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RESEARCH ARTICLE

Renewable Energy Investment and Business Models

*Dr. Rajesh Singh Shekhawat

*Assistant Professor, Department of Electrical Engineering, at B K Birla Institute of Engineering and Technology, Pilani

ABSTRACT

Despite the rapid growth in global investment in renewable energy technologies, in 2024, this amounted to a record high of USD 807 billion, but the majority of global energy transition is happening in some of the most advanced economies and in China, where together global REn discusses 90% of energy transition investments, particularly solar PV technologies (Solar PV: USD 554 billion, 69%). To achieve the internationally agreed climate targets, an estimated annual investment of nearly USD 1.4 trillion in renewable power has been needed between 2025 and 2030, almost double the current investment portfolio, highlighting the design of business models to mobilise and de-risk capital at scale as a current practitioner and policy concern. The primary models of renewable energy investment – including centralized utility-scale (CUPPA, YieldCo and merchant), distributed (direct ownership, TPO/L, SaaS subscription) and community based (energy cooperatives, community solar, crowdfunding) are examined and synthesized with their respective policy and capital market instruments: feed-in tariff, tax rebates, and green bonds. Adopting ideas from the energy-policy and operations-management literature, the paper classifies business models based on two dimensions: ownership structure, and deployment size, and provides a comparative analysis of the models based on illustrative examples of performance on the dimensions of capital-intensity, consumer-accessibility, scalability, risk-transfer, and revenue-predictability. The study reveals that none of these business models is the superior one in all these attributes; corporate PPAs and YieldCos optimise for the largest scale and transfer of investor risk, but these are not the most accessible models of operation; community model and subscription model maximise accessibility, but at the expense of scalability and the amount of capital per unit of capacity. They end with policy implications for bridging the investment gap in emerging markets and suggestions for the way forward in research on hybrid and blended finance business model innovation.

Keywords: *Business Models for Renewable Energy investment, Power Purchase Agreements, Energy Communities, Green Bonds, Feed-in tariffs, Third-party ownership, Energy transition finance-Power and renewable energy..*

INTRODUCTION

The global energy transition is now in a stage where financing and institutional consideration have become key factors rather than technology, to overcome the remaining challenges of renewables deployment. Collectively, investments in renewable power, grid and battery storage surpassed those in fossil fuels for the first time in 2024, while costs of renewable technologies have declined to the point that 91% of all new renewable power capacity installed worldwide is more-cost competitive than any new fossil-fuel technology available. However, even as the amount of investment that needs to increase, the growth rate is decreasing: renewable energy investment grew 7.3% year-on-year in 2024, sharply down from 32% growth the previous year and an average of nearly USD 1.4 trillion annually is needed between 2025 and 2030 to support a 1.5°C pathway (International Renewable Energy Agency [IRENA] & Climate Policy Initiative [CPI], 2025).

This overall total of capital invested contains a multitude of various and constantly developing solution models that actually implement capital mobilization, risk distribution and delivery of renewable energy to the end user.

*Assistant Professor, Department of Electrical Engineering, at B K Birla Institute of Engineering and Technology, Pilani.

Email-id: P20170503@pilani.bits-pilani.ac.in

Corresponding Author: Dr. Rajesh Singh Shekhawat
Assistant Professor, Department of Electrical Engineering, at B K Birla Institute of Engineering and Technology, Pilani

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The same technology (a solar panel or a wind turbine) can be financed and monetized in a multitude of ways: have a vertically integrated power company use the rooftop space, buy from a company with a long-term power purchase agreement (P.P.A.), lease to a homeowner by a technology expert third party, or have a community solar company collectively own the technology. The capital commitment, operational risk, and RoI – financial return – vary for each setup, and each has evolved in response to a unique policy context, market maturity and customer segment – according to Richter (2012).

In this paper we are concerned with two related questions. What is the scale and technology mix and distribution (geographically) of the current landscape of renewable energy investment? Second, what are the core business models by which this investment is organized, where do they differ on important parameters like ownership, risk sharing and availability, and what could this difference in the structure of investment mean for bridging the huge investment gap which remains, unequal as it is? The paper brings together the newest empirical investment data obtained from IRENA, Climate Policy Initiative and the literature of operations management, energy policy and business models (B2B) for the purpose of developing an integrated classification framework and comparative analysis to support investors when choosing between financing structures and to support policymakers in designing enabling frameworks.

2. Literature Review

2.1 Policy-Driven Financing Instruments

In many markets, policy instruments have been put in place to remove investment risk in the absence of merchant markets, enabling the successful deployment of renewables in the early stages and sustaining that momentum since. The two predominant types of policies are feed-in tariffs (FiTs), which pay a set price for renewables over the contract term, and capital-side incentives, such as investment tax credits or up-front rebates. Alizamir, de Véricourt, and Sun (2016) create efficient frameworks for the design of feed-in tariff policies, taking learning curves of PV technology costs into account, and Babich, Lobel, and Yücel (2020) directly compare the policies of feed-in tariff and tax rebate as two policy instruments for encouraging the investment in solar panel technologies and conclude that policy effectiveness depends on capacity-constrained supply chains, and on the budget and adoption goals of the government. These policy-design studies show that financial support options significantly affect the rate of renewables deployment and their allocation, beyond changes in the relative cost curve.

2.2 Market-Driven Procurement: corporate power purchase agreement (PPA)

2.5 Community & peer to peer energy business models

With renewable subsidies declining in many mature markets, a growing number of corporate PPAs have become a market-driven procurement solution, as generators can count on a steady income stream from the contract and corporate offtakers can achieve greater price stability and use clean energy as proof of their sustainability efforts. There are two main types of PPAs: the "sleeved" PPA (physical PPA), where the two parties are physically connected and the electricity is delivered from the generator to the corporate offtaker, which has been the predominant variant in Europe; and the "synthetic" (virtual/financial) PPA, which uses the strike price method to determine the settlement and prevail in the United States. Market-driven procurement methods, such as corporate PPAs and merchant deals, will add some 20 per cent of global utility-scale solar and wind capacity by the end of the period, and more than 33 per cent if China (with policy-driven procurement still prevailing) is not included, according to the International Energy Agency (2023).

2.3 Seeking a Utility Business Model Evolution

Depending on how decentralized renewable generation disrupts the "centralized-generation revenue model," it is possible for incumbent utilities to take one or more of various strategic positions: either be vertically integrated building and owning renewables projects, or take the role of a project developer/how a project is financed, or be a non-proprietary service provider where the supplier is no longer playing a role in building or owning generation projects. This taxonomy remains a benchmark for categorising incumbent actors' adaptation to distributed and market-oriented renewables and forms the basis of the classifying Dimension of ownership-structure, defined in Section 3.

2.4 Models of Third Party Ownership (TPO) and Non-Ownership Models

Non-ownership business models have been key to solar power's customer-sited distributed energy adoption in the segments where households and small businesses lack capital and expertise: typically, those that own the PV asset lease it out to the parties who can use it (through a PPA) and that parties who need a specific unit purchase the electricity it generates. Agrawal et al. (2022) formally examine these non-ownership solar business models and show how they can unlock solar markets for customers constrained by capital or risk-averse, compared with direct ownership models, while shifting performance and technology risk to the third-party owner. Taking this one step further are subscription models that advance the "Solar-as-a-Service" concept by turning the customer's contract for renewable power into just another motor bill, shifting responsibility for asset ownership away from both investors and customers.

Business models that pool resources across different participants, including community-based distributed generation, exist where DGs are not available to individual consumers, such as customers who rent their homes or whose roofs face the wrong direction or who lack the funds to install them. As policy support has faded, Nolden, Barnes and Nicholls (2020) show how the community energy business models in England have changed into three archetypal stages, and how new actors—communities, finance brokers, venues and software developers—are becoming the intermediaries facilitating the creation of more complex commercial deals on the community's behalf, potentially a vital mechanism for keeping communities engaged in a post-subsidy era. Overall, a more general empirical typology of business models for energy communities, based on revenue streams, customers and types of resources was proposed by Reis, Gonçalves, Lopes and Antunes (2021), identifying 144 energy community models that can be divided into three main groups: the customer-owned type; the third-party-service type; and the energy-community type, which can serve as a systematic typology to compare community models with the utility-scale and distributed-ownership types mentioned above.

The Capital Market Instruments – Green Bonds and Project Finance topic provides a general introduction to the Green Bond market and the project-finance model.

All these business models are based on capital-raising instruments that raise capital for the underlying investment. Green bonds are now a significant source of financing for renewable energy, with over 62% of the green bond proceeds in the period 2007-21 earmarked for renewable energy related projects, and the available evidence suggests that the number of green bonds issued is positively related to renewable energy related investment and lending, especially in transitioning Asian economies. But currency risk, political stability and parallel creditworthiness of the offtaker issues – prominent in developing economies – have created an underusage of green bonds or green-finance instruments in general, providing an impetus for further innovations in the forms of green bonds, including floating rate, outcome-linked and asset-linked green bond structures that could help reduce the exposure of investors to risk in these markets. The first in-depth layer of the capital market also has direct links to the business-model layer; the corporate PPA or YieldCo is effective as much as the debt and equity instruments that fund the project.

2.6 Synthesis

Table 1 combines the six renewable energy business model archetypes from literature and synthesised according to their key value proposition, primary financing source and typical risk allocation.

Business Model Archetype	Core Value Proposition	Primary Capital Source	Risk Allocation	Representative Source
Utility-scale corporate PPA (sleeved / synthetic)	Long-term price certainty for both generator and corporate offtaker without subsidy dependence	Project finance debt + corporate offtake-backed equity	Price/volume risk shared via fixed or floor pricing; offtaker credit risk borne by generator	IEA (2023); Corporate PPA market reports
YieldCo / project-finance-backed IPP portfolio	Aggregation of operating renewable assets into a low-risk, dividend-yielding public vehicle	Public equity + long-term project debt	Operating and merchant-price risk retained within portfolio; investors receive stabilized yield	Richter (2012)
Third-party ownership (TPO) / leasing / RESCO	Removes upfront capital and O&M burden from the host customer	Third-party developer equity and debt, repaid via host payments	Asset and performance risk transferred from customer to third-party owner	Agrawal, Toktay, & Yücel (2022)
Solar-as-a-Service (subscription)	Predictable, often lower, recurring energy payment with no ownership responsibility	Provider-financed capex, recovered through subscription fees	Provider bears asset and performance risk; customer bears counterparty/provider-solvency risk	Agrawal, Toktay, & Yücel (2022)
Community solar / energy cooperative	Enables participation (and shared savings) for customers unable to host on-site generation	Member equity, cooperative financing, and increasingly commercial debt	Risk shared across community members; increasing reliance on intermediaries for complex contracts	Nolden, Barnes, & Nicholls (2020); Reis, Gonçalves, Lopes, & Antunes (2021)

Business Model Archetype	Core Value Proposition	Primary Capital Source	Risk Allocation	Representative Source
Feed-in-tariff / tax-rebate-supported ownership	Guaranteed or subsidized revenue stream that de-risks early-stage or small-scale investment	Owner equity supplemented by policy-guaranteed revenue or upfront rebate	Policy design allocates risk between government (price risk) and owner (volume/performance risk)	Alizamir, de Véricourt, & Sun (2016); Babich, Lobel, & Yücel (2020)

Table 1. Synthesis of renewable energy business model archetypes.

3. The Global Renewable Energy Investment Landscape

Before classifying business models, it is useful to establish the scale and composition of the investment they are mobilizing.

Table 2 summarizes key figures from recent IRENA and Climate Policy Initiative reporting.

Metric	Value	Year	Source
Total global renewable energy investment	USD 807 billion	2024	IRENA & CPI (2025)
Solar PV investment (share of total)	USD 554 billion (69%)	2024	IRENA & CPI (2025)
Battery storage manufacturing investment	USD 74.5 billion (+112% y/y)	2024	IRENA & CPI (2025)
Share of investment in advanced economies + China	≈ 90%	2024	IRENA & CPI (2025)
Global renewable capacity investment growth	USD 448B → USD 570B (+27%)	2022–2023	IRENA (2024)
Required annual investment for 1.5°C-aligned pathway	≈ USD 1.4 trillion / year (2025–2030)	Target	IRENA (2025)

Table 2. Key global renewable energy investment metrics.

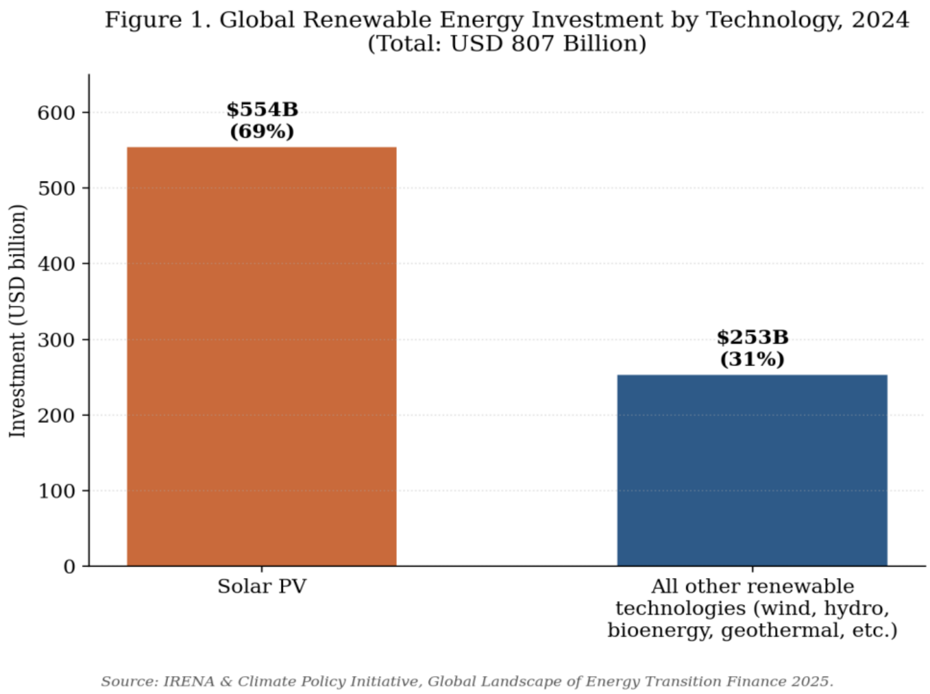

Figure 1. Global renewable energy investment by technology, 2024.

Investment in solar PV is also by far the largest among current renewables, as shown in Figure 1, and costs are still being dramatically reduced; the technology can be used not only as a centralised utility-scale technology, but also as fully distributed technologies, as discussed in Section 4. This unique multi-scalability of solar PV has direct implications for its appropriate business model: it is compatible with all four quadrants of the business model classification adopted in Section 4.1, which likely helps explain the large proportion of investment in solar PV compared with other, more scale-limited technologies such as wind.

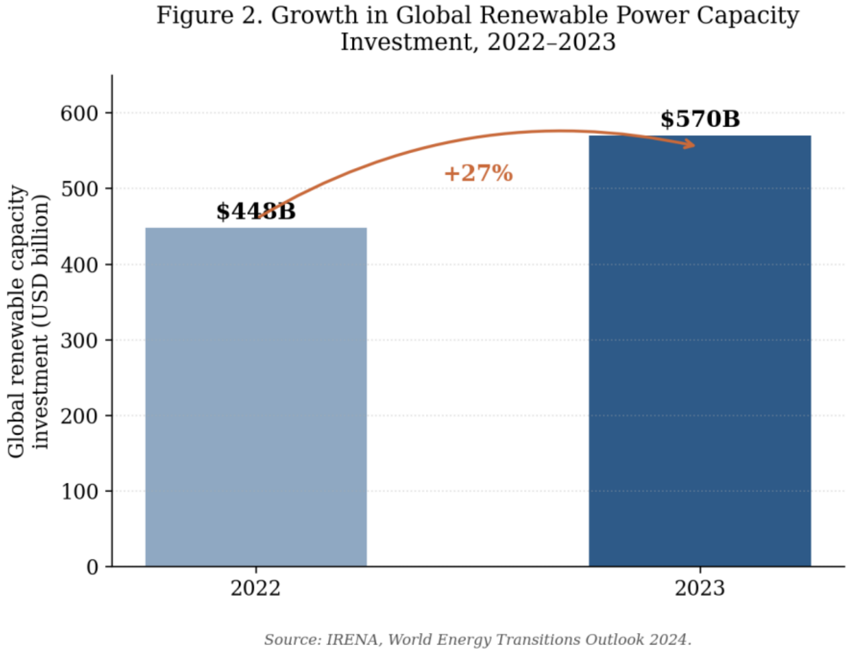

Figure 2. Growth in global renewable power capacity investment, 2022–2023.

Figure 2 shows the strong year-on-year growth in renewable capacity investment reported ahead of the record USD 807 billion 2024 figure, though it is worth noting that successive IRENA reports have refined and broadened the technology and investment-category scope covered between report editions, so year-on-year comparisons across different report vintages should be interpreted as indicative of strong directional growth rather than as a strictly continuous single time series. What both figures agree on is the underlying conclusion most relevant to this paper's focus: despite record absolute investment levels, growth decelerated in 2024 relative to 2023 even as the required investment trajectory to meet climate targets continues to steepen, and approximately 90% of this investment remains concentrated in advanced economies and China (IRENA & CPI, 2025), leaving emerging and developing economies — which will host a large share of future energy demand growth — comparatively starved of capital. This concentration motivates the discussion of investment barriers in Section 5.

4. A Classification Framework for Renewable Energy Business Models

4.1 Two-Dimensional Classification

Building on Richter's (2012) utility business model spectrum and the ownership-structure distinctions developed by Agrawal et al. (2022) and Reis et al. (2021), this paper classifies renewable energy business models along two dimensions: (i) deployment scale, ranging from centralized/utility-scale to fully distributed/on-site generation, and (ii) ownership structure, ranging from customer or community ownership to third-party or institutional ownership. Figure 3 maps twelve representative business model archetypes onto the resulting quadrants.

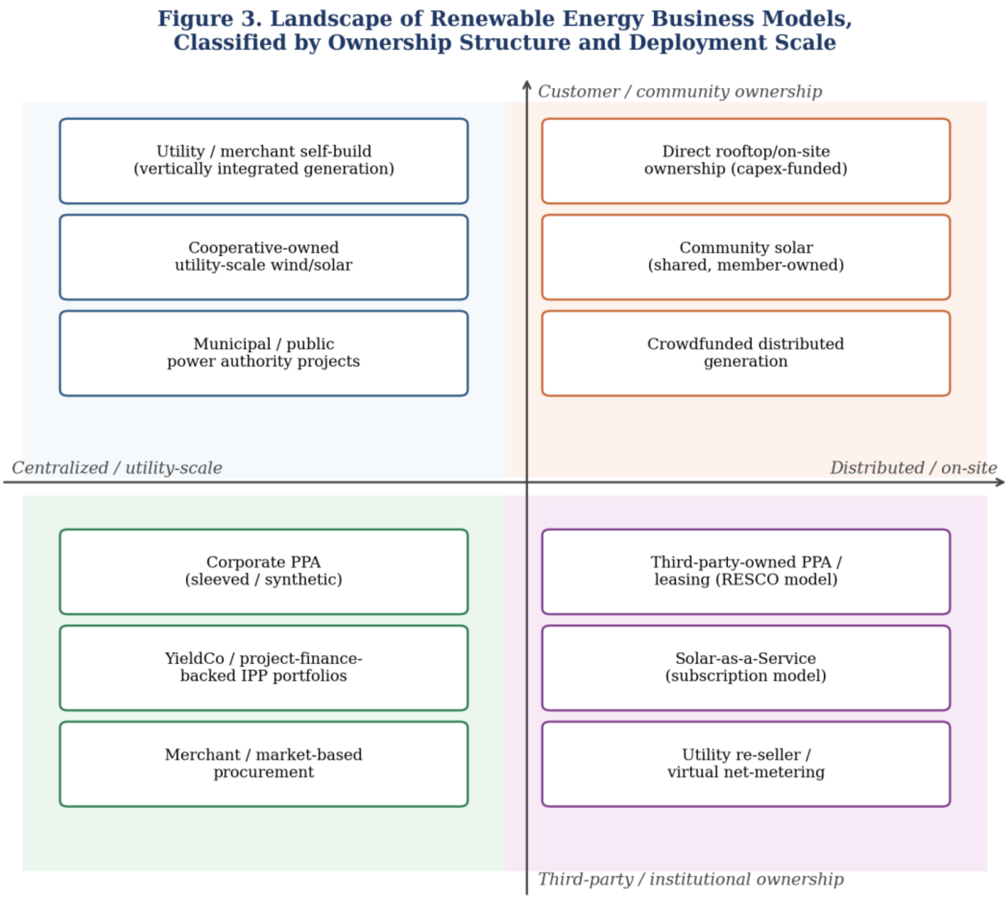

Figure 3. Landscape of renewable energy business models, classified by ownership structure and deployment scale.

The entire classification exemplifies a structural pattern: in the upper quadrants (customer/community ownership), the customer or community would directly and solely own the capital and receive the capital and performance risk and the economic benefits, whereas in the lower quadrants (third-party/institutional ownership), the capital and the capital and performance risk would be pooled to specific investors and/or developers, and the customer or community would receive a share of the economic benefit. Over the last 10 years, innovation in business models—most notably third-party ownership, Solar-as-a-Service, and community-solar-with-intermediary—has been interpreted as an ongoing attempt to remove the up-front investment and risk hurdles that the direct-ownership model (upper-left/upper-right, in past decades) imposed on adoption.

4.2 Comparing the performance of business models

For example, to compare four well-documented archetypes—corporate PPA, YieldCo, Solar-as-a-Service and community solar, Figure 4 displays illustrative expert-judgement assignments on capital intensity of the investor, consumer accessibility, scalability, investor risk transfer, and revenue predictability. Use these scores as illustrative; they encapsulate a pattern of qualitative statements from the reviewed literature in a comparable visual format, rather than being based on a specific quantitative data set.

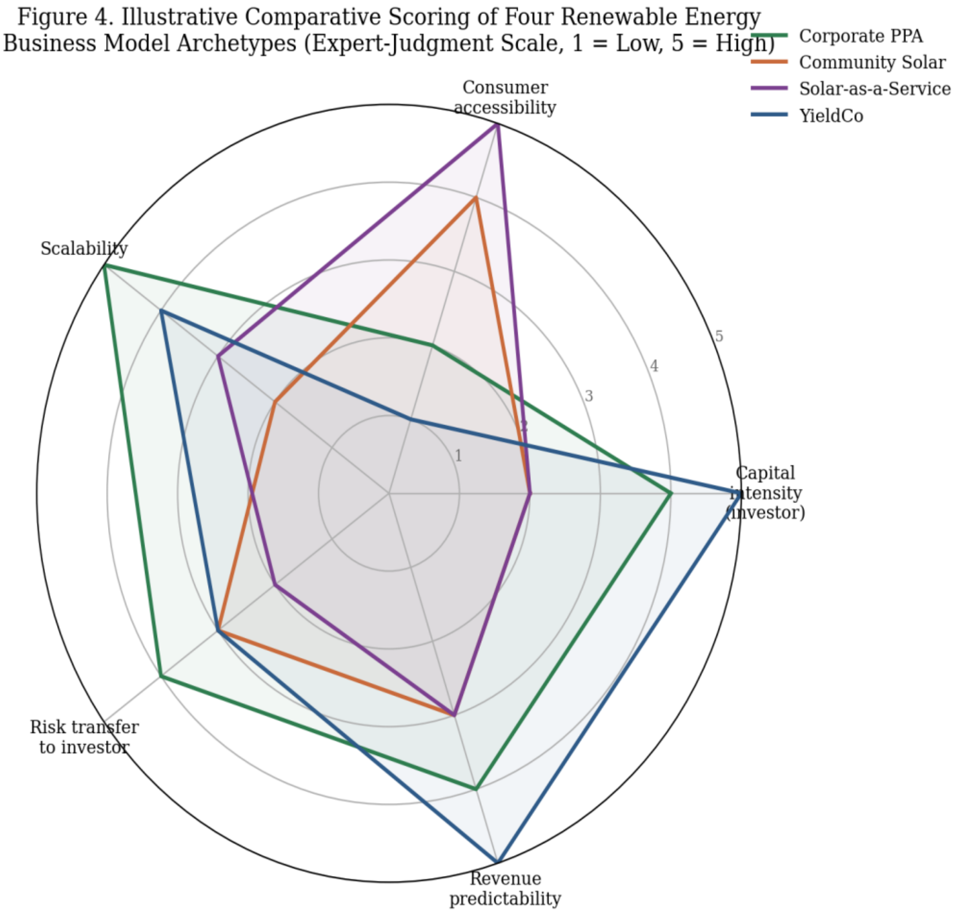

Figure 4. Illustrative comparative scoring of four renewable energy business model archetypes.

As shown in Figure 4, there is a clear relationship – corporate PPAs rate highly on scalability, risk transfer and revenue predictability; their downside effect on consumer accessibility reflects their institutional-investor focus; Solar-as-a-Service and community solar achieves the opposite numbers, maximising accessibility at the cost of scalability, risk transfer and a more predictable institutional-grade return. No single archetype prevails across all five dimensions, reflecting the underlying observation that it is not a question of one winning business model converging to dominate renewable energy markets, but of multiple distinct business models existing in parallel. For comparison, Table 3 presents key characteristics of each of the four archetypes, including the typical size of a project, the driving factor that leads to investor returns, as well as the issue of 3rd party ownership/leasing.

Dimension	Corporate PPA	YieldCo	TPO / Leasing	Solar-as-a-Service	Community Solar
Typical project scale	Utility-scale (MW–GW)	Portfolio of utility-scale assets	Commercial / residential (kW–MW)	Residential / small commercial	Distributed, shared (kW–MW)
Customer capital outlay	None (offtake contract only)	Public share purchase (investor)	None to low	None (subscription fee)	Low–moderate (membership stake)
Market maturity (as of literature reviewed)	High in North America / Europe	Mature in US; growing elsewhere	Mature in mature retail markets	Emerging / growing	Mature in EU; policy-dependent
Primary investor return driver	Contracted offtake price	Dividend yield from asset portfolio	Host payments over contract term	Subscription fee cash flow	Member equity return / savings share

Table 3. Comparative summary of representative business model archetypes.

5. Investment Barriers and the Emerging-Market Gap

This focus – on advanced economies and China, where IRENA & CPI estimates about 90% of all global renewable investment is concentrated – is driven not so much by less competitive resource potential in emerging and developing economies many of which have better solar and wind resource potential, but a much more specific and challenging set of investment barriers. Green-finance literature tells us that, because of their disproportionate impact on emerging-market renewable investment, factors such as currency and macroeconomic risk, offtaker creditworthiness, and woody grid infrastructure have all been suggested as triggers for the market standardisation of potentially risk-mitigating structures like asset-backed or floating-rate green bonds to gear investor returns towards project or even ecological performance. The illustrative comparison shown in Fig. 5 on barrier severity in the advanced and emerging markets is based on the discussion found in the examined literature.

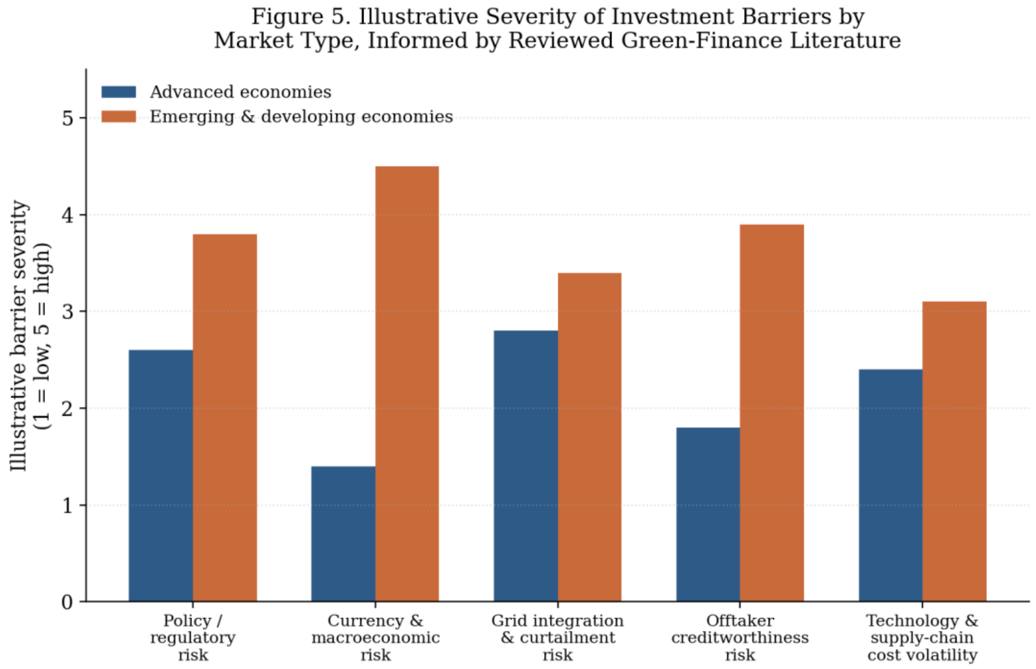

Figure 5. Illustrative severity of investment barriers by market type.

Based on the literature reviewed on green bonds and green infrastructure financing, the literature places the most emphasis on currency and macroeconomic risk and offtaker creditworthiness risk, as shown in Figure 5. The pattern indicates that, complement to business-model choices and the fact that risk allocation (micro-level) for projects through finance structures is governed by business model selection, risk mitigation/enhancement instruments (macro-level) that directly tackle macro-level barriers highlighted here rather than the micro-level remain essential to close the investment gap.

6. Discussion and Implications

Based on this analysis, three implications emerge. First, for investors, business model selection should be approached more as a portfolio decision based on risk taking capacity and return aspiration, rather than a unique search for the “next best” business model; institutional investors who are looking for a stable, bond-like return may find YieldCo or corporate-PPA-backed business models more attractive, while those who are looking for distributional/content objectives and access, may find community solar or blended third-party ownership business models more aligned with these objectives – despite less scalability. Second, within the technology and market-maturity spectrum, policy support and market mechanisms – in the form of feed-in-tariffs and tax rebates – have remained complementary for investors and project developers in mature markets, where corporate offtake markets exist; and are even more so for community projects and smaller-scale projects that do not reach these markets. Third, and most critically, particularly closing the gates to new markets where substantial investments were required to achieve a combined total of roughly USD 1.4 trillion annually for the period 2025-2030 would likely require business-model innovation – taking proven business models, such as third-party ownership and community solar, to new markets as well as financial-risk mitigation instruments tailored to the barriers to currency, politics and creditworthiness at play in these markets and as identified in Section 5 – in addition to organic market-driven business model diffusion.

7. Limitations and further research

- Comparative scoring in Figure 4 and the barrier-severity comparison in Figure 5 are example (qualitative) syntheses, not empirical results from a quantitative survey or econometric model; an expert-elicitation or investor-survey study could empirically validate and refine them.
- Year-on-year investment data reported in successive editions of IRENA's reports reflect dynamic inclusion/desorption of technology and category scope due to the evolution of technology and categories in general; as mentioned in Section 3, a harmonised and methodologically consistent time series will strengthen future trend analysis.
- This review focusses on business models for the electricity sector, with the application in renewable heating and transport receiving a relatively thin treatment due to the different nature of the technology and of its customers, which requires dedicated business model analysis.
- In practice, hybrid business models that mix features of various business models mapped in Figure 3 are emerging, such as community-owned assets financed via corporate PPA offtake, or YieldCoords with an embedded subscription-based retail component.
- A key direction for future research is empirical country-level analysis of which combinations of business-models and risk-mitigation-instruments can most effectively mobilise private capital in emerging market countries, thereby providing direct input in the discussion in Section 6.

8. Conclusion

This paper has outlined the global RE investment landscape and the main business models through which investments are organised and realised. While 2024 investments of USD 807 billion, led by solar photovoltaics, and a decelerating growth rate are two key characteristics, so too is the ongoing and pronounced geographic concentration of investments in advanced economies and China, which will not fill the approximately USD 1.4 trillion annual investment need for 2025-2030. Classification of business models based on two dimensions (ownership structure and deployment scale) shows that a consistent trade-off exists between scalability/investor risk transfer and consumer accessibility, as well as no dominant archetype that dominates both dimensions, suggesting that it is important to have a diverse business-model ecosystem operating in parallel as opposed to convergence on one particular business model. Filling the “investment gap” in emerging markets will likely take some more creative use of “proven” business-model innovations like third-party ownership, community solar, or corporate PPAs coupled with some more sophisticated risk-mitigation financial instruments that flavor the market in order to overcome the currency, political and creditworthiness obstacles that continue to prevent capital from flowing into the country that needs it the most.

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