important form of realising the rights of natural resource asset owners. (Xu Yingbiao & Liu Mingxin, 2024)[17] In real-world transactions, blue carbon resources possess public goods attributes, and their service values are multidimensional, making property rights definition more challenging. This necessitates legal clarification of carbon property rights ownership and the separation and definition of blue carbon ownership, usage rights, income rights, and transfer rights (Li Shu-juan et al., 2023)[8]. For example, coastal vegetated systems such as mangroves occupy intertidal and subtidal zones, which are often contested spaces from a legal perspective. Who owns blue carbon assets and who has the right to trade carbon credits for specific blue carbon projects are also contentious issues. (Macreadie et al., 2022)[10]

2.2.2 Unified Standard Certification Mechanism

A unified standard certification mechanism is a crucial means for facilitating market-based blue carbon transactions and minimising transaction costs. In accordance with the MRV (Measurable, Reportable, Verifiable) principles established by the United Nations Framework Convention on Climate Change (UNFCCC, 2007)[16], only carbon sink projects certified through standardised procedures can generate blue carbon credits recognised by the market. This principle provides the foundational framework for harmonising global blue carbon standards. Current blue carbon standard certification faces significant fragmentation issues, constraining market circulation efficiency. At the international level, methodologies vary markedly between institutions and regions. China's Accounting Methods for Ocean Carbon Sink incorporates shellfish and macroalgae into carbon sink calculations, whereas Verra's Verified Carbon Standard (VCS) – a leading global certification body – currently does not recognise the carbon sink value of such ecosystems, citing scientific controversy over their net carbon sequestration capacity. This divergence necessitates complex standard conversions for cross-border transactions. Furthermore, existing standards predominantly focus on three traditional blue carbon systems: mangroves, salt marshes, and seagrasses. Certification frameworks for emerging blue carbon ecosystems, such as deep-sea coral reefs and halophytes, remain largely undeveloped.

2.2.3 Efficient Transaction Operation Mechanism

The blue carbon trading market is developing diversely, and the design of blue carbon trading operational mechanisms must consider the trading demands during the cultivation, growth, and maturity phases of blue carbon. Carbon prices exhibit variations under different transaction operating mechanisms. Currently, from the perspective of trading objects, the global blue carbon trading market is primarily divided into two categories: carbon-based direct trading and non-carbon-

based indirect trading. From the perspective of trading entities, carbon-based direct trading is further divided into voluntary markets, compliance markets, and inclusive markets. Voluntary markets (e.g., CCER) are based on voluntary carbon neutrality commitments from buyers (including enterprises, institutions, and individuals) and are suitable for corporate ESG strategies, product carbon neutrality labels, and carbon offsets for public welfare activities. Transaction prices in voluntary markets are typically higher than those in quota markets. Compliance markets (e.g., EU-ETS) involve mandatory emissions-reducing enterprises that must purchase carbon credits to offset excess carbon emissions. However, countries impose limits on offset quotas to promote corporate carbon reduction and emissions cuts, and such demand-side restrictions inevitably influence the formation of blue carbon prices. In the inclusive market, buyers are primarily small and medium-sized enterprises, communities, households, and individuals. Policies or commercial incentives are used to promote public participation in decentralised carbon reduction activities, fostering a stronger societal carbon neutrality atmosphere. Non-carbon-based indirect transactions utilise financial instruments such as funds, bonds, loans, and mortgages, as well as market-based measures like blue carbon industry development, to support blue carbon project financing, maximise the value of blue carbon assets, and optimise social and ecological benefits.

2.2.4 Robust Market Supervision Mechanism

Establishing a market supervision mechanism to maintain a fair and orderly market order is a crucial safeguard for the mature development of the blue carbon trading market. Creating a blue carbon trading center or platform, where transactions are conducted within a regulated exchange or system, helps enhance transparency, standardize processes, and ensure fund security. Blue carbon trading started late and is currently conducted primarily in voluntary markets. Compared with compliance markets, which already have strict quota supervision systems in place, the blue carbon market needs to strengthen the management of potential risks and compliance oversight.

3.Current Progress and Core Challenges in China's Blue Carbon Market

3.1 Development Status and Key Achievements

3.1.1 Preliminary Establishment of a National Blue Carbon Policy Framework

China ranks among the earliest nations to incorporate blue carbon into its marine management and greenhouse gas management policy agenda. As early as 2012, the State Council issued The 12th Five-Year Plan for the development of China's Marine Economy, explicitly advocating the utilisation of 'blue carbon sinks'. In 2015, The Opinions on Accelerating the Advancement of Ecological Civilisation were proposed, integrating marine carbon sinks into the overarching design of ecological civilisation development and mandating their application as a means to control greenhouse gas emissions. In 2019, The Implementation Plan for the National Pilot Zone for Ecological Civilisation (Hainan) proposed piloting marine ecosystem carbon sink initiatives and researching blue carbon standards and trading mechanisms. In 2020, the National Development and Reform Commission (NDRC) and the Ministry of Natural Resources (MNR) jointly issued the General Plan for Major Projects on the Protection and Restoration of Key Ecosystems in China (2021–2035), which included the deployment of a 'Major Project for Coastal Zone Ecological Protection and Restoration'. In 2021, the Central Financial and Economic Affairs Commission emphasised that The 14th Five-Year Plan period represents a critical phase for achieving carbon peaking, stressing the need to leverage the carbon sequestration capacity of oceans and enhance the incremental carbon sink potential of ecosystems. In January 2022, the MNR, NDRC, and National Forestry and Grassland Administration (NFGA) jointly issued the Planning for Major Engineering Projects on Coastal Ecological Protection and Restoration (2021–2035), strengthening theoretical research, technological breakthroughs, and standardisation in coastal zone ecological conservation and restoration.

Beyond establishing policy frameworks, Chinese scientists have fostered productive collaboration with national policymakers and enterprises, forming innovation consortia that provide theoretical and technical underpinnings for national policy innovation. In 2013, Chinese scientists established the China Ocean Carbon Alliance (COCA) with government departments and corporate experts. The Future Ocean Alliance (FOA) was founded in 2014, launching China's Blue Carbon Initiative. By 2019, Chinese scientists co-initiated the Global Ocean Negative Carbon Emissions (Global-ONCE), which has since expanded to include 79 scientific teams from 35 countries. On 18 July 2025, China hosted the International Blue Carbon

Forum in Hainan, bringing together experts, scholars and industry representatives from China, Norway, Brazil, Indonesia, Belgium, Germany, France, Canada and other nations. The event systematically showcased technological achievements in mangrove restoration, shellfish carbon sinks and related fields.

3.1.2 Accelerated and Active Exploration of Local Blue Carbon Marketisation

Since 2021, China's blue carbon marketisation process has begun to accelerate. In June 2021, the mangrove afforestation project in Zhanjiang, Guangdong Province, completed China's first transfer of 5,880 tCO_2e of carbon emissions reductions. In January 2022, Lianjiang County, Fujian Province, completed China's first fisheries carbon credits transaction. In September 2023, Shenzhen, Guangdong Province, completed the first auction of mangrove carbon credits. The transition from carbon sink agreement subscriptions to successful auctions marks China's entry into the market-based trading phase for blue carbon value realisation. In July 2024, the 10-year mangrove carbon sink development rights in Huidong County, Guangdong Province, were successfully transferred, pioneering the first mangrove carbon sink development rights transaction. In November 2024, Shenzhen collaborated with Enping City in Jiangmen to complete the auction of carbon credits from the mangrove forest conservation project in Zhenhai Bay, Enping. This transaction drew upon Shenzhen's mangrove carbon credit methodology and auction mechanism, achieving cross-regional standard recognition and advancing the development of the blue carbon trading market within the Guangdong-Hong Kong-Macao Greater Bay Area.

3.1.3 Blue Carbon Trading Service System Gradually Taking Shape

Local pilot projects have taken the lead in methodological exploration. In 2020, Dapeng New Area in Shenzhen issued the first local marine carbon sink accounting guidelines, identifying seven tradable carbon sink types, including mangroves, salt marshes, shellfish, and algae. In 2021, the Luoyang River Mangrove Ecological Restoration Project in Quanzhou, Fujian Province, completed a transaction based on the 'Mangrove Afforestation Carbon Sequestration Project Methodology' developed by Xiamen University. In 2023, the MNR issued the Accounting Methods for Carbon Sink, China's first comprehensive national standard for blue carbon accounting. This methodology expands the scope of blue carbon accounting to six major categories: mangroves, salt marshes, seagrass meadows, phytoplankton, large algae, and shellfish. The development of blue carbon trading markets or platforms has also begun. In 2021, the Xiamen Property Rights Exchange Centre (XPREC) established China's first marine carbon sink trading platform, which has gradually grown into the largest local blue carbon market in terms of trading volume. By April 2025, the XPREC had completed 220,000 tCO_2e of blue carbon transactions, accounting for approximately 80% of the national blue carbon market (Jin Xuan, 2025)[6]. In 2022, Hainan province established the first carbon emissions trading centre targeting the international market, with the Hainan International Carbon Emissions Centre aiming to promote Hainan's blue carbon methodologies as internationally recognised standards through the market-based trading of blue carbon products. Cross-regional cooperation between domestic local markets has also seen breakthroughs. In March 2024, the XPREC and the Ningbo Property Rights Exchange Centre jointly established the nation's first cross-provincial blue carbon ecological account for Xiangshan County, Zhejiang Province.

3.1.4 Blue Carbon Financial Tools are Becoming Increasingly Diverse

Since 2017, Shenzhen, Weihai, and Xiamen have successively established "Blue Carbon Funds" to purchase marine carbon sinks for investing in blue carbon projects in impoverished areas, supporting marine ranching, mangrove conservation, and carbon inclusive initiatives. Industrial Bank's Qingdao branch issued the nation's first wetland carbon sink loan, with Qingdao Jiaozhou Bay SCO Demonstration Zone Development Company obtaining an 18-million-yuan loan using Jiaozhou Bay wetland carbon sinks as collateral, specifically earmarked for marine wetland protection. In 2022, Lianjiang County, Fujian Province, completed the country's first digital CNY marine fishery carbon sink transaction involving 1,000 tCO_2e. China Life P&C-Weihai launched the first marine carbon sink index insurance to compensate for seagrass bed losses post-disasters. In 2023, ICBC Yangjiang Branch facilitated the first marine carbon sink expected revenue rights-backed loan. In 2024, Xiamen Property Rights Exchange Center and PICC P&C Xiamen introduced the nation's first property safety insurance for blue carbon trading. The development of blue carbon finance has provided crucial market-based support for realizing the value of blue carbon. The participants in the blue carbon market have also evolved from early government and research institution dominance to a diverse landscape now involving numerous enterprises, financial institutions, social organizations, and

individuals.

Table 1 Representative Blue Carbon Transaction Projects in China

Trading Hours	Subject of the Transaction	Transaction Price (Yuan /tCO_2e)	Method of Transaction	Buyer Entity	Scenario Innovation
2021.6	Mangrove Carbon Sinks	66	Agreement Subscription	NGOs	Zhanjiang Mangrove Forest Establishment Project, Guangdong Province.
2021.9	Mangrove Carbon Sinks	Not Disclosed	Platform Trading	Bank	Quanzhou Luoyang River Mangrove Ecological Restoration Project, Fujian Province.
2021.11	Mangrove Carbon Sinks	250	Purchase Carbon-neutral Flights Directly	Individual	Xiamen Airlines Has Partnered with Industrial Bank's Xiamen Branch to Offer 50,000 'Carbon-Neutral' Flight Tickets Priced at 10 Yuan Each, Offsetting 2,000 tCO_2e of Carbon Emissions from Air Travel (through the Carbon Sink Project at the Luoyang River Mangrove Ecological Restoration Project in Quanzhou, Fujian Province).
2022.1	Marine Fisheries Carbon Sinks	8	Platform Trading	Bank	Lianjiang Marine Aquaculture Project (Algae and Shellfish), Fujian Province.
2022.5	Mangrove Carbon Sinks	100	Platform Trading	Enterprise	Haikou Mangrove Restoration Project, Hainan Province.
2022.10	Marine Fisheries Carbon Sinks	20	Digital CNY Payments	Enterprise	Lianjiang Marine Aquaculture Carbon Sink (Bivalve Molluscs), Fujian Province.
2023.2	Marine Fisheries Carbon Sinks	106	Auction	Enterprise	Xiangshan Marine Aquaculture Carbon Sink (Algae), Zhejiang Province.
2023.4	Marine Fisheries Carbon Sinks	Not Disclosed	Carbon Account	Individual	"Blue Carbon + Justice" Carbon Sink Judicial Compensation in Xiangshan, Zhejiang Province.
2023.6	Mangrove Carbon Sinks	Not Disclosed	Options Agreement	Enterprise	The 10-year Carbon Sink from the Mangrove Afforestation Project in Yanpuwan, Cangnan, Zhejiang Province, is Pending Inclusion in the China Carbon Emission Reduction (CCER) Scheme Before Completion of Trading.
2023.9	Mangrove Carbon Sinks	485	Auction	Enterprise	Shenzhen Mangrove Conservation Project, Guangdong Province.
2023.9	Salt Marsh Carbon Sinks	Not Disclosed	Platform Trading	Enterprise	Yancheng National Rare Bird Nature Reserve Salt Marsh Ecological Restoration Project, Jiangsu Province.
2024.7	Mangrove Carbon Sinks	400	Platform Trading	Enterprise	Huidong Mangrove Creation Project Phase 10 Carbon Sink Development Right, Guangdong Province.
2024.7	Salt Marsh Carbon Sinks	Not Disclosed	Platform Trading	Institution	Alternative Ecological Restoration of Salt Marshes in the Yancheng National Nature Reserve for Rare Birds, Jiangsu Province
2024.7	Salt Marsh Carbon Sinks, Seagrass Meadows Carbon Sinks	44.4	Platform Trading	Enterprise	Ecological Restoration Project for the Yellow River Estuary Salt Marsh and Seagrass Meadows in Dongying, Shandong Province. Carbon-for-Compensation.
2024.11	Mangrove Carbon Sinks	1000	Platform Trading	Individual	Zhangzhou Jiulong River Estuary Mangrove Restoration Project, Ecological Public Interest Litigation, Fujian Province.

Trading Hours	Subject of the Transaction	Transaction Price (Yuan /tCO_2e)	Method of Transaction	Buyer Entity	Scenario Innovation
2024.11	Mangrove Carbon Sinks	336	Auction	Enterprise	Jiangmen Mangrove Ecological Restoration Project, Guangdong Province.
2025.4	Marine Fisheries Carbon Sinks	100	Platform Trading	Individual	Fuzhou Lvjuren Ecological Technology Co., Ltd. Has Developed an 'Sedimentary and Refractory Carbon' Carbon Credits Product for Alternative Ecological Restoration in Illegal Fishing Cases, Fujian Province.
2025.6	Marine Fisheries Carbon Sinks	100	Agreement Subscription	Institution	Zhoushan's 'Carbon Offsetting' (Shellfish Carbon Sinks) and Alternative Ecological Restoration in Illegal Fishing Cases, Zhejiang Province.
2025.6	Mangrove Carbon Sinks	557.7	Platform Trading	Individual	Shenzhen Mangrove Conservation Project. Alternative Ecological Restoration for the Illegal Seabed Sand Extraction Case, Guangdong Province.
2025.6	Marine Fisheries Carbon Sinks	164	Auction	Enterprise	Oyster Farming Project in Houmen Town, Shenzhen-Shantou Special Cooperation Zone, Guangdong Province.

Source: Compiled from publicly available information

3.2 Core Challenges in Blue Carbon Marketisation

Presently, whether driven by fulfilling international climate governance obligations under the Paris Agreement, advancing the implementation of China's dual carbon strategy, or addressing the practical need for high-quality ecological conservation to empower high-quality development, the market-based pathway for realising blue carbon value has become markedly significant and urgent. However, a series of institutional shortcomings pose tangible challenges to the orderly advancement of blue carbon marketisation. These shortcomings encompass gaps in the legal framework, fragmented standards and certification systems, and immature market mechanisms. These factors directly constrain the effective conversion of blue carbon's ecological value into economic value, hindering the full realisation of marine carbon sinks' supportive role in achieving the dual carbon goals.

3.2.1 Incomplete Legal Framework for Transactions

Blue carbon trading lacks nationwide legal or administrative regulations specifically designed for blue carbon. Its legal status within national climate change mitigation actions remains undefined, and blue carbon is currently excluded from China's national greenhouse gas inventory system. There are gaps in defining the rights attributes of blue carbon and establishing guiding principles for its conservation, development, and utilisation. Core issues such as property rights demarcation, benefit distribution, and regulatory responsibilities lack uniform national standards, significantly increasing market uncertainty. China's existing carbon markets primarily comprise the mandatory national carbon emissions trading market (China Carbon Emission Allowances, CEA) launched in 2021 and the voluntary emissions reduction trading market (China Certified Emission Reduction, CCER) initiated in 2024. The multi-tiered policy framework for the national carbon market—comprising administrative regulations, ministerial measures, normative documents, and technical standards—has been largely established (MEE, 2024)[12]. This comprehensive legal system provides crucial safeguards for its development. Currently, this market covers approximately 5.1 billion tCO_2e of carbon dioxide emissions annually, accounting for over 40% of China's total carbon dioxide emissions, making it the world's largest carbon market in terms of greenhouse gas emissions coverage. In contrast, the CCER remains in the foundational stage of institutional development, primarily operating under departmental regulations such as the 'Administrative Measures for Voluntary Greenhouse Gas Emission Reduction Trading' issued by the Ministry of Ecology and Environment (MEE) and the State Administration for Market Regulation (SAMR). Its legal standing is relatively low, and blue carbon has yet to become a core trading category. Transactions for blue carbon projects completed under local pilot schemes largely rely on regional regulations, such as the 'Zhoushan Municipal Measures for the

Management of Ocean Carbon Sink (Blue Carbon) Development and Trading', lacking the legal authority at the national level. This makes it difficult to support the formation of a unified national market.

3.2.2 Inadequate Standards and Certification Framework

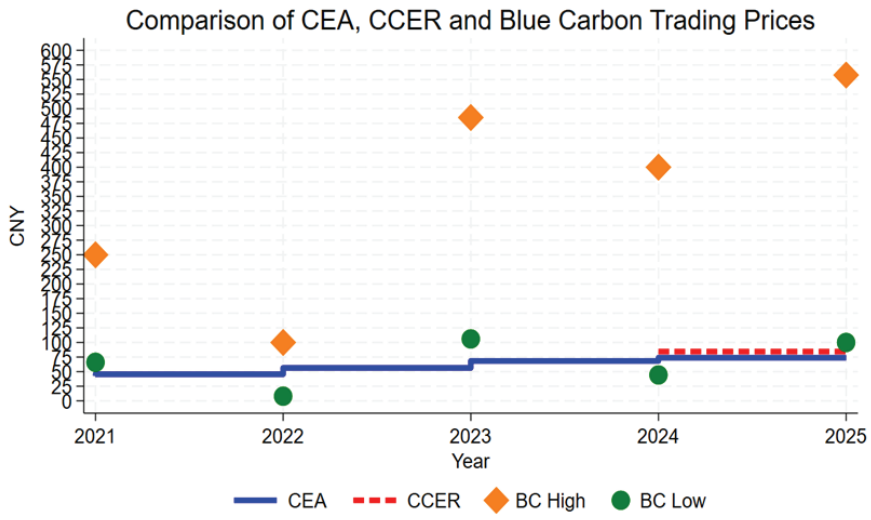
Despite diverse methodological explorations in local blue carbon projects, a unified national blue carbon accounting standard system remains unestablished. Furthermore, no coordinated standardisation mechanism has been formed across relevant departments. The MEE previously solicited greenhouse gas voluntary emission reduction project methodologies from the public, receiving 361 submissions. Ultimately, only four methodologies were approved in the first batch, with mangrove afforestation being the sole blue carbon project included (MEE, 2024)[12]. Among the three internationally recognised core blue carbon ecosystems (mangroves, salt marshes, and seagrass beds), national methodologies for salt marshes and seagrass beds remain absent. Similarly, methodologies for fisheries carbon sinks explored at the local level in China—such as shellfish aquaculture and algae cultivation—have not been incorporated into the national CCER system. Furthermore, China's CCER methodologies exhibit significant discrepancies with internationally recognised standards such as the Verified Carbon Standard (VCS). Taking mangroves as an example, the CCER methodology, designed for operational simplicity, diverges markedly in aspects including carbon pool selection, additionality assessment, crediting period definition, leakage quantification, and project boundary delineation. Certain requirements are comparatively lenient, resulting in limited international recognition. This lack of standard alignment directly constrains the international conversion of China's blue carbon resource value. Currently, only the Zhanjiang mangrove project in Guangdong Province has obtained certification under both the Verified Carbon Standard (VCS) and the Climate, Community and Biodiversity Standards (CCB), thereby qualifying for international trading.

3.2.3 Immature Market Trading Mechanisms

Presently, China's voluntary carbon market (CCER) serves only as a supplementary function to the national carbon emissions trading market (CEA), with markedly insufficient market activity. According to data from the National Carbon Market Information Network, since its reactivation until 21 August 2025, the CCER market has recorded a cumulative trading volume of merely 2,492,611 tCO_2e. This falls short of the weekly trading volume (3,153,852 tCO_2e) achieved by the CEA during the same period (15-21 August 2025). Due to institutional design prioritising 'emission reduction' objectives over 'carbon sink enhancement', the trading mechanisms of the two markets have failed to achieve full integration. Furthermore, stringent regulatory thresholds exist: carbon offsets purchased by enterprises from the voluntary market may not exceed 5% of their own emission reduction quotas during allocation settlement. This restriction has significantly dampened corporate purchasing interest. Supply-side constraints remain pronounced: only two mangrove restoration projects are currently registered and participating in CCER trading. The Xiapu Yantian Township and Changchun Town mangrove restoration project in Ningde, Fujian, achieves average annual emissions reductions of 1,085 tCO_2e, while the Jiulong River Estuary (Longhai) mangrove project in Zhangzhou contributes 1,720 tCO_2e annually. Neither project scale suffices to support the CCER market's demand for large-scale transactions. Since 2021, local blue carbon trading has exhibited characteristics of 'small scale and scattered distribution'. Most transactions consist of sporadic one-off contractual transfers or small-scale auctions, lacking sustained, stable, and large-scale trading activities. This has resulted in the market losing its core price discovery function. Regarding transaction prices, blue carbon projects exhibit significant volatility: mangrove projects range from a low of ￥66/tCO_2e of carbon dioxide equivalent to a high of ￥1,000/tCO_2e; fisheries carbon sinks range from a low of just ￥8/tCO_2e to a high of ￥164/tCO_2e. This excessive price disparity fails to accurately reflect the comprehensive ecological and economic value of blue carbon projects and makes it difficult to provide investors with stable return expectations. More notably, despite blue carbon's high carbon sequestration efficiency and significant ecological value, its transaction prices remain substantially lower than green carbon. In 2024, the transaction price for the Yellow River Delta salt marsh project in Dongying, Shandong, was approximately ¥44.4/tCO_2e, compared to approximately ¥70/tCO_2e for forest carbon sinks during the same period. This price also falls below the average transaction price in the CCER market from its 2024 restart to August 2025 (approximately ¥85/tCO_2e). Beyond being influenced by the core factor of cyclical market supply and demand, the current agreement transfer prices for pilot projects in many regions are largely administratively guided rather than fully market-determined. This reflects

the breakthrough signal of local blue carbon markets moving from 'zero-to-one', rather than the value expression of a mature market.

Figure 1 Comparison of CEA, CCER and Blue Carbon Trading Prices



Source: Calculated based on publicly available data from the National Carbon Market Information Network (https://www.cets.org.cn.)[13] and other sources.

Notes:

1. The CEA market commenced in July 2021, with annual average transaction prices of ￥42.9/tCO₂e in 2021, ￥45.6/tCO₂e in 2022, ￥56.4/tCO₂e in 2023, and ￥68.3/tCO₂e in 2024;

2. The CCER market commenced in January 2024, with an average transaction price of ￥84.4/tCO₂e since inception;

3. Blue carbon transactions lack continuity and are fragmented, precluding the calculation of an average price. Comparisons are thus based on annual peak and trough prices. Notably, 2024 witnessed a record high of ￥ 1,000/tCO₂e, reflecting judicial penalty pricing that lacks comparability and is therefore excluded from analysis.

3.2.4 Blue Carbon Projects Exhibit Shortcomings in Risk Management Capabilities

Blue carbon ecosystems may be damaged by human activities such as urban expansion, agricultural development, aquaculture, shoreline destruction, and wastewater discharge, or may degrade and lose their carbon sequestration functions due to natural changes, posing high risks of value loss. In early 2008, low temperatures in Guangxi caused widespread freezing of mangrove forests. Additionally, blue carbon conservation and restoration projects require significant upfront investments, particularly for carbon sequestration projects that require long-term monitoring. Development and MRV costs are high, and the return on investment cycle is lengthy, making it difficult to attract social and commercial capital. Project funding sources are overly reliant on government budgets and charitable donations, creating significant pressure on sustained funding, which may lead to fluctuations in carbon credits. According to statistics, from 2019 to 2023, there were a total of 28 mangrove ecosystem protection and restoration projects nationwide, covering an area of 3,346.21 hectares. During this period, approximately 10.687 billion yuan in financial support was provided by central and local governments, with an average investment of 3.19 million yuan per hectare (Li Jianping, 2024)[7]. The more project funding relies on government support, the lower the activity of the blue carbon market becomes, and the longer the path to achieving market-based blue carbon value. It is important to note that a national blue carbon trading information platform has not been established, and there are no mandatory regulations for disclosing key information such as blue carbon project resources, certification, and transactions. This leads to information asymmetry in the market, making it difficult to promptly identify 'bluewashing' behaviour, which could potentially trigger carbon financial risks through fake carbon credits.

4.Building New Pathways for China's Blue Carbon Value Realisation

Globally, blue carbon development is gaining momentum, and the realisation of blue carbon value is increasingly being integrated into national ecological competitiveness. Leveraging the strong driving force of China's national 'dual carbon'

strategy and its growing body of pilot experience, combined with innovative market-based pathways for value realisation, China is fully capable of transforming its vast blue carbon resource advantage into a competitive edge in addressing climate change and achieving sustainable development.

4.1 Strengthen Systematic Legislation to Lay a Solid Institutional Foundation

Refine the legal framework governing blue carbon. Accelerate the compilation of the National Ecological and Environmental Code, establishing a dedicated section on green and low-carbon development (including a chapter on climate change response). Systematically incorporate the dual carbon goals and green transition requirements into the legal framework, providing principled and forward-looking legal norms for emerging ecological fields such as blue carbon. Simultaneously establish an 'Ecological Protection Chapter' explicitly designating blue carbon ecosystems (mangroves, salt marshes, seagrass meadows, etc.) as priority conservation targets. Authorise the State Council and relevant departments to formulate supporting regulations for realising the value of ecological products, providing overarching planning and institutional foundations for resolving core issues such as blue carbon property rights demarcation and market mechanism gaps.

Revise the national 'Administrative Measures for Voluntary Greenhouse Gas Emission Reduction Trading' to formally recognise blue carbon projects' legal status within the China Certified Emission Reduction (CCER) mechanism. Integrate blue carbon into China's national greenhouse gas inventory system and establish substantive and procedural rules for its full incorporation into the unified national carbon market. Given blue carbon's high dependence on marine natural resources, the 'Blue Carbon Resource Management Regulations' should be enacted to clearly define property rights attribution, establish comprehensive transaction protocols, and delineate interdepartmental regulatory responsibilities. Building upon the existing unified natural resource rights registration system, detailed rules and operational procedures for blue carbon property rights registration should be refined to achieve standardised and traceable registration.

Strengthen the blue carbon methodology framework by concentrating research efforts on developing carbon sink measurement methodologies for seagrass beds, salt marshes, and key marine aquaculture species (such as oysters and kelp). Expedite their inclusion in the national CCER methodology catalogue to ensure all blue carbon project types have a legal basis for development. Simultaneously, accelerate the narrowing of technical gaps between China's CCER methodologies and internationally recognised standards (such as VCS and Gold Standard). Promote international alignment on key indicators (including carbon pool accounting scope and additionality verification criteria) to remove standardisation barriers for China's blue carbon projects accessing global markets.

4.2 Build a Multi-tiered Blue Carbon Market to Stimulate Market Dynamics

Establish a multi-tiered, differentiated blue carbon market system to facilitate the comprehensive integration of blue carbon into the national carbon market framework. This will create a unified blue carbon trading market characterised by high standards and transparent, regulated transactions, gradually increasing market scale and activity. Optimise compliance market trading rules to permit non-compliant entities (such as public welfare organisations and ESG-oriented enterprises) to participate in trading. Gradually expand the proportion of blue carbon CCERs eligible for offsetting within the national carbon emissions trading market (e.g., from the current 5% to 10%-15%), while broadening the scope of offset applications. This will foster effective market demand incentives, thereby enhancing the intrinsic value of blue carbon assets.

Consolidate the foundation of the voluntary carbon market by reducing administrative intervention and establishing a mature, market-driven price formation mechanism to prevent price distortions caused by excessive local government guidance. Encourage enterprises to purchase blue carbon as a key means of achieving ESG objectives and fulfilling social responsibilities. Establish an official blue carbon purchase certification system and information disclosure platform to enhance transaction transparency and credibility. Accelerate the development of inclusive markets by encouraging the establishment of personal carbon accounts nationwide and optimising carbon revenue distribution systems (e.g., through personal carbon sink credits, charitable carbon sink subscriptions, and carbon-neutral flight/ferry tickets). This will channel blue carbon dividends directly to local communities, ecological conservation participants, and vulnerable groups, substantially boosting public engagement in blue carbon initiatives. The 2022 designation of Xiamen's Guomao Tiancheng Residential Community as China's first 'zero-carbon community' achieving community carbon neutrality through blue carbon offsets exemplifies such

public engagement scenarios (Lian Wei, 2023)[9].

Strengthen coordination among existing local blue carbon trading centres to explore establishing regional blue carbon trading hubs (e.g., in the Guangdong-Hong Kong-Macao Greater Bay Area and Yangtze River Delta). Develop integrated 'blue carbon plus' products to promote deep integration of carbon sinks with coastal tourism, green exhibitions, ecological fisheries, and marine culture industries. This approach achieves diversified value accumulation across regions, sectors, and multiple stakeholders.

4.3 Promote Diversified Blue Carbon Financial Innovation and Activate Blue Carbon Assets

Promote and deepen the 'blue carbon plus finance' model, extending products such as 'marine carbon sink loans' and blue carbon pledge financing from pilot regions nationwide. Rushan, Shandong province, has secured a ¥50 million pledge loan against anticipated oyster carbon sink revenue rights, while Zhoushan has launched a mussel carbon sink pledge financing product. Such successful experiences can be replicated across coastal provinces through specialised guidance from the China Banking and Insurance Regulatory Commission (CBIRC). Simultaneously, drawing on local initiatives such as Zhangzhou securing the inaugural blue carbon loss insurance policy for mangrove projects in 2024, financial institutions should be encouraged to develop innovative products based on blue carbon assets. These include blue bonds, blue carbon insurance, and blue carbon trust funds, explicitly covering carbon sink losses caused by marine disasters like typhoons and red tides. Integrating blue carbon into Ecology-Oriented Development (EOD) projects will drive innovation in blue carbon financial applications.

Establish a national or regional blue carbon development fund, adopting a government-guided, market-oriented operation model to attract long-term capital and patient capital, and mobilise social capital to provide long-term, low-cost financial support for blue carbon projects. Explore blue carbon futures and other derivative transactions. When conditions are ripe, launch blue carbon futures, options, swaps, and other financial derivatives to provide risk hedging tools and help investors manage price risks. Strengthen international cooperation, connect global blue carbon markets, issue offshore blue yuan bonds, and attract international capital to invest in China's blue carbon projects.

4.4 Strengthening International Technical Cooperation to Advance Blue Carbon Industry-Research Integration

Whilst the nation's international commitments to climate change have catalysed the blue carbon market, policy-driven measures alone cannot sustain its long-term prosperity. The expanding developmental needs of the blue carbon industry itself constitute the core prerequisite for the market's enduring vitality. The value of blue carbon stems from significant scientific discoveries, and technological advancement constitutes the core foundation for its industrial development. This represents a distinct characteristic distinguishing blue carbon value realisation from other ecological products. The industrial support role of cutting-edge blue carbon technologies manifests primarily in three aspects:

Firstly, through in-depth research into the regulatory mechanisms governing blue carbon formation processes, new models, business formats, and application scenarios for the blue carbon industry are continually cultivated, integrating carbon science, carbon ecology, and carbon economics. In recent years, Chinese scientists have emerged as one of the leading groups in international blue carbon research. Original theories such as the 'Marine Microbial Carbon Pump' (MCP) have gained widespread recognition within the global scientific community and have been incorporated into reports by the UNEP. Research by scholars including Jiao Nianzhi and Dai Minhan indicates that relying solely on natural marine carbon sinks is insufficient to achieve carbon neutrality goals. Systematic investigation into marine negative emissions theory and methodologies is required, alongside the development of implementable technical pathways and action plans (Jiao Nianzhi & Dai Minhan, 2022)[4]. Accordingly, technical solutions have been proposed to transform traditional carbon sources into sinks, including integrated land-sea emission reduction and carbon sequestration, restoration of degraded marine areas to enhance sequestration, comprehensive sequestration in marine aquaculture zones, and alkalisation of wastewater from sewage treatment plants for carbon sequestration upon discharge into the sea.

Secondly, by establishing scientific standards for marine carbon sinks, support is provided for the development of blue carbon trading systems. The technical pathways proposed by ONCE build upon MRV (Measurable, Reportable, Verifiable)

requirements by introducing the higher-order NOCE-3R standard—Reasonable, Reliable, Reproducible. This framework has secured approval from the International Organisation for Standardisation (ISO) to establish the 'Ocean Negative Emissions and Carbon Neutrality' International Standard Working Group (ISO-TC8WG15) (Jiao Nianzhi, 2025)[5].

Thirdly, strengthening international collaborative innovation in blue carbon technologies represents a critical pathway to overcoming industrial bottlenecks and enhancing global influence. China may leverage the ONCE programme to establish transnational technical cooperation platforms, jointly founding 'Blue Carbon Technology Joint Laboratories' with international institutions such as the Institute of Marine Research (Norway) and the Indonesian Mangrove Research Centre. These laboratories should prioritise tackling common technological challenges including carbon sequestration regulation in tropical and subtropical mangroves and deep-sea carbon sequestration monitoring. Concurrently, deepen alignment with the EU's Horizon 2020 blue carbon projects, establishing regular exchange mechanisms in areas such as mutual recognition of carbon measurement methodologies and sharing of ecosystem restoration technologies. For instance, drawing on Germany's experience with 'blue carbon remote sensing satellite constellations' could enhance China's three-dimensional monitoring network (satellite + UAV + underwater sensors), promoting deeper compatibility between blue carbon technical standards and international systems. Furthermore, initiate the 'Global Blue Carbon Young Scientists Training Programme' to jointly cultivate multidisciplinary talent with institutions, thereby building intellectual reserves for international blue carbon technology cooperation.

These endeavours present a pivotal opportunity for China to develop internationally recognised blue carbon project methodologies and certification standards. This will help resolve the longstanding challenges of inconsistent standards and difficulties in mutual recognition that have hindered China's blue carbon industry development, providing robust scientific and technological support for blue carbon marketisation.

5.Conclusions and Outlook

Realising the value of blue carbon represents not only a crucial measure for global collaborative action against climate change and China's fulfilment of international emission reduction commitments, but also a proactive choice in advancing Chinese-style modernisation characterised by harmonious coexistence between humanity and nature. China's practical experience has fully demonstrated the feasibility and developmental potential of commercialising blue carbon value. Local pilot schemes—such as the mangrove carbon sink trading in Zhanjiang; the fishery carbon sink pilot in Lianjiang; and the judicial trading of mussel carbon sinks in Zhoushan—have explored market-based pathways for blue carbon through multiple dimensions, including trading models, product innovation, and scenario integration. The powerful policy impetus of the national 'dual carbon' strategy has formed an organic synergy with pragmatic innovation at the local level. Managers, scientists and enterprises have formed cross-sector innovation consortia; financial institutions piloted 'ocean carbon sink loans'; the private sector participated in blue carbon project investments; and public welfare organisations promoted blue carbon science communication. Attention and participation from all parties continue to intensify. Combined with the public's strong endorsement of the concept of 'harmonious coexistence between humanity and nature, symbiosis between humans and the sea', these factors have collectively created unprecedented favourable conditions for establishing China's blue carbon marketisation system.

Nevertheless, the overall effectiveness of realising blue carbon value in China remains insufficient: market development commenced relatively late, and transaction volumes remain fragmented (blue carbon CCER trading in 2025 accounted for merely 0.3% of the national carbon market total), falling far short of unlocking the latent value of China's vast blue carbon resources, including mangroves, seagrass beds, and fisheries carbon sinks. While foundational consensus on blue carbon marketisation exists, the disconnect between theoretical understanding and practical implementation requires bridging through systematic institutional design. The core challenge lies in transforming the implicit ecological value of blue carbon ecosystems into carbon credits or carbon sink products characterised by clear property rights, scientific measurement, standardised verification, and seamless trading. The core challenges in blue carbon marketisation centre on ambiguous property rights, inconsistent measurement and certification standards, dysfunctional market price discovery mechanisms, and limited application scenarios. Consequently, China's blue carbon marketisation requires a four-dimensional support system

encompassing ‘institutional frameworks, trading mechanisms, capital mobilisation, and technological innovation’: Strengthen systematic legislation to solidify the institutional foundation; Developing multi-tiered blue carbon markets to stimulate market momentum; Promoting diversified blue carbon financial innovation to unlock blue carbon assets; Advancing blue carbon technological innovation and industrial integration aligned with global scientific frontiers.

Currently, global blue carbon trading occurs almost exclusively within voluntary markets, with very limited practice in integrating it into mainstream compliance markets at scale. Even within the EU-ETS—the world’s most mature and active carbon market—blue carbon transactions account for less than 1% of total volume. Consequently, there is strong advocacy for incorporating blue carbon as high-quality carbon offset credits into emissions trading schemes. The United Nations COP29 conference, which concluded in November 2024, approved Article 6.4 of the 2015 Paris Agreement. This provision establishes a global carbon market mechanism overseen by the United Nations, designed to support climate action by increasing demand for carbon credits. It is not difficult to foresee that as the carbon peak target period draws nearer, the global blue carbon market will witness tremendous growth. More importantly, in the long term, as we approach net-zero emissions, carbon pricing could be set according to the cost of direct greenhouse gas capture, with revenues used to fund carbon removal from the atmosphere. This would fundamentally alter our perception of commodities. (Bill Gates, 2021)[2] Blue carbon, with its high carbon sequestration value, is poised to become the most sought-after commodity in the market, positioning the blue carbon market as an emerging sector underpinned by cutting-edge technology. Institutionally, existing national blue carbon markets exhibit relatively narrow gaps in awareness and development levels. Although China’s blue carbon market development commenced later, its close integration with frontier technologies will constitute a significant competitive advantage for future market growth. In this sense, China’s blue carbon value realisation has not been ‘start at a disadvantage’. Moreover, China’s practical experiences and case studies in blue carbon value realisation will provide valuable insights for the global blue carbon market’s development.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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