INTELLECTUAL PROPERTY RIGHTS IN GREEN TECHNOLOGIES: DO PATENTS HINDER OR ACCELERATE CLIMATE INNOVATION?

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ABSTRACT

Climate change has made the rapid development and dissemination of green technologies a global imperative. Intellectual property rights (IPRs), particularly patents, play a role by incentivizing innovation while potentially restricting access to technologies essential for decarbonization. This tension between innovation and accessibility forms the central focus of this paper. Although patents encourage private investment and risk-taking in research and development (R&D), their restrictive effects become problematic when protected technologies are indispensable for addressing the climate crisis.

Green technologies, including renewable energy systems, carbon capture mechanisms, energyefficient appliances, and electric mobility solutions, must be deployed rapidly and extensively to achieve the objectives of the Paris Agreement. However, patent thickets, high licensing costs, and fragmented ownership structures can hinder technology transfer and deepen inequalities between the Global North and Global South.

This article critically examines whether the existing IPR framework promotes or obstructs climate innovation through doctrinal, economic, and comparative legal analysis. It evaluates the TRIPS Agreement, technology-transfer commitments under the Paris Agreement, and national patent frameworks in India, the United States, the European Union, and China. It also examines mechanisms such as compulsory licensing, patent pools, and open-source ecological innovation. Case studies involving Tesla's open patent initiative, China's solar photovoltaic expansion, and proprietary carbon capture technologies illustrate how patents can facilitate or impede technological diffusion.

The study argues that while patents remain important incentives for initial innovation, the current international IP framework is inadequate for the urgency and scale of climate action. It advocates climate-specific TRIPS flexibilities, global climate patent pools, open-source licensing models, and public-interest technology-access strategies. Reconciling intellectual

property protection with climate justice is therefore a legal, economic, and ethical necessity. Effective reform must balance innovation incentives with equitable access, ensuring that intellectual property supports global climate mitigation and adaptation while enabling developing countries to obtain essential green technologies.

Keywords: Green technologies, Climate innovation, Patents, TRIPS, Compulsory licensing, Patent pools, Climate change, IPR policy.

1. Introduction

Climate change has become the defining global challenge of the twenty-first century, reshaping legal, economic, and scientific discourse. The Intergovernmental Panel on Climate Change (IPCC) warns that rising greenhouse gas emissions are pushing the planet toward irreversible ecological tipping points, threatening water security, food systems, public health, biodiversity, and coastal regions. Addressing these challenges requires not only effective environmental governance but also the rapid development and dissemination of green or environmentally sound technologies (ESTs), which are essential for climate mitigation and adaptation under the UNFCCC and the Paris Agreement.

In this context, intellectual property rights (IPRs), particularly patents, play a crucial role. Patents grant inventors exclusive rights for a limited period, encouraging investment and innovation in sectors such as renewable energy, electric mobility, carbon capture, and sustainable engineering. However, applying traditional patent principles to climate technologies creates a significant dilemma. While patents incentivize innovation, the climate crisis demands rapid, affordable, and equitable access to technologies that are essential for global sustainability.

This tension is particularly evident in developing countries, which face the greatest climate impacts despite contributing the least to global emissions. High licensing costs, proprietary restrictions, and unequal technological capacity often limit access to patented green technologies, reinforcing global technological disparities under the TRIPS framework. As a result, calls for greater IP flexibility—similar to those proposed during the COVID-19 vaccine patent debates—have intensified.

At the same time, initiatives such as Tesla's open patent policy, China's flexible licensing approach to solar technology, and the growth of open-source environmental innovation demonstrate that technological progress can also flourish beyond traditional patent monopolies. These examples challenge the assumption that strong patent protection is the only driver of innovation.

This article examines the relationship between IPRs and green technologies through international law, comparative jurisprudence, economic theory, and case-based analysis. It argues that while patents remain important for encouraging innovation, the existing global IP framework is not fully aligned with the urgency and equity demands of the climate crisis. Effective climate action requires not only innovation but also the rapid and equitable dissemination of green technologies.

2. Understanding Green Technologies and the Patent Paradox

2.1 What Constitutes Green Technology?

[1]Green or "environmentally sound technologies" (ESTs) include innovations that reduce pollution, [2]enhance energy efficiency, conserve resources, [3]enable waste reduction, and mitigate climate impacts. Examples include:

- [4]Renewable energy equipment (solar PV, wind turbines)
- Energy storage & battery technologies
- High-efficiency appliances
- Carbon capture and storage (CCS)
- Electric vehicle technology
- Biodegradable materials
- Water purification systems
- Waste-to-energy technologies

These technologies require high initial R&D investment, making patents an important tool for commercial viability.

[1] United Nations Environment Programme, *International Environmental Technology Centre: Environmentally Sound Technologies*, UNEP, https://www.unep.org/explore-topics/technology
[2] Intergovernmental Panel on Climate Change, *Climate Change 2022: Mitigation of Climate Change—Contribution of Working Group III to the Sixth Assessment Report* 117–32 (P.R. Shukla et al. eds., Cambridge Univ. Press 2022).
[3] United Nations Framework Convention on Climate Change, *Technology Mechanism*, UNFCCC, https://unfccc.int/topics/technology
[4] International Energy Agency, *Energy Technology Perspectives 2023* 25–49 (2023)

2.2 The Patent Paradox in Climate Technologies

[5]Patents serve two conflicting roles:

[6]Incentivisation Role

- Encourage private investment in R&D
- Provide financial rewards
- Promote commercialization and competition among innovators

Access-Restriction Role

- [7]Increase technology costs
- [8]Limit manufacturing and technology transfer
- [9]Create entry barriers for developing countries
- Enable "evergreening" and monopolistic control
- [10]Slow down global diffusion of urgently needed technologies

[11]The balance between these roles determines whether patents accelerate or impede climate innovation.

3. International Legal Framework: TRIPS and Climate Technology Transfer

[5] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 151–73 (2022).
[6] Keith E. Maskus, *Encouraging International Technology Transfer* 79–103 (UNCTAD-ICTSD Issue Paper No. 7, 2004).
[7] Carlos M. Correa, *Intellectual Property Rights, the WTO and Developing Countries* 233–52 (Zed Books 2000).
[8] Peter Drahos & John Braithwaite, *Information Feudalism: Who Owns the Knowledge Economy?* 201–28 (Earthscan 2002).
[9] Joseph E. Stiglitz, *Economic Foundations of Intellectual Property Rights*, 57 DUKE L.J. 1693, 1708–22 (2008).
[10] Jerome H. Reichman, *Of Green Tulips and Legal Kudzu: Repackaging Rights in Subpatentable Innovation*, 53 VAND. L. REV. 1743, 1760–78 (2000).
[11] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 7–8, Apr. 15, 1994, 1869 U.N.T.S. 299.

[12]Climate technologies exist within a complex international legal architecture that balances intellectual property protection with developmental and environmental needs. [13]The most influential frameworks are the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and the UNFCCC–Paris Agreement regime, which both regulate—directly or indirectly—the global flow of environmentally sound technologies (ESTs). [14]Yet, despite the urgent global need for affordable climate technologies, current international regimes remain fragmented, under-enforced, and heavily biased in favour of patent-holding nations and private corporations. [15]This expanded section provides a sophisticated analysis of how TRIPS and other international frameworks shape access to climate technologies and where they fall short.

3.1 TRIPS Agreement: Prioritising Patent Protection Over Environmental Necessity

[16]Adopted in 1994 as part of the WTO framework, TRIPS is the most comprehensive multilateral treaty governing intellectual property.
[17]Under Article 27, patents must be available for *all fields of technology* without discrimination. This includes:

- Renewable energy technologies
- Carbon capture systems
- Battery storage solutions
- Green hydrogen processes
- Water purification and waste-management technologies

Absence of Environmental Exceptions

[12] Agreement on Trade-Related Aspects of Intellectual Property Rights, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[13] Agreement on Trade-Related Aspects of Intellectual Property Rights, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[14] Paris Agreement art. 10, Dec. 12, 2015, T.I.A.S. No. 16-1104.
[15] United Nations Framework Convention on Climate Change, May 9, 1992, 1771 U.N.T.S. 107.
[16] Agreement on Trade-Related Aspects of Intellectual Property Rights, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[17] Agreement on Trade-Related Aspects of Intellectual Property Rights art. 27, Apr. 15, 1994, 1869 U.N.T.S. 299.

[18]Unlike other areas—e.g., pharmaceuticals, where public health emergencies led to interpretive flexibility—TRIPS contains no explicit exceptions for climate technologies. [19]The rigid formulation of Art. 27 reflects a 20th-century view of innovation that did not anticipate climate emergencies.

Implications

- [20]Developing nations cannot easily exclude climate-related inventions from patentability.
- [21]States are bound to enforce strong patent protection even when such enforcement impedes access to essential environmental technologies.
- TRIPS enforces a uniform IP system across countries with vastly different capacities, needs, and vulnerabilities.

Structural Asymmetry

Developed countries—responsible for the majority of historical emissions—hold most climate technology patents. TRIPS thus reinforces existing technological hierarchies and makes climate mitigation more expensive for the Global South.

3.2 TRIPS Flexibilities: Are They Sufficient for Climate Technology Needs?

[22]Although TRIPS provides flexibilities intended to protect national interests, their practical use for climate technologies remains limited.

Key Flexibilities

1. Compulsory Licensing (Article 31)

[18] World Trade Organization, *Declaration on the TRIPS Agreement and Public Health*, WT/MIN(01)/DEC/2 (Nov. 14, 2001).
[19] Carlos M. Correa, *Trade Related Aspects of Intellectual Property Rights: A Commentary on the TRIPS Agreement* 267–82 (Oxford Univ. Press 2020).
[20] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 27–28, Apr. 15, 1994, 1869 U.N.T.S. 299.
[21] Keith E. Maskus, *Encouraging International Technology Transfer* 79–103 (UNCTAD-ICTSD Issue Paper No. 7, 2004).
[22] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 6, 30–31, Apr. 15, 1994, 1869 U.N.T.S. 299.

[23]Allows states to authorize use of a patent without the owner's consent.

Challenges:

- [24]Procedural complexity
- [25]Requirement of prior negotiation (Art. 31(b)) except in emergencies
- Limited capacity of many countries to manufacture patented green technologies
- Risk of diplomatic and trade repercussions

[26]While compulsory licensing is powerful, its use has primarily been restricted to pharmaceuticals (*Natco v. Bayer* in India is a key example), not climate technologies.

2. Government Use Provisions

[27]Governments may use patented technologies for public purposes. However, climate technologies often involve complex multi-party ownership, making enforcement difficult.

3. Parallel Importation (Art. 6)

Permits importing patented goods sold elsewhere at lower prices. Though useful for generic goods, it provides limited relief for large-scale infrastructure technologies like wind turbines or CCS systems.

4. Exceptions under Article 30

Allows limited exceptions that do not "unreasonably prejudice" the patent-holder. In practice, its scope is interpreted narrowly.

Conclusion on TRIPS Flexibilities

[23] Agreement on Trade-Related Aspects of Intellectual Property Rights art. 31, Apr. 15, 1994, 1869 U.N.T.S. 299.
[24] Carlos M. Correa, *Trade Related Aspects of Intellectual Property Rights: A Commentary on the TRIPS Agreement* 321–46 (Oxford Univ. Press 2020).
[25] World Trade Organization, *Declaration on the TRIPS Agreement and Public Health*, WT/MIN(01)/DEC/2 (Nov. 14, 2001).
[26] Natco Pharma Ltd. v. Bayer Corp., (2014) 6 SCC 335 (India).
[27] Carlos M. Correa, *Intellectual Property Rights, the WTO and Developing Countries* 233–52 (Zed Books 2000).

TRIPS flexibilities were designed primarily for public health concerns, not global environmental emergencies. Their utility for climate technology access remains theoretical rather than practical.

3.3 The Doha Declaration Analogy: Why Climate Change Needs Its Own Waiver

[28]The Doha Declaration on TRIPS and Public Health (2001) established that public health emergencies justify overriding patent protections.
Climate change arguably presents an even greater, long-term existential threat.

Arguments for a Doha-like Declaration on Climate Technologies

- [29]Climate change threatens the human right to life, health, housing, food, and water.
- [30]Global mitigation requires widespread and affordable access to climate technologies.
- Patent barriers exacerbate inequality and delay climate action.

Why It Has Not Happened

- [31]Strong political resistance from major patent-owning states (U.S., EU, Japan).
- Climate technologies are controlled predominantly by private corporations, not governments.
- Divergent geopolitical interests and fears of losing competitive advantage.

Without a binding declaration, TRIPS flexibilities remain underutilised for climate action.

3.4 Technology Transfer Obligations Under the UNFCCC and Paris Agreement: Aspirational but Weak

UNFCCC (1992)

[32]Article 4(5) obligates developed countries to:

[28] World Trade Organization, *Declaration on the TRIPS Agreement and Public Health*, WT/MIN(01)/DEC/2 (Nov. 14, 2001).
[29] Office of the United Nations High Commissioner for Human Rights, *Understanding Human Rights and Climate Change* (2015).
[30] World Intellectual Property Organization, *Green Technology Book* 17–31 (2023).
[31] Peter Drahos & John Braithwaite, *Information Feudalism: Who Owns the Knowledge Economy?* 201–28 (Earthscan 2002).
[32] United Nations Framework Convention on Climate Change art. 4(5), May 9, 1992, 1771 U.N.T.S. 107.

- Promote, facilitate, and finance technology transfer
- Support capacity building in developing nations

However, these obligations are not legally enforceable. They depend on political will, not legal compulsion.

Paris Agreement (2015)

[33]Article 10 strengthens the commitment to technology development and transfer, establishing:

- The Technology Mechanism
- [34]The Technology Executive Committee (TEC)
- The Climate Technology Centre and Network (CTCN)

These institutions promote cooperation and provide technical support.

Key Weaknesses

- [35]No power to override patents or compel licensing
- [36]Funding remains inconsistent and insufficient
- Lack of clear compliance or dispute settlement mechanisms
- Technology transfer remains largely voluntary and market-based

Outcome

The Paris system reinforces *aspirational cooperation* but lacks the binding force necessary to counteract TRIPS obligations.

3.5 The TRIPS–UNFCCC Conflict: A Clash of Normative Priorities

The coexistence of TRIPS and the Paris Agreement produce a structural conflict:

TRIPS	Paris Agreement
Protects private rights	Prioritizes global climate goals

[33] Paris Agreement art. 10, Dec. 12, 2015, T.I.A.S. No. 16-1104.
[34] United Nations Framework Convention on Climate Change, *Technology Mechanism*, https://unfccc.int/ttclear
[35] United Nations Environment Programme, *International Environmental Technology Centre: Environmentally Sound Technologies*, https://www.unep.org/explore-topics/technology (last visited July 22, 2026).
[36] World Intellectual Property Organization, *Green Technology Book* 81–96 (2023).

TRIPS	Paris Agreement
Enforced by WTO dispute settlement	Lacks binding enforcement
Led by trade ministers	Led by environmental policymakers
Strong protections and sanctions	Soft law and cooperative language

This asymmetry means:

- Trade interests override climate interests in global legal hierarchy.
- WTO rules are enforceable; climate commitments are not.
- Patent holders benefit from legal certainty; climate technology users face uncertainty.

Systemic Result

The global IP regime prioritizes innovation **incentives** ***even when they conflict with planetary survival requirements.***

3.6 International Patent Landscape: Concentration in the Global North

The majority of patents in key climate technology sectors are held by:

- United States
- European Union
- Japan
- South Korea
- China (rapidly rising)

Developing countries—Africa, South Asia, Latin America—own less than 5% of global climate technology patents.

Implications

- Technology transfer becomes a one-way, expensive process.
- Dependence on foreign technology deepens structural inequalities.
- Lack of domestic intellectual capital limits local innovation tailored to geographic conditions.

This creates a system where those least responsible for climate change are dependent on those most responsible for solutions.

3.7 Export Controls and Strategic Patents: A New Cold War in Climate Technologies

[37]Some countries treat advanced climate technologies—particularly semiconductors for EVs, hydrogen catalysts, and energy storage materials—as strategic assets.

[38]Emerging Trends

- [39]Export controls on critical minerals and advanced manufacturing equipment
- [40]Restrictions on cross-border R&D collaboration
- National security framing of energy transitions

[41]These policies make technology transfer even more difficult, revealing a geopolitical layer to climate innovation governance.

3.8 Global Calls for Reform: Towards a Climate-Compatible IP Regime

[42]Scholars, NGOs, developing nations, and UN bodies increasingly call for:

- [43]A TRIPS climate waiver
- A global climate patent pool
- Mandatory public-interest licensing for publicly funded research
- Climate-specific flexibilities in TRIPS interpretation
- Strengthened Technology Mechanism under the Paris Agreement

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[37] International Energy Agency, *Global Critical Minerals Outlook 2024* 18–45 (2024).
[38] Organisation for Economic Co-operation and Development, *The Role of Critical Minerals in Clean Energy Transitions* 12–29 (2023).
[39] International Energy Agency, *Global Critical Minerals Outlook 2024* 76–95 (2024).
[40] United Nations Conference on Trade and Development, *Technology and Innovation Report 2023: Opening Green Windows* 109–28 (2023).
[41] World Intellectual Property Organization, *World Intellectual Property Report 2024: Making Innovation Policy Work for Development* 211–30 (2024).
[42] World Intellectual Property Organization, *Green Technology Book* 95–118 (2023).
[43] World Health Organization, World Intellectual Property Organization & World Trade Organization, *Promoting Access to Medical Technologies and Innovation* 311–26 (2d ed. 2020) (discussing patent pools and public-interest licensing as collaborative IP mechanisms applicable by analogy to other global public goods).

- Greater participation of developing countries in standard-setting bodies

[44]These proposals reflect growing recognition of the contradiction between global climate needs and the current IPR architecture.

3.9 Synthesis: A Fragmented System Unfit for a Planetary Emergency

Core Findings

1. [45]TRIPS provides strong patent protection but weak mechanisms for access.
2. [46]UNFCCC and Paris encourage technology transfer but cannot compel it.
3. Patent ownership remains deeply unequal, reinforcing global hierarchies.
4. [47]Licensing, technology transfer, and diffusion remain market-driven rather than justice-driven.
5. International systems prioritise innovation incentives over climate necessity.

Conclusion

The international legal framework governing climate technology is profoundly misaligned with the urgent requirements of global climate action. A reformed, climate-conscious IP regime—balancing innovation and universal access—is essential to overcome systemic barriers.

4. Patents as Drivers of Climate Innovation

[48]The conventional justification for patents is that they incentivize technological innovation by granting inventors temporary monopolies in exchange for public disclosure. [49]This framework has strongly influenced the development of green technologies, particularly in capital-intensive industries such as renewable energy, energy storage, electric mobility, carbon capture and

[44] Peter Drahos & John Braithwaite, *Information Feudalism: Who Owns the Knowledge Economy?* 221–40 (Earthscan 2002).
[45] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 7, 8, 27–31, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[46] Paris Agreement art. 10, Dec. 12, 2015, T.I.A.S. No. 16-1104; United Nations Framework Convention on Climate Change art. 4(5), May 9, 1992, 1771 U.N.T.S. 107.
[47] World Intellectual Property Organization, *Green Technology Book* 95–118 (2023).
[48] Agreement on Trade-Related Aspects of Intellectual Property Rights art. 7, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[49] Robert P. Merges, *Justifying Intellectual Property* 1–35 (Harvard Univ. Press 2011).

storage (CCS), hydrogen systems, and climate-resilient agriculture. [50]While patents can also impede diffusion, their positive role in stimulating invention, commercialization, and industry formation is undeniable. Understanding how patents *accelerate* climate innovation is essential to crafting a balanced intellectual property strategy for the climate era.

4.1 Patents Attract Investment by Reducing Market Uncertainty

[51]Green technologies require substantial financial investment before reaching commercial maturity. The development cycle—from concept to demonstration to commercialization—can span decades and involve significant risk. [52]Patents play a critical role in reducing investor uncertainty by protecting innovators from imitation during the most vulnerable stages of development.

Economic Benefits

- Reduced Risk Premium: Investors, venture capitalists, and private equity funds are more willing to finance long-gestation climate technologies when exclusive rights ensure potential returns.
- Market Signaling: Strong patent portfolios indicate technological credibility and maturity, helping startups secure funding.
- Strategic Asset Creation: Patents serve as intangible assets that companies can leverage for mergers, licensing, or technology partnerships.

Sectors Where Patents Are Critical

- [53]Battery technology (solid-state, lithium-sulfur, sodium-ion)
- Hydrogen electrolyser systems
- Advanced solar cell materials (perovskites)
- Carbon capture solvents and processes

[50] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 151–73 (2022).
[51] World Intellectual Property Organization, *Green Technology Book* 41–58 (2023).
[52] Organisation for Economic Co-operation and Development, *OECD Science, Technology and Innovation Outlook 2023* 117–36 (2023
[53] nternational Energy Agency, *Energy Technology Perspectives 2023* 55–102 (2023).

- Offshore wind turbine designs

Without patents, private actors may underinvest in R&D due to fear of rapid imitation, jeopardizing technological advancement.

4.2 Disclosure Requirements Stimulate Follow-on Innovation

[54]A fundamental condition of patent protection is the obligation to publicly disclose technical details. [55]This requirement contributes immensely to climate innovation by expanding the global pool of technical knowledge.

Benefits of Disclosure

- [56]Technical diffusion: Even if patented technologies cannot be commercialized without permission, the knowledge itself becomes accessible to engineers, researchers, and startups.
- [57]Incremental innovation: Competitors can innovate around existing patents, improving efficiency, reducing cost, or developing alternative approaches.
- Avoidance of redundancy: Public disclosure prevents duplication of research efforts, allowing resources to be directed toward unexplored areas.

In sectors such as solar PV, wind energy, and smart grid systems, patent disclosures have accelerated collective learning and contributed to more rapid technological evolution.

4.3 Patents Facilitate Commercialization and Standardization in Climate Technologies

Innovation alone does not guarantee climate impact; technologies must reach the market and scale competitively. Patents help create commercially viable pathways by enabling structured business models.

Commercialization Support

[54] Agreement on Trade-Related Aspects of Intellectual Property Rights art. 29, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[55] Robert P. Merges, *Justifying Intellectual Property* 85–104 (Harvard Univ. Press 2011).
[56] Suzanne Scotchmer, *Innovation and Incentives* 53–78 (MIT Press 2004).
[57] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 156–67 (2022).

- Licensing Models: Patents enable companies to license technologies to manufacturers worldwide, accelerating global deployment.
- Joint Ventures: Corporations collaborate through cross-licensing, sharing proprietary components to develop integrated climate solutions.
- Spin-Off Ecosystems: University patents facilitate startup formation, particularly in areas such as clean energy materials, carbon sequestration, and environmental biotechnology.

Standardization Benefits

[58]Climate technologies often require interoperability across regions, sectors, and platforms. Patents enable the formation of:

- [59]Standard-essential patents (SEPs) for EV charging systems
- Grid-interoperability standards in smart energy networks
- Hydrogen purity and safety standards

The development of technical standards is critical for cost reduction and global compatibility.

4.4 Public–Private Partnerships (PPPs) Depend on Patent Ownership Clarity

[60]Many breakthrough climate technologies originate in collaborations between governments, research institutions, and private firms. These partnerships depend heavily on clear intellectual property frameworks.

Role of Patents in PPPs

- They clarify ownership of research outputs.
- They enable commercialization of publicly funded innovations.
- They incentivize private entities to engage in long-term environmental research.
- They allow universities and national laboratories to license technologies for public benefit.

[58] Jorge L. Contreras, *The Cambridge Handbook of Technical Standardization Law: Competition, Antitrust, and Patents* 3–24 (Cambridge Univ. Press 2017).
[59] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 170–78 (2022).
[60] World Intellectual Property Organization, *Green Technology Book* 59–78 (2023).

Examples include:

- The U.S. Department of Energy's support for battery innovations at Argonne National Laboratory
- Germany's Fraunhofer Institutes advancing solar PV efficiency
- India's public research on green hydrogen and biofuels

Without patents, private actors may shy away from PPPs due to the inability to secure competitive advantage.

4.5 Patents Enable Technology Markets to Function Efficiently

[61]Climate technologies increasingly operate within global markets characterized by licensing, joint development agreements, mergers, and technology acquisitions. [62]Robust patent protection fosters market activity.

Market Benefits

- [63]Technology Transfer Markets: Patents create tradable rights that facilitate exchange through licensing, reducing barriers for smaller firms.
- [64]Competition Among Innovators: Companies compete not only on price but on technical superiority, driving rapid innovation cycles.
- Specialization: Firms can focus on niche areas—battery management software, turbine blade materials, smart grid algorithms—knowing their innovations are protected.

These dynamics create a healthy innovation ecosystem that would otherwise stagnate.

4.6 Patents Promote Long-Term Research Commitment

[65]Climate innovation often requires long-term, high-risk R&D—sometimes across decades. For example:

[61] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 164–82 (2022).
[62] Robert P. Merges, *Justifying Intellectual Property* 131–56 (Harvard Univ. Press 2011).
[63] Keith E. Maskus, *Encouraging International Technology Transfer* 79–103 (UNCTAD-ICTSD Issue Paper No. 7, 2004).
[64] Organisation for Economic Co-operation and Development, *OECD Science, Technology and Innovation Outlook 2023* 145–70 (2023).
[65] International Energy Agency, *Energy Technology Perspectives 2023* 85–118 (2023).

- Solid-state battery research has been ongoing for over 30 years.
- [66]Hydrogen fuel technologies date back to the 19th century but became commercially viable only recently.
- Carbon capture R&D has spanned multiple scientific generations.

Patents ensure innovators can recover investments from such prolonged efforts.

[67]Encouraging Deep-Tech Development

Patent protection allows companies to:

- Sustain highly specialized research teams
- Invest in pilot plants and demonstration projects
- Pursue long-term, unprofitable early research phases

Without patent incentives, many cutting-edge climate technologies might never leave the laboratory.

4.7 Patents Encourage Private Sector Leadership in the Climate Transition

[68]Governments alone cannot meet climate innovation demands. The private sector—startups, mid-sized firms, and large multinationals—plays a crucial role.

Private Sector Contributions

- [69]Most EV battery breakthroughs come from private firms (Panasonic, CATL, LG Chem).
- Solar efficiency advancements have been driven by companies such as LONGi and First Solar.
- [70]Carbon capture technologies are dominated by private-sector innovations.

[66] Suzanne Scotchmer, *Innovation and Incentives* 127–58 (MIT Press 2004).
[67] World Intellectual Property Organization, *Green Technology Book* 41–78 (2023).
[68] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 164–82 (2022).
[69] International Energy Agency, *Energy Technology Perspectives 2023* 119–54 (2023).
[70] World Intellectual Property Organization, *Green Technology Book* 19–54 (2023).

[71]By protecting investments and ensuring competitive advantage, patents enable the private sector to lead technological transformation.

4.8 Patents Can Indirectly Reduce Costs Over Time

[72]A counterintuitive but important observation is that strong patent regimes can eventually reduce global technology costs. Patents encourage multiple firms to innovate concurrently, leading to rapid advancements and efficiency gains.

Examples

- [73]Solar photovoltaic panels dropped in cost by over 85% despite early patent protection.
- [74]Lithium-ion battery prices fell more than 90% due to competition driven by diverse proprietary approaches.
- EV production costs have steadily decreased as patents pushed companies toward more efficient designs.

Thus, patents create competitive pressure that often yields long-term cost reductions—even if short-term prices remain high.

4.9 Synthesis: The Pro-Innovation Role of Patents

[75]Patents accelerate climate innovation primarily by:

1. Attracting investment
2. Reducing risk
3. Enabling commercialization

[71] Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, in *The Rate and Direction of Inventive Activity* 609, 615–22 (Nat'l Bureau of Econ. Research ed., Princeton Univ. Press 1962).
[72] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 164–82 (2022).
[73] Bronwyn H. Hall & Christian Helmers, *Innovation and Diffusion of Clean/Green Technology: Can Patent Commons Help?*, in *Innovation for Sustainable Development* 193–214 (2013).
[74] International Energy Agency, *Energy Technology Perspectives 2023* 101–42 (2023).
[75] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 151–82 (2022).

4. Facilitating standardization
5. Supporting public–private collaboration
6. Providing clarity in technology markets
7. Encouraging long-term research
8. Stimulating global competition

However, as other sections show, the challenge lies in ensuring that the *benefits of innovation* translate into *equitable diffusion*. In isolation, patents strengthen invention; in excess, they obstruct climate action. Their role is therefore catalytic—but only when balanced with mechanisms that support global technology access.

5. Patents as Barriers to Global Climate Technology Access

[76]While patents play a foundational role in incentivizing early-stage innovation, they increasingly create structural barriers to the global diffusion of green technologies—diffusion that is essential for achieving climate mitigation and adaptation goals. [77]The urgency of climate action places the spotlight on the limitations of a traditional IP system designed for commercial exclusivity, rather than global public goods. [78]This expanded section analyses how patent rights obstruct access, amplify inequality, and impede the world's ability to meet its climate commitments.

5.1 High Licensing Costs and Proprietary Control: The Price of Exclusivity

[79]Patents give inventors the legal right to exclude others from manufacturing, selling, or using a technology. [80]While these exclusive rights create commercial incentives, they also elevate costs for states, utilities, corporations, and communities seeking to adopt climate-friendly technologies.

Economic Barriers

[76] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 24–41 (2023).
[77] Carlos M. Correa, *Trade Related Aspects of Intellectual Property Rights: A Commentary on the TRIPS Agreement* 349–67 (Oxford Univ. Press 2020).
[78] World Intellectual Property Organization, *Green Technology Book* 95–118 (2023).
[79] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 28–30, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[80] Robert P. Merges, *Justifying Intellectual Property* 131–56 (Harvard Univ. Press 2011).

- [81]Royalty rates on patented technologies can significantly inflate the cost of renewable energy infrastructure, carbon capture systems, and energy-efficient industrial machinery.
- Developing countries must negotiate licensing fees in foreign currencies, adding exchange rate vulnerabilities and increasing the overall financial burden.
- Complex licensing agreements often bundle patents with proprietary software, maintenance contracts, and long-term supply agreements.

Impact on Public Infrastructure

[82]Critical climate technologies—smart grids, electric mobility systems, waste-to-energy plants—often require access to proprietary standards and designs. [83]High costs delay deployment or force governments to choose cheaper, less efficient alternatives.

Corporate Control

[84]Patent holders can strategically time price reductions or licensing expansions to coincide with market dominance, limiting competition in regions with high climate vulnerability.

[85]Thus, patent-based exclusivity transforms essential environmental technologies into expensive commodities that many nations cannot afford.

5.2 Fragmented Patent Ownership and Patent Thickets: A Minefield for Adoption

[86]Modern climate technologies—such as wind turbines, hydrogen electrolysers, and battery management systems—are rarely covered by a single patent. Instead, they involve hundreds or even thousands of interlocking patents held by multiple corporations, universities, and research institutions.

[81] Keith E. Maskus, *Encouraging International Technology Transfer* 79–103 (UNCTAD-ICTSD Issue Paper No. 7, 2004).
[82] International Energy Agency, *Energy Technology Perspectives 2023* 143–76 (2023).
[83] United Nations Conference on Trade and Development, *Technology and Innovation Report 2023: Opening Green Windows* 143–67 (2023).
[84] Peter Drahos & John Braithwaite, *Information Feudalism: Who Owns the Knowledge Economy?* 201–28 (Earthscan 2002).
[85] Carlos M. Correa, *Trade Related Aspects of Intellectual Property Rights: A Commentary on the TRIPS Agreement* 349–67 (Oxford Univ. Press 2020).
[86] World Intellectual Property Organization, *Green Technology Book* 59–96 (2023).

Patent Thickets

A patent thicket is a dense web of overlapping intellectual property claims that firms must navigate to commercialize or use a technology.

This creates:

- High transaction costs for negotiating access to multiple patents.
- Barrier to entry for new firms or developing-country manufacturers.
- Risk of litigation, making investment uncertain.
- Delays in deployment while negotiations occur.

For example, advanced lithium-ion batteries involve patents on:

- Cathode chemistry
- Anode composition
- Electrolyte formulations
- Manufacturing techniques
- Battery management software

A manufacturer cannot legally produce batteries without securing rights to dozens of these patents.

Anti-Competitive Effects

Patent thickets enable dominant firms to:

- Consolidate market power
- Exclude smaller competitors
- Shape global standards in their favour

This restricts the global availability of climate technologies and increases dependency on a handful of multinational corporations.

5.3 Delayed Dissemination During a Climate Emergency

[87]The most critical limitation of patents in the climate context is temporal. Climate science underscores the need for rapid, large-scale deployment of mitigation and adaptation technologies. In contrast, patent exclusivity lasts 20 years, often during the most commercially significant phase of a technology's lifecycle.

Temporal Mismatch

- Climate action must occur within the next decade to prevent catastrophic warming.
- Patent monopolies restrict access precisely when global deployment must accelerate.
- Delays—whether in licensing negotiations, patent disputes, or commercialization—have irreversible environmental consequences.

Slow Uptake in Developing Countries

The delay caused by patent barriers disproportionately harms nations:

- With limited R&D capacity
- Facing climate vulnerability
- Dependent on foreign technology
- Constrained by weak institutional capacity

In these countries, every year of delay increases long-term adaptation costs and heightens vulnerability to extreme climate events.

Technological Lock-In

Patented technologies may dominate markets prematurely, even when more sustainable open technologies exist, creating "lock-in" effects that persist long after patents expire.

5.4 Weak Technology Transfer Under the Paris Agreement: A Structural Failure

[88]Although the Paris Agreement emphasizes the importance of climate technology transfer (Article 10), it contains no robust legal mechanisms to ensure it. Technology transfer remains dependent on:

- Voluntary cooperation

[87] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 24–41 (2023).
[88] Daniel Bodansky, *The Art and Craft of International Environmental Law* 231–42 (Harvard Univ. Press 2010).

- Bilateral agreements
- Private licensing decisions

Why Technology Transfer Fails

1. **Private Ownership of Climate Technologies**
    - Most green technologies are owned by corporations, not states.
    - International law cannot compel companies to license patents globally.
2. **Lack of Enforcement Mechanisms**
    - The Paris Agreement focuses on ambition rather than compulsion.
    - The Technology Mechanism has no authority to override patent rights.
3. **TRIPS Dominance**
    - The WTO's TRIPS Agreement has binding dispute settlement mechanisms.
    - In contrast, climate treaties rely on soft law and political commitments.

Resulting Inequities

[89]Developed countries—historically responsible for the majority of emissions—retain control over technologies needed by developing nations to mitigate and adapt. [90]This reproduces colonial patterns of dependency and prevents equitable climate transitions**.**

5.5 The Global South's Structural Disadvantages in Accessing Patented Technologies

[91]Countries in the Global South face systemic barriers that magnify the impact of patent restrictions.

Institutional and Financial Constraints

- Limited negotiating power in licensing agreements
- Weak patent landscaping and due diligence capacity

[89] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 95–108 (2023).
[90] United Nations Conference on Trade and Development, *Technology and Innovation Report 2023: Opening Green Windows* 143–67 (2023).
[91] United Nations Conference on Trade and Development, *Technology and Innovation Report 2023: Opening Green Windows* 129–67 (2023).

- Insufficient domestic manufacturing ecosystems
- High-interest financing for climate infrastructure projects

Dependence on Imported Technologies

Countries lacking indigenous R&D rely on imported technologies that remain expensive due to:

- Patents
- Proprietary standards
- Import tariffs
- Technology-specific trade agreements

Climate Vulnerability

[92]Ironically, the country's most in need of affordable green technologies—[93]Bangladesh, Kenya, Nepal, Pacific Island states—are the least able to afford patented systems.

Barrier to Innovation Capacity

[94]Patent monopolies in the Global North restrict access to foundational technologies, preventing developing countries from creating their own adaptations suited to local conditions. [95]This stunts global innovation diversity.

[92] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 95–108 (2023).
[93] United Nations Conference on Trade and Development, *Technology and Innovation Report 2023: Opening Green Windows* 143–67 (2023).
[94] Carlos M. Correa, *Trade Related Aspects of Intellectual Property Rights: A Commentary on the TRIPS Agreement* 349–67 (Oxford Univ. Press 2020)
[95] Keith E. Maskus, *Encouraging International Technology Transfer* 79–103 (UNCTAD-ICTSD Issue Paper No. 7, 2004).

5.6 Patents and the Political Economy of "Green Colonialism"

A deeper critique frames the issue as one of green colonialism—a system where wealthy nations control the technologies required for global survival, thereby perpetuating dependency and inequality.

Features of Green Colonialism

- Dominance of multinational corporations in clean tech sectors
- Trade agreements that restrict compulsory licensing
- Export controls on strategic climate technologies
- Uneven accumulation of climate-related IPR in the Global North
- Lack of meaningful participation of developing countries in standard-setting bodies

This dynamic mirrors historical patterns of technology monopolization and resource extraction, raising profound ethical questions about justice, sovereignty, and equity in the climate era.

5.7 The Ethical Imperative: Why Patent Barriers Are Unacceptable in a Climate Crisis

[96]Climate technologies—unlike consumer electronics or luxury goods—serve a global public good essential to human survival. When patents restrict access to these technologies:

- [97]Mitigation targets become unattainable
- Loss and damage escalate
- [98]Human rights, including the right to life and a healthy environment, are endangered
- Intergenerational equity is compromised

[99]Thus, the ethical case against rigid patent control over essential climate technologies is overwhelming. A system that prioritizes profit over planetary survival is not only economically inefficient—it is morally untenable.

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[96] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 24–41, 95–108 (2023).
[97] Office of the United Nations High Commissioner for Human Rights, *Understanding Human Rights and Climate Change* 1–16 (2015).
[98] Human Rights Council, The Human Right to a Clean, Healthy and Sustainable Environment, Res. 48/13, U.N. Doc. A/HRC/RES/48/13 (Oct. 8, 2021).
[99] Edith Brown Weiss, *In Fairness to Future Generations: International Law, Common Patrimony, and Intergenerational Equity* 15–39 (United Nations Univ. 1989).

Synthesis of Section 5

Patents hinder global climate technology access through multiple pathways:

- High licensing fees
- Legal uncertainty
- Market concentration
- Temporal delays
- Weak international technology transfer mechanisms
- Structural economic inequities

In a climate emergency, these barriers are unacceptable. The need to reconfigure the global IP regime is not merely a matter of policy preference; it is a planetary necessity.

6. Comparative Perspectives

[100]A comparative analysis of intellectual property regimes reveals that the relationship between patents and climate innovation varies significantly across jurisdictions, reflecting differences in industrial capacity, developmental priorities, legal traditions, and geopolitical strategies. Understanding these contrasting approaches is essential for evaluating the global feasibility of inclusive climate technology diffusion. [101]This section examines four major legal and economic systems—the United States, the European Union, China, and India—each representing distinct philosophies of IP governance and climate policy.

6.1 United States: Strong Patent Enforcement and Market-Driven Innovation

[102]The United States maintains one of the strongest patent protection regimes in the world. Its legal and economic culture views robust IPR protection as a non-negotiable foundation for technological progress, particularly in sectors requiring extensive R&D investment.

Key Features

1. **Stringent Patent Standards and Litigation Culture**

[100] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 173–201 (2022).
[101] Organisation for Economic Co-operation and Development, *OECD Science, Technology and Innovation Outlook 2023* 61–92 (2023).
[102] Robert P. Merges, *American Patent Law: A Business and Economic History* 289–325 (Cambridge Univ. Press 2020).

- [103]The U.S. Patent and Trademark Office (USPTO) enforce rigorous patent examination, granting broad rights to innovators.
- Litigation is common; patent assertion entities ("patent trolls") play a visible role in shaping enforcement dynamics.

2. **Strong Private Sector Dominance**
   - Companies such as Tesla, GE Renewable Energy, First Solar, and ExxonMobil hold extensive patent portfolios in batteries, wind turbines, solar technologies, and carbon capture systems.
   - Private investment, venture capital, and market incentives drive much of climate technological development.
3. **Limited Use of Compulsory Licensing**
   - The U.S. rarely invokes compulsory licensing, viewing it as an intrusion on free markets.
   - The Bayh–Dole Act encourages commercialization of publicly funded inventions, but "march-in rights" are almost never exercised—even in the face of urgent public needs.

Implications for Climate Innovation

- [104]Accelerator at the invention stage: The U.S. excels in early-stage innovation due to strong patent protection and abundant R&D funding.
- [105]Barrier at the diffusion stage: High costs, proprietary control, and competitive secrecy can hinder global adoption, especially in developing countries.

[106]The U.S. model illustrates that strong patents can support innovation but may obstruct equitable access unless complemented by deliberate technology-sharing policies.

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[103] James Bessen & Michael J. Meurer, *Patent Failure: How Judges, Bureaucrats, and Lawyers Put Innovators at Risk* 27–58 (Princeton Univ. Press 2008).
[104] Organisation for Economic Co-operation and Development, *OECD Science, Technology and Innovation Outlook 2023* 61–92 (2023).
[105] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 173–201 (2022).
[106] **190.** Keith E. Maskus, *Encouraging International Technology Transfer* 79–103 (UNCTAD-ICTSD Issue Paper No. 7, 2004).

6.2 European Union: Balancing Exclusive Rights with Public Interest and Sustainability

The European Union represents a hybrid model that combines strong IPR protection with proactive climate governance and competition law frameworks.

Key Features

1. **Innovation Funding Through Public Institutions**
    - Initiatives such as ***Horizon Europe*, the *Green Deal*, and the *Innovation Fund* support R&D** in renewable energy, hydrogen, energy efficiency, and circular economy technologies.
    - The EU strategically aligns climate policy with industrial policy.
2. **Competition Law as a Corrective Mechanism**
    - [107]The European Commission actively monitors for patent abuse, anti-competitive licensing, and restrictive exclusive agreements.
    - [108]Competition law encourages FRAND (fair, reasonable, and non-discriminatory) licensing, especially in energy and environmental sectors.
3. **Climate Policy Integration**
    - [109]The EU Emissions Trading System (ETS), Renewable Energy Directive (RED II), and Energy Efficiency Directives create high demand for green technology innovation and deployment.
4. **Soft-Law Approaches to Technology Sharing**
    - [110]The EU encourages—but does not mandate—voluntary patent pools, open innovation clusters, and technology partnerships.

Implications for Climate Innovation

[107] Consolidated Version of the Treaty on the Functioning of the European Union arts. 101–102, Oct. 26, 2012, 2012 O.J. (C 326) 47.
[108] European Commission, *Guidelines on the Applicability of Article 101 of the Treaty on the Functioning of the European Union to Horizontal Co-operation Agreements*, 2023 O.J. (C 259) 1.
[109] Jorge L. Contreras, *The Cambridge Handbook of Technical Standardization Law* 245–70 (Cambridge Univ. Press 2017).
[110] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources (Recast), 2018 O.J. (L 328) 82; Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on Energy Efficiency (Recast), 2023 O.J. (L 231) 1.

- The EU successfully balances innovation and diffusion within its territory.
- However, strong patent enforcement and regulatory focus within Europe do not necessarily translate into enhanced technology access for the Global South.

The EU presents a *moderate model*—more flexible than the U.S. but still insufficient for addressing global technology equity.

6.3 China: State-Led Innovation, Flexible IP Enforcement, and Rapid Scaling

China's rise as a global leader in solar photovoltaics, batteries, electric vehicles, and wind energy is inseparable from its distinctive approach to intellectual property and industrial policy.

Key Features

1. **State-Driven Industrial Policy**
    - Centralized planning, subsidies, and strategic investment under initiatives like *Made in China 2025* promote rapid development and manufacturing capacity.
2. **Historically Flexible IP Enforcement**
    - Earlier decades saw weak enforcement of foreign patents, facilitating imitation, learning-by-doing, and adaptation.
    - This flexibility enabled domestic firms to acquire technological capabilities quickly.
3. **Rapid Scaling and Cost Reduction**
    - China's mass manufacturing capacity drove global price declines in solar panels, EV batteries, and wind turbines.
    - Lower costs accelerated renewable energy adoption worldwide, particularly in developing countries.
4. **Transition Toward Stronger IP Protection**
    - As China becomes a major patent-holder, especially in batteries and EV technologies, it is strengthening its IP system to protect domestic innovation.

Implications for Climate Innovation

- China demonstrates that rapid diffusion is possible when IP restrictions are minimized or strategically managed.
- However, as China shifts toward stronger IP enforcement, similar barriers may arise globally in the future.

China's experience suggests that flexible IP governance—combined with state-led industrial policy—can dramatically accelerate climate technology deployment.

6.4 India: Public-Interest-Oriented Patent Law and Climate Technology Priorities

India follows a TRIPS-compliant but strongly public-interest-oriented approach to intellectual property. Its patent system reflects broader constitutional commitments to development, welfare, and social justice.

Key Features

1. **Strict Patentability Standards**
    - Section 3(d) of the Indian Patents Act prevents evergreening and requires genuine innovation.
    - While Section 3(d) is famous in pharmaceutical contexts, its principles apply equally to climate-related inventions.
2. **Robust Compulsory Licensing (CL) Provisions**
    - India issued a landmark CL in *Natco Pharma v. Bayer* (2012), setting global precedent for using TRIPS flexibilities.
    - India could employ similar tools for climate technologies.
3. **Emphasis on Technology Transfer and Indigenous Manufacturing**
    - Programs such as "Make in India," the National Solar Mission, and domestic EV policies promote local manufacturing and reduce import dependence.
4. **Climate Vulnerabilities and Developmental Realities**

- India needs affordable access to green technologies for its energy transition, adaptation strategies, and SDG commitments.

Implications for Climate Innovation

- [111]India's legal framework prioritizes access and affordability, making it more aligned with climate justice principles.
- [112]However, without adequate domestic R&D investment, India remains dependent on foreign technology, which may limit the effectiveness of its IP flexibilities.

India's model demonstrates that balancing innovation with public interest is possible—but requires complementary industrial and research policies.

6.5 Comparative Synthesis: Lessons from Divergent Models

United States

→ *Innovation thrives; diffusion suffers.*

[113]Strong patents create world-leading innovation but restrict global access.

European Union

→ *Balanced but inward-focused.*

[114]The EU blends innovation with sustainability and competition law but does not address global inequities.

China

→ Diffusion thrives; innovation adapted through flexibility.

[115]Flexible IP enforcement accelerated global renewable energy deployment but now faces transition challenges.

India

[111] The Patents Act, No. 39 of 1970, §§ 83–92, amended by the Patents (Amendment) Act, No. 15 of 2005 (India).
[112] United Nations Conference on Trade and Development, *Technology and Innovation Report 2023: Opening Green Windows* 155–75 (2023).
[113] Robert P. Merges, *American Patent Law: A Business and Economic History* 289–325 (Cambridge Univ. Press 2020).
[114] United Nations Conference on Trade and Development, *Technology and Innovation Report 2023: Opening Green Windows* 143–67 (2023).
[115] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 173–201 (2022).

→ Access and social justice prioritized.

[116]A public-interest patent system supports equitable diffusion but requires stronger innovation ecosystems.

Key Takeaways

1. No single model optimally balances innovation and diffusion.
2. Patent rigidity correlates with slower diffusion, particularly outside the inventor's jurisdiction.
3. State intervention—through subsidies, licensing policies, or relaxed IP enforcement—can dramatically accelerate green technology uptake.
4. Developing countries need flexible IP regimes combined with strong industrial strategies to benefit from global innovation.
5. The global climate challenge demands harmonization of these models, ensuring the strengths of one can compensate for the shortcomings of others.

7. Case Studies: How IPR Affects Green Technology Deployment

[117]Case studies serve as empirical evidence of the complex relationship between intellectual property protection and the diffusion of climate technologies. The following examples demonstrate how patents can accelerate innovation in some contexts while creating systemic barriers in others. [118]Together, they illustrate that the impact of IPR is shaped by geopolitical incentives, market structures, regulatory choices, and technological maturity levels.

7.1 Tesla's Open Patent Strategy: Rethinking Innovation Incentives

[119]Tesla's 2014 announcement that it would not initiate patent lawsuits against good-faith users of its electric vehicle (EV) technology marked a notable departure from conventional patent protection strategies in high-tech industries. [120]Elon Musk described traditional patent

[116] The Patents Act, No. 39 of 1970, §§ 83–92, amended by the Patents (Amendment) Act, No. 15 of 2005 (India).
[117] World Intellectual Property Organization, *Green Technology Book* 95–118 (2023).
[118] International Energy Agency, *Energy Technology Perspectives 2023* 32–61 (2023).
[119] Tesla, *All Our Patent Are Belong to You* (June 12, 2014), https://www.tesla.com/blog/all-our-patent-are-belong-you
[120] Elon Musk, *All Our Patent Are Belong to You*, Tesla Blog (June 12, 2014).

enforcement as "fences that stifle innovation," arguing that climate change demanded a more collaborative approach**.**

Impact on the EV ecosystem

- [121]Market Acceleration: Competitors, startups, and suppliers gained access to Tesla's battery management systems, electric drivetrain designs, and charging technologies, lowering entry barriers.
- Network Effects: Widespread use of Tesla-compatible charging infrastructure contributed to the proliferation of EV charging stations.
- Reputational Capital: Tesla's open-patent gesture enhanced its brand image as a mission-driven company, indirectly increasing consumer demand.

Critical limitations

- Tesla's patents are not entirely unrestricted; "good faith" conditions introduce legal ambiguity.
- By opening older patents while developing newer, more advanced proprietary technologies, Tesla balances openness with competitive advantage.

This case demonstrates that strategic openness—not total abandonment of IP—can both accelerate industry growth and provide indirect commercial benefits.

7.2 China's Solar Photovoltaic (PV) Revolution: The Power of Flexible Enforcement

[122]China's dominance in the global solar market did not emerge solely from indigenous innovation. [123]Historically, China adopted a flexible approach to intellectual property enforcement, facilitating learning-by-doing, imitation, and reverse engineering.

Key factors in China's rise

- **[124]Government Subsidies**: Massive public investment in R&D and manufacturing capacity.

[121] Jorge L. Contreras, *Patent Pledges*, 47 Ariz. St. L.J. 543, 560–74 (2015).
[122] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 173–201 (2022).
[123] Dieter Ernst & Barry Naughton, *China's Emerging Industrial Economy: Insights from the IT Industry*, in *China's Growing Role in World Trade* 39–76 (Robert C. Feenstra & Shang-Jin Wei eds., Univ. of Chicago Press 2010).
[124] International Energy Agency, *Energy Technology Perspectives 2023* 84–112 (2023).

- [125]**Selective IP Enforcement**: Early periods of lax enforcement allowed domestic firms to understand and replicate foreign technologies.
- [126]**Economies of Scale**: Lower production costs led to significant global price reductions, making solar energy more accessible worldwide.

Global consequences

- Solar PV prices dropped by over 85% between 2010 and 2020.
- Developing countries could adopt solar power systems at far lower costs.

Although controversial, China's experience illustrates that strict IPR regimes are not always conducive to rapid diffusion, especially in emerging industries crucial for climate action.

7.3 Carbon Capture and Storage (CCS): When Patents Become Bottlenecks

[127]Carbon capture and storage technologies are critical for decarbonizing hard-to-abate sectors such as steel, cement, and heavy industry. [128]However, CCS technologies remain dominated by a small number of multinational corporations that hold significant patent portfolios.

Barriers

- [129]High Licensing Fees: CCS patents often involve complex bundles of rights covering chemical processes, capture materials, and storage methods.
- Technological Complexity: The lack of standardization makes interoperability difficult, increasing dependence on proprietary solutions.
- [130]Limited Deployment: Developing countries face major obstacles in adopting CCS due to cost and licensing restrictions.

Lessons learned

[125] International Renewable Energy Agency, *Renewable Power Generation Costs in 2023* 18–31 (2024).
[126] Organisation for Economic Co-operation and Development, *OECD Science, Technology and Innovation Outlook 2023* 93–118 (2023).
[127] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 53–61 (2023).
[128] International Energy Agency, *CCUS in Clean Energy Transitions* 19–42 (2020).
[129] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 173–201 (2022).
[130] World Intellectual Property Organization, *Green Technology Book* 95–118 (2023).

[131]The CCS case underscores that technological exclusivity can slow deployment in areas where global mitigation targets depend on rapid scaling.

7.4 COVID-19 Vaccine Waivers as a Climate Analogy

The COVID-19 pandemic revealed sharp inequities in global access to life-saving technologies. Calls for TRIPS waivers highlighted the limitations of the global IP regime during emergencies.

Relevance to climate technologies

- Climate change is a slow onset but existential global emergency.
- The same arguments used for public health apply equally—if not more urgently—to climate technologies.
- Vaccine inequity foreshadows similar risks in green technology diffusion.

This analogy strengthens the argument for global IPR reform tailored to planetary crises.

8. Do Patents Hinder or Accelerate Climate Innovation? A Synthesis

[132]The debate over whether patents hinder or accelerate climate innovation is not resolved through simple binaries. Instead, it requires a nuanced, context-sensitive understanding of how IPR functions at multiple stages of technological development—research, demonstration, commercialization, scaling, and global diffusion. [133]The effect of patents varies substantially across these stages, and the climate crisis introduces temporal, moral, and distributive considerations that traditional IP theories were not designed to accommodate.

[134]This synthesis section integrates doctrinal analysis, economic theory, and empirical case studies to articulate a more holistic framework for evaluating the relationship between patents and climate action.

8.1 The Innovation Incentive Function: Why Patents Matter

[131] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 24–41 (2023).
[132] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 7–8, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[133] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 173–201 (2022).
[134] Robert P. Merges, *Justifying Intellectual Property* 25–68 (Harvard Univ. Press 2011).

[135]Patents play a crucial role in stimulating early-stage innovation, particularly in technologies requiring large upfront investments and long gestation periods. Climate technologies such as hydrogen electrolysers, advanced battery chemistries, offshore wind turbines, and carbon capture systems emerge from decades of high-cost R&D undertaken by private firms, universities, and public–private partnerships.

Economic Rationale

Under classical economic theory, patents:

- Reduce uncertainty for investors
- Provide temporary monopoly rents to recoup R&D expenses
- Enable firms to secure financing and enter high-risk markets
- Encourage disclosure that stimulates follow-on innovation

In sectors such as renewable energy and energy efficiency, patent rights have unquestionably spurred technological breakthroughs.

Innovation Clusters and Technological Momentum

[136]Patent-driven ecosystems often form "innovation clusters"—such as Silicon Valley for cleantech startups or Shenzhen for solar panel manufacturing. These clusters generate virtuous cycles of:

- [137]Skills development
- Standardization
- Private investment inflows
- Technological cross-pollination

[135] Agreement on Trade-Related Aspects of Intellectual Property Rights art. 7, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[136] Organisation for Economic Co-operation and Development, *OECD Science, Technology and Innovation Outlook 2023* 61–92 (2023).
[137] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 173–201 (2022).

Thus, patents can be catalytic during the *innovation* phase.

8.2 The Diffusion Dilemma: When Patents Become Barriers

[138]The central problem is that the climate crisis is fundamentally a diffusion problem, not merely an innovation problem. Technologies already exist that could drastically reduce emissions, but their global deployment is slow, uneven, and exclusionary.

Diffusion Barriers Created by Patents

Patents often:

- Restrict domestic manufacturing in developing countries
- Raise prices through licensing fees
- Require negotiations with multiple rights-holders (patent thickets)
- Limit interoperability due to proprietary standards
- Allow patent-holders to influence the pace and geography of deployment

These barriers disproportionately affect countries that need green technologies the most but have the least financial capacity to access them.

Temporal Misalignment

[139]The climate timeline demands rapid global adoption, but patent terms extend 20 years, creating structural lags between invention and equitable access. [140]For climate technologies, a delay of even five years can mean the difference between meeting and missing mitigation targets.

Structural Inequality

Patents exacerbate technological inequality:

[138] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 24–41, 95–108 (2023).
[139] Agreement on Trade-Related Aspects of Intellectual Property Rights art. 33, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[140] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 24–41 (2023).

- 70% of climate technology patents are owned by entities in the Global North.
- Less than 2% originate from Africa, despite the continent's vulnerability.
- Many developing nations import patented technologies at premium prices, limiting scale.

Thus, patents can disproportionately burden regions with the least historical responsibility for emissions.

8.3 The Stage-Specific Impact of Patents: A Dynamic View

To reconcile competing perspectives, it is essential to understand how patent impacts shift across the technological lifecycle.

1. Invention Stage

(Accelerating Role)

- Strong patent protection encourages private actors to innovate.
- R&D-intensive technologies thrive under predictable IP regimes.

2. Commercialization Stage

(Ambivalent Role)

- Patents assist firms in securing investment and partnerships.
- But they can also restrict collaboration due to exclusivity.

3. Deployment Stage

(Restrictive Role)

- Patents often impede wide-scale adoption, particularly in developing countries.
- [141]Licensing terms become crucial determinants of access.

4. Global Diffusion Stage

[141] Robert P. Merges, *Justifying Intellectual Property* 69–103 (Harvard Univ. Press 2011).

(Highly Restrictive Role)

- [142]Patent monopolies restrict cross-border technology transfer.
- TRIPS rules limit national flexibilities to override patent barriers.
- [143]Countries without manufacturing capacity depend on costly imports.

Thus, patents help at the invention stage but hinder at the diffusion stage—and climate change requires accelerated diffusion above all.

8.4 Patents and the Climate Justice Framework

[144]Climate innovation cannot be evaluated solely through economic or legal lenses—ethical dimensions are equally critical.

Climate justice demands:

- Equitable access to mitigation tools
- Prioritizing vulnerable nations
- Shared technological responsibility
- Intergenerational equity

[145]Patents, by restricting access to essential technologies, often conflict with these norms. When IP protection overrides the needs of populations facing existential climate threats, it becomes ethically indefensible. [146]The human rights implications of climate technology access are increasingly recognized in international law scholarship**.**

8.5 The Paradox of Competition: When Patents Hinder Market Transformation

[147]In some cases, patents prevent the emergence of competitive, mass-market technologies.

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[142] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 27–31, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[143] Keith E. Maskus, *Encouraging International Technology Transfer* 79–103 (UNCTAD-ICTSD Issue Paper No. 7, 2004).
[144] Edith Brown Weiss, *In Fairness to Future Generations: International Law, Common Patrimony, and Intergenerational Equity* 15–39 (United Nations Univ. 1989).
[145] Office of the United Nations High Commissioner for Human Rights, *Understanding Human Rights and Climate Change* 1–16 (2015).
[146] Human Rights Council, The Human Right to a Clean, Healthy and Sustainable Environment, Res. 48/13, U.N. Doc. A/HRC/RES/48/13 (Oct. 8, 2021).
[147] World Intellectual Property Organization, *World Intellectual Property Report 2022: The Direction of Innovation* 173–201 (2022).

Examples:

- [148]Proprietary battery chemistries prevent widespread EV affordability.
- Exclusive wind turbine patents limit domestic manufacturing in India and Africa.
- [149]Monopolistic CCS patents delay industrial decarbonization.

Competition is essential for reducing costs, increasing innovation, and expanding access. But patents suppress competition precisely when green technologies need to become ubiquitous.

8.6 Alternative Innovation Models: Evidence Against Patent Necessity

Case studies challenge the assumption that innovation collapses without patents.

Tesla's open patents

→ Innovation increased, market expanded, EV adoption accelerated.

China's solar industry

→ Flexible IP practices created the world's most efficient renewable energy market.

Open-source hardware communities

→ Decentralised engineering solutions (e.g., wind turbines, microgrids) are emerging globally.

Publicly funded R&D

→ Much climate technology innovation originates from universities and government research programs where patent incentives are secondary.

These examples illustrate that innovation ecosystems can thrive even when exclusivity is reduced—even eliminated.

8.7 Synthesis: A Balanced Conclusion

[150]The relationship between patents and climate innovation is dualistic, non-linear, and contingent.

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[148] International Energy Agency, *Global EV Outlook 2024* 67–89 (2024).
[149] International Energy Agency, *CCUS in Clean Energy Transitions* 79–108 (2020).
[150] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 7–8, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.

[151]Patents Accelerate Climate Innovation When:

- [152]Technologies require high capital investment.
- Private actors dominate R&D.
- [153]Early-stage innovation needs financial protection.
- Disclosure fuels secondary innovation.

Patents Hinder Climate Innovation When:

- Technologies must diffuse rapidly across the globe.
- Licensing costs restrict access.
- Proprietary standards limit interoperability.
- Multiple patents create thickets and negotiation burdens.
- Developing countries cannot afford to participate.

The Core Synthesis:

[154]Patents are an effective tool for innovation, but they are poorly suited to the urgent global need for diffusion. [155]Because climate technologies must be rapidly deployed across all countries—not only where they are invented—the current patent model is structurally misaligned with the goals of climate governance.

[156]This misalignment is not inevitable; it reflects the limitations of a 20th-century IPR system trying to solve a 21st-century planetary crisis. [157]Reimagining patent governance through climate-specific TRIPS reforms, patent pools, compulsory licensing, and open-source models can reconcile innovation incentives with global survival needs.

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[151] Robert P. Merges, *Justifying Intellectual Property* 205–44 (Harvard Univ. Press 2011).
[152] Organisation for Economic Co-operation and Development, *OECD Science, Technology and Innovation Outlook 2023* 61–92 (2023)
[153] Agreement on Trade-Related Aspects of Intellectual Property Rights art. 29, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[154] Intergovernmental Panel on Climate Change, *Climate Change 2023: Synthesis Report* 24–41, 95–108 (2023).
[155] World Intellectual Property Organization, *Green Technology Book* 11–38 (2023).
[156] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 7, 8, 31, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[157] World Health Organization, World Intellectual Property Organization & World Trade Organization, *Promoting Access to Medical Technologies and Innovation: Intersections Between Public Health, Intellectual Property and Trade* 283–312 (3d ed. 2020) (discussing compulsory licensing and other TRIPS flexibilities that are also relevant to technology-access frameworks).

9. Rethinking the IPR Model for Climate Technologies

9.1 Compulsory Licensing for Climate Technologies

Compulsory licensing (CL) can balance private and public interests. India's CL framework (e.g., *Natco v. Bayer*) proved its effectiveness in pharmaceuticals. Climate mitigation arguably meets TRIPS' "national emergency" threshold.

A climate-specific CL policy could:

- Enable domestic manufacturing of green technologies
- Lower prices
- Encourage voluntary licensing by corporations

9.2 Patent Pools for Shared Innovation

Patent pools aggregate multiple patents under a unified licensing framework.
Benefits include:

- Reduced transaction costs
- Easier access for developing nations
- Faster diffusion

UNFCCC and WIPO have explored climate patent pools, but participation is voluntary.

9.3 A TRIPS Climate Waiver

[158]Like the COVID-19 vaccine waiver proposal, a **Climate Technology Waiver** could:

- [159]Temporarily relax IP rules for essential green technologies
- Allow cross-border manufacturing
- Stimulate global innovation and competition

[158] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 7, 8, 31, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[159] World Trade Organization, *Ministerial Decision on the TRIPS Agreement*, WT/MIN(22)/30, WT/L/1141 (June 17, 2022).

9.4 Open-Source Green Technologies

[160]An emerging movement promotes open hardware, open algorithms, and open-source engineering for climate solutions.

[161]Examples:

- Tesla open patents
- Open-Source Ecology
- International Renewable Energy Agency (IRENA) open database

This model encourages collaboration and affordability.

9.5 Public Funding for Climate R&D

If public funds finance research, results should remain accessible:

- Government-funded patents can adopt open licensing
- Universities can adopt socially responsible licensing frameworks

10. Policy Recommendations.

To harmonize climate goals with innovation incentives, a multi-level, multi-actor reform strategy is essential. The following recommendations are designed to address systemic shortcomings in the current IPR architecture.

10.1 International-Level Reforms

1. [162]A "Doha Declaration on Climate Technologies"

Inspired by the Doha Declaration on Public Health, a climate-specific declaration should:

- Affirm that climate technologies are essential for global survival.

[160] World Intellectual Property Organization, *Green Technology Book* 95–118 (2023).
[161] Carlos M. Correa, *Trade Related Aspects of Intellectual Property Rights: A Commentary on the TRIPS Agreement* 349–412 (Oxford Univ. Press 2020).
[162] World Trade Organization, *Declaration on the TRIPS Agreement and Public Health*, WT/MIN(01)/DEC/2 (Nov. 14, 2001).

- [163]Explicitly recognize the right of states to use TRIPS flexibilities without fear of trade retaliation.
- [164]Authorize compulsory licensing for mitigation and adaptation technologies.

2. Establish a Global Climate Technology Patent Pool

Under the joint leadership of WIPO, UNFCCC, and UNEP, a global patent pool could:

- [165]Aggregate key patents for renewable energy, energy storage, CCS, and climate-resilient agriculture.
- Offer standardized, low-cost licensing.
- Encourage collaboration among governments, corporations, and research institutions.

3. TRIPS Amendments for Climate Emergency

Climate change should qualify as a "national emergency" or "extreme urgency" under Article 31. This would:

- Simplify compulsory licensing procedures.
- Protect states from trade disputes when accessing essential technologies.

4. Incentivizing Open-Source Climate Innovation

The WTO and UNFCCC could encourage open-source models by:

- Funding open-innovation platforms.
- Offering tax incentives or recognition programs for companies that voluntarily share patents.

10.2 National-Level Reforms

1. [166]Strengthening Compulsory Licensing Frameworks

[163] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 7, 8, 31, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.
[164] Carlos M. Correa, *Trade Related Aspects of Intellectual Property Rights: A Commentary on the TRIPS Agreement* 349–412 (Oxford Univ. Press 2020).
[165] World Intellectual Property Organization, *WIPO GREEN Strategic Plan 2024–2028* 8–24 (2024).
[166] Agreement on Trade-Related Aspects of Intellectual Property Rights arts. 7, 8, 31, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.

States should:

- [167]Expand CL provisions to include all climate technologies.
- [168]Reduce procedural burdens for issuing CLs.
- Establish transparent pricing guidelines.

2. Public Funding with Public Returns

When governments finance R&D:

- Resulting patents should be made available under open or socially responsible licensing.
- Universities should integrate public interest into licensing contracts.

3. Domestic Manufacturing and Technology Transfer

Countries should:

- Invest in local manufacturing capacity for solar panels, EV batteries, and wind components.
- Mandate technology transfer in foreign investment agreements.

4. National Climate Patent Offices

Specialized patent divisions could:

- Accelerate examination of green patents.
- Monitor anti-competitive licensing practices.
- Promote patent landscaping for domestic industries**.**

10.3 Corporate and Industry-Level Reforms

1. Voluntary Licensing and Tiered Pricing

[169]Companies can:

[167] World Trade Organization, *Declaration on the TRIPS Agreement and Public Health*, WT/MIN(01)/DEC/2 (Nov. 14, 2001).
[168] World Trade Organization, *Declaration on the TRIPS Agreement and Public Health*, WT/MIN(01)/DEC/2 (Nov. 14, 2001).
[169] World Intellectual Property Organization, *WIPO GREEN Strategic Plan 2024–2028* 8–24 (2024).

- Offer differentiated pricing for developing countries.
- License older technologies freely while protecting cutting-edge innovations.

2. Collaboration Through Standard-Essential Patents (SEPs)

[170]As green technologies mature, standardization becomes crucial:

- SEPs enable interoperability in EV charging, smart grids, and renewable energy systems, FRAND (fair, reasonable, and non-discriminatory) licensing terms prevent abuse.

3. Corporate Social Responsibility (CSR) for Climate Innovation

[171]Corporations should incorporate environmental technology sharing as part of:

- Sustainability reporting, ESG obligations, Net-zero transition commitments

4. Open Hardware and Collaborative Engineering

Industry-led open hardware initiatives can democratize manufacturing and repair systems in developing countries.

[170] Jorge L. Contreras, *The Cambridge Handbook of Technical Standardization Law: Competition, Antitrust, and Patents* 225–48 (Cambridge Univ. Press 2017).
[171] Global Reporting Initiative, *GRI 305: Emissions 2016* (consolidated 2021) (reporting standards relating to greenhouse gas emissions and climate disclosures)

11. Conclusion

The intersection of intellectual property rights and green technologies exposes a profound structural dilemma within global governance: how can the world maintain strong incentives for innovation while ensuring universal access to technologies essential for planetary survival? As this article demonstrates, patents play a dual role—they stimulate high-cost R&D but simultaneously restrict the diffusion of knowledge and limit the global capacity to combat climate change.

The climate crisis differs from previous technological epochs in both scale and urgency. Traditional IP frameworks were not designed for technologies that must diffuse rapidly across borders, markets, and socio-economic strata. Delays caused by patent restrictions are not mere inefficiencies; they are existential threats. When essential technologies remain inaccessible due to monopolistic controls, licensing barriers, or prohibitive costs, the world risks locking itself into a trajectory of irreversible ecological harm.

The case studies analyzed—Tesla's open patents, China's solar expansion, patent dominance in CCS, and parallels with COVID-19 vaccine inequity—reveal that the relationship between patents and climate technologies is not inherently adversarial but highly context-dependent. Strategic openness, flexible enforcement, and collaborative innovation models can accelerate deployment far more effectively than rigid proprietary systems.

The policy recommendations offered in this paper underscore the need for transformative global legal reforms. A climate-specific TRIPS flexibility regime, global patent pools, public-interest licensing mandates, open-source innovation platforms, and targeted national reforms together create a more equitable ecosystem for climate technology governance. These reforms are not merely legal or economic measures—they are ethical obligations grounded in climate justice, intergenerational equity, and shared global responsibility.

Ultimately, the world must shift from an innovation system centered solely on proprietary gain to one guided by humanitarian necessity and planetary stewardship. Intellectual property must evolve to meet the demands of the Anthropocene.