GLOBAL RENEWABLES CONGRESS

World Future Council

IET International Energy Transition

The Policy Implications of a People-Driven, Bottom-Up Energy Revolution

THE CASE OF PAKISTAN AND IMPLICATIONS FOR POLICYMAKING IN THE GLOBAL SOUTH

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Executive Summary

The case of the ongoing energy revolution Pakistan reveals the implications of abundant, inexpensive behind-the-meter solar PV in fast forward. Consumers will continue to adopt distributed generation technologies even in the absence of government support policies and in the face of considerable regulatory barriers. In the Global South, self-consumption can be understood as a practical response by households and businesses to gaps in the services (or the quality of services) provided by the main grid, particularly where reliability, affordability, and quality of supply are insufficient. Extremely low-cost solar PV panels (and increasingly cheap battery energy storage) will radically change electricity systems in the coming years. This trend is now emerging in markets far beyond Pakistan as well, including South Africa, Sierra Leone, Nigeria and many others.

Failing to account for the growth and dynamics of distributed generation is likely to result in significant political and financial costs. Restrictive policies may temporarily slow the uptake of distributed generation, but they are unlikely to stop it. Instead, they risk delaying adjustment and increasing the likelihood of disruptive system impacts, such as unregistered behind-the-meter PV and battery deployment, potential grid defection, and emerging grid stability challenges. **A proactive policy approach is therefore needed.**

The era of captive electricity consumers is over as self-consumption has become a viable alternative to purchasing electricity from the grid. Customers are increasingly moving towards self-consumption or even grid defection if the services provided by the centralized system are not equally good (or better) than self-produced electricity. Policy failure (or simply myopia) when planning the centralized electricity system will push consumers further into self-consumption. **The only real long-term solution to avoid more and more consumers shifting towards self-consumption is to offer these or better services via the centralized grid – or to provide products and services that complement self-produced electricity.**

Several analyses have analysed the solar PV revolution in Pakistan that unfolded over the past two years (IEEFA, 2024; Renewables First, 2025a, 2025b; TransitionZero & PRIED, 2025; REN21, 2025). However, few analysts have depicted the implications of this bottom-up revolution in the broader, global context of the energy transition. **What lessons do the disruptions experienced in Pakistan offer for policymakers across the Global South?**

This report focuses on implications for policymaking in the Global South, with its intertwined challenges of de-risking investments, the risk of load shedding and the need to provide energy access for all. Nonetheless, many of the considerations presented in this report also apply for countries in the Global North.

This report attempts to highlight the implications of cheap, behind-the-meter solar PV (and BESS) for energy policy makers in the Global South and elsewhere. It highlights implications for policymaking in terms of rate design, capacity payments, electricity system planning, tracking of (unregistered) distributed generation, self-consumption policies and grid expansion planning and financing.

1.1. Implications for policymaking in the Global South

This ongoing energy revolution and the availability of abundant, inexpensive behind-the-meter solar PV have important implications for policymaking in the Global South. In line with the sub-chapters of the report below, the implications can be summarized as following:

Electricity price levels and price structure (rate design)

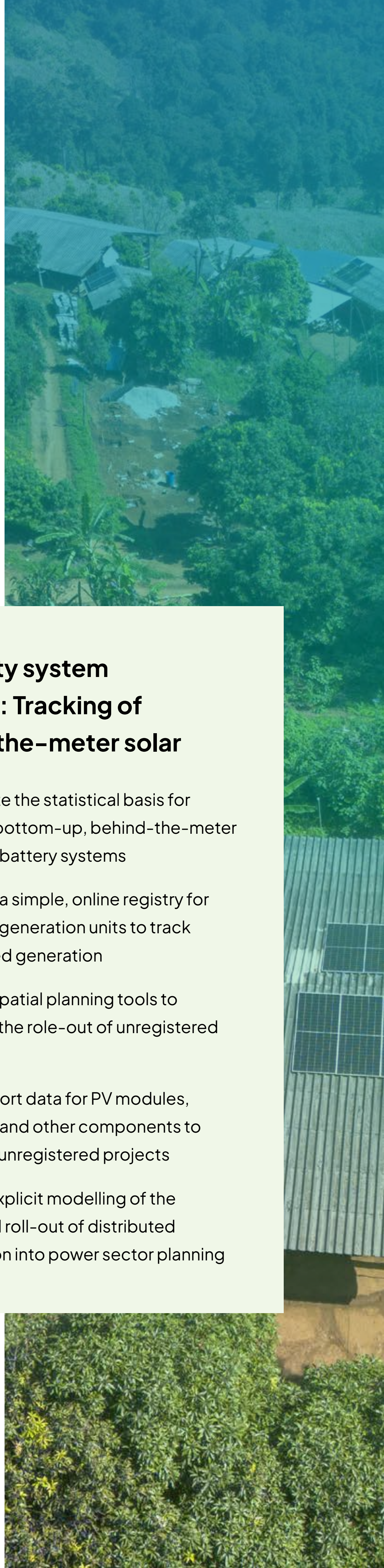
- Enable for low grid-based electricity prices by smart system planning and avoiding inflexible surcharges and levies
- Reduce electricity prices by excluding "legacy costs" from the electricity bill
- Establish time-variable electricity tariffs and grid usage fees

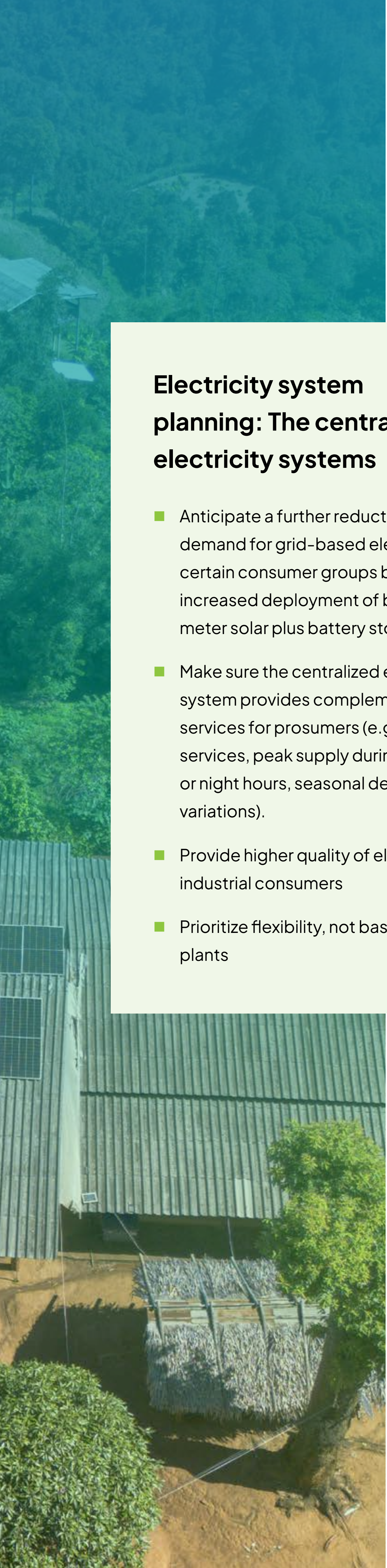
Capacity payments and take-or-pay contracts

- Avoid generous capacity payments to finance fossil fuel-based power plants
- Consider the adverse effects of locking-in long-term fossil-fuel supply contracts
- Avoid "take-or-pay" contracts for fossil fuel based power plants and LNG procurement
- Include flexibility clauses in PPAs signed with fossil fuel based power plants

Electricity system planning: Tracking of behind-the-meter solar

- Triangulate the statistical basis for tracking bottom-up, behind-the-meter solar and battery systems
- Establish a simple, online registry for all power generation units to track distributed generation
- Use geospatial planning tools to estimate the role-out of unregistered system
- Track import data for PV modules, batteries and other components to estimate unregistered projects
- Include explicit modelling of the expected roll-out of distributed generation into power sector planning





Electricity system planning: The centralized electricity systems

- Anticipate a further reduction in demand for grid-based electricity for certain consumer groups because of increased deployment of behind-the-meter solar plus battery storage
- Make sure the centralized electricity system provides complementary services for prosumers (e.g., ancillary services, peak supply during evening or night hours, seasonal demand variations).
- Provide higher quality of electricity for industrial consumers
- Prioritize flexibility, not base-load plants

Self-consumption and prosumer policies

- Avoid uniform flat-rate compensation for excess solar electricity and implement flexible and time-variable tariffs
- Establish incentives for time-shifting solar PV production and export (via battery storage) to align with system peak demand
- Move towards time-differentiated electricity prices for prosumers to incentivize storage adoption and system friendly influx of electricity
- Increase visibility of DG assets via advanced metering infrastructure
- Use remotely controllable distributed generation for grid stability

Grid expansion planning and financing

- Consider electricity grid investments as a public service, financed (partially) via the general budget
- Prioritize financial support for grid infrastructure through national funds and international donors, while gradually shifting public financing away from large-scale power generation projects.
- Move from deterministic, load-growth-driven grid expansion planning to probabilistic, distribution-level hosting capacity analysis

2 The Case of Pakistan: A people-driven energy revolution based on unsubsidized PV deployment

Distributed generation and self-consumption have rapidly become the "new normal" in power systems worldwide, driven by the falling costs of rooftop solar and battery energy storage systems (BESS) and by consumers' demand for affordable, reliable electricity. Customers in very diverse market settings are increasingly investing in behind-the-meter solar and storage regardless of policy incentives, demonstrating that these technologies are now economically rational choices rather than niche alternatives.

The energy transition in the Global South is accelerating sharply. Extremely low-cost solar PV panels (and increasingly cheap battery energy storage) will radically change electricity systems in the coming years. Already today, the largest share of Chinese solar panel export is now directed towards the Global South (see Figure 1) - with China being by far the largest exporter worldwide (around 80%).

The ongoing energy revolution that has unfolded in Pakistan over the past years reveals the developments in fast-forward. Inexpensive solar and storage are widely available in the 21st century, and consumers will continue to adopt them even in the face of regulatory barriers. Ignoring this reality will not prevent deployment but will instead push systems into the informal or unregistered space, leading to severe challenges in terms of energy system planning.

In essence, this new reality requires a paradigm shift. Instead of integrating distributed energy sources into the centralized electricity system, the new scale of self-consumption will require policymaker **to build the centralized energy system around distributed generation.**

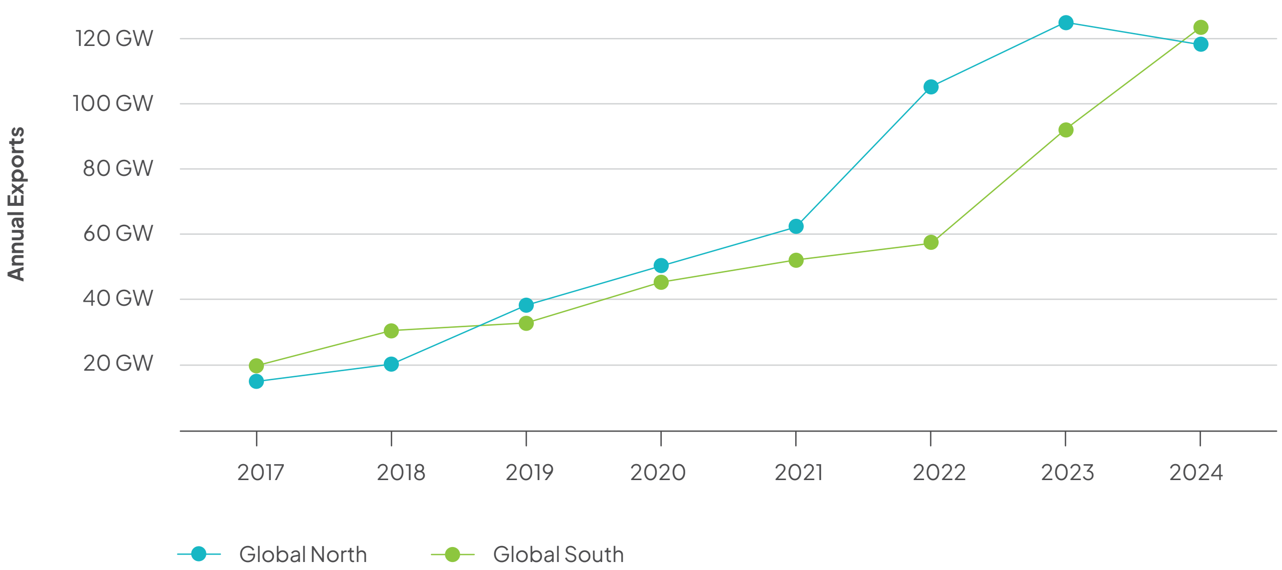
It is time for policymakers to wake up to this new reality, move beyond resistance and actively integrate distributed resources into planning, regulation, and market design, recognizing them as an inherent and permanent component of the national electricity system and shaping policies that harness, rather than hinder, the solar revolution.

Failing to account for the growth and dynamics of distributed generation is likely to result in significant costs. Restrictive policies (e.g., higher fixed charges) may temporarily slow the uptake of distributed generation, but they are unlikely to stop it. Instead, they risk delaying adjustment and increasing the likelihood of disruptive system impacts, such as unregistered behind-the-meter PV and battery deployment, potential grid defection, and emerging grid stability challenges. A proactive policy approach is therefore needed.

The era of captive electricity consumers is over as self-consumption has become a viable alternative to purchasing electricity from the grid. Customers will move towards self-consumption or even grid defection if the services provided by the centralized system are not equally good (or better) than self-produced electricity. The remaining degree of "captivity" depends on solar radiation level and seasonal variation. In sunny regions, solar PV and battery storage can provide up to 97% of residential demand. In the northern hemisphere, the share will be lower (Ember 2025d).

Figure 1: China's solar panel exports by destination (Global North; Global South)

Source: Author based on Jones & Copsey (2025)



2.1. Drivers for self-consumption in the Global South

When discussing distributed generation and self-consumption policies in the Global South, it is important to avoid uncritically applying the standard assumptions and policy narratives developed in the Global North. The global debate related to self-consumption policies was largely shaped by experiences and discussions taking place in Europe and North America, focusing on the apparent injustices caused by some (wealthy) consumers opting out of grid-based electricity (via partial self-consumption) and leaving the other non-prosumer customers with paying higher cost related fixed costs of the electricity system. These debates were frequently emotionally charged and run under titles such as "utility death spiral" or "desolidarization". From a simplified "western" perspective, prosumers opt into self-consumption to save (a bit) of money via self-consumption, where as they could receive similar services via grid-based electricity.

These debates and arguments cannot be layered onto the policy debate in the global south. Customer in the global south often do not receive stable and low-cost electricity via the grid – they opt into self-consumption because grid-based electricity is often unreliable and expensive.

Figure 2: Consumers demands and drivers for self-consumption

Source: Author

RESILIENCE

Protection against external shocks, such as disruptions to grid infrastructure or fossil fuel import constraints.

RELIABILITY

Access to stable electricity supply, including continuity during periods of load shedding.

LOW COST

Lower and more predictable electricity costs.

SUSTAINABILITY / LOW CARBON

Environmental and climate protection

Self-consumption can be understood as a practical response by households and businesses to gaps in the services provided by the main grid, particularly where reliability, affordability, and quality of supply are insufficient. In such contexts, distributed generation offers a way to enhance resilience, ensure more stable access to electricity, and support lower-cost and lower-carbon energy provision.

The only real long-term solution to avoid more and more consumers shifting towards self-consumption is to offer these or better services via the centralized grid – or to provide products and services that complement self-produced electricity. In many countries of the Global South, electricity consumers are confronted with and have paid the price for mismanagement and wrong strategic decisions in central electricity system planning that took place over the past decades.

2.2. The case of Pakistan: The official power generation mix dominated by fossil fuels versus “unofficial” reality characterized by solar PV for self-consumption

When looking only at the official energy statistics and the installed capacity of various power generation technologies, the case of Pakistan is not outstanding. As of 2025, the installed capacity in Pakistan amounted to roughly 46 GW, with thermal power plants and hydro power dominating (NEPRA 2026).

In 2025 (July 2024 to March 2025), hydro accounted for roughly 30% of electricity generation, whereas thermal power plants provided 40%, nuclear 19%, and renewables 4% respectively (NEPRA 2026). The share of utility scale solar PV project in the Pakistan energy mix is marginal, accounting for roughly 1.2 GW of installed capacity (Renewables First, 2025a; Transition Zero 2026). Net metered solar PV reached around 6.1 GW in by mid-2025 (Jowett, 2025).

However, the “unofficial” reality looks very different. In the past four years, Pakistan has imported around 45.6 GW of solar modules from China. This figure almost equals the total installed power generation capacity of 46 GW. Cumulative solar PV imports in the past decade have surpassed 50 GW (Renewables First, 2025d).

Even though it is not 100% clear how many of these PV modules have been installed in terms of unregistered project for self-consumption, It is plausible that several tens of gigawatts are already installed, with additional capacity under development or in the project pipeline. Estimates range from 16 to 26 GW of unregistered systems deployed behind-the-meter, in grid-deprived areas, or in captive power plants (Renewables First, 2025d). The total installed net metering based PV capacity reached more than 6 GW in 2025 – a fraction of the unregistered systems. Pakistan’s peak demand is about 30 GW (in the summer of 2024) (Renewables First, 2025a).

Figure 3: The installed capacity of grid connected, registered power generation technologies

Source: Author based on Ember 2025b and Renewables First, 2025d

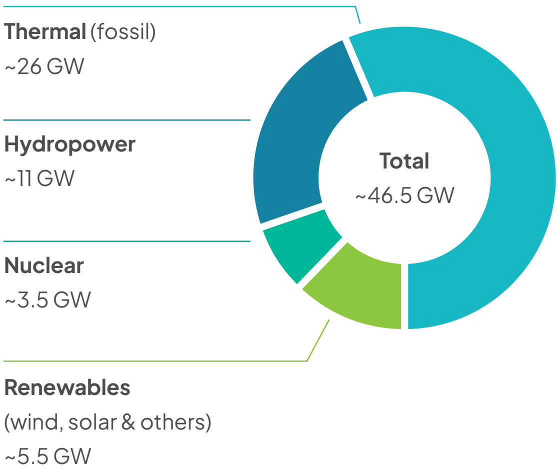
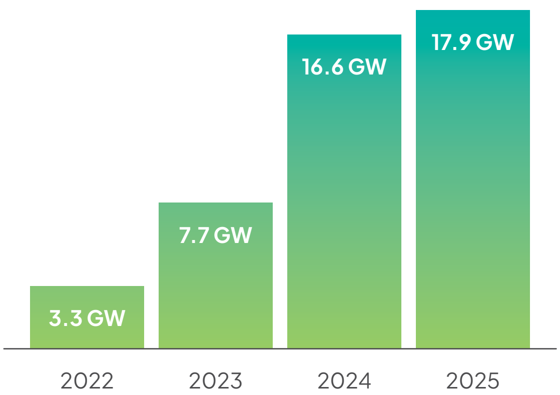


Figure 4: Solar PV Module Capacity Imported from China (year/GW)

Source: Author based on Ember 2025b and Renewables First, 2025d

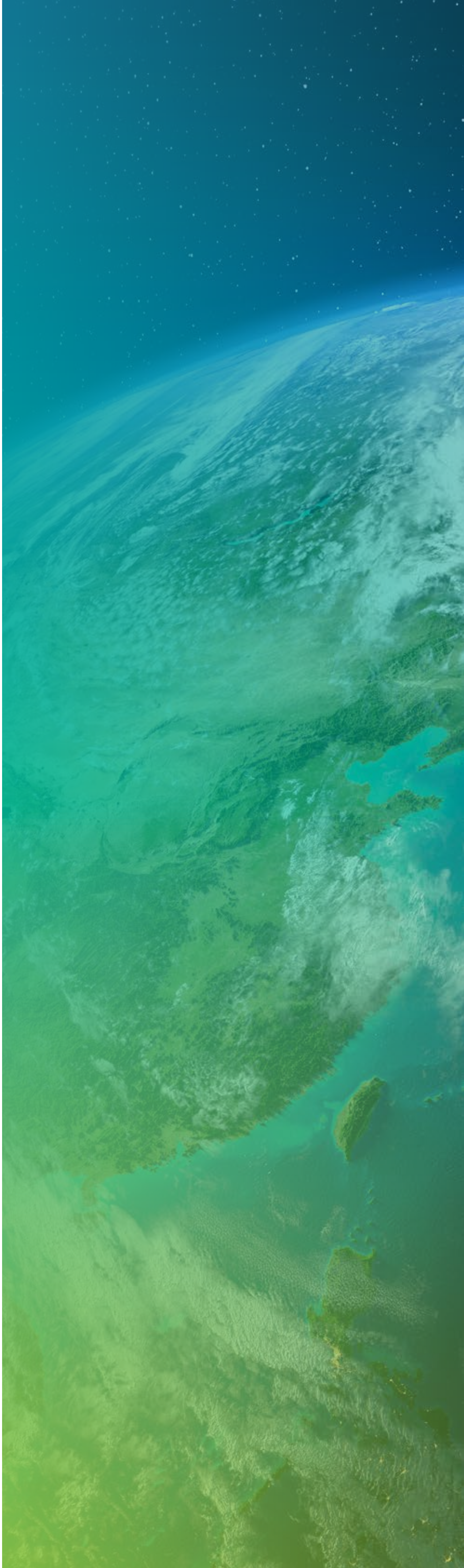


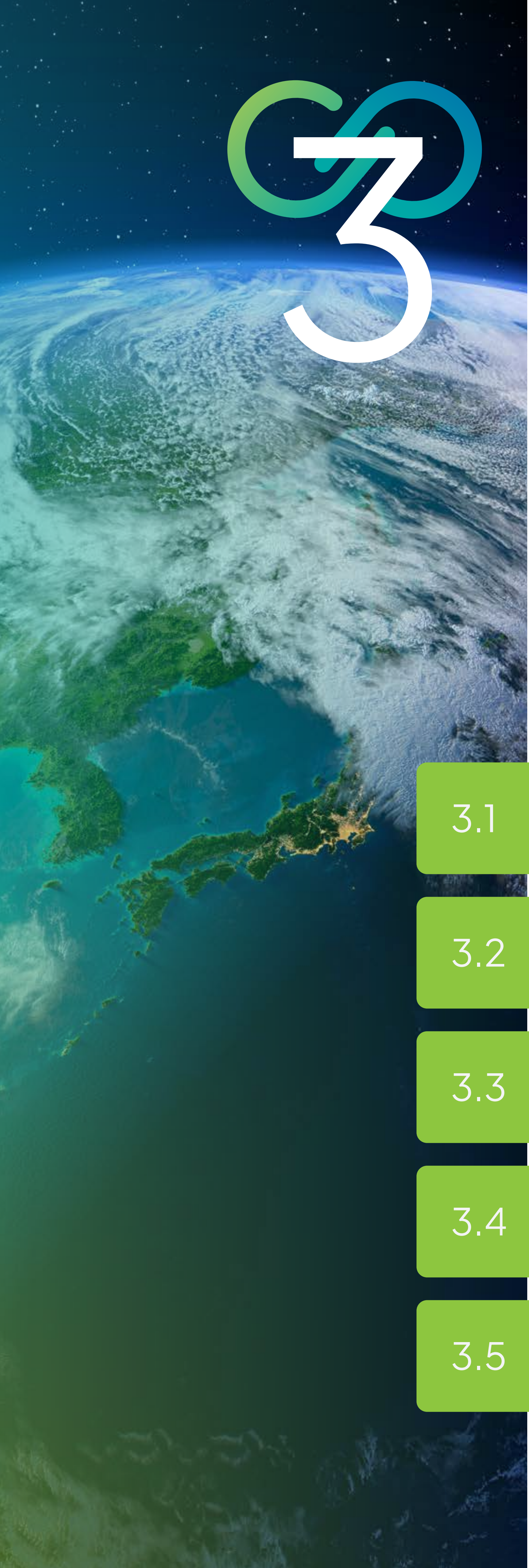
At the same time, recent analyses show that Pakistan's consumption of grid-based electricity is declining as alternative energy sources, especially solar, grow rapidly across different user segments (Renewables First 2025a; 2025c). Although the number of residential consumers rose by around 6 % in FY2024, overall household electricity sales from the grid grew only modestly (about 1 % YoY) (Renewables First, 2025a).

In 2025, grid-based electricity consumption in the commercial sector fell substantially by about 23 % year-on-year, while the industrial sector separately saw an 11 % decline in grid electricity use — indicating that businesses are turning to self-generation and other energy sources as a response to high tariffs and supply issues (Renewables First, 2025c).

The utilization rate of many fossil fuel based power plants decreased sharply in the past years. Between fiscal year 2022 and fiscal year 2024, utilization of imported coal plants declined sharply from 78% to 11%. Over the same period, utilization of local coal plants fell from 81% to 70%, while RLNG power plants dropped from 51% to 31% (Renewables First, 2025d).

In addition, the next wave of distributed generation is just building up: The falling costs of battery energy storage will broaden the scope and depth of electricity consumers opting for self-production. Pakistan imported an estimated 1.25 gigawatt-hours (GWh) of BESS in 2024. Estimates suggest that this could increase to 8.75GWh, or 26% of the projected peak demand in 2030 (Institute for Energy Economics and Financial Analysis. (2025).





Lessons learned from Pakistan and implications for policymaking in the Global South

This report attempts to highlight the implications of cheap, behind-the-meter solar PV (and BESS) for energy policy makers in the Global South and elsewhere. It highlights implications for policymaking in terms of:

3.1	**Electricity price levels and price structure (rate design)**
3.2	**Capacity payments and take-or-pay contracts**
3.3	**Electricity system planning: The centralized electricity systems and tracking of behind-the-meter solar**
3.4	**Self-consumption and prosumer policies**
3.5	**Grid expansion planning and financing**

3.1. Electricity price levels and price structure (rate design)

Electricity pricing in Pakistan is characterized by **significant cost increases, a high proportion of fixed charges and capacity payments,** limited adoption of time-of-use tariffs, and inflexible grid usage fees.

Electricity prices in Pakistan have increased significantly over the past decade, with some reports indicating an increase of about 155% since 2021, often surpassing the costs of rent (Samaa News, 2024). Major reasons were rising power purchase costs, and periodic fuel cost and quarterly indexation mechanisms that pass higher generation and capacity payments on to consumers. NEPRA's State of Industry reports note that high tariffs are linked to structural issues such as expensive generation mix, "take-or-pay" capacity payments, transmission losses, and circular debt, which collectively raise the revenue requirements of distribution companies and lead to higher consumer-end tariffs (NEPRA, 2023, 2024). In recent years, additional increases have also been driven by fuel price adjustments and capacity charges paid to independent power producers, with periodic surcharges and tariff revisions continuing to add to electricity costs for households and industry (NEPRA, 2024; Daily Times, 2026).

The limited implementation of time-of-use (ToU) tariffs across all consumer groups in Pakistan has constrained the effectiveness of price signals intended to shift demand away from peak hours, as many residential and smaller commercial consumers still face uniform or minimally differentiated rates. NEPRA's State of Industry reports note that while ToU metering has been introduced for selected consumer categories, its incomplete coverage reduces incentives for load management and limits the potential to optimize system efficiency and control peak-driven generation costs (NEPRA 2023, 2024).

In Pakistan, electricity grid usage fees — reflected in transmission and distribution (T&D) charges within end-user tariffs — are largely fixed and not significantly time-variable, meaning consumers pay regulated network costs that do not change much by hour of use. NEPRA's State of Industry reports indicate that these charges are determined through periodic tariff determinations based on revenue requirements of transmission and distribution companies, which makes them relatively inflexible and less responsive to peak-time system conditions compared to more dynamic pricing structures (NEPRA 2024).

Legacy costs and circular debt have significantly shaped Pakistan's electricity price structure, as accumulated unpaid subsidies, system losses, and under-recoveries are repeatedly incorporated into tariffs through surcharges and financing costs passed on to consumers. Recent analysis by Renewables First shows that circular debt has remained structurally persistent — reaching around PKR 2.4 trillion in FY2024 despite tariff adjustments — while rising capacity payments and sector inefficiencies continue to add to liabilities that ultimately contribute to higher end-user prices (Renewables First, 2025a).

Implications for policymaking in the Global South

To provide an attractive product that can compete with self-produced power, electricity would first of all need to become more affordable. At the same time, time-varying (with lower costs during peak solar PV periods) need to be established, to also allow non-prosumers the reap the benefits of renewable energy based power systems. Equally, grid usage fees would need to become flexible to incentivize demand-side flexibility.

High costs for power generation in the Global South are often related to high-risk perception and high costs of capital. Policymakers have tried to mitigate this risk by shifting some of the price risk towards electricity consumers – by indexing PPA prices to fuel price variations, providing capacity based payments, and take-or-pay contract (see also Section 3.2). However, these measures lead to higher grid-based electricity prices and are now accelerating the shift towards self-consumption in many countries.

Enable for low grid-based electricity prices by smart system planning and avoiding inflexible surcharges and levies

Smart system planning should prioritize least-cost electricity pathways by maximizing the integration of low-cost renewable technologies such as solar PV and wind, while ensuring efficient grid utilization. Policymakers should avoid inflexible surcharges and levies, such as broad capacity market payments, that can unnecessarily raise grid-based electricity prices and push consumers into less expensive self-consumption.

Establish time-variable electricity tariffs

Establish time-variable electricity tariffs, such as time-of-use and real-time pricing, to better reflect system conditions and enable consumers to benefit from lower prices during periods of high solar PV generation. Such pricing structures can improve demand flexibility, enhance system efficiency, and ensure that the cost benefits of power systems with high shares of solar PV are shared across all consumer groups.

Reduce electricity prices by excluding "legacy costs" from the electricity bill

Electricity tariffs should signal the true current cost of generation, transmission, and distribution. Legacy items — such as old capacity payments, fuel levies, or past contractual losses — are sunk costs, meaning that they cannot be changed by today's consumption decisions, and charging today's users for them distorts price signals. Legacy liabilities are macro-fiscal challenges, not operational costs. Therefore, they should be addressed through alternative financing solutions such as general taxation, government budget allocations, sovereign or green bonds, or debt restructuring (World Bank, 2020).

Establish time-variable grid usage fees

Grid usage fees need to become more flexible. In order to provide lowest cost electricity to consumers (and compete with self-consumption based electricity), not only the energy related part of the electricity price needs to become more flexible (e.g., time-of-use rates) but also the grid usage related part.

For instance, in Australia so-called "solar sponge tariffs" are time-of-use network pricing mechanisms that offer significantly lower grid electricity charges during periods of abundant midday solar generation to encourage consumption when renewable supply is high and reduce peak-time stress on the grid, thereby aligning consumption with flexible grid usage and reducing overall network costs (Australian Government Department of Energy, 2025).

3.2. Capacity payments and take-or-pay contracts

The case of Pakistan illustrates the long-term, negative impact of generous capacity payments for (fossil fuel based) power plants. Initially, they payments were intended to de-risk investments into large-scale, coal and gas power plants. However, today these generous capacity payments fire back, pushing consumers into self-consumption and undermining investment security and revenues for fossil fuel based power producers.

As early as 1994, the Pakistani government introduced generous capacity based payments for IPPs, with subsequent modifications in the following years and decades. This mechanism was designed to attract private investment into generation at a time of severe capacity shortages by reducing commercial risk and ensuring debt servicing. The policy was considered to be an essential de-risking policy for coal based IPPs in the 1990s. **However, over time this "take-or-pay"/ capacity payment regime became a major fiscal burden** and driver of circular debt, prompting later renegotiations and reform proposals (e.g., shifting toward "take-and-pay" models) to reduce capacity payment obligations and align payments with actual generation and demand as the sector matured (bulk power tariff structure with capacity and energy components; about capacity price covering fixed costs; take-or-pay critiques).

Under Pakistan's Power Policy of 1994 (Government of Pakistan, 1994), the government formally introduced structured capacity payments for Independent Power Producers (IPPs) through bulk power tariffs that separated revenue into a capacity price (to cover fixed costs, debt service, and return on equity) and an energy price (paid per unit of electricity actually delivered to the grid) — thereby guaranteeing fixed payments regardless of actual dispatch levels and insulating investors from demand fluctuations (capacity price assured on a monthly basis).

The Power Policy 2002 reinforced this structure explicitly and further standardized tariff design — e.g., specifying a two-part tariffs and (notably) denominating tariffs in Pakistan Rupees — again.

The Power Generation Policy 2015 continued the two-part tariff approach and explicitly allowed minimum take-or-pay provisions in PPAs (i.e., reinforcing capacity-payment style revenue assurance where agreed) (Government of Pakistan, 2015), while NEPRA's consumer-end tariff methodology codified capacity charges as a pass-through component of the power purchase price (National Electric Power Regulatory Authority, 2015).

By the 2020s, with capacity payments widely viewed as a key driver of high tariffs and circular debt, the government pursued renegotiations and restructuring: ADB notes MoUs in August 2020 to commence renegotiation of IPP contracts (Asian Development Bank, 2021), and Reuters reports 2024 moves to revise/terminate several IPP PPAs early to reduce the burden of fixed capacity-payment obligations embedded in consumer bills (Reuters, 2024); similar cost-reduction claims for revised IPP agreements were publicly reported in January 2025 (Arab News, 2025).

Rising capacity payments to independent power producers have significantly increased the fixed cost portion of tariffs. In the past years, the structure of the electricity price in Pakistan shifted and the cost related to capacity payment now exceed the share related to electricity generation (energy share). An already very high share of capacity related payments (40% in 2021/22) increased further to more than 60% in just two years.

In addition, Pakistan entered into long-term, take-or-pay LNG procurement contracts. These arrangements have had adverse implications for both the government and energy consumers, as payment obligations persist regardless of actual demand. Consequently, Pakistan continues to bear significant price risk even in periods when the gas is not required.

Pakistan has faced a significant LNG oversupply due to falling domestic demand, leaving it with unused cargoes and forcing the government to explore resale, offshore storage, or deferrals under long-term contracts (Reuters, 2025a). In total, about 120 cargoes per year have been contracted with Qatar (the vast majority) and Italy's Eni. For the coming year (2025-2026), Pakistan is set to cancel about 45 cargoes - almost 40% - due to reduced demand (Yousafzai 2025). The glut has also had measurable financial consequences, including potential losses of about $378 million per year for domestic producers and broader costs associated with managing surplus imports (Reuters, 2025b).

Table 1: The components of electricity prices in Pakistan (capacity, energy)

Source: NEPRA (2022b, 2023, 2024), Table 33

Fiscal year	Capacity share	Energy share
FY2021-22	40.7%	59.3%
FY2022-23	50.8%	49.2%
FY2023-24	61.5%	38.5%

Implications for policymaking in the Global South

Overly generous capacity payments for fossil fuel-based generation risk locking in inflexible assets and creating long-term financial and structural burdens that are increasingly misaligned with evolving demand patterns. Policymakers should therefore prioritize market designs and contractual frameworks that preserve adaptability, avoid stranded costs, and support a gradual shift toward more flexible and system-responsive resources.

Avoid generous capacity payments to finance fossil fuel-based power plants and consider the adverse effects of locking-in long-term fossil-fuel supply contracts

From a (static), short-term perspective, generous capacity payments seem to be a simple solution to provide investment security for investments into large-scale (fossil fuel based) power generation infrastructure. From a dynamic, longer-term perspective, capacity payments will likely push customers further towards self-consumption by increasing the electricity price and hindering time-variable tariffs. What is intended to be policy support for investments in coal and gas might eventually become the final nail in the coffin in the economic viability of large-scale power plants.

Avoid “take-or-pay” contracts for fossil fuel based power plants and LNG procurement

Avoid entering “take-or-pay” contracts for fossil-fuel power plants, as these agreements require payment for a fixed amount of power or energy whether it is used or not. Avoid locking into rigid, long-term take-or-pay LNG procurement contracts by aligning contract volumes and durations with realistic demand forecasts and incorporating periodic review, volume-flexibility, and downward adjustment clauses.

Include flexibility clauses in PPAs signed with fossil fuel based power plants

Prioritize more flexible contracting structures, so that fossil assets can operate as backup and balancing resources without locking systems into unnecessary generation and costs as renewable penetration increases. Structure electricity PPAs for fossil fuel plants with flexible volume commitments that allow the offtaker to pay for a minimum guaranteed capacity while adjusting the actual energy purchased based on system needs and renewable generation levels.

3.3. Electricity system planning: The centralized electricity systems and tracking of behind-the-meter solar

The case of Pakistan illustrates the implications of ignoring bottom up, disruptive developments in the energy sector. Pakistani policymakers – including the national regulator (NEPRA) – have traditionally relied on official grid-based statistics and plans that count only large-scale and grid-tied projects (e.g. utility power plants or net-metered solar), thereby overlooking the surge of bottom-up distributed energy installations that are unregistered or off-grid (PRIED 2025; Renewables First, 2024b).

As a result, a large wave of behind-the-meter rooftop solar PV systems remains undocumented in official data. Pakistan does not maintain a comprehensive online registry of such distributed generation, so aside from partial records of net-metering licenses, most small-scale solar and battery installations go untracked – leaving policymakers without a full view of this consumer-driven energy transition and underscoring the need to integrate bottom-up developments into national energy planning.

This has implications for planning the centralized electricity system as a whole. The old approach of focusing on deployment and financing of large-scale, fossil fuel based power plants to supply grid-based electricity is no longer appropriate. Policymakers in Pakistan are now re-negotiating costly take-or-pay contracts and restructuring long-term LNG purchase commitments.

Implications for policymaking in the Global South

The case of Pakistan reveals an urgent need to adopt energy system planning and modelling and to take bottom-up developments better into account. Key elements for policymakers to take into consideration is the triangulation of the statistical basis for tracking bottom-up, behind-the-meter solar and battery systems, based on geospatial planning, tracking module imports and a simple, online registry.

Triangulate the statistical basis for tracking bottom-up, behind-the-meter solar and battery systems

To triangulate the statistical basis for tracking bottom-up, behind-the-meter solar and battery systems, a simple, mandatory online registry should be established for all distributed generation units, including installations that were not captured under net metering or similar programs. This should be complemented by geospatial planning tools that map system locations to support infrastructure planning, grid integration, and more accurate capacity estimates. In parallel, tracking import data for PV modules, batteries, and related components can provide an additional proxy indicator to validate deployment trends and identify gaps in official installation records.

Establish a simple, online registry for all power generation units to track distributed generation

A simple, mandatory online registry should be created for all power generation units, including behind-the-meter systems that were not captured under net metering or similar programs. This can help to close existing data gaps and improve visibility of distributed capacity. The registration process should be fully digital, user-friendly, and designed to take no more than 10 minutes, capturing only essential parameters such as system size, location, technology type, and commissioning date. Provide incentives for online registration rather than penalties.

Use geospatial planning tools to estimate the role-out of unregistered system

Geospatial planning tools can be used to estimate the rollout of unregistered distributed generation by using satellite imagery to identify likely installation patterns and capacity clusters. These spatial insights help approximate the scale and location of systems missing from official records, improving demand forecasting, network planning, and the targeting of registration and support measures (World Bank 2021, GIZ 2022).

Track import data for PV modules, batteries and other components to estimate unregistered projects

Tracking detailed import data for PV modules, batteries, and related components can help estimate the scale and timing of distributed generation installations that are not captured in official registries. By comparing import volumes with reported deployment figures, policymakers can identify gaps, improve monitoring of unregistered projects, and refine market and grid planning assumptions (see Ember 2025b, 2025c).

Include explicit modelling of the expected roll-out of distributed generation into power sector planning

Power-sector planning should incorporate explicit modelling of the expected roll-out of distributed generation, using scenario-based projections of uptake (e.g. rooftop PV and batteries) combined with spatial and temporal generation profiles to estimate impacts on underlying and operational demand (see, for instance, EAMO 2023). This approach is supported by dedicated projection studies (such as solar PV and battery uptake reports) that use demographic, economic, technology-cost and historical installation data to produce regionally differentiated capacity forecasts that feed into long-term demand and adequacy modelling (see, for instance, Green Energy Markets 2024).

With regards to planning the centralized electricity system in the light of increasing self-consumption, it is crucial to anticipate further reductions of demand (for certain consumer groups). At the same time, complementary services for prosumers can be provided, as well as high quality electricity for specific industrial consumers. As baseload power plants are no longer required, policymakers should shift the focus towards procuring peaker power plants.

Anticipate a further reduction of demand for grid-based electricity for certain consumer groups because of increased deployment of behind-the-meter solar plus battery storage

A further reduction in reliance on grid-based electricity can be anticipated as battery storage technologies continue to decline in cost and improve in performance. More affordable and efficient storage will enable a wider range of consumer groups, including households, commercial users, and small industries, to increase the share of electricity they self-produce and consume locally.

Over time, this trend is likely to reinforce higher levels of energy autonomy among prosumers and shift the role of the centralized grid toward providing backup, balancing, and reliability services rather than serving as the primary source of electricity.

Make sure the centralized electricity system provides complementary services for prosumers (e.g., ancillary services, peak supply during evening or night hours, seasonal demand variations)

The centralized electricity grid provides essential complementary services for prosumers by delivering reliable power during periods when on-site generation is insufficient or unavailable, thereby ensuring continuity of supply and overall system stability.

Provide higher quality of electricity for industrial consumers

Policy frameworks should support the provision of higher quality electricity supply for industrial consumers with sensitive and energy-intensive processes. This includes ensuring strong performance in voltage magnitude stability, frequency control, waveform purity (e.g., low harmonics/THD), and sufficient power capability such as short-circuit strength and surge handling capacity.

Prioritize flexibility, not base-load plant

Policies should prioritize incentives for electricity system flexibility, not base load power plants. For instance, flexible “peaker” plants are better suited to balance steep ramps and short-term fluctuations in electricity systems with high shares of variable renewable energy. Open-cycle gas turbine plants, in particular, can provide rapid-response capacity but are expected to operate only for several hundred hours per year, limiting their overall emissions and climate impact while supporting system reliability. Incentive structures should therefore be designed to reward availability, flexibility, and rapid dispatch capability, rather than total electricity output, to ensure economic viability under low utilization rates.

3.4. Self-consumption policies and prosumers

Pakistan has adopted a net metering policy in 2015 (NEPRA 2015), starting with "classic" net metering, which legally recognized consumers as "prosumers," allowed systems up to 1 MW, and introduced bi-directional metering with bill credits for excess generation.

Subsequent amendments between 2017 and 2020 simplified interconnection procedures, clarified technical standards, and streamlined billing and settlement processes, reducing transaction costs and encouraging residential, commercial, and industrial uptake. Falling solar module prices and rising retail tariffs amplified these incentives, leading to strong growth in rooftop PV capacity and making net metering a central driver of Pakistan's distributed solar market (NEPRA 2017a, 2017b, 2018, 2020, 2022).

In recent years (2022–2025), policy attention has shifted from promotion to system integration and financial sustainability. Rapid solar expansion increased reverse power flows and reduced utility sales revenues, prompting NEPRA and distribution companies to tighten technical screening, strengthen monitoring requirements, and review compensation structures for exported electricity. Ongoing consultations have considered adjustments such as:

- reduce surplus valuation,
- move from net metering to net billing (time-of-use settlement),
- possible grid or capacity charges to balance consumer incentives with cost recovery and grid reliability (IEEFA, 2025; Arab News, 2025a; pv magazine, 2025b).

Implications for policymaking in the Global South

Traditional policy frameworks for self-consumption are becoming increasingly misaligned with the realities of decentralized generation. The growing volume of self-consumed electricity and unregistered systems requires policymakers to shift from simple capacity support toward strategies that actively manage when and how solar power is used and exported.

Self-consumption policies can play a central role in aligning distributed generation with system needs, particularly by encouraging storage adoption, demand-responsive behavior, and improved asset visibility.

Avoid uniform flat-rate compensation for excess solar electricity and implement flexible and time-variable tariffs

The (market) value of electricity from solar PV decreases with increasing shares of solar PV in the overall electricity system. Therefore, maintaining uniform flat-rate compensation for surplus solar electricity is no longer an efficient or appropriate policy approach. Compensation for excess electricity should become more flexible and time-variable, aligning more closely with real-time system conditions and grid needs.

Establish incentives for time-shifting solar PV production and export (via battery storage) to align with system peak demand

Therefore, policymakers need to provide implicit incentives to reduce the influx of solar PV to the electricity grid during peak solar PV production hours (e.g., 10am to 3pm) and shift them to hours that align with peak demand periods (e.g., evening peaks after sunset).

Move towards time-differentiated electricity prices for prosumers to incentivize storage adoption and system friendly influx of electricity

Moving toward time-differentiated electricity prices for prosumers can encourage investment in storage technologies and align self-generation with system needs by shifting consumption and feed-in to periods of higher grid value (CEER 2020).

Increase visibility of DG assets via advanced metering infrastructure

Increasing visibility of distributed generation (DG) assets, such as rooftop PV and behind-the-meter batteries, enables grid and system operators to better monitor real-time production, consumption, and flexibility potential across the network. Improved data access and integration support more accurate forecasting, faster operational decisions, and more efficient use of these assets for stability and ancillary services (AEMO 2017). Achieving visibility of distributed generation assets requires advanced metering infrastructure, reliable communication systems, standardized data protocols, and secure platforms to collect and integrate real-time operational data (IEA 2024, IEA PVPS 2024).

Use remotely controllable distributed generation for grid stability

Grid operators and system operators can use remotely controllable distributed generation (DG) assets, such as rooftop PV systems and behind-the-meter battery units, to actively support grid stability by adjusting generation or load in response to real-time network conditions. By aggregating and dispatching these flexible resources, operators can provide services like frequency regulation, voltage support, and peak load management without relying solely on centralized infrastructure (IEA PVPS 2024).

3.5. Grid expansion planning and financing

Pakistan's electricity grid faces significant structural and operational challenges, including persistent transmission bottlenecks that restrict the efficient flow of power from surplus generation in the south to high-demand areas in the north. As a result, system operators are often forced to curtail lower-cost generation and rely on more expensive thermal plants, increasing overall system costs.

Regulators have also documented severe overloading in the 500 kV and 220 kV network, with critical sections of the grid operating near or above capacity during peak demand, reflecting long-standing underinvestment in network upgrades and coordinated planning, and contributing to reliability problems and loss of economic potential (NEPRA, 2026).

Financing transmission and distribution grid expansion through ratepayer contributions — including surcharges and grid-usage fees — faces significant structural, financial, and political constraints in Pakistan. As a result, reliance on tariff-based financing alone is unlikely to mobilize the scale of capital required for timely grid modernization and expansion without complementary reforms and alternative financing instruments (NEPRA 2024; Renewables First 2025a, World Bank 2024). **Already today, Pakistan uses national funds to co-finance grid expansion.** In particular, the Federal Public Sector Development Programme (PSDP) is the primary public capital budget used to finance large, strategic electricity transmission and grid expansion projects (Ministry of Finance, 2024).

Implications for policymaking in the Global South

Electricity grid expansion planning becomes particularly difficult when viewed through two closely connected problems: first, estimating how much electricity customers will need in the future, and second, ensuring that the large, fixed costs of long-lived infrastructure can be recovered reliably over time. Uncertainty about future grid-based electricity demand creates planning insecurity because utilities must commit to large, long-lived investments without knowing whether future consumption will be high enough to justify the capacity or low enough to leave costly assets underutilized and financially stranded.

Consider electricity grid investments as a public service, financed (partially) via the general budget

While generation costs are declining due to cheaper PV, wind, BESS, and related technologies, investment needs in the grid are rising. Covering part of grid-related fixed costs through the general public budget, rather than electricity price surcharges, can help avoid further tariff increases that might otherwise prompt consumers to reduce grid use or shift to self-generation, thereby eroding the utility's revenue base and complicating cost recovery.

A useful analogy is public investment in roads and other transport infrastructure. Given the scale and speed required to build coherent networks, many countries financed these assets through general public budgets rather than user charges alone.Similarly, the coming wave of electrification — across transport, heating, and industry — will require investment at a scale that may be difficult to fund solely through electricity system revenues such as tariffs and surcharges. Complementary funding sources, including public budgets and donor finance, are therefore likely to be needed.

Prioritize financial support for grid infrastructure through national funds and international donors, while gradually shifting public financing away from large-scale power generation projects

Development banks such as the World Bank and the Asian Development Bank should prioritize support for grid investments. Transmission and distribution networks are capital-intensive, long-lived, and typically regulated assets with elevated policy and revenue risks, which often makes them less attractive to private investors than generation projects.

In contrast, power generation — particularly renewables — has become more modular, lower cost, and easier to finance privately. Public and concessional capital can therefore have the greatest impact by targeting persistent funding gaps in grid infrastructure, which is essential for integrating new capacity and ensuring reliable access.

Move from deterministic, load-growth-driven grid expansion planning to probabilistic, distribution-level hosting capacity analysis

Distributed generation combining rooftop PV plus battery energy storage systems can materially defer or avoid traditional grid investments by reducing peak demand, smoothing load profiles. These resources can relieve thermal and voltage constraints on feeders and substations, postpone upgrades to transformers and lines. For grid planning, this requires moving from deterministic, load-growth-driven grid expansion planning to probabilistic, distribution-level hosting capacity analysis and non-wires alternatives (NWAs) (Celli et al. 2024; Keen et al. 2022).

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