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Clean Energy Perspectives on Security and Resilience

Whose Energy Security? Rethinking Social and Economic Security and Resilience in Clean Energy Systems

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Executive Summary

Clean energy is now, on average, the cheapest way to generate new electricity in much of the world. Yet falling technology costs have not translated evenly into affordable bills, reliable supply, or fiscally sustainable utilities.

This paper argues that energy security is not a single condition, but a set of competing claims made by households, industry, investors, and governments. A credible framework therefore needs to make these trade-offs visible rather than average them away. The paper develops a three-pillar framework: (I) affordability, (II) reliability, and (III) outcomes. It applies this framework to four countries representing distinct transition pathways: Chile, a high-renewables system; Kenya, an emerging economy expanding electricity access; Nigeria, a fossil-fuel-dependent economy in transition; and South Korea, an advanced, import-dependent industrial economy. It then stress-tests the framework against two major energy shocks: the 2021–2023 energy crisis following Russia's invasion of Ukraine and the 2026 Strait of Hormuz chokepoint crisis associated with the Iran conflict.

The analysis shows that energy-security priorities depend strongly on system configuration. High-renewables systems face challenges around transmission, storage, and system flexibility; import-dependent industrial economies face exposure to international fuel prices and supply disruptions; and access-constrained economies face persistent financing and infrastructure gaps. The paper therefore proposes differentiated policy responses: faster transmission permitting and strategic investment in storage for high-renewables systems; pre-crisis hedging and demand-aligned clean-energy investment for import-dependent industrial economies; and blended finance and stronger mini-grid regulation for access-constrained economies. Across all cases, the paper recommends adopting firm and delivered levelized cost of electricity (LCOE) as a core investment metric and making "whose security?" an explicit planning question. The central message is that an energy system cannot be considered secure simply because energy is available or generation is cheap. Security depends on who can afford energy, who can rely on it, and what outcomes the system delivers when conditions change.

Key messages:

- Cheap generation does not guarantee delivered security. Renewable generation costs have remained at historically low levels, but this success increasingly represents an affordability (Pillar I) story only. Chile shows that even where generation is cheap and abundant, inadequate transmission and storage (Pillar II) can contribute to system instability, curtailment, and higher consumer costs.
- A clean generation mix does not guarantee equity. Kenya's electricity system is roughly 80% renewable, yet tariff design and unresolved mini-grid regulation leave affordability (Pillar I) and last-mile access (Pillar II) unresolved. The binding constraint is therefore not simply technology, but governance and institutional design. Equity is not a residual concern to be added at the end; it is a central dimension that the three-pillar framework is designed to expose.
- Subsidies are not a substitute for reform. Nigeria's open-ended tariff subsidies protect neither reliability nor fiscal sustainability (Pillars II and III). They can instead add to fiscal pressures while industry increasingly turns to costly self-generation.

- Wealth and institutional capacity do not insulate economies from fuel-price shocks; diversified clean energy generation can reduce exposure to them. South Korea, an advanced OECD economy, remained highly exposed to international fuel-price and supply shocks associated with the 2026 Iran conflict because its electricity system continues to rely heavily on imported fossil fuels. By contrast, greater diversification into domestic renewable generation can reduce exposure to international fuel-price volatility, although it does not eliminate other energy-security risks.
- Policy should make clear which groups are being protected, which may remain exposed, and over what timeframe. The paper therefore proposes differentiated recommendations for high-renewables systems, import-dependent industrial economies, and access-constrained economies, alongside six cross-cutting reforms.

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1. Introduction

Energy security has traditionally been defined around physical supply, built on the “four A’s” of availability, accessibility, affordability and acceptability that have anchored the field since the oil shocks of the 1970s (APERC, 2007). As Cherp and Jewell (2014) observe, this framework never specified for whom energy should be available or affordable. This is a conceptual ambiguity, and it becomes costly once a definition developed largely around mature, fuel-importing economies are applied to contexts and stakeholders whose underlying energy-security challenges are fundamentally different. Falling technology costs have made solar PV and wind the least-cost source of new generation in most markets (IRENA, 2026a), yet this has not automatically produced affordable bills for low-income households, reliable supply during shocks, or fiscally sustainable utilities. Where improvements have occurred, their benefits, costs, and risks have often been distributed unevenly across households, industry, investors, and governments. The gap between declining generation-level costs and delivered energy security, and the question of whose security a given policy instrument actually serves, are therefore two central but under-analysed features of the energy transition and the organising problems of this paper.

The paper addresses four research questions: (1) Under what conditions do clean energy systems deliver affordable, reliable and inclusive energy across stakeholder groups, compared with fossil-fuel systems, across the Global North and South? (2) How do prevailing business models and policy instruments shape investment incentives, risk allocation and distributional outcomes? (3) How do clean and fossil-fuel systems compare under stress, and what market structures and regulatory frameworks best align clean energy transitions with social equity and economic security? (4) Given that “energy security” means different, and at times conflicting, things to different stakeholders, how can an analytical framework make these differences explicit rather than obscure them behind a single indicator?

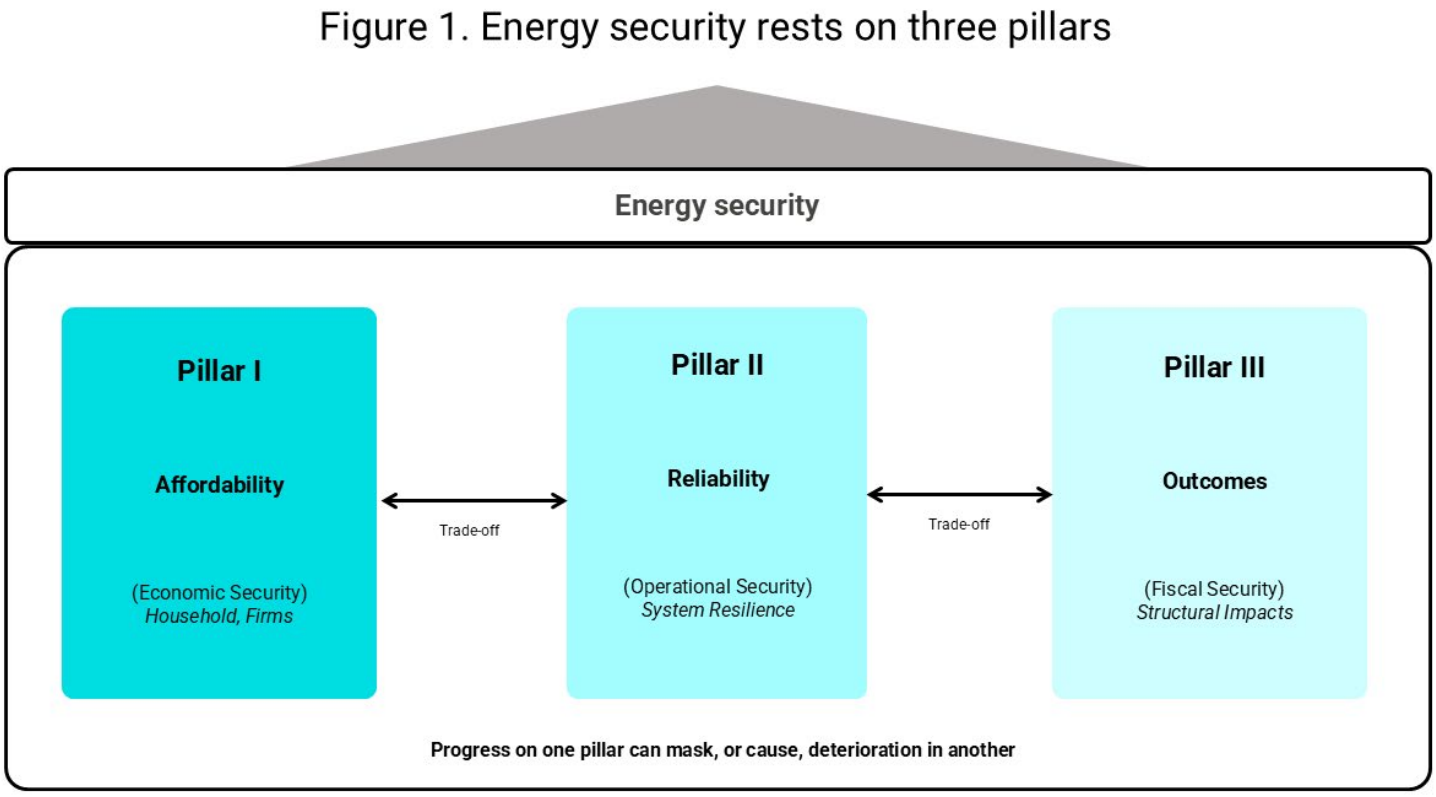
The paper proceeds in six stages. Section 2 develops a three-pillar analytical framework – affordability; reliability; and outcomes – bringing together conceptual tensions that the literature often treats as separate. Section 3 benchmarks clean and fossil-fuel technologies against this framework using the latest available secondary data. Section 4 applies the framework across four country cases selected to represent distinct transition pathways: Chile (high-renewables), Kenya (emerging economy expanding access), Nigeria (fossil-fuel-dependent economy in transition) and South Korea (an advanced, import-dependent industrial economy). Section 5 synthesises these cases, stress-tests the framework against two major global energy shocks, and asks explicitly whose security each case’s evidence describes. Section 6 sets out differentiated policy recommendations, and Section 7 concludes the findings.

2. A Three-Pillar Analytical Framework for Rethinking Energy Security

Energy security, this paper argues, is not a single condition to be achieved but a set of claims made by different actors, at different scales, over the same physical system – claims that are frequently in tension with one another.

This multidimensional understanding of energy security is captured in Figure 1 through three interconnected pillars: affordability, reliability, and outcomes. Together, they provide a framework for examining not only whether energy systems are secure, but whose security is being assured, through which dimensions, and with what consequences for other actors and over time.

Figure 1: Energy security rests on three pillars



Source: Author's own

Table 1 sets out how the pieces fit together before the pillars are discussed in turn.

Table 1: Comparison of wind and solar penetrations across markets (excludes other renewables)[1]

Pillar	Core Question	Stakeholder tension folded in	Where the Global North/South divergence is sharpest
I. Affordability	Is energy affordable and accessible, and to whom?	Household vs. industry vs. investor vs. government definitions of "affordable" (Section 2.1)	Global South: absence of a baseline, cost of capital 2–3x higher. Global North: price volatility around an existing, largely reliable system
II. Reliability	Does the system perform under normal conditions and under stress?	Industrial-user (production continuity) vs. investor (revenue continuity) definitions of "reliable" (Section 2.2)	Global South: last-mile and mini-grid reliability. Global North: grid integration of variable renewables
III. Outcomes	Does the system strengthen or undermine a country's long-run fiscal and institutional capacity?	The two-directional relationship between energy security and economic growth (Section 2.3)	Global South: subsidies substituting for reform. Global North/advanced economies: planning inertia and the fiscal and institutional costs of maintaining legacy energy infrastructure

Source: Author's own

2.1 Pillar I – Affordability: Economic Security for Households and Firms

Affordability covers energy costs across user groups, distributional impacts, and access gaps. This pillar is about economic security rather than physical supply: energy poverty erodes household resilience, constrains industrial competitiveness, and has historically been a source of social and political instability when tariff shocks are poorly sequenced.

The clearest test of "for whom" is affordability itself, which appears explicitly in the IEA's mainstream definition of energy security as the uninterrupted availability of energy at an affordable price (IEA, 2022). Cherp and Jewell (2014) and Sharifuddin (2013) distinguish at least three vantage points: the household, who wants a low price; the investor, for whom "affordability" in the original four-A's framework meant whether capital to build supply was available on acceptable terms; and the government, whose concern is subsidy intensity or import-bill stability. A low-cost, clean generation mix does not, on its own, guarantee an affordable bill at the meter, since generation cost and delivered cost are shaped by different structures and policy choices (Table 2). Affordability failures are rarely failures of technology cost; they are failures of tariff design, subsidy targeting, or capital-cost pass-through – failures of fiscal design and institutional capacity as much as of pricing. A government that freezes consumer tariffs, for instance, may be choosing household affordability at the direct cost of investor returns and government fiscal space, ultimately compromising the more reliable service that a properly capitalised system might otherwise deliver.

Table 2: Affordability disaggregated by stakeholder, with points of conflict.

Stakeholder	What 'affordable' means	Primary metric	Where it conflicts with other stakeholders
Household / consumer	Bill as a share of disposable income; price predictability	Energy expenditure as % of household income	Tariffs low enough for households can fall below cost-recovery, undermining utility solvency and investor returns
Industry / manufacturer	Landed cost per kWh competitive with export peers, delivered without interruption	USD/kWh vs. regional and global competitor benchmark	Cost-recovery tariffs can raise average system cost, conflicting with residential affordability
Investor / financier	Risk-adjusted return sufficient to clear the cost of capital	WACC; project IRR vs. hurdle rate	Bankable, cost-reflective tariffs are often the opposite of the low, politically palatable tariffs households and governments prefer
Government / utility	Fiscal exposure that is sustainable; subsidy that is targeted and time-bound	Subsidy as % of budget; utility cost-recovery ratio	Political pressure to freeze tariffs conflicts with fiscal sustainability and investor bankability

Sources: APERC (2007); Sharifuddin (2013); Cherp and Jewell (2014).

This pillar is also where the Global North/South divergence is sharpest. In the Global North, the energy security conversation of the past five years has been dominated by exposure to acute geopolitical shocks – chiefly the 2021–2023 crisis following Russia's invasion of Ukraine and the 2026 Iran war (examined in Section 5) – a problem of volatility around an already-high baseline of supply. In the Global South, and especially in sub-Saharan Africa, the problem is of a different kind. As of the most recent tracking, 655 million people worldwide still lack electricity access, the great majority in sub-Saharan Africa, where roughly 47% of the population (around 600 million people) remains unconnected (World Bank et al., 2026). For this population, the reference problem is not volatility around a high baseline; it is the absence of a baseline.

The IEA's Cost of Capital Observatory finds that the cost of capital for a structurally identical clean energy project is two to three times higher in emerging and developing economies than in advanced economies or China, driven overwhelmingly by regulatory, political and currency risk rather than technology or resource quality (IEA, 2025a). Least-developed countries, despite holding roughly two-thirds of the global population without electricity access, received only USD 3.7 billion in international clean energy finance in 2024 – an 11% decline on the previous year, and less than a quarter of the USD 15 billion a year the IEA estimates is needed to close sub-Saharan Africa's access gap by the mid-2030s (IEA, 2025b).

A single global energy security agenda therefore risks importing a Global North problem definition – diversification and price stability around an existing, reliable system – into a Global South context, where the prior and more urgent problem is building the system in the first place, at a cost of capital the market itself makes unusually punishing. This is not an argument that the two agendas are incompatible: both converge on reducing exposure to volatile, imported, fossil-priced energy through domestic clean generation. Rather, the point is that the instruments differ: diversification and storage investment for the Global North's dominant risk; de-risking instruments – sovereign and multilateral guarantees, blended finance, concessional debt, regulatory stability – for the Global South's.

2.2 Pillar II – Reliability: Operational Security

Reliability concerns the dependability of the energy system under normal operating conditions and its capacity to maintain performance during external shocks. It is the pillar most closely aligned with the traditional energy-security canon. In renewables-heavy systems, however, the locus of risk increasingly shifts from fuel supply – "will the tanker arrive?" – to system integration: can variable generation be balanced, transmitted, and stored reliably? Transmission, storage, system flexibility, and grid operations therefore become as important as, and in some contexts more important than, generation capacity itself in determining operational security.

This pillar is where the tension between industrial and investor definitions of "reliability" is sharpest. For an industrial user – a factory, a cement plant, a food processor – energy security is, in the first instance, an engineering and production-continuity problem: will power be available, at the required voltage and frequency, without interruption? Price matters, but reliability dominates because the cost of an unplanned outage is frequently far larger than the marginal cost difference between grid and self-generated power. Where grid reliability is poor enough, this logic drives large-scale, decentralised exit into industrial self-generation – leaving the grid worse off, since the paying, high-load-factor industrial customers who most improve a utility's revenue base are precisely the ones best able to defect (Energy for Growth Hub, 2026).

For an investor or financier, energy security places greater emphasis on something close to the opposite: not that power flows without interruption, but that revenue flows without interruption – that a project's cash flows are predictable enough, and its risks sufficiently well priced to clear the cost of capital. Investors consistently identify regulatory risk as the single largest driver of financing cost across emerging markets, ahead of political and currency risk, because these risks are compensated through price: a higher required return, and therefore a higher tariff, on projects perceived as riskier (Clean Air Task Force, 2024). The investor's definition of security is accordingly satisfied by instruments such as sovereign guarantees, Power Purchase Agreements (PPAs) with creditworthy off-takers, political risk insurance, that reduce risk to the financier without necessarily improving the physical reliability experienced by industrial users.

The tension is structural: A tariff high enough to be bankable raises the landed cost of power for industry; a tariff low enough to preserve industrial competitiveness, or politically palatable enough for a government to sustain, frequently falls below the level required to clear investors' hurdle rates. The segment of the market serving the least reliable, least commercially attractive customers is correspondingly the segment that struggles hardest to raise commercial debt – a pattern Section 4's case studies illustrate repeatedly.

2.3 Pillar III – Outcomes: Structural and Fiscal Security

Outcomes encompass the broader structural and fiscal consequences of an energy system, including energy access, employment, industrial competitiveness, and impacts on public finances. The key question is whether the energy system strengthens or undermines a country's long-run capacity to finance its own transition, sustain public budgets, and capture productive benefits. It also concerns whether the transition replaces one form of external dependence – such as imported fossil fuels – with another, such as external capital on unfavourable terms, or creates new forms of domestic dependence through open-ended subsidies. Structural and fiscal security therefore captures not simply what an energy system costs today, but whether its economic and institutional foundations remain viable over time.

This pillar is where the growth relationship matters most. The majority of energy security literature treats the relationship between energy security and economic growth as one-directional: secure, affordable energy is an input to growth, and growth increases the resources available to invest

in further security (Zakari & Musibau, 2023; Azimi et al. 2025; ESM 2026). The evidence supports that relationship but complicates it in two ways. First, where energy insecurity is severe, it imposes a real, countable cost on growth separate from the cost of high prices. Unreliable power acts like a tax on output, and evidence across multiple countries finds a consistent gradient in which deteriorating grid reliability drives firms to self-generation, which further erodes utility revenue and reliability, in a self-reinforcing cycle (e.g. Energy for Growth Hub, 2026; Ozturk, 2010). Second, the relationship also runs the other way: rapid, geographically concentrated economic growth – through new industrial, mining or data-centre demand – can itself create the reliability and transmission problems that then threaten to choke off that same growth, rather than simply resulting from prior security (Mural et al. 2026; Hasan, 2026). Growth is therefore simultaneously the primary justification for investing in energy security and one of the primary sources of new stress on the systems that deliver it – a point Chile's and South Korea's case studies in Section 4 will illustrate. Together, these three pillars structure the rest of this paper. Sections 3 and 4 test the framework against the latest available secondary data and case studies; Section 5 shows that the pillars are not merely additive but interact, revealing, for each country case, whose security is being prioritised, whose is being deferred, and on what timeline.

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3. Benchmarking Clean and Fossil-Fuel Energy Systems

The framework is applied through a review of publicly available evidence on a range of clean energy technologies and systems, including utility-scale solar and onshore wind, hydropower, battery storage, rooftop solar, mini-grids, geothermal power, and green hydrogen, and compares their performance with fossil-fuel alternatives. The analysis asks a practical question: do declining clean-energy generation costs translate into more affordable and secure energy for households and businesses, or are the benefits absorbed elsewhere in the energy system? The comparison considers not only the cost of generation, but also the infrastructure, financing, institutional arrangements, and distribution of costs and benefits that determine whether lower-cost energy ultimately improves energy security.

3.1 Global Cost Stabilisation, Regional Divergence

As Table 3 below shows, the steep cost declines in renewable energy since 2010 have been substantial: utility-scale solar PV and onshore wind costs have fallen by 89% and 71%, respectively, over this period. More than 90% of utility-scale renewable capacity commissioned in 2024 generated electricity at a lower levelised cost of electricity (LCOE) than the least-cost new fossil-fuel plant. Renewables in operation avoided an estimated USD 467 billion in fossil-fuel costs globally that year (IRENA, 2026a). This apparent stability, however, conceals sharply divergent regional trajectories that speak directly to Pillar I's Global North–South comparison. Solar PV costs in China, India and Brazil are roughly one-third of the level recorded in Central America and the Caribbean, while Germany, despite being a mature market, records an LCOE above the European average – highlighting that market maturity does not automatically translate into lower cost. Dispatchable technologies show a contrasting picture: hydropower and geothermal costs have risen by 41% and 53% respectively since 2010. This reflects the specific, lower-output characteristics of projects commissioned in 2025, however, rather than any underlying increase in the technology's cost (IRENA, 2026a; Balkan Green Energy News, 2026).

Table 3: Global weighted average levelised cost of electricity by clean energy technology, 2025, with changes since 2010.

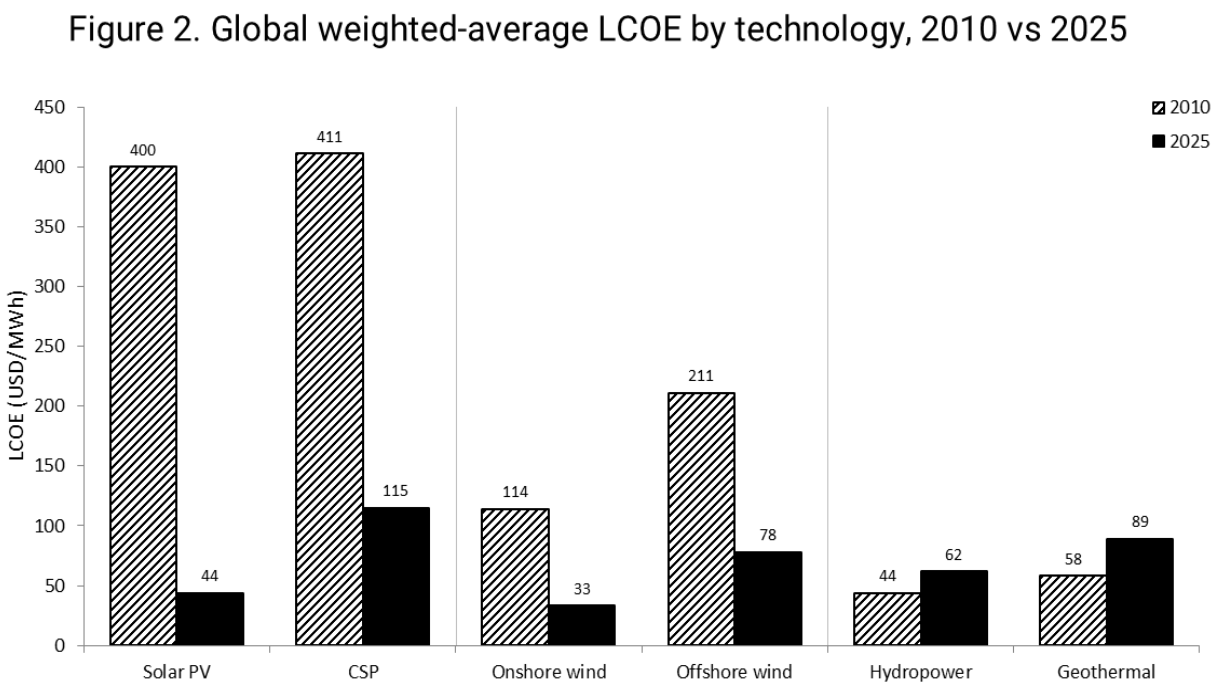
Technology	2025 Global LCOE (USD/MWh)	Change vs. 2010	Note
Utility-scale solar PV	44	−89%	Flat vs. 2024; China $36, India $35, Brazil $37, Germany $65
Concentrated solar power	115	-72%	High but falling; volatile year-on-year
Solar-plus-storage (firm, 95% reliability)	54–82 (high-resource sites)	<$100 in 2020	IRENA's "firm LCOE" metric; projected −30% by 2030
Onshore wind	33	−71%	China remains the low-est-cost market
Offshore wind	78	−63%	US remains a high-cost out-lier

Hydropower	62	+41%	Cost pressure from civil works, retrofits
Geothermal	89	+53%	Site-specific; Kenya among lowest cost globally

Sources: IRENA (2026a, 2026b); PV Tech (2026a, 2026b); Energy-Storage News (2026).

Furthermore, as Figure 2 below shows, the percentage changes also mask a large difference in scale: solar PV, onshore wind, and concentrated solar power are still descending steep cost curves from historically high starting points, while hydropower and geothermal were already comparatively cheap in 2010, so their percentage increases translate into far smaller absolute cost movements.

Figure 2: Global weighted-average LCOE by technology, 2010 vs. 2025 (USD/MWh).



2010 values are derived from the percentage changes reported in Table 3 (2010 value = 2025 value ÷ (1 + % change)); solar-plus-storage is excluded, as IRENA's earliest comparable firm-LCOE estimate dates only to 2020. Sources: IRENA (2026a, 2026b); Balkan Green Energy News (2026).

3.2 From Headline Cost to Delivered Cost

The most consequential recent development is IRENA's "firm LCOE" metric, which captures the cost of continuous, dispatchable electricity from hybrid solar-plus-storage systems rather than the cost of raw single-technology generation. In high-resource regions, firm-level LCOE fell to roughly USD 54-82/MWh in 2025, down from more than USD 100/MWh in 2020, with a further 30% decline projected by 2030 (IRENA, 2026b). The gap between generation cost and the cost of delivering reliable power is therefore narrowing, but it has not closed – and remains widest precisely where financing costs are highest: in the Global South.

3.3 Falling Costs, Widening Financing Gaps

Falling technology costs at the project level sit awkwardly alongside a widening financing gap at the system level (Pillar III). Global public financing for clean energy in developing countries reached only USD 24.6 billion in 2024 – marginally above 2023, but well below the USD 31.4 billion peak of 2016 (IEA, 2025b). Least-developed countries received just USD 3.7 billion in 2024, an 11% decline from the previous year. Africa alone requires an estimated USD 15 billion a year to reach universal electricity access within a decade; yet less than USD 2.5 billion a year is currently being committed – a sixfold shortfall driven less by inadequate public finance than by the continued failure to mobilise private capital at scale, with international public finance still accounting for over 70% of current flows (IEA, 2025b). Independent benchmarking corroborates this pattern at the firm and project level: the Clean Air Task Force's (2024) assessment of WACC across the African power sector, and DNV's (2025) analysis of financing conditions for African renewables both attribute the bulk of the premium to regulatory, political and currency risk rather than differences in technology or resource-quality. This finding echoes the same conclusion reached by the IEA's Cost of Capital Observatory (Section 2.1) and underpins this paper's treatment of structural and fiscal security (Pillar III) as fundamentally a governance problem – a distinction that runs through the case studies that follow.

Photo credit: Antonio García via Unsplash

4. Case Study Analysis

This section examines four country cases in depth, drawing on publicly available tariff data, regulatory documents, grid performance reports, and assessments following major energy shocks. Each case is assessed against the three-pillar framework to show how different policy choices and business models shape investment, distribute risks and costs, and affect households, businesses, governments, and other stakeholders.

4.1 Chile: When Cheap Generation Meets Costly Delivery

Chile is close to completing a structural transition to a renewable-dominated power mix (ACERA, 2026). In 2025 the National Electric System generated 87 TWh, of which renewables supplied 63.3% and non-conventional renewables (NCRE, excluding large hydropower) 42.4% (ACERA, 2026). Installed solar (11,717 MW) and wind (5,971 MW) capacity each now exceed installed gas capacity (4,865 MW) (Comisión Nacional de Energía [CNE], 2025). Against Pillar I's affordability criterion at the wholesale level, Chile is a clear success: competitive supply tenders in the 2025/01 round attracted 708 bids and cleared at USD 64.5/MWh (CNE, 2025).

Yet the same system illustrates precisely how system-level resilience (Pillar II) can weaken even as generation-level performance improves. Renewable curtailment reached 6,084 GWh in 2025, up 7.8% year on year (ACERA, 2026; Ember Energy/Suárez, 2025). ACERA estimates that without this curtailment, NCRE would have supplied 49.4% of generation rather than 42.4% of generation, pointing to significant efficiency losses from transmission congestion concentrated around the solar-rich northern grid, with curtailment losses estimated at roughly USD 125 million in the first five months of 2025 alone (ACERA, 2026; Ember Energy/Suárez, 2025). The consequences of under-investment in delivery infrastructure became particularly stark on 25 February 2025 ("25F"), when the failure of a single high-voltage transmission line caused a nationwide blackout affecting over 90% of the population (Coordinador Eléctrico Nacional, 2025). Consumer tariffs, meanwhile, rose by around 60% as temporary price-stabilisation mechanisms unwound in 2024–2025, leaving consumers to repay an estimated USD 6 billion debt to generators through 2035 (Americas Quarterly, 2024; Argus Media, 2026).

These pressures are not driven by supply alone. Growing demand from desalination plants, data centres, and mining in the northern region is itself contributing to network saturation and curtailment, creating the growth feedback loop outlined in Section 2.3 (REGlobal, 2025; pv magazine, 2025). Chile's response – new "Necessary and Urgent Works" fast-track mechanisms, a rapidly expanding storage pipeline (1,575 MW operating, 737 MW under testing, 6,770 MW under construction by end-2025), and a proposed acceleration of coal-plant closures to 2035 (ACERA, 2026; La Tercera, 2025) – suggests growing recognition that the principal challenge has shifted from expanding generation capacity to integrating and managing an increasingly renewable-dominated system (pv magazine Latinoamérica, 2026). In practical terms, Chile has got very good at building cheap solar and wind capacity, but the transmission corridors, storage, and market rules needed to deliver that power reliably haven't kept pace.

4.2 Kenya: Clean Generation, Uneven Equity

Kenya presents a markedly different configuration from Chile. Electrification in Kenya rose from roughly 37% in 2013 to 79% by 2023, with urban areas already at full access, driven substantially by the Last Mile Connectivity Project (LMCP), which has connected 9 million rural people since 2015 and is co-financed by the European Investment Bank, the African Development Bank (AfDB), the European Commission and the French Development Agency (IEA, 2025c).

Kenya's generation mix is overwhelmingly clean: approximately 80% of grid power comes from renewables, led by geothermal (39.5%), hydro (24.2%), wind (13.2%) and solar (3.3%) (Energy and Petroleum Regulatory Authority [EPRA], 2025), complemented by the 300 MW Lake Turkana wind farm, Africa's largest (African Development Bank [AfDB], n.d.).

On Pillar I (affordability), however, Kenya's performance is markedly weaker than its clean generation mix would suggest. EPRA's tariff schedules show domestic rates ranging from roughly KES 12–16.5/kWh for low-consumption "lifeline" customers up to considerably higher standard rates, before fuel-cost, forex and inflation pass-through levies are added – making effective residential rates among the highest in the East African Community (EPRA, 2025). Low marginal generation costs are therefore not translating into correspondingly low end-users' prices as the technology cost data in Section 3 would imply. The remaining access gap is concentrated in areas where the grid is less economically viable; Kenya's National Energy Compact 2025-2030 targets an additional 5.1 million connected households through a mix of on-grid and off-grid solutions (Government of Kenya/World Bank, 2025).

Yet the off-grid pathway faces significant regulatory uncertainty. Kenya's Energy (Mini-Grid) Regulations, drafted in 2022, remain in draft form, while a 15-kilometre buffer zone around existing grid infrastructure excludes many potentially viable sites from private development (EPRA, 2022). Developers also report no clear protocol for compensation or asset transfer when the national grid eventually reaches an area their mini-grid already serves – a risk IRENA (2016) has identified as central to mini-grid bankability. Mini-grid developers are widely reported as among the segment of Kenya's clean energy sector that international financiers find hardest to finance through commercial debt (Fajardo et al., 2025; IFC, 2020), providing a direct illustration of the investor-security logic set out in Section 2.2.

This uncertainty extends beyond mini-grids. Kenya operated under a moratorium on new PPAs from 2018 until Parliament lifted it in November 2025, subject to the adoption of a competitive-auction procurement system that EPRA must operationalise within twelve months (World Bank, 2025; Bowmans, 2025). While the reform is intended to improve procurement efficiency and cost discipline, the transition also introduces a new layer of bankability uncertainty for developers.
The Kenyan case demonstrates that a predominantly clean and relatively reliable generation system (Pillars II and, partly, III) can coexist with persistent challenges in affordability and equity (Pillar I). The central constraints lie less in the availability of clean generation than in the institutional and financial arrangements governing how electricity is priced, delivered, and extended to underserved communities. Kenya therefore illustrates a critical distinction within the energy transition: a clean electricity system is not necessarily an inclusive or affordable one.

4.3 Nigeria: Subsidy as a Substitute for Reform

Nigeria illustrates a third configuration, in which improvements in generation costs have yet to translate into system-level affordability or reliability, while fiscal subsidies continue to compensate for unresolved structural weaknesses. Under the Electricity Act 2023 and its 2025 amendment, Nigeria has begun devolving generation, transmission and distribution authority to willing states; by early 2026, more than a dozen states had assumed some regulatory oversight from the national regulator, the Nigerian Electricity Regulatory Commission (NERC, 2026). This devolution is best understood not as a resolution of Nigeria's structural weaknesses, but as a redistribution of the risks associated with them: states now assume greater responsibility for tariff-setting and reliability while facing significant political constraints on cost-reflective pricing. In this sense, subnational devolution extends rather than replaces the subsidy logic that has defined the sector, shifting responsibility for managing the consequences of weak revenue recovery without resolving the underlying financial shortfall (ibid).

Nevertheless, reliability remains markedly weak. Nigeria's national grid has collapsed at least 222 times between 2010 and 2022, roughly a dozen times in 2024–2025, and at least three times between December 2025 and January 2026 alone (The Guardian Nigeria, n.d.). Average available generation capacity fell 17.5% between Q4 2025 and Q1 2026, from 5,400 MW to 4,458 MW (ThisDay, 2026), even as the Presidential Power Initiative – a partnership with Siemens targeting 7,000 MW of reliable transmission capacity – remains under implementation (Siemens, n.d.). On Pillar III, the fiscal picture is equally revealing: by holding end-user tariffs at July 2024 levels, the Federal Government incurred an electricity subsidy of N358.32 billion (roughly USD 230 million) in Q1 2026 alone, a decline from the prior quarter driven by lower offtake rather than improved cost recovery, while legacy sector debt exceeded N4 trillion (Vanguard News, 2026; Premium Times, 2025).

These reliability failures carry directly measurable economic costs. The World Bank estimates unreliable electricity costs the Nigerian economy roughly USD 25 billion annually, equivalent to 5–7% of GDP, while manufacturers are willing to pay up to three times the cost-reflective tariff to self-generate power (World Bank, n.d.). The result is large-scale decentralised exit from the grid. Commercial and industrial captive generation now exceeds 6,500 MW, surpassing the national grid's typical output, with firms such as the Dangote Group generating over 1,500 MW independently (The Electricity Hub, 2025); Lagos State alone has estimated off-grid capacity potential exceeding 19 GW (SEforALL, 2024). This represents industry purchasing its own security through self-generation, consistent with the continuity logic outlined in section 2.2, but at considerable cost. Self-generation is estimated to cost roughly twice as much as grid electricity in Nigeria and South Africa, and up to four times the grid cost elsewhere in Africa (Energy for Growth Hub, 2026). As high-load-factor customers exit the grid, the revenue base available to finance system improvements is further weakened, reinforcing the growth-security feedback loop identified in Section 2.3. Comparative utility assessments consequently place Nigeria at the weakest end of the spectrum among African peers (Energy for Growth Hub, 2026). Nigerian manufacturers report grid electricity costs of roughly 15 US cents/kWh, comparable to or higher than those in Vietnam (8 cents) and China (10 cents), rising to around 30 cents through self-generation, while working-capital interest rates of 27–35% further compound the cost disadvantage relative to comparator economies at 3–9% (TheCable, n.d.).

Without a credible, time-bound reform trajectory, subsidy policy risks becoming a mechanism for managing the symptoms of structural weakness rather than resolving them. It does not prevent poor service for households (Pillar I), restore system reliability (Pillar II), or create productive assets capable of reducing future fiscal exposure (Pillar III). Nigeria therefore illustrates a particularly damaging configuration in which the state bears growing fiscal costs, firms increasingly purchase their own energy security, and the electricity system itself becomes progressively less capable of financing the investments required for recovery.

4.4 South Korea: Advanced-Economy Exposure and the Limits of Domestic Insulation

South Korea represents a fourth, analytically distinct configuration: an advanced, high-income, technologically sophisticated economy that nonetheless remains highly dependent on imported fossil fuels. In 2024, more than 80% of South Korea's total energy use came from fossil fuels, and the country is the world's fourth-largest crude oil importer and third-largest importer of Liquefied Natural Gas (LNG) – natural gas cooled to a liquid state for tanker transport, exposing importers to volatile global prices rather than fixed pipeline contracts (The National Interest, n.d.). This dependence is concentrated in electricity generation: coal and gas together account for approximately 58% of generation, nuclear around 31%, and renewables only about 10% - the lowest renewable share among the cases examined in this paper, and one of the lowest among advanced economies (IEEFA, 2026a). Unlike Chile, Kenya or Nigeria, South Korea's exposure cannot be explained by weak institutions, scarce capital or underdeveloped markets. Rather it reflects a long-standing strategic choice in generation mix that has persisted even as renewables have become cost-competitive with fossil generation across most global markets.

That exposure became acute during the 2026 Iran war. LNG fuel costs alone, at roughly USD 0.075/kWh prior to the conflict (equivalent to approximately USD 10/MMBtu), already sat within KEPCO's industrial retail tariff range of approximately USD 0.069–0.089/kWh (KRW 95–123/kWh), leaving little to no headroom between input fuel costs and consumer prices as the crisis began (Center for Strategic and International Studies [CSIS], n.d.). The government's emergency response, including fuel price controls, efforts to secure alternative oil and gas supplies, a temporary easing of coal-generation restrictions, and an accelerated schedule for restarting five idled nuclear reactors (Enerdata, n.d.), was not a failure of physical infrastructure, unlike Chile's blackout or Nigeria's grid collapses; rather it was a scramble to substitute away from suddenly expensive imported fuels under crisis conditions (Enerdata, n.d.).

The fiscal costs (Pillar III) of this exposure are significant. IEEFA's 2024 analysis estimated that South Korea's fossil-fuel-oriented power mix cost the country an additional USD 17 billion in 2022 relative to a more diversified alternative (IEEFA, 2024) – a structural vulnerability that the 2026 Strait of Hormuz shock has since stress-tested under real crisis conditions. The comparison with Nigeria's quarterly subsidy bill is instructive despite different mechanisms involved. Whereas Nigeria's Pillar III burden takes the form of a subsidy that compensates for unresolved sectoral weaknesses, South Korea's is closer to the implicit cost of maintaining an import-dependent system: the country continues to bear the economic exposure associated with imported fuels that could increasingly be displaced by domestic renewable generation.

The case also provides the clearest empirical grounding for the industry-versus-investor tension identified in Section 2.2, but at the scale of national energy planning. Electricity demand is forecast to grow by around 1.8% annually, reaching 129 GW by 2038, driven largely by semiconductor fabrication and data-centre expansion (Korea Times, 2026). These industries require reliable, high-quality electricity on investment timelines that favour rapidly deployable generation. The 11th Basic Plan for Long-Term Electricity Supply and Demand, finalised in February 2025, responded by prioritising new LNG-fired capacity and small modular nuclear reactors, even though IEEFA estimates that tripling renewable capacity by 2030 could meet the same demand growth (World Nuclear News, n.d.; IEEFA, 2025). The resulting tension is therefore not between technological feasibility and economic capacity, but between rapidly growing demand, short-term planning priorities, and longer-term diversification.

South Korea consequently illustrates a distinct form of energy insecurity: planning and sequencing can sustain import dependence even where capital, institutional capacity, and increasingly competitive domestic alternatives are available. Unlike Chile, where transmission constraints limit the integration of renewable generation; Kenya, where tariff and mini-grid governance constrain inclusion; and Nigeria, where subsidies compensate for persistent sectoral weakness, South Korea's central challenge lies in aligning demand growth and investment decisions with a more resilient generation strategy.

Table 4: Summary comparison across the four case studies.

Dimension	Chile	Kenya	Nigeria	South Korea
Transition pathway	High-renewables system	Emerging economy expanding access	Fossil-fuel-dependent economy in transition	Advanced, import-dependent economy under acute geopolitical stress
Renewable share of generation	63.3% (NCRE 42.4%)	~80%	Predominantly gas/hydro; renewables marginal on-grid	~10% (coal+gas ~58%, nuclear ~31%)
Binding constraint (pillar)	Transmission and curtailment (II)	Tariff design and mini-grid governance (I)	Cost-reflective pricing and fiscal sustainability (III)	Political economy and planning sequence (III)
Reliability signal	Nationwide blackout, Feb 2025	Rural/last-mile gap	Recurrent grid collapses	Emergency fuel caps, nuclear restarts (2026)
Affordability signal	Tariffs up ~60% amid stabilisation unwind	Tariffs among region's highest despite clean mix	N358.3bn quarterly subsidy	LNG cost approaching retail ceiling
Dominant stakeholder tension	Growth-driven demand reinforcing the congestion it depends on	Investor risk-pricing of regulatory ambiguity vs. household affordability	Industry self-generation vs. grid revenue base; tariff-freeze vs. investor bankability	Industrial demand-growth continuity vs. diversification investment
Dominant policy lesson	Cheap generation does not guarantee delivered security	Clean supply does not guarantee inclusive affordability	Subsidy substitutes for reform without buying reliability	Generation-cost competitiveness does not guarantee adoption

Source: Author's own.

5. Cross-Case Synthesis and Stress-Testing

The four cases reveal how different energy systems respond when exposed to external shocks and competing demands. This section brings the cases together to identify what strengthens energy security, where vulnerabilities persist, and how gains in one dimension of security can create costs or risks elsewhere. It first tests the framework against two major energy shocks and then draws out the broader implications for system design, policy choices, and the distribution of costs and benefits.

5.1 Two Shocks Compared: 2021–2023 and 2026

The 2021–2023 global energy price crisis and the 2026 Iran war provide a useful stress test for the framework. The two shocks differed in their transmission mechanisms. The 2021–2023 crisis was driven primarily by sanctions and rerouted trade flows; after Brent crude reached roughly USD 139/barrel in March 2022, prices broadly normalised within a year as Europe secured alternative LNG supplies (CNBC, 2022). The 2026 Iran war generated a more direct physical disruption, which the IEA characterised as the largest supply disruption in the history of the global oil market (IEA, 2026). The disruption at the Strait of Hormuz, through which roughly 20% of global oil and gas trade passes, pushed prices towards USD 120/barrel within weeks and European gas prices up by 60–70% (TradingEconomics, n.d.). The EU entered the crisis with gas storage at around 37% of working capacity, leaving it more exposed than at comparable stages of the earlier crisis (European Gas Hub, 2026a, 2026b; ACER, n.d.).

Both shocks reinforce the framework's central proposition: dependence on imported fossil fuels transmits international price and supply shocks into domestic energy systems, while a greater share of domestic clean generation can reduce this exposure. The four cases, however, demonstrate that such insulation is neither automatic nor sufficient. Chile, despite generating almost two-thirds of its electricity from renewables and therefore having limited exposure to imported gas-price shocks, experienced a major reliability failure arising from transmission weakness. This illustrates that fuel-price insulation (Pillars I and III) and operational resilience (Pillar II) depend on different investment and governance regimes and can therefore move independently. Kenya's predominantly clean generation mix similarly limits exposure to international fuel-price volatility but does not resolve the tariff-design and regulatory uncertainties constraining affordability and inclusion. Nigeria combines continued exposure to fossil-fuel cost pressures with chronic reliability failures and deepening fiscal exposure, capturing neither the price-insulation benefits of clean generation nor the reliability benefits of sustained investment in the conventional system.

South Korea provides the sharpest counterexample. As an advanced economy with deep capital markets and high institutional capacity, it would be expected to have greater capacity to absorb an external energy shock without resorting to emergency measures. Instead, its high dependence on imported fossil fuels left it substantially exposed through the fuel-price channel. South Korea's emergency nuclear restarts and fuel-price controls represent the same basic form of reactive substitution observed in lower-income systems: replacing or containing an abruptly expensive fuel source after the shock has occurred. The difference is that South Korea possessed the financial, institutional, and technical capacity to reduce this exposure in advance through faster deployment of domestic renewable generation.

The South Korean case therefore reinforces a broader cross-case finding: economic capacity does not automatically produce energy security. Domestic clean-generation capacity is a stronger determinant of insulation from external fuel-price shocks than GDP per capita or institutional capacity alone, provided that generation is supported by the transmission, storage, and market infrastructure required to convert capacity into reliable electricity.

The cases thus distinguish between two dimensions that are often conflated in energy-security debates: insulation from external fuel shocks and resilience of the domestic electricity system are complementary but not interchangeable objectives.

5.2 Mapping the Pillars onto Generation, Delivery and Distribution

Read together, Sections 3 and 4 show that "energy security" is itself decoupling into distinct system-level problems that require different policy instruments. These problems, however, map onto the three pillars already established rather than requiring a competing taxonomy. Generation-level security, primarily within Pillar I, concerns whether sufficient, low-cost, low-carbon generation capacity exists. This is increasingly responsive to market competition and technological cost reductions: more than 90% of new utility-scale renewable capacity now undercuts the cheapest new fossil-fuel alternative, including across most developing-country markets (IRENA, 2026a). Delivery-level security, central to Pillar II, concerns whether that capacity can be transmitted, stored, and balanced reliably. This is increasingly the binding constraint in advanced renewable systems such as Chile and requires long-duration infrastructure investment, often supported by public or blended finance, that differs from the project-finance models that have successfully scaled generation. Distributional and fiscal security, central to Pillar III, concerns who pays, on what terms, and whether the underlying financing and tariff arrangements are fiscally sustainable. This is fundamentally a governance and distributional problem rather than a technology problem, and it is where the Global North–South divergence identified in Sections 2.1 and 3 is most evident: differences in the cost of capital increasingly determine whether reductions in generation costs translate into affordability gains for end-users.

South Korea demonstrates why generation-level cost competitiveness does not necessarily translate into generation-level diversification. Its low renewable share reflects a combination of industrial demand growth and planning inertia that has outweighed the same cost signals accelerating diversification elsewhere. This exposes a political-economy dimension of Pillars I and III that is less prominent in Chile, Kenya, and Nigeria, where capital scarcity and financing conditions account for more of the observed divergence. The same dynamic is likely to recur in other advanced, industrially intensive economies facing rapidly growing demand from electrification, AI infrastructure, and semiconductor manufacturing.

The implication is that market structures centred primarily on generation-level competition, including competitive auctions and merchant tariffs, are necessary but no longer sufficient. Delivering genuine energy security requires complementary instruments for transmission, storage, system flexibility, tariff design, fiscal sustainability, and demand management, calibrated to the very different financing and institutional environments illustrated by these four cases.

5.3 Whose Security, Deferred to When?

The four cases converge on the same conclusion: progress in one dimension of security routinely comes at the expense, or at least the deferral, of another. This distributional question, rather than any single pillar in isolation, is the paper's central finding. In Chile, wholesale-market and investor security has advanced faster than consumer and system security; the resulting transmission deficit has increased system costs and contributed to higher tariffs, shifting the costs of deferred grid investment onto consumers. In Kenya, strong generation-level security has been achieved without a corresponding resolution of household affordability and mini-grid investor concerns. In Nigeria, government efforts to protect households through tariff restraint have occurred alongside deteriorating utility and investor security, leaving an under-capitalised sector carrying more than N4 trillion (approximately USD 2.9 billion) in debt, while industry has increasingly purchased its own security through self-generation. This further erodes the utility revenue base needed to resolve the deferred investment gap.

In South Korea, industrial and export-sector security has been prioritised ahead of national fuel-price and fiscal security, with the deferred exposure becoming acute during the 2026 Iran war.

None of these configurations are accidents of poor policy design that can be corrected through a single intervention. Each reflects a structural tension identified in Section 2: between regions, between households and investors, between competing definitions of affordability, and between economic growth and the energy security it both requires and can undermine. The practical task for policymakers is therefore not to eliminate these tensions in the abstract, but to make them explicit in each major policy or investment decision: whose security is being strengthened, whose is being deferred, what costs are being shifted, and on what timeline is the deferred claim expected to be addressed? The following section translates this principle into a set of practical priorities for policy and investment.

Photo credit: Francis Tokede via Unsplash

6. Policy Recommendations

The preceding analysis shows there is no single policy prescription that can align clean energy transitions with the three pillars of energy security – affordability, resilience, and socio-economic outcomes – across different system configurations. The appropriate response instead depends on where the principal constraints lie, how risks are distributed, and which dimensions of security and development have been prioritised, compromised, or deferred.

For advanced, high-renewables systems (the Chile pattern):

- Institutionalise fast-track transmission permitting: make mechanisms such as Chile's "Necessary and Urgent Works" process a standard component of electricity planning rather than an emergency response to emerging grid constraints.
- Make curtailment costs transparent: require systematic measurement and public reporting of curtailment volumes and associated costs, ensuring that investment decisions account for delivery infrastructure alongside new generation capacity.
- Treat storage as a strategic reliability asset: establish minimum storage capacity or duration requirements linked to peak demand, congestion, and curtailment risk, treating storage as a strategic reliability asset in much the same way that fossil-dependent systems have historically treated fuel storage.
- Sequence tariff reform carefully: phase out temporary price-stabilisation mechanisms in a predictable and well-communicated manner. Rapid tariff increases, even when necessary for cost recovery, can trigger affordability pressures that undermine the reliability gains such reforms are intended to deliver

For advanced, import-dependent industrial economies (the South Korea pattern):

- Align industrial demand with clean-energy deployment: connect planning for demand growth from semiconductor fabs, AI data centres, and other energy-intensive industries explicitly to accelerated renewable and storage deployment, rather than defaulting to additional LNG capacity or unproven small modular nuclear.
- Build energy-price and supply resilience before crises: establish permanent fuel-price hedging and strategic reserve mechanisms – including diversified long-term LNG contracts, price-stabilisation instruments, pre-agreed protocols for nuclear restart – before supply or price shocks occur, rather than during a crisis.
- Align demand beneficiaries with clean-energy investment: require or incentivise large industrial and data-centre consumers driving incremental demand to co-invest in dedicated renewable and storage capacity or long-term PPAs, aligning the beneficiaries of demand growth with the investment required to reduce import exposure.
- Track the fiscal exposure of import dependence: establish a recurring fiscal benchmark for fossil-fuel dependence, drawing on estimates such as IEEFA's USD 17 billion 2022 estimate) alongside conventional LCOE metrics, to make the long-run economic exposure of continued import dependence explicit to policymakers and legislators.

For emerging and access-constrained economies (the Kenya and Nigeria patterns):

- Expand blended and risk-sharing finance: deploy guarantees, first-loss capital, equity-type instruments to segments that commercial lenders are unlikely to finance alone, including mini-grid developers and early-stage decentralised renewable energy companies.
- Strengthen mini-grid regulation: establish clear and enforceable rules governing compensation, asset ownership and grid integration when the national grid reaches communities already served by private mini-grids, reducing the regulatory uncertainty documented in Kenya.
- Link tariff support to measurable performance: replace open-ended, non-cost-reflective tariff subsidies with time-bound, milestone-based support tied explicitly to improvements in reliability, revenue collection and service quality. This would avoid the Nigerian pattern of fiscal commitment without commensurate performance improvement.

» Strengthen transmission and distribution finance: improve the balance sheets and liquidity of transmission and distribution companies, not only generation firms. Nigeria's accumulated sector debt demonstrates how financial weakness anywhere along the electricity value chain can undermine reliability, regardless of generation costs or capacity.

Cross-cutting recommendations, applicable across all system configurations:

» Adopt delivered or firm-level LCOE as the core investment metric: move beyond headline generation LCOE to assess the cost of reliable electricity at the point of consumption. The relevant comparison is not simply the cost of generating electricity, but the cost of delivering it reliably.

» Institutionalise resilience stress-testing: test energy systems against major historical and plausible future shocks, using 2021–2023 and 2026 as reference scenarios. Stress tests should distinguish fuel-supply exposure – addressed through diversification and domestic generation – from delivery-failure exposure – addressed through transmission, storage, and market design. Treating these as interchangeable risks creates significant planning gaps.

» Separate technology costs from political-economy constraints: distinguish between the technology and capital-cost dimensions of generation security, which have improved substantially with recent cost trends, and the political-economy and sequencing constraints that shape investment decisions. South Korea demonstrates that cost competitiveness alone does not guarantee diversification or greater resilience.

» Target concessional finance where access needs are greatest: direct a larger share of concessional and public climate finance towards least-developed countries, weighting allocation more heavily towards energy-access and development needs rather than technical readiness alone.

» Make "whose security?" an explicit planning question: every energy-planning and investment document should specify whose security is being assessed – households, industry, investors, utilities, or government. As Section 2.1 and Table 2 demonstrate, measures that improve investor security may increase household costs, while measures that protect household affordability may weaken utility finances and deter investment.

» Treat new industrial demand as part of energy-security planning: incorporate industrial and data-centre demand growth as an endogenous component of energy-security planning rather than as an exogenous forecast that supply must simply accommodate. Assess how major new loads will affect generation requirements, transmission congestion, storage needs, and import exposure before such investments are approved.

Taken together, these recommendations point to a shift from a generation-centred conception of the clean energy transition to a system-wide approach: aligning generation, networks, finance, tariffs, demand growth and institutional arrangements in ways that distribute the benefits and risks of the transition more equitably.

7. Summary and Conclusion

This paper examined whether clean energy systems can deliver affordable, reliable and inclusive energy; how their performance compares with fossil-fuel systems across the Global North and South; and, following the three-pillar framework developed in Section 2, for whom these outcomes are secured. Evidence from Chile, Kenya, Nigeria and South Korea points to a more nuanced conclusion than either transition optimism or transition scepticism suggests.
The evidence shows that the fundamental economics of clean energy changed decisively. Renewable technologies are now cost-competitive with, and often cheaper than, fossil-fuel alternatives, including across much of the Global South. Yet, lower generation costs do not automatically translate into affordable, reliable, or inclusive electricity. Across the cases, investment in generation has in some instances outpaced the transmission, storage, system flexibility, market institutions, and distributional mechanisms needed to convert low-cost generation into secure electricity services. Chile illustrates emerging transmission and curtailment risk in a rapidly expanding renewable system; Kenya highlights unresolved tariff, regulatory and inclusion challenges despite a predominantly clean mix; Nigeria demonstrates how persistent fossil-fuel dependence and weak sector finances produce a cycle in which subsidies substitute for structural reform; and South Korea shows how planning inertia and industrial demand pressures can sustain fossil-fuel dependence even where the economic and technical conditions for diversification are increasingly favourable.

A central lesson across these different contexts is that energy security is not determined by generation costs or fuel availability alone. It depends on how risks, costs, and benefits are distributed across the wider energy system. A measure that improves investor security may increase costs for households; protecting household affordability may weaken utility finances; expanding industrial capacity may increase system-wide demand and import exposure; and delaying investment in networks or flexibility may shift costs into the future. These trade-offs are evident across both the Global North and South, although their consequences differ according to institutional capacity, financing conditions, levels of access, and the maturity of existing energy systems. Energy security is therefore ultimately a question not only of what energy systems can deliver, but of whose security they prioritise and who bears the associated costs and risks.
The policy implication is clear: the next phase of the clean energy transition must move beyond generation deployment towards system-wide energy security. Policymakers should treat transmission, storage, market design, financial resilience, affordability, and the managed replacement of legacy infrastructure as integral components of the transition rather than secondary considerations. Investment and planning frameworks should assess the cost of delivering reliable electricity, not simply the cost of generating it; stress-test systems against both fuel and infrastructure shocks; align rapidly growing industrial and data-centre demand with new clean-energy and network investment; and direct concessional finance towards contexts where high financing costs and energy-access needs remain major constraints.

Ultimately, the success of the clean energy transition should be judged not only by how much renewable capacity is deployed or how cheaply electricity can be generated, but by whether energy systems can deliver affordability, resilience, and equitable socio-economic outcomes. This requires making explicit whose security is being protected, whose risks are being deferred, and whether the institutional and financial arrangements underpinning the transition are capable of sustaining its benefits over time. The transition is therefore not simply a shift in the technologies used to generate electricity; it is a transformation of the systems, institutions, and distributional relationships through which energy security is produced.

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Glossary

AfDB: African Development Bank – a multilateral development finance institution owned by African and non-African member states, which finances infrastructure (including energy) projects across the continent.

CNE: Comisión Nacional de Energía – Chile's National Energy Commission, the technical regulator that runs supply tenders, sets tariffs, and oversees the electricity and fuels sectors.

Cost-reflective tariff: An electricity tariff designed to recover the full cost of supplying power – including generation, transmission and distribution costs, as well as an appropriate return on investment–as opposed to a subsidised or administratively capped tariff.

Renewable Curtailment: The deliberate reduction of renewable electricity output below the amount that could otherwise be generated, typically because available transmission, storage or demand cannot absorb the power.

CSIS: Center for Strategic and International Studies – a Washington, D.C. foreign-policy think tank.

DFI: Development finance institution – a state-backed or publicly supported financial institution, such as the World Bank or African Development Bank, that provides financing for projects or markets perceived as too risky, costly or long-term for commercial lenders alone.

EPRA: Energy and Petroleum Regulatory Authority – Kenya's regulator for electricity, petroleum and renewable energy, covering tariff approval, licensing, and (relevant to your mini-grid discussion) the rules governing mini-grid development and grid integration.

Equity (in this paper): The distribution of the costs, risks and benefits of the energy transition across income groups, regions and generations. This use is distinct from “equity” as a financial term referring to ownership capital, which is used only in Section 4.

Firm LCOE: A levelised cost of electricity that accounts for the cost of delivering continuous or dispatchable power from a hybrid system, such as solar combined with battery storage, rather than the cost of the raw, intermittent output of a single generation technology.

Four A’s: The traditional four-dimensional definition of energy security – availability, accessibility, affordability and acceptability – that emerged in the aftermath of the 1970s oil shocks.

IEEFA: Institute for Energy Economics and Financial Analysis – a US-based think tank producing financial and policy analysis on the energy transition.

KEPCO: Korea Electric Power Corporation – South Korea's state-controlled electric utility, responsible for transmission, distribution and much of retail electricity supply; it sets the domestic tariffs your paper compares against import fuel costs.

LCOE: Levelised cost of electricity – the average cost of generating one unit of electricity over the lifetime of an energy asset, incorporating relevant capital, operating and financing costs. It is commonly used to compare generation technologies.

LNG: Liquefied Natural Gas – natural gas cooled to a liquid state for transport by tanker rather than pipeline, making it globally tradeable but exposed to volatile international prices and shipping-route disruptions (e.g., the Strait of Hormuz). Central to this paper's South Korea case, where heavy LNG import reliance drives exposure to external price and supply shocks.

Mini-grid: A small, localised electricity network, typically serving a defined community or area, that can operate independently of or in parallel with the national grid and is often powered partly or wholly by renewable energy.

NERC: Nigerian Electricity Regulatory Commission – Nigeria's national electricity regulator, responsible for licensing, tariff-setting and oversight of the power sector before the 2023 Electricity Act began devolving some of that authority to states.

NCRE: Non-conventional renewable energy – a Chilean and Latin American policy classification for renewable generation excluding large-scale hydropower. Large hydro is tracked separately because of its distinct environmental and dispatch profile (reservoir effects, hydrological variability), and because including it would inflate headline renewable-share figures without reflecting growth in newer technologies. National targets and subsidy schemes in the region are therefore usually set against NCRE share, not total renewable share.

PPA: Power purchase agreement – a long-term contractual arrangement under which a buyer agrees to purchase electricity from a generator at specified terms, including an agreed price or pricing mechanism.

Sovereign guarantee: A legally binding commitment by a government to meet specified financial obligations if the designated public entity or project counterparty fails to do so, thereby reducing the lender’s or investor’s risk.

WACC: Weighted average cost of capital – the blended rate of return a project is expected to earn to satisfy both lenders and equity investors. In this paper, WACC is used as a standard proxy for the financing conditions and perceived risk associated with investing in a particular market.