Accelerating the Energy Transition in Emerging Markets

Strategies for unlocking investment

March 13, 2025

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About this report

This report was commissioned by the Climate Investment Funds (CIF), a multilateral climate fund housed within the World Bank and produced by BloombergNEF. It aims to improve understanding of how the CIF can unlock capital, spur the progress of clean technologies, and accelerate the energy transition in emerging markets. By analyzing an array of approaches, such as targeting technology deployment, driving coal phase-out efforts and pushing forward clean hydrogen, this report lays out potential pathways for CIF and other development institutions to provide quick, effective and lasting support for clean energy in emerging economies.

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About

The over $12 billion CIF is the pioneer multilateral climate fund, mobilizing low-cost finance for energy transitions and sustainable development in more than 80 countries. Established in 2008, CIF delivers funding exclusively through six AAA-rated multilateral development banks. In a world first, in 2025, CIF accessed capital markets to unlock private sector capital through the CIF Capital Markets Mechanism (CCMM).

CIF's high-quality funding mobilizes over $8 in co-financing for every $1 invested. This lowers risk and enables first-of-their-kind investments in clean energy, industry decarbonization, resilience and nature-based solutions. Our approach empowers developing countries, promotes just transitions and accelerates transformational change. Learn more on cif.org/

The Clean Technology Fund

CIF's $8.6 billion Clean Technology Fund aims to address the significant financing gap for energy transitions by mobilizing capital at scale and directing it towards high-impact programs in developing countries. In 2025, the CIF Capital Markets Mechanism (CCMM) raised $500 million for CTF through its inaugural bond issuance.

CTF invests in renewables; energy efficiency, storage, and integration; sustainable transport; and industry decarbonization. It supports developing countries by contributing concessional resources for the demonstration, deployment, and transfer of low-carbon technologies. With almost 40 million metric tons of CO2 equivalent in annual greenhouse gas emissions reduced or avoided since 2008, CTF achieves an expected co-financing ratio of 1:10.1.

BloombergNEF (BNEF) is a strategic research provider covering global commodity markets and the disruptive technologies driving the transition to a low-carbon economy. Our expert coverage assesses pathways for the power, transport, industry, buildings and agriculture sectors to adapt to the energy transition. We help commodity trading, corporate strategy, finance and policy professionals navigate change and generate opportunities.

[1] All data points for CIF and CTF are as of December 2023.

Acknowledgments

This report was commissioned by the Climate Investment Funds (CIF) and produced by BloombergNEF (BNEF).

Within CIF, the preparation of the report was managed and supported by Tariye Gbadegesin, Hugh Searight, Alessandra De Leo, Michael Robert Ward, Daniel Morris, and Paul Pulickal Mathew. Special thanks to former CIF colleagues who contributed to this work: Mafalda Duarte, Neha Sharma, Rahul Madhusudanan, Abishek Bhaskar, and Maria Ann Dumpert.

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It relies on the inputs of a broad range of experts who contributed their views, time and advice to the preparation of this document. For their comments, the report authors would like to thank Amanda Penistone (UK Government), Sumeet Manchanda (European Bank for Reconstruction and Development), Joseph Roshin Mathai (International Finance Corporation), Tendai Lilian Chakanaka Madenyika (International Finance Corporation), Joan Miguel Carrillo Cortada (Inter-American Development Bank), Matthieu Pegon (Inter-American Development Bank), Kidanua Abera Gizaw (African Development Bank), Kader Sanfo (African Development Bank), Andrey Shlyakhtenko (International Finance Corporation), Archi Rastogi (Green Climate Fund), Oscar Garcia (The Global Energy Alliance for People and Planet), Bright Ntare (Rwanda National Fund for Environment and Climate Change), Leonardo Beltran (Center on Global Energy Policy and Chair of CIF's E&L Advisory Group).

Section 1. Executive summary

Clean energy technologies have undergone a remarkable transformation over the past decade. Costs have dropped dramatically, and the perceived risk of investment has significantly declined. Solar and wind have emerged as the cheapest sources of electricity in many markets. And newer technologies are paving the way for decarbonizing hard-to-abate sectors and integrating more renewables into the grid. Yet, despite these global strides, energy transition investment in emerging markets[2] has remained constrained.

Accelerating the Energy Transition in Emerging Markets explores how the Climate Investment Funds (CIF) can help unlock investment flows in and to emerging markets. Focusing on five key technologies – solar, on- and offshore wind, batteries and clean hydrogen – the report considers how targeted interventions can drive down costs, speed buildout and establish an environment conducive to these technologies' deployment.

As the climate crisis continues to intensify, limiting global warming to 2C will require a comprehensive strategy that aligns stakeholder efforts around three key pillars: accelerating the deployment of mature technologies, phasing out carbon-intensive activities, and supporting the development and deployment of new technologies[3]. These pillars inform the structure of this study, with a particular focus on supporting renewables, speeding the phase-out of coal, and accelerating the development and deployment of clean hydrogen.

Accelerating the deployment of renewable energy technologies

Accelerating deployment of both established renewables and newer technologies is vital to decarbonizing the world's power systems and meeting future demand.[4] To effectively scale renewables in emerging markets, three high-impact measures are necessary: supporting an enabling environment, addressing country and market risks and accelerating economic competitiveness.

- **Most emerging markets have a renewable energy target but lack the policies to bring it to fruition.** While many countries have set renewable energy goals, weak policy frameworks and insufficient market structures prevent those targets from translating into actionable

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2 Full list of countries is available in Appendix C.

3 The pillars that form the structure of this report are based on the BloombergNEF NetZero Pathfinders framework. NetZero Pathfinders is a BNEF public resource that simplifies the search for policymakers to find, design and implement decarbonization strategies. It is available at www.netzeropathfinders.com.

4 For the purpose of this report, established renewables include photovoltaic solar (PV) and onshore wind, while newer renewable energy technologies encompass batteries and offshore wind. Co-located batteries, solar PV and onshore wind solutions are analyzed in the "Accelerating coal phase-out" section.

progress. The depth of policy frameworks also varies significantly by income level. Higher-income emerging markets are better equipped to implement advanced regulatory mechanisms, while lower-income markets often lack the technical and institutional capacity to design effective policies.

- **Technical assistance is the most effective mechanism to unlock investment in countries with weak enabling environments.** Improving a country's enabling environment is the first crucial step to raising attractiveness for investors, and several emerging markets can still benefit from technical assistance mechanisms.
- **The need for technical assistance for market design increases as renewable penetration grows.** As penetration of intermittent generation grows, countries need to ensure the power system can handle increased renewable penetration or achieve 24/7 production of low-carbon generation. Support can help design markets capable of integrating higher renewable shares while maintaining system stability.
- **Mechanisms that address perceived risks to investing in emerging markets are fundamental.** These can include payment guarantees, political risk insurance and support to enhance revenue stability and improve creditworthiness of offtakers.
- **Concessional debt is a crucial tool for advancing deployment in less-mature markets.** In regions with nascent renewable energy sectors, concessional debt can reduce financing costs, mitigate investment risks and catalyze private sector participation, accelerating adoption and capacity expansion.
- **As technology costs and risks decline, the impact of concessional debt in accelerating competitiveness of wind and solar from fossil fuels is no longer transformative in mature markets.** As the cost of PV and onshore wind reaches grid parity in many mature markets, the need for concessional debt for these technologies diminishes.
- **For battery storage systems, financial mechanisms targeting both equity and debt can play a pivotal role in reducing the cost of electricity.** A reduction of 10% in the expected equity internal rate of return (IRR) leads to a 4.5-6.2% drop in the levelized cost of electricity (LCOE) of a four-hour utility-scale battery storage project. Increasing the loan tenor from 10 years to 16 years results in a 4% reduction, while a 10% drop in interest rates leads to a 2.3% reduction in the LCOE.
- **Capex reductions can also unlock significant declines in LCOEs for battery storage projects.** A 5% reduction on the capex of a four-hour utility-scale battery project can lower its LCOE by 4%.
- **For these newer renewable energy technologies, a combination of mechanisms that tackle equity, debt and capex simultaneously can be the most effective approach.** Integrated financial solutions combining concessional debt and equity, equity guarantees, and capex subsidies can help achieve competitive costs and facilitate scalability for these emerging technologies.

Accelerating the phase-out of coal

Coal is the largest source of CO_2 emissions, and the early retirement of coal-fired power plants offers a significant decarbonization opportunity for emerging markets. Effectively transitioning away from coal in these markets typically requires addressing economic, policy and technical barriers, while ensuring energy security and a just transition for affected workers and communities.

- **An integrated approach is fundamental to an early and just transition away from coal in emerging markets**. In this case, the enabling environment must not only pave the way for renewables but also address the social and economic aspects of the transition away from coal. Similarly, accelerating the cost-competitiveness of renewable energy must go hand in hand with financial instruments to support or compensate early retirement of coal plants.

- **Support from development finance institutions (DFIs) can reduce uncertainty, guide investment decisions and help governments design and implement holistic transition strategies.** This can be achieved through technical assistance to address the complexities of coal phase-outs and ensure robust planning for renewable energy integration, socioeconomic impact management and mitigation, and support for policy and regulatory reforms.
- **As coal plants retire, their replacement must provide clean energy and grid stability. Co-locating renewables with storage is one of the best ways to ensure this stable supply, but the cost of these projects needs to fall considerably for them to be competitive with coal.** In South Africa, for example, a 15-26% reduction in the LCOE of PV co-located with storage would be necessary for the technology to start competing with running coal plants by 2027.
- **Mechanisms that address capex, cost of debt and cost of equity are thus critical for getting these projects off the ground.** For instance, for a PV project co-located with storage in South Africa in 2027, a 1% reduction in the cost of equity leads to a 0.35-0.36% drop in the LCOE. Similarly, a 1% reduction in the cost of debt for operation results in a 0.30-0.33% decrease in LCOE, while a 1% decline in the battery capex drives the LCOE down by 0.27%
- **To help drive down these financing costs, CIF and DFIs can offer concessional financing including risk guarantees.** By reducing both the financing costs and the perceived risks of renewables co-located with storage, these mechanisms can lower the cost of capital and attract private investment. Additionally, offering grants to reduce capex could play a pivotal role in improving the cost-competitiveness of renewables co-located with storage, particularly in emerging markets where initial investment costs remain a key barrier for newer technologies.
- **Even as the LCOE of renewables projects drops, financial instruments to support or compensate early retirement of coal plants remain critical for effectively transitioning away from the fossil fuel.** Mechanisms such as coal asset buyouts, compensation schemes and transition-linked loans provide critical pathways to manage stranded assets and support a just transition for workers and communities dependent on the coal sector.

Accelerating the development and deployment of clean hydrogen

New technologies that can complement clean electrification will be critical for decarbonizing harder-to-abate sectors, and dozens of emerging markets are establishing green hydrogen production targets.

- **Reaching net zero could require a significant expansion of hydrogen production.** Under BloombergNEF's Net Zero Scenario, hydrogen production will need to more than quadruple in the coming decades, from 94 million metric tons of fossil-fuel-based output today, to 390 million tons of clean hydrogen supply by mid-century.
- **Many emerging markets have published hydrogen strategies or roadmaps, but policy support remains insufficient. DFIs can play a transformative role by supporting governments in designing national hydrogen strategies, regulatory frameworks, demand-side policies and infrastructure roadmaps.** Thirty emerging markets across various income levels have already developed a hydrogen strategy out of the 108 emerging markets assessed. Another 20 countries are in the process of preparing their own. Yet getting

these projects off the ground can be more easily said than done. Unlike more-mature renewable energy sectors, green hydrogen requires coordinated actions across policy, regulation, infrastructure planning and market development to attract investment at scale. Without clean policies, incentives, and regulatory certainty, private capital remains hesitant and project risks remain high.

- **Developing strong green hydrogen policy requires analyzing the opportunities, risks and priorities that make each market unique.** The effectiveness of policy support hinges on understanding the sector-specific and technology-neutral approaches that best align with country's priorities, economic realities and available resources.
- **Financial support for green hydrogen projects in emerging markets requires a case-by-case evaluation.** The lack of scaling in developed markets amplifies risks and uncertainties for emerging economics, while unresolved storage and transportation issues coupled with high logistical costs and competitive pressure from established markets may hinder the economic viability of hydrogen industries.

Section 2. State of the energy transition

The window to reach net-zero emissions by 2050 is rapidly closing, but there is still time to get on track if decisive action is taken now. Fast progress across developed and emerging markets, and a wide range of technologies, are needed to keep global warming below 2C.

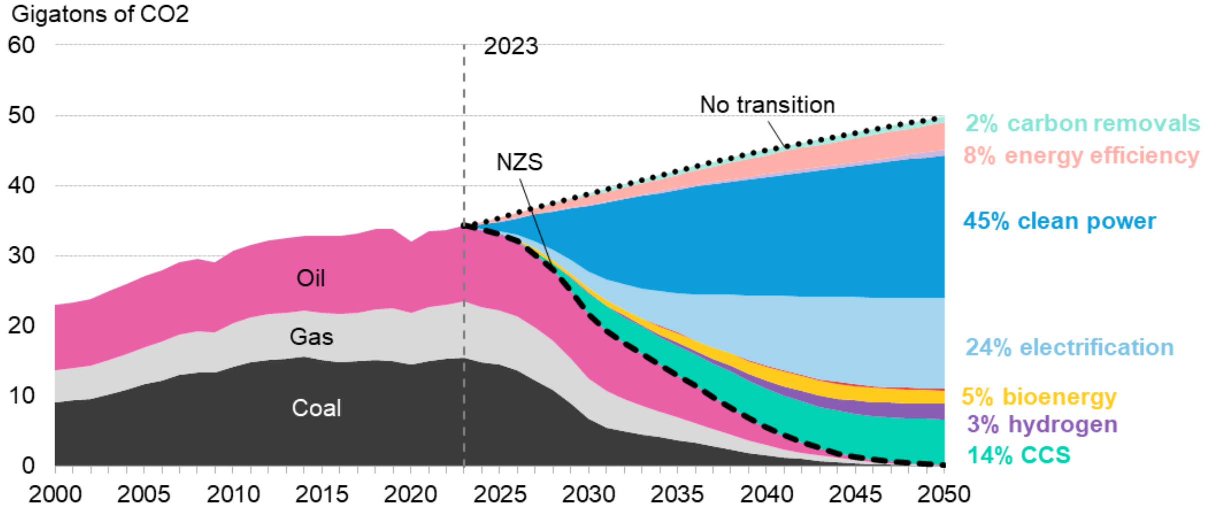
Thanks to extraordinary progress achieved over the past decade, some established clean technologies already cost less than fossil fuels. These include wind and solar power projects in most of the world, batteries in certain countries, and electrified vehicles in a small but growing number of nations. However, such technologies do not always flourish at the scale needed to reach net zero, especially in lower-income markets.

While the current suite of cost-competitive zero-carbon technologies is poised to cut emissions meaningfully over coming decades, more will be needed to end CO2 emissions entirely. Less-established technologies will be required to provide around-the-clock zero-carbon power, to decarbonize industry and transport, to cut emissions associated with livestock production and to meet other challenges.

2.1. Technology trends

In BNEF's Net Zero Scenario,[5] cleaning up the power sector accounts for almost half of emissions avoided between today and 2050, compared with a no-transition scenario where there is no further action on decarbonization. The electrification of end-use sectors, including road transport, buildings and industry, accounts for another quarter (Figure 1).

Figure 1: CO2 emissions reductions from fuel combustion by measure, Net Zero Scenario versus no transition scenario



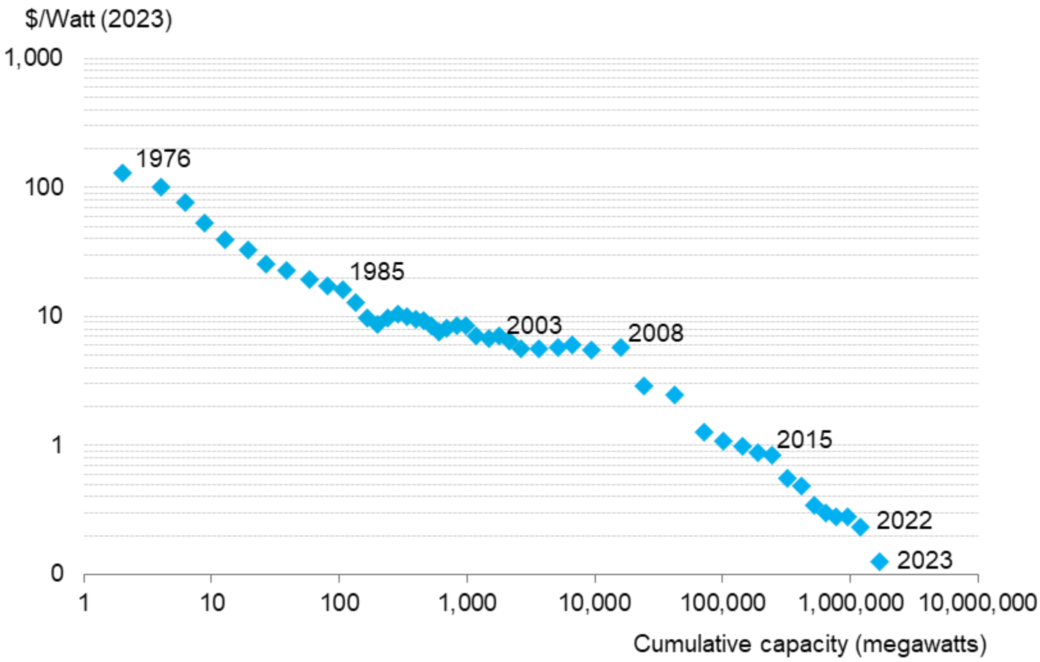
Source: BNEF's New Energy Outlook 2024. Note: The 'no transition' scenario is a hypothetical counterfactual that models no further improvement in decarbonization and energy efficiency.

[5] The Net Zero Scenario is part of the *New Energy Outlook*, an annual report laying out BloombergNEF's long-term energy and climate scenarios for the transition to a low-carbon economy. Anchored in real-world sector and country transitions, it provides an independent set of credible scenarios covering electricity, industry, buildings and transport, as well as the key drivers shaping these sectors until 2050.

Technology improvements and cost declines drive deployment of renewable energy technologies

The Net Zero Scenario requires, among other things, a tripling of renewable energy capacity by 2030, followed by another doubling by 2040. Solar is the poster child for the power of the experience curve in energy: the price of modules has fallen from $30 per watt in 1976 – which, adjusted for inflation, is $129.09 in today's money – to $0.125 at the end of 2023 and $0.099 per watt as of June 2024 (Figure 2).

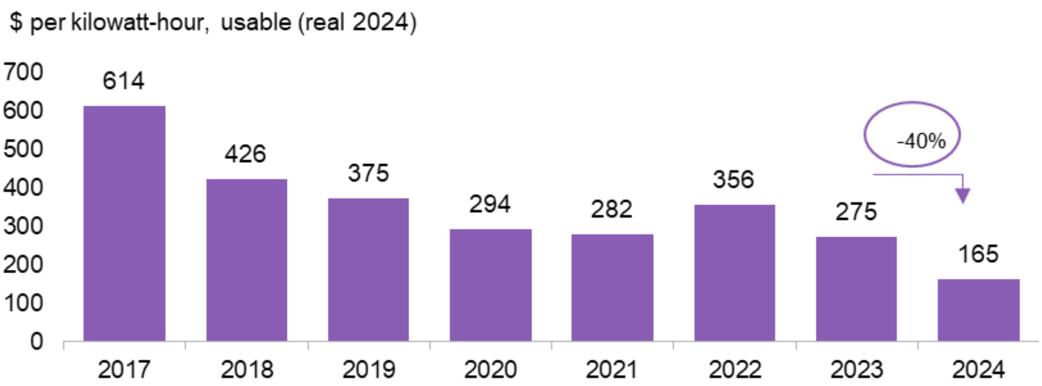
Figure 2: Price of solar modules and cumulative deployment, 1976-2023



Source: BloombergNEF

The technological development of batteries has been more complex, but the price of a kilowatt-hour (kWh) of usable capacity for a four-hour system suitable for stationary storage applications was 73% lower in 2024 than in 2017 (Figure 3).

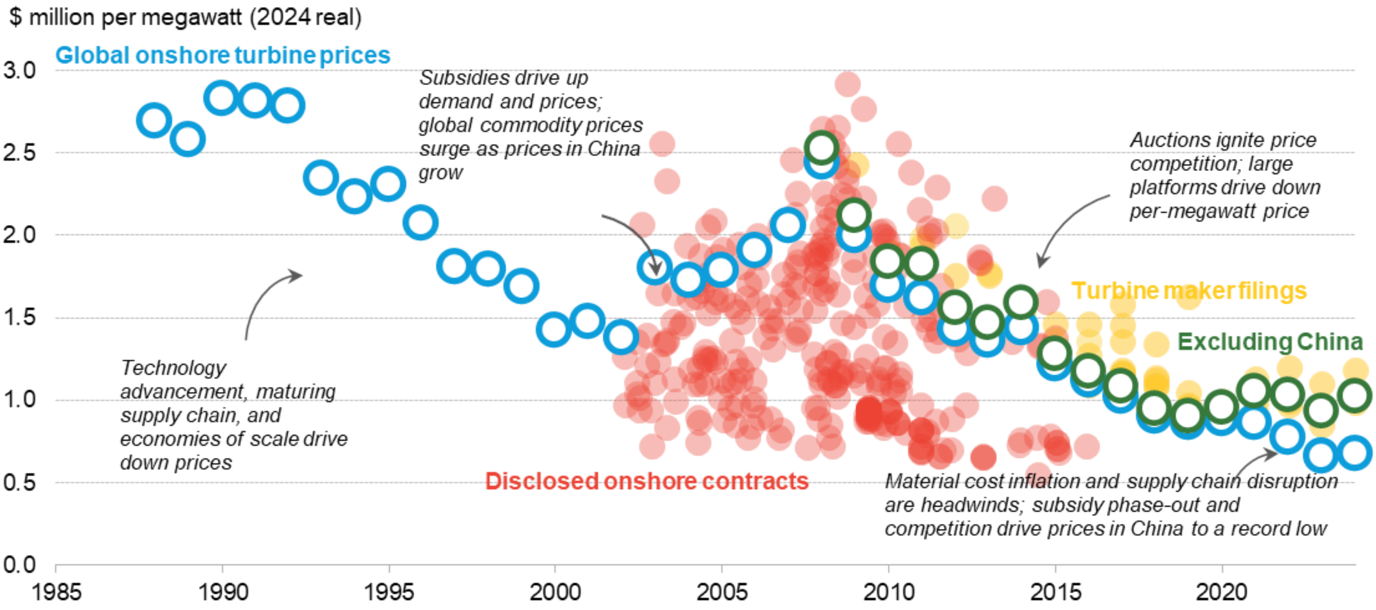
Figure 3: Historical prices for turnkey energy storage of four-hour duration



Source: BloombergNEF

Wind turbine price developments have been less drastic, but per-megawatt prices for turbines in 2023 were typically half what they were in 2014 (Figure 4). Wind turbines are also getting much, much bigger: The average onshore wind turbine installed in the year 2000 had a rated capacity of under 1 megawatt (MW), a hub height of about 75 meters and had rotor blades nearly 27 meters long (Figure 4). An average onshore wind turbine installed in 2023 had a rated capacity of 4.4MW and stood 140 meters tall with blades as long as 72 meters. This translates to generally much higher capacity factors, since larger-diameter blades sweep out larger areas, and are up higher where the wind blows more consistently.

Figure 4: Price of wind turbines worldwide, and key drivers

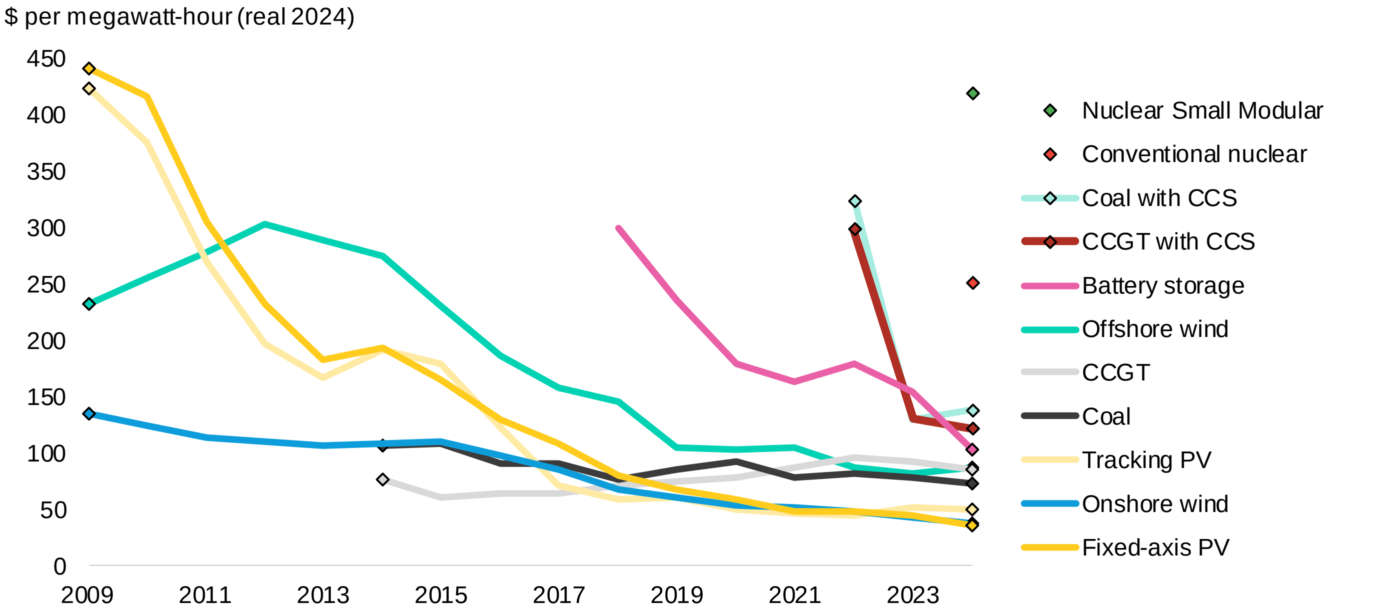


Source: BloombergNEF

As result, using a global average, PV and onshore wind have become the cheapest source of new power generation (Figure 5). While the average cost of offshore wind has seen steep declines over the past decade, prices increased 5% between 2023 and 2024 to $87/MWh because of more expensive turbines in most markets around the world. As such, there is still scope for steep cost reductions to pre-pandemic levels by the end of this decade, BNEF expects that by 2035, offshore wind will observe a cost reduction of 22% compared with 2024 figures, while onshore wind reaches a 26% decrease.

Utility-scale battery storage with a four-hour duration remains expensive, but it has reached a historic low, projected to drop below $100/MWh in 2025. Still, the LCOE for renewable technologies cannot be directly compared with storage, since the last is about energy shifted and not generated.

Figure 5: Global LCOE benchmarks, 2009-24



Source: BloombergNEF. Note: The global benchmarks are capacity-weighted averages using the latest country estimates – apart from nuclear, hydrogen and carbon capture and storage (CCS), which are simple averages. Offshore wind includes offshore transmission costs. Coal- and gas-fired power include carbon pricing where policies are already active. Levelized costs of electricity (LCOEs) do not include subsidies or tax-credits and are shown by financing date. CCGT refers to combined-cycle gas turbine, while PV stands for photovoltaic solar.

Driven by significant declines in technology costs, renewables represented 91% of net global capacity additions in 2023 (Figure 6). In emerging markets, excluding China, wind and solar accounted for 77% of the capacity added (Figure 7).

Figure 6: Global share of net power generation capacity additions

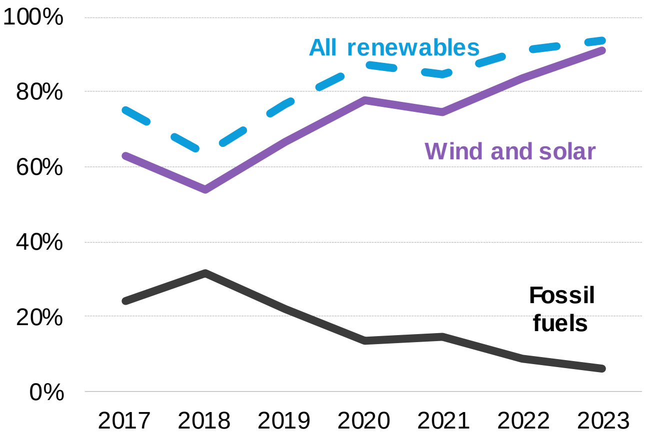
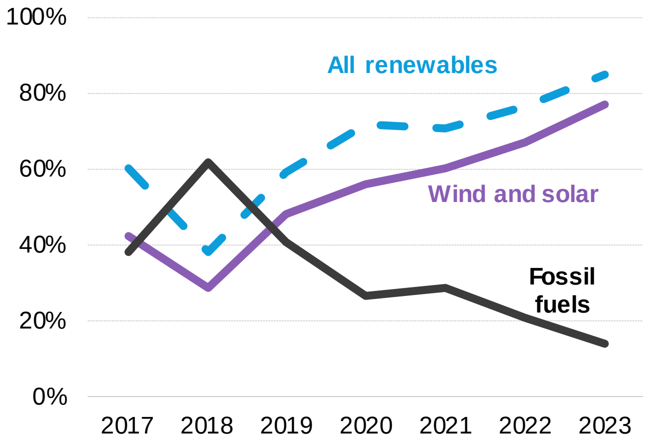


Figure 7: Net power generation capacity additions in emerging markets (excl. China)



Source: BloombergNEF

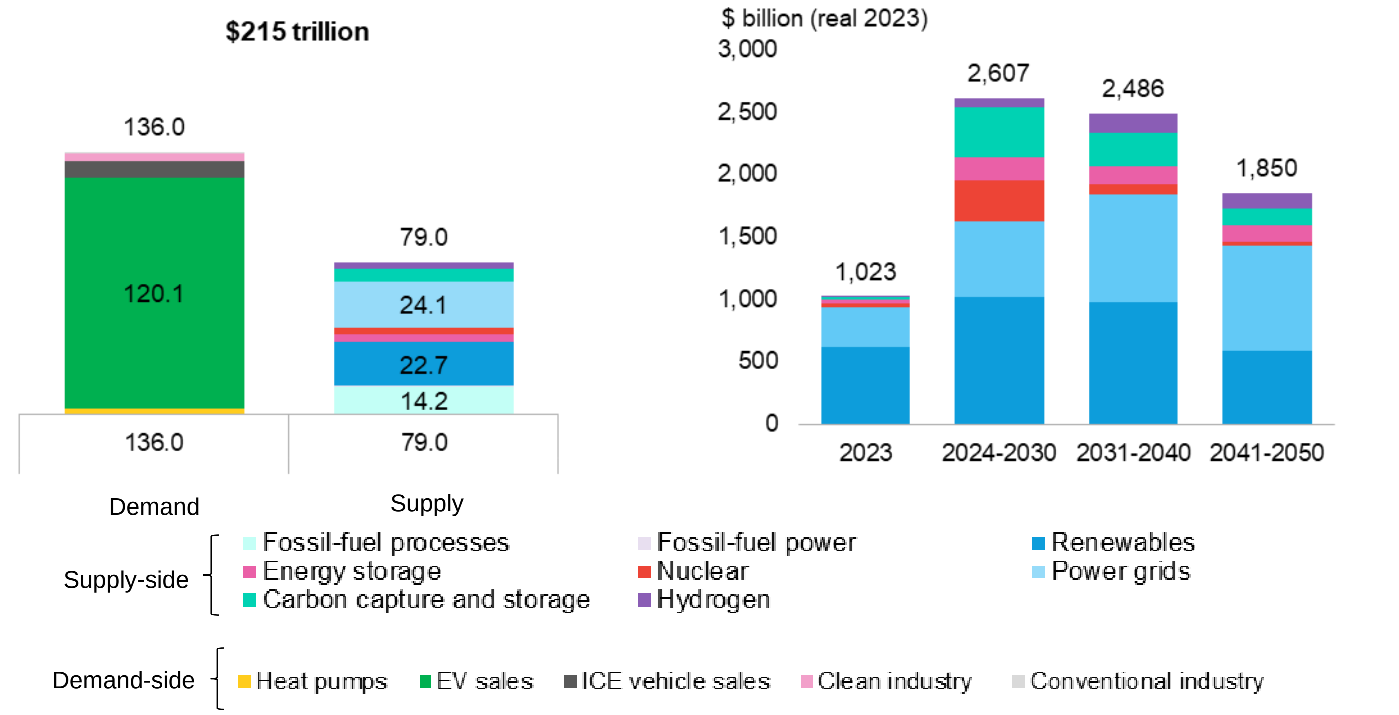
2.2. Energy transition investment

Reshaping and decarbonizing today's energy systems will require a substantial scale-up of capital directed toward low-carbon assets and infrastructure. In BNEF's NEO Energy Outlook's Net Zero Scenario, global investment in the power, transport, industry, and buildings sectors totals $215 billion between 2024 and 2050 (Figure 8).

Nearly two-thirds (63%) of this investment is in demand-side products, mostly for passenger vehicles, both electric and those based on internal combustion engines (Figure 9). The remaining third flows into energy supply technologies (both fossil fuels and low-carbon), including renewables, energy storage, nuclear, power grids, carbon capture and storage, hydrogen and fossil-fuel power and processes.

Figure 8: Global investment and spending across 2024-2050, Net Zero Scenario

Figure 9: Actual versus annualized supply-side energy transition investment across 2023-2050, Net Zero Scenario



Source: BloombergNEF. Note: Low-carbon energy supply includes renewable energy, nuclear, energy storage, hydrogen and carbon capture and storage (CCS). Excludes transmission and distribution (T&D) and large hydro and energy efficiency. 2023 data is actual investment; all other bars in Figure 9 are annualized. ICE refers to internal combustion engine. The New Energy Outlook follows a sectoral and country-level modeling approach. The modeling employs a series of interlinked sector-focused bottom-up models at a regional, country and sub-country-level granularity, building on sector and regional expertise of BNEF analysts and proprietary data. For more, see about.bnef.com/new-energy-outlook.

Cleaner power generation can drive the bulk of the aggressive emissions cuts needed this decade, enabling more time to tackle 'hard-to-abate' areas like steelmaking and aviation, where cost-competitive low-carbon solutions have yet to scale. As result, renewable energy alone accounts for nearly 40% of the supply investment in 2024-2030.

Emerging markets saw less than 18% of total renewable energy investment in 2023

Emerging markets (excluding China) saw $116 billion invested in renewable energy in 2023 (the last year for which complete data is available), up 35% from the year prior (Figure 10). This investment includes utility-scale solar, wind, biomass and waste, geothermal, marine and small hydro projects, and small-scale PV.

Passing the $100 billion threshold for the first time, emerging markets received 17.5% of global investments in renewables in 2023, up from 13% in 2014. That's roughly in line with the trend of the last decade: these economies have seen 17% – or $682 billion – of the world's renewable energy investment since 2014. Despite this growing share, however, emerging markets (excluding China) still lag far behind developed economies on the investment front. China is the heavy hitter in the group, with nearly 42% of the global total in 2023. Developed markets as a group accounted for 41.1%.

The all-time high in renewable energy investment in emerging markets, in 2023, was largely thanks to solar investment reaching a record $78 billion. Utility- and small-scale solar together accounted for 68% of renewable energy investment in emerging markets that year. Small-scale solar has led that growth. With cheaper costs and higher dissemination rates, small-scale solar has been one of the top technology choices for many emerging markets. Wind is growing, but it still has a long way to go in emerging markets. Wind investment jumped by more than a third year-on-year, but this investment is concentrated in a handful of markets. Brazil and India, for example, were responsible for 31% the total investment in wind in 2023.

Figure 10: New-build renewable energy investment, by trade category

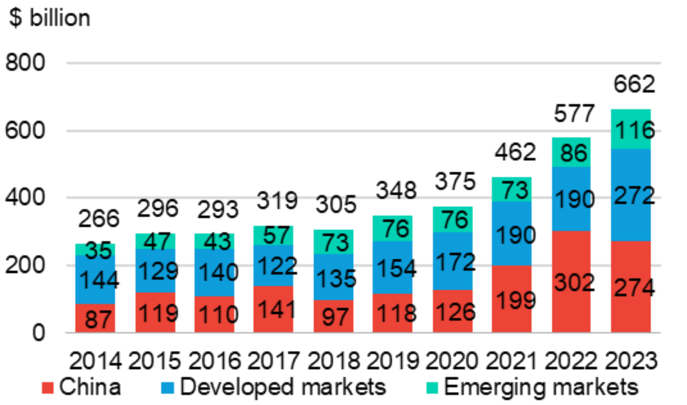
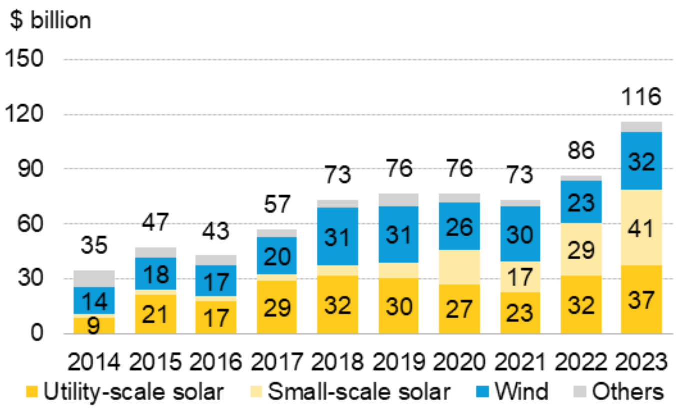


Figure 11: New-build renewable energy investment in emerging markets, by technology

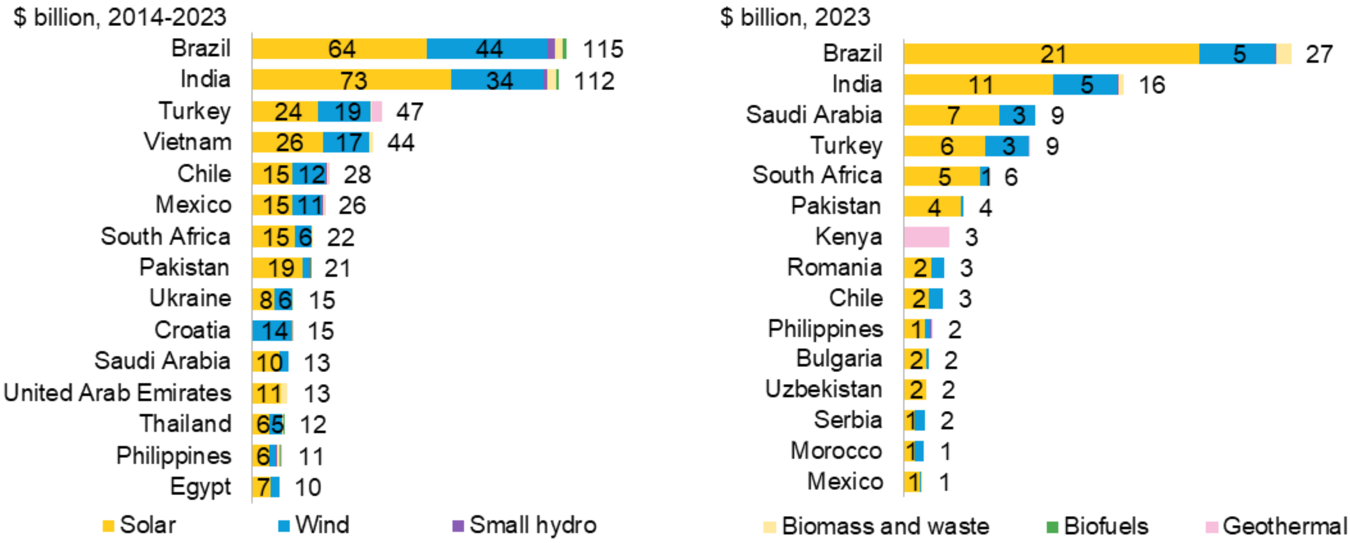


Source: BloombergNEF. Note: Data includes new-build asset finance and small-scale solar investment globally. BNEF's renewables data includes a global buffer for small-scale solar due to difficulties in tracking individual projects. In the chart, the buffer is included in the series for developed markets but not for emerging markets due to the lack of a market breakdown.

A few emerging markets concentrate the majority of renewable energy investment

Renewable energy investment remains highly concentrated in a relatively small number of markets. Fifteen emerging markets concentrated 84% of new-build clean energy investment in 2023, or $98 billion, over the last 10 years, 15 markets accounted for 78% of all investment in emerging markets. Brazil reached a record high for investment in 2023, attracting $27 billion – or a fifth of the cumulative total it attracted over the last decade – in one year alone. Most investment over the last decade was concentrated in solar and wind, which attracted $64 billion and $44 billion, respectively, and both notched record levels of deployment. Brazil is blessed with the natural resources necessary for these technologies to function, but supportive policies such as auctions and net metering have helped them get off the ground.

Figure 12: Top 15 emerging markets (excluding China) for renewable energy investment



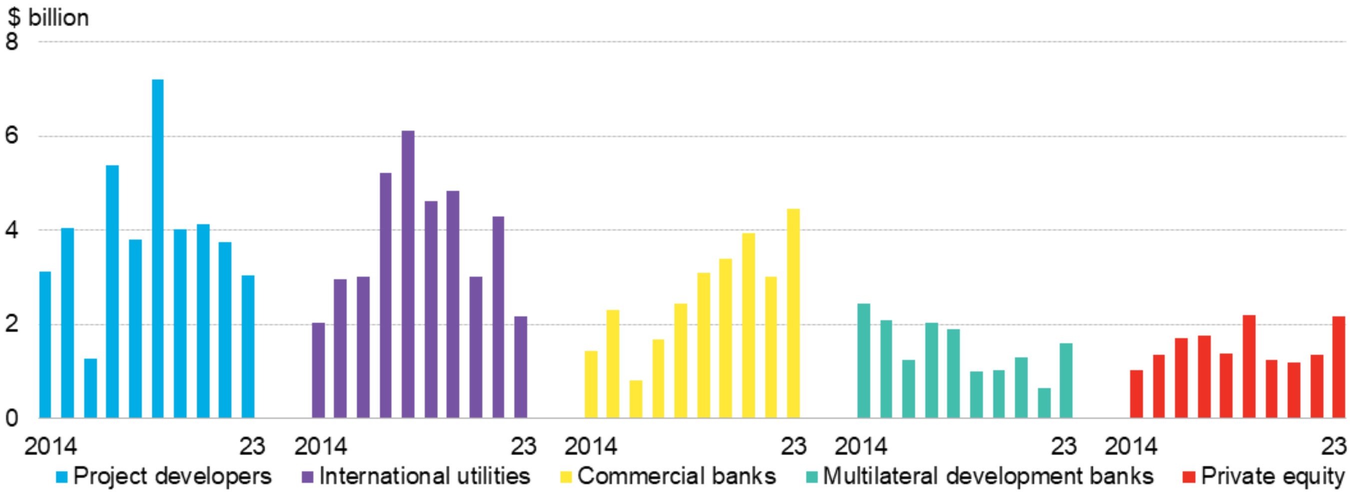
Source: BloombergNEF. Note: Includes new-build asset finance and small-scale solar investment. Small hydro is up to 50 megawatts.

Commercial banks led emerging markets' foreign investment in 2023

Commercial banks were the largest foreign investors in emerging markets in 2023, accounting for some $4 billion, or 15% of the total amount registered that year. Project developers and utilities followed, with $3 billion and $2 billion, respectively. This reflects a shift in investment trends.

Over 2014-2023, project developers and international utilities were the biggest investors, pouring a total of $86 billion, or 37% of the cumulative figure, into emerging markets. At $25 billion, commercial banks were the third-largest investor group over the decade, while private equity reached $19 billion. Multilateral development banks (MDBs) came in last for investment over the 10-year period, at $15 billion, but annual foreign investment for renewable energy projects from MDBs rose 61% from 2022 to 2023, from $0.6 billion to $1.0 billion.

Figure 13: Foreign direct investment to utility-scale renewable energy in emerging markets, by type of investor



Source: BloombergNEF. Note: Excludes undisclosed data. Excludes China.

Section 3. Accelerating the deployment of renewable energy technologies

Thanks to extraordinary progress made over the past decade, technologies that emit zero carbon dioxide already exist – and are increasingly cost-competitive with their fossil-fueled rivals. This list includes wind and solar power projects in most of the world, and electrified vehicles in a small but growing number of markets.

Decarbonizing the global power system is a foundational step toward ensuring that climate commitments are met. In the Net Zero Scenario of BNEF's *New Energy Outlook*, 45% of global emissions abatement between now and 2050 comes from the clean power sector. New solar and wind build each account for 17-18% of this abatement when compared with a 'no transition' scenario. Such a buildout of renewable energy technologies will, in turn, require deploying grid flexibility solutions such as battery storage and demand-response technologies – and a significant scaleup of investment in the transmission and distribution networks.

The shift to a clean power system is well on the way thanks to the increased cost-competitiveness of zero-carbon electricity generation technologies and large, established supply chains, yet it is not evenly spread out around the globe. Despite the increasing cost-competitiveness of wind and solar PV in many markets, renewables deployment at scale remains mostly concentrated in higher-income nations.

Accelerating the deployment in emerging markets of both established renewables, such as photovoltaic solar (PV) and onshore wind, and newer renewable energy technologies, such as batteries and offshore wind, is a critical next step in decarbonizing the global power system. This section identifies and assesses the most impactful measures for doing so. It begins by laying out the four stages that countries pass through in the process of scaling technologies. It then delves into three high-impact measures to unlock capital flows:

- Supporting an enabling environment
- Addressing risks
- Accelerating economic competitiveness

3.1. Assessing market readiness

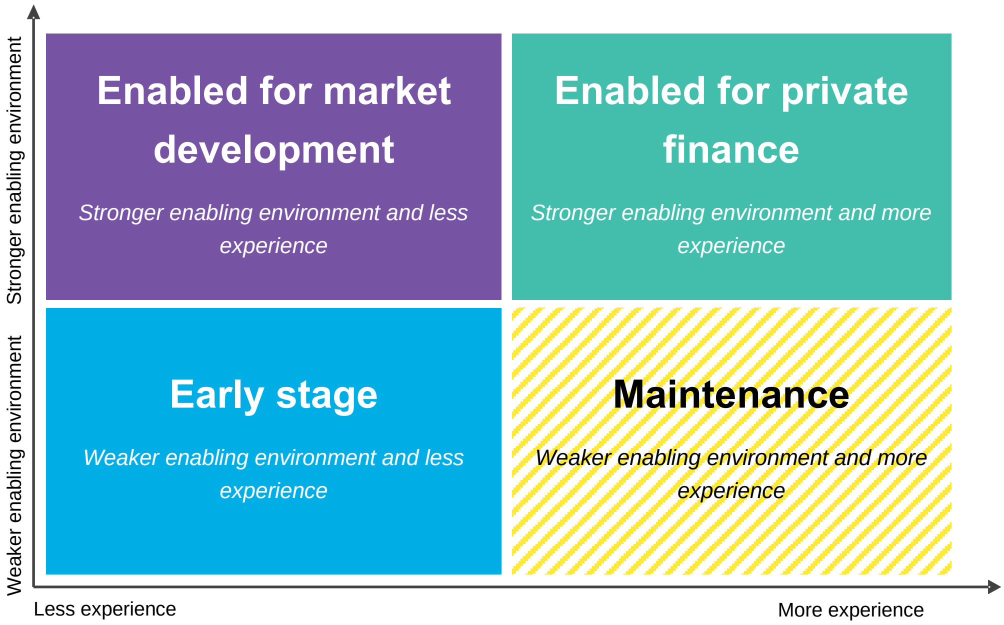
Each emerging market presents unique characteristics, challenges and opportunities for clean energy deployment. Macroeconomic conditions, natural resources necessary for renewable generation, progress in energy transition initiatives, and country-specific risks vary significantly. Effective investment allocation in emerging markets therefore requires a thorough analysis to pinpoint where and how investments can have the most significant impact.

Identifying a market's maturity regarding renewable energy development is key. To support this analysis, BNEF has developed the Energy Transition Stages Framework, depicted in Figure 14, which aims to where emerging markets in their energy-transition journey, and how ready they may be to put public and private investment to work. The framework allows for a first glimpse into where and how the growth of each technology can be best supported.

Most countries have historically passed through four main stages in the process of becoming attractive for private finance and deploying clean energy technologies at scale:

- **Early stage.** Little or no policy is present, with no significant technology deployment. In this stage, policymakers need support implementing policies to kick-start activity. Development institutions and philanthropic organizations can play an important role by providing technical assistance.
- **Enabled for market development.** Once appropriate policies and regulations are in place, the country is ready for deployment of the technology. However, unlike in developed nations, where first movers usually have advantages, in emerging markets, the cost of entering a market early presents additional costs and risks. This is normally related to a lack of experience from stakeholders and untested policies, regulations and infrastructure. A certain level of funding from governments, development institutions or philanthropic organizations can lower first-mover costs, help prove the technology in a specific country and lower risk perception among investors.
- **Enabled for private finance.** As the risk perception diminishes, private investment can quickly flow into financing the technology, boosting the market's 'experience'. Support from development organizations may remain necessary to continue lowering risk when external circumstances could push private investors away from the market, such as when high political, economic or currency risk is present.
- **Maintenance.** As penetration of the renewable technology grows, well-crafted policies can help avoid market saturation. One strategy is to implement early-stage policies to deploy complementary technologies, such as storage to support wind and solar penetration.

Figure 14: Energy transition stages framework



Source: BloombergNEF

Understanding what stage(s) countries are at for each technology is fundamental to identifying which stakeholders and mechanisms can have the greatest impact – and how.

Energy Transition Stages Framework: Methodology

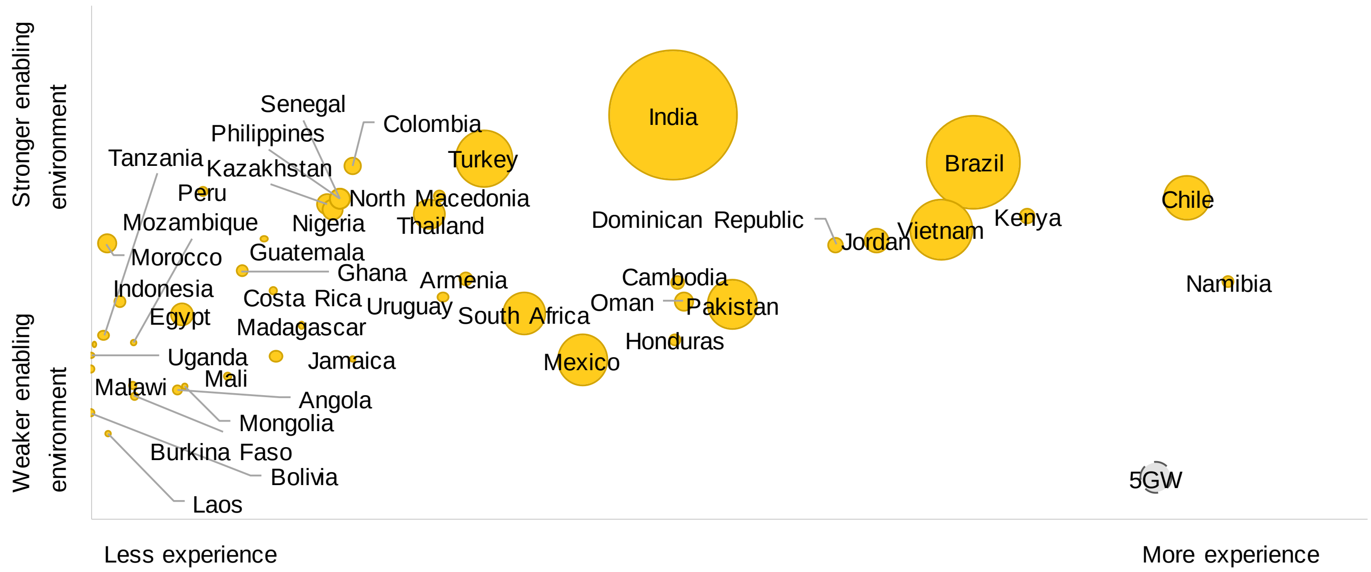
Two key factors help determine where a country falls on the framework above: the enabling environment (y-axis) and its experience deploying a given technology (x-axis). BNEF has sought to quantify each of these for individual nations and technologies through the data collected by BNEF's Climatescope.[6]

- **The enabling environment[7]** includes the market's key policies, operating rules, incentives and barriers to investment for each clean energy technology. Policies include but are not limited to auctions, feed-in tariffs, net metering, clean energy targets, nationally determined contributions (NDCs), net-zero targets, priority grid access for renewables, energy access targets and barriers.
- **The level of experience[8]** in deploying each technology includes asset financing from private investors, market infrastructure and completion of projects. Markets with greater experience in deploying renewable energy capacity typically offer lower risks, technology costs and costs of capital for developers.

Energy Transition Stages Framework: Technology-specific results

Figure 15 illustrates where countries fall on the framework for two technologies observed in this report: solar PV and onshore wind.

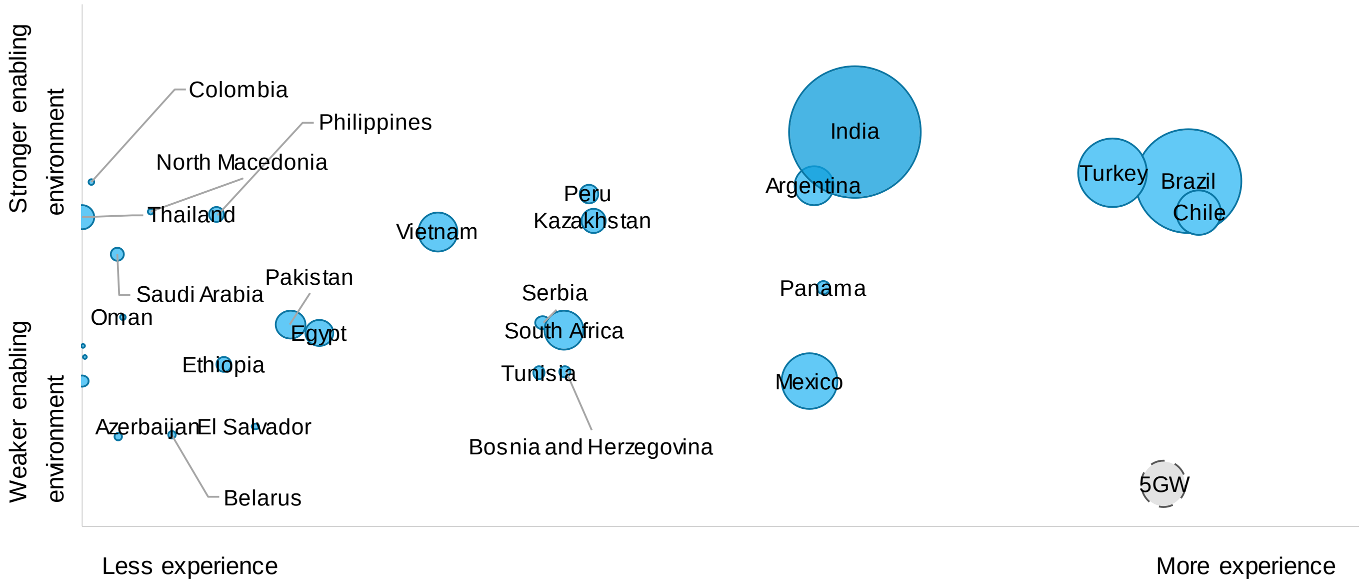
Figure 15: Energy transition stages framework results for PV (top) and onshore wind (bottom)



[6] Climatescope is an annual online market assessment tool, report and index that includes market-level data on the energy transition for over 140 markets, including 110 emerging markets and 30 developed ones. For more details see www.global-climatescope.org.

[7] For details on enabling environment methodology, please refer to Appendix B.1.

[8] For details on experience methodology, please refer to Appendix B.2



Source: BloombergNEF. Note: Adjusted axis for visualization. Bubble size refers to the country's total installed capacity of the selected technology in 2023. 'Enabling environment' based on Climatescope 2024 "market enabling environment" score. 'Experience' refers to the share of overall capacity the technology accounts for in a country, its electrification rate, and share of private investment in the technology (solar photovoltaics and onshore wind only). GW refers to gigawatts, while MW refers to megawatts.

Newer technologies often lack both widespread targeted incentives and capacity deployment, severely limiting availability of data and thus the ability to compare distinct levels of market evolution. As such, there are no Energy Transition Stages Framework results for batteries, hydrogen and offshore wind.

3.2. Supporting an enabling environment

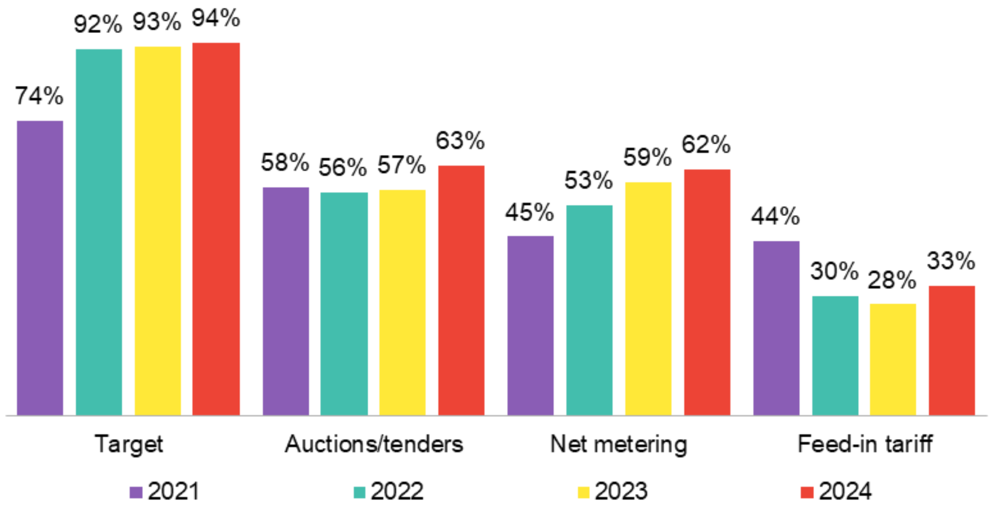
Most emerging markets have a renewable energy target but lack the policies to bring it to fruition

BNEF estimates that 94% of the emerging markets surveyed in Climatescope in 2024 had implemented a renewable energy target, up from 74% in 2021 (Figure 16). However, while most markets have introduced renewable energy goals, many lack supportive policies to achieve these ambitions.

The implementation of auctions for clean power is a major route for emerging markets to attract investment and facilitate the deployment of renewable energy projects. Yet while this policy is present in 63% of surveyed emerging markets as of 2024, the adoption rate has been much slower than for net-zero targets or net metering.

Net metering has experienced growth in recent years and is now present in 62% of the emerging markets surveyed by Climatescope in 2024, up from 45% just a few years ago. This policy is particularly instrumental in expanding distributed solar energy. Feed-in tariffs are the only policy type experiencing a decline, mostly due to a shift toward auctions and tenders.

Figure 16: Share of surveyed emerging markets with key renewable power policies on the books

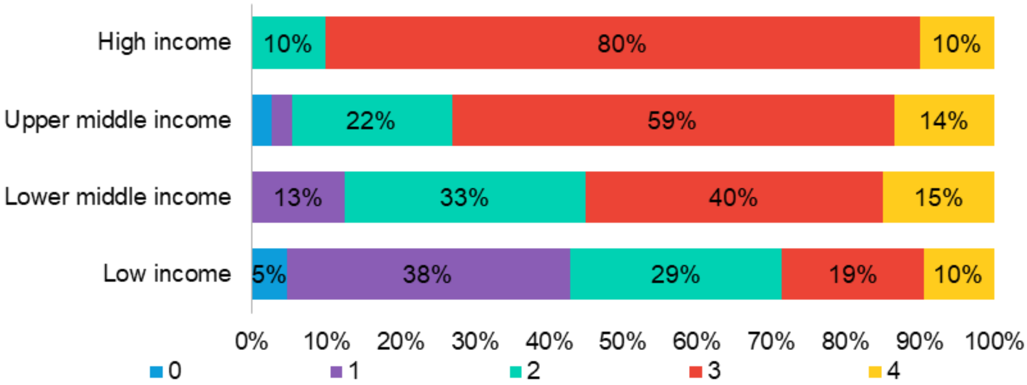


Source: BloombergNEF. Note: Includes 108 emerging markets surveyed through the end of July 2024. Renewable energy target years vary across included markets. The most popular year for target adoption is 2018, while most targets are set for 2030.

The depth of policy frameworks varies significantly by income level

Upper-middle- and high-income emerging markets tend to have a more robust presence of clean power policies. Over 90% of high-income emerging markets had implemented three or more renewable energy policies by year-end 2024, a number that number falls to 73% in upper-middle-income countries and 55% in lower-middle income countries (Figure 17). Low-income markets have the least comprehensive policy frameworks, and only 29% of the countries in this group have three or more policies in place.

Figure 17: Number of renewable energy policies that emerging markets have in place, by market income level



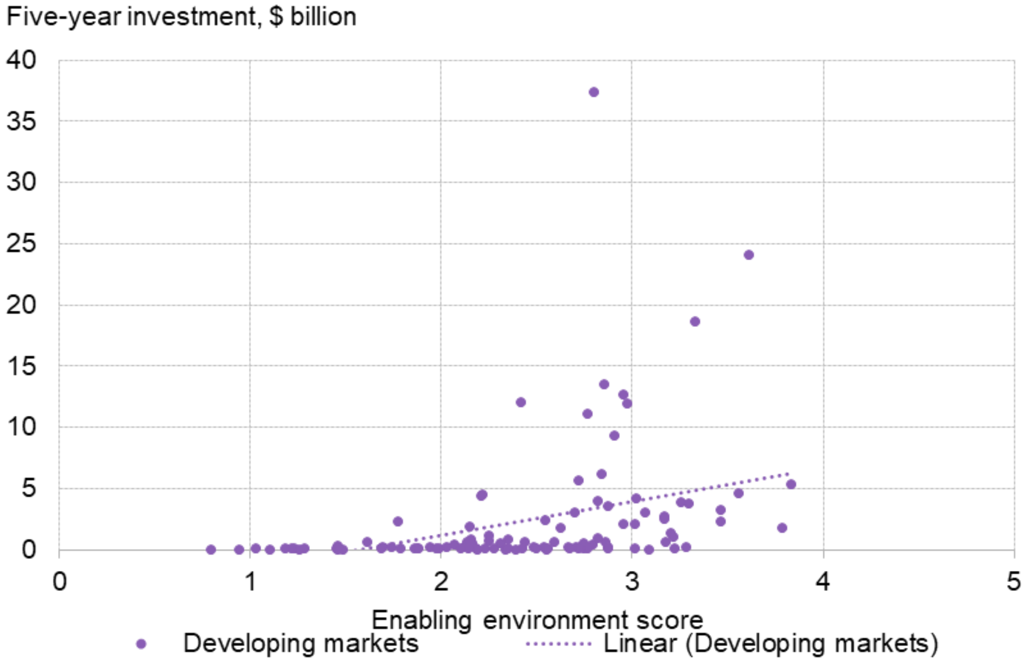
Source: BloombergNEF. Note: Includes 108 emerging markets surveyed through the end of July 2024. Considers renewable energy targets, auctions/tenders, net metering, and feed-in tariffs policies.

Renewable energy investment thrives in strong enabling environments

Stable, well-defined enabling environments are critical for attracting clean energy investment, particularly private capital. Such environments include policy mechanisms explicitly designed to accelerate renewables deployment such as auctions, feed-in tariffs, tax incentives, or national targets. But they also include broader power sector policies and regulations to foster competition and transparency. Unbundled, un-monopolized power markets are the most conducive to investment and deployment, particularly when private players can sign clear, long-lasting power purchase agreements (PPAs). Similarly, lack of a proper enabling environment is one of the key barriers to unlocking capital across emerging markets.

This relationship becomes clear when comparing the robustness of a country's enabling environment with levels of investment flows for renewable energy. The 15 markets with the highest enabling environment scores in Climatescope 2024 attracted 224 times more investment for renewable energy projects than the 15 countries with the weakest enabling environments. The top countries recorded on average $16.7 billion in investments over 2019-2023, or $3.3 billion per year. Meanwhile, the 15 countries at the bottom of the ranking attracted on average less $75 million over the five-year period, or less than $15 million per year.

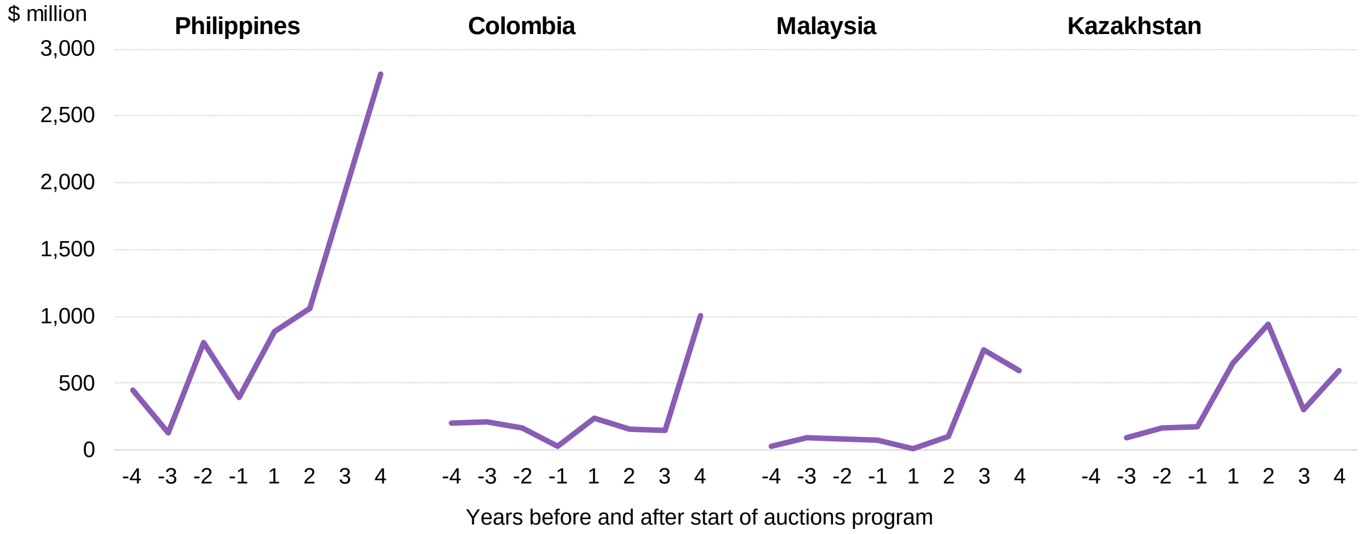
Figure 18: Enabling environment score in Climatescope 2024 versus five-year renewable energy investment (2019-2023)



Source: BloombergNEF. Note: 'Investment' includes new-build asset finance and small-scale solar. 'Score' refers to each market's Climatescope Fundamentals score, which encompasses key policies, market structure and barriers that could hinder investment. Investment includes new-build asset finance for renewable energy and small-scale solar photovoltaics. Brazil and India are not featured on the chart for visualization purposes but included on the trendline. China is not included.

Renewable energy auctions continue to be one of the most successful mechanisms to boost investment, as they create a transparent and competitive bidding process. The Philippines, Colombia, Malaysia, and Kazakhstan are examples of countries where auctions have been pivotal for helping grow investment and accelerate deployment of clean power plants. On average, these countries saw investment quadruple in the four years following the launch of auctions mechanisms compared with the four years prior (Figure 19). Successful auctions are usually paired with a roadmap for the clean power sector and other supportive policies.

Figure 19: Renewable energy investment in the years before and after implementation of renewable energy auctions



Source: BloombergNEF. Note: 1 refers to year of auction implementation.

Technical assistance is the most effective mechanism for unlocking investment in countries with weak enabling environments

Grants for technical assistance to support a country's renewable energy enabling environment are, in many cases, the most impactful mechanism for scaling up a market's renewable energy sector and attracting investment flows. Among other things, technical assistance programs can help countries:

- Develop renewable energy targets and roadmaps
- Create policy incentives, such as feed-in tariffs, auctions and net metering
- Establish a new regulatory framework that is appealing to investors
- Support planning and renewable energy integration
- Provide capacity-building initiatives to prepare institutions to manage renewable energy programs and projects

When done well, technical assistance creates an environment where projects become attractive for investors and unlock significant amounts of capital. This is particularly true in countries with weak enabling environments that have received limited or no flows of investment to clean technologies. On the flip side, for early-stage countries, financial support channeled directly to renewable energy projects (in the form of grants or concessional finance) is unlikely to enable the sector to scale up.

Many countries can benefit from technical assistance support to unlock investments

Countries where technical assistance can make the greatest impact typically fall in the 'early-stage' quadrant of the Energy Transition Stages Framework. In this stage, nations have a weak enabling environment and little or no experience in deploying clean energy technologies. Improving a country's enabling environment is a crucial step in raising attractiveness for investors, and supportive measures must consider factors that go beyond technology-specific policies. Acknowledging economic and political factors is necessary to evaluate what actions from development institutions have the greatest impact in ensuring the financial viability of projects and address market failures that increase risks.

Energy Transition Stages Framework: Early-stage results for selected countries
Lower enabling environment, lower experience

- **Solar PV:** Angola, Bolivia, Burkina Faso, Ecuador, Jamaica, Laos, Madagascar, Malawi, Mali, Mongolia, Mozambique, Tanzania, Tunisia, Uganda, Zambia
- **Onshore wind:** Azerbaijan, Bangladesh, Belarus, Bosnia and Herzegovina, Egypt, El Salvador, Ethiopia, Oman, Serbia, South Africa, Sri Lanka, Tanzania, Tunisia
- **Batteries:** Bulgaria, Burkina Faso, Ethiopia, Myanmar, Nigeria, Peru, Zimbabwe
- **Offshore wind:** All emerging markets

Most markets where renewable energy investment has not yet flourished are lower- or middle-income markets. While improving technical assistance grants for policy and enabling environments in these markets may result in lower emissions reductions per dollar of investment, compared to wealthier nations, the social impact can be greater. Renewable energy projects in these regions often bring critical development benefits, such as:

- Increased energy access
- Job creation in renewable energy industries
- Enhanced energy security and lower electricity prices by reducing reliance on expensive and volatile fossil-fuel imports

Market design assistance can play a bigger role as renewable penetration grows

The need for new and improved policies in more-established renewable energy markets is expanding. Power market design is critical for handling the increased penetration intermittent generation technologies. In addition to a competitive dispatch signal, markets can ensure that flexible low-carbon loads are encouraged through scarcity pricing in a wholesale market, dynamic tariffs to encourage power users to load shift, or capacity payments that consider carbon intensity. Ancillary service markets, which competitively tender key grid services as the share of non-spinning generation rises, can also be initiated and standardized to encourage the scale-up of energy storage system deployment.

Development organizations can support market design through technical assistance to help countries address bottlenecks to the continued growth of renewable energy and support the growth of energy storage technologies.

Unique challenges lead to higher complexity in offshore wind policy and regulation

Offshore wind policy and regulation are significantly more complex than for onshore wind due to unique challenges associated with marine environment. Offshore wind projects also require specialized infrastructure including port facilities and unique transmission systems, both of which demand coordinated regulatory frameworks.

In most emerging markets, these policies are nonexistent. Without a clear sector roadmap, appropriate permitting processes, maritime planning and incentives to attract investment, these countries may struggle to build offshore wind projects. Technical assistance for countries with high potential for the technology can accelerate its development in key markets.

Vietnam offshore wind endeavors highlight the challenges faced by emerging markets

Vietnam's PDP VIII, approved in May 2023, set a goal of installing 6GW of offshore wind by 2030. The implementation plan allocated the planned capacity among four regions, with the largest capacities distributed between North Vietnam (2.5GW) and South-Central Vietnam (2GW).

In November 2024, Vietnam's offshore wind sector was officially regulated by the amended Electricity Law. The Ministry of Industry and Trade has published a draft policy to provide guidelines and further details for the sector following the new law's approval. Critical regulations include incentives for projects, investment approval, developer selection process and site survey procedures. We expect this draft policy to be approved in 2025, which will help to kickstart Vietnam's offshore wind sector by providing clear and certain regulations for project development.

This timeline may be overly optimistic. Offshore wind project timelines are long, usually spanning eight to nine years. Currently, Vietnam is in the initial stages of conducting maritime spatial planning (MSP) to identify suitable zones for wind development.

The MSP process is intricate and time-consuming due to its multi-sectoral nature, involving consultations with numerous stakeholders at both regional and central levels, including local authorities, the Ministry of Defense, and the Ministry of Public Security. Key regulatory foundations identified by the Ministry of Industry and Trade (MOIT) are lacking, including clearly defined offshore wind development zones, procedures for conducting site surveys, and guidelines for investment approval processes.

To address these challenges, in January 2024, the Vietnamese government established an interministerial working group tasked with clearing regulatory barriers. The MOIT working group has been specifically tasked with developing a pilot program in which the government will conduct site surveys for offshore wind projects, aiming to streamline regulatory processes and accelerate progress towards achieving the offshore wind targets outlined in PDP VIII.

3.3. Addressing risks

Country-, market- and currency-related risks continue to limit investment in many markets

Despite progress in establishing sector-specific renewable energy policies, many countries continue to struggle to attract significant investment flows into their renewable energy sectors. Sometimes these challenges persist event in cases where governments have implemented ambitious renewable energy targets, competitive procurement processes and strong permitting frameworks. While these sector-specific efforts are fundamental and must be deployed, three critical barriers can often block primary investment: country, market and currency risks.

Country risk encompasses broader political, regulatory and macroeconomic uncertainties that influence a country's overall investment attractiveness. Even with sector-specific policies in place, factors such as political instability, weak governance and macroeconomic volatility can create a high-risk environment for investors. These include:

- Political and regulatory uncertainty, such as changes in government policies, delays in project approvals or retroactive changes to subsidies
- Macroeconomic instability, such as high inflation, exchange rate volatility and currency instability, which can increase the cost of financing and affect project revenues

- Utilities and grid infrastructure that limit the ability to integrate renewables into the grid and monetize renewable energy projects

In order to protect investors from challenges related to policy delays and retroactive changes, political and regulatory risk guarantees can be deployed. These guarantees provide financial compensation to investors in case of unexpected changes to policies, such as the removal of subsidies. Additionally, technical assistance to strengthen policies and regulatory frameworks can further improve investor confidence.

Market risk relates to the uncertainty around a project's revenue streams. Including fluctuating electricity prices, demand volatility, or reliance on riskier offtakers. Even in countries with clear policies, the absence of long-term contracts, stable pricing mechanisms or creditworthy offtakers can make projects unattractive to investors. More specifically:

- Revenue volatility caused by lack of long-term PPAs or mechanisms that guarantee a stable revenue for renewable energy projects expose projects to fluctuating electricity prices.

Financially unstable utilities, common in many emerging markets, increase the risk of delayed payment or non-payment for electricity generated. Market risk-related barriers can be addressed by deploying mechanisms that enhance revenue stability and improve offtaker creditworthiness. Instruments such as contracts for difference (CfDs) and long-term PPAs ensure predictable and stable revenues for developers, hedging exposure to price fluctuations. To mitigate offtaker risks, payment guarantees, and credit enhancement programs can safeguard revenues, even in markets with financially unstable utilities.

Currency risk can also hinder foreign investment in emerging markets. Many developing economies rely on external investors to scale deployment, and exchange rate volatility can impact investor returns and increase financing costs. It can also introduce uncertainties into project cash flows, particularly when contracts are paid in local currency but financed in foreign currency. In particular:

- Currency exchange fluctuations can determine whether or not renewable energy projects are bankable, increase costs of capital and even lead to loan defaults.
- Project revenues can be severely impacted when local currency, which is typically the currency of revenues, faces high levels of depreciation against the investment currency.

Addressing currency risk requires targeted interventions, including hedging instruments and greater access to financing in the local currency.

3.4. Accelerating economic competitiveness

Concessional finance and other mechanisms from development organizations have the potential to kick-start new sectors and help crowd-in private capital. However, to determine whether concessional finance is necessary to ensure the financial viability of a project, evaluating the economics of each technology is also key

Levelized cost of electricity (LCOE) and levelized cost of capacity (LCOC) are key metrics for comparing technologies and assessing their competitiveness

LCOE[9] is the long-term offtake price on a megawatt-hour basis required to recoup all project costs and achieve a required equity hurdle rate on the investment. The key components of an LCOE include the capital expenditure (capex), operational expenditure (opex) and financing costs (Table 1). Other aspects that need to be factored to estimate an LCOE include fuel costs, if applicable, plant capacity factor and project lifetime.

Table 1: Key components of LCOEs

Capital expenditure (capex)			Operational expenditure (opex)		Financing costs	
The upfront investment needed to build a power plant			*The expenses needed to maintain the power plant*		*The cost of capital used to finance the power plant*	
Development costs	Equipment costs	Balance of plant costs	Fixed opex	Variable opex	Cost of debt	Cost of equity

Source: BloombergNEF

The levelized cost of capacity (LCOC) – frequently used for utility-scale battery, gas reciprocating engine and open cycle gas turbine (OCGT) plants – is the long-term offtake price on a kilowatt-per-year basis required to recoup all the project costs and achieve a required equity hurdle rate on the investment. In other words, it is the ‘full’ lifetime cost assessment of one kilowatt (kW) of a utility-scale power plant.

In practice, battery storage power generators can recoup their project costs through various revenue streams if a market is structured to enable it. These can include wholesale energy markets, ancillary services, capacity mechanisms, or even via some shorter- and longer-term PPAs. Contracts can be structured around two components: one per megawatt-hour ($/MWh); another per kilowatt per time period, such as a year ($/kW/yr). In this context, the LCOE is the strike price assuming the generator gets all the revenue through MWh payments. Similarly, the LCOC is the strike price needed to recoup costs and hit the minimum return that equity investors expect, or the hurdle equity return on investment, assuming all the revenues are in $/kW/yr. Like the LCOE, the levelized cost of capacity incorporates both fixed and variable project costs.

Debt-equity ratio plays a critical role in determining the overall cost of capital of a renewable energy project

The debt-equity ratio (gearing ratio) indicates the balance between the amount of money provided by equity investors and the amount of money from debt providers. Given that renewable energy projects are capital intensive, the gearing ratio (and cost of capital overall) plays a critical role in project economics and technological competitiveness.

Debt is generally less expensive than equity because debt providers tend to take on lower risk. By contrast, equity providers expect higher returns to compensate for a higher risk, and their returns depend on project profitability.

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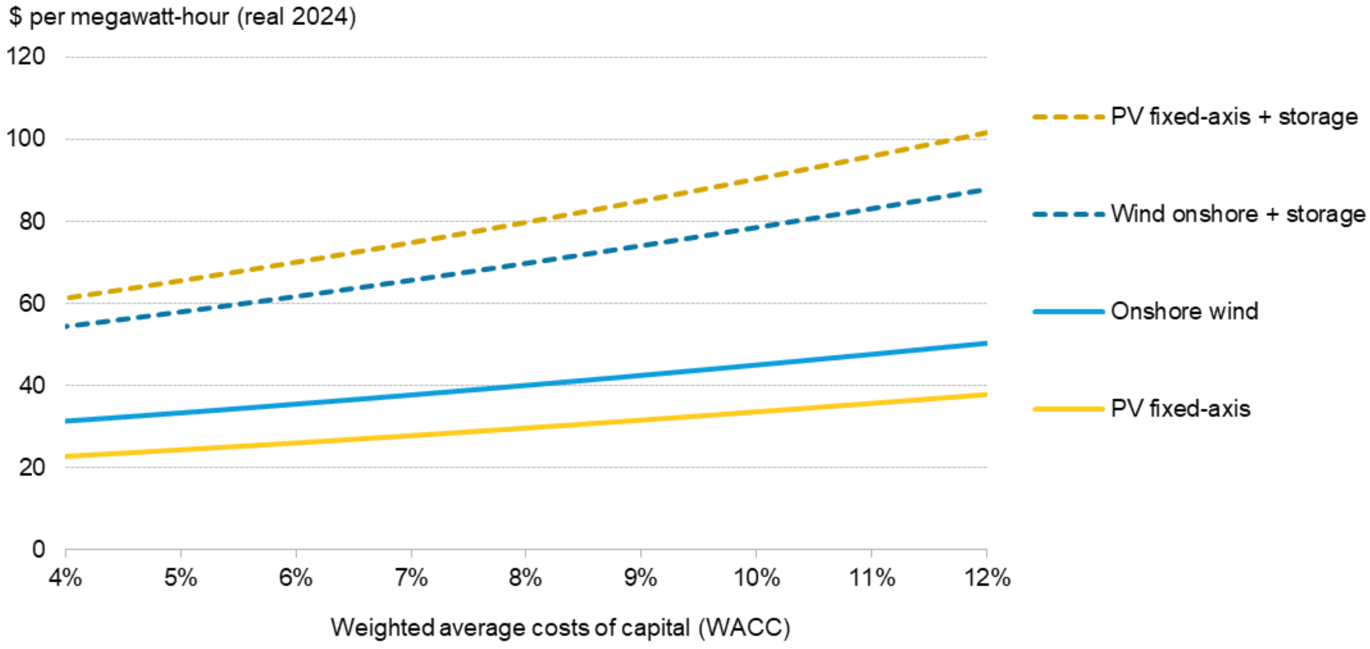
[9] BNEF’s LCOE estimates exclude costs of grid connection and transmission. They also exclude subsidies or incentives as they are intended to assess the true economic viability of technologies outside the bounds of policy support.

Generally, debt accounts for 60-80% of the overall financing for more established renewable energy technologies, such as wind and solar. Conversely, for emerging technologies, such as batteries, equity tends to make up 60-80% of finance, increasing the overall cost of capital.

A higher share of equity typically results in a higher weighted average cost of capital (WACC), which leads to higher LCOEs. For a project financed in 2024 in India (Figure 20), LCOEs for utility-scale PV rose at $1.91/MWh for each percentage-point increase in the cost of finance and rose at a rate of $2.40/MWh for wind. For more capex-intensive PV and onshore wind projects co-located with batteries in India, these rates were $5.42/MWh and $4.25/MWh, respectively.

Figure 20: Impact of weighted average cost of capital (WACC) on LCOEs in India



Source: BloombergNEF. Note: WACC is the rate a company is expected to pay (on average) on all its capital investments. Chart considers an operational project in 2024. PV refers to solar photovoltaics. For each megawatt of wind and PV with storage, the energy storage size assumed is 50% of the MW wind or PV capacity compared to the four-hour duration battery output (eg, a 50MW PV project assumes a 25MW battery).

The decline in the cost of PV and wind technology means that we can anticipate two tipping points in the competitive economics between different technologies

The first tipping point occurs when the cost of new-build wind and solar becomes cheaper than the cost of building a new gas or coal plant for bulk generation. From this point on, wind and solar would be built preferentially for bulk generation. The second tipping point occurs when it gets cheaper to build and operate new onshore wind or solar PV than to run an existing amortized coal or gas plant providing bulk electricity. Once the LCOE of solar or wind falls below the short-run marginal cost of an existing fossil-fuel plant, it makes economic sense to replace that plant with a new unit of renewable capacity.

The impact of lowering the cost of debt in more-mature wind and solar markets

Tipping point one is a key aspect for evaluating if new renewable energy projects already outcompete fossil-fuel-fired projects in cost, or for ascertaining when this moment will be reached. To evaluate the impact of concessional finance in accelerating this tipping point, BNEF has produced – for Vietnam, Turkey and South Africa – two LCOE scenarios:

- **Higher concessionality scenario** is our lowest-cost concessional finance scenario. It assumes that the total project cost is financed by CIF at a 400bps discount to MDB rates. Other assumptions are available in Appendix A.
- **Lower concessionality scenario** is our highest-cost concessional finance scenario, but lower than the country benchmark. It assumes that the total project cost is financed by CIF at a 200bps discount to MDB rates.

Specifically, we explore a range bounded by two hypothetical capitalization structure scenarios – higher LCOE and lower LCOE, detailed in Table 2 – and compare the LCOEs including concessional capital against our benchmark LCOEs with commercial debt only.

Table 2: Capitalization structure

Country	LCOE concessionality scenario	Debt Interest	CIF discount to MDB rates	CIF loan	MDB	Local commercial lenders	Gearing ratio	Tenor
South Africa	Higher	1,500bps	400bps	31.25%	37.5%	31.25%	80%	18 years
South Africa	Lower	1,500bps	200bps	25%	25%	50%	80%	18 years
Vietnam	Higher	1,000bps	400bps	33%	18%	49%	75%	15 years
Vietnam	Lower	1,000bps	200bps	20%	21%	59%	75%	15 years
Turkey	Higher	1,200bps	400bps	25%	30%	20%	75%	20 years
Turkey	Lower	1,200bps	200bps	15%	25%	35%	75%	20 years

Source: BloombergNEF. Note: Gearing ratio refers to debt-equity ratio.

The benchmark scenario in each of the three markets assumes that renewable projects are financed only on local commercial financing terms, which are here based on BloombergNEF data collected on the ground. The two concessional capitalization scenarios presented above are tested using BloombergNEF's proprietary project finance model, the Energy Project Asset Valuation Model. The impact of the blended concessional finance is a function of the prevailing cost of capital available to renewable project developers locally as well as the lending rates that multilateral development banks are likely to offer.

As technology costs and risks drop, the impact of concessional finance in more-mature wind and solar markets is less pronounced

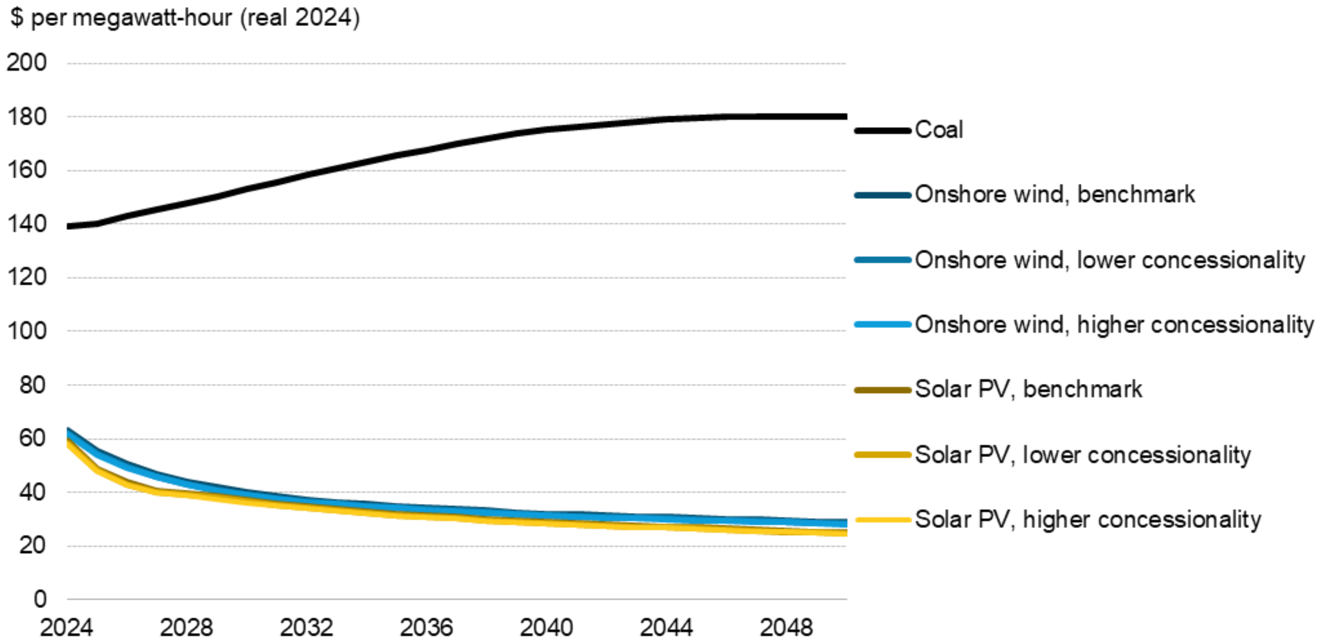
Over the past decade wind and solar costs have plummeted, renewable energy capacity has boomed, and technology risk has declined. As a result, the impact of concessional finance as a mechanism to reduce cost of debt for these projects in mature markets – or markets with some experience in deploying onshore wind and PV – is no longer transformative for two main reasons:

- Onshore wind and/or PV have become cheaper than their fossil-fuel rivals in many emerging markets. Thus, cheaper capital makes little difference to the relative economics. This is the case of South Africa and Turkey. Concessional debt provided in markets that have already reached tipping point 1 may risk crowding-out private capital.

- In markets where wind or PV are not yet outcompeting fossil fuel-powered plants – such as Vietnam for onshore wind – cheaper loans alone may not be enough to significantly shift this tipping point earlier.

In South Africa, for instance, renewables are already substantially cheaper on a levelized basis than new coal plants without concessional financing. Solar PV costs around $48/MWh, and onshore wind costs $55/MWh, while new coal-fired capacity costs $140/MWh. Lowering the costs further through concessional finance or grant scenarios is not needed to drive this tipping point (Figure 21).

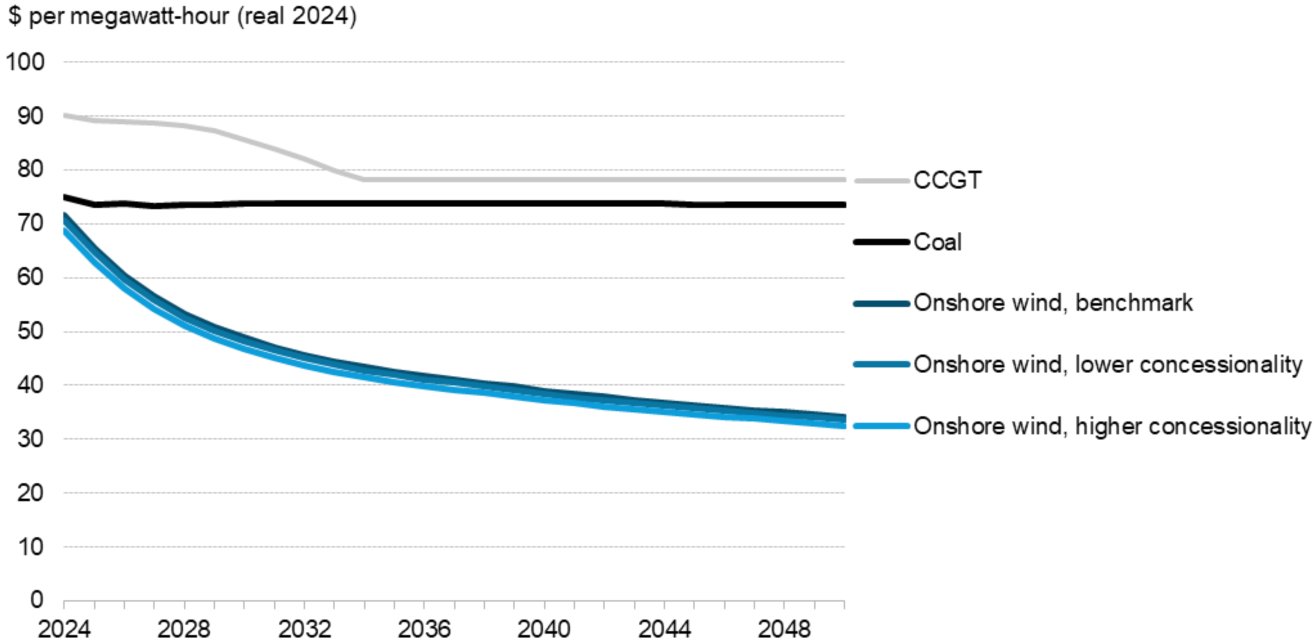
Figure 21: New solar PV and onshore wind versus coal, South Africa



Source: BloombergNEF. Note: Solar photovoltaic (PV) includes fixed-axis only. Minimum concessionality assumes that 25% of the total project cost is financed by CIF at a 200bps discount to MDB rates. Maximum concessionality scenario assumes that 31.25% of the total project cost is financed by CIF at a 400bps discount to MDB rates. For more details on methodology and assumptions please refer to the Appendix A. For fossil fuels, maximum and minimum ranges are defined by assumptions on technology cost variation, no concessionality included.

In Turkey, onshore wind plants have only recently become cheaper than their fossil-fuel counterparts, with their $66/MWh price tag now beating $89/MWh for CCGT and $73/MWh for coal. While concessionality can accelerate the rate at which renewables become cheaper than fossil-fuel plants, its support is likely not needed to raise competitiveness (Figure 22).

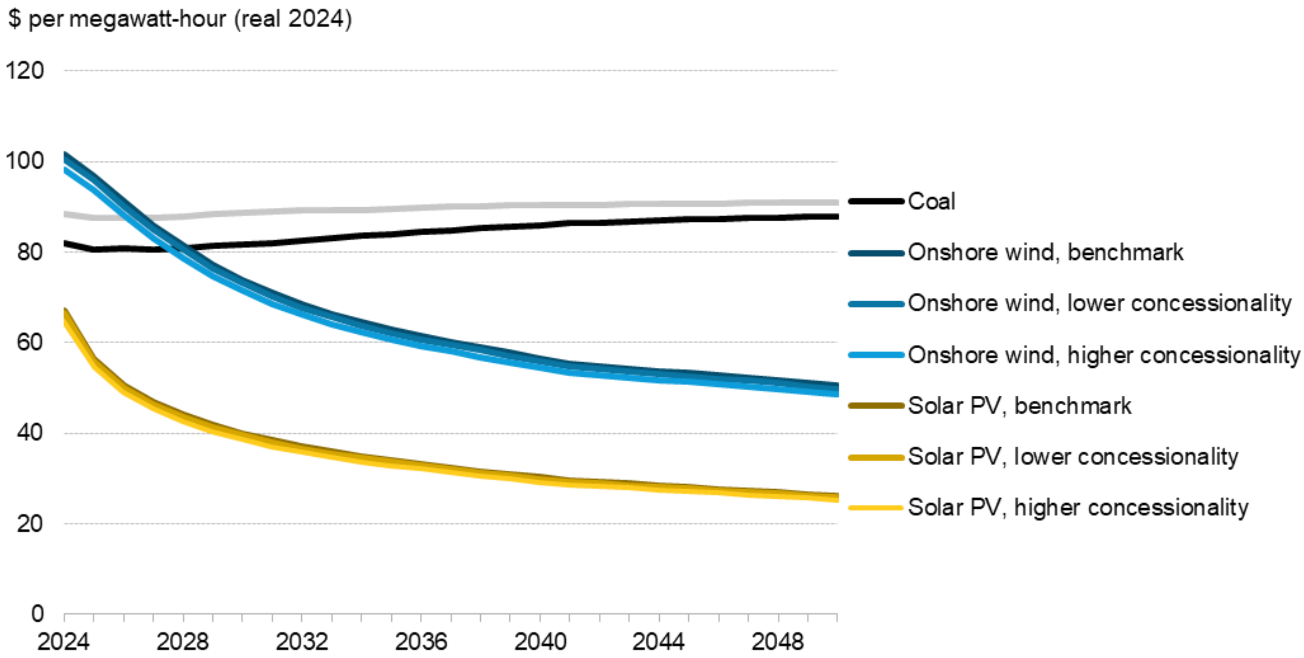
Figure 22: New onshore wind versus coal and CCGT, Turkey



Source: BloombergNEF. Note: Minimum concessionality assumes that 15% of the total project cost is financed by CIF at a 200bps discount to MDB rates. Maximum concessionality scenario assumes that 25% of the total project cost is financed by CIF at a 400bps discount to MDB rates. For more details on methodology and assumptions please refer to Appendix A. CCGT is combined cycle gas turbine. For fossil fuels, maximum and minimum ranges are defined by assumptions on technology cost variation, no concessionality included.

In Vietnam, solar PV is the cheapest source of new bulk electricity generation: at $56/MWh, it is already outcompeting its fossil-fuel-based counterparts in 2025. New onshore wind plants ($96/MWh), however, remain more expensive than new coal ($80/MWh) and combined-cycle gas turbines ($87/MWh). Still, concessional debt would be unlikely to accelerate the competitiveness of onshore wind in Vietnam and bring forward the date when the technology's costs will be on par with those of coal.

Figure 23: New solar PV and onshore wind versus coal and CCGT, Vietnam



Source: BloombergNEF. Note: Solar photovoltaic (PV) includes fixed-axis only. Minimum concessionality assumes that 20% of the total project cost is financed by CIF at a 200bps discount to MDB rates. Maximum concessionality scenario assumes that 33% of the total project cost is financed by CIF at a 400bps discount to MDB rates. For more details on methodology and assumptions please refer to the Appendix A. CCGT is combined cycle gas turbine. For fossil fuels, maximum and minimum ranges are defined by assumptions on technology cost variation, no concessionality included.

The impact of lowering the cost of debt in less-mature wind and solar markets

Concessional debt remains a crucial tool for advancing deployment in less-mature markets

While concessional debt is no longer critical to accelerating the cost-competitiveness of wind and solar technologies in many more-mature markets, it remains a crucial tool for advancing deployment in less-mature markets, or in markets with little or no experience in deploying these technologies. In this context, concessional debt can help reduce financing costs, lower overall project risks and provide a demonstration effect that can help crowd-in commercial capital.

Countries where these mechanisms can be most impactful tend to have a strong enabling environment in place, but limited experience in deploying renewables. These would fall in the ‘enabled for development’ quadrant in Figure 14 and are highlighted below. In addition, countries where concessional debt can have a greater impact on reducing the overall project cost will present high capex, short loan tenors and high cost of capital.

As wind and solar technology risk has reduced significantly across the globe over the past years, before deploying capital to less-mature markets, it is also essential to evaluate the root causes of limited investment flows in each country. In some cases, markets may need a combination of concessional finance and mechanisms to address country and market risk to crowd-in private finance and effectively scale the technology.

Energy transition stages framework: Enabled for market development results for selected countries

Higher enabling environment, lower experience

- **Solar PV:** Armenia, Colombia, Ghana, Guatemala, Kazakhstan, Morocco, Nigeria, North Macedonia, Peru, Philippines, Senegal, Thailand Turkey, Uruguay
- **Onshore wind:** Colombia, Kazakhstan, Morocco, Peru, Philippines, Thailand, Vietnam

Emerging clean energy technologies

Unlike wind and solar, newer clean energy technologies in emerging markets have yet to achieve economic competitiveness. While sector-specific policies are a critical first step, targeted financial support may be needed to reduce perceived technology risks and establish a track record, paving the way for commercial finance to scale deployment.

Optimizing finance structures is key to accelerating deployment of battery storage systems

Financing costs significantly impact the LCOE of battery storage systems. Understanding the specific impact of loan terms, interest rates and equity return expectations is essential to identifying how development organizations can most effectively reduce costs and accelerate the deployment of the technology.

In order to discuss the mechanisms that can most effectively reduce the cost of four-hour battery storage systems in emerging markets and accelerate the deployment of the technology, this section examines the impact of financial adjustments on battery storage LCOE for three gearing ratios: 70% debt/30% equity (70:30), 50% debt/50% equity (50:50) and 30% debt/70% equity (30:70). The LCOE increases 5% as the gearing ratio shifts from 70:30 to 30:70, highlighting the higher cost of equity finance compared with debt.

As discussed on the start of the subsection 3.4, debt is generally less expensive than equity because debt providers tend to take on lower risk. In contrast, equity providers expect higher returns to compensate for higher risk, and their returns depend on project profitability.

Each of the scenarios in Figure 24 adjust one financial assumption – interest rate, loan tenor or equity internal rate of return (IRR) – while holding others constant, with the benchmark scenario serving as the baseline. India has been used a as proxy for project technical assumptions, market rates, capex and opex due to data availability. Financial assumptions do not necessarily reflect India’s market and are available on Table 3.

Table 3: Assumption applied to sensitivity analysis of LCOE under different scenarios and gearing ratios for four-hour utility-scale battery storage

Scenario	Note	IRR (%)	Interest rate (bps)	Term loan (years)
Benchmark	Benchmark scenario	15	1052	10
Lower interest rate	Applies a 10% reduction on interest rate	15	947	10

Longer term loan	Increases term loan from 10 to 16 years, aligned with the benchmark for PV	15	1052	16
Lower IRR	Applies a 10% reduction on IRR	13.5	1052	10

Source: BloombergNEF. Note: India has been used a as proxy for project technical assumptions, market rates, capex and opex due to data availability. Financial assumptions, available on the table above, do not necessarily reflect India's market reality.

A reduction of 10% in the expected equity internal rate of return leads to a significant drop in the LCOE, even in high-debt scenarios (70:30 gearing ratio). In a 70:30 scenario, lowering the IRR by 10% leads to a 4.5% reduction in the LCOE compared with the reference scenario, while in the 30:70 scenario the LCOE drops 6.2%.

Mechanisms targeting debt also remain relevant and can play a pivotal role in reducing LCOE, especially in high-debt configurations. Extending the loan tenor lowers annual repayment obligations, improving project cash flows and reducing the overall cost of financing. Increasing the loan tenor from 10 years to 16 years, in line with mature clean energy projects, leads to a 4% reduction on the 70:30 ratio scenario, the second-most-effective among the scenarios analyzed. Meanwhile, by lowering interest rates by 10%, the LCOE in the higher debt ratio scenario declines 2.3%, compared with the reference scenario.

Figure 24: Sensitivity analysis of levelized cost of electricity (LCOE) for four-hour utility-scale battery storage under different finance scenarios and gearing ratios, 2025

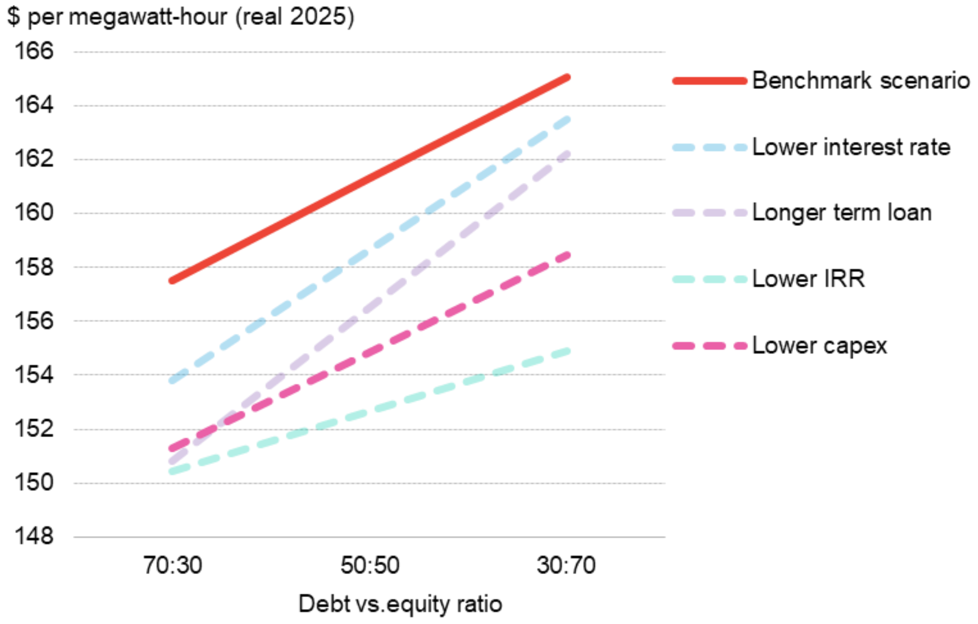
Source: *BloombergNEF. Note: India is used as a proxy for technical assumptions, market rates, capex and opex due to data availability. Interest rates, tenor of loan and internal rate of return (IRR) assumptions are available on Table 3. Battery assumptions are included in Table 12.*

Capex reductions can unlock significant LCOE declines

Capex plays a critical role in determining the LCOE for a four-hour battery storage project, as it represents a large portion of the total project costs. Battery storage technologies are particularly sensitive to upfront costs, including equipment, installation and supporting infrastructure. Reducing the capex not only decreases the overall project cost, but also directly improves financial metrics, as financing costs are proportional to the capex.

By lowering the capex by 5% compared with the reference scenario, the LCOE falls by 4% across the three debt-equity scenarios. In the 70:30 gearing ratio structure, the LCOE reached after a 5% reduction in capex is similar to the LCOE reached by lowering the IRR by 10% or extending the loan tenor from 10 to 16 years.

Figure 25: Sensitivity analysis of levelized cost of electricity (LCOE) for four-hour utility-scale battery storage under different finance and capex scenarios and gearing ratios, 2025



Source: BloombergNEF. Note: India is used as a proxy for technical assumptions, market rates, capex and opex due to data availability. Interest rates, tenor of loan and internal rate of return (IRR) assumptions are available on Table 3. Battery assumptions are included in Table 12.

In newer technologies, a combination of mechanisms that tackle equity, debt and capex simultaneously can be the most effective approach

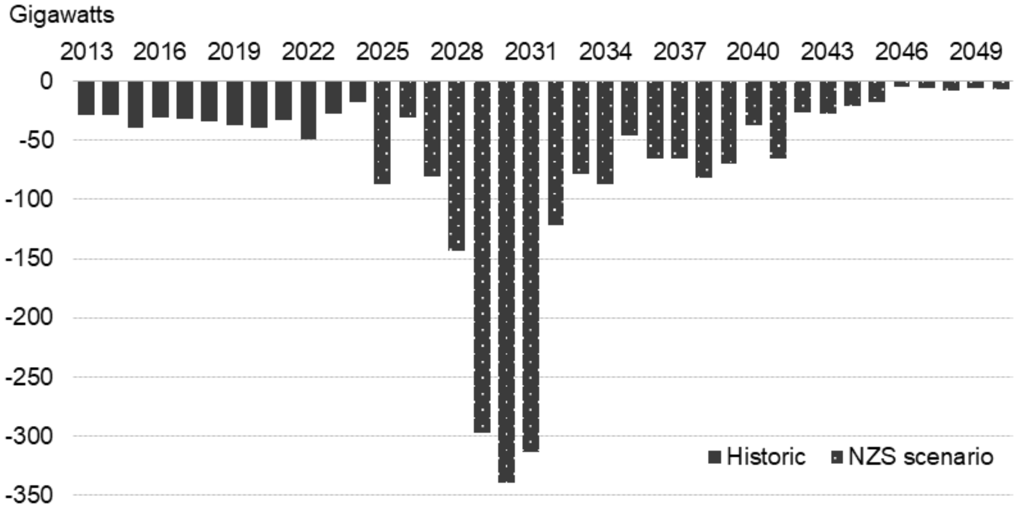
To achieve the lowest LCOEs for newer and riskier technologies, such as battery storage, a combination of mechanisms that tackle equity, debt and capex simultaneously can be the most effective approach. For instance, mechanisms to reduce IRR while unlocking debt to reach a 70:30 ratio would lead to a 9% drop in the LCOE, or an absolute reduction of $14.6/MWh, compared with the 30:70 reference scenario.

Mechanisms that shift to a higher debt-to-equity ratio and reduce equity IRR generally include risk guarantees and first-loss protections to mitigate project risks and make lenders more willing to provide higher levels of debt. Concessional financing programs can help extend loan tenor and reduce interest rates. Technical assistance grants for feasibility studies, resource assessment and capacity building can help lower capex by improving project planning and reducing inefficiencies. Upfront capital grants for project to offset high cost of initial deployments can also significantly drop capex.

Section 4. Accelerating the phase-out of coal

Coal is the largest source of CO2 emissions in the world, which means that phasing out this fossil fuel is a foundational step toward meeting global climate targets and transitioning to a net-zero future. Under BNEF's Net Zero Scenario, the world must retire 979 gigawatts of coal-fired generating capacity over 2025-2030, most of it located in emerging markets

Figure 26: Global coal capacity retirements under BNEF's Net Zero Scenario



Source: BloombergNEF's New Energy Outlook 2024

An integrated approach is fundamental to an early and just transition away from coal

The retirement and repurposing of coal plants is critical for meeting climate goals, but doing so requires a comprehensive and integrated approach., one that addresses socio-economic, policy and technical barriers. It will also need to ensure energy security and a 'just transition' for affected workers and communities. For markets looking to phase out coal:

1. **Policies and regulatory frameworks** will need clear timelines to reduce uncertainty and guide investment decisions. These should take the social and economic needs of local communities into account.
2. **Costs for building clean firm power** must fall**.** Today, the high cost of co-locating renewables with storage remains a barrier to replacing coal in many markets.
3. **Financial instruments** will be necessary to manage stranded coal assets and compensate utilities while also enabling investment in clean energy.

4.1. Building a supportive enabling environment for a just transition

A strong enabling environment is critical for countries that wish to achieve an early and just transition away from coal. It ensures that technical, financial and social aspects of the coal phase-out are addressed comprehensively. For emerging markets, this involves improving policy and regulatory frameworks, building institutional capacity and addressing the socioeconomic impact of the transition. Development finance institutions are uniquely positioned to provide the technical assistance and capacity-building initiatives required to build such an enabling environment.

DFIs support have the potential to reduce uncertainty, guide investment decisions and help governments design and implement holistic transition strategies

The report *Early Phase-Down of Coal Plants: The Role of Development Finance Institutions*, published by Boston University's Global Development Policy Center, highlights three categories in which DFIs can provide enabling environment support through grants for technical assistance and capacity building:

- Technical assistance and planning support
- Socioeconomic impact mitigation
- Policy and regulatory reforms

These interventions have the potential to reduce uncertainty, guide investment decisions and help governments design and implement holistic transition strategies that are transparent, equitable and aligned with climate goals.

Technical assistance and planning support

DFIs can provide targeted technical assistance to address the complexities of coal phase-outs and ensure robust planning for renewable energy integration. These can include:

- **Power sector planning:** Assisting governments in creating comprehensive energy transition plans that align coal phase-outs with renewable energy deployment and grid modernization.
- **Utilities support:** Providing technical expertise to utilities for decommissioning coal plants, improving operational efficiency, and preparing for renewable integration.
- **Overcoming legal barriers:** Supporting governments in navigating legal complexities, such as negotiating coal contracts.
- **Transparent and holistic coal retirement frameworks**: Developing transition plans that clearly outline the financial, environmental and social aspects of coal retirements.
- **Assessment of costs and benefits:** Conducting detailed studies on the economic, environmental and social costs and benefits of coal plant retirements to inform government policies and private sector investment decisions.

Socioeconomic impact mitigation

Mitigating and managing the socioeconomic impacts of phasing out coal is essential. Many communities are dependent on coal, and the early retirement of coal plants can lead to job losses, economic decline in coal regions and social dislocation and public discontent if not managed carefully. DFIs can play a crucial role in helping governments address these immediate impacts while creating future economic opportunities for those affected. Effective efforts prioritize social dialogue, stakeholder engagement and targeted financial support, and can include:

- **Worker training programs:** Financing and designing training programs to equip workers with skills for new employment opportunities, prioritizing sectors like renewable energy.
- **Inclusive stakeholder engagement:** Facilitating dialogue with affected workers, communities and local governments to ensure their needs and perspectives are integrated into transition planning.

- **Clear communication strategies:** Supporting governments in developing transparent and inclusive communication campaigns to build public awareness and support for the benefits of transitioning away from coal.
- **Economic diversification support:** Supporting the development of alternative industries and economic activities to reduce reliance on coal.

Policy and regulatory reforms

Strong policy and regulatory frameworks are essential to phasing out coal and scaling up renewable energy. DFIs can help governments by:

- **Helping countries eliminate policies that favor coal:** Supporting the removal of coal subsidies, preferential tariffs and outdated regulations that hinder the energy transition.
- **Supporting pro-renewable policies:** Assisting in designing renewable energy policies, in line with what was discussed in Section 3.

4.2. Accelerating the cost competitiveness of renewable energy projects

As coal plants retire, their replacement must provide both clean dispatchable energy and grid stability. Co-locating storage with renewables is the most commercially viable option, but the cost of batteries can still be a significant barrier to scaling adoption, especially in emerging markets. This is particularly important for achieving tipping point 2, discussed in subsection 3.4.

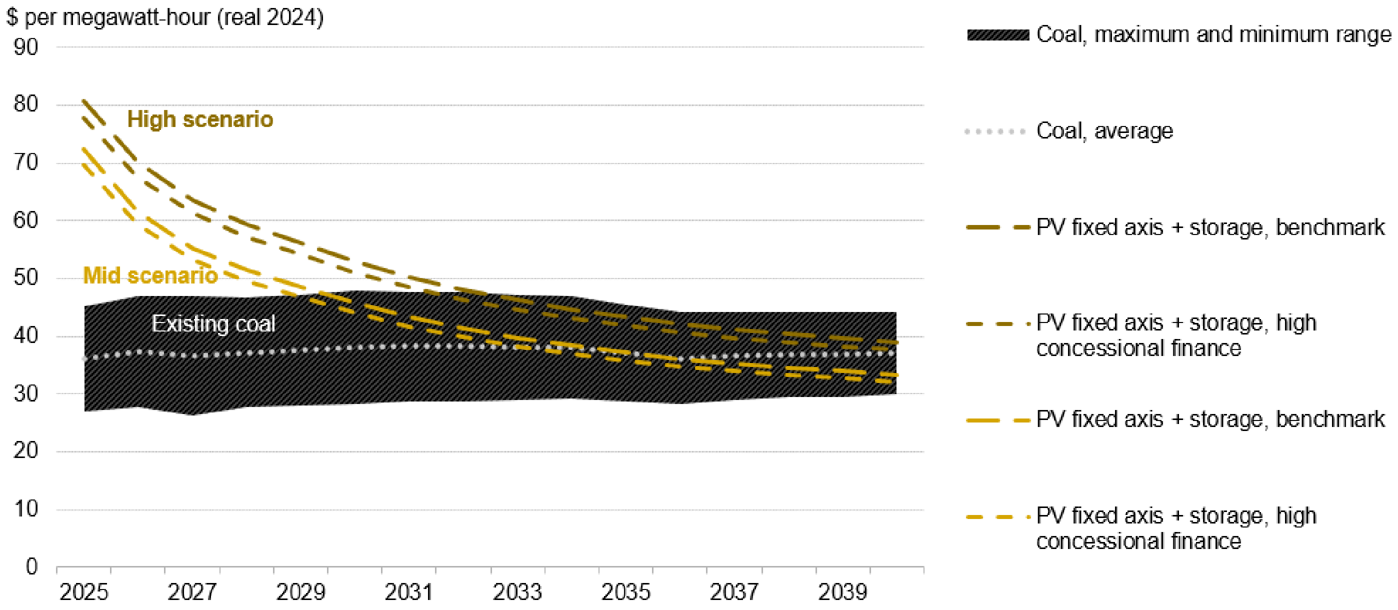
Additional support is critical to enhance cost competitiveness of renewables co-located with storage and replace coal

As result, additional support to accelerate the cost competitiveness of these power plants – as compared with the cost of running existing coal plants – will be necessary to accelerate a transition away from coal in emerging markets.

The tipping point 2 analysis is a key metric for evaluating if renewable energy projects already outcompete fossil-fuel-fired projects in cost, or for ascertaining when this moment will be reached. To discuss the potential impact of concessional debt in accelerating tipping point 2 between existing coal plants in South Africa and both co-located PV with storage (Figure 27) and co-located onshore wind with storage (Figure 29), assuming batteries are sized at 50-25% of PV and wind power capacity with four hours of discharge duration, BNEF has produced a sensitivity analysis for mid- and high-cost benchmark scenarios (Table 2) considering the assumptions in Appendix A.

In our high scenario, utility-scale PV co-located with storage starts to compete with existing coal plants in 2033, while in our mid scenario this tipping point is reached in 2030. In both scenarios, concessional debt can reduce the LCOEs by an average of 3.7% per year over 2025-2030 and shift tipping points to one year earlier. Note that in each of these cases, PV and storage may not fully replace the generation profile of the coal plant given the size of batteries relative to PV and discharge duration assumptions.

Figure 27: Cost of new solar PV + storage, compared to coal running costs, South Africa



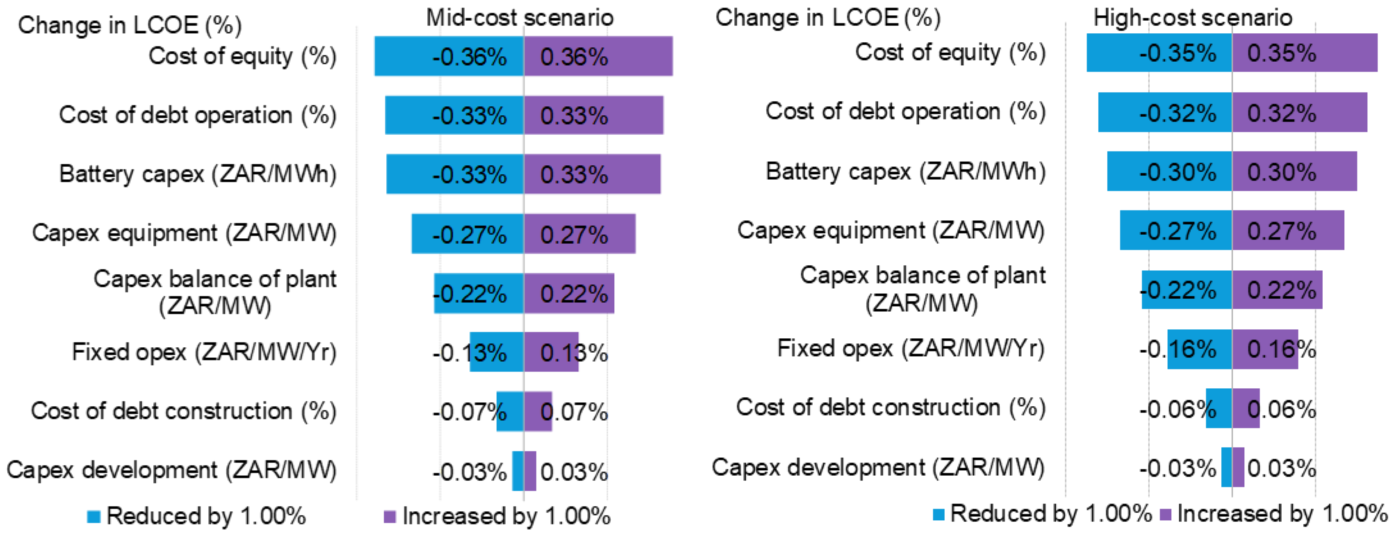
Source: BloombergNEF. Note: India is used as a technical proxy for batteries due to limited data availability. PV refers to solar photovoltaic. Energy storage size assumed is 50% of the PV megawatt capacity for a four-hour duration battery (eg, a 10MW PV project assumes a 5MW battery). Battery assumptions are included on Table 12.

In order to accelerate the competitiveness of co-located PV such that the technology can start competing with running coal plants by 2027[10], a 26% drop from the high-benchmark-scenario LCOE would be required. The required decrease from the mid-scenario LCOE is lower, at 15%. Achieving these decreases will require a combination of mechanisms that address capex, cost of debt and cost of equity.

Financing costs play a pivotal role in driving down the LCOE of PV projects collocated with storage. The sensitivity analysis below demonstrates that in 2027, a 1% reduction in the cost of equity leads to a 0.36% drop in the LCOE in the mid scenario, and a 0.35% reduction in the high scenarios. Similarly, a 1% reduction in the cost of debt for operation results in a 0.33% and 0.30% decrease in LCOE across the mid and high scenarios, respectively. A decline in the battery capex is the third-most-impactful intervention and leads to a 0.27% drop for each reduction of 1% in both scenarios (Figure 28).

[10] Project analyzed considers a 2027 operation date to indicate an earliest available operational date, allowing for the fastest retirement of coal plants as possible.

Figure 28: LCOE sensitivity analysis, PV fixed axis + storage, 2027

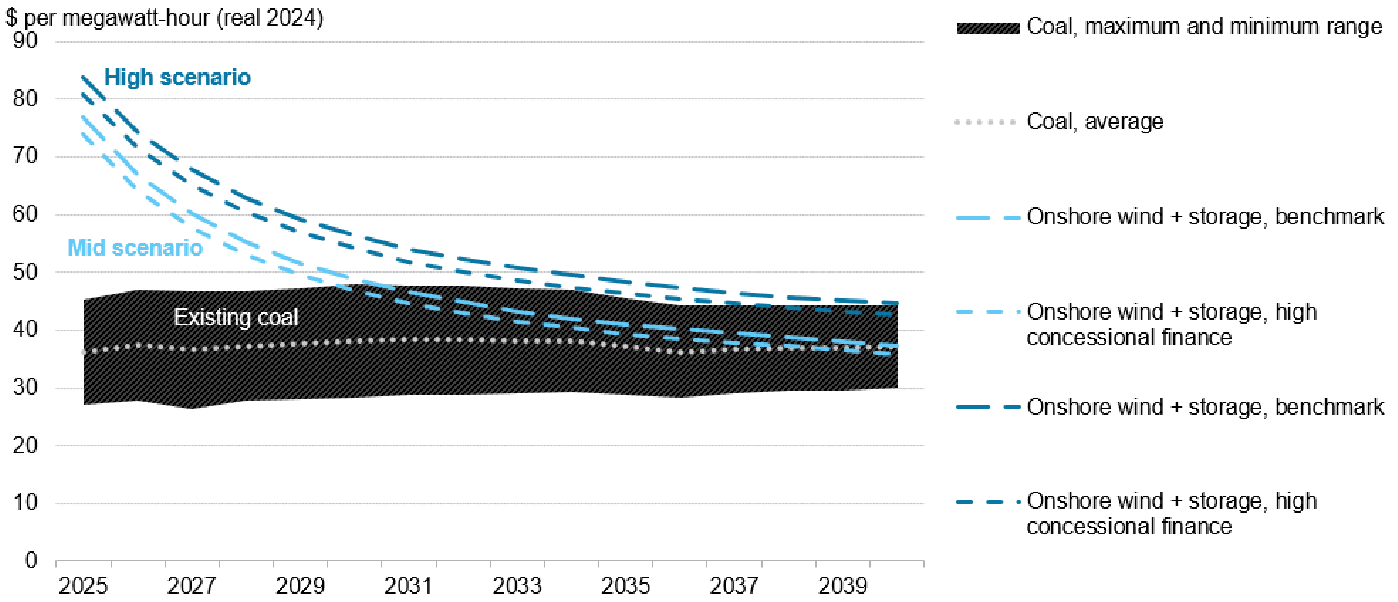


Source: BloombergNEF. Note: Considers a solar photovoltaic (PV) fixed axis + storage project in South Africa operational in 2027. India is used as a technical proxy for batteries due to limited data availability. ZAR refers to South African Rand, MW is megawatt, and LCOE is levelized cost of electricity.

In our high scenario, onshore wind co-located with storage does not start competing with existing coal plants before 2040. However, in our mid scenario, this tipping point is reached by 2030. In both scenarios, concessional debt reduces the LCOE by an average of 4% per year over 2025-2031, accelerating the tipping point by one year on the mid scenario.

In order to accelerate even further the competitiveness of onshore wind co-located with storage, so that the technology can start competing with coal plants by 2027, a 33% drop from the high scenario would be required. The required decrease from the mid-scenario LCOE is lower, at 24%. As with PV co-located with storage, achieving these decreases will require a combination of mechanisms that address capex, cost of debt and cost of equity.

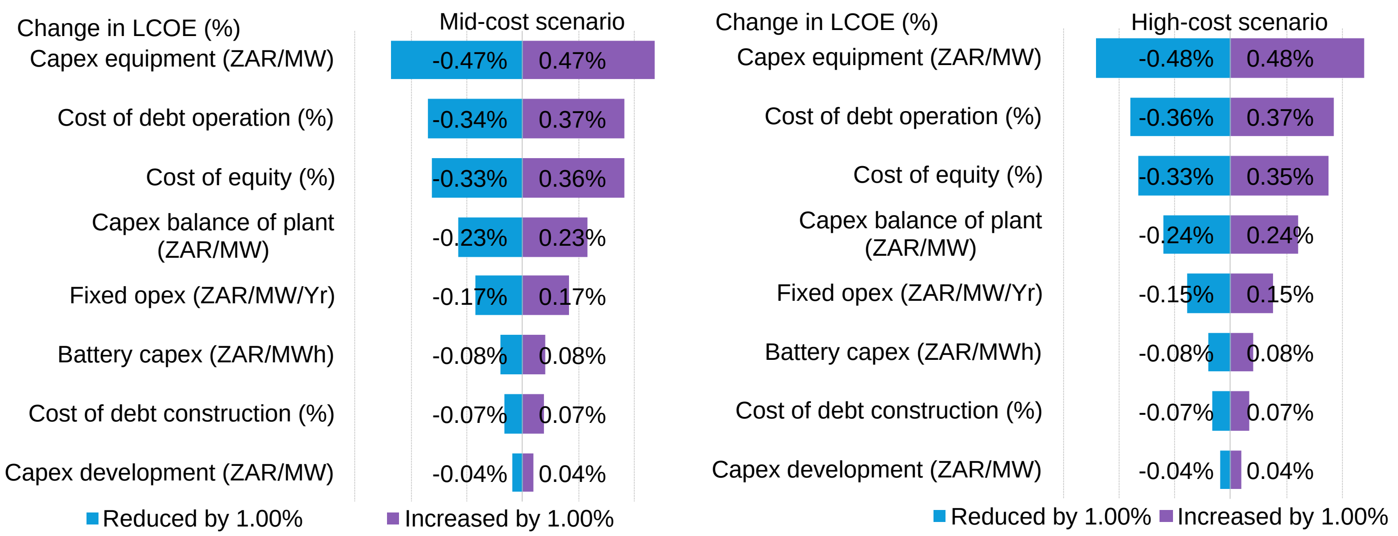
Figure 29: Cost of new onshore wind + storage, compared to coal running costs, South Africa



Source: BloombergNEF. Note: India is used as a technical proxy for batteries due to limited data availability. Energy storage size assumed is 25% of the wind megawatt capacity for a 4-hour duration battery (eg, a 20MW Wind project assumes a 5MW battery). Battery assumptions are included on Table 12.

The sensitivity analysis below demonstrates that in 2027, the most significant financial factor is capex equipment, where a 1% reduction leads to a 0.47% drop in LCOE in the mid scenario and a 0.48% drop in the high scenario. The factor with the second-greatest impact is the cost of debt for operation, with a 1% reduction resulting in a 0.34% decrease in the mid scenario and a 0.36% drop in the high scenario. Finally, a 1% reduction in the cost of equity reduces the LCOE by 0.33% in the mid scenario and 0.35% in the high scenario. This analysis reinforces the importance of mechanisms that target equity, debt and capex to accelerate competitiveness.

Figure 30: LCOE sensitivity analysis, Onshore wind + storage, 2027



Source: BloombergNEF. Note: Considers an onshore wind + storage project in South Africa operational in 2027. India is used as a technical proxy for batteries due to limited data availability. ZAR refers to South African Rand, MW is megawatt, and LCOE is levelized cost of electricity.

DFIs can reduce financing costs through concessional financing and risk guarantees

By both reducing the financing costs and lowering the perceived risks of renewables co-located with storage, these mechanisms can lower the cost of capital and attract private investment. Additionally, offering grants to reduce capex can play a pivotal role in improving the cost-competitiveness of renewables co-located with storage, particularly in emerging markets where initial investment costs remain a key barrier for newer technologies.

Still, it is important to recognize that supporting the economic competitiveness of renewables co-located with storage at scale may require utilizing newer and creative mechanisms and a larger-than-usual scale of financing. An integrated approach, combining multiple mechanisms, may thus be needed.

4.3. Financial instruments to support or compensate early retirement of coal plants

Retiring coal plants early is sometimes more easily said than done. Such retirements can be expensive, impacted stakeholders need to be compensated, and additional investment may be required to bring the plan to fruition. Financial instruments to mitigate these economic impacts may include:

- **Coal asset buyouts**, where MDBs and other stakeholders purchase coal plants to decommission them ahead of schedule. Some MDBs have already initiated these programs: for example, the Asian Development Bank's Energy Transition Mechanism is designed to accelerate the transition away from fossil fuels in Southeast Asia.
- **Transition-linked loans and green bonds**, where private capital is channeled into projects supporting coal phase-outs while promoting renewable energy deployment. For example, the European Investment Bank (EIB) has supported green bonds targeted at energy transition projects in emerging markets, emphasizing the role of private capital in the transition.
- **Carbon pricing mechanisms**, which can generate revenue that can be re-invested into coal retirement strategies.
- **Compensation schemes**, which provide direct financial assistance to utilities and operators to offset revenue losses.
- **Debt-for-climate swaps**, which can enable countries to redirect portions of their debt repayment obligations toward financing climate projects, including coal plant retirements.

Section 5. Accelerating the development and deployment of clean hydrogen

The current suite of cost-competitive zero-carbon technologies – wind, solar, batteries and electrified transport, among others – is poised to cut emissions meaningfully over the coming decades. But to zero out emissions entirely, more technologies will be required to provide around-the-clock clean power, decarbonize high-temperature industrial processes, cut emissions associated with livestock, and solve other challenges related to the energy transition.

Green hydrogen is one of the key solutions to decarbonizing hard-to-abate sectors; it also serves as a case study for piloting and deploying new technologies. Policymakers must take care when strategizing how best to scale up these nascent climate solutions. While technology-specific incentives can encourage producers to manufacture or deploy a certain technology, governments also risk 'picking winners' among the technology solutions, potentially leading to suboptimal outcomes.

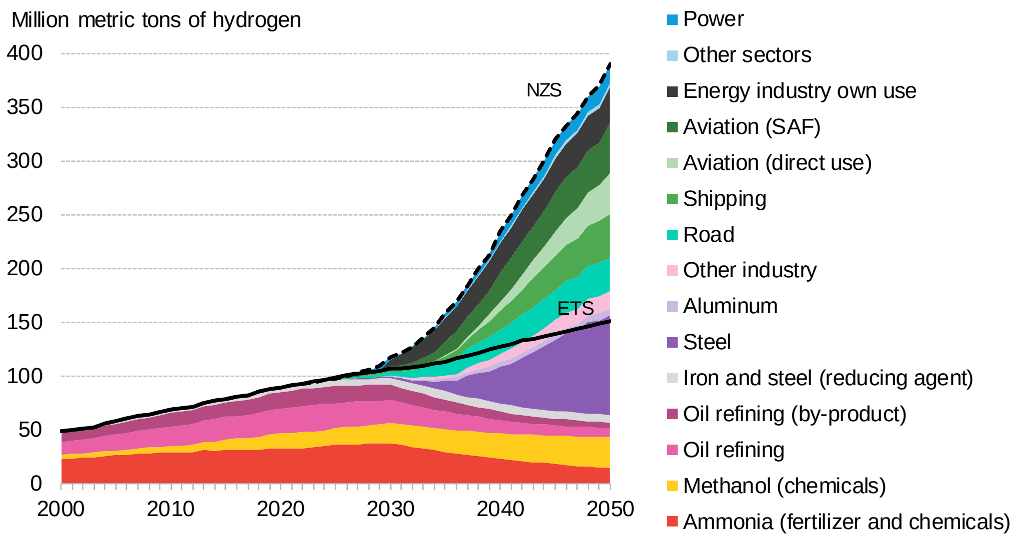
5.1. Hydrogen technology trends

Reaching net zero requires a fourfold expansion of hydrogen production

Under BNEF's Net Zero Scenario hydrogen production will need to more than quadruple in the coming decades, from 94 million metric tons (Mt) of fossil-fuel-based output today, to 390Mt of clean hydrogen supply by mid-century.

Most of the growth in hydrogen demand is driven by use in three sectors: iron and steel production, aviation (including both direct hydrogen use and as feedstock in sustainable aviation fuel production), and long-distance shipping (Figure 31). In the Net Zero Scenario, iron and steel manufacturing uses a combined 99Mt of hydrogen come 2050 – a quarter of annual volumes at mid-century and more than the entire world hydrogen demand today. Aviation accounts for 22% and shipping for 10% of demand.

Figure 31: Global hydrogen demand by sector and application



Source: BloombergNEF. Note: Energy industry own use includes energy consumed to produce final energy carriers from primary energy carriers and energy industry own use. ETS refers to BNEF's Economic Transition Scenario, which describes an energy transition driven by least-cost technologies and with no policy support beyond what is in place today. NZS refers to BNEF's Net Zero Scenario, which lays out a pathway to net-zero emissions with no overshoot by 2050. SAF refers to sustainable aviation fuel. Assumes gravimetric energy density of 140 megajoules per kilogram for hydrogen.

The sectors that rely most heavily on hydrogen in 2050 in the Net Zero Scenario are those that are hardest to electrify, either because of the lack of commercially available electric processes, (for instance, in primary steel production), or because of the low energy density of batteries, which limits their use in electric vehicles over long distances in aviation, shipping and trucking. Hydrogen could also be an important vector in the decarbonization of high-heat industrial sectors (such as steel, where it is also used for its chemical properties) and through direct and indirect use in commercial transport (aviation, shipping, long-haul trucking).

Today, about three-quarters of hydrogen production is 'gray' hydrogen produced from unabated fossil fuels. The associated emissions of these processes are as high as 3% of total human-made CO2 emissions. Switching from gray hydrogen to clean hydrogen, which includes both blue and green hydrogen,[11] is thus vital for decarbonizing incumbent uses, such as ammonia production for fertilizers and chemicals, methanol production for plastics and chemicals, and oil refining.

By 2050, thanks to the falling costs of renewables and electrolyzers, electrolysis using clean electricity becomes the dominant pathway for hydrogen production in the NZS, meeting 94% of all demand, or 367Mt (Figure 32). New electrolyzers drive significant increases in power demand, with resulting capacity build.

[11] Renewable or 'green' hydrogen refers to hydrogen produced with renewable electricity. 'Blue' hydrogen is hydrogen from fossil fuels that is produced with carbon capture and storage (CCS), to zero out emissions. Gray hydrogen is produced with fossil fuels with no CCS component.

Figure 32: Hydrogen consumption by type of production in selected sectors, Net Zero Scenario

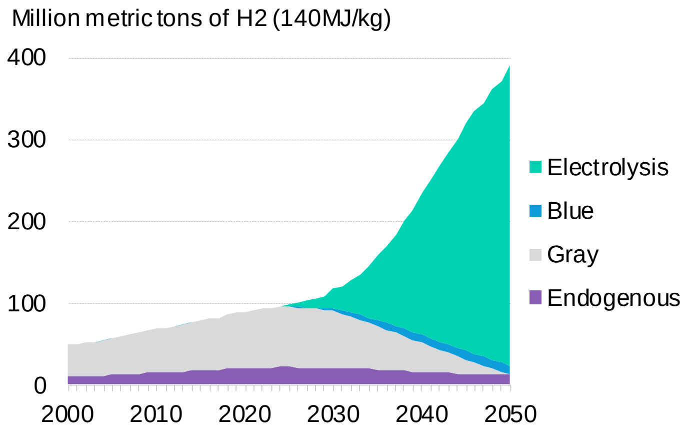
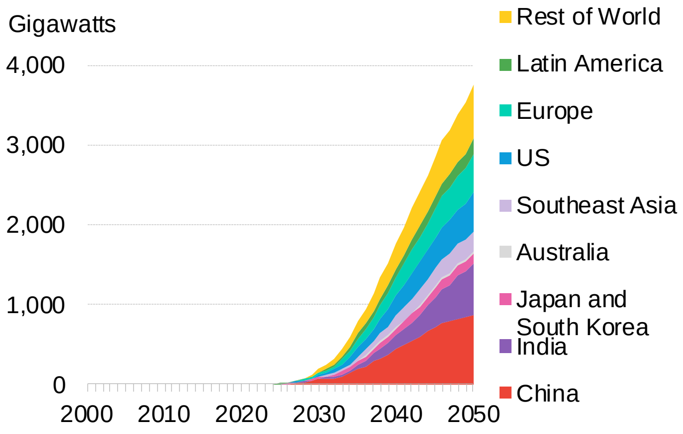


Figure 33: Cumulative electrolyzer capacity by region, Net Zero Scenario

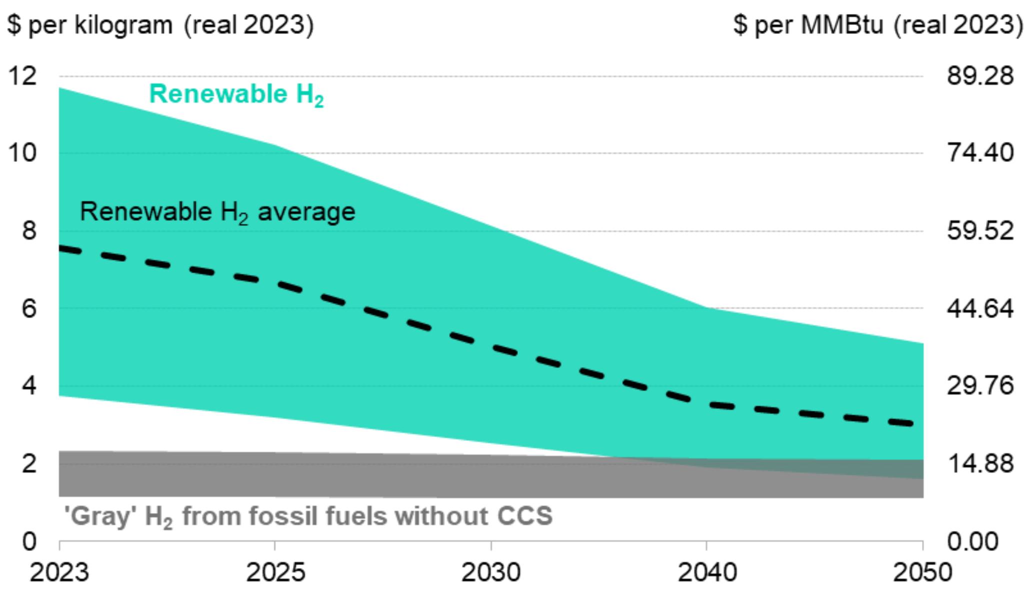


Source: BloombergNEF. Note: MJ/kg refers to megajoules per kilogram of hydrogen.

Renewable hydrogen will not be cheaper than gray in most markets even by 2050

Without subsidies or carbon prices, renewable hydrogen is unlikely to become competitive with 'gray' hydrogen made from fossil fuels in most markets even by 2050. China and India are the two markets that could potentially see green hydrogen compete with gray by 2040 due to their low renewable hydrogen costs and high costs to produce gray hydrogen. Worldwide, the average levelized cost of renewable hydrogen (LCOH2) falls 34% by 2030 to $5.02 per kilogram and another 40% by 2050 to $3.01/kg, for a total drop of 60% over 2023-2050. Levelized gray hydrogen costs stay at about $1.11-$2.35/kg in our forecast for the 12 modeled markets.

Figure 34: LCOH2 for newly built plants in 12 markets, by financing year



Source: BloombergNEF. Note: The renewable hydrogen range considers the cheapest LCOH2 for each market at a varying utilization rate and models using alkaline electrolyzers. The right axis shows the hydrogen cost expressed in units of energy, where 1 million British thermal units

(MMBtu) of energy is the equivalent of the energy contained in 7.44kg of H2 at the higher heating value. Markets include Australia, Brazil, China, Germany, India, Japan, Spain, UK, Texas, Utah, New York and Saudi Arabia.

5.2. Supporting clean hydrogen

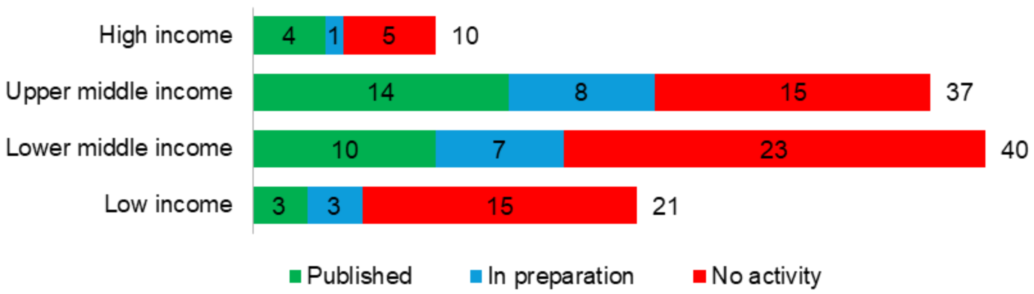
Clean hydrogen enabling environments

Unlike more mature renewable energy sectors, clean hydrogen requires coordinated actions across policy, regulation, infrastructure planning and market development to attract investment at scale. Without clear policies, incentives, and regulatory certainty, private capital remains hesitant and project risks remain high. DFIs can play a transformative role by supporting governments in designing national hydrogen strategies, regulatory frameworks, demand-side policies and infrastructure roadmaps. The effectiveness of policy support hinges on understanding the sector-specific and technology-neutral approaches that best align with countries' priorities, economic realities and available resources.

Emerging markets aim to engage in the global hydrogen economy

Research from BNEF shows that as of January 2025, 30 emerging markets across different income levels have already developed a hydrogen strategy or roadmap out of the 108 emerging markets assessed. Another 20 countries are in the process of preparing hydrogen strategies or roadmaps. This marks substantial growth since 2020, when Chile, alone among emerging markets, had a hydrogen strategy in place. It also indicates a growing recognition of hydrogen's potential as a crucial component in the future economic landscapes of emerging markets.

Figure 35: Status of hydrogen strategies in emerging markets



Source: BloombergNEF. Note: Mapped data show strategies for 108 emerging economies surveyed in Climatescope as of January 2025.

Of the 30 emerging markets that have implemented a hydrogen policy, a third have set a 2030 hydrogen electrolyzer target, while 13 have established a hydrogen production target for the same year.

For instance, Vietnam recently unveiled its hydrogen strategy, with plans to produce 100,000-500,000 metric tons of hydrogen annually by 2030, and then scaling up to 20 million tons per year by 2050.

The interest in developing renewable hydrogen projects is timely for many emerging markets, which often have good solar and wind resources, as well as potential for biomass and hydroelectricity. As developed markets increasingly impose stringent measures to reduce emissions, many emerging economies hope to export green hydrogen and clean products.

While interest in hydrogen among emerging markets soars, policy support remains insufficient

Annual investments in the energy transition are primarily being deployed to relatively established clean energy technologies. Investments in industrial decarbonization have remained much lower due to the high costs and nascent status of the required technologies, as well as the lack of policy support to overcome these challenges.

Policy intervention enabled solar, wind and other established renewable technologies to scale up and become cost-competitive through public subsidies and private investments. Now, industrial sectors and hydrogen production plants require financial resources – including public subsidies – to become economically competitive in the near term with status-quo solutions.

Balancing supply and demand of a new technology can be especially tricky. Policy support must enable both clean hydrogen production capacity and industrial offtake agreements to keep pace.

Policies can target hydrogen production and uptake to allow lowest-cost abatement technologies to compete

Technology-specific support

Incentives designed to support the uptake of a specific technology are often needed in the early stages of technology deployment, when the economics are challenging. These incentives can also make it easier for governments to meet broader goals, like building a local supply chain in a certain sector.

Technology-neutral support

A technology-neutral policy, on the other hand, could drive companies to compete against each other to provide least-cost solutions that maximize emissions reductions. In this approach, the market chooses the technologies with the most potential in the energy transition.

However, the technologies that are cheaper today may win out in the short term over more nascent and expensive solutions that have the potential for greater scale and abatement capacity in the long run. This approach can also slow down the transition: companies will hedge risks by investing in many solutions before picking the one that they wish to scale; subsequently, governments will be left subsidizing various outcomes before winners take off.

Table 4: Examples of policy approaches to support the deployment of clean hydrogen

	Technology-specific	Technology-neutral
Sector-specific	Government offers support to hydrogen solutions applied to the steel sector	Government offers support to all low-carbon solutions to decarbonize the steel sector
Sector-neutral	Government offers support to hydrogen solutions across all sectors	Government offers support to all low-carbon technologies to decarbonize any sector

Source: BloombergNEF

In theory, policy should be used to support key sectors that would not otherwise be able to decarbonize, in a technology-neutral manner, in order to arrive at an economically optimal outcome. However, since facilitating technology-neutral competition can take longer and hydrogen in select sectors is seen as strategically important, policymakers may choose to focus public funding efforts on specific players.

Governments must determine the best hydrogen use-cases and where to deploy support

When thinking about how to deploy public funding efforts to support hydrogen, governments should consider which sectors require it versus which sectors can already decarbonize with solutions that are already widely accessible.

Recognize the feasibility of applying hydrogen to unavoidable or high-potential markets

Policymakers can ask: Do we have unavoidable sectors, such as ammonia production, oil refining, and methanol production, that can use green hydrogen as a drop-in chemical in their existing processes? Or are there high-potential applications, such as steel, that could use green hydrogen as a feedstock, but that may require retrofits to existing production plants?

If the unavoidable sectors are not part of the country's economy, then the government may only be concerned with the economics of stimulating the supply side by supporting new hydrogen production projects. If boosting supply is the focus, then land availability and renewable energy production capacity will be key to enabling green hydrogen production. That said, it's important to note that there is currently insufficient demand to absorb the proposed hydrogen production projects, so ensuring offtake may play a role in planning.

Consider whether a neutral or specific approach to policymaking is most viable

If any of these scenarios are the case, then the government can boost the unavoidable sectors directly to procure green hydrogen and its derivatives, support the high-potential sectors to retrofit plants to utilize green hydrogen, or spark green hydrogen production projects through sector- and technology-specific or sector-neutral and technology-specific support.

If the government is working with a stringent budget to deploy new technologies, then targeted hydrogen support to unavoidable and high-potential use cases, or ramping up hydrogen supply, is more efficient than neutral support for potentially experimental solutions.

Policy support mechanisms vary depending on a government's resources and goals

Three major incentive mechanisms to support hydrogen production and uptake are being explored by governments today: direct grants and preferential-rate loans, tax credits linked to investments or output, and competitive auctions. These policy mechanisms can apply to any of the technology/sector support combinations. While they typically pertain to the supply side, they could also be applied to the demand side (Table 5).

Table 5: Policy mechanisms to stimulate the hydrogen market

Mechanism	Description
Direct grant or preferential loans	Governments can offer developers upfront funds to invest in hydrogen infrastructure or procure hydrogen, either unconditionally or at a low-interest rate

Tax credits	Governments can effectively reduce the tax bill of companies by subsidizing the capital expenditure (investment-linked tax credit) or the operating expenditure (output-linked tax credit)
Competitive auction	Governments can offer a competitive bidding auction where the lowest-cost abatement projects are awarded funding

Source: BloombergNEF

Grants and preferential-rate loans are typically targeted at a specific technology, but they can also be implemented in a technology-neutral way. They are always awarded to specific projects or companies, sometimes through a competitive process.

Tax credits reduce the amount of income that is subject to tax. Output-linked tax credits are designed to incentivize the uptake of hydrogen or another low-carbon technology by awarding subsidies based on the realized quantity produced. Investment-linked tax credits subsidize the project's capital expenditure, although manufacturers become fully responsible for the plant after completing the project, unless they are able to redeem another credit or incentive to support operations. Tax credits are principally used in North America.

Competitive auctions entail project developers bidding for funding, evaluated on the basis of how much hydrogen the project will produce, or tons of carbon abated per subsidy dollar. Governments could award the least-cost abatement solutions when allocating budget while also preserving funds for less-established, higher-cost technologies that need more support to commercialize, a process known as stratified bidding. This would involve several rounds of bidding with increasing price ceilings and set budgets per phase within a single auction. Governments could alternatively implement an auction for hydrogen projects exclusively, a model used by the EU Innovation Fund to accelerate hydrogen supply.

Beyond these considerations, auctions can be designed in a number of ways: Governments may offer developers a fixed subsidy over the contract length (**fixed premium**), regardless of revenues, or a variable premium over the contract length where they top up project revenues to an agreed upon strike price (**contract for difference**). A **carbon contract for difference** (CCfD) is a type of CfD where the carbon price, such as the EU ETS, is accounted for in the payable subsidy amount.

If governments stimulate hydrogen production capacity, then securing demand through domestic or international markets is imperative

Countries must consider: Drive up domestic consumption, or lean on the possibility of fulfilling international demand?

Hydrogen incentives typically target production, but securing demand for that supply is equally essential, and the type and availability of hydrogen consumers should determine where governments focus their resources.

If a country is home to the unavoidable hydrogen use-cases of ammonia, oil and methanol, then policymakers can consider stimulating the uptake of clean hydrogen from these sectors through a mix of incentives and regulations. Before mandating the switch, policymakers should evaluate the capabilities of the domestic hydrogen supply or the feasibility of importing and storing hydrogen.

If a country is not home to the unavoidable use cases of hydrogen but is investing in building out the domestic hydrogen supply chain, then international demand and the feasibility of becoming a hydrogen exporter become more topical.

The economics of competing in international markets and exporting hydrogen and its derivatives to industrials overseas will hinge on several factors: trading hub infrastructure, pipeline and storage capabilities, whether markets utilize a carbon market and a carbon border adjustment mechanism, and the competing cost of producing hydrogen in those markets versus importing hydrogen that may be subject to import tariffs.

Mandates are effective, but can drive up domestic prices in the meantime

Mandates are a sure-fire way to drive hydrogen consumption, provided they can be enforced. However, consumption mandates for a new technology can be politically challenging to implement when the technology requires new capital investment for the sector to use it, as is the case with hydrogen and steelmaking. Policy that focuses on existing hydrogen consumers is a good early step to build hydrogen demand.

Mandates can lead to unintended consequences for consumers, however: Companies may raise their prices and pass the added costs down the value chain, unless governments pair the mandate with an incentive to help the company procure the technology without losing profits. This could take form in a demand-side carbon contract for difference (CCfD) – a type of competitive auction where the government assists the company in producing low-carbon hydrogen while maintaining profits.

Appendix A. Assumptions for concessional finance scenarios

A.1. Levelized cost of electricity (LCOE) scenarios

Table 6: Concessional finance scenario

Financing	Debt			Equity
Lenders/ Sponsors	CIF loan	Development bank loan	Local commercial loan	Commercial sponsors
All-in rates	200bps discount to MDB rates (lower concessionality scenario) and 400bps discount to MDB rates (higher concessionality scenario)	MDB rates	BNEF country benchmark	BNEF country benchmark

Source: BloombergNEF. Note: MDB refers to multilateral development banks.

Table 7: Interest rates and loan tenor assumptions

Country of project	South Africa	Vietnam	Turkey
Interest rate	1500bps	300bps	1200bps
Project currency	ZAR	VTN	TRY
Loan tenor	18 years	15 years	20 years

Source: BloombergNEF. Note: ZAR is South African Rand, VTN is Vietnamese Dong, TRY is Turkish Lira.

Table 8: South Africa capitalization structure

LCOE scenario	CIF loan	MDB	Local commercial lenders	Debt	Commercial sponsors (equity)
Lower concessionality	25% with 200bps discount to MDB rates	25%	50%	80%	20%
Higher concessionality	31.25% with 400bps discount to MDB rates	37.5%	31.25%	80%	20%

Source: BloombergNEF

Table 9: Vietnam capitalization structure

LCOE scenario	CIF loan	MDB	Local commercial lenders	Debt	Commercial sponsors (equity)
Lower concessionality	20% with 200bps discount to MDB rates	21%	59%	75%	25%
Higher concessionality	33% with 400bps discount to MDB rates	18%	49%	75%	25%

Source: BloombergNEF

Table 10: Turkey capitalization structure

LCOE scenario	CIF loan	MDB	Local commercial lenders	Debt	Commercial sponsors (equity)
Lower concessionality	20% with 200bps discount to MDB rates	33%	47%	75%	25%
Higher concessionality	33% with 400bps discount to MDB rates	40%	27%	75%	25%

Source: BloombergNEF

A.2. Levelized cost of electricity (LCOE) sensitivity scenarios for co-located batteries

Table 11: LCOE sensitivity analysis parameters for South Africa

WACC	Solar PV (fixed axis) + storage	Onshore wind + storage
Debt financing	1500bps	1500bps
IRR	15.95%	15.95%
Tenor	18 years	18 years
Cost of debt ratio	80%	80%

Source: BloombergNEF. Note: WACC refers to weighted average cost of capital.

A.3. Batteries assumptions for levelized cost of electricity (LCOE) analysis

Table 12: Battery assumptions

Fixed O&M (% of capex)	Daily cycles	Cycle life	Roundtrip efficiency
1%	1	7,500	90%

Source: BloombergNEF

Appendix B. Methodology for Energy Transition Stages Framework

The Energy Transition Stages Framework analyzes a country's readiness for developing clean energy technologies. The methodology rests on two main pillars: the enabling environment and experience.

B.1. Enabling environment

- The enabling environment includes the market's key policies, operating rules, incentives and barriers to investment for each technology. Policies include auctions, feed-In tariffs, net-metering, clean energy targets, nationally determined contributions (NDCs), net zero targets, priority grid access for renewables, energy access targets and utility liberalization.
- The enabling environment scores, which are determined based on over 60 indicators in the Climatescope methodology, range from 0 to 5, with "5" signaling the most comprehensive environment for renewable energy deployment and "0" indicating the least comprehensive environment. The scores are awarded based on the availability of each policy or indicator, with adjustments for policies directed to each target technology covered in this project.

Table 13: Highest and lowest enabling environment scores for solar PV in emerging markets

Highest enabling environment		Lowest enabling environment	
Country	Enabling environment	Country	Enabling environment
India	2.96	Guinea	0.94
Romania	2.76	Lesotho	0.92
Turkey	2.76	Eritrea	0.81
Brazil	2.74	South Sudan	0.80
Colombia	2.72	Turkmenistan	0.80

Source: BloombergNEF

The enabling environment is structured around four individually weighted categories: policy, power sector, barriers and incentives, and currency variation. The weight of each category is listed below. Categories are further divided into indicators and subindicators, all of which are also individually weighted.

Table 14: Enabling Environment structure

Category	Category weight	Indicator	Indicator weight on category score	Indicator weight on total score	# of indicators	# of sub-indicators
Policy	55%	Renewable Energy	65.5%	36.0%	9	49
Policy		Climate Change	28.0%	15.4%	4	10

Policy		Flexibility	6.50%	3.6%	2	5
Power sector	30%	General	37.5%	11.3%	7	7
Power sector		Wholesale	37.5%	11.3%	6	6
Power sector		Decentralized energy	12.6%	3.8%	9	9
Power sector		Flexibility	6.30%	1.9%	6	7
Power sector		Ancillary services	6.30%	1.9%	2	2
Barriers and incentives	10%	General	66.7%	6.7%	9	9
Barriers and incentives		Decentralized energy	33.3%	3.3%	1	1
Currency variation	5%	Currency variation	100%	5.0%	1	1

Source: BloombergNEF.

B.2. Experience

A market's experience in deploying a given technology includes asset financing from private investors, market infrastructure and completion of projects. Markets with greater experience in deploying renewable energy capacity typically offer lowered risks, technology costs and costs of capital for developers. Experience scores are determined by:

- Installed capacity of the selected technology by year-end 2023
- Five-year private finance flows for the selected technology
- The country's national electrification rate in 2023

Table 15: Highest and lowest experience scores for solar PV in emerging markets

Highest experience		Lowest experience	
Country	Experience	Country	Experience
Namibia	25.82	Niger	0.05
Chile	24.89	Ecuador	0.08
China	24.10	Botswana	0.24
El Salvador	21.40	Tanzania	0.29
Kenya	21.26	Morocco	0.35

Source: BloombergNEF

As with the enabling environment, results are technology specific.

- Experience scores are calculated based on the following formula: ((The share of the selected technology capacity in total 2023 installed capacity) * (The share of private investment in total selected technology investment in the last 5 years)) * (The 2023 access to electricity rate) * 100)
  - Installed capacity is measured in megawatts. The share of the technology in total installed capacity is a percentage.
  - Investment is measured in US dollars. The share of private investment in total investment in the last five years is a percentage.
  - Access to electricity rates are national percentages.

Appendix C. Country coverage list

Number	Country	Region	World Bank Income Group	OECD status
1	Algeria	Africa	Lower middle income	non-OECD
2	Angola	Africa	Lower middle income	non-OECD
3	Benin	Africa	Lower middle income	non-OECD
4	Botswana	Africa	Upper middle income	non-OECD
5	Burkina Faso	Africa	Low income	non-OECD
6	Burundi	Africa	Low income	non-OECD
7	Cameroon	Africa	Lower middle income	non-OECD
8	Central African Republic	Africa	Low income	non-OECD
9	Chad	Africa	Low income	non-OECD
10	Democratic Republic of the Congo	Africa	Low income	non-OECD
11	Egypt	Africa	Lower middle income	non-OECD
12	Eritrea	Africa	Low income	non-OECD
13	Ethiopia	Africa	Low income	non-OECD
14	Ghana	Africa	Lower middle income	non-OECD
15	Guinea	Africa	Low income	non-OECD
16	Ivory Coast	Africa	Lower middle income	non-OECD
17	Kenya	Africa	Lower middle income	non-OECD
18	Lesotho	Africa	Lower middle income	non-OECD
19	Liberia	Africa	Low income	non-OECD
20	Madagascar	Africa	Low income	non-OECD
21	Malawi	Africa	Low income	non-OECD
22	Mali	Africa	Low income	non-OECD
23	Mauritania	Africa	Lower middle income	non-OECD
24	Morocco	Africa	Lower middle income	non-OECD
25	Mozambique	Africa	Low income	non-OECD
26	Namibia	Africa	Upper middle income	non-OECD
27	Niger	Africa	Low income	non-OECD
28	Nigeria	Africa	Lower middle income	non-OECD
29	Republic of the Congo	Africa	Lower middle income	non-OECD
30	Rwanda	Africa	Low income	non-OECD

31	Senegal	Africa	Lower middle income	non-OECD
32	Sierra Leone	Africa	Low income	non-OECD
33	Somalia	Africa	Low income	non-OECD
34	South Africa	Africa	Upper middle income	non-OECD
35	South Sudan	Africa	Low income	non-OECD
36	Sudan	Africa	Low income	non-OECD
37	Tanzania	Africa	Lower middle income	non-OECD
38	Togo	Africa	Low income	non-OECD
39	Uganda	Africa	Low income	non-OECD
40	Zambia	Africa	Lower middle income	non-OECD
41	Zimbabwe	Africa	Lower middle income	non-OECD
42	Armenia	Asia-Pacific	Upper middle income	non-OECD
43	Azerbaijan	Asia-Pacific	Upper middle income	non-OECD
44	Bangladesh	Asia-Pacific	Lower middle income	non-OECD
45	Cambodia	Asia-Pacific	Lower middle income	non-OECD
46	Georgia	Asia-Pacific	Upper middle income	non-OECD
47	India	Asia-Pacific	Lower middle income	non-OECD
48	Indonesia	Asia-Pacific	Lower middle income	non-OECD
49	Kazakhstan	Asia-Pacific	Upper middle income	non-OECD
50	Kyrgyzstan	Asia-Pacific	Lower middle income	non-OECD
51	Laos	Asia-Pacific	Lower middle income	non-OECD
52	Malaysia	Asia-Pacific	Upper middle income	non-OECD
53	Mongolia	Asia-Pacific	Lower middle income	non-OECD
54	Myanmar	Asia-Pacific	Lower middle income	non-OECD
55	Nepal	Asia-Pacific	Lower middle income	non-OECD
56	Pakistan	Asia-Pacific	Lower middle income	non-OECD
57	Philippines	Asia-Pacific	Lower middle income	non-OECD
58	Singapore	Asia-Pacific	High income	non-OECD
59	Sri Lanka	Asia-Pacific	Lower middle income	non-OECD
60	Tajikistan	Asia-Pacific	Lower middle income	non-OECD
61	Thailand	Asia-Pacific	Upper middle income	non-OECD
62	Turkmenistan	Asia-Pacific	Upper middle income	non-OECD
63	Uzbekistan	Asia-Pacific	Lower middle income	non-OECD

64	Vietnam	Asia-Pacific	Lower middle income	non-OECD
65	Albania	Europe	Upper middle income	non-OECD
66	Belarus	Europe	Upper middle income	non-OECD
67	Bosnia and Herzegovina	Europe	Upper middle income	non-OECD
68	Bulgaria	Europe	Upper middle income	non-OECD
69	Croatia	Europe	High income	non-OECD
70	Moldova	Europe	Upper middle income	non-OECD
71	Montenegro	Europe	Upper middle income	non-OECD
72	North Macedonia	Europe	Upper middle income	non-OECD
73	Romania	Europe	Upper middle income	non-OECD
74	Russia	Europe	Upper middle income	non-OECD
75	Serbia	Europe	Upper middle income	non-OECD
76	Turkey	Europe	Upper middle income	OECD
77	Ukraine	Europe	Lower middle income	non-OECD
78	Argentina	Latin America and Caribbean	Upper middle income	non-OECD
79	Bolivia	Latin America and Caribbean	Lower middle income	non-OECD
80	Brazil	Latin America and Caribbean	Upper middle income	non-OECD
81	Chile	Latin America and Caribbean	High income	OECD
82	Colombia	Latin America and Caribbean	Upper middle income	OECD
83	Costa Rica	Latin America and Caribbean	Upper middle income	OECD
84	Dominican Republic	Latin America and Caribbean	Upper middle income	non-OECD
85	Ecuador	Latin America and Caribbean	Upper middle income	non-OECD
86	El Salvador	Latin America and Caribbean	Lower middle income	non-OECD
87	Guatemala	Latin America and Caribbean	Upper middle income	non-OECD
88	Haiti	Latin America and Caribbean	Lower middle income	non-OECD
89	Honduras	Latin America and Caribbean	Lower middle income	non-OECD
90	Jamaica	Latin America and Caribbean	Upper middle income	non-OECD
91	Mexico	Latin America and Caribbean	Upper middle income	OECD
92	Nicaragua	Latin America and Caribbean	Lower middle income	non-OECD
93	Panama	Latin America and Caribbean	Upper middle income	non-OECD
94	Paraguay	Latin America and Caribbean	Upper middle income	non-OECD
95	Peru	Latin America and Caribbean	Upper middle income	non-OECD
96	Uruguay	Latin America and Caribbean	High income	non-OECD

97	Venezuela	Latin America and Caribbean	Low income	non-OECD
98	Bahrain	Middle East	High income	non-OECD
99	Iraq	Middle East	Upper middle income	non-OECD
100	Jordan	Middle East	Upper middle income	non-OECD
101	Kuwait	Middle East	High income	non-OECD
102	Lebanon	Middle East	Upper middle income	non-OECD
103	Oman	Middle East	High income	non-OECD
104	Palestine	Middle East	Lower middle income	non-OECD
105	Qatar	Middle East	High income	non-OECD
106	Saudi Arabia	Middle East	High income	non-OECD
107	Tunisia	Middle East	Lower middle income	non-OECD
108	United Arab Emirates	Middle East	High income	non-OECD

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