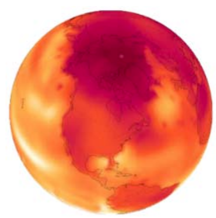
MIT Alumni for Climate Action

The Critical Role of Emerging and Developing Economies (EMDEs) in the Clean Energy Transition



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Credits

The MIT Alumni for Climate Action (MACA) is a non-partisan group of Massachusetts Institute of Technology alumni and affiliated members. The following MACA members wrote this document:

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Executive Summary

The global economy is in a period of rapid clean energy transition: clean technologies are becoming more competitive, more convenient, and scaling far faster than any predictions. Yet the world faces an economic and energy challenge to accelerate this deployment even further, especially across the Global South. Emerging Markets and Developing Economies (EMDEs) will play a pivotal role in determining whether the world remains below 2°C of warming. Unlike many advanced economies, whose apparent decoupling of economic growth from carbon emissions has been facilitated in part by outsourcing carbon-intensive industrial production abroad, EMDEs must pursue industrialization and expand access to adequate and reliable electricity while simultaneously decoupling economic growth from fossil fuel use.

A major question addressed in this paper is how to deploy clean energy even further and faster so that fossil fuels will be displaced in EMDEs over the course of the coming decades. Renewable energy deployment has already accelerated significantly, in both developed nations and EMDEs, yet global emissions continue to grow because clean energy is largely supplementing rather than replacing fossil fuels except in a few countries. In many instances, clean energy has been deployed mainly at the margins of existing energy systems. Accelerating the clean energy transition in EMDEs has consequently become both a development priority and a global necessity to avoid the worst effects of climate change.

Although low-cost clean energy such as solar and wind are increasingly available, their deployment can remain two to three times more expensive in EMDEs than in developed economies. This is mainly due to systemic risk arising from national, regional and international conditions. In many emerging markets, macroeconomic risks (including exchange rate volatility, elevated sovereign premiums, and limited capital market depth) drive up the cost of capital and weaken project economics. Reducing these risks and lowering financing costs can therefore be one of the most effective ways to mobilize clean energy investments at the scale needed.

Two other key issues highlighted in the paper are the importance of leveraging regional comparative advantages based on renewable energy capacity factors and the need for a systems approach to clean energy deployment. The EMDEs and the Global South have natural competitive advantages across many clean energy alternatives. Depending on the location, these nations and regions possess some of the world's best solar, wind, hydro, and geothermal resources, particularly across Southeast Asia, Africa, and Latin America. Realizing the full value of these resources, requires looking beyond individual technologies. Clean energy systems must integrate complementary generation, storage, smart grids, and demand flexibility to maintain reliability when renewable energy output does not match demand. The resulting resilience and redundancy across EMDEs offer exceptional development potential that can improve project economics.

This study concludes with the recommendation that rather than relying primarily on mandates, governments accelerate the transition in EMDEs by making clean energy the most economically attractive option. Climate financing for EMDEs should be viewed by developed countries not as developmental assistance, but as a shared economic investment. Success will require coordinated action among governments, multilateral institutions, financial markets, academia, and civil society. The rewards are substantial: greater energy security, stronger economic development, poverty reduction, and a more stable climate for all.

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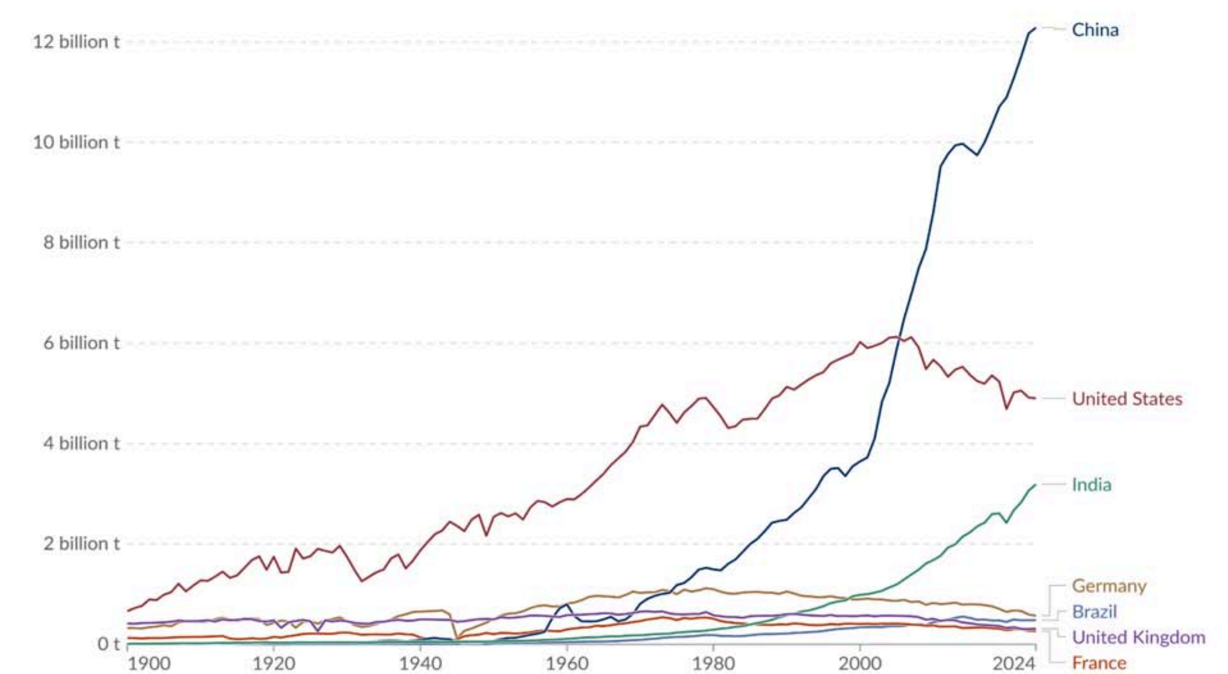
1. Introduction

Economic progress fuels an ever-growing demand for energy. In a world still deeply reliant on carbon-intensive systems, this demand puts pressure on global carbon dioxide and other greenhouse gas emissions (or CO_{2e}) emissions. This factor is not new, but its impact has been intensifying since the Industrial Revolution, especially in developed nations that are responsible for most of the accumulations of CO_{2e} in the atmosphere. These emissions have been increasing during the last decades as EMDEs have been accelerating their economic development and catching up with advanced economies, e.g. China. Therefore, despite substantial advances in clean energy and energy efficiency, which are slowly decoupling carbon emissions from economic activity, the accumulation of CO_{2e} in the atmosphere will continue to grow, until and unless countries can significantly accelerate the decarbonization process.

Any discussion of energy needs and emissions must reflect the basic value that every nation has the right to sustainable economic development and poverty reduction (United Nations, 2015). Following World War II, Western countries experienced an exceptional period of economic growth known as the "Golden Age of Capitalism" (1945-1973). According to Maddison (2001), during this period, these countries grew ≈ 4–5% per year. And recently during the last decades, China has experienced even greater economic growth, from being a poor developing nation in the 1960s to the world's second-largest economy today. From 1990 to 2020, China's economy grew ≈ 9 - 10 % per year (Bolt & van Zanden, 2024), resulting in an exponential increase in its emissions. To better understand how carbon-intensive the global economy is, consider how emissions in major countries increased during the periods mentioned since the beginning of the 20th century (Fig. 1).

Figure 1. Annual carbon dioxide emissions from major regions



Source: Our World in Data, based on Global Carbon Budget (2025), Accessed on: August 7, 2026.

Since 2000, developed countries have slowed their annual increase in emissions, while EMDEs have accelerated them. This does not mean that wealthy countries are emitting less; rather, the increase in their emissions has slowed as their economic growth has reached the threshold of development of their current economic potential. Another major underlying reason for these patterns is that a considerable fraction of global production is being outsourced to EMDEs (Box #1). This pattern can be better understood by examining the relationship between economic growth and emissions through the income elasticity of CO_2 emissions. Emissions from EMDEs are projected to continue rising well beyond the 2030s, implying that global efforts remain insufficient to keep warming below the 2°C threshold. As these countries expand their economies and trade in manufactured goods grows, they will continue to put pressure on emissions. This decoupling trajectory is still not enough given the cumulative emissions since the Industrial Revolution. In other words, the carbon budget needed to limit warming to 2°C would already be reached well before the year 2050 with >50% probability (IPCC, 2023). According to the (IEA (2025d), absent strong mitigation policies, EMDEs are projected to account for most global emissions by the end of the century.

Box #1. Inclusion of outsourcing in per capita emissions in the UK, EU, and US

The UK stands among the earliest advanced economies to fully phase out coal, advancing a steady, cross-party policy agenda aimed at gradually decoupling economic growth from emissions. As a result, its per capita emissions have declined to levels not seen since the late 19th century.
The key question, therefore, is how much carbon emissions the UK (and other rich nations in Europe and North America) effectively import through trade (outsourcing), and to what extent the per capita emissions they are responsible for would increase if these embedded emissions were fully accounted for?
The short answer is to a significant extent. To better understand the extent of this shift, it is worth looking at how much imported carbon emissions increase per capita emissions in developed countries:

- UK per capita emissions rise by ~40-60% (ONS, 2024)
- EU per capita emissions rise by ~ 20–30% (EUROSTAT, 2026)
- US per capita emissions rise by ~ 10-30% (Our World in Data, 2025)

The key question, therefore, is whether decoupling is occurring rapidly and deeply enough to reconcile continued economic development with effective climate action. EMDEs appear to be moving toward a more favorable relationship between economic growth and CO_2 emissions (Box #2), but the transition remains incomplete. The elasticity trends suggest a gradual shift away from carbon-intensive growth toward a more emissions-efficient growth model, rather than widespread absolute decoupling (World Bank, 2025). In other words, economic growth is increasingly generating fewer additional emissions, but emissions in many EMDEs are still rising.

Future technological advances could further accelerate this transition by providing alternatives that are increasingly competitive with, or even cheaper and more convenient than, fossil-fuel-based technologies. However, the speed at which these alternatives are developed and deployed will depend not only on technological progress, but also on supportive policies, appropriate market incentives, access to finance, and the ability to overcome the high upfront costs and infrastructure constraints that continue to limit deployment in many EMDEs.

Box #2. Elasticity of CO_2 with respect to GDP

The **elasticity of CO_2 emissions with respect to GDP** helps us assess the extent to which a country, region, or the global economy is decoupling economic growth from carbon emissions. It measures the percentage change in CO_2 emissions associated with a 1% change in GDP.

- **Elasticity > 1:** CO_2 emissions increase faster than GDP, indicating that economic growth is becoming more carbon-intensive.
- **Elasticity ≈ 1:** CO_2 emissions increase roughly in proportion to GDP, meaning there is little or no decoupling.
- **0 < Elasticity < 1:** CO_2 emissions continue to increase, but more slowly than GDP, indicating relative decoupling.
- **Elasticity < 0:** CO_2 emissions decline while GDP continues to grow, indicating absolute decoupling, the point at which economic growth is accompanied by a genuine decline in emissions.

So, how well are EMDEs doing?

The evidence suggests that EMDEs have made some progress, although the pace of decoupling remains insufficient to meet global climate objectives.

- **2000–2025:** CO_2 emissions elasticity remained **broadly around 0.9–1.1** (Freire-Gonzalez et al., 2024), reflecting limited and uneven decoupling.
- **Early 2000s:** Rapid industrialization, rising energy demand, and continued reliance on fossil fuels kept emissions growth broadly aligned with, and in some cases above, GDP growth.
- **After 2010:** Improvements in energy efficiency, the expansion of renewable energy, and structural changes in some economies contributed to increasing relative decoupling, with elasticity gradually moving below 1.
- **2030–2040** (illustrative and scenario-dependent): Elasticity could decline to approximately 0.6–0.9, suggesting stronger relative decoupling.
- **2041–2050** (illustrative and scenario-dependent): Elasticity could potentially fall within a range of approximately 0.5 to −0.1, indicating continued relative decoupling and, in the more ambitious scenarios, a transition toward modest absolute decoupling.

In addition, new clean energy generation is currently changing the energy dynamics primarily at the margins. With few exceptions, like China (IEA 2021a), the established energy structure is still hard to decarbonize, and renewable energy has mostly supplemented rather than displaced fossil fuels (Wallace-Wells, 2026). Accelerating clean energy deployment requires addressing the diverse development stages within EMDEs—ranging from low-income countries to major emerging economies—while also reflecting their distinct industrial, financial, and geopolitical contexts. This challenge is particularly severe for EMDEs and demands targeted support from developed countries, given that CO_2 emissions pose a global threat. Addressing this threat will require close cooperation between advanced economies and the Global South, leveraging their complementary comparative advantages to generate mutual economic benefits while easing key constraints such as high costs of capital, inadequate electricity grid infrastructure, persistent fossil fuel subsidies in many countries, and the difficulty of reducing costs in hard-to-decarbonize sectors.

How can these countries sustain long-term economic growth without intensifying CO_2 emissions? Unlike developed countries, many EMDEs still face rapidly rising energy demand due to urbanization, and the goals of reducing poverty , eliminating electrification gaps and building a modern industrial economy.

While significant challenges, they create an opportunity window to make a direct leap towards clean energy alternatives such as solar and wind energy, mini grids, modes of transportation powered by electricity, batteries and other means of storage, especially in high-resource countries such as Chile, Brazil, India, Middle Eastern countries, among others. On the other hand, there are structural challenges for the transition period in EMDEs, mainly because energy demand is still growing rapidly, and fossil fuels are usually available to cover gaps in supply.

Since capital is expensive and poverty reduction remains a priority, clean energy may remain a lower priority unless the two are coupled (Kammen, 2015; Prin & Motherway, 2023). As shown in the examples of Pakistan and South Africa (Box #3), prioritizing clean energy will speed up poverty reduction by enabling local industry, enabling schools to connect to the internet, and aiding farmers by providing pumping capability for water. The ability to expand clean energy in small increments, instead of needing to build big power plants and transmission lines, accelerates and distributes the benefits of clean energy.

For these reasons the wide deployment of clean energy in EMDEs is badly needed and must be cheaper, more reliable and convenient, issues that will be analyzed further later on. In simple terms, this result could be achieved by focusing on reducing the cost of capital factor and mapping a global roadmap for competitive advantages by regions in clean energy projects that can offset the higher cost of capital in EMDEs. But it is very complex to structure and coordinate projects among nations, regions, and stakeholders. Additionally, it will be important to establish cost-competitive and more affordable clean energy in sectors that are are hard to decarbonize (such as the manufacture of steel and the aviation industry), through targeted R&D that enables future economic viability and mitigates potential cost burdens for consumers (MACA Roadmap, 2021). Finally, it is critical to develop national and multilateral energy policies to establish favorable infrastructure and market conditions and policy tools to reduce the cost of various clean energy alternatives and eliminate fossil fuel subsidies. The newly announced Fossil Fuel Treaty resulting from the recent Santa Marta Conference on Transitioning Away from Fossil Fuels is a step in this direction (Governments of Colombia and Netherlands, 2026).

Box #3. Microgrids reduce need for centralized energy

In many cases, individuals and organizations in areas with either no electricity or limited connection to the grid are moving forward to install solar & battery to meet their needs. Pakistan and South Africa represent good examples among EMDEs (Shah, 2025, Molelekwa, 2026). This can result in satisfaction of a large portion of the demand for new energy outside normal planning processes. In Pakistan, 24 GW of solar panels had been installed outside the grid by the end of 2025. South Africa saw about 8.3 GW of solar installed by users themselves, compared to only 2.8 GW by the utility sector. These installations can accelerate a country's move towards clean energy, reducing the need for public/utility funding. They provide a new opportunity for grids, using techniques such as Virtual Power Plants (VPPs) where individual solar & battery systems are aggregated to provide energy to the grid in return for cash. Everybody can benefit, residents and organizations can earn money for their contributions, the move to renewable energy is more rapid, and the need for grid upgrades and new utility scale generation such as solar/wind/storage is reduced.

In the context of policy development, instead of relying on mandates, or bans, countries can boost the transition by reducing the cost factor of financing mechanism in EMDEs, simplifying permitting and regulatory processes, developing supply-chains for clean energy alternatives, and coordinating special

R&D between academic institutions and market needs, for example where startups may require financial guarantees to get them thought the transition from trials to commercialization These policies will not force or guarantee implementation, but they encourage clean energy to be the economically rational option.

Accelerating clean energy deployment in EMDEs is not merely a climate change issue and a development goal but a shared economic responsibility. It reflects the opportunity costs of both advanced economies and EMDEs, embodies a question of equity in acting before the most severe climate damage happens, and underscores that climate finance abroad functions as a form of risk mitigation at home. Urgent needs are to reduce the perceived risks of clean energy projects, to incentivize R&D in key sectors that today are too expensive to decarbonize, and stimulate investments in EMDEs. Finally, clear economic policy coordination is needed which otherwise has the potential to provoke financial and security crises, especially in some oil producing EMDEs (Pastukhova et al., 2026).

2. Cost of capital in EMDEs

The cost of capital is a major barrier to clean energy deployment in emerging markets and developing economies. Although clean energy options, like solar and wind alternatives, are readily available in developing countries, costs are often two to three times higher than in the developed world (IEA, 2023a). In EMDEs, there are several variables that influence the cost of capital. To find ways to reduce it, mechanisms are being developed that can help lower cost and mobilize investments on the scale needed (Table 1). This is mainly due to systemic risk that is dependent on several factors, including national, regional and international conditions.

In COP29 developed countries committed in principle to mobilize $300 billion per year of climate finance by 2035 through the New Collective Quantified Goal (NCQG) (UNFCCC COP29, 2024). In addition, the Baku process included an aspiration goal to mobilize $1.3 trillion annually from public and private sources combined, with developed countries taking the lead. At COP30 in Belém, countries agreed to the $1.3 trillion per year target in climate finance by 2035 (UNFCCC COP30, 2025a;UNFCCC 2025b). Developed nations also committed to triple adaptation finance by 2035 and advance planning for the Loss and Damage Fund.

The idea behind the initiatives at COP29 was that the $300 billion will help to raise the rest in financial markets. To help attain this goal, reaching more than $1.3 trillion annually by 2035, COP30 emphasized the need to improve access to finance, strengthen multilateral development banks, expand private-sector participation, and reform elements of international financial architecture to accelerate climate investment even further. These commitments represent an important political milestone, but their success will depend on whether they lower the cost of capital.

Current levels of clean energy financing in EMDEs are dependent on the countries and regions, including scale, system readiness, and risk pricing (IEA 2021b). China accounts for roughly two-thirds of clean energy investment across EMDEs, and China, India, and Brazil together account for more than three-quarters. Excluding China, annual clean energy investment in EMDEs needs to rise from about $260 billion today to $1.4–1.9 trillion by the early 2030s (IEA, 2023a). This includes increases in grid and storage capacities, which make transmission, system flexibility, and utility capability central rather than peripheral. In addition, mobilizing private finance is critical, requiring much more concessional capital, with the IEA estimating a need for $80–100 billion a year by the early 2030s to bring in the private investment required outside China.

Table 1. Country type, binding constraint, and policy response

Country type	Most likely binding constraints	First-line policy responses
Frontier / fragile system	Macro-risk premia, weak project bankability, sovereign fiscal space	Multilateral Development Bank intermediation, payment security, utility reform, project preparation, concessional public support
Lower-middle-income reformer	Foreign exchange mismatch, shallow local capital markets, weak bankability	Foreign exchange facilities, local-currency lending, guarantee vehicles, procurement reform, transmission, utility strengthening
Upper-middle-income system with some market depth	Shallow long-term domestic finance, selective macro-risk premia, scaling constraints	Refinancing platforms, green bond benchmarks, institutional-investor crowd-in, targeted guarantees
Small climate-vulnerable sovereign	Sovereign fiscal space, resilience investment gaps, small-scale market constraints	Debt-for-climate tools, concessional and non-debt-creating finance, project aggregation, resilience support
Large domestically intermediated system	Grid integration, utility performance, long-term scaling finance	Transmission, grid flexibility, utility reform, domestic market deepening, refinancing tools

Note: Country type is a starting point, with countries within the same category sometimes facing different binding constraints and requiring different instruments.

Although these constraints vary across countries, they share a common consequence. First they increase the perceived risk of clean energy investments, and then raise the cost of capital, finally slowing deployment. Hence, clean energy investment remains concentrated in a small number of large emerging economies. The subsequent section focuses on five structural constraints that impact the cost of capital. Their mitigation could decrease capital scarcity. Later sections then examine capacity factors as a regional advantage and readiness as including both a technology and systems approach.

The five structural constraints which are the focus here include:

A. Macroeconomic risk premium

This reflects a broader spectrum of factors that are not part of the specific aspects of a project's economic viability. Investors observe not only the economic viability of a project but also the broader macroeconomic spectrum, such as sovereign credit risk, inflation, fiscal imbalances, capital inflows and outflows, and political uncertainty. All of these are reflected in a risk premium that influences repayment feasibility. As a consequence, identical solar or wind projects can face dramatically different weighted average costs of capital (WACC) across countries. For example, the cost of capital for a utility-scale solar project was estimated to be approximately 10% in South Africa, an EMDE, compared with 4% in Germany, with the analysis suggesting that the difference was driven primarily by macroeconomic and sovereign risk rather than project-specific risk (Persaud, 2023).

B. Foreign exchange (FX) mismatch

One of the variables that is factored into the macroeconomic risk premium is FX. Clean energy projects are often funded in US dollars or Euros which implies a long-term financial option, but revenues are earned in local currency. So, any depreciation increases debt services in local currencies, leading to perceived increase in FX risk. This is one of the reasons why developers cannot diversify or manage this risk efficiently (Box #4). As a result, financial markets demand higher returns and shorter loan terms, further increasing the scarcity of capital. This risk gap adds around 300-600 basis points to the cost of capital in EMDEs relative to developed nations (Persaud, 2023). The FX factor is one of the biggest barriers to investment in clean energy. To put it into perspective, 500 basis points translates to a 5% increase in the cost of capital; if the 10-year US Treasury bond has a yield of approximately 4.0%, then the exchange rate will raise the cost of capital to approximately 9.0%.

Box #4. Foreign exchange (FX) risk as a cost driver

The case of Malawi in 2024 is a good example of how exchange rate risk can become a major limitation for clean energy projects, if some interventions are not factored in. In this case, Acumen (global nonprofit impact-investment organization) gave a $2 million loan with 50% repayment in local currency, Malawian kwacha, while the remaining currency risk was hedged through TCX, which specializes in development funds (TCX, 2026). The transaction also included an EU-supported subsidy to offset hedging costs. Without all of this, the project would have been less economically viable and financially bankable.

The case of Malawi shows that exchange rate hedging can become an additional capital cost burden that, without support, can sometimes make a project economically unviable. Mitigating the exchange rate cost factor can make many clean energy projects viable and pave the way for increased investment in EMDEs.

C. Shallow domestic capital markets

The shallowness of domestic capital markets is one reason why projects cannot avoid FX risk by borrowing locally, since domestic banks tend to lend short-term in these markets, while pension and insurance funds have limited capacity to provide long-term financial options for 20–30-year projects. Improving local financial markets is therefore a key element to scale up domestic investment in the clean energy transition (IEA, 2023a). This market condition reinforces the FX mismatch and exposes projects for better or worse to global financial conditions.

D. Weak project bankability

At the project-level risk, they frequently fail to reach financial requirements, basically for predictable and enforceable cash flows. Common barriers are poorly structured PPAs (Power Purchase Agreements), fragile utilities (often from financially distressed state-owned utilities), delayed transmission, and inconsistent procurement, and regulatory changes, among other things. These weaknesses raise the project risk, increase due diligence costs, and discourage private capital. Therefore, mitigating weak project bankability, in addition to better project preparation, requires improvements in the conditions mentioned above.

These factors also highlight the importance of institutional credibility and policy continuity. Investors are more likely to commit to long-term capital when contracts are enforceable and procurement processes, market rules, and regulatory frameworks are transparent and reasonably predictable over the life of a project

E. Limited visibility of sovereign and climate-related risks

In recent years, financial markets have started to take climate risks more seriously. Even so, they still do not have reliable ways to discern between countries based on how climate resilient they are, how well adaptation investments perform, or where sector level vulnerabilities lie. This is one of the reasons why markets may overprice risk and fail to recognize improvements over long-term stability. Investors tend to apply broad country risk premia that may overestimate actual project macroeconomic risks while failing to recognize natural capacity factors and improvements in climate resilience. The development of standardized measures of climate adaptation, infrastructure resilience, and sector-specific governance, could allow rating agencies and investors to discern risk more accurately.

Taking these five constraints together can partly explain why the cost of capital in EMDEs is higher, and why this can delay the resources needed to cover the investment gap required in these regions. The cost of capital for utility scale solar in EMDEs averages 10.6%, compared to 4% in the EU. Since solar and wind are technologies whose total costs are 70–90% driven by capital expenditures, competitiveness is determined by financing conditions, not technology costs (Persaud, 2023). By addressing these constraints, particularly FX risk, sovereign risk pricing, and domestic capital market development, competitiveness could be stimulated more than through continued reductions in technology costs alone. The UN GISD Alliance (2025) concludes that multilateral mechanisms to mitigate foreign exchange risk could reduce currency risk premia, significantly lower the cost of capital, and mobilize more than $1 trillion per year in additional private investment for clean energy projects in EMDEs. (UN GISD Alliance, 2025).

A substantial body of work already addresses parts of this problem. The Climate Policy Initiative’s currency-risk work is the clearest recent contribution on foreign exchange mismatch (CPI, 2024b). It reviews a range of hedging and local-currency approaches and shows that there is no single fix, only trade-offs in scale, sustainability, replicability, and market-building impact. A second strand focuses on the wider cost-of-capital gap, that Multilateral Development Banks and Development Finance Institutions have tended to focus on project-level micro-risk, even though the larger cost wedge in many EMDEs comes from macro risk, especially sovereign spreads and foreign exchange risk, which public institutions are also better placed to help absorb or share (Persaud, 2023).

A third strand focuses on sovereign tools, which are ways to create fiscal space and support resilience, e.g. through sovereign balance-sheet management (IDB Group, 2024). Sovereign debt service is being used for ocean protection and conservation, though only indirectly impacting climate, through a sustainable development project in Barbados with IDB and the Nature Conservancy. Fiscal space directly impacts borrowing costs through sovereign risk ratings with small changes in credit rating having significant effects of the borrowing costs.

A fourth strand focuses on capital recycling and domestic intermediation. ReInvest+, launched by the International Development Bank Group (IDB Group, 2025), starts with climate loans already on local bank balance sheets, converts them into investment-grade hard-currency securities using insurance against political and foreign exchange risks, and recycles the proceeds into new climate lending. Its importance lies in closing the gap between local banks and global institutional capital.

Taken together, these strands point to the same conclusion: there is no single financing fix for EMDEs. The right starting point is the country setting, then the binding constraint, and only then the instrument. A fragile power market, a reforming lower-middle-income country, an upper-middle-income system with some domestic depth, a small climate-vulnerable sovereign, and a large domestically intermediated economy may all need more clean energy, but they do not need the same financial solution. Country type is the starting point, and two countries in the same broad category may still require very different responses.

A climate justice approach pushes the framework one step further. The question is not only whether clean power is built, but who benefits once it is built. Clean energy investments may not be judged solely by installed capacity or emissions avoided, but also by whether it expands reliable local access, keeps power affordable, protects communities from displacement without meaningful compensation, and creates visible local economic gains. That matters especially in EMDEs, where large projects can otherwise become extractive in structure: green in technology, but with minimal local benefit. The lesson from contested hydropower projects, e.g. in Myanmar, is that a project can add low-carbon generation while still failing a justice test if surrounding communities bear the costs and see little of the power, revenue, or development benefit (Mills-Novoa and Borgias, 2025).

India and Ecuador illustrate why the response cannot be standardized across EMDEs (Table 2). India is a large country with local financial savings and domestic banks, and regional consumption driving its capital. Indian green-finance flows at roughly INR 3.7 trillion in FY2021/22 (CPI, 2024a), so the main bottleneck is not foreign mismatch but whether the power system can absorb clean energy at speed. Recent reporting points to transmission delays, missing supply agreements, and grid-integration constraints as major barriers (Reuters 2025a).

Ecuador, in contrast, has used the dollar as its national currency so the hard-currency debt versus local-currency revenue mismatch is nearly absent, although hidden FX risks remain through its dependence on external liquidity and a strong balance of payments needed to sustain dollarization. Instead, the more severe constraints are power-system weakness, drought exposure, underinvestment, and the fiscal and regulatory conditions needed to attract private capital (World Bank, 2024a).

The implication is straightforward: India needs a response centered on transmission, grid flexibility, utility reform, procurement discipline, and the deepening of a domestic market, while Ecuador needs a response centered on system resilience, stronger sector rules, credible incentives for private participation, and public-balance-sheet support for enabling infrastructure. In both countries, more finance matters, but the type of finance that is useful differs because the bottleneck is different.

Table 2: Different Markets, Different Clean Energy Transition Pathways

Region	Defining Characteristic	Primary Constraint	Strategic Priority
India	Large economy with significant domestic financing capacity and market	Transmission bottlenecks, grid integration and utility performance	Grid expansion, storage and better project execution
Ecuador	Dollarized economy dependent on external USD inflows; heavily dependent on hydropower	Drought exposure, underinvestment and limited fiscal and regulatory framework	Energy diversification, system resilience and credible investment frameworks
Jamaica/ Barbados	Small, climate vulnerable island economy	Disaster exposure, sovereign risk and financing costs	Resilient infrastructure, risk transfer instruments and prearranged financing
Rural Africa	Limited electricity access and dispersed communities	Affordability, infrastructure gaps and unreliable service	Solar mini-grids, flexible financing and productive local enterprises

3. Capacity factors for regional advantage

Capacity factor is the ratio of the electricity actually delivered by an energy source with the electricity that it could theoretically deliver if it operated at its rated capacity continuously over the same period. For example, a 100 MW solar farm could theoretically produce 876,000 MWh in a year if it operated at full capacity every hour, but if it actually produces 219,000 Mwh, its capacity factor is 25%. For solar and wind, capacity factor is influenced by resource availability (sunlight and wind respectively) as well as equipment availability, curtailment, and grid conditions. Capacity factor is different from efficiency as it measures how much of the asset's potential output was actually delivered, whereas efficiency measures how effectively an input is converted into useful energy. Regional differences in geography, climate, natural resources, and technological capacity create highly unequal conditions that are reflected in capacity factors; this is reflected in regional performance and competitiveness in clean energy (Table 3).

Capacity factors are one of the important elements affecting regional advantages and competitiveness. When combined with financing conditions and effective policy design, capacity factors can be leveraged to enable more efficient deployment of clean energy in EMDEs. Better-defined capacity factors by regions driven by both better natural resources and improving technologies can make clean energy projects in EMDEs more attractive. Moving away from one-size-fits-all approaches will permit adopting models that reflect local realities such as differences in resource quality, both natural and human resources and technology, storage potential, system-wide decarbonization needs, and fair access to clean energy. These tailored strategies can help counterbalance the higher cost of capital that many EMDEs face. But for projects to have a better financial viability, these advantages need to be embedded within a broader global roadmap that builds on each region's specific strengths.

A quick overview of capacity factors highlights the most reliable clean energy options that are already competitive with fossil fuels today. Solar photovoltaic (PV) capacity factors lie between ≈15% and 25%, with values approaching 30% in desert environments (Bamisile, 2025). Onshore wind falls between 25–45%, while offshore wind performs even better at around 40–55% (Opoura, 2025). Hydropower generally operates in the 35–50% range or higher, especially given its ability to provide dispatchable energy (IRENA, 2015). Because these capacity factors vary significantly by location (Table 4), clean energy potential is highly geography-dependent. This uneven distribution creates natural comparative advantages across regions and technologies, opening the door for complementary, cross-regional use of different renewable energy sources. Regional cooperation can compensate to some degree for the higher cost of capital the EMDEs face.

Table 3: Typical Capacity Factor Ranges

Energy Source	Typical Capacity Factor	Variables impacting capacity Factor	Where it is naturally competitive
Solar PV	~15-25%	Sunlight, shading, weather, latitude, tracking, grid constraints	India, Chile, Egypt
Onshore wind	~25-45%	Wind resource, turbine design, site quality, curtailment, grid constraints	Brazil, India, South Africa
Offshore wind	~35-50%	Wind speeds, site conditions, turbine availability, grid constraints	Vietnam, Brazil, India
Geothermal	~70-95%	Resource quality, maintenance, reservoir management	Indonesia, Kenya, Philippines, Mexico, Andean countries
Hydropower	~35-50%	Water availability, rainfall/snowpack, reservoir operations, flow constraints	Brazil, Ethiopia, Vietnam, Andean foothills
Natural gas	~10-80%	Whether used for peak demand or continuous generation, fuel costs, electricity demand	Egypt, Nigeria
Nuclear	~80-95%	Refuelling outages, maintenance, forced outages (availability of suitable fresh water for cooling)	China, India

Note: Andean countries include Argentina, Bolivia, Chile, Colombia, Ecuador, Peru, and Venezuela.

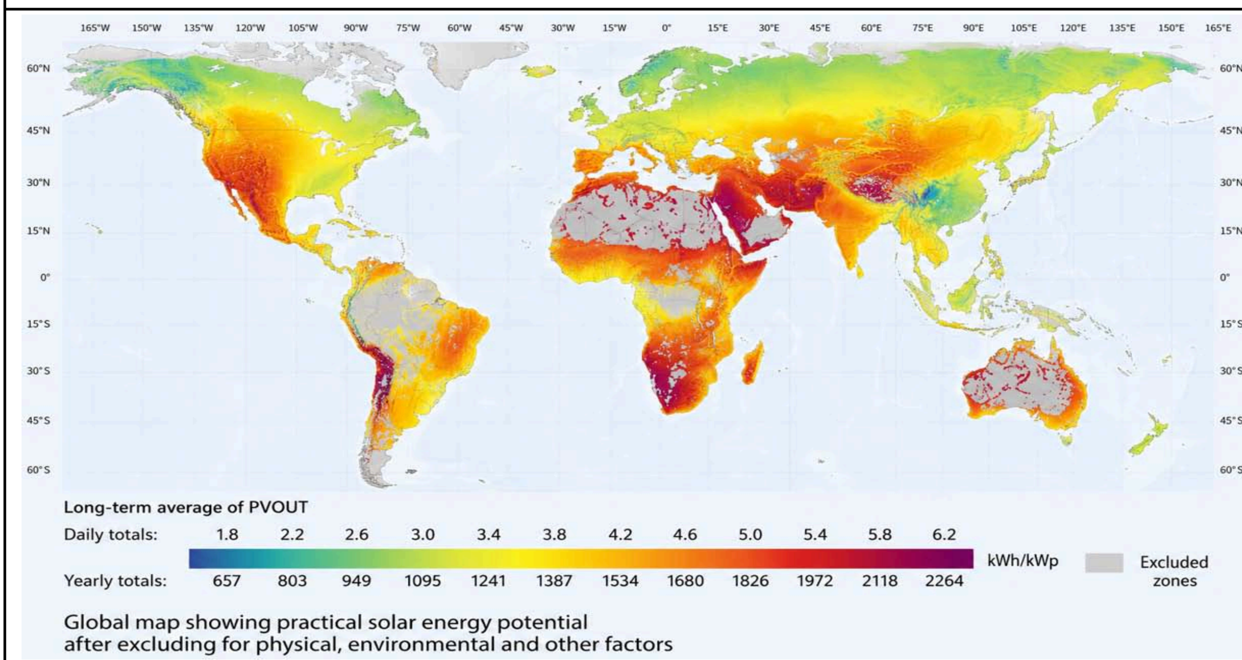
A. Regions with high solar capacity factors in EMDEs

Among the regions with the highest solar capacity factors (Figure 2), from 22% to more than 30%, are specific areas of Latin America, such as northern dry regions of Mexico, the Andes, Atacama, the Northeast of Brazil, among others, Middle East and North Africa, Sub-Saharan Africa, and specific regions of India (World Bank, 2020). The drivers for this are high irradiation, low seasonality from the equator up to sub-tropical regions that are either dry regions or high-altitude areas; the Atacama Desert is widely considered one of if not *the* best regions on Earth for solar energy, extending from the Pacific coast up to high altitudes of the Andes.

Table 4. EMDEs clean energy roadmap by capacity factors advantage

Region type	Competitive edge	Regional and global role
High solar capacity factors (Middle East and North Africa, specific regions of Latin America and Africa)	Cheapest electrons	Regional electricity generation and green fuels exporter
High wind capacity factors (specific regions of Latam, Africa and Southeast Asia)	Stable renewables	Grid backbone
Hydro-rich (specific regions of Latam, Africa and Southeast Asia)	Stable renewables	Grid backbone and flexibility hubs
Geothermal (Rift regions)	Baseload	Reliability anchor

Figure 2. Potential of photovoltaic solar energy by country



Source:[ESMAP/World Bank (2020), Global Photovoltaic Power Potential by Country](), Accessed on: August 7, 2026.

The real strategic edge lies in solar energy's uniquely low global levelized cost of energy (LCOE), paired with its growing ability to store power despite its intermittent nature. That variability is no longer a dealbreaker since energy may now be stored in batteries, with other options becoming available in the future (MACA GAF, 2025). The logistics and cost competitiveness of these alternatives may still require further R&D, along with scaling, before they represent a viable opportunity cost. Many technological challenges remain in bringing effective solutions to the marketplace, especially in EMDEs. Among the energy storage alternatives, battery costs have fallen sharply in recent years, making solar even more competitive. Looking ahead, continued R&D could shift the economics.

B. Regions with high wind capacity factors

Some of the most promising regions for developing wind energy offering both high capacity factors and strong temporal complementarity include Patagonia, Northeast Brazil, East Africa, Central Asia, and specific corridors along major mountain ranges such as the Andes and the Himalayas. Those regions can develop capacity factor potential of 35–50% onshore, and >50% offshore (IRENA, 2019). The strategic advantage to be considered more significant is the stable generation profile which can complement solar energy, notably at night. This allows built-in storage and grid balancing, and it enables high renewable penetration with lower battery needs.

C. Geothermal regions with high capacity factors

With sustained R&D, Enhanced Geothermal Systems (EGS) and closed-loop geothermal technologies could become cost-competitive across much of the world, potentially rivaling gas and coal-fired power generation. Progress in drilling, by leveraging expertise from the oil and gas sector, where Canada and the United States hold strong competitive advantages, could help accelerate the scale-up of EGS in EMDEs. Improvements in reservoir stimulation and subsurface modeling are also steadily lowering costs and reducing uncertainty. An additional advantage is the opportunity to transition skilled labor from the oil and gas industry into EGS deployment. In the meantime, the most competitive geothermal regions in EMDEs are concentrated in the East African Rift, Indonesia, Mexico's volcanic belt, Central America, and the Andes from Colombia to Patagonia. In these areas, geothermal plants can achieve capacity factors of roughly 70–90%, operating much like baseload power (IGA, 2026). A key advantage of geothermal energy is its ability to provide reliable, clean electricity 24/7, helping to reduce system costs (storage capacity) associated with variability caused by rainfall patterns, which impact the capacity of hydropower plants and other power generation plants that use water for cooling. However, its main drawbacks include very high upfront capital costs, very important as EMDEs face higher capital cost, and the potential risk of induced seismic activity.

D. Intermittent system-level models

Beyond depending on a single capacity factor, EMDEs regions must develop systems such as wind and solar energy that can work in a complementary fashion. For example, solar peaks during daytime and wind often peaks at night (or seasonally). A combination of solar and wind capacity can reduce variability and storage needs that are critical for EMDEs as the need for batteries is lowered, improving asset utilization.

Another key factor is geographic balancing through continental regional grids. This becomes especially important in regions with contrasting seasonal and temporal energy generation patterns. Continents such as Africa and South America span from austral zones to equatorial regions and from highland mountain ranges to large regions at sea level, encompassing highly diverse climates and local conditions from extremely arid areas like the Sahara and the Atacama Desert to vast rainforest systems. Studies on geographically interconnected power systems suggest that spatial balancing can reduce storage needs by roughly 30%, with evidence from South America and Sub-Saharan Africa indicating even larger reductions in storage costs and capacity due to high renewable resource diversity (Yang et al., 2023).

E. Capacity factors versus cost of capital: the EMDE paradox

As mentioned before, EMDEs typically face financing costs two to three times, or even higher, than those in advanced economies, yet they often benefit from better capacity factors. This creates a meaningful offset with higher capacity factors that translate into greater total energy (kWh) and generation capacity (MW) as well as better revenue per asset, leading to higher internal rates of return that can partially counterbalance higher capital costs. However, this offset may often be insufficient under current risk conditions. Moreover, if EMDEs succeed in reducing their cost of capital, for instance via mitigation of foreign exchange and other risk factors, they could unlock substantially larger flows of private finance, enabling the scale of investment required to curb future carbon emissions.

This EMDE reference map can help to visualize a key strategic takeaway. Clean energy generation is not a contest between nations but a source of energy security for all through a combination of geographic specialization, integration, and coordination or cooperation. It focuses on taking advantage of local capacity factors, developing interconnected regions, exploiting diverse complementary technology capacity factors, and aligning finance with development needs. Capacity factors, whose significance is often not properly appreciated, represent a natural advantage that, combined with technology, can significantly boost the competitiveness of clean energy. Yet financial and political barriers—and poor system design—often hold this potential back. Then a regionalized roadmap can help unlock it, reducing storage needs, lowering emissions, strengthening reliability, and making energy more affordable for communities.

4. Technology as a systems approach

The previous sections showed that unlocking clean energy in EMDEs requires matching finance to the actual bottleneck in each country, and that natural resource advantages such as high solar irradiance, strong wind corridors, geothermal heat create meaningful comparative advantages that can partly offset the higher cost of capital these economies face.

But there is a third constraint that sits between capital and resources: system design. Countries and regions can have excellent financing conditions and outstanding natural resources and still fail to deploy clean energy reliably, affordably, or at scale because they are making technology choices in isolation rather than designing and deploying integrated systems. Technologies need to be chosen to integrate into systems that are reliable, affordable, and built around each region's specific strengths. While capacity factors create the potential for development of clean energy, systems design is essential to help to realize the full potential and create the full value locally, regionally, and globally.

The importance of systems design is not an abstract point with examples in EMDE energy history (IEA, 2023b). Countries with outstanding solar resources may build large PV farms, but without storage, flexible demand management, or transmission to move power where it is needed, the electricity can arrive at the wrong time or cannot reach the users who need it (IEA, 2025a). Rich wind corridors may produce abundant energy in remote areas, but without a strong and stable grid connection, that energy can stay stranded. Another possibility is that strong hydropower systems can deliver reliable output for decades, until an unanticipated and prolonged drought, worsened by climate change, exposing the danger of over-reliance on a single resource. Finally, ambitious green hydrogen programs may attract political attention and early investment, but without cheap clean power, reliable water supply, storage infrastructure, and committed buyers, the program can stall prior to reaching commercial scale.

Each of these is a real pattern even when the technology is sound, due to limitations or lack of adequate system design. The rest of this section explains what a successful systems approach looks like across three dimensions, including how technologies are combined, how they are deployed, and how the grid is built to support them. These factors are particularly important in EMDEs.

A. Complementary energy technologies grounded in regional resources

In Section 3 above, we mapped the capacity factor advantages of different EMDE regions, including the Atacama's solar irradiance, Patagonia's wind, East Africa's geothermal resources. For an effective systems approach, these advantages act as the starting point and the challenge becomes what combination of technologies can transform these specific strengths into a reliable and affordable energy supply.

Effective system approaches almost always need a portfolio (Table 5) rather than a single technology solution. For example, in high-solar regions**,** solar PV can be paired with battery storage which will help to shift midday generation to evening peaks, or desalination using surplus energy can be used to produce fresh water at a low marginal cost. Alternatively, where power is cheap enough, pairing with industrial processes generating heat, green hydrogen (World Bank, 2024b), or ammonia for export or local use may be viable options (MACA GAF, 2025).

Table 5. Technology roles in a regional systems approach

Technology	Primary role in the system	Key system complement
Solar PV	Low-cost daytime generation	Storage, flexible demand, transmission
Wind	Nighttime and seasonal complement to solar	Grid interconnection, forecasting
Hydro (dispatchable)	Flexibility and balancing reserve	Climate-risk planning, drought resilience
Geothermal	Firm baseload power	Grid stability, reduces storage need
Battery storage	Temporal shifting, frequency response	Solar, wind, EV charging

Wind power generation in high-wind corridors can be used to complement solar, reducing overall storage requirements. Wind often peaks at night or in seasons when solar output is suboptimal. In hydropower-rich regions**,** solar can be a dispatchable power and a flexible resource for a grid with high renewable penetration, accounting for drought risk, ecological impact, or even transnational river dependencies that are growing more acute under climate change. In geothermal regions, it represents reliable, continuous low-carbon power where the resource and institutional conditions exist, providing the baseload demand that helps system operators integrate a large share of variable renewable energy sources without stability risk.

The systems planning principle, optimizing locally and connecting regionally, applies in EMDEs. Individual projects should be built around local resource advantages. Regional and national grids should connect these projects so that solar, wind, hydro, geothermal, storage, and flexible demand reinforce and complement one another rather than competing for limited finances.

B. New deployment paradigms

EMDEs already have power grids, fossil-fuel-centered powered generation and existing energy infrastructure. What is different is that their energy demand is still growing rapidly, so much of the infrastructure needed to serve future homes, businesses, and industry is yet to be built. This creates a genuine leapfrog opportunity (IEA, 2025b). Instead of expanding by simply replicating the centralized, one-way electricity model of the 20th century, EMDEs can direct new investment towards distributed, digital, locally productive clean energy systems. In this model, communities, campuses, industrial parks, hospitals, ports and cities can generate, store, manage and share power more intelligently while still connecting to the larger grid for stability and security.

The traditional electricity model assumes large central power plants, long-distance transmission and passive consumers. Clean energy enables a radically different architecture, one that is already emerging across EMDEs in pieces and which should be supported and nurtured. Clean energy allows an architecture that is distributed, digital, flexible, locally productive systems connected to larger grids.

Microgrids and mini-grids are often framed as rural electrification tools, but that framing may be too narrow. When designed around productive economic uses, irrigation, cold storage, food processing, hospitals, small industry, ports, they become local economic development platforms (World Bank, 2023). The stronger model is grid-connected self-sufficiency with communities, hospitals, ports or industrial zones that normally exchange power with the main grid but can operate independently during outages. This improves resilience without sacrificing efficiency.

Hybrid energy ecosystems can be used to take this further at a regional level (Box 5). Coastal regions can co-locate solar or wind generation, desalination, and green hydrogen/ammonia production, sharing infrastructure and creating multiple revenue streams from the same clean power sources. Agricultural regions can pair solar with irrigation, cold storage, and biomass from crop residues. Mining regions can use clean power for electrified operations and local mineral processing. Urban districts can combine rooftop solar, community batteries, EV charging, and variable demand into systems where homes and businesses become active energy players rather than passive consumers. Aggregated across many buildings, these distributed assets function as virtual power plants, providing grid services (US Dept of Energy, 2023) that currently require large, dedicated infrastructure. This is the architecture EMDEs can build from the start, rather than retrofit later.

C. Modern grids: The undervalued core of clean energy systems

As the Introduction and Section 2 both noted, transmission bottlenecks and grid integration constraints are already having an impact in major EMDEs. A good example is India's stranded renewable projects

(Reuters, 2025), awarded but unable to come online, more than doubled in nine months from over 20 GW to more than 50 GW. This has been attributed to unfinished transmission lines, legal delays, regulatory delays and lack of signed power-purchase agreements with buyers. Ecuador's 2024 blackouts (Reuters, 2024a) were not simply a story of resource scarcity. Drought reduced hydropower output, but the nationwide outage also exposed deeper system fragility: underinvestment in transmission, poor maintenance, limited backup generation and overdependence on climate-sensitive hydropower.

Box #5. Why the Amazon Matters for Ecuador's Energy Security

The impact on Ecuador's water basins was drastic; the flow of the Paute River was severed, reducing its hydropower generation capacity by around 40% (WMO, 2026a). The major drought was intensified by the 2023–24 El Niño event across almost all the Amazon basin, and it played a critical role in Ecuador's water security. Through evapotranspiration, this vast rainforest generates atmospheric moisture flows - "flying rivers" - transporting moisture from the Amazon basin towards the Andean foothills, sustaining rainfall over Ecuador's hydropower watersheds. Several factors influenced the hydrological droughts of 2024, caused mainly by the reduction of moisture recycling, the most important being El Niño, deforestation, and global warming. So, protecting the Amazon is not only a biodiversity and climate objective; it is also an essential component of long-term energy security for hydro-dependent countries such as Ecuador.

Preliminary estimates suggest that there is a risk correlation with more relevant events as climate models indicate a higher probability of future El Niño and other cyclical impacts meaning the conditions that contributed to Ecuador's energy crisis in 2024 could become more frequent and more severe (WMO, 2026b). Strengthening power system resilience therefore requires not only investment in grid infrastructure, storage, and dispatchable generation, but also policies that conserve the Amazon's hydrological functions across all nations that share the Amazon basin. This vast rainforest must be viewed not only as a global carbon sink but also as critical natural infrastructure that underpins water, food, and energy security, and economic resilience across much of South America.

Grid modernization requires action across three layers (IEA, 2023a). First, transmission expansion is needed to connect high-resource regions to cities, industrial clusters, ports, and export corridors. Without transmission modernization, the capacity factors described generate potential that cannot reach demand. Second, distribution upgrades enable rooftop solar, EV charging, microgrids, and two-way power flows at the local level. Many EMDE distribution systems are not specifically designed for any of these and are ripe for improvement. Finally, digital intelligence, including smart meters, advanced inverters, automated sub-stations, distributed energy resource management systems, and AI-enabled dispatch are essential for optimal grid performance. Without real-time visibility and control, a grid with high renewable penetration may be very difficult to operate reliably.

The rules governing clean energy development in EMDEs matter as much as the hardware. Grid modernization also requires interconnection standards, grid codes for distributed resources, microgrid regulations, EV charging standards, cybersecurity frameworks and tariff structures that reward demand flexibility. A weak grid raises project risk and financing cost. A modern grid reduces uncertainty, improves asset utilization, and makes clean energy investment more bankable, directly addressing the cost-of-capital challenge identified in Section 2.

D. Resilience and redundancy as core design criteria

EMDEs face a compounding challenge: energy demand is rising, existing grids are often already stressed, climate exposure is among the highest in the world, and geopolitical tensions and supply chain disruptions create unanticipated and difficult to plan supply disruptions. The instability that results from inadequate clean energy investment in EMDEs is not contained within these economies – it propagates through global climate outcomes, insurance markets, and disaster costs (Box #6). Building resilient clean energy systems in EMDEs is therefore both a development imperative and a form of global risk management. That resilience must be designed from start, not added as an afterthought. In fossil fuel systems, energy security meant fuel reserves, strategic petroleum stockpiles and diversified supplier relationships. While many events have challenged the notion of reliable fossil fuel energy supply and stable costs, clean energy systems clearly do not rely on fuel stockpiles in the same way.

Box #6. The cost of ignoring the warning signs

Even in an advanced country like the United States, climate change is increasingly showing up not as an abstract environmental concern or a problem that future generations will have to grapple with, but as a household cost here and now. Homeowners' insurance is becoming more expensive and, in some places, harder to keep. The US Federal Insurance Office (US Department of the Treasury, 2025) found that average homeowners' premiums rose 8.7% faster than inflation from 2018 to 2022. Households in the highest climate-risk ZIP codes paid 82% more than those in the lowest-risk ZIP codes, while nonrenewal rates were about 80% higher. Treasury's conclusion was direct: climate-related events are making insurance both more costly and less available. This strain is no longer theoretical. The Los Angeles Times (Darmiento & Lin, 2025) reported that, before the January 2025 fires, insurers had already declined to renew thousands of policies in parts of Los Angeles County. One California homeowner saw his annual premium rise from $4,500 to $18,000 and then lost coverage before his home was destroyed.

The exposure is even greater when it comes to flooding. Standard homeowners' policies generally do not cover flood damage, and only about 6% of U.S. households carry flood insurance (Associated Press, 2025). This is why support for emerging and developing economies should not be viewed as charity, but rather as an opportunity cost for both EMDEs and developed nations. It is a form of self-protection. When poorer countries cannot finance clean energy and resilience, the world locks in more emissions and more instability—and the costs return through higher disaster losses, insurance stress, and more volatile household expenses in countries like the United States. NOAA (2025) recorded 27 U.S. billion-dollar weather and climate disasters in 2024, while the National Association of Insurance Commissioners (2026) reported a 10.4% national average increase in homeowner rates in 2024, with six states above 20%.

In a connected climate global support of leapfrogging, innovative clean energy development projects and transition away from fossil fuels in EMDEs, achieved through their individual and cooperative agencies, is essential for the protection of all inhabitants of planet Earth.

Their security comes instead from redundancy distributed across the whole system. Diversified generation portfolios protect against a drought, cloud cover event, or low wind period, avoiding system downtime in many cases. Distributed clean energy storage spread across homes, businesses, and grid substations rather than concentrated in single large facilities offer more energy security. Another factor is the demand in flexible, e.g. EV charging, water pumping, and cold storage, and the timing of some industrial load can be shifted to absorb surpluses or reduce stress during shortfalls. A clean energy system can add redundant grid pathways and regional interconnection, so that power can reach critical load centers even when part of the network is disrupted. Moreover, critical-component reserves must be ensured, e.g. transformers, inverters, battery modules, and switchgear, which may face long manufacturing lead times when ordered after a grid event, and because EMDEs often have limited domestic sourcing (IEA 2025a). Additionally, clean energy systems in EMDEs require trained local operators and repair capability, which reduces recovery time after faults and builds the domestic capital that clean energy systems require over the long run. Finally, critical facilities such as hospitals, telecom and utility systems, ports, and emergency shelters need islanding capability, i.e. the ability to operate independently during main-grid disruptions. This is especially important in EMDEs where the social cost of power outages is high and backup diesel generation is both expensive and emissions intensive.

Climate resilience must also be built into the physical design of every system component. Solar panels, wind turbines, grids, batteries, hydrogen systems, and industrial clusters should be designed and sited for future conditions – heat, drought, flooding, storms, and sea level rise – not just historical averages (IEA, 2020). A clean energy system that fails during extreme weather provides neither development benefits nor the investment returns that attract further capital.

5. Conclusions and Recommendations

Emerging Markets and Developing Economies will play a critical role in determining the trajectory of global CO_{2e} emissions over the coming decades. Much of the world's future growth in population, energy demand, industrial production, and infrastructure build will occur in these economies. At the same time, EMDEs have a legitimate and urgent need to expand energy access, accelerate economic development, and reduce poverty. The central challenge is therefore not simply how to reduce emissions in EMDEs but how these economies can continue to grow while building cleaner, more secure, affordable and resilient energy infrastructure.

The analysis presented in this paper suggests that for much of the clean energy transition, the principal barriers are increasingly economic and systemic rather than purely technological. Core technologies such as solar, wind, hydropower, geothermal energy, and battery storage are commercially available and increasingly competitive. Yet their deployment in many EMDEs continues to be constrained by financing costs, infrastructure limitations, grid readiness, project bankability, and other country-specific regulatory and institutional risks. Important technological and cost barriers nevertheless remain in specific sectors that are difficult to decarbonize, requiring continued R&D, commercialization, and scaling.

At the same time, many EMDEs possess an important countervailing advantage: some of the world's strongest renewable energy resources, high solar irradiation, favorable wind regions, hydro-resources and geothermal potential can produce capacity factors that improve project economics and in some cases, partially offset higher financing costs. The opportunity is therefore to combine these resource advantages with improved financing conditions and effective system design to deliver reliable, affordable, and competitive energy.

The three principal themes of this paper form an integrated strategy:

- Finance is the enabler: Reducing the cost of capital and addressing the particular risks that make projects expensive can substantially improve clean energy economics. This includes not only

mobilizing more capital, but also reducing foreign-exchange, sovereign, market, regulatory, and project risks that make capital more expensive.
- Regional comparative advantage is the opportunity: Countries and regions should develop the energy resources in which they possess natural advantages rather than follow a uniform global technology prescription. Higher capacity factors and complementary regional resources can improve economics, reduce system costs, and create broader opportunities for industrial and economic development.
- Systems design is the execution layer: Generation must be integrated with grid, storage, complementary energy sources, distributed systems, flexible demand and resilience if clean energy is to provide reliable and affordable energy at scale

MACA's central recommendation is to approach clean energy in EMDEs as more than a climate response. It is simultaneously a development strategy, an energy security strategy, and an investment strategy - one that connects financing mechanisms of Section 2, the regional resource advantages of Section 3, and the systems approach of Section 4 to deliver energy that is reliable, affordable, bankable, and resilient. See Box #7 for Uruguay as an example.

Box #7. Uruguay: A Blueprint for the Clean Energy Transition

Uruguay demonstrates how coordinated financing, utilizing regional resource advantages, and integrated energy-system planning can accelerate a clean energy transition and create strategic advantages. Through transparent renewable-energy auctions, long-term purchasing agreements, and a credible public utility, the country attracted private investment while reducing investor uncertainty. Its electricity system combines hydropower, wind, biomass, and solar to improve reliability, reduce dependence on fossil fuels, and strengthen energy security. By 2025, renewable sources supplied 98% of its electricity (UNSDG, 2026).

Our framing leads to five practical recommendations:
1. **Make reducing the cost of capital a central objective of climate finance**: For capital intensive technologies such as solar and wind, financing conditions can be as important as technology costs. Climate finance should therefore focus not only on mobilizing capital, but on reducing the sovereign, foreign exchange, market, and project risks that make capital more expensive in EMDEs. The appropriate mechanisms should reflect the specific constraints of each country.
2. **Build clean energy strategies around regional comparative advantages**: EMDEs should build around renewable-energy resources with superior local capacity factors rather than follow a uniform technology prescription. Complementary technologies and regional interconnections can reduce variability and improve system reliability. Abundant low cost electricity can also create broader economic advantages by supporting manufacturing, mineral processing, agricultural processing and other productive activities. Clean energy can therefore be part of a broader strategy for industrial and economic development.
3. **Treat grids, storage and system integration as core clean energy investments**: Renewable generation alone does not constitute an energy transition. Transmission, distribution, storage, digital controls, and demand should therefore be developed alongside generation to improve reliability, asset utilization, and bankability. EMDEs also have an opportunity to use microgrids, distributed solar, storage, and digital management to expand energy access without simply reproducing the centralized system of developed economies.

4. **Connect clean energy deployment directly to development and poverty reduction:** Clean energy will have greater economic and political value when it addresses immediate development priorities. Reliable and affordable electricity can support agriculture, food processing, education, healthcare, manufacturing and local enterprise. Investments should therefore be evaluated not only by installed capacity or tonnes of CO_{2e} avoided but also by the economic opportunities they create and their contribution to poverty reduction (Box 8).
5. **Design energy security and resilience into the system from the beginning:** Clean energy security depends on diversity, storage, interconnection, redundancy, flexibility, and local operating capability. Infrastructure should also be designed for future climate conditions, including heat, drought, flooding, storms, and changing hydrological patterns rather than solely on historical averages. Resilience should not be regarded as an additional cost but a strategy that reduces investment risk, strengthens projects bankability, protects economic development, and improves energy security.

Box #8. From Framework to Evidence: A Potential Research Agenda

The framework developed in this paper identifies three interconnected requirements for accelerating the clean energy transition in EMDEs. The next step is to determine which policies, financing mechanisms, technologies, and deployment models work best under real-world conditions.
This creates an opportunity to connect systems-level energy analysis with rigorous empirical evaluation. Organizations such as climate and poverty action organizations, universities, development institutions, governments, and local partners could contribute complementary capabilities.
A practical research agenda could focus on four questions:

- Which financing mechanisms most effectively increase clean energy adoption and investment?
- Which clean energy investments produce the most development and poverty-reduction benefits?
- Where can distributed systems such as micro-grids, storage, and distributed solar enable leapfrogging?
- What factors such as pricing, financing, reliability, trust, convenience, and institutional capacity determine successful adoption and scaling?

The objective should not be to identify a single model for all EMDEs but to build evidence into *what works, under what conditions, for whom, and at what cost*.

Taken together, these recommendations reinforce a broader point: investment in the clean energy transition in EMDEs should not be viewed as foreign assistance or foreign aid. The consequences of inadequate investment (including higher emissions, climate-related disasters, insurance losses, supply-chain disruption, migration pressures, and geopolitical risks) extend well beyond national borders. Supporting clean energy deployment in EMDEs is therefore an investment in global risk reduction, economic stability, energy security, and shared prosperity.

EMDEs have a remarkable opportunity: much of their future energy infrastructure has yet to be built. This creates the possibility of leapfrogging directly towards cleaner, more distributed, resilient, and digitally managed energy infrastructure. This is particularly true for Africa but is relevant for all. Rather than replicating the energy systems of the past, EMDEs can help shape the energy systems of the future using regionally abundant renewable sources, new technologies and innovative financing to support both economic growth and lower emissions. The opportunity is not simply to decarbonize, but to build an energy infrastructure that is more affordable, secure, resilient, and better aligned with development goals. This provides a platform to turn the clean energy transition into a powerful engine for growth and shared prosperity.

6. Glossary

Term	Definition
Bankability	It is the financial and structural quality of a project, asset, or company that meets a lender's criteria, making it low-risk and credible enough to secure debt financing or outside capital.
Capacity factor	The electricity actually generated over a period divided by the maximum that could have been generated at continuous full output. It measures utilization, not technological efficiency.
CO_{2e} (carbon dioxide equivalent)	CO_{2e} is a standard unit of measurement used to combine and compare the impact of different greenhouse gases based on how much global warming they cause.
CO_{2e}-GDP elasticity	The percentage change in CO_{2e} emissions associated with a 1% change in GDP. Values between 0 and 1 indicate increasing relative decoupling, negative values indicate absolute decoupling.
Concessional Finance/ Capital	Financing provided on more favorable terms than normal market finance, such as lower interest rates, longer maturities, or below-market return requirements.
Cost of Capital	The required rate of return or financing cost associated with debt and equity used to fund and investment. It reflects the return investors and lenders require for providing capital and is summarized by the weighted average cost of capital (WACC).
Curtailment	Deliberate reduction of available electricity generation often because the grid cannot absorb, transmit, or use all of the power being produced.
Decoupling	A reduction in the relationship between economic growth and CO_{2e} emissions. Relative decoupling occurs when emissions grow more slowly than GDP, absolute decoupling occurs when emissions decline while GDP grows.
Dispatchable generation	Electricity generation that can be increased, decreased, or scheduled in response to system demand.
Energy Security	The ability to provide reliable and affordable energy while limiting exposure to shortages, price volatility, and geopolitical disruption.
Foreign Exchange (FX) Mismatch	A situation in which project financing is denominated in a foreign currency, such as USD or EUR, while project revenues are primarily earned in local currency. Currency depreciation can increase the local-currency burden of debt service.
Global South	A broad term commonly used to describe emerging and developing economies, particularly in Africa, Latin America, Asia, and parts of the Middle East. In this paper it is used broadly in reference to EMDEs.

Grid integration	The technical and operational process of incorporating generation, storage, demand, and other resources into the electricity system while maintaining reliability and stability.
Grid Flexibility	The ability of an electricity system to respond to changes in supply and demand through storage, transmission, demand response, or flexible generation.
Islanding	The ability of a facility or local grid to disconnect from the wider grid and continue operating independently.
Levelized cost of energy (LCOE)	Current relative cost of energy production including building and operation over the lifetime of the production facility.
Microgrid/ mini-grid	A localized electricity network serving a defined community or facility. A microgrid may also disconnect from and operate independently of the main grid.
Multilateral Development Bank	An international financial institution owned by multiple governments that provides financing, guarantees, technical assistance, and other support for economic development.
Power Purchase Agreement (PPA)	A long-term contractual agreement under which a buyer agrees to purchase electricity from a power producer, generally establishing the price and other conditions governing the sale. PPAs are important to project bankability because they can provide predictable revenues.
Resilience	The ability of an energy system to withstand, adapt to, and recover from disruptions such as extreme weather, equipment failures, supply disruptions, or cyber events.
Risk Premium	The additional return investors require because of country-level conditions such as inflation, fiscal imbalances, sovereign credit risk, political uncertainty, and capital-flow volatility.
Sovereign Risk	Chance that a nation will fail to pay its debts or change its laws, resulting in harms to foreign financial investments.
Variable renewable energy	Renewable electricity generation whose output changes with weather and time of day (typically solar and wind).
Virtual Power plant (VPP)	A digitally controlled network of distributed generation, batteries, and flexible loads operated as a single power system resource.
Weighted average cost of capital (WACC)	The average rate of return required by all providers of capital to a project, weighted according to their respective shares of debt and equity. It is a key measure of financing cost and project competitiveness.

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