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Pakistan’s next power chapter: From solar success to system reform

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TransitionZero

Pakistan's solar boom has been an exciting, and unexpected, good news energy transition story. Driven by high energy prices following Russia's invasion of Ukraine, the availability of increasingly cheap solar PV from China, and enabled by the government's support to inter-connectors and net metering, up to 30 GW of solar has appeared across the country in a highly distributed manner. This phenomenon has given the people of Pakistan who can afford PV access to reliable, low cost and low carbon power, and reduced the country's fossil fuel import bill by $12bn since the more recent Middle East energy crisis.

While these two numbers are positive indicators, and often catch the headlines, Pakistan's power sector is facing fiscal and structural stresses that pre-date the two energy crises in the last four years. Therefore, how Pakistan approaches the next phase of its energy transition is critical. It presents an opportunity to both address these wider challenges and to ensure that the momentum caused by the solar surge catalyses a wider system transformation. If done well, a broader set of positive stories and development metrics will be delivered across Pakistan's society and economy.

To address this, Pakistan needs to develop a system-level plan that responds to the inter-connected challenges of energy security and fiscal sustainability. Strengthening energy resilience is not just a case of shifting to affordable and domestic energy generation solutions. It is an opportunity to ease fiscal pressures over time by reducing exposure to volatile imports, improving system efficiency and aligning investment decisions more closely with evolving demand as part of a wider economic transition.

Achieving such system transformation will require coordinated action across a range of public and private actors, both within and outside of Pakistan. The top challenges that need to be addressed are:

1. **Circular debt and fixed obligations:** This remains large enough to distort every policy choice, from tariff reform to investment confidence.

2. **Transmission constraints and geographic mismatch:** Generation in the south must reach northern load centres, making the north-south corridor strategically critical.

3. **Bottom-up disruption outpacing institutions:** The transition from net metering to net billing reduces the financial incentive to export excess power to the grid. However, it does not reverse the long-term momentum of distributed generation and could accelerate storage adoption to maximise self-consumption.

4. **System operability in a high-inverter world:** More solar means less synchronous generation online, raising issues like inertia and frequency response, unless Pakistan invests in grid-forming capabilities, ancillary service markets, and modernised distribution controls.

5. **Navigating a young coal fleet:** A significant portion of Pakistan's coal fleet is young (5-10 years old), underutilised, continues to be paid via high-capacity payments, and carries Chinese debt. Any refinancing arrangement will need political approval from both Islamabad and Beijing.

The combined effect of these challenges has resulted in an energy crisis that is being felt acutely by households, industry, and public finances alike. Load-shedding, higher tariffs, and widening gaps in energy access risk becoming more entrenched, particularly for lower-income consumers and smaller businesses. At the same time, rapid uptake of behind-the-meter solar is reshaping demand, and whilst this is welcome, renewable energy deployment, grid operation, and revenues are being impacted, putting further strain on the institutions responsible for managing the system.

This paper explores a range of pathways that Pakistan could pursue, including doubling down on reinforcing a centralised grid or pivoting towards a more distributed model.

While both offer benefits, we recommend a strategic hybrid of modernising the grid while unlocking distributed solar and storage. This will cut costs, build resilience and crowd-in investment. With credible implementation, confidence will follow, and with confidence, inclusive prosperity, and resilience to future shocks.

Through a Letter of Intent, the Government of Pakistan has committed to working with the Pakistan-China Institute (PCI) and the Carbon Trust to take a system-level approach to the country's energy transition. A transition that is just, sustainable, and economically robust. Energy planning software company TransitionZero will also contribute to this work.

Why Pakistan's power market is at a turning point

The country's power market structure remains heavily shaped by a single-buyer model and long-term take-or-pay contracts, with dispatch and system planning designed for a more predictable, centralised electricity system. That model has struggled to adapt as Pakistan moved from shortage to surplus capacity in certain periods while still experiencing shortages in practice due to affordability constraints, fuel availability, transmission bottlenecks, and high system losses.

The forces rapidly reshaping the system

(1) Circular debt and the capacity payment 'trap'

Pakistan's circular debt has reached levels that materially constrain national fiscal space and investor confidence in the power sector. By March 2025, circular debt was reported at approximately Rs1.689 trillion (≈$6.04 billion). Even where the stock fluctuates with government interventions, including a government injection of Rs780 billion and commercial borrowing of Rs1.255 trillion (≈$4.49 billion), the underlying drivers, losses, under-recoveries, and fixed obligations remain a persistent drag.

(2) A coal build-out that solved one problem but created new risks

Investments under the China Pakistan Economic Corridor (CPEC) added significant coal-fired generation capacity to Pakistan's grid. Analysis puts this at around 8,500 MW of coal within a wider CPEC generation portfolio (built and planned) – see table below. Much of this capacity is linked to imported coal exposure and long-term contractual obligations. While these assets helped end acute shortages, they also introduced long-lived fixed costs into a system that is now facing demand uncertainty and further disruption from the rapid increase in distributed generation and self-consumption.

Project	Capacity (MW)	Status	Chinese partner	Construction (start-end)
Sahiwal Coal Power Plant	1,320	Operational	Huaneng Shandong/ Shandong Ruyi	2015-2017
Port Qasim Coal Power Plant	1,320	Operational	PowerChina/Qatar Al-Mirqab	2015-2018
Hub Coal Power Plant	1,320	Operational	China Power Hub Generation Co.	2017-2019
Thar Block II (Engro)	660	Operational	CMEC	2016-2019
Thar Block I/ Shanghai Electric	1,320	Operational	Shanghai Electric	2019-2023
ThalNova (Thar Block II)	330	Operational	Hub Power Company Limited (HUBCO), Thal Limited, Novatex Limited, China Machinery Engineering Corporation (CMEC), and Descon Engineering Limited.	2019-2023
Lucky Electric Power Plant (Karachi)	660	Operational	SEPCOIII Electric Power Construction Co Ltd	2019-2022
Gwadar Coal Power Plant	300	Planned/delayed	China Communications Construction Company	Not started
Oracle/Thar Block VI	1,320	Planned	SEPCO (Shandong Electric Power Construction Corporation / SEPCOIII)	Not started

(3) Rapid behind-the-meter solar expansion and mounting pressure on the grid

Pakistan's energy transition is unusual because it is not only government-led, but also being driven by both household and business consumers installing rooftop solar to manage costs and reliability. Solar generation rose from less than 2% of the energy mix in 2020 to 10.3% in 2024. It then more than doubled to 24% in the first five months of 2025, becoming the largest source of generation for the first time.

Regulatory reforms are now attempting to rebalance incentives. The National Electric Power Regulatory Authority (NEPRA) has shifted new consumers from net metering towards net billing under updated prosumer regulations, creating a clearer spread between the value of exported electricity and the retail tariff paid for imports.

However, even with reduced export credits, the long-term direction is clear: solar plus storage costs continue to fall globally, and consumers will increasingly prefer self-supply when grid electricity is expensive or unreliable. This shift also has major financial implications. In FY2025 alone, the government was set to pay Rs2.14 trillion in capacity charges, including Rs1.069 trillion for state-owned plants and Rs707 billion for CPEC projects. These costs persist regardless of how much electricity is actually purchased from the grid. As more consumers reduce grid consumption, these fixed, system-wide costs are spread over a shrinking base, exacerbating a self-reinforcing imbalance that drives tariffs up for those least able to exit the grid.

Reinvest, shrink or reinvent the grid?

Pakistan's current grid model assumes that most consumers remain reliant on the network and that central planners can optimise dispatch and expansion accordingly. Yet as higher-income consumers move partially or fully to behind-the-meter solar (and increasingly batteries), grid revenues erode while fixed costs remain, which are often borne by lower-income consumers.

Pakistan therefore faces three broad strategic choices:

1. Double down on a centralised national grid and try to restore viability through deep reform and investment.
2. Actively pivot towards distributed power, mini-grids, local solar and storage, and virtual power plants (VPPs), while also reducing dependence on long-distance power flows.
3. Build a hybrid model by preserving and modernising the backbone grid, while accelerating distributed solutions where they are cheaper and more resilient.

This is not solely a technology debate. It is a governance and political economy debate about how Pakistan wants power to be produced, paid for, and controlled.

Five challenges facing Pakistan's energy transition

1. Circular debt and fixed obligations

Circular debt remains large enough to distort every policy choice, from tariff reform to investment confidence.

2. Transmission constraints and geographic mismatch

Generation in the south must reach northern load centres, making the north-south corridor strategically critical. Pakistan has invested in major transmission infrastructure such as the Matiari-Lahore ±660 kV High Voltage Direct Current line (often referenced as a key north-south 'spine').

3. Bottom-up energy transition outpacing institutions

Moving from net metering to net billing weakens incentives to export electricity to the grid, but it does not reverse the long-term momentum of distributed generation. Instead, it is likely to drive faster uptake of storage, enabling consumers to capture, store and consume more of their own generation behind the meter.

4. System operability in a high-inverter power system

More solar means less synchronous generation online, raising issues like inertia, frequency response, voltage control, and fault levels, unless Pakistan invests in grid-forming capabilities, ancillary service markets, and modernised distribution controls.

5. Navigating a young coal fleet

A significant portion of Pakistan's coal fleet is relatively young, built during investment cycles between 2015 and 2020. If those plants are underutilised and continue to be paid via high-capacity payments, they can impose decades of costs on consumers and the state. Younger plants also mean these plants are likely to have higher buyout costs with their valuation closer to full book value. This increases the risk for any refinancing arrangement and creates a political risk premium that could increase future financing costs for coal transition activities in Pakistan.

Early retirement is therefore costly. Analysis has highlighted why an 'energy transition mechanism' approach often becomes more viable once plants are older and more of their debt has been repaid. For young coal plants, the compensation and financial complexity can be much higher.

This leads to the central political economy dilemma:

- **If Pakistan closes coal plants early,** does the government compensate investors and if so, how?
- **If Pakistan keeps coal plants online,** do consumers keep paying capacity charges even as cheaper renewables (and behind-the-meter solar) grow?
- **If Pakistan renegotiates,** what happens to investor confidence and the future cost of capital?

Pakistan needs a credible answer because without it, every pathway carries a significant financing penalty.

> **"The coal question is not ideological, it is balance sheet reality: young plants mean high buyout complexity, but keeping them on capacity payments can lock consumers into decades of avoidable costs. Pakistan needs a ranked, rules-based retirement and refinancing framework that reduces uncertainty, shares costs credibly, and protects the investment climate."**
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> **Mustafa Sayed**
> Executive Director, Pakistan-China Institute

Three strategic pathways for Pakistan's power system

01

Pathway 1: Double down on a centralised national grid

What it looks like

- Reinforces the single-buyer and central dispatch model, while reforming it.
- Invests heavily in transmission expansion and constraint relief along the north-south corridor.
- Pursues utility-scale renewables where resource quality is best, supported by grid upgrades.

Why it's compelling

- Central control can feel 'safer' in a system facing volatility.
- National industrial competitiveness often depends on bulk, reliable power.

The challenges

- Requires large, sustained capital and institutional capability. Doubling down is fiscally and politically risky without rapid tariff and governance reform.
- There is a fiscal trade-off for early plant retirement (upfront compensation and concessional finance) or continued plant operation (decades of capacity payments, suppressed renewable investment and higher retail tariffs).
- There are risks of investing in a grid whose revenue base continues to erode due to behind-the-meter adoption.
- This pathway does not automatically solve the equity issue if wealthier consumers continue to self-supply.

This pathway can only work if Pakistan can credibly (a) restructure circular debt, (b) reform tariffs without social backlash and (c) create a grid experience reliable and affordable enough that consumers choose to stay connected.

Three strategic pathways for Pakistan's power system

02

Pathway 2: Distributed energy as the new normal - mini grids and behind the meter solar and storage

What it looks like

- Accelerates distributed generation, batteries and mini-grids in industrial clusters, commercial zones and remote/weak-grid areas.
- Enables aggregators and virtual power plants to deliver 'grid-like' services from thousands of small assets (flexibility, reserve, balancing).
- Reforms regulation so that mini-grids can interconnect, island, and trade energy where economic.

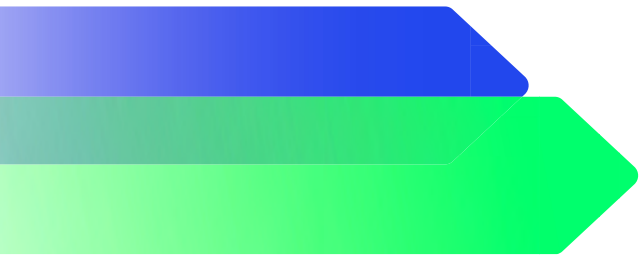
Why it's compelling

- Matches the reality on the ground: consumers are already moving in this direction.
- Can be faster and more modular than large grid projects.
- Can improve resilience, reducing exposure to wide-area outages.

The challenges

- Without a plan, this pathway could accelerate the national grid's decline, shrinking revenues while fixed costs remain.
- This shift risks fragmenting the system and stranding costly grid and generation assets, as more consumers self-supply while long-term capacity obligations remain.
- Technical operability becomes harder unless distribution networks are modernised and new market mechanisms are created for flexibility and stability services.

This pathway can only work if Pakistan designs new rules for cost recovery, interconnection and fairness, so that distributed adoption doesn't simply shift costs onto lower-income consumers.



Three strategic pathways for Pakistan's power system

03

Pathway 3: Strategic hybrid, keep the backbone grid, decentralise the edges

This pathway combines both strategies and remains the most workable, politically.

What it looks like

- Preserves and modernises the backbone grid, especially the north-south transmission spine.
- Actively incentivises distributed generation and mini-grids where they reduce losses, improve resilience, or avoid expensive network upgrades.
- Turns distributed energy into a system asset through aggregation (VPPs), pricing reform and an ancillary services framework so that rooftop solar and batteries contribute to reliability rather than undermine it.
- Creates an explicit coal transition plan using negotiated refinancing, targeted early retirement pilots, and transition finance where possible. The plan should be sequenced to avoid compromising energy security but could target the highest emitters and/or most financially burdensome plants first. Having a priority list of coal plants to phase out or phase down is therefore critical.

Why it's compelling

- Acknowledges that Pakistan's grid is still essential for national cohesion, industrial growth and power sharing across regions.
- Accepts that decentralisation is happening anyway and makes it constructive rather than destabilising.
- Gives policymakers a way to protect vulnerable consumers while enabling innovation.

The challenges

- Requires coordination across Central Power Purchasing Agency (CPPA)/ market design, distribution company incentives, NEPRA regulation, and National Transmission and Dispatch Company planning i.e. governance complexity.
- Only credible if explicitly designed with clear rules for cost-sharing, grid access, and coordination.

Reforms are needed across all pathways

Regardless of the pathway, a number of reforms are essential:

1. Design a fair way to pay for the wires

As prosumers grow, Pakistan needs tariffs that recover network costs without punishing electrification goals or creating an inequitable burden on non-solar customers. The shift to net billing is one step towards clearer price signals, but it must be accompanied by a broader 'grid' strategy. Tariff reform should go further by separating energy, capacity, and network charges, and define how prosumers contribute to fixed grid costs to keep the system financially stable. International experience, such as Brazil's liberalised transmission auction regime and India's Tariff-Based Competitive Bidding framework, shows how clear, transparent tariff structures can attract private capital and drive down system costs through competition. Reform should also strive to liberalise grid investment, including Build-Operate-Transfer models, where private investors build and operate grid assets for a set period before transferring them back to the state.

2. Build flexibility and stability in markets

Distributed resources can support the grid but only if there are mechanisms in place that value flexibility (fast response, reserves, voltage support). Aggregation/VPP models can package small assets into products the system operator can use.

3. Plan the coal transition explicitly

Early retirement frameworks and refinancing approaches for coal plants can reduce long-run costs, but the timing and compensation structures matter, especially for young plants. A credible strategy must include a clear operating rulebook. It should be one that: sets out transparent metrics to classify and rank plants (in order of priority for retirement/phase down); defines a valuation and compensation method that distinguishes fairly between young and old assets; and establishes a prioritised order of payments for CPPA (Guarantee) Ltd, and assigns institutional ownership so that early pilots can scale into a fiscally credible national retirement programme. With this in mind, the strategy might include:

- targeting the most economically burdensome plants first (with consideration for the highest emitting);
- piloting one or two negotiated plant retirements/plant repurposing; and
- using blended finance or transition finance structures to share costs.

4. Align grid planning with Pakistan's climate and energy ambitions

Pakistan's stated ambitions include major emissions reductions and higher renewable shares, which require grid readiness.

Seeing the issues and opportunities laid out, the next step is to underpin that debate with transparent, system-wide modelling that stress-tests different futures: rapid distributed uptake, slower demand growth, early coal retirement, or prolonged capacity lock-in. Only by quantifying those pathways can policymakers see clearly who pays, when and how much."

Matt Gray
Co-founder and CEO, TransitionZero

A pragmatic proposition

We believe a strategic hybrid approach, combining a resilient backbone grid with deliberate decentralisation offers Pakistan the best chance to:

- Preserve national cohesion and industrial reliability, particularly in the face of external supply shocks.
- Harness the speed, affordability and resilience of distributed solar and storage, which are already reshaping demand across the country.
- Manage its coal legacy through planned, investable transition mechanisms, rather than allowing fiscal pressures to drift and deepen with each crisis.

The recent energy crisis has reinforced a central lesson of this paper: resilience cannot be retrofitted in moments of stress; it must be designed into the system. Pakistan now has a narrow but important window to translate crisis into reform and to build a power system that is more affordable, secure and responsive to the needs of its people and economy.

Now is the moment for funders to demonstrate bold, collective leadership. We call on development banks, philanthropic institutions and financial actors to support Pakistan's energy transition not as emergency relief, but as a strategic investment in long-term energy security, fiscal resilience, and inclusive growth.

> **Pakistan's transition will be won in the system, not at the margins. A strategic hybrid - modernising the grid while unlocking distributed solar and storage - can cut costs, build resilience and crowd-in investment. With credible implementation, confidence will follow, and with confidence, inclusive prosperity."**
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> **Andrew Lever**
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