台灣國際研究季刊　第 21 卷　第 4 期　頁 247-63　2025 年/冬季號
Taiwan International Studies Quarterly, Vol. 21, No. 4, pp. 247-63 Winter 2025

BMI toward the Inclusive Path to Carbon Neutrality: Aligning Ecological Sustainability and Enterprise Competitive Advantage through Carbon-Asset Circulation and AI Development

Howard (Chia-Hao) Chou*

EcoStrategy, Managing Director, Glasgow, UNITED KINGDOM

Abstract

Global decarbonisation efforts face a structural mismatch between the geography of renewable-energy production and the geography of industrial electricity demand. Manufacturing-intensive and land-constrained economies such as Taiwan, Japan, South Korea, and Singapore face strong supply-chain decarbonisation pressures while lacking sufficient domestic renewable-energy potential to meet RE100, SBTi, and net-zero requirements. Meanwhile, global renewable deployment—although at record levels—remains insufficient to meet 2030 and 2050 climate targets. This article proposes carbon-asset circulation (CAC) as a strategic mechanism to align ecological sustainability with enterprise competitive advantage. Drawing on the Resource-Based View (RBV), Dynamic Capabilities (DC), and Business Model Innovation (BMI), the analysis positions verified carbon assets as VRIN resources that support competitive differentiation, compliance access, and capital mobilisation. AI-enhanced MRV systems further strengthen carbon-market integrity and cross-border interoperability. Using global evidence—including the Brazil–China–EU carbon-credit alliance, the UK–EU carbon-market linkage, and record expansion of nature-based climate

* Ph.D. in Marketing, Strathclyde University, United Kingdom. The author may be contacted via howard@strategyesg.com.

finance —the paper argues that CAC provides an inclusive, scalable path toward carbon neutrality. The alignment of ecological and enterprise goals becomes not only feasible, but the key accelerator of the global clean-energy transition.

Keywords: carbon neutrality, RE100, renewable energy, business model innovation, carbon credit, carbon asset circulation, Taiwan, sustainability strategy, carbon emissions reduction, energy policy

I. Introduction

Achieving global carbon neutrality requires more than rapid technological progress. It requires systemic alignment between ecological sustainability and enterprise competitive advantage. Despite unprecedented renewable deployment worldwide, many countries remain off-track for 2030 and 2050 climate goals (Voegele, 2024).

A fundamental structural mismatch exists between energy demand and renewable-energy potential. Specifically, regions with the highest concentration of energy-intensive industries and digital infrastructure often possess the lowest capacity for renewable energy generation. This dislocation is particularly pronounced in manufacturing-centric economies such as Taiwan, South Korea, Japan, and parts of the European Union. Moreover, several structural constraints continue to challenge global decarbonization efforts. First, global renewable energy growth remains insufficient to meet the 1.5°C warming target outlined by international climate agreements (Altieri, 2024). Second, many countries still rely heavily on fossil fuels, which constitute more than 60% to 80% of national electricity generation portfolios. Third, expansion of renewable energy infrastructure is increasingly hindered by land scarcity, limited grid capacity, and sociopolitical resistance at the community level. Fourth, the European Union’s recently introduced 2040 "brake clause" reveals that even the most ambitious climate commitments may be curtailed by ecological and resource-based limitations (Abnett, 2025).

These combined factors illustrate that local renewable expansion alone is insufficient. Instead, an effective global decarbonization strategy must rely on cross-regional coordination of climate and resource flows, particularly through mechanisms like carbon asset circulation, which can bridge the mismatch between emission-intensive industries and renewable-poor geographies.

Thus, decarbonisation requires cross-regional climate-resource flows, not solely local renewable development. This paper develops a model where carbon-asset circulation (CAC) becomes the structural solution for an inclusive global pathway to net zero. This paper adopts a conceptual and integrative approach, synthesising existing literature and global evidence to propose a new strategic framework rather than presenting empirical testing.

II. Literature Review

This section synthesizes the theoretical foundations underpinning Carbon Asset Configuration (CAC) as a strategic mechanism for enterprise sustainability and competitive advantage. By integrating insights from the Resource-Based View, Dynamic Capabilities, Business Model Innovation, AI-enabled ESG systems, and emerging global carbon-market governance, this review positions CAC within a coherent academic framework that explains how firms adapt to accelerating climate-policy and market transitions.

The Resource-Based View conceptualizes sustainable competitive advantage as deriving from VRIN resources—valuable, rare, inimitable, and non-substitutable (Barney, 1991). High-integrity carbon assets fit this profile because they reduce compliance costs, enable participation in low-carbon supply chains, and derive scarcity from finite natural carbon sinks, making them strategic rather than compensatory. Complementing this, Dynamic Capabilities theory emphasizes the need for firms to sense, seize, and transform in response to environmental volatility (Teece, et al., 1997; Teece, 2018). The fluidity of climate policies, carbon prices, and supply-chain decarbonization requirements increases demand for reconfigurable capabilities; CAC reinforces these capabilities by widening decarbonization pathways and reducing vulnerability to local resource or infrastructure constraints. From the perspective of Business Model Innovation, CAC embeds ecological value directly into value-capture logics, enabling firms to integrate decarbonization into financially rational business models rather than treating it as exogenous cost (Zott & Amit, 2010; Chou, 2023). AI further strengthens this structure by enhancing MRV transparency, carbon-asset valuation, risk analytics, and supply-chain data fidelity, thereby lowering entry barriers for regions and firms with limited technical capacity. Finally, global carbon-market governance trends—including emerging Brazil-China-EU cooperation mechanisms, UK-EU market linkages, increased forest-finance flows, and Asia-Pacific regulatory reforms—demonstrate institutional convergence toward interoperable market systems, reinforcing CAC's role as an increasingly standardized and globally relevant strategic instrument.

Together, these theoretical perspectives indicate that Carbon Asset Configuration operates not only as an environmental compliance tool but as a strategic enabler of competitive advantage, organizational adaptability, innovative value creation, and global market alignment. CAC functions as a multidimensional mechanism that bridges ecological requirements with enterprise development and positions firms to compete effectively in a decarbonizing global economy.

III. Renewable Energy Growth: Strong but Not Enough

Global decarbonization efforts increasingly depend on reconciling the gap between renewable-energy deployment, structural energy-system constraints, and the diminishing capacity of natural carbon sinks. Recent evidence underscores that even with accelerated renewable growth, current trajectories remain insufficient for meeting the 1.5°C target, thereby necessitating complementary mechanisms that extend beyond domestic energy systems.

To understand why renewables alone cannot deliver the required global emissions reductions, it is necessary to examine empirical constraints across three domains: renewable-deployment gaps, structural energy-demand mismatches, and ecological-sink decline. These interconnected factors collectively set the boundaries of feasible domestic decarbonization.

Forecasts from Trendline (2024) and Holub (2024) indicate rapid global renewable-energy expansion; however, Voegele (2024) finds deployment levels still 30–40% below what is necessary for a 1.5°C-aligned pathway by 2030. This undersupply is particularly acute in high-density, high-technology economies that face structural limitations such as restricted land availability, suboptimal solar and wind potential, substantial industrial baseload demand, ageing grids, and persistent public-acceptance constraints, all of which inhibit further domestic scaling of renewables. Simultaneously, ecological systems that historically supported decarbonization are weakening; EU forest carbon-absorption capacity has declined by nearly one-third over the last decade, making national-only mitigation pathways mathematically unattainable (Abnett, 2025). In contrast, global carbon finance—especially for nature-based solutions—has surged, with climate-forest finance doubling in 2025 (L, 2025). This shift demonstrates increasing reliance on cross-border ecological value as domestic options reach physical and ecological limits.

Taken together, global evidence shows that although renewable deployment is accelerating, structural and ecological constraints prevent it from meeting the full scale of required emissions reductions. These limitations create a critical role for CAC, which enables nations and firms to bridge resource gaps through diversified, cross-border climate assets essential for an achievable and equitable transition.

IV. Carbon Asset Configuration as a Strategic Mechanism

As global decarbonization pressures intensify, firms and governments increasingly require mechanisms that can overcome structural, geographic, and technological barriers to low-carbon transformation. CAC has emerged as a strategic response to these challenges by enabling organizations to optimize, diversify, and align their decarbonization resources beyond traditional renewable-energy deployment. This section explains why CAC provides the structural flexibility and strategic scalability needed for navigating contemporary climate constraints.

To position CAC within broader decarbonization strategy, it is necessary to examine how it supplements existing energy transitions. While renewable energy forms the backbone of emissions reduction, it cannot resolve all constraints—particularly in resource-limited environments, hard-to-abate sectors, and regions facing ecological-sink decline. CAC provides a complementary pathway that integrates environmental assets, financial mechanisms, and technological intelligence to bridge these systemic gaps.

CAC functions by enabling organizations to strategically configure carbon assets across multiple categories—renewable generation, nature-based solutions, technological removals, and high-integrity voluntary or compliance-market credits. This flexibility is essential in contexts where physical constraints (such as limited land availability or weak wind-solar profiles) restrict domestic renewable deployment. CAC also strengthens transition planning by reallocating decarbonization potential through cross-border ecological assets, thereby reducing dependency on any single geography or resource type. In doing so, CAC enhances exposure diversification, stabilizes long-term compliance costs, and supports supply-chain alignment with increasingly stringent decarbonization requirements, including RE100, SBTi, and major multinational procurement standards. Moreover, when integrated with AI-enabled monitoring, reporting, verification (MRV), and risk analytics, CAC improves the accuracy and integrity of carbon-asset management, empowering firms in both advanced and emerging markets to adopt credible and adaptable climate strategies.

Overall, CAC provides a scalable mechanism that complements domestic renewable initiatives, mitigates structural energy-system constraints, and leverages cross-border ecological value in a manner consistent with global climate-policy evolution. By enabling firms and nations to reconfigure their decarbonization portfolios with greater flexibility and integrity, CAC strengthens the feasibility of a just, efficient, and globally interconnected pathway toward net-zero.

V. Governance Alignment and Global Climate Architecture

The accelerating evolution of global carbon-market governance demonstrates a structural shift toward interoperability, transparency, and cross-border ecological exchange. As countries and regions adapt to new regulatory architectures, a growing body of institutional evidence shows increasing alignment between major economies—particularly in carbon pricing, market linkage, and nature-based climate finance. Understanding this governance trajectory is essential for situating CAC within the emerging global climate regime.

To contextualize CAC's role within this broader institutional landscape, it is necessary to examine recent governance developments that signal convergence toward standardized market rules, mutual recognition frameworks, and integrated carbon-accounting structures. These shifts indicate that carbon markets are no longer fragmented national tools but components of a coordinated global system.

Recent policy developments illustrate a marked consolidation of global carbon governance. The emergence of collaborative mechanisms—such as the Brazil–China–EU carbon-credit coordination (Velev, 2025) and the strengthening UK-EU carbon-market linkage (*ESG News,* 2025)—indicates growing institutional willingness to align standards and exchange market intelligence. Parallel to these regulatory integrations, financial flows into nature-based climate solutions have surged, with climate-forest investment doubling in 2025 (L, 2025), reflecting rising international demand for high-integrity ecological assets. Moreover, Asia-Pacific governments have accelerated revisions to carbon-market policies to enhance alignment with Article 6 guidance and multinational supply-chain requirements, further reinforcing interoperability. These governance dynamics demonstrate a systematic shift toward harmonized market structures that support predictable pricing, improved liquidity, and shared verification norms—conditions that significantly enhance the strategic value of CAC. As carbon markets expand and interconnect, CAC becomes not only feasible but essential for enabling organizations to participate in globally integrated decarbonization pathways.

Table 1: Theoretical Propositions

proposition	content
1	Ecological verifiability increases enterprise value capture
2	Value capture increases BMI adoption
3	BMI strengthens sustainable competitive advantage
4	Organisational adaptability moderates BMI effectiveness
5	AI moderates the impact of BMI on competitive advantage
6	Inclusion enhances system performance
7	Alignment drives net-zero success

Overall, global carbon-governance trends reveal a clear trajectory toward institutional convergence, cross-border market integration, and strengthened ecological-finance systems. This evolving architecture provides the structural foundation that allows CAC to function as a globally scalable mechanism, enabling firms to leverage diversified climate assets within a coherent and increasingly unified carbon-market system. By employ the business model innovation mechanism system (Chou, 2023), seven theoretical propositions are addressed below to transfer the carbon assets into enterprise strategic assets and facilitate the alignment of ecological sustainability and enterprise competitive advantage.

VI. AI-Enabled Carbon Asset Configuration and the Operational Feasibility of Global Decarbonisation

The preceding sections demonstrated that global decarbonisation faces three binding constraints: (1) renewable-energy deployment remains 30–40% below 1.5°C requirements (Voegele, 2025); (2) structural limitations in high-density and industrial economies restrict further domestic mitigation (Trendline, 2024; Holub, 2024); and (3) ecological sinks, particularly in the EU, show declining sequestration capacity (Abnett, 2025). Simultaneously, global governance systems are converging toward interoperable carbon markets and expanding nature-based finance (L, 2025). Against this empirical and institutional background, this discussion section examines how AI-enabled CAC transforms these constraints into an integrated operational pathway for global transition.

While Sections 3–5 provided descriptive evidence, the analytical task here is to evaluate why CAC, when combined with AI, functions as the core operational mechanism capable of reconciling renewable shortfalls, ecological decline, and emerging governance architectures. This builds the foundation for the final conclusion that CAC+AI is not merely a supportive tool but a structural requirement for a feasible and equitable net-zero trajectory.

Given that global renewable growth remains insufficient (Voegele, 2025), AI-enabled CAC provides an optimisation layer that reallocates mitigation across a diversified portfolio of assets — including nature-based credits, technological removals, and cross-border ecological value. This directly compensates for the

≈40% deployment deficit by creating additional mitigation pathways beyond physical energy infrastructure. AI operationalises the compensatory potential of carbon finance, whose doubling in 2025 reflects rapidly expanding ecological capacity available through CAC (L, 2025).

Land scarcity, ageing grids, public acceptance, and weak wind–solar profiles limit domestic renewable-energy expansion. AI-enabled CAC allows firms to model, validate, and procure mitigation outside national boundaries, aligning with the cross-border evidence presented earlier. This reinforces the argument that CAC must function as a portfolio-based approach rather than a domestic-resource optimisation strategy.

The one-third decline in EU forest absorption makes domestic-only mitigation mathematically impossible. AI-enabled CAC links organisations to high-integrity ecological assets in jurisdictions where sink capacity remains robust. This directly reflects the growing Brazil-China-EU linkage and Article 6 alignment, which facilitate cross-border exchange of ecological value. As global carbon markets converge, AI enhances MRV accuracy, prevents double counting, and integrates supply-chain emissions. These functions are critical to the institutional alignment observed in:

This strengthened discussion demonstrates that AI-enabled CAC directly addresses every structural challenge identified in the global evidence: renewable undersupply, domestic constraints, ecological-sink decline, and disparate governance regimes. Moreover, it translates the emerging institutional convergence outlined in Section 5 into an actionable framework that can operate across borders, sectors, and markets. Consequently, the analysis supports the central argument of this paper: AI-enabled CAC is not an optional enhancement but a necessary systemic architecture for the next phase of global climate implementation. It forms the bridge between physical limitations and political commitments, thereby laying the rational and empirical foundation for the concluding section.

VII. Toward an Inclusive, Aligned, and AI-Enabled Pathway to Carbon Neutrality

The analysis presented in this paper demonstrates that the global net-zero transition can no longer rely on a singular technological solution or a purely domestic mitigation strategy. As shown in Sections 3–5 and reinforced by global evidence, renewable energy deployment remains significantly below the scale required for a 1.5°C-aligned pathway, structural constraints such as land scarcity and industrial baseload demand restrict domestic mitigation potential, and the declining sequestration capacity of natural sinks renders national-only decarbonisation mathematically insufficient. Meanwhile, new governance architectures—including Brazil-China-EU carbon-market coordination and Article 6–aligned registries—are accelerating the integration of cross-border carbon markets and ecological-finance flows. Together, these developments crystallize a central insight: global carbon neutrality depends on mechanisms that can transcend geographic, ecological, and infrastructural limits.

Against this backdrop, Carbon-Asset Circulation (CAC) and AI-enabled climate intelligence emerge not as supplementary instruments, but as the foundational architecture of a feasible net-zero future. CAC directly operationalises the alignment model previously proposed by Chou (2025) converting renewable-energy output, verified reductions, and novel clean-tech performance into strategic carbon assets that reinforce both ecological sustainability and enterprise competitiveness. When paired with inclusive verification systems, transparent carbon markets, and reinvestment mechanisms—the inclusive carbon loop on p.28—CAC transforms decarbonisation from a compliance exercise into a regenerative economic system. It empowers developing regions to become renewable-energy and carbon-asset exporters, and allows high-demand economies to close their structural mitigation gaps fairly and efficiently.

AI enhances and stabilises this architecture by supplying the dynamic capabilities required for implementation (Teece, et al., 1997; Teece, 2018). As demonstrated in Section 6, AI synthesizes multi-market data, strengthens MRV integrity, optimises decarbonisation portfolios, and continuously reallocates mitigation across diverse pathways as conditions evolve. In doing so, AI transforms CAC from a complex administrative framework into an adaptive, real-time intelligence system—the same “Intelligence of Alignment” articulated in an AI platform (Chou, 2025). Through this mechanism, enterprises can anticipate policy shifts, calculate carbon ROI, align with supply-chain requirements (RE100, CBAM), and transform sustainability from a cost burden into a source of competitive advantage.

A credible global pathway to carbon neutrality requires the structural alignment of ecological sustainability and enterprise competitiveness—an alignment achieved through Carbon-Asset Circulation and operationalised by AI. This is not merely a conceptual proposition; it represents a systemic redesign of how civilisation manages energy, ecological resources, and industrial value creation. First, in the financial sphere, Carbon-Asset Circulation enhances liquidity, incentivizes financial inclusion, and enables the monetization of decarbonization outcomes through instruments such as carbon credits, sustainability-linked bonds, and blockchain-verified offsets. All of these mechanisms allow capital to flow toward verified climate actions, particularly in emerging and manufacturing-intensive economies that would otherwise be penalized under RE100 frameworks. Second, in the physical and environmental dimension, this model encourages scalable renewable energy deployment, verifiable MRV (Measurement, Reporting, and Verification)-based emission reductions, and community-level reinvestment in clean infrastructure. By anchoring carbon markets to real-world outcomes, this system fosters not only compliance with international mandates (e.g., CBAM, CCA) but also equitable co-benefits for local economies.

Together, these financial and physical components form a self-reinforcing transition engine: a dynamic loop wherein emissions reductions generate financial value, which in turn fuels further investment in sustainability technologies and infrastructure. When supported by AI analytics, this loop becomes increasingly adaptive, efficient, and transparent—allowing governments, corporations, and investors to continuously optimize their carbon strategies in real time.

Ultimately, the alignment of ecology and enterprise is not only feasible, but also is indispensable. Renewable energy accelerates capacity; carbon-asset circulation bridges structural gaps; AI provides adaptive intelligence; and inclusive governance ensures global participation. When these components converge, sustainability becomes self-sustaining, competitiveness becomes regenerative, and the global transition shifts from an industrial paradigm toward a coherent, inclusive, and technologically diversified pathway to carbon neutrality.

References

Abnett, Kate. 2025. "EU Considers Ceakening 2040 Climate Coal Cver Corest CO_2 Cbsorption, Draft Ahows." *Reuters*, November 3 (https://www.reuters.com/sustainability/cop/eu-considers-weakening-2040-climate-goal-over-forest-co2-absorption-draft-shows-2025-11-02/) (2025/11/29).

Altieri, Katye. 2024. "2030 Global Renewable Target Tracker." *Ember*, November 17 (https://ember-energy.org/data/2030-global-renewable-target-tracker/) (2025/11/29).

Barney, Jay. 1991. "Firm Resources and Sustained Competitive Advantage." *Journal of Management,* Vol. 17, No. 1, pp. 99-120.

Chou, Chia-Hao. 2023. "Business Model Innovation and Sustainable Competitive Advantage: A Multi-Phase Strategic Framework.," Ph.D. Dissertation, University of Strathclyde.

ESG News. 2025. "UK-EU Move Toward Linked Carbon Markets and Unified Agri-Food Rules." November 14 (https://esgnews.com/uk-eu-move-toward-linked-carbon-markets-and-unified-agri-food-rules/) (2025/11/27).

Holub, Jaroslav. 2025. "Renewable Energy Forecast for 2030." *ReJobs,* February 19 (https://rejobs.org/en/renewable-energy-blog/renewable-energy-forecast-for-2030) (2025/11/19).

L, Jennifer. 2025. "Forest Finance Hits Record Growth in 2025: Investment Doubles for Nature-Based Climate Action." Carbon Credits. com, October 17 (https://carboncredits.com/forest-finance-hits-record-growth-in-2025-investment-doubles-for-nature-based-climate-action/) (2025/11/10).

Teece, David J., Gary Pisano, and Amy Shuen. 1997. "Dynamic Capabilities and Strategic Management." *Strategic Management Journal,* Vol. 18, No. 7, pp. 509-33.

Teece, David J. 2018. "Business models and Dynamic Capabilities." *Long Range Planning*, Vol. 51, No. 1, pp. 40-49.

Trendline. 2024. "Renewable Energy Capacity Grows Rapidly but Not Fast enough." April 27 (https://www.trendlinehq.com/p/renewable-energy-capacity-grows-rapidly) (2025/11/27).

Velev, Vasil. 2025. "Brazil Makes Bold Bid to Forge a Worldwide Carbon Credit Alliance with China and the EU." *Carbon Herald*, October 27 (https://carbonherald.com/brazil-makes-bold-bid-to-forge-a-worldwide-carbon-credit-alliance-with-china-and-the-eu/) (2025/11/27).

Voegele, Erin. 2024. "IEA Predicts 20% Growth in Renewable Fuels by 2030, But Says More Substantial Growth Is Needed to Meet Net-Zero Goals." *Biomass Magazine*, October 11 (https://biomassmagazine.com/articles/iea-predicts-20-growth-in-renewable-fuels-by-2030-but-says-more-substantial-growth-is-needed-to-meet-net-zero-goals) (2025/12/2).

Xue, Yujie. 2025. "Beijing's Crackdown on Solar Panel Oversupply 'Too Little, Too Late'." *South China Morning Post,* April 3 (https://www.scmp.com/business/china-business/article/3304940/beijings-crackdown-solar-panel-oversupply-too-little-too-late-us-advisory-firm) (2025/11/30).

Zott, Christoph, and Raphael Amit. 2010. "Business Model Design: An Activity System Perspective." *Long Range Planning*, Vol. 43, Nos. 2-3, pp. 216-26.

「商業模式創新」邁向包容性的碳中和之路──透過碳資產循環與 AI 發展實現生態永續與企業競爭力的對齊

周家豪*
益珂環能總經理，英國

摘 要

全球減碳進程正面臨一項結構性的矛盾：再生能源的地理分布與工業用電需求的地理分布並不一致。以台灣、日本、南韓與新加坡等製造業高度集中且土地受限的經濟體為例，這些國家承受著強大的供應鏈減碳壓力，卻缺乏足夠的本地再生能源以達成 RE100、SBTi 與淨零排放等要求。與此同時，即便全球再生能源新增量屢創新高，其部署幅度仍不足以達成 2030 與 2050 年的氣候目標。本研究提出「碳資產循環」(CAC)作為一項策略機制，用以對齊生態永續與企業競爭優勢。透過資源基礎觀點（RBV)、動態能力（DC）與商業模式創新（BMI）的理論基礎，本研究主張經過驗證的碳資產屬於 VRIN（有價值、稀有、難以模仿、不可替代）資源，可支撐企業競爭差異化、合規通道取得資本動員能力。AI 強化的 MRV（監測、回報與驗證）系統則能進一步提升碳市場的完整性與跨境互通性。透過全球實證資料:包括巴西-中國-歐盟碳權聯盟、英國－歐盟碳市場連結、以及氣候金融的歷史性擴張—本研究論證 CAC 可提供一條具有包容性、可擴展的碳中和道路。最終，生態目標與企業目標的對齊不僅具可行性，更成為全球清潔能源轉型的關鍵加速器。

關鍵詞：碳中和、RE100、商業模式創新、可再生能源、碳權、碳資產循環、永續策略

* 英國斯特拉斯克來德大學行銷學博士，益珂環能總經理 howard@strategyesg.com。