Journal of Environmental Economics & Chemical Processes (JEECP)

https://doi.org/10.22034/jeecp.2026.2087395.1003

Journal Homepage: *WWW.JEECPJournal.com*

Journal of Environmental Economics & Chemical Processes (JEECP)

ORIGINAL RESEARCH PAPER

Financing the Green Transition: A Finance-Technology Matching Framework with Multi-Case Plausibility Probe

Mahdi Khazaei * ; Abdolhossein Zameni

Department of Management, University of Niagara Falls Canada, Niagara Falls, Ontario, Canada.

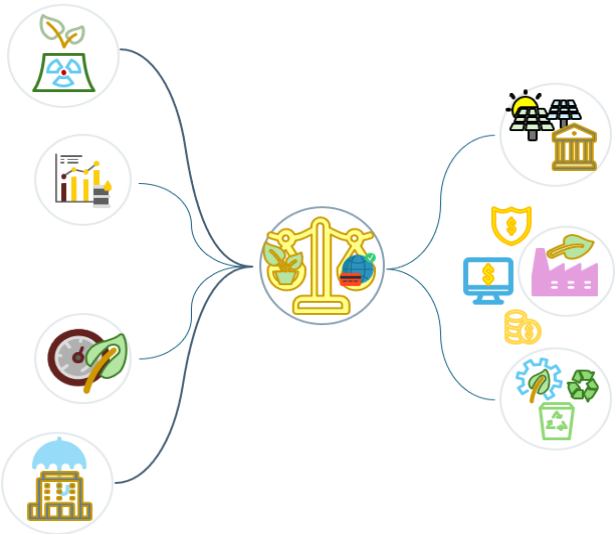
P A P E R I N F O

Paper history:
Received: 05/06/2026
Revised: 06/09/2026
Accepted in revised form: 06/16/2026
Published: 09/30/2026

***Keywords*:**
Sustainable Finance;
Capital Allocation;
Transition Finance;
Blended Finance.

A B S T R A C T

Sustainable finance has reached scale, yet capital allocation across green technologies remains uneven. This paper develops a finance-technology matching framework that explains why some green technologies attract bankable capital while others do not. Grounded in information asymmetry, financial intermediation, capital structure, and real-options theory, the framework identifies six measurable technology attributes: maturity, capital intensity, cash-flow visibility, policy dependence, impact measurability, and institutional context, and proposes an empirical proxy for each. A systematic literature review of 71 sources retained from 1,684 screened records (2020-2026) and an illustrative multi-case plausibility probe covering utility-scale solar PV, first-of-a-kind green hydrogen, and circular-economy textile recycling show that observed financing patterns are internally coherent with the predicted attribute profile of each technology. Mature, contracted, and measurable assets attract labelled debt at declining cost of capital; first-of-a-kind transition technologies experience financing-induced cancellation when policy and offtake conditions fail to compensate for real-option value; circular-economy ventures collapse when revenue contractibility breaks down despite favorable impact narratives. The paper formulates six testable propositions linking attribute profiles to expected financing structures and pricing. As a conceptual and systematic-review contribution, the paper synthesizes and reinterprets existing published evidence and does not present primary or proprietary data. The contribution is to convert the qualitative claim that sustainable finance is uneven into a falsifiable matching theory with observable empirical content.



1. Introduction

Sustainable finance is now large enough to matter for macro-level capital allocation. Global energy investment is on track for approximately USD 3.3 trillion in 2025, with USD 2.2 trillion flowing to clean energy and infrastructure [1]. Aligned green, social, sustainability, and sustainability-linked debt reached USD 1.05 trillion in 2024 [2], and global impact investing assets under management stood at USD 1.571 trillion [3]. Aggregate volume conceals an allocation problem. Capital flows easily to mature renewable power with

* Corresponding Author: Mahdi Khazaei
E-mail address: khazaei7@gmail.com
ISSN: 3116-0050
URL: https://www.jeecpjournal.com/article_735341.html

Please cite this article as: M. Khazei, & A.H. Zamani, *Journal of Enviromental Economics & Chemical Processes (JEECP)*, 2026, *3*(3), 171-181. https://doi.org/10.22034/jeecp.2026.2087395.1003

/© 2026 The Author(s). Published by Power of New Vision Movement Institute.

contracted revenue, and much less easily, sometimes withdrawing abruptly, from first-of-a-kind industrial decarbonization, circular-economy ventures, and emerging-market projects that combine capital intensity, weak revenue contractibility, policy dependence, and limited impact measurability. The first-ever year-on-year decline in announced 2030 low-emissions hydrogen capacity, from 49 to 37 Mtpa and driven mainly by electrolysis cancellations [4], and the February 2024 bankruptcy of Renewcell despite high-profile brand commitments [5] illustrate that environmental value does not by itself produce financeability. The sustainable finance literature has examined instruments, green bonds [6-9], sustainability-linked debt [10,11], green credit [12,13], impact investing [14], and blended finance [15], largely in isolation. Recent work on financing sustainability also emphasizes that economic models, investment mechanisms, public-private partnerships, and impact-measurement systems must be connected rather than treated as separate streams [16]. Asset-pricing work shows that ESG preferences [17], carbon risk [18], and carbon tail risk [19] are priced. Less attention has been paid to the matching problem: which financial structures fit which technologies, and which combinations predict financing success uncontracted versus failure.

This paper develops a finance-technology matching framework grounded in information asymmetry [20,21], financial intermediation [22,23], capital structure [24,25], and real-options theory [26]. It identifies six technology attributes, operationalizes each with proposed proxies, derives six falsifiable propositions, and applies the framework to three contrasting cases: utility-scale solar PV (mature, contracted, measurable); first-of-a-kind green hydrogen (immature, , policy-dependent); and circular-economy textile recycling (distributed, weakly contractible, measurement-fragmented). The paper is explicitly a conceptual and systematic-review contribution: it synthesizes and reinterprets published academic and institutional evidence and does not present primary or proprietary data, and the illustrative cases in Section 8 are confirmatory plausibility probes rather than tests on previously unseen data. The contribution is to convert the qualitative claim that sustainable finance is uneven into a falsifiable matching theory. Where Polzin and Sanders [27] argue that different transition technologies need different financing sources at different stages, this paper specifies which attributes drive the gap, how they can be measured, and what pricing and structural patterns the framework predicts.

The paper proceeds as follows. Section 2 sets out theoretical foundations. Section 3 reports the systematic literature review protocol. Section 4 develops the matching lens with operational proxies. Section 5 applies it to four green innovation domains, including external-validity boundaries and a short emerging-market comparison. Section 6 examines the principal financial mechanisms. Section 7 identifies critical tensions. Section 8 reports the multi-case plausibility probe. Section 9 presents the framework, six testable propositions, and limitations. Section 10 concludes.

The matching framework integrates four traditions in finance and financial economics. Each has been deployed separately in sustainable finance research; integrating them clarifies why some green technologies attract capital while others do not, and why the structure of capital matters as much as its volume.

1.1. Information asymmetry and signalling

Akerlof [20], Spence [28], and Stiglitz and Weiss [21] show that markets in which sellers know more than buyers can collapse into adverse-selection equilibria absent credible signals or institutional structures. Green technology investment faces exactly this friction: investors cannot easily distinguish strong environmental performance from labelled but operationally weak projects. ESG rating divergence [29] and ESG rating uncertainty [30] measure the gap. The EU Green Bond Standard [31], ICMA's Green Bond Principles [32], and IFRS S2 [33] function as signalling devices that compress it.

1.2. Financial intermediation

Diamond [22] and Holmstrom and Tirole [23] establish that intermediaries reduce monitoring costs through delegation, and that monitoring intensity affects outside-investor willingness to fund constrained borrowers. This logic underpins the role of bank credit, supervisory oversight, and verification regimes in green technologies, particularly for SMEs and emerging-market projects without public bond access [34,35].

1.3. Capital structure under uncertainty

Myers and Majluf [25] show that asymmetric information generates a pecking order (internal finance, then debt, then equity). Green innovation often violates the conditions under which conventional debt dominates: outcomes are uncertain, collateral may be limited, and future cash flows are noisy. Early-stage innovation therefore typically requires equity-like instruments, blended structures, or public guarantees that reduce adverse-selection costs before commercial debt becomes viable [27].

1.4. Real options under policy uncertainty

Dixit and Pindyck [26] show that investments with irreversibility, long payback, and high uncertainty have positive option value of waiting. Climate policy volatility, carbon-pricing uncertainty, and technology cost trajectories all introduce these features. Real-options reasoning explains why investors may delay capital commitments to first-of-a-kind projects with positive expected NPV, why guarantees and contracts-for-difference dominate naive subsidies, and why policy credibility is itself a financial input. Pástor et al. [17] and Bolton and Kacperczyk [18] further show that investor preferences and carbon-risk pricing jointly determine green-asset returns; Ilhan et al. [19] document priced downside climate exposure.

These traditions imply that sustainable finance is most effective when financial structures address the specific information, intermediation, capital-structure, and option-value frictions of particular green technologies. The next sections operationalize this implication.

2. Method

The review follows the management-research SLR methodology of Tranfield, Denyer, and Smart [36] and the PRISMA 2020 reporting standard [37]. The choice of an SLR rather than a meta-analysis reflects the conceptual nature of the matching framework: synthesis is qualitative-thematic across heterogeneous designs, not quantitative pooling of effect sizes.

The review question is: which financial structures match which green-technology attribute profiles, and under which conditions does mismatch produce financing failure? Scope: peer-reviewed academic articles and reports from recognized institutions (IEA, ICMA, IFRS Foundation, IOSCO, OECD, NGFS, IFC, Climate Bonds Initiative, Convergence, GIIN, IRENA, Hydrogen Council, UNEP FI), primarily January 2020 to April 2026, with foundational pre-2020 works retained were canonical. Boolean search strings combined three concept blocks (instruments, technologies, financial outcomes); full strings are reported in Appendix A. Table 1 summarizes the protocol and record counts; Figure 1 reports the PRISMA-style selection flow.

The review was conducted by a single coder, with three procedural safeguards: explicit written decision rules finalized before screening; retention of all borderline cases for full-text review; and triangulation of every retained source used to support a main-text empirical claim against at least one alternative. These safeguards reduce but do not eliminate single-coder bias, which is acknowledged again in Section 9.3.

Table 1. Systematic literature review protocol and record counts

Stage	Procedure	Records / result
Search execution	Boolean searches in Scopus and Web of Science Core Collection (January-April 2026); SSRN, Google Scholar (top-200), and institutional repositories as supplements.	Scopus 1,247; Web of Science 893; SSRN 187; Google Scholar 64; institutional 36. Combined 2,427.
Deduplication	Automated DOI and title matching; manual verification of borderline duplicates.	Unique records: 1,684.
Title-abstract screening	Inclusion: peer-reviewed or institutional, direct finance-technology link, 2020-2026 or foundational. Exclusion: general ESG-returns studies without technology link, non-peer-reviewed commentary, predatory venues.	Retained: 287.
Full-text assessment	Quality assessment using five academic criteria and four institutional criteria (Appendix B).	Retained: 92.
Final inclusion	Cross-checking overlap; retention of the most authoritative or recent source per claim.	Final synthesis: 71 (47 articles; 24institutional).

Note. Follows Tranfield et al. [36] and PRISMA 2020 [37]. Searches conducted January-April 2026.

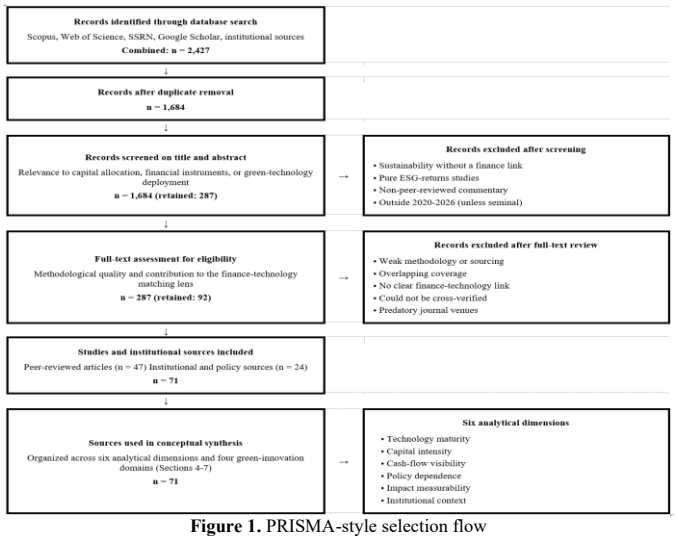


Figure 1. PRISMA-style selection flow

Note. Adapted from Page et al. [37]. The flow reports records identified, screened, assessed, and included in the synthesis. Side panels report exclusion reasons and the six analytical dimensions used in the synthesis

3. Results and Discussion

3.1. The Finance-Technology Matching Lens

Finance prices risk; green innovation changes the type and timing of risk. The structure of capital must therefore be matched to the structure of the technology, not only to the magnitude of its environmental claim. Six attributes are central, summarized with their financing implications, best-fit instruments, and binding domains in Table 2. Investors and lenders need to be able to observe the asset, assess risks, estimate cash flows, verify impact, and exit or recover capital under acceptable conditions [38,39]. When this match holds, sustainable finance produces transition value, capital structure, governance, and technology risk aligned. When it does not, sustainable finance produces symbolic finance, labels growing faster than deployment.

Table 2. Matching attributes, financing implications, best-fit instruments, and binding domains

Attribute	Implication for financing	Best-fit instruments	Where binding
Maturity (TRL)	Lower maturity raises due-diligence costs; debt is harder to justify.	Grants, venture capital, demonstration finance before refinancing with debt.	First-of-a-kind hydrogen, CCUS, advanced recycling.
Capital intensity	High upfront capex amplifies interest-rate, construction, and overrun risk.	Project finance, concessional tranches, offtake contracts, public risk sharing.	Industrial decarbonization, large-scale storage.
Cash-flow visibility	Weak or delayed revenue reduces bankability.	Long-term contracts, regulated revenue models, milestone funding, patient equity.	Circular economy, hydrogen export projects.
Policy dependence	Reliance on carbon prices, subsidies, or procurement creates political risk.	Credible transition plans, policy stability, guarantees, CfDs, scenario analysis.	Low-carbon fuels, electric-vehicle infrastructure.
Impact measurability	Unclear impact raises greenwashing risk and investor scepticism.	Taxonomies, external review, digital MRV, project-level reporting.	Circular economy, transition-finance labelling.
Institutional context	Country, currency, and governance risks affect bankability independently of asset characteristics.	Blended finance, multilateral guarantees, local-currency instruments, project preparation.	EMDE renewables and grids; cross-border projects.

Note. Compiled by the author(s) drawing on Polzin and Sanders [27], Pástor et al. [17], Giglio et al. [39], International Energy Agency [1,40], and International Capital Market Association [32,4]

3.1.1. Operationalization with empirical proxies

A weakness of the conceptual sustainable-finance literature is that key constructs are rarely operationalized in ways that future empirical work can replicate. Table 3 proposes a measurable proxy and a primary data source for each attribute. The proxies use existing publicly accessible data sources (IEA, IRENA, OECD, Climate Bonds Initiative, IFRS, World Bank, IMF), operate at the project or issuance level where possible, and combine continuous (technology readiness level (TRL), capex per kW, contract tenor) and categorical (assurance scope, sovereign rating buckets) measures. Empirical work should report sensitivity to proxy choice.

Table 3. Operationalization of the six matching attributes

Attribute	Conceptual definition	Proposed empirical proxy	Primary data sources
Technology maturity	Progress from R&D to commercial deployment.	TRL (1-9); years since first commercial-scale deployment; share of installed base in commercial operation.	IEA Clean Energy Technology Guide; Mission Innovation TRL tracker.
Capital intensity	Upfront capex relative to output capacity.	Capex per unit of capacity (USD/kW or USD/tonne); share of project cost incurred before first revenue.	IRENA Renewable Power Generation Costs; BloombergNEF; IJGlobal.
Cash-flow visibility	Predictability and contractibility of revenue.	Share of projected revenue under long-term offtake (PPA, regulated tariff, capacity payment); weighted-average tenor.	Project-finance databases; offtake registries; regulator filings.
Policy dependence	Sensitivity of project economics to policy support.	Subsidy intensity (subsidy as % of expected revenue); policy-volatility index (material changes in 5 years).	OECD Inventory of Support; IEA Policy Database; IRENA Policies and Measures.
Impact measurability	Existence and use of accepted MRV frameworks.	Share of issuance with second-party opinion; taxonomy alignment indicator; assurance scope.	Climate Bonds Initiative; ICMA databases; EU Platform on Sustainable Finance; IFRS Foundation.
Institutional context	Country financial-system quality and FX/sovereign risk.	Sovereign credit rating; local-currency bond-market depth (% of GDP); capital-account openness.	World Bank; IMF; OECD; rating agencies.

Note. Proposed proxies and primary data sources. Alternatives (e.g., tax-credit equivalent for subsidy intensity, counterparty-weighted contract tenor) are reasonable.

3.2. Green Innovation Domains and Financing Fit

Mature clean infrastructure is closer to conventional project finance and labelled debt markets; hard-to-abate sectors, circular-economy ventures, and digital verification systems require different combinations of capital, governance, and risk sharing. Table 4 reports a structured synthesis of twelve high-relevance empirical studies underpinning the discussion.

3.2.1. Mature clean infrastructure: renewables, grids, and storage

Utility-scale renewable power, grids, and storage remain the most finance-ready segment. IRENA [42] reports that 91% of utility-scale renewable capacity commissioned in 2024 delivered electricity below the cheapest new fossil-fuel alternative, with utility-scale solar PV at a global weighted-average levelized cost of electricity (LCOE) of USD 0.043/kWh and total installed cost (TIC) of USD 691/kW (an 11% year-on-year decline and 87% below 2010 levels). The weighted-average cost of capital (WACC) for renewable projects also declined in 2024, consistent with the matching argument that mature contracted assets attract lower-cost capital.

Standards such as ICMA's Green Bond Principles [32] and the EU Green Bond Standard [31] reduce information asymmetry; Flammer [6], Tang and Zhang [7], and Baker et al. [9] document positive issuance returns and modest pricing effects consistent with non-pecuniary motives. Two qualifications matter. Grid investment lags generation investment, creating a system bottleneck [43]. Emerging markets and developing economies (EMDEs) outside China face higher capital costs, currency risk, weaker pipelines, and policy uncertainty [40,44,45], even mature technologies may fail to attract private capital there without local-currency finance, project-preparation support, and public risk sharing.

3.2.2. Emissions-intensive sectors and transition technologies

Industrial decarbonization, carbon capture, and low-carbon fuels combine capital intensity, technical complexity, policy dependence, and uncertain demand. The 2024-2025 contraction in the green-hydrogen pipeline illustrates the matching problem at scale. Of the IEA's approximately 520 GW announced electrolyser project pipeline to 2030, only about 4% had reached final investment decision (FID) or were under construction by mid-2024 [46]. One year later, potential 2030 low-emissions hydrogen production declined from 49 to 37 Mtpa, the first recorded decline, with electrolysis accounting for more than 80% of the drop [4]. Equinor scrapped its Norway-Germany hydrogen export project in September 2024 and postponed the FID for its 600 MW H2H Saltend plant to 2027. Projects that reached FID typically combined modular scale, co-location with an industrial buyer, and captive or sovereign-backed offtake; projects that failed combined gigawatt scale, export orientation, and offtake assumed rather than contracted. This is the matching pattern the framework predicts.

ICMA [31], OECD [47], GFANZ [48], and the Transition Plan Taskforce [49] all emphasize that credible transition finance requires science-based targets, contracted offtake, and accountability. Empirical work suggests green finance can support innovation in hard-to-abate sectors when policy and supervisory conditions are conducive [12,13], with the external-validity caveat in Section 5.5.

3.2.3. Circular economy and resource-efficiency ventures

Circular-economy ventures are environmentally valuable but financially difficult to standardize: value comes from avoided waste, product reuse, sharing, or service-based models, none of which is easily captured by a single physical asset or predictable revenue contract. The February 2024 bankruptcy of Renewcell illustrates the limit. The Swedish textile-to-textile recycler operated an industrial-scale plant from late 2022 with a 60,000-tonne nameplate capacity, but Q3 2023 production reached only ~6,500 tonnes and the firm reported zero sales in November 2023 despite letters of intent from H&M, Inditex, and Levi's [5]. The post-bankruptcy private-equity acquisition by Altor in June 2024 restored the asset under a structure more consistent with the matching prediction (patient capital, longer hold horizons).

Corvellec and Stowell [5] argue that the structural barrier to circular transition is the dependence of circular ventures on conventional profitability under competitive conditions set by linear incumbents. Reviews by Agrawal and Hockerts [14], Chiappini et al. [50], and Agrawal et al. [51] document that circular models typically lack the scale and contractibility for labelled bond issuance and require private equity, relationship lending, or impact capital. Impact investing is built around intentionality, evidence, and measurement [52], but faces the same credibility constraint as ESG-labelled finance when measurement is weak.

3.2.4. Digital technologies as enabling infrastructure

Digital technologies support sustainable finance in two distinct ways, which are often conflated but raise different governance questions. **Digital monitoring, reporting, and verification (MRV) and reporting systems**. The first category collects, standardizes, and reports environmental performance data so that investors and assurance providers can verify use of proceeds and impact. A concrete example is satellite- and sensor-based emissions or land-use monitoring linked to green-bond reporting, increasingly aligned with the decision-useful climate disclosures required under IFRS S2 [33]. These systems primarily reduce measurement cost and improve the credibility of impact claims.

Artificial-intelligence and blockchain applications for green finance. The second category processes data and re-engineers financial infrastructure rather than simply reporting it. Concrete examples include blockchain-based tracking of green-bond proceeds to create tamper-evident audit trails [53] and artificial-intelligence-based climate-risk analytics that screen portfolios for physical and transition exposure. The fintech literature shows how such digital financial architectures can reshape intermediation, payment systems, and inclusion in values-based financial markets, including Islamic finance [54]. These tools can lower analytical cost and widen access, but they also introduce model and data-governance risks.

Across both categories, regulators and standard-setters [55,56] are increasingly focused on greenwashing and sustainable-bond integrity. Three cautions apply: artificial-intelligence systems can reproduce data bias, blockchain can record poor-quality data immutably, and digital dashboards can convey false precision. Digital tools should therefore be treated as governance infrastructure that complements, rather than substitutes for, standards, assurance, and accountability [57,58].

Table 4. Structured synthesis of twelve high-relevance studies

Study	Setting / data	Method	Key finding	Implication for matching
Flammer [6]	Global corporate green bonds, 2013-2018.	Event study and panel regression.	Positive announcement returns; improved institutional ownership and environmental performance.	Labelled debt fits mature, observable assets when reporting is credible.
Tang & Zhang [7]	International green bonds, 28 countries, 2007-2017.	Event study.	Positive announcement returns; no consistent green premium; improved liquidity.	Information and clientele effects matter beyond yield differential.
Zerbib [8]	Green bonds, 2013-2017.	Matched-pair yield analysis.	Small negative green premium (~-2 bp).	Pricing effect modest; issuer credibility matters more than label.
Pástor, Stambaugh, & Taylor [17]	Theoretical model.	Equilibrium asset pricing.	Green assets earn lower expected returns; can outperform under demand shocks.	Cost of capital depends on preferences and shocks, not only fundamentals.
Bolton & Kacperczyk [18]	U.S. equities.	Cross-sectional asset pricing.	Carbon risk priced; high-emission stocks earn higher returns.	Carbon-intensive technologies face a risk premium.
Krueger, Sautner, & Starks [59]	Institutional investor survey.	Cross-sectional survey.	Climate risks viewed as financially relevant; engagement preferred over divestment.	Climate risk shapes allocation through stewardship.
Ilhan, Sautner, & Vilkov [19]	U.S. equity options.	Option-implied tail risk.	Carbon-intensive firms show higher downside tail risk.	Investors price downside climate exposure in derivatives.
Berg, Koelbel, & Rigobon [29]	ESG rating providers.	Decomposition of rating divergence.	Large provider divergence from scope, measurement, weighting.	Information frictions impede capital matching.
Avramov, Cheng, Lioui, & Tarelli [30]	Equilibrium model and panel.	Theory and empirical.	ESG rating uncertainty reduces sustainable demand and the green premium.	Better ESG information lowers cost of capital for credible projects.
Kölbel & Lambillon [10]	Corporate SLBs, 2020-2022.	Matched-pair primary-market analysis.	SLBs price ~29 bp below matched conventionals at issuance; first SLB drives the premium.	Novelty and signalling, not step-up size, explain the SLB premium.
Feldhütter, Halskov, & Krebbers [11]	SLBs, secondary market.	Same-day yield-spread matching.	1-2 bp lower yield; 14-39% target-miss probability; pricing depends on penalty size; no mispricing.	Step-up priced when calibrated against achievable targets.
Ma, Iqbal, Bouri, & Zhang [13]	Chinese high-carbon sector.	Difference-in-differences.	Green finance increases green innovation in high-carbon sectors.	Transition finance can support hard-to-abate industries under policy support.

Note. Studies selected for direct contribution to the matching argument, methodological transparency, and publication quality. The full synthesis draws on 71 included so

3.2.5. External validity: a note on the green-credit evidence

A substantial share of the empirical evidence on green credit and green innovation comes from China [12,13,60]. The Green Credit Guidelines (2012) and provincial pilots create policy variation that supports difference-in-differences and quasi-experimental designs, and the findings are robust within that institutional setting. Generalization to market-based financial systems requires caution: China's green-credit regime operates through policy-bank-led lending with strong state coordination, directed mandates, and supervisory targets that have no close analogue elsewhere. The matching framework is intended to be institutionally agnostic, the six attributes apply across contexts, but the empirical magnitudes documented in Chinese studies should not be transposed without independent estimation. Other large emerging markets have developed distinct green-finance models that the framework can accommodate and that broaden the evidence base beyond China. India illustrates a directed-lending channel: the Reserve Bank of India brought small renewable-energy projects within priority-sector lending and, in 2023, introduced a framework for green deposits alongside sovereign green-bond issuance [61], reflecting a deliberate practice among emerging-market central banks of steering credit toward national developmental priorities. Brazil illustrates a development-bank channel: the national development bank (BNDES) deploys blended and matchfunding structures that use concessional public capital to crowd in private finance for renewable and nature-based projects [62]. South Africa illustrates a procurement-and-taxonomy channel: it was the first emerging economy to issue a green bond (2012) and has published a national green-finance taxonomy to standardize classification, alongside the renewable-energy procurement programme discussed below. Across these cases, the institutional-context attribute operates through different mechanisms—directed lending, development-bank intermediation, and structured procurement—none of which reduces to the Chinese policy-bank model, reinforcing the caution against transposing Chinese magnitudes to other settings.

3.2.6. Emerging-market comparison: two contrasting green projects

To make the cash-flow-visibility and institutional-context attributes concrete in an emerging-market setting, consider two green projects in southern Africa that share strong renewable resources but differ sharply in financeability. The first is South Africa's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), launched in 2011. Structured around competitive

auctions, standardized 20-year power-purchase agreements (PPAs) with the state utility Eskom, and credit-enhancement and security arrangements, the programme had procured on the order of 6,300 megawatts of wind and solar capacity and mobilized roughly USD 17–20 billion of predominantly private investment across successive bid windows, with bid tariffs falling sharply over time [63]. In matching terms, REIPPPP scores high on cash-flow visibility (contracted, sovereign-backed offtake) and on institutional context (a standardized, repeatable procurement framework); these attributes—not the underlying solar and wind technology, which is mature globally—are what rendered the projects bankable.

The second is Namibia's Hyphen green-hydrogen and green-ammonia project, an approximately USD 10 billion export-oriented scheme designed to produce around two million tonnes of green ammonia annually from roughly 3 GW of electrolysis paired with 3.5 GW of solar and 4 GW of wind. Despite comparable renewable resources and an active national hydrogen strategy, the project remained pre-final-investment-decision: a cornerstone non-binding offtake arrangement with a European utility was abandoned in 2025 amid weak hydrogen demand, and the project advanced largely through concessional support, including a USD 10 million pre-investment facility from the African Development Bank to fund engineering studies and de-risk the venture [64]. In matching terms, Hyphen scores low on technology maturity (first-of-a-kind integration at gigawatt scale) and on cash-flow visibility (uncontracted export offtake), so even a supportive institutional context and abundant resources were insufficient to attract commercial capital absent concessional and blended structures. The comparison isolates the framework's logic within a single region and technology family: two green projects with similar resource endowments and broadly comparable institutional settings diverged because their attribute profiles differed on cash-flow visibility and maturity. It mirrors, at the emerging-market level, the solar-versus-hydrogen contrast developed in the global cases of Section 8, and underscores that in emerging markets the binding constraint is frequently revenue contractibility and bankable offtake rather than environmental merit or resource quality.

3.3. Financial Mechanisms Linking Innovation to Deployment

Figure 2 places the principal financial mechanisms in their broader market context

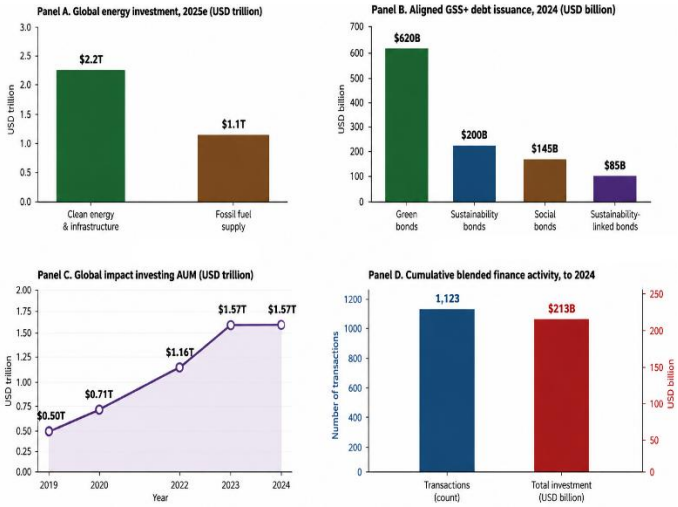


Figure 2. Scale and composition of sustainable finance flows

Note. Panel A: IEA [1]. Panel B: Climate Bonds Initiative [2]; within-total shares are indicative. Panel C: GIIN [3]. Panel D: Convergence [15].

3.3.1. Green bonds

Green bonds remain the most visible sustainable-finance instrument: standardized, with recognizable disclosure, and able to finance identifiable assets at scale. Empirical evidence is mixed but constructive [6-9], modest pricing effects coexist with real signalling effects. The principal weakness is additionality: a green bond can finance a new project, refinance an existing asset, or relabel activity that would have happened anyway.

3.3.2. Sustainability-linked debt: a closer empirical look

SLBs link coupon payments to issuer-level sustainability performance targets rather than ring-fencing proceeds. Kölbel and Lambillon [10] examine 102 SLBs matched against same-issuer conventional bonds and find SLBs price approximately 29 basis points below matched conventionals at primary issuance, with savings typically exceeding the maximum potential step-up penalty, a "free lunch" pattern. The premium is uncorrelated with step-up size; the issuer's first SLB attracts the largest premium, consistent with a novelty and signalling interpretation.

Feldhütter, Halskov, and Krebbers [11], in the *Journal of Financial Economics*, refine this analysis using same-day yield-spread matching against non-SLB bonds from the same issuer. They find a 1-2 basis-point lower yield on the SLB label, well below the primary-market figure. Two further results sharpen the matching interpretation. First, the average probability of missing the sustainability performance target is 14-39%, indicating that issuers set targets that are easy to reach. Second, contrary to Kölbel and Lambillon's primary-market finding, secondary-market SLB prices depend strongly on the size of the potential penalty, the market is informationally efficient in pricing penalty conditional on its design. Mariani et al. [65] report comparable yield differentials. Banque de France [66] notes that the typical 25-basis-point step-up is small relative to credit-rating-linked step-ups of around 125 basis points, and that early-repayment clauses can weaken the binding force of the penalty mechanism.

SLBs reprice risk, but the repricing is small (1-2 bp on secondary markets) and target-setting is calibrated to keep miss probabilities tolerable. From a real-options perspective, a 25-bp step-up against a 14-39% miss probability carries low option value relative to the underlying technological or policy risk. SLBs play a useful signalling role for first-time issuers where green-bond use-of-proceeds frameworks are difficult to apply, but the matching framework does not treat them as substitutes for credible transition planning, contracted offtake, or risk-sharing structures.

3.3.3. Green credit, banks, and supervisory pressure

Banks remain central because many firms do not access public bond markets. Dikau and Volz [34] show that central bank mandates and supervisory structures increasingly shape green finance; NGFS [35] reports rising attention to climate and nature-related financial risks. Chinese evidence [12,13,60] shows green credit can redirect firm incentives, with the external-validity caveat noted in Section 5.5. Recent green-banking work in the Journal of Environmental Economics & Chemical Processes similarly emphasizes environmental-project risk assessment, resource allocation to green projects, and the design of green financial products as practical banking mechanisms for sustainable development [67]. Green credit works best where firms already have credible projects, usable data, and policy signals that make low-carbon investment commercially rational.

3.3.4. Impact investing, patient capital, and blended finance

Impact investing combines financial return with intentional and measurable environmental or social impact, with assets under management (AUM) of USD 1.571 trillion in 2024 [3]. It fits green innovation where outcomes are valuable but hard to capture through conventional debt, circular-economy models, climate adaptation, early-stage clean-technology firms. The principal weakness is scalability: high due-diligence costs, inconsistent metrics, and mission drift if funds grow without preserving intentionality [14,50]).

Blended finance is most relevant where public value is high but commercial bankability is weak. Convergence [15] reports 1,123 transactions with USD 213 billion in total investment. Effective blended finance should pass three tests: mobilize capital that would not otherwise enter; allocate risk to the party best able to manage it; and create learning or market infrastructure that reduces the need for subsidy over time [68].

3.4. Critical Tensions

Three structural tensions recur across the review (Table 5). A further three, green innovation vs. financial returns, impact measurement vs. innovation logic, and SLB penalty design vs. signalling, are addressed in the relevant prior sections and reported in expanded form in Appendix C.

Table 5. Three principal tensions in technology-driven sustainable finance

Tension	Core conflict	Implication for matching
Labelled finance vs. additionality	Labels can grow faster than incremental environmental impact; primary-market SLB premiums are uncorrelated with step-up size and attenuate to 1-2 bp on secondary markets [10,11]	Effective matching depends on external review, taxonomy alignment, project-level reporting, and credible transition planning.
Global capital vs. EMDE needs	Capital is concentrated in mature jurisdictions; EMDEs face higher costs and weaker pipelines [44,69].	Local-currency instruments, blended finance, and project preparation are critical complements.
Private finance vs. policy credibility	Many transition technologies depend on tax credits, carbon pricing, and procurement; policy volatility undermines bankability [47,41].	Policy stability is itself a financial input; credible transition plans are part of capital matching.

Note. Each tension reflects a structural source of mismatch and points to a corresponding design implication. The full six-tension set is reported in Appendix C.

3.5. Illustrative Application: A Multi-Case Plausibility Probe

This section applies the matching framework to three contrasting cases that span the attribute space: (A) utility-scale solar PV; (B) first-of-a-kind green hydrogen; and (C) textile-to-textile recycling. The objective is illustrative plausibility, not statistical validation. The framework was developed before the cases were analyzed, but the cases themselves were chosen with knowledge of their financing outcomes, a confirmatory plausibility probe that tests whether the framework can account for known outcomes, not whether it predicts unknown ones. A genuine predictive test would require application to cases with outcomes unknown at the time of analysis, or larger-sample empirical work using the proposed proxies (Section 9.2). The cases demonstrate internal coherence of the framework with observed financing patterns; they do not establish external validity, and they cannot rule out macro-rate, demand-shock, or sector-specific confounders. Section 8.4 discusses these limitations explicitly.

3.5.1. Case selection and method

Cases were selected using purposive theoretical sampling [70,71] to maximize variation across the six attributes while holding the time window constant (2022-2026). Each case spans a different technology domain (Section 5). Data sources include IRENA [42], IEA [1,43,46], Climate Bonds Initiative [2], Convergence [15], regulatory filings, and peer-reviewed analyses [5,72]. All factual claims in Tables 6 and 7 are triangulated against at least two independent sources; quantitative figures are individually sourced in-table.

3.5.2. Attribute scoring and observed outcomes

Table 6 reports attribute scores using the proxies defined in Table 3. Table 7 compares the financing structure that the framework would predict from the attribute profile with the financing pattern actually observed. Because cases were selected with knowledge of outcomes, the comparison documents internal coherence; it does not establish predictive accuracy on unseen cases.

Table 6. Attribute scoring across three cases

Attribute (proxy)	Case A: Utility-scale solar PV	Case B: First-of-a-kind green hydrogen	Case C: Textile-to-textile recycling
Maturity (TRL)	High (TRL 9; > 20 years commercial deployment).	Low to medium (electrolysis TRL 7-8; system integration TRL 5-6 at scale).	Medium (chemical recycling TRL 7-8; commercial-scale operation < 3 years).
Capital intensity	Falling: USD 691/kW global weighted-average TIC in 2024, down 11% YoY and 87% from 2010 [42].	High: electrolyser installed cost USD 2,000-2,600/kW outside China, USD 600-1,200/kW in China in 2024 [4]; current LCH 1.5-6× fossil hydrogen, gap of USD 1.5-8/kg [46].	High per unit; Renewcell's Ortviken plant 60,000-tonne nameplate vs. ~6,500 tonnes Q3 2023 production [5].
Cash-flow visibility	High: share of revenue under PPA or regulated tariff typically > 80% over 15-20 years [42].	Low: only ~4% of the ~520 GW announced electrolyser pipeline had reached FID by mid-2024 (IEA, 2024); cancelled projects had offtake "assumed not contracted."	Low: letters of intent from H&M, Inditex, Levi's not converted into contracted offtake; zero sales reported November 2023 [5].
Policy dependence	Moderate: auction-based PPAs reduce policy sensitivity; carbon-pricing complement.	Very high: economics depend on production tax credits (US IRA §45V), CfDs, mandates; sensitive to policy reversal (IEA, 2025c).	Moderate: depends on EPR regimes and EU textile circularity mandates still emerging.
Impact measurability	High: EU-Taxonomy-aligned, second-party opinions standard, IFRS S2 applicable.	Medium: ICMA Climate Transition Finance Handbook applicable; renewable-electricity sourcing disputed.	Medium: third-party LCA available; average climate-impact reduction ~0.5% of EU textile-product impact, with 8% sensitivity-analysis probability of net increase [72].
Institutional context	Strong in mature markets; weaker in EMDEs where capital costs are materially higher [45].	Mixed: most cancellations were in mature jurisdictions (Norway, UK, US, Germany, Australia), so high institutional quality is necessary but not sufficient.	Strong (Sweden, EU); does not compensate for revenue-contractibility weakness.

Note. Scoring uses the proxies and data sources in Table 3. Quantitative figures are reported where institutional data permit; qualitative scores are used where measurement is descriptive.

Table 7. Predicted versus observed financing structures

Case	Predicted financing structure	Observed financing pattern
Case A: Utility-scale solar PV	Green bonds, project finance, syndicated green loans; falling cost of capital as maturity and contracted revenue compound.	Internally coherent. WACC declined in 2024; LCOE at USD 0.043/kWh; 91% of newly commissioned utility-scale renewables below cheapest fossil alternative [42]. Renewable power constitutes the dominant share of aligned green-, social-, sustainability-, and sustainability-linked-bond issuance [2].
Case B: First-of-a-kind green hydrogen	Blended finance, public guarantees, contracts-for-difference, anchor offtake contracts; high attrition without these supports.	Internally coherent. First-ever annual decline in announced 2030 capacity (49 → 37 Mtpa), driven > 80% by electrolysis [4]; ~4% of pipeline at FID by mid-2024 [46]; surviving projects exhibit modular scale and captive offtake; Equinor Norway-Germany pipeline, BP Australia REH, several Air Products US projects cancelled or scaled back.
Case C: Textile-to-textile recycling	Impact funds, private equity, patient capital, relationship-based brand partnerships; vulnerability to financing collapse when revenue contractibility fails.	Partially coherent. Renewcell relied on a mix of public equity, strategic-investor financing (H&M Group), and short-term shareholder loans. February 2024 bankruptcy followed failure of contracted revenue to materialize. Post-bankruptcy acquisition by Altor (June 2024) restored the asset under patient capital, consistent with matching prediction.

Note. Predictions follow from the attribute profile in Table 6 and the matching in Table 2. Observed patterns triangulated against at least two independent sources for each substantive claim.

3.5.3. Cross-case discussion

Three patterns of coherence emerge. First, the attribute profile of each case is consistent with the direction of the observed financing outcome. Case A's profile (high maturity, high contractibility, high measurability) aligns with labelled debt and falling cost of capital; Case B's profile (low maturity, low contractibility, very high policy dependence) aligns with the observed pipeline attrition in the absence of guarantees or contracted offtake; Case C's profile aligns with the observed financing collapse despite strong brand commitments. Second, binding attributes differ across cases. In Case B, the binding attributes are cash-flow visibility and policy dependence: high institutional quality did not save projects when offtake was assumed rather than contracted. In Case C, the binding attribute is revenue contractibility: letters of intent from globally significant brands proved non-enforceable substitutes for purchase orders. Third, all three cases had strong environmental narratives, yet only Case A converted narrative into bankable capital at scale, consistent with the central claim that fit between attribute profile and capital structure, not environmental value alone, produces financeability.

3.5.4. Alternative explanations and limitations

Three alternatives cannot be ruled out. First, the 2022-2024 rise in global interest rates affected all three cases through the cost-of-debt channel; this macro factor cannot be separated from the matching mechanism without a counterfactual. Second, green-hydrogen cancellations could reflect demand-side disappointments (steel, chemicals, aviation) rather than general matching failure. Third, the Renewcell collapse coincided with a broader fashion-industry slowdown in late 2023 and early 2024. The cases therefore provide a plausibility test, not a causal estimate.

3.6. Framework, Testable Propositions, and Limitations

3.6.1. The framework

The framework (Figure 3) links four elements: technology attributes, governance infrastructure, capital-structure fit, and sustainability outcomes. Technology attributes shape initial financeability; governance infrastructure, taxonomies, disclosure standards, assurance, transition plans, public guarantees, digital monitoring, reporting, and verification (MRV), mediates the movement from technical potential to investable assets; capital-structure fit determines the instruments deployed; outcomes include deployment, emissions reduction, innovation learning, lower future financing costs, and verifiable additionality. A feedback loop captures cumulative learning: verified operating data lowers future due-diligence costs. Contextual moderators, macro-financial conditions, policy stability, country risk, capital-market depth, investor preferences, sectoral path dependence, condition the framework's operation. The six propositions in Table 8 sit at specific transition points and are labelled accordingly in Figure 3.

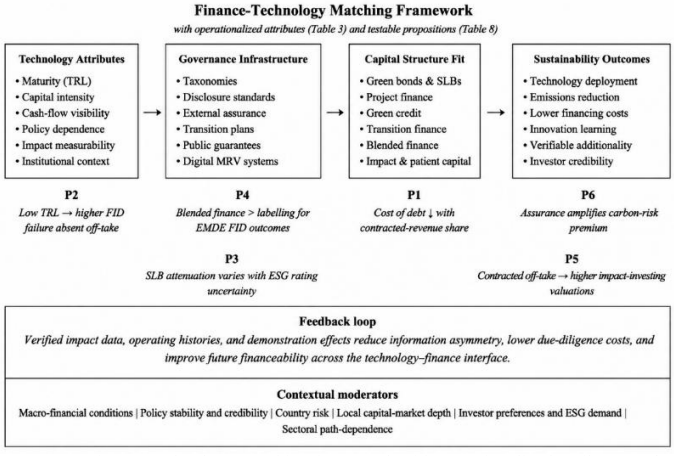


Figure 3. Finance-technology matching framework with operationalized attributes and testable propositions

Note. The framework links technology attributes (Table 3 proxies), governance infrastructure, capital-structure fit, and sustainability outcomes. Proposition badges P1-P6 indicate where each Table 8 proposition applies. The dashed feedback loop captures cumulative learning.

3.6.2. Six testable propositions

Table 8 reports six directional propositions, each with a feasible empirical design using existing project-finance, fixed-income, or venture-financing data.

The propositions are not exhaustive; they are the most accessible entry points for empirical work.

Table 8. Six falsifiable propositions

#	Proposition	Empirical test (suggested design)
P1	Cost of debt for green-technology projects declines monotonically with cash-flow visibility (share of revenue under long-term contract), controlling for sovereign rating, technology, and macro-rate environment.	Cross-sectional regression of project-finance pricing spreads on contracted-revenue share, using IJGlobal or BloombergNEF project-level data.
P2	First-of-a-kind transition technologies (TRL 6-7) exhibit higher FID failure rates than commercial-stage technologies (TRL 8-9) in the absence of contracted offtake or sovereign-backed guarantees, even when institutional quality is high.	Survival analysis of announced-to-FID timing in the IEA Hydrogen Projects Database, with TRL, offtake type, and policy support as covariates.
P3	Among SLBs, the primary-secondary yield-spread attenuation is faster for issuers with high ESG-rating uncertainty than for issuers with consensual ratings; secondary-market penalty pricing is stronger for issuers with above-median target ambition.	Difference-in-differences on the primary-secondary spread by ESG-rating dispersion bucket; interaction of secondary-market spread with target-ambition score (e.g., SBTi alignment).
P4	In EMDE markets, blended-finance participation is more strongly associated with project FID than green-bond labelling, after controlling for sovereign risk and project size.	Logit or hazard model of FID outcomes for EMDE renewable and transition projects, with structure type as the main covariate.
P5	Impact-investing valuations for circular-economy ventures are positively associated with the share of revenue under multi-year contracted offtake, beyond the effects of brand commitments such as letters of intent.	Cross-sectional valuation study using PitchBook or Crunchbase, with contract-share measures coded from regulatory filings.
P6	Investor pricing of carbon risk interacts with disclosure assurance quality: third-party assurance amplifies the carbon-risk premium documented by Bolton and Kacperczyk [18], particularly in IFRS S2 jurisdictions.	Asset-pricing test with assurance scope, IFRS S2 jurisdiction, and their interaction as covariates, using post-2024 cross-section.

Note. Propositions are stated in directional form. Each is testable using existing project-finance, fixed-income, or venture-financing

3.6.3. Boundary conditions and limitations

The framework applies to investment in green technologies and projects, not to ESG portfolio construction. It assumes a market-based or hybrid financial system; in purely directed-credit systems, binding constraints differ. It treats institutional context as a moderator, not an outcome.

Although the framework is developed for green technologies, its core logic is not intrinsically environmental, and a reasonable question is whether it extends to other innovation domains. The six attributes—maturity, capital intensity, cash-flow visibility, policy dependence, impact measurability, and institutional context—describe any capital-intensive, high-uncertainty innovation domain, so the framework could in principle apply to biotechnology, nanotechnology, advanced materials, and other deep-technology sectors in which financeability turns on technology attributes rather than on environmental claims alone. Two recalibrations would be required. First, the impact-measurability attribute is here defined around environmental monitoring, reporting, and verification and taxonomies; in a non-green domain it would be redefined around the relevant outcome metric, such as clinical-trial evidence and regulatory approval milestones in biotechnology. Second, the policy-dependence attribute reflects climate and energy policy; other domains face different regimes, such as health-technology assessment or safety regulation. Subject to these recalibrations, the central proposition—that the structure of capital must fit the structure of the technology—generalizes beyond the green context, and testing the framework in adjacent innovation domains is a promising direction for future research. Four limitations should be acknowledged. First, the SLR was conducted by a single coder; procedural safeguards (Section 3) reduce but do not eliminate bias. Second, the multi-case probe in Section 8 is illustrative, not causal. Third, the empirical proxies in Table 3 are starting points; empirical work should report sensitivity. Fourth, the green-credit evidence base draws heavily on China (Section 5.5); cross-country empirical work in market-based systems is a priority.

4. Conclusions

Sustainable finance scales some green technologies more easily than others because of matching. Mature technologies with visible assets, predictable cash flows, and measurable environmental benefits attract green bonds, project finance, and green lending at falling cost of capital. Riskier transition technologies, circular-economy ventures, and EMDE projects need blended finance, patient capital, guarantees, and stronger governance; in their absence, capital withdraws even from projects with strong environmental narratives. The framework converts this pattern into a six-attribute lens with proposed proxies, six testable propositions, and an illustrative multi-case probe whose internal coherence with observed outcomes motivates the larger-sample empirical work proposed in Section 9.2.

Three implications follow. Regulators should focus on comparability, verification, and transition credibility rather than disclosure volume, and should support measurement infrastructure in EMDEs. Banks and investors should select structures that fit attribute profiles rather than assume that labelled debt is universally suitable, the SLB evidence in particular shows step-up structures do not substitute for credible transition planning. Researchers should test the propositions empirically, with priority on cross-country project-level work that moves beyond the China-centric green-credit evidence base.

Author Contributions

All authors contributed equally to the conception, preparation and writing of this manuscript.

Conflict of Interest

The authors, while observing publication ethics in the referencing, declare the absence of interest of conflict.

Acknowledgement

The authors gratefully acknowledges the support provided by the University of Niagara Falls Canada in conducting this research.

AI-Assisted

The authors retain full responsibility for the accuracy, originality, integrity, legality, and ethical compliance of all text, data, tables, figures, analyses, references, and conclusions, and have verified all AI-assisted outputs. Any fabrication, falsification, manipulation, plagiarism, copyright infringement, or other misuse of AI remains solely the responsibility of the authors and does not transfer or diminish their accountability for the published work.

[1] References

[2] International Energy Agency, *World energy investment 2025*. (2025a). https://www.iea.org/reports/world-energy-investment-2025

[3] Climate Bonds Initiative, *Sustainable debt global state of the market 2024*. (2025). https://www.climatebonds.net/data-insights/publications/global-state-market-2024

[4] Global Impact Investing Network, *Sizing the impact investing market 2024*. (2024a). https://thegiin.org/publication/research/sizing-the-impact-investing-market-2024/

[5] International Energy Agency, *Global hydrogen review 2025*. (2025c). https://www.iea.org/reports/global-hydrogen-review-2025

[6] H. Corvellec, A. F. Stowell, *Journal of Circular Economy*, 2024, **2(1)**, 1-4.

[7] C. Flammer, *Journal of Financial Economics*, 2021, **142(2)**, 499-516.

[8] D. Y. Tang, Y. Zhang. *Journal of Corporate Finance*, 2020, **61**, 427-445.

[9] O. D. Zerbib, *Journal of Banking & Finance*, 2019, **98**, 39-60.

[10] M. Baker, D. Bergstresser, G. Serafeim, J. Wurgler, *Annual Review of Financial Economics*, 2022, **14**, 415-437.

[11] J. F. Kölbel, A.-P. Lambillon. *Swiss Finance Institute Research Paper,*2023*,* 1-33.

[12] P. Feldhütter, K. Halskov, A. Krebbers, *Journal of Financial Economics*, 2024, **162**, 944-959.

[13] F. Chen, X. Zeng, X. Guo, *Finance Research Letters*, 2024, **63**, 283-292.

[14] L. Ma, N. Iqbal, E. Bouri, Y. Zhang, *Resources Policy*, 2023, **85(Part B)**, 47-57.

[15] A. Agrawal, K. Hockerts, *Journal of Small Business & Entrepreneurship*, 2021, **33(2)**, 153-181.

[16] Convergence, *State of blended finance 2024*. (2024). https://www.convergence.finance/resource/state-of-blended-finance-2024/view

[17] A. Zameni, *Financing sustainability: Economic models and investment*. In: A. Chakir, R. Bansal, J. F. Andry, F. Rabby, M. Hussain, eds. Green society, environmental strategies and sustainable development. Springer, 2025, pp. 203-228.

[18] Ľ. Pástor, R. F. Stambaugh, L. A. Taylor, *Journal of Financial Economics*, 2021, **142(2)**, 550-571.

[19] P. Bolton, M. Kacperczyk, *Journal of Financial Economics*, 2021, **142(2)**, 517-549.

[20] E. Ilhan, Z. Sautner, G. Vilkov, *The Review of Financial Studies*, 2021, **34(3)**, 540-571.

[21] G. A. Akerlof, T*he Quarterly Journal of Economics*, 1970, **84(3)**, 488-500.

[22] J. E. Stiglitz, A. Weiss, T*he American Economic Review*, 1981, **71(3)**, 393-410.

[23] D. W. Diamond, *The Review of Economic Studies*, 1984, **51(3)**, 393-414.

[24] B. Holmstrom, J. Tirole, *The Quarterly Journal of Economics*, 1997, **112(3)**, 663-691.

[25] F. Modigliani, M. H. Miller, *The American Economic Review*, 1958, **48(3)**, 261-297.

[26] S. C. Myers, N. S. Majluf, *Journal of Financial Economics*, 1984, **13(2)**, 187-221.

[27] A. K. Dixit, R. S. Pindyck, *Investment under uncertainty*. Princeton university press, 1994.

[28] F. Polzin, M. Sanders, *Energy Policy*, 2020, **147**, 863-879.

[29] M. Spence, *The Quarterly Journal of Economics*, 1973, **87(3)**, 355-374.

[30] F. Berg, J. F. Koelbel, R. Rigobon, *Review of Finance*, 2022, **26(6)**, 315-344.

[31] D. Avramov, S. Cheng, A. Lioui, A. Tarelli, *Journal of Financial Economics*, 2022, **145(2)**, 642-664.

[32] European Commission. *Official Journal of the European Union*, L. 2023. https://eur-lex.europa.eu/eli/reg/2023/2631/oj

[33] International Capital Market Association, *Green bond principles: Voluntary process guidelines for issuing green bonds*. (2025a). https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/

[34] IFRS Foundation, *IFRS S2 climate-related disclosures*. (2023). https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s2-climate-related-disclosures/

[35] S. Dikau, U. Volz, *Ecological Economics*, 2021, **184**, 22-42.

[36] Network for Greening the Financial System, *Annual report 2024*. (2024). https://www.ngfs.net/en/publications-and-statistics/publications/annual-report-2024

[37] D. Tranfield, D. Denyer, P. Smart, *British Journal of Management*. 2003, **14(3)**, 207-222.

[38] M. J. Page, J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, J. M. Tetzlaff, E. A. Akl, S. E. Brennan, R. Chou, J. Glanville, J. M. Grimshaw, A. Hróbjartsson, M.M. Lalu, T. Li, E. W. Loder, E. Mayo-Wilson, S. McDonald, D. Moher. *BMJ*, 2021, **372**, 1-9.

[39] H. Hong, G. A. Karolyi, J. A. Scheinkman, T*he Review of Financial Studies*, 2020, **33(3)**, 11-23.

[40] S. Giglio, B. Kelly, J. Stroebel, *Annual Review of Financial Economics*, 2021, **13**, 15-36.

[41] [International Energy Agency, *Scaling up private finance for clean energy in emerging and developing economies*. (2023). https://www.iea.org/reports/scaling-up-private-finance-for-clean-energy-in-emerging-and-developing-economies

[42] International Capital Market Association, *Climate transition finance handbook*.(2025b). https://www.icmagroup.org/assets/documents/Sustainable-finance/2025-updates/Climate-Transition-Finance-Handbook-November-2025.pdf

[43] International Renewable Energy Agency, *Renewable power generation costs in 2024*. (2025). https://www.irena.org/Publications/2025/Jul/Renewable-power-generation-costs-in-2024

[44] International Energy Agency, *World energy outlook 2025*. (2025b). https://www.iea.org/reports/world-energy-outlook-2025

[45] International Finance Corporation, *Challenges of green finance: Private sector perspectives from emerging markets*. (2023). https :// www.ifc.org / content/ dam/ifc/ doc/ 2023/ challenges-of-green-finance.pdf

[46] International Finance Corporation, *Emerging market green bonds 2024*. (2025). https://www.ifc.org/content/dam/ifc/doc/2025/emerging-market-green-bonds-2024.pdf

[47] International Energy Agency, *Global hydrogen review 2024*. (2024). https://www.iea.org/reports/global-hydrogen-review-2024

[48] Organisation for Economic Co-operation and Development, *OECD guidance on transition finance*. (2022).

[49] Glasgow Financial Alliance for Net Zero, *Financial institution net-zero transition plans: Fundamentals, recommendations, and guidance*. (2022). https://assets.bbhub.io/company/sites/63/2022/09/Recommendations-and-Guidance-on-Financial-Institution-Net-zero-Transition-Plans-November-2022.pdf

[50] Transition Plan Taskforce, *Disclosure framework*. (2023). https://www.ifrs.org/content/dam/ifc/2023/disclosure-framework-oct-2023.pdf

[51] H. Chiappini, N. Marinelli, R. N.-U.-D. Jalal, G. Birindelli, *Management and Policy Journal*, 2023, **14(7)**, 232-257.

[52] R. Agrawal, S. Agrawal, A. Samadhiya, A. Kumar, S. Luthra, V. Jain, *Geoscience Frontiers*, 2024, **15(4)**, 669-683.

[53] Global Impact Investing Network., *Core characteristics of impact investing*. (2019). https://thegiin.org/publication/post/core-characteristics-of-impact-investing/

[54] P. Christodoulou, M. Psillaki, G. Sklias, S. A. Chatzichristofis, *Finance Research Letters*, 2023, **58**, 397-405.

[55] N. Alam, L. Gupta, A. Zameni, *Palgrave Macmillan*, 2019.

[56] International Organization of Securities Commissions, *Supervisory practices to address greenwashing.* (2023). https://www.iosco.org/library/pubdocs/pdf/IOSCOPD750.pdf

[57] International Organization of Securities Commissions, *Sustainable bonds report*. (2025). https://www.iosco.org/library/pubdocs/pdf/IOSCOPD796.pdf

[58] T. Lagoarde-Segot, *Current Opinion in Environmental* Sustainability, 2024, **66**, 397-402.

[59] J. Dempere, E. Alamash, P. Mattos, *Frontiers in Sustainability*, 2024, **5**, 51-65.

[60] P. Krueger, Z. Sautner, L. T. Starks, *The Review of Financial Studies*, 2020, **33(3)**, 1067-1111.

[61] M. Song, Q. Xie, Z. Shen, *Energy Policy*, 2021, **153**, 267-278.

[62] Reserve Bank of India, *Framework for acceptance of green deposits*. (2023). https://www.rbi.org.in/Scripts/NotificationUser.aspx?Id=12487

[63] Climate Policy Initiative, *The state of green banks 2025: Learnings from green financing structures around the world*. (2025). https://www.climatepolicyinitiative.org/publication/the-state-of-green-banks-2025-learnings-from-green-financing-structures-around-the-world/

[64] A. Eberhard, R. Naude, *Journal of Energy in Southern Africa*, 2016, **27(4)**, 1-14.

[65] African Development Bank, *African Development Bank approves $10 million to catalyse Namibia's large green hydrogen project*. (2025). https://www.afdb.org/en/news-and-events/press-releases/african-development-bank-approves-10-million-catalyse- namibias-large-green-hydrogen-project-89480

[66] M. Mariani, A. Caragnano, M. Amoruso, M. Zito. *International Journal of Business and Management*, 2018, **13(7)**, 1-80.

[67] Banque de France, *Sustainability-linked bonds, an effective tool for decarbonisation?* Eco Notepad. (2022). https://www.banque-france.fr/en/publications-and-statistics/publications/sustainability-linked-bonds-effective-tool-decarbonisation

[68] A. Najarzadeh. *Jeecpjournal*, 2024, **1(1)**, 1-5.

[69] G20 Sustainable Finance Working Group, *2024 G20 sustainable finance report*. (2024). https://g20sfwg.org/wp-content/uploads/2024/10/2024-G20-Sustainable-Finance-Report.pdf

[70] Organisation for Economic Co-operation and Development, *Climate finance provided and mobilised by developed countries in 2013-2022*. (2024). https://doi.org/10.1787/19150727-en

[71] K. M. Eisenhardt, *Academy of Management Review*, 1989, **14(4)**, 532-550.

[72] R. K. Yin, *Case study research and applications, 2018,* **6**, 200-224.

[73] G. Sandin, M. Lidfeldt, M. Nellström, *Sustainability*, 2025, **17(5)**, 931-954.