

Article Review

## Green Technological Investments and Their Impacts on Ecological Innovation in Entrepreneurship

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Submitted: 19/11/2025

Revised: 27/11/2025

Accepted: 30/11/2025

### Abstract

*Green technology investments-public and private capital invested in renewable energy, resource efficiency, circular economy solutions, and other low-carbon technologies-are widely argued to catalyze ecological (eco-) innovation among entrepreneurial firms. This review synthesizes theoretical frameworks and empirical evidence on how green investments influence ecological innovation in entrepreneurship. We organize the literature around four mechanisms-finance and risk reduction, knowledge/technology transfer, market signaling and demand creation, and institutional/policy levers-and summarize sectoral heterogeneity, enabling conditions, barriers, and policy implications. Two short summary tables highlight empirical studies and policy instruments; a conceptual figure illustrates the mechanisms linking green capital to eco-innovation. We conclude with practical recommendations for entrepreneurs, investors, and policymakers and point to promising directions for future research.*

**Keywords:** *Green technology, investments, innovation, entrepreneurship.*

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### Introduction

The UN SDGs, especially in climate action and environmental sustainability, are gaining more focus. Green and emerging technologies offer a vital opportunity to further these goals by accelerating the shift toward environmentally responsible production, consumption, and infrastructure [1–5].

Entrepreneurial activity represents a key vehicle for bringing green technologies to market: small firms and startups often pursue radical product or business-model innovations that incumbent firms avoid because of organizational inertia, risk aversion, or lock-in to existing technologies. Indeed, sustainable entrepreneurship tends to thrive in the “new entrant” space, as incumbents may face structural barriers and be less willing to disrupt existing business models. Hockerts and Wüstenhagen [6], argue that new entrants are more flexible and open to sustainable innovations, while incumbents are more constrained by existing routines and legitimacy concerns. Sustainable entrepreneurs also report higher perceived institutional barriers and financing constraints (e.g., risk, lack of support) compared to conventional entrepreneurs.

Entrepreneurs are typically more willing to experiment with up-and-coming renewable energy systems, circular-economy solutions, bio-based materials, and digital sustainability tools. For instance, university spin-offs in sustainable energy (wind, solar, biomass) demonstrate high risk-taking and innovation behavior, particularly when embedded in rich collaborative networks [7]. Through absorptive capacity, startups can integrate external knowledge (from universities, research institutions) into their green

product and process innovations [8]. This relative agility positions entrepreneurial ventures as central players in the transition to low-carbon and resource-efficient economies. Green entrepreneurs frequently pioneer in renewable energy, energy efficiency, and circular business practices [9,10].

Entrepreneurial ecosystems nevertheless remain structurally resource constrained. The scarcity of internal capital, restricted access to traditional bank lending, and intrinsically higher uncertainty surrounding green technologies often hinder development during the early stages. Green startups often face more severe financing constraints than other new firms, due to information asymmetries, unproven technologies, and uncertain demand. It is here that access to green capital-targeted financial resources explicitly channeled toward environmental or climate-related innovation can make an outsized difference in enabling eco-innovation and determining whether promising ideas move beyond prototype stages [11–13].

Policymakers, multilateral agencies, and private investors have, over the last decade, increasingly recognized this challenge and deployed numerous financial and policy instruments to stimulate green innovation. Mechanisms include green bonds that mobilize large-scale, low-cost capital for environmentally aligned projects; dedicated green venture funds that provide early-stage equity financing; subsidies and tax credits that reduce operational costs or incentivize R&D activities; feed-in tariffs and renewable portfolio standards that create predictable revenue streams for renewable energy entrepreneurs; and green public procurement programs that generate early markets for innovative, sustainable products and services [14,15].

Empirical evidence supports the importance of these instruments. For example, green bond issuance has been linked to improvements in firms' environmental performance and increases in R&D for eco-innovation. Green finance (e.g., green funds, bonds) has been shown to alleviate financing constraints, thereby boosting firms' green technology innovation. Furthermore, the interaction between technological innovation and green finance is mutually reinforcing higher levels of green finance amplify innovation's impact on renewable energy consumption and CO<sub>2</sub> reduction. Feed-in tariffs (FITs) provide long-term revenue certainty, which is particularly valuable for renewable energy start-ups, despite risks associated with regulatory changes. Each of these instruments operates through distinct channels, which range from alleviating financial constraints to shaping demand expectations, and yet altogether they have reshaped the innovation landscape for sustainability-oriented startups [16–19].

## **Material and method**

This overview begins by outlining the general definitions and scope of the topic, followed by an exploration of key areas including theoretical frameworks on how green investments drive eco-innovation, strategies for financing and addressing resource limitations, risk mitigation and signaling, knowledge transfer, network formation, and capability development. It also addresses the market dynamics, empirical evidence, and the role of green capital in fostering green innovation. Furthermore, it examines the heterogeneity of these processes, the significance of instrument design particularly the distinctions between capital, regulation, and procurement and the persistent challenge of early-stage financing for green startups. The review concludes by discussing barriers to progress and enabling conditions for success. To gain a comprehensive understanding of these interconnected themes, each topic was critically analyzed. A thorough and systematic scientific search was conducted across major academic databases, using targeted keywords that highlight related concepts. Relevant literature from key agencies and peer-reviewed sources was included, with the collected material categorized by themes and extensively reviewed. The search also encompassed prestigious databases such as Scopus, JSTOR, Web of Science, and Google Scholar, employing pre-established keywords.

## **Definitions and scope**

Green technology investments are financial resources channeled specifically into technologies, projects, or firms whose core business is environmental improvement. Examples include renewable energy, energy-efficient products, and waste-to-resource options. These involve public subsidies, concessional finance, green bonds/funds, corporate venture capital with environmental mandates, and impact investments. Ecological innovation in entrepreneurship means the development, diffusion, or adoption of products, processes, organizational forms, or business models by entrepreneurial firms that reduce environmental impacts or enable resource-efficient outcomes. Eco-innovation encompasses everything from incremental process optimizations to radical new technologies that transform markets. This review focuses on empirical and conceptual literature that deals with the causal or associative relationship between

green finance/investment and eco-innovation outcomes for entrepreneurial firms-which include SMEs and start-ups-and the institutional or policy contexts that mediate those relationships. Large incumbent R&D-only studies are considered where relevant mechanisms translate to smaller actors [20,21].

### **Theoretical pathways: How green investments influence eco-innovation**

Scholars identify several complementary mechanisms by which green investments can impact ecological innovation among entrepreneurs. We describe below four principal pathways and the underlying theory behind each.

#### ***Financing and overcoming resource constraints***

Startups and small firms are particularly financially constrained: they have limited retained earnings, face difficulties in accessing bank credit, and their projects are perceived as very risky. Targeted green investment-either equity, debt, or grants-directly alleviates their financing constraints, thereby allowing them to devote resources to R&D, prototyping, and commercialization of eco-innovations. There is support from empirical studies at the corporate level, while the same logic also applies to entrepreneurial ventures [22].

#### ***Risk reduction and signaling***

When public agencies or reputable green funds invest, the funding sends a signal that reduces information asymmetry and perceived technical or market risks. This may attract follow-on private capital, customers, and industrial partners that can accelerate diffusion. Instruments such as government co-investment, guarantees, and proof-of-concept grants have an important de-risking role.

#### ***Knowledge transfer, networks and capability building***

Beyond just money, green investments often come with much-needed nonfinancial assets: technical assistance, managerial expertise, network access, and partnerships with research institutions. Venture funds with sector expertise, climate-oriented accelerators, and public R&D programs can transfer this tacit knowledge, while helping entrepreneurs develop absorptive capacity for eco-innovation. University-industry-government partnerships also create knowledge flows essential for deep-tech green innovations.

#### ***Market***

Green investment-linked policy instruments are, for example, feed-in tariffs, public green procurement, and renewable portfolio standards that create predictable demand and revenue streams for green products and services. Predictable markets lower commercialization risk and encourage entrepreneurs to innovate for that demand. Public procurement has been shown to stimulate firm innovation when it creates early and sustained demand for greener products.

### **Empirical evidence**

The empirical literature has grown rapidly. Findings vary by dataset, country, firm type, and instrument, but consistent patterns appear.

#### ***Green capital promotes green innovation***

Panel studies of listed firms and firm-level datasets show positive correlations between green investment and eco-innovation metrics, such as green patenting and R&D expenditure on green projects. For example, one comprehensive Chinese firm-level analysis found that green investment significantly enhances firms' green innovation, with the effect being stronger in private firms and competitive industries, largely via easing financing constraints.

#### ***Heterogeneity***

Effects are heterogeneous: green investment is more effective for private firms and startups with limited internal capital than for state-backed incumbents; highly competitive sectors appear to magnify the innovation response; capital intensity and technology maturity shape results-nascent deep-tech requires longer horizons. A few studies also find that innovation responses are stronger where investments are combined with supports for building capability.

#### ***Instrument design matters-capital vs. regulation vs. procurement***

Purely financial injections are the most effective when combined with non-financial support or regulatory signals. Public procurement and feed-in tariffs, for instance, have historically accelerated renewable energy technologies by providing revenue certainty. Conversely, poorly targeted subsidies create rent-seeking without sustained innovation.

#### ***Early-stage financing remains a bottleneck for green startups***

Systematic literature reviews note that early-stage green startups still face financing gaps: angel and seed funding for environmentally oriented ventures is constrained by higher perceived risk and longer time-

to-market, especially for hardware and deep-tech innovations. Blended finance, accelerators, and stepped public funding are some mechanisms that show promise in empirical and review studies.

**Table 1. Selected empirical studies on green investment**

Study (author, year)	Country / sample	Instrument / variable	Key finding
Zhang, Shou & Li (2024)	China; listed firms 2012–2022	“Green investment” flows to firms (financial)	Positive effect on green patenting and R&D; stronger for private firms and competitive industries; mechanism: alleviating financing constraints
Mukherjee (2024)	Global literature	Early-stage finance types	Identifies persistent seed/angel gaps; highlights role of blended finance and accelerators to bridge gaps.
OECD (2014)	Cross-country policy analysis	FITs, RE incentives	Policy certainty (e.g., feed-in tariffs) attracted investment and spurred renewable innovation; design matters for cross-border flows.
Fusillo et al. (2025)	EU/Italy; firm data	Green public procurement (GPP)	GPP associated with higher probability of firms introducing green innovations.

**Table 2. Common green finance instruments and typical effects on entrepreneurship**

Instrument	Typical direct effect on entrepreneurs	Common co-benefits / risks
Green equity / VC funds	Provide growth capital; technical mentoring if sector-specialist	Follow-on financing attracted; risk of short horizons if VC exit pressure
Green bonds / concessional debt	Lower cost capital for capital-intensive projects	Enables scaling; may exclude early-stage startups without credit history
Grants / proof-of-concept funding	Support R&D and prototypes; non-dilutive	High impact for early stages; limited scale per project
Public procurement (GPP)	Creates demand pull, early market for new products	Can de-risk commercialization; procurement design determines innovation incentives

**Barriers and enabling conditions**

*Barriers*

Financing gaps at earliest stages: Many green hardware/deep-tech ideas require significant prototyping capital before product market fit can be reached. Angel/seed markets often undersupply these stages.

Regulatory uncertainty: unstable policy expectations—for example, abrupt elimination of subsidies—reduce expected returns and consequently deter entrepreneurial innovation.

Limited absorptive capacity: The firms that lack skilled personnel or R&D networks may not benefit from the available funds alone.

Misaligned incentives and short-termism: investors seeking quick exits may push entrepreneurs toward incremental or marketable features rather than deeper system innovations.

*Enablers*

Blended finance/de-risking instruments include guarantee facilities and first-loss capital, which mobilize private investors in risky but high-impact green ventures.

Sector-specific accelerators and technical assistance: accelerate firm capabilities, attract appropriate investors.

Stable, predictable demand signals: Long-term price/tariff policies or procurement commitments create pathways to commercialization. Networks which link research, industry, and finance: university spinouts and clusters benefit strongly where the flow of knowledge is supported [23].

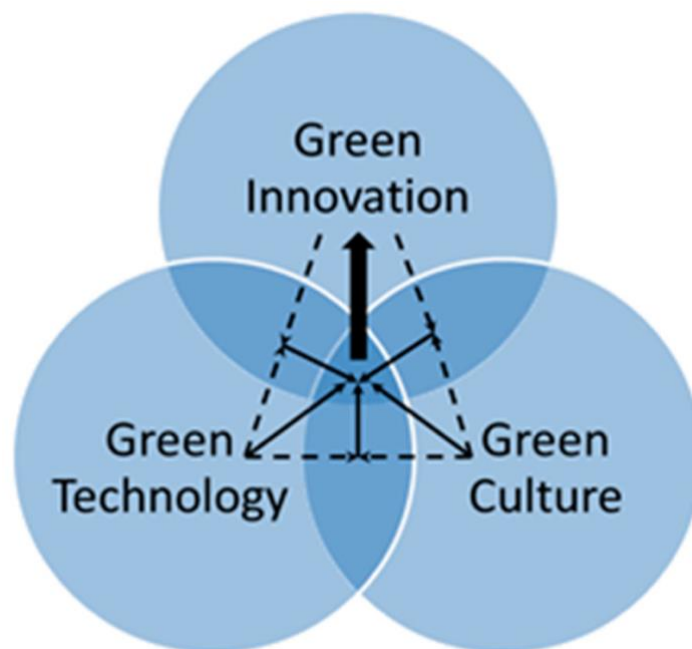
### Policy and investor implications

From reviewed evidence, a few implications arise:

Design finance instruments to match technology maturity: early-stage grants and proof-of-concept funding are most effective for green technologies in the nascent stage, while green bonds and concessional debt suit scale-up stages. Blended finance structures can bridge capital gaps across stages. Combine capital with capability building investments that incorporate technical assistance, mentoring, or links to labs generate better innovation outcomes than pure capital injections. This makes sector-specialist funds and accelerators especially valuable. Strategic use of demand-side instruments: public procurement and credible price support create predictable markets that reward innovation and unlock private capital. Procurement criteria should increasingly favor life-cycle environmental performance to provide a premium for eco-innovation.

Reduce policy volatility: Long-term, consistent policy frameworks lessen perceived risk and mobilize sustained investment into entrepreneurial eco-innovation. Measure outcomes beyond dollars invested: Investors and policymakers should monitor downstream innovation outcomes, such as patents, product launches, and emissions avoided, to measure effectiveness.

Figure 1. Implications for entrepreneurs should consider green capital not only as finance but as a bundled source of learning, networks, and legitimacy. Practical steps include Apply blended funding (grant + equity) when possible, to reduce dilution and obtain support for prototyping. Taylor & Francis Online Target investors or programs offering sector expertise and market linkages. Engage early with potential procurers or off-takers, including public buyers, to align product development with demand requirements. SpringerLink 9. Directions for future research While the literature is expanding, there are still gaps: Causal evidence at the level of startups: More quasi-experimental and panel studies identifying causal effects of specific instruments on entrepreneurial eco-innovation are needed, for example, by exploiting policy discontinuities or randomized grant experiments. Frontiers Longitudinal studies of impact and survival: how green investment affects firm survival, scaling, and net environmental impact over longer horizons deserve deeper study. Taylor & Francis Online Comparative cross-country analyses: Which institutional mixes- finance instruments plus regulatory frameworks-produce the largest innovation multipliers across contexts? OECD Investor behavior and exit dynamics: research into how investor time horizons and exit expectations shape the type of eco-innovation pursued by entrepreneurs would inform fund design. IFC 10. Conceptual model (figure) This is a compact conceptual figure showing four mechanisms that link green investments to eco-innovation outcomes in entrepreneurship. These are: (1) financing relief, (2) de-risking and signaling, (3) knowledge & capability transfer, and (4) creation of demand through policy instruments. The figure stresses a feedback loop-successful Eco innovation can, in turn, attract more investment and stronger policy support [24–26].



**Figure 1.** Venn/conceptual model of green technology, green innovation, and enabling culture/networks (source: conceptual frameworks in the literature).

## Conclusion

In entrepreneurship, green technology investments matter for ecological innovation, but their effectiveness depends critically on instrument design, firm capabilities, sector characteristics, and policy stability. Financial capital is necessary yet often insufficient: the most effective interventions combine money with capability building, credible demand signals, and de-risking mechanisms that attract additional private capital. For entrepreneurs, the key to successful eco-innovation lies in matching financing strategy to technology maturity and finding investors who can provide supportive nonfinancial resources. And for policymakers and investors, the message is clear: tailor instruments to stage, combine finance with technical support, and create predictable demand to turn green capital into durable innovations and measurable environmental impact.

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