SCIEPublish

Article

Mechanism Obstacles and Path Breakthroughs for International Low-Carbon Technology Sharing

Xiaomei Wang *

School of International Affairs and Public Administration, Ocean University of China, Qingdao 266000, China

* Corresponding author. E-mail: michellewxm@126.com (X.W.)

Received: 14 May 2025; Accepted: 4 July 2025; Available online: 21 July 2025

ABSTRACT: The deepening of global climate governance urgently needs to solve the institutional predicament between the monopoly and sharing of low-carbon technologies. In analyzing the institutional obstacles to the sharing of low-carbon technology, the study found significant asymmetric conflicts between developed and developing countries in technology supply, institutional rules, and market dynamics. The current international rule system (such as the Agreement on Trade-Related Aspects of Intellectual Property Rights and Bilateral Investment Agreement) has solidified the "central-periphery" pattern of technology distribution through tools such as "prohibition provisions on compliance requirements" and "green patent barriers", resulting in developing countries facing dual pressures of "compliance costs" and "technology dependence". In contrast, developed countries have fallen into the predicament of "innovation involution" due to the mismatch of technological application scenarios. Based on the theory of the technology life cycle and the perspective of subject complementarity, there is a structural mutual benefit space in the supply and demand of low-carbon technologies among different countries: developing countries can shorten the industrial decarbonization cycle through technology sharing, while developed countries rely on technology diffusion to digest excess capacity and consolidate their dominance in rules. By deconstructing the practical effectiveness of the low-carbon patent sharing platform and the defensive patent licensing model, it is highly feasible to reconstruct the technology sharing incentive framework with the "open-source mechanism". Constructing a multi-level incentive mechanism to promote corporate participation, introducing dynamic defensive patent commitments, strengthening institutional capacity building, establishing a coordinated regulatory mechanism, and enhancing stakeholder compliance mechanisms are institutional optimization pathways. These provide a legal basis for harmonizing the exclusivity of intellectual property rights with the public nature of climate governance, and also offer strategic references for China's participation in the formulation of global low-carbon technology regulations.

Keywords: Low-carbon technology; Technological monopoly; Technology sharing; Structural complementarity; Technology sharing platform

1. Introduction

While reshaping the paradigm of human existence, industrial civilization has also pushed climate governance into the contradictory predicament of "global public domain" and "private rights of technology". The 1.5 ℃ temperature control target established by the Paris Agreement essentially creates a hard legal constraint on national emission reduction obligations. However, the conflict between "intellectual property protection" and "climate justice" has led to a contradiction between the monopoly of low-carbon technologies and the demand for their sharing. Although developing countries, including China, have strengthened their emission reduction commitments through policy documents such as *Strengthening Response to Climate Change—China's Nationally Determined Contributions*, the monopoly of low-carbon technologies still puts their low-carbon transformation at risk of a "commitmental-capacity" break. Therefore, driven by the logic of collective action in climate governance, countries urgently need to break through the binary opposition between "compulsory licensing" and "voluntary sharing" of low-carbon technologies and explore a rebalancing path between property rights rules and public interests.

The current emission reduction strategies in climate governance can be summarized into two categories: the first is to achieve stock reduction through industrial scale control; the second is to restructure the production mode by relying on low-carbon technological innovation. The latter has become the priority option of the international community

https://doi.org/10.70322/ces.2025.10009

because it combines the effectiveness of emission reduction and economic growth. However, the monopoly of low-carbon technologies has led to a "center-periphery" distribution pattern of low-carbon technologies—developed countries benefit from monopolies such as patent protection, while high licensing costs and a gap in tacit knowledge constrain developing countries. Take China's energy transition as an example. However, the *13th Five-Year Plan for the Development of Renewable Energy* clearly states the goal of "promoting the localization level of raw materials, product preparation technologies, production processes and production equipment throughout the entire industrial chain", a large number of key technology patents are still concentrated in European and American enterprises, resulting in many industries in China being unable to obtain effective low-carbon technology support. As a result, the policy ambition of reducing emissions cannot be achieved [1]. Under the current global low-carbon technology governance system, breaking down technological monopoly barriers and promoting the sharing of multinational technology have become core challenges for China and other developing countries in achieving low-carbon transformation.

2. An Argument on the Necessity of Sharing Low-Carbon Technologies from a Win-Win Perspective

2.1. Low-Carbon Technology Is Not a Broad Ecological Benefit Optimization

Low-carbon technology falls under the category of green technology or environmentally friendly technology. Its essential feature lies in achieving absolute reduction of carbon emissions through industrial technological innovation, rather than optimizing ecological benefits in a broad sense [2]. The term "low-carbon technology" as mentioned in this article specifically refers to technologies that directly reduce carbon emissions (such as carbon capture and renewable energy), which is distinguished from the broader concept of "green technology" (including ecological restoration and other technologies). Low-carbon technologies can be classified into two categories based on the degree of innovation: progressive technologies (such as energy efficiency improvement processes) reduce carbon emissions per unit of output through marginal improvement, focusing on the rational use of existing patents; Breakthrough technologies (such as hydrogen production, carbon capture and storage) have triggered intense conflicts between intellectual property protection and global public interests by disrupting existing production models. Compared to progressive technologies, breakthrough technologies are more related to the effectiveness of climate governance and are the focus of international law to reconcile the exclusivity of private rights with climate justice. However, its controversy lies in that its research and development costs are highly dependent on patent monopoly incentives. Still, the overly long technology lock-in period will exacerbate the gap in emission reduction capabilities between developed and developing countries. Therefore, this study explicitly defines breakthrough low-carbon technologies as the research subject, and the term 'low-carbon technologies' used hereafter refers to this category of technologies.

Currently, most technology sharing platforms focus on breakthrough technological innovations, such as Carbon Capture and Storage (CCS) and other frontier technologies, which are crucial for global environmental governance. However, the success of technology transfer relies not only on these revolutionary technologies but also on the sharing and dissemination of incremental technologies used in everyday operations. For example, optimization designs like energy efficiency improvements and renewable energy integration technologies. These incremental technologies can significantly reduce carbon emissions in the short term and have wide adaptability and operability. Therefore, it is recommended to include incremental technologies within the scope of global technology sharing platforms. By promoting such technologies, developing countries and emerging markets can achieve technological progress more quickly, without having to wait for more expensive and complex breakthrough technologies [3]. Furthermore, promoting incremental technologies helps accelerate the dissemination of technology, especially in resource-constrained regions, where environmental benefits can be achieved at a lower cost. By enhancing the sharing of incremental technologies, we can ensure broader accessibility and drive a global low-carbon transition.

2.2. Structural Obstacles Exist in the Sharing of Low-Carbon Technologies

Although existing research generally recognizes the core value of low-carbon technologies in climate governance, it lacks an in-depth analysis of the structural obstacles to multinational sharing. For instance, the academic community's focus on the circulation of low-carbon technologies (research and development → verification → production) has mostly been concentrated on economic efficiency analysis, while overlooking the contradictions and conflicts between technological monopolies based on patents and the technological acquisition demands of developing countries [4]. For instance, according to Article 66, Paragraph 2 of the *Agreement on Trade-Related Aspects of Intellectual Property Rights* (TRIPS Agreement), "developed countries have the obligation to encourage enterprises to transfer technologies to the least developed countries". However, the Bilateral Investment Agreement (BITS) led by the United States and

Europe have adopted "prohibition provisions on performance requirements", such as Article 8 of the *United States Model Bilateral Investment Agreements* (BIT Model), "Restricting the host country from requiring technology sharing on the condition of market access" essentially weakens the ability of developing countries to use domestic policy tools to eliminate the monopoly of low-carbon technologies. In the game practices of various countries, the gap in low-carbon technologies among different countries has further intensified: Developed countries consolidate their technological monopolies by means of "green patent barriers" (such as carbon capture technology patent pools), while developing countries are forced to bear the dual pressure of "compliance costs" and "technology dependence" due to the strict application of flexible provisions in the *Agreement on Trade-Related Aspects of Intellectual Property Rights* (such as mandatory licensing under Article 31). Take the photovoltaic industry as an example, although China accounts for 70% of the global module production capacity, the patents for the preparation process of thin-film batteries are still held by European and American enterprises such as First Solar, forcing the industrial upgrading to be constrained by the accumulation of licensing fees and the hidden technological gap [5]. Against this backdrop, relying solely on domestic technological iterations in developing countries is difficult to break through the structural predicament. Only by exploring appropriate paths for sharing low-carbon technologies can a substantial leap in emission reduction efficiency be achieved.

At present, the international framework for sharing low-carbon technologies can be classified into three categories based on the technology life cycle: research and development cooperation (such as cross-border joint laboratories), patent licensing (such as the authorization of standard essential patents), and institutional coordination (such as multilateral carbon tariff mechanisms) [6]. Among them, patent licensing, as the core link in the transformation of technological achievements, carries the structural contradiction between the strong protection demands of developed countries for intellectual property rights and the inclusive access demands of developing countries. In the field of low-carbon technology, developed countries monopolize the formulation of technical standards due to their first-mover advantage, while developing countries, lacking institutional discourse power, are forced to accept asymmetric terms in technology transfer. This institutional paradox highlights the inherent contradictions in the governance of low-carbon technologies: on the one hand, the global public nature of the climate crisis demands open and shared technologies; on the other hand, the existing intellectual property system, by strengthening patent exclusivity, turns low-carbon technologies into a geopolitical leverage. In terms of global climate governance, technology sharing has significant collective action value; from the perspective of benefit distribution, such a sharing mechanism can achieve a win-win scenario, where developed countries can monetize their technologies, and developing countries can build capacity.

2.3. Low-Carbon Technology Sharing: Bridging Emission Commitments and Technological Disparities in Developing Countries

For developing countries, the necessity of sharing low-carbon technologies stems from the structural imbalance between global emission reduction commitments and the uneven distribution of technology. During the process of industrialization, the high-carbon path dependence and the insufficient supply of low-carbon technologies have formed a sharp opposition, trapping many developing countries in the economic transformation period in a common predicament: The strengthening of environmental regulations has given rise to an urgent demand for low-carbon technologies, but the lagging domestic R&D capabilities have led to a heavy reliance on external inputs for technology supply. This contradiction is particularly evident in energy-intensive industries, where research and development as well as the transformation of key decarbonization technologies are often concentrated in developed countries, although developing countries have set ambitious emission reduction targets, they are still constrained by barriers to obtaining core technologies [7]. The tension of international rules has further exacerbated the "dual lag in quality and quantity" of technology supply. In the transformation chain of technological achievements from basic research to industrial application, developing countries generally face institutional bottlenecks: On the one hand, the strong protectionist tendency of intellectual property rights has raised the threshold for technology sharing; On the other hand, the fragmentation of international collaboration mechanisms has weakened the effectiveness of technology diffusion. This asymmetry between the system and technological capabilities forces the technology recipient countries to bear the dual pressure of emission reduction responsibility and technological weakness when addressing the climate crisis.

2.4. System Coupling in Low-Carbon Technologies: North-South Synergies

For developed countries, the necessity of sharing low-carbon technologies stems from the structural mismatch between technology supply and demand. Although such countries have an advantage in technological research and development, the transformation of their industrial structure leads to a large number of low-carbon technologies being

difficult to effectively transform in the domestic market. The innovative characteristics of low-carbon technologies - including the strong specificity of application scenarios and the high frequency of technological iterations - determine that their promotion needs to be highly dependent on the collaborative adaptation of the external market. When developed countries transfer high-carbon production links to developing countries through industrial relocation, a systematic gap emerges between the local retained technological application scenarios (such as intensive industries) and the existing technological supply directions (such as decarbonization solutions for traditional industries), leading to a predicament of over research and underapplication of technological achievements [8]. The underlying cause of this predicament can be attributed to the collaborative failure of "technology, system, and market." Although government regulation, economic level, and public awareness have jointly promoted the prosperity of technological research and development, the unidirectional upgrading of the industrial structure has compressed the space for technological transformation. Furthermore, in the process of pursuing industrial competitive advantages, developed countries often alienate low-carbon technologies into strategic assets rather than public goods, further intensifying the conflict between technological monopolies and the global demand for emission reduction [9]. In the long run, if developed countries fail to reconstruct the technology diffusion mechanism through shared paths, they may face the dual crises of innovation competition and the lack of climate responsibility.

Developed countries and developing countries have structurally complementary characteristics in low-carbon technologies. Developing countries have a rigid demand for mature and directly convertible low-carbon technologies, while developed countries urgently need to absorb excess capacity and expand market space through technology diffusion [10]. The former can rapidly narrow the gap in industrial decarbonization capacity through the introduction of technology, while the latter strengthens its dominant position in the global value chain by means of technology output. This complementarity breaks the traditional narrative of "technological dependence" and turns to the logic of collaborative governance based on mutually beneficial exchanges. For developing countries, sharing low-carbon technologies is not only a breakthrough to break the "high-carbon lock", but also a strategic lever to reconstruct industrial competitiveness. By taking over the technology transfer from developed countries, developing countries can shorten the technology iteration cycle and achieve leapfrog development in areas such as clean energy and energy efficiency improvement. For developed countries, the sharing of low-carbon technologies will not weaken their innovation advantages. Instead, it can reduce the sunk cost of technologies through economies of scale. At the same time, it can embed technical standards into the markets of developing countries and consolidate their rule-making rights. Suppose both sides can move beyond the zero-sum game thinking and coordinate the mismatch between technology supply and demand through international mechanisms. In this case, the sharing of low-carbon technologies may become a "win-win" practice in global climate governance.

2.5. The Low-Carbon Technology Sharing Models Practiced by Developing Countries and Their International Promotion Pathways

In the global practice of sharing low-carbon technology, India's wind power industry provides a representative case. India has introduced and localized wind power technologies through various mechanisms, particularly by forming diversified technology transfer pathways at the corporate level. Specifically, Indian companies have acquired technological knowledge through multiple forms, including technology licensing, joint ventures, mergers and acquisitions, and the establishment of international R&D centers in collaboration with foreign companies. Notably, the model of acquiring foreign companies through mergers and acquisitions, complemented by independent R&D, such as Suzlon establishing an R&D center in Europe, has significantly enhanced its technological innovation capabilities. On the other hand, foreign-funded companies' wholly owned subsidiaries (WFOEs) established in India, while bringing advanced manufacturing technologies, have a limited impact on the subsidiary's local innovation capabilities since the intellectual property remains controlled by the parent company. In contrast, joint ventures where Indian local companies hold a majority stake and actively engage in R&D tend to achieve better results in technology absorption and re-innovation. Furthermore, since 2003, the Indian government has utilized the Electricity Act and the "Generation-Based Incentive Policy" (GBI) to create a performance-oriented and clear market environment, significantly attracting independent power producers and international investors, which has indirectly promoted the transfer and localization of advanced wind power technologies [11]. Therefore, India's experience indicates that providing local companies with sufficient control and R&D incentives in institutional design, along with a long-term stable policy environment, helps to foster the in-depth development of technology sharing platforms. This provides important experiential support for developing countries to participate in the construction of global technology sharing platforms.

Brazil has played a significant role in international low-carbon technology sharing by establishing a legal framework for CCS (Carbon Capture and Storage), becoming the first country in South America to have dedicated CCS legislation. This provides policy support for low-carbon technology development and attracts international investment. Petrobras, Brazil's national oil company, plans to invest $16.3 billion in CCS and other low-carbon initiatives in its 2025–2029 business plan, significantly increasing its commitment to low-carbon technologies. Additionally, Brazil has demonstrated the global cooperation potential of CCS technology through its collaboration with Norway's state-owned energy company, Equinor, on the Northern Lights project. Brazil has also signed a CCS memorandum of understanding with Norway and established a trilateral cooperation mechanism with the United States, further advancing international collaboration in low-carbon technologies. The Brazilian CCS Association and the Low-Carbon Technology Association (SFLCT) have played a key role in policy formulation. Through their cooperation with international organizations and multilateral institutions, they have demonstrated the importance of policy stability and international cooperation in achieving net-zero goals.

Based on India's Nationally Determined Contributions (NDC) proposal, the establishment of a diversified financing mechanism led by the governments of developed countries, along with the creation of a global low-carbon technology sharing repository through technology procurement, presents a more operational model of international cooperation. India's NDC advocates for incorporating low-carbon technologies into the category of global public goods and establishing a multinational technology sharing system. However, the compulsory removal of patent protection may suppress corporate innovation incentives, which could hinder technological progress. By adopting a government-led financing purchase model, it is possible to protect the intellectual property rights of companies while promoting the effective transfer and application of technology worldwide [12].

3. Norms and Obstacles for International Low-Carbon Technology Sharing

Currently, the international community primarily promotes low-carbon technology sharing through the formulation of principled international agreements. The typical norms mainly include the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

3.1. Institutional Framework for Low-Carbon Technology Sharing under the UNFCCC and the Principle of Common but Differentiated Responsibilities

The United Nations Framework Convention on Climate Change (UNFCCC) is a convention adopted by the United Nations General Assembly on 4 June 1992, which is dedicated to establishing a cooperative mechanism to combat global climate change [13]. (Background on the UNFCCC) The member states of the convention recognize that most of the greenhouse gases from the past to the present have originated from developed countries [14]. The emissions of greenhouse gases also exhibit varying trends across different countries. Therefore, the developed country members of the convention proposed that different member states should undertake obligations and responsibilities of different degrees - the "common but differentiated responsibilities" [14]. According to this principle, developed countries should bear the primary responsibilities in combating climate change and assist developing countries in jointly improving the global climate situation. This conference, for the first time, established low-carbon technology sharing as an official agenda and positioned it as a key mechanism to coordinate the contradiction between clean energy technology and intellectual property protection. The UNFCCC categorizes all member states into Annex I and non-Annex I parts according to different responsibilities. Developing countries are generally located in the non-Annex I area of the convention. The sharing of low-carbon technologies provides developing countries located in the non-Annex I group with the opportunity to access advanced technologies from developed countries. This principle requires developed countries to bear the primary responsibility for emissions reductions in climate governance, while also providing necessary support to developing countries to promote global climate improvement.

3.2. Institutional Innovations and Execution Dilemma in Low-Carbon Technology Sharing under the Kyoto Protocol: The Case of the Clean Development Mechanism (CDM)

As a follow-up legal document to the UNFCCC, the Kyoto Protocol made substantial progress in the establishment of low-carbon technology sharing mechanisms [14]. The Kyoto Protocol emphasizes that whether it is patented technology or non-patented proprietary technology, processes and empirical practices, it is not only necessary to ensure the transfer through appropriate forms of financial assistance, but also to "formulate policies and programmes to facilitate the effective transfer of environmentally beneficial technologies that are public or publicly controlled. And

create a favorable environment for the private sector to promote and enhance the transfer and acquisition of environmentally beneficial technologies. The Kyoto Protocol also emphasizes the establishment of a more unified solution mechanism, using "cooperation" to highlight the common obligations of developing and developed countries in climate change governance [14]. The cooperation emphasized in the protocol is based on the asymmetric duties constructed for non-Annex I and Annex member states, and repeatedly emphasizes the main obligations of developed countries.

The protocol has established the Clean Development Mechanism (CDM) for low-carbon sharing in 12 articles. This mechanism is also one of the most innovative and flexible achievements of the Kyoto Protocol. It aims to "allow its contracting parties, namely developed countries, and non-contracting parties, namely developing countries, to transfer and obtain project-level emission reduction offsets, thereby implementing greenhouse gas emission reduction projects in developing countries". In other words, developed countries can fulfill their obligations under the protocol by helping developing countries reduce emissions (including the sharing of low-carbon technologies) through the CDM mechanism. However, the CDM mechanism has three preconditions. First, each member state must voluntarily join the emission reduction project; Second, the project itself must have a truly controllable and long-term beneficial effect on mitigating climate change. Thirdly, the effect of emission reduction must be accomplished through the project itself. If developing countries can achieve such emission reduction results regardless of whether they are assisted by the project or not, then such a project does not meet the requirements under the CDM mechanism [15].

The Kyoto Protocol established low-carbon technology sharing as a key mechanism for addressing climate change, laying the foundation for the corresponding institutional framework. However, during the subsequent Cancun Climate Conference, significant differences in positions on technology sharing persisted between developed and developing countries. Developing countries identified intellectual property protection as a major barrier, whereas developed countries held a contrary view. The conference failed to bridge these differences, and meanwhile, low-carbon technology resources remained highly concentrated in developed countries. This uneven distribution of technology severely constrains the effectiveness of the UNFCCC and the Kyoto Protocol in achieving their established goals. Although the UNFCCC and the Kyoto Protocol have laid a principle foundation for the sharing of low-carbon technologies, there are structural flaws in their rule designs: Firstly, they rely on the "moral consciousness" of developed countries and lack mandatory constraints; Secondly, the conflict between intellectual property protection and the public interest in climate has not been effectively coordinated, which has led to the sharing of low-carbon technologies remaining at the level of a declarative commitment.

3.3. Regulatory Contestations and Dilemmas of Exception Clauses in Low-Carbon Technology Transfer under Bilateral Investment Treaties (BITs): Technology Transfer Requirements (TTRs)

Given the voluntary nature of the commitments under the UNFCCC and the Kyoto Protocol, the practice of low-carbon technology sharing between developed and developing countries predominantly depends on bilateral investment Treaties (BITs).

In Bilateral Investment Treaties (BITs), technology transfer accompanying investment is the main way for sharing low-carbon technologies. This approach often encourages foreign parties to share low-carbon technologies through preferential systems for foreign investment, including market access and operational stages in the host country. Large multinational enterprises are willing to carry out technology transfer to enter the capital market of the host country, that is, to invest in corresponding technologies and establish joint ventures with domestic companies to jointly conduct technological research and development. The rules or policies of the host country that explicitly or implicitly require foreign-funded enterprises to transfer relevant technologies, production processes, or other proprietary technologies during the stages of foreign investment access and operation stages are regarded as the technology transfer fulfillment requirements of the host country [16]. However, such implementation requirements are currently strictly resisted by most developed countries. Since the Agreement on Trade-Related Investment Measures (TRIMS) itself does not provide specific regulations for the implementation requirements of technology transfer but only gives member states some abstract principles for application, therefore, most of the issues regarding the performance requirements of technology transfer need to be limited by bilateral investment agreements. However, in terms of practical implementation, developed countries refuse to accept the performance requirements of technology transfer to protect core intellectual property rights. For instance, the United States, Canada, and Japan have all stipulated the rules prohibiting the performance requirements of technology transfer in their bilateral investment agreements concluded with other countries. "In the latest series of bilateral or regional free trade agreements signed, most have set up special investment chapters and included provisions prohibiting the performance requirements of technology transfer" [17]. For developing

countries, compliance requirements for technology transfer are a favorable prerequisite for the host country to introduce low-carbon technologies through the foreign investment access and approval system. Therefore, the spread of the prohibition rules has undoubtedly dealt a heavy blow to developing countries. As a result, most developing countries do not support the application of prohibition rules for compliance with technology transfer requirements.

Although TRIMS has not specified the requirements for the performance of technology transfer in Bilateral Investment Treaties, nor has it mentioned the way to set up encouraging investment measures involving public interests in human survival and development, most of the Bilateral Investment Treaties signed by developed countries have stipulated exceptional provisions for the application of the prohibition rule on the performance of technology transfer. Article 12 of the United States Model Agreement on Bilateral Investment (BIT) grants "the discretionary power of the corresponding foreign investment review and supervision authority of the host country" [18]. Additionally, Article 30 of TRIPS grants contracting parties the right to make limited exceptions to the grant of patent rights, provided that such exceptions must not affect the normal development and application of patents. It must not cause unreasonable damage to the legitimate rights and interests of the patentee. The "measures necessary for the protection of human, animal and plant life or health" and "measures related to the protection of exhausted biological and abiotic natural resources" stipulated in Article 12 of the United States Model Bilateral Investment Treaties (BIT Model) are regarded as exceptions to the prohibition rule on the performance requirements of technology transfer. However, its use shall not be "implemented in any unreasonable way" and "shall not constitute a disguised restriction on international trade or investment" [19]. Therefore, the host country may circumvent the prohibition rules on performance requirements of technology transfer through the above-mentioned exceptions. However, due to the controversy over the interpretation of exceptional provisions and the scarcity of disputes and arbitration cases related to the application of such environmental exceptional provisions, it is difficult to have specific and unified practical standards. Judging from existing arbitration cases, the environmental exception clause is strictly interpreted [17], which makes it difficult for the host country to overcome the barrier of intellectual property protection by taking advantage of this exception clause to introduce new technology. Moreover, even if the environmental protection exception is met, it will still be condemned by developed countries on the grounds of violating the prohibition rule of technology transfer performance requirements.

4. A Better Mechanism to Resolve Sharing Obstacles—A Low-Carbon Technology Sharing Platform

4.1. Innovative Logic and Practical Breakthroughs of the Low-Carbon Technology Sharing Platform

To address the limitations of investment-driven technology transfer, a new type of technology cooperation mechanism centered on sharing—the Low-Carbon Technology Sharing Platform—has emerged. In 2008, Sony, IBM, and other private enterprises established the eco-patent commons. Enterprises participating in this sharing platform publicly disclose their patents, most of which are related to low-carbon technological innovations. Any other participants on the sharing platform can use the patents on the platform at no cost This sharing platform relies on private enterprises voluntarily disclosing ecological patents, thus naturally avoiding the obstacles of patent rights protection. Other participants, through the use of patents on the platform and their application in production and business operations, not only substantially reduce carbon emissions but also encourage eco-technology innovation, ultimately achieving sustainable human development and collectively combating global climate change [20].

Typical case: From Eco-Patent Commons to Tesla's Open Source Project. The Low-Carbon Patent Sharing Platform demonstrates significant synergistic effects: participants, while offering their patents for free use by others, can also access and apply other patented technologies within the platform to commercial practices. This mutually beneficial and win-win mechanism encourages private enterprises to carry out cooperative development. At the same time, due to the mutual disclosure of patents, backward technologies are excluded, and the flaws of existing patent technology solutions are made clear at a glance, prompting private enterprises to conduct in-depth research, development, and innovation better [21]. This kind of innovation is not accomplished by a single party alone. All participants can carry out innovations based on the already disclosed patents. Therefore, the resulting new patent solutions are diverse rather than singular, enhancing the timeliness and precision of environmental problem governance.

The low-carbon patent sharing platform is more effective than technology transfer accompanied by investment in popularizing the wide use of low-carbon technologies, reducing the cost of low-carbon technological innovation, breaking through the conflicts between developed and developing countries regarding patent protection, and encouraging joint research and development in the field of low-carbon technologies between developing and developed countries [22]. For developing countries, the high patent licensing fees for low-carbon technologies of multinational enterprises in developed countries often put them under significant pressure. They no longer have sufficient funds to

support subsequent research, development, and innovation. Moreover, the technologies licensed by developed countries may not necessarily be the most advanced or effective ones currently available [23]. The low-carbon patent sharing platform can effectively address these two major problems. For example, in 2014, Elon Musk launched an open-source initiative based on the platform [24], making Tesla's renewable energy patents publicly available. His public statement emphasized that, during the early stages of the company, patents were indeed a core asset, and the team had made significant efforts to secure patent protection. However, as the company grew, the patent system gradually evolved into a structural barrier inhibiting innovation, failing to achieve its original purpose of encouraging innovation. The essence of technological leadership, Musk argued, lies not in the quantity of patents held but in a company's ability to attract top-tier technical and innovative talent. For such talent, continuous innovation is the primary driving force behind their R&D activities, and the open-source initiative provides the institutional support needed to achieve their technological innovation goals [25]. Based on Musk's discourse, core technical R&D personnel in large tech companies typically do not oppose patent disclosure. At the same time, corporate managers often excessively exercise patent rights to maintain market competitiveness and profit margins. This, particularly in the field of low-carbon technologies, has significantly hindered the efficiency of technological iteration. The low-carbon patent-sharing platform fosters collaboration between companies, enabling the continuous development of technological innovation and enhancing the technological acquisition capabilities of developing countries, thereby becoming an effective model of a sharing mechanism. Empirical evidence shows that this platform model offers a more efficient path for low-carbon technology sharing between the private sector and state actors (including governments of both developed and developing countries). Tesla's open-source initiative has indeed significantly accelerated the development of the global electric vehicle industry through technology sharing. According to the "2023 Impact Report", it's open-source technologies now cover core areas such as battery management and autonomous driving algorithms. More than 1.8 million Tesla electric vehicles worldwide have contributed to an annual reduction of over 20 million tons of CO_2 emissions, with a total lifecycle CO_2 reduction of 51 tons per vehicle. As of 2023, Tesla has made over 300 patents publicly available, covering key areas such as battery technology, autonomous driving, and motor design. Among these, patents related to battery management systems (BMS) have been adopted by several companies, significantly enhancing the industry's battery performance and safety.

4.2. Micro-Practice of Multinational Corporations in Low-Carbon Technology Sharing

In addition to the open patent platform model, multinational corporations have established more targeted technology sharing mechanisms by creating patent pools and global R&D networks. Studies have shown that technology companies, such as Microsoft and Siemens, have significantly promoted the global diffusion of low-carbon technologies through systematic technology openness strategies.

Microsoft enables technology sharing through open-source, cross-platform tools, and cloud ecosystems. GitHub Copilot serves 1.8 million paying developers and 77,000 enterprises. Azure AI supports a diverse range of models and has 60,000+ customers. Power Platform reaches 48 million monthly active users with low-code/no-code innovation. Microsoft and LinkedIn have collectively provided digital skills training to 14.1 million people globally, including AI-related content [26].

Siemens, on the other hand, has developed a global R&D network through the MindSphere IoT operating system, forming a technology-sharing system in the energy and industrial sectors. This system encompasses joint laboratories, technology transfer agreements, and professional training. The 2023 report disclosed that 46.8% of its patent portfolio is related to the United Nations SDGs, and it has achieved modular software and hardware and partner ecosystem collaboration through the open digital platform Xcelerator, accelerating the transfer and large-scale application of low-carbon technologies [27].

These micro-level practices demonstrate that enterprise-led technology sharing mechanisms can effectively fill the gaps left by macro-level institutional frameworks. Overall, the technology-sharing practices of multinational corporations not only validate the feasibility of market-driven operations but also provide replicable commercial paradigms for global low-carbon technology governance through the establishment of standardized technology transfer channels and knowledge diffusion networks. This bottom-up sharing model complements intergovernmental cooperation, jointly advancing the achievement of global climate governance objectives.

4.3. Regulatory Framework: Access and Operation

The open source model is the primary basis for the operation of the low-carbon technology sharing platform, which originates from the open source software licensing mechanism supported by the Royal Society of the United Kingdom.

At the beginning, the open-source mechanism was mainly applied in the development industry of computer software systems, primarily facilitating the sharing of the "source code" of software design among enterprises. Subsequently, the modification and distribution of software were no longer restricted by the original patent license. The emergence of open-source mechanisms has further accelerated the renewal and upgrading of software systems, improved the efficiency of software, and also significantly reduced the cost of software innovation, eliminating the unnecessary reinvestment for developers to apply special patches and upgrades to existing software. However, people never thought that the open-source model would also make certain contributions in the field of environmental protection. Just like software technology, low-carbon technology is more efficient when individuals or enterprises collaborate, rather than when one patentee or enterprise holds exclusive rights and undertakes subsequent innovations independently. When enterprises or individuals disclose their respective low-carbon technology patents, other participants can conduct research and development based on their patents. At this point, the research and development costs previously completed by individuals are distributed among the majority of other participants, thus significantly reducing the cost of innovation [28]. The open-source model is not static but a dynamic and evolving mechanism. Publicly disclosed patents will change along with the continuous evolution and update of products and knowledge. Moreover, unlike other closed and centralised R&D models, the decision-making and operation models of the open-source model include different agendas, methods, and ways to exercise priorities, which better reflect autonomy.

The initial goals of the Low-Carbon technology sharing platform were two-point. The first was to provide strategies for accelerating and promoting environmental protection and technological innovation [29]. The second was to promote and encourage joint cooperation and innovation among private enterprises, so as to improve the renewability, emission reduction, pollution prevention, and other performance of existing technologies, thereby better governing the global environment [30]. Take patent sharing as an example, a large amount of patent information is stored and incorporated on the website managed by the World Business Council for Sustainable Development (WBCSD), facilitating searches by other participants of the platform. The patent information on the platform is open to all other participating individuals or enterprises for their free use. Of course, the period and scope of such free use will also vary according to different "patent defensive termination conditions" (defensive termination). Meanwhile, the patents of the low-carbon technology sharing platform will also be made public to many stakeholders.

The prerequisite for different entities joining the low-carbon technology sharing platform is that the technologies they provide are carbon-beneficial. These benefits can manifest in various forms, including energy savings, reduction of waste and pollution, prevention of environmental damage, the use of eco-friendly materials or components, reduced material consumption, and enhanced renewable capacities, among others [30]. Participating enterprises and individuals gain benefits from two aspects. One is to showcase the environmental protection technologies mastered by individuals or enterprises from the perspectives of public relations and the market, indirectly promoting these technologies. Secondly, it is to declare to the world that the enterprise or technology itself is environmentally friendly and that the business strategy centres on contributing to the sustainable development of the environment. Due to the two benefits brought by the mechanism, some enterprises may use environmental protection as a cover or exaggerate the environmental protection functions of their own technologies to obtain market profits and reduce expenditures on patent licensing fees; however, the technologies themselves do not affect environmental protection [31]. If such a situation occurs, enterprises will be penalized by losing their membership of the platform and potentially damaging their public trust.

4.4. Idealized Mechanism: Third-Party Supervision and Proportion of Openness

To ensure the fairness and transparency of the platform's governance structure, particularly to safeguard the adequate representation of developing countries in the decision-making process, it is recommended that third-party regulatory bodies be introduced into the platform's governance, such as the United Nations Environment Programme (UNEP). This mechanism would ensure that the platform takes into full account the needs and interests of developing countries when designing policies and sharing technologies. Specifically, third-party regulatory bodies can play an independent role in reviewing and assessing the platform's policies, technology transfer agreements, patent licenses, *etc.*, ensuring that all parties adhere to the principles of fairness and transparency, and preventing any country or enterprise from unfairly monopolizing or marginalizing the resources of developing countries through the platform mechanism. Additionally, by regularly convening a multinational technology transfer committee or technical review panel, this approach can amplify the voices and influence of developing countries in the decision-making process, ensuring their interests are not overlooked in the platform's governance. Furthermore, third-party regulatory bodies can provide technical assessments, policy recommendations, and other forms of support to developing countries, helping them

effectively absorb, digest, and utilize shared technologies, thereby ensuring the sustainability of technology transfer. These mechanisms will not only enhance the platform's fairness and transparency but also drive the global low-carbon technology sharing mechanism to better align with the principle of "common but differentiated responsibilities".

To further promote the fulfilment of technology transfer obligations by developed countries and enhance the measurability of their responsibilities in global low-carbon cooperation, this paper proposes the introduction of a Minimum Patent Openness Ratio as a quantifiable indicator under the principle of "common but differentiated responsibilities". This indicator can be defined as "the proportion of low-carbon technology patents shared by developed countries through publicly available licensing mechanisms (such as FRAND licenses, patent pools, open licenses, *etc.*) relative to their total number of relevant patents within each specified cycle under the UN framework". It is recommended to set an initial threshold of 25% to 30%, with gradual increases over time. Furthermore, this ratio should be tailored to the research and development capacities and patent holdings of different countries, with differentiated roadmaps developed accordingly. Transparent review and disclosure mechanisms should be established by institutions such as WIPO and the UNFCCC Technology Executive Committee, accompanied by incentive measures (e.g., technology credits, financing facilitation) to encourage developed countries to comply. Such quantifiable indicators will help transform soft law provisions into practical, actionable policy tools, thereby strengthening the sustainability and accountability of global technology cooperation.

4.5. The Limitations and Legal Risks of Open Source and Defensive Licensing

Although open source and defensive licensing models offer significant advantages, they also present notable limitations. One key challenge lies in enforcement: most open-source licenses rely on voluntary compliance and lack robust international enforcement mechanisms. In jurisdictions with weak intellectual property enforcement capabilities, particularly in the Global South, violations of open licensing terms are often left unremedied. Furthermore, these models may enable certain actors to engage in free-riding [32], benefiting from shared technologies without making reciprocal contributions, thus undermining the sustainability and fairness of global technology diffusion efforts. Defensive licensing strategies, such as patent pledges or collective licensing pools, may be selectively or opportunistically employed, sometimes as public relations tools, while proprietary rights are maintained elsewhere. Finally, there is the potential for abuse, where entities may re-license or incorporate open technologies into proprietary frameworks, thereby restricting downstream access and transparency.

In the open-source technology sharing mechanism, developing countries can access cutting-edge technologies at no cost and benefit from technological advancements. However, they also face the risk of technological dependence. When developing countries become overly reliant on open-source technologies, it may lead to insufficient local innovation, a lack of independent research and development capabilities, and long-term dependence on external technologies. To address these challenges, it is essential to strengthen local research and development (R&D) and innovation capabilities. Incentives, such as tax reductions and R&D subsidies, should be provided to technology enterprises in developing countries to encourage localized R&D and drive the innovation and iteration of indigenous technologies.

Additionally, support should be given for the localization and adaptation of technologies, encouraging developers and businesses to make adjustments to open-source technologies to better align with local market demands and technical environments. Furthermore, enhancing the training and cooperation of technical talent is crucial. This can be achieved by establishing technology training centers and innovation accelerators, as well as by collaborating with international research institutions and multinational companies to improve the technical expertise and innovation capabilities of local R&D personnel. Developing countries should also formulate strategies for technological independence based on their specific needs and resources. A long-term strategy should be developed to ensure that technology sharing and independent innovation complement each other, rather than being mutually exclusive. The implementation of these measures will enable developing countries to not only enjoy the benefits of open-source technologies but also avoid excessive reliance on external technologies, thereby fostering the sustainable enhancement of their independent innovation capabilities.

In conclusion, establishing an open, cooperative, and institutionally resilient low-carbon technology sharing platform is a key mechanism for promoting global equitable access to technology. However, the effective operation of this platform not only relies on international norms and institutional design but also requires active participation from countries to develop complementary strategies and ensure the effective alignment of domestic systems with international platforms.

5. Recommendations for the Pathway of Implementing a Low-Carbon Technology Sharing Platform in China

Given the pivotal role of the platform mechanism in global technology sharing, China, as a major emitter of carbon and a key driver of technological transformation, has a responsibility to respond and engage at the national strategic level actively. This section will propose feasible pathway recommendations for China to advance the construction and participation in the low-carbon technology sharing platform, based on the aforementioned platform logic and the country's specific context. This initiative not only represents a significant commitment to fulfilling international climate obligations but also serves to promote the structural optimization of its low-carbon industries and enhance its international competitiveness.

Currently, China faces multiple practical challenges in acquiring low-carbon technologies accompanied by significant investment. First, even if foreign enterprises agree to license low-carbon technologies to domestic enterprises for use, domestic enterprises still need to pay high technology licensing fees. Second, as high-end and advanced low-carbon technologies are largely in the hands of developed countries, developed countries led by the United States will make a big fuss under the pretext of patent protection. Moreover, the question of whether the implied technology transfer requirements during foreign investment approvals fall under the category of mandatory technology transfer remains unclear at this stage. Finally, although environmental protection exception clauses are introduced in most bilateral investment agreements of developed countries, China can invoke these clauses to exercise discretionary power and impose mandatory technology transfer requirements; however, there is no clear and unified interpretation of the applicable conditions and defined scope. Therefore, China still needs to be cautious when invoking these exception clauses to promote the sharing of low-carbon technologies.

5.1. Path One: Building a Multi-Layered Incentive Mechanism to Promote Corporate Participation

To actively promote and implement the low-carbon technology sharing platform, first of all, our country needs to encourage more enterprises to join this platform. For domestic enterprises, it is necessary to count the number of private enterprises with low-carbon technologies in the country, and then encourage them to join the platform through corresponding financial support measures. This fiscal measure includes corresponding tax reduction and exemption by the government, as well as preferential loans and financing for banks and fund organizations. For instance, China has already implemented a series of tax incentive policies in the field of low-carbon technologies. These policies not only alleviate the financial burden on enterprises but also encourage more companies to engage in the research, development, and application of low-carbon technologies. Specifically, reference can be made to the policy that exempts corporate income tax for enterprises implementing Clean Development Mechanism (CDM) projects. Enterprises undertaking CDM projects, such as hydrofluorocarbon (HFC) and perfluorocarbon (PFC) CDM projects, which transfer 65% of the greenhouse gas emission reduction revenue to the state, and nitrous oxide (N_2O) CDM projects, which transfer 30% of the emission reduction revenue to the state, enjoy specific tax exemptions. For the income derived from implementing such CDM projects, from the year in which the enterprise first receives the emission reduction revenue, the corporate income tax is exempt for the first three years and halved for the fourth to sixth years. This concrete tax reduction policy provides strong fiscal support for the promotion and application of low-carbon technologies [33].

Similarly, in the early stages of the commercialization of carbon capture and storage (CCS) technologies, government financial subsidies serve as one of the most rapid and effective financing mechanisms. This is likely due to the current weak market structure for CCS technologies, which forces corporate consortia to rely on government subsidies, making projects more susceptible to political influence [34]. Therefore, using government subsidies to incentivize corporate participation in low-carbon technology sharing platforms can not only drive the development of CCS technologies but also provide valuable insights for promoting other low-carbon technologies [35].

For foreign enterprises, since most low-carbon technologies are currently in the hands of developed countries, encouraging private enterprises from developed countries to join the platform is the key for China to obtain low-carbon technologies through the low-carbon technology sharing platform. However, based on China's development experience, encouraging private enterprises from developed countries to join the platform solely through the domestic government, banks, and public institutions presents significant challenges. Therefore, our country needs to actively seek incentives and assistance from international organizations. The United Nations Environment Programme Finance Initiative (UNEP Finance Initiative for short) has put forward a series of proposals regarding the sharing of low-carbon technologies. This includes providing corresponding country risk insurance for the low-carbon special Fund, *etc.* The specific institutions providing such insurance include the World Bank's Multilateral Investment Guarantee Agency (MIGA) and the U.S. Government's Overseas Private Investment Corporation. In addition to national risk insurance, the above-

mentioned institutions can also establish low-carbon policy risk insurance to promote the implementation of "national appropriate emission reduction actions". However, such insurance is only applicable to the grandfathering scenario of the free allocation method in carbon emission trading practices [36]. In addition, some public organizations can also contribute funds to establish specialized organizations responsible for the implementation of low-carbon projects. Such organizations can provide financial incentives for developed countries to invest in low-carbon projects in developing countries and for enterprises that actively participate in the low-carbon technology sharing platform [37].

5.2. Path Two: Introducing Defensive Patent Licensing (DPL) Rules

Regarding the licensing rules of low-carbon technology sharing platforms, China can draw on the defensive patent license model (DPL). Defensive patent licensing is a standardized open patent licensing model, which is mainly used to encourage the creation of broad, decentralized and open innovation communities (OIC), where all the innovative technologies provided by participants in this network are patented for defensive purposes. Any participant in the network can use the patented technologies provided by other participants for free. For instance, in a low-carbon patent sharing platform, it is necessary to unite the independent owners, enterprises, other suppliers, and related customers of different low-carbon technology patents for defensive purposes to carry out collaborative innovation [38]. Defensive patents mainly emerge in contrast to aggressive patents. A group of patent holders often obtains the letter through patent infringement lawsuits to secure corresponding compensation amounts and make huge profits, and is also known as "patent trolls". However, such aggressive patent litigation is not prohibited by law. It is precisely because of the exclusive nature of patent rights that aggressive patent rights groups or organizations have become "legalized" [39]. Drawing on the defensive patent licensing model can effectively prevent the Chinese government and enterprises from being threatened by aggressive patent litigation outside the platform.

Defensive patent licensing operates through a series of bilateral obligations. If applied to an environmental protection patent sharing platform, it can grant each member a permanent, worldwide, and royalty-free patent license related to low-carbon technologies. It helps each member obtain a patent portfolio composed of a series of patents and documents such as existing low-carbon technology patents, application patents, provisional terms, and potential future updates of existing technologies. However, the above-mentioned license must meet four conditions: First, every member of the platform (here, the member refers to both the licensor and licensee who implement the defensive patent license) needs to waive the right to file infringement lawsuits against other members for their use of the patent. Even if some members do not currently own low-carbon technology patents, they can still commit to giving up their exclusive rights control over the low-carbon patent technologies they obtain in the future within the platform. Secondly, each member is required to provide a patent portfolio of all existing and future technical information related to low-carbon technologies. Thirdly, each member must bind all future potential successors of rights (here, successors of rights include both the overall patent technology and the successors of partial patent technologies in the patent portfolio) to the patent commitments made by joining the platform and the signed peace terms; Fourth, if any member intends to withdraw from the sharing, they need to notify other members and those who are about to join within six months. Moreover, before the expiration of the six-month period, he still needs to continue licensing the patent to other members as a defensive patent and cannot revoke his commitment. If he withdraws the commitment and files a lawsuit against other members, then the other members can also withdraw the patent commitment they originally made. However, the defensive license previously made by the member who violates the patent commitment remains valid for the other members [40].

To prevent potential technology leakage and intellectual property disputes arising from member withdrawals, it is recommended that multiple global low-carbon technology platforms incorporate legal protection mechanisms and technical control provisions in their institutional design. Specifically, patent recall mechanisms can be established through contractual agreements and platform regulations, which would require members to return or revoke certain licensed patents registered on the platform upon their withdrawal. This would prevent the diversion of key technologies originally intended for sharing into proprietary technologies that restrict competition. Furthermore, data privacy protection is a core issue in platform governance. To prevent enterprises from engaging in unfair competition by utilizing technical data from other parties obtained during their participation on the platform, it is essential to include purpose limitation clauses and obligations for data deletion or anonymization in the data exchange agreements. Additionally, dynamic tracking mechanisms should be implemented to ensure that sensitive data is no longer held by the withdrawing member. Therefore, it is advisable for platforms to embed patent recall clauses within contractual terms, clearly defining deadlines, scope, compensation, and legal validity; establish obligations for data deletion and legal

accountability within data privacy agreements; and set up arbitration or neutral third-party institutions to address intellectual property and data disputes arising from member withdrawals.

5.3. Path Three: Strengthening Institutional Capacity Building to Promote the Multilateral Collaboration Mechanism of Low-Carbon Technology Sharing Platforms

The effective operation of low-carbon technology sharing platforms depends on the coordinated development of institutional capacities among all participating parties. While developed countries currently dominate in the field of technological research and development, their technology diffusion faces constraints due to market saturation and limited application scenarios. On the other hand, developing countries often suffer from structural weaknesses such as insufficient technology absorption capabilities and weak intellectual property management systems. To bridge this capacity gap, it is essential to rely on the coordination role of international organizations such as the United Nations Environment Programme (UNEP) and the World Intellectual Property Organization (WIPO) to establish a systematic capacity-building framework. First, an international technical assistance program can be established, led by international organizations, to create a low-carbon technology transfer fund that provides targeted technical training and intellectual property management consulting services to developing countries, with a focus on enhancing their capabilities in technology assessment, patent strategy, and compliance application. Second, regional low-carbon technology demonstration centres should be established in developing countries to strengthen the ability to implement and industrialize technologies through equipment sharing, case-based teaching, and scenario-based training, effectively reducing technology adaptation costs. At the same time, efforts should be made to actively promote the construction of "North-South cooperation" research and development alliances, encouraging research institutions and enterprises from developed countries to participate in low-carbon technology projects led by developing countries. Through knowledge sharing and talent mobility mechanisms, the independent innovation capabilities of developing countries can be systematically enhanced, thus ensuring the sustainable development of the technology sharing platform.

In the process of building technology sharing platforms, in addition to the authorization and management of explicit knowledge such as patents, the transfer of tacit knowledge is also a key element in achieving capacity building. Tacit knowledge encompasses experiential skills such as equipment operation, system maintenance, and fault diagnosis, which are often difficult to codify through literature or contracts. To enhance the effectiveness of low-carbon technology sharing platforms, it is essential to design diversified knowledge internalization mechanisms. Specifically, multinational technical training centres can be established to improve the on-site operational capabilities of technical personnel from developing countries through on-the-ground training. Virtual simulation platforms can be developed, utilizing AR/VR or digital twin technologies for simulated operations and remote skills training, particularly suited for technologies such as wind energy and biomass.

Additionally, a "mentor-based" technical cooperation mechanism should be promoted, where experienced technicians are stationed on-site to provide guidance, establishing a long-term collaboration model of "learning by doing". Furthermore, a technical knowledge community and dynamic Q&A system can be formed within the platform to facilitate "learning in practice" and reduce knowledge gaps. These mechanisms will help transform the platform from a "static information repository" to a "dynamic capacity-building vehicle", effectively supporting the localization and re-innovation capabilities of developing countries.

5.4. Path Four: Building a Coordinated Regulatory Mechanism to Improve the International Institutional Framework for Low-Carbon Technology Sharing

The core regulatory challenge faced by low-carbon technology sharing lies in the institutional differences across countries in intellectual property protection, environmental regulations, and trade policies. Although the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) has established international benchmarks for intellectual property protection, there is an institutional conflict between its rigid provisions and the urgent need of developing countries to access low-carbon technologies. To achieve effective regulatory coordination, a three-pronged strategy is recommended: first, promote multilateral negotiations on the flexibility provisions of TRIPS within the World Trade Organization framework, creating special exceptions for compulsory licensing of low-carbon technologies for developing countries; second, revise bilateral investment agreements and free trade agreements to include specific clauses on technology transfer, clarifying the rights and obligations of contracting parties; and third, establish an international oversight body for technology transfer, setting transparency standards for technology sharing and dispute resolution procedures to ensure fairness and operational feasibility in technology transfer. This institutional design aims

to reconcile the conflict between the protection of private intellectual property rights and the public interest of climate governance, providing a stable institutional framework for the global flow of low-carbon technologies.

5.5. Path Five: Strengthening Stakeholder Compliance Mechanisms to Build an Incentive and Constraint System for Low-Carbon Technology Sharing

The effectiveness of implementing low-carbon technology sharing platforms fundamentally depends on the compliance behaviour of diverse stakeholders. Enterprises, due to concerns over technology spillover risks and market competition, often lack the willingness to share technologies. Governments meanwhile are constrained by domestic political and economic limitations, making it difficult for them to effectively promote technology transfer. To enhance the participation of these entities, a systematic incentive and constraint mechanism needs to be established. In terms of trust mechanisms, a dual structure that includes legal safeguards and arbitration procedures should be developed, thereby reducing the risk of technology leakage by establishing specialized dispute resolution bodies for technology sharing and improving confidentiality clauses. Regarding incentive measures, a differentiated policy toolset can be designed, including tax incentives such as increased R&D expense deductions and value-added tax exemptions for enterprises that share core low-carbon technologies, as well as direct financial support such as subsidies for patent pool participation. On the international coordination front, the transparency framework established under the Paris Agreement should be leveraged to integrate technology sharing commitments into the assessment criteria of Nationally Determined Contributions (NDCs), while using climate finance leverage to encourage developed countries to fulfil their technology transfer obligations.

6. Conclusions and Discussions

This study systematically examines the institutional barriers and breakthrough pathways for international low-carbon technology sharing, revealing the systemic conflict between technological monopolies and the public nature of climate governance within the current international rule system. Through an analysis of international norms such as the TRIPS Agreement and bilateral investment treaties, this paper identifies significant asymmetric conflicts between developed and developing countries in terms of technology supply, institutional rules, and market dynamics. These conflicts not only result in developing countries facing dual pressures of “compliance costs” and “technological dependence”, but also trap the technological achievements of developed countries in the dilemma of misaligned application scenarios. Based on technology lifecycle theory and the perspective of complementary stakeholders, this study proposes an innovative approach to reconstruct the technology sharing incentive framework through an “open-source mechanism”, offering a new solution to reconcile the exclusivity of intellectual property rights with the public nature of climate governance.

The main theoretical contributions of this study are reflected in three areas: First, it develops an “institutional barriers-pathway breakthrough” analytical framework that systematically explains the institutional tension in low-carbon technology sharing. Unlike previous studies that primarily focus on the economic efficiency of technology transfer, this paper specifically addresses the normative conflicts between intellectual property systems and climate governance goals, thereby expanding the theoretical perspective of global environmental governance. Second, it introduces new governance tools such as defensive patent licensing, enriching the theoretical paradigm of technology transfer. This study finds that the limitations of traditional compulsory licensing models in practice urge a reevaluation of the incentive mechanisms for technology sharing, with the open-source mechanism, based on voluntary participation, potentially offering greater sustainability. Finally, through a comparative case study, the research verifies the complementary potential of countries at different stages of development in technology sharing. The experiences of Brazil’s CCS legislation and India’s photovoltaic industry development indicate that South-South cooperation and North-South collaboration can serve as effective pathways to break through technological monopolies.

From a practical standpoint, this study reveals the significant role of low-carbon technology sharing platforms as a form of institutional innovation. Cases such as Tesla’s open-source initiative demonstrate that by constructing multidimensional mechanisms that include patent sharing, capacity building, and regulatory coordination, transaction costs in technology transfer can be effectively reduced. Specifically, the “minimum patent openness ratio” quantitative indicator proposed in this paper provides a new approach for transforming soft law obligations into actionable institutional tools. This indicator not only enhances the transparency and predictability of international technological cooperation but also provides specific quantifiable targets for ongoing international negotiations, such as the technology finance dialogue at COP28. By setting the MPOR, countries can establish clear commitments regarding technology

sharing, which not only facilitates the global dissemination of technologies but also integrates with existing tools such as Technology Readiness Levels (TRL) and the Paris Agreement's transparency framework, creating a more comprehensive and coordinated international technology-sharing system. Moreover, the study emphasizes the key role of tacit knowledge transfer in technology sharing and proposes specific measures, such as establishing multinational technical training centres, to enhance the technological absorption capacity of developing countries.

This study has several limitations: First, it primarily employs qualitative analysis, lacking a quantitative assessment of how different incentive measures impact technology diffusion rates. Second, the case analysis focuses on macro-institutional aspects, with insufficient examination of micro-level corporate practices. Lastly, the empirical foundation of the policy recommendations requires further strengthening. Future research could delve into the following directions: Future research will be based on tools such as the Bass diffusion model to construct a prediction framework for the transfer of low-carbon technologies and quantitatively evaluate the marginal effects of different policy tools; conducting micro-empirical studies on multinational enterprise technology transfer strategies; and tracking and evaluating policy implementation effects, especially quantifying the long-term impact of open-source licensing on technological innovation. Additionally, with the development of digital technologies, emerging tools such as blockchain on technology sharing platforms also warrant attention.

In conclusion, low-carbon technology sharing is a critical component of global climate governance. By addressing technological monopolies through institutional innovation and constructing a fair and efficient technology sharing mechanism, not only can the temperature control goals of the Paris Agreement be achieved, but the collaborative development of the global green economy can also be promoted. As a responsible major power, China should actively engage in the formulation of international rules and promote the establishment of a more inclusive and balanced global technology governance system.

Ethics Statement

This study did not involve human or animal subjects, therefore ethical approval was not required.

Informed Consent Statement

Not applicable as the study did not involve human participants.

Data Availability Statement

No external datasets were used in this study. All data were derived from publicly available literature or author analysis.

Funding

This research received no external funding.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Zou C, Huang YC, Hu SL, Huang Z. Government participation in low-carbon technology transfer: An evolutionary game study. *Technol. Forecast. Soc. Chang.* **2023**, *188*, 1–13.
2. Gu WN, Gao X. Research on the Spatio-Temporal Pattern and Multidimensional Mechanism Spatial Effects of China's Green and Low-Carbon Technological Innovation. *Prog. Geogr.* **2025**, *44*, 256–270.
3. Wang FQ, Li HM, Cao YC, Zhang CY, Ran YL. Knowledge Sharing Strategy and Emission Reduction Benefits of Low Carbon Technology Collaborative Innovation in the Green Supply Chain. *Front. Environ. Sci.* **2022**, *9*, 783835.
4. Wen H, Chen JJ. Technological Innovation and Energy Transition: A Literature Review. *Sci. Technol. Entrep. Mon.* **2022**, *35*, 142–148.
5. Liu XX, Zhao YQ, Gong JB, Liu JP, Zhu JK. The Development and Current Situation of flexible copper indium gallium selenide thin-film solar Cell technology. *Vac. Low Temp.* **2020**, *26*, 377–384.
6. Cantono S, Silverberg G. A Percolation Model of Eco-innovation Diffusion: The Relationship between Diffusion, Learning Economies and Subsidies. *Technol. Forecast. Soc. Chang.* **2009**, *76*, 487–496.

7. Alola AA, Victor BF, Obekpa HO. Adebayo TS. Explaining the environmental efficiency capability of energy mix innovation among the nordic countries. *Energy Rep.* **2024**, *11*, 233–239.
8. Rifkin J. *Zero Marginal Cost Society*; Citic Press: Beijing, China, 2014; pp. 87–89.
9. Kerzman J. *Low-Carbon Technological Innovation and the US Economic Hegemony 2.0*; Dongbei University of Finance and Economics Press: Dalian, China, 2015; pp. 124–127.
10. Jee SJ, Hötte K, Ring C, Burrell R. Making intellectual property rights work for climate technology transfer and innovation in developing countries. *arXiv* **2024**, arXiv:2408.12338.
11. Hayashi D. Knowledge flow in low-carbon technology transfer: A case of India's wind power industry. *Energy Policy* **2018**, *123*, 104–116.
12. Gu GX, Shen SY, He XQ, Wang Z. Research on Carbon Governance of International Low-Carbon Technology Financing under the Constraint of Carbon Neutrality Goals. *Geogr. Res.* **2023**, *42*, 842–856.
13. Background on the UNFCCC: The International Response to Climate Change. 2018. Available online: http://unfccc.int/essential-background/items/6031.php (accessed on 14 May 2025).
14. Kyoto Protocol to the United Nations Framework Convention on Climate Change, Art. 10(c), December 11th, 1997, U.N. Doc. *FCCC/CP/*1997/7/Add.1, 37 I.L.M. 22. 1998. Available online: https://legal.un.org/avl/ha/kpccc/kpccc.html (accessed on 11 December 1997).
15. THE CLIMATE CHANGE WORKING GRP. AND AFRICAN TASK FORCE OF THE U.N.'S ENV'T PROGRAMME FIN. INITIATIVE, AND YET IT MOVES: SUCCESS STORIES AND DRIVERS OF CDM PROJECT DEVELOPMENT IN SUB-SAHARAN AFRICA. 2012. Available online: https://www.unepfi.org/regions/africa-middle-east/re-launch-of-and-yet-it-moves-success-stories-and-drivers-of-cdm-project-development-in-sub-saharan-africa-2/ (accessed on Day 12 January 2012).
16. Huang ZZ, Dong R. On the Prohibition Rules of Performance Requirements in International Investment. *J. China Youth Univ. Political Sci.* **2010**, *2*, 89–93.
17. Han JY. China's Response under the New Trend of Regulation of Technology Transfer Requirements. *Guangdong Soc. Sci.* **2017**, *3*, 221–229.
18. Hu ML. The Coordination of International Investment and Environmental Protection from the Perspective of the American BIT Model. *J. Beijing Inst. Technol.* **2016**, *1*, 150–156.
19. He Y. Research on the Prohibition Rules of Technology Transfer Performance Requirements in Bilateral Investment Agreements—Also on China's Position in the Negotiations of the China-Us Bilateral Investment Agreement. *Contemp. Law* **2014**, *28*, 153–160.
20. The Eco-Patent Commons, 2018. ECO-PATENT COMMONS. Available online: https://ecopatentcommons.org/ (accessed on 13 November 2018).
21. Chen KH, Zhang C, Feng Z, Zhang Y, Ning L. Technology transfer systems and modes of national research institutes: Evidence from the Chinese academy of sciences. *Res. Policy* **2022**, *51*, 1–20.
22. An KX, Wang C, Cai WJ. Low-carbon technology diffusion and economic growth of China: An evolutionary general equilibrium framework. *Struct. Chang. Econ. Dyn.* **2023**, *65*, 253–263.
23. Hall B, Helmers C. Innovation and Diffusion of Clean/Green Technology: Can Patent Commons Help? *J. Environ. Econ. Manag.* **2013***, 66*, 33–51.
24. Derclaye S. 2009. Should Patent Law Help Cool the Planet? An Inquiry from the Point of View of Environmental Law—Parts I& 1I. *Eur. Intellect. Prop. Rev.* **2009**, *5*, 227–235.
25. Elon Musk. All Our Patent Are Belong to You, TESLA MOTORS. Available online: http://www.teslamotors.com/blog/all-our-patent-are-belong-you (accessed on 14 January 2008).
26. Microsoft.2024.Microsoft 365. Available online: https://www.microsoft.com/investor/reports/ar24/index.html (accessed on 18 October 2024).
27. Siemens.2023.MindSphere. Available online: https://assets.new.siemens.com/siemens/assets/api/uuid:960abaa5-9485-4359-9e66-ca3ccd2b10a3/sustainability-report-fy2023-peru.pdf (accessed on 7 December 2023).
28. Xiao X. Research on the Legal System of Environmental Protection Patent Sharing. *Times Law* **2011**, *1*, 65–272.
29. Mejia C, Kajikawa K. Patent research in academic literature. Landscape and trends with a focus on patent analytics. *Front. Res. Metr. Anal.* **2024**, *9*, 1–17.
30. Eco-Patent Commons Brochure 2009. Available online: https://lehors.wordpress.com/wp-content/uploads/2009/10/eco-patentcommons-les-20091014.pdf (accessed on 20 December 2009).
31. WORLD BUS. COUNCIL FOR SUSTAINABLE DEV., THE ECO-PATENT COMMONS: A LEADERSHIP OPPORTUNITY FOR GLOBAL BUSINESS TO PROTECT THE PLANET 1-2. Available online: http://www.wbesd.org/web/projects/ecopatent/Eco-patentUpdatedJune2010.pdf (accessed on 9 November 2018).
32. Wang MY, Liu Y, Shi WQ, Li MM, Zhong C. Research on the Strategy of Cross-regional Collaborative Sharing of Low-Carbon Technologies and Emission Reduction Benefits under Carbon Trading Policies. *Syst. Eng. -Theory Pract.* **2019**, *39*, 1419–1434.

33. Compilation of Tax and Fee Preferential Policy Guidelines for Supporting Green Development. Available online: https://www.gov.cn/xinwen/2022-06/01/content_5693350.htm (accessed on 1 June 2022).
34. Zou C, Huang YC, Ye Z, Qian XY. Analysis of low-carbon technology transfer strategies based on a quadrilateral evolutionary game. *Energy Econ.* **2024**, *138*, 1–16.
35. Billson M, Pourkashanian M. The evolution of European CCS policy. *Energy Procedia* **2017**, *114*, 5659–5662.
36. Qu GH, Wang YF, Xu L, Qu WH, Zhang Q, Xu ZS. Low-Carbon Supply Chain Emission Reduction Strategy Considering the Supervision of Downstream Enterprises Based on Evolutionary Game Theory. *Sustainability* **2021**, *13*, 2827.
37. UNEP. Financing a Global Deal on Climate Change. Vulnerability. 2006. Available online: http://www.unepfi.org/fileadmin/documents/CEO-briefing-adaptation (accessed on 19 November 2019).
38. Gomulkiewicz RW. Open Source License Proliferation：Helpful Diversity or hopeless Confusion? *Wash. Univ. J. Law Policy* **2009**, *32*, 261–266.
39. Magliocca GN. Blackberries and Barnyards, Patent Trolls and the Perils of Innovation. *Notre Dame Law Rev.* **2013**, *82*, 1808–1838.
40. Wang YF, Xu P, Hu YY. Research on Defensive Patent Licensing Strategies for Protecting Open Innovation Communities. *Intell. Explor.* **2014**, *11*, 69–73.