Assessment of Pakistan's Energy Landscape and Energy Transition Mechanism (ETM) Feasibility in Pakistan

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Executive Summary

Pakistan's power sector is undergoing a period of acute structural stress, characterized by rising electricity demand, high generation costs, foreign exchange exposure, and growing climate commitments. Globally, electricity demand is expanding faster than overall energy consumption, with renewables and nuclear supplying most of the recent growth. However, coal remains the largest single source of electricity worldwide and a major contributor to energy-related carbon emissions, underscoring the need for accelerated and managed coal phase-out strategies consistent with the Paris Agreement.

In Pakistan, the energy mix remains heavily fossil-fuel dependent. Coal capacity expanded rapidly from near zero in 2015 to over 7 GW by 2023, largely under the China Pakistan Economic Corridor (CPEC). While these additions improved short-term supply adequacy, they have locked in long-term fiscal liabilities through high, dollar-indexed capacity payments and imported fuel dependence. Despite an installed capacity exceeding 45 GW, Pakistan faces persistent circular debt, underutilized thermal plants, and limited flexibility to integrate low-cost renewables due to contractual and grid constraints.

This report evaluates the feasibility of applying an Energy Transition Mechanism (ETM) in Pakistan, drawing on the Asian Development Bank's blended-finance framework for early retirement of fossil fuel assets and reinvestment in clean energy and just-transition measures. Pakistan's power sector profile characterized by surplus capacity, high-cost coal assets, foreign exchange stress, and emerging policy alignment with renewable energy aligns closely with ETM objectives.

A multi-criteria screening framework was applied to Pakistan's eight operational coal-fired power plants (≈7.3 GW) to identify candidates for early retirement. Plants were assessed across four weighted dimensions: socio-economic impact, environmental performance, technology, and grid dependency. The results indicate that early retirement potential varies significantly across the fleet. The highest-ranked candidates are the publicly owned Jamshoro 660 MW unit and the smaller subcritical Thar lignite plants (Thar Energy Limited and ThalNova, 330 MW each). Jamshoro 660 is identified as a priority candidate due to its public ownership, commissioning delays, reliance on imported coal blends, and limited system-criticality under conditions of surplus capacity.

The analysis finds that early retirement of selected coal plants could deliver meaningful fiscal relief, reduce fuel imports, improve system efficiency, enable greater renewable energy integration, and avoid tens of tons of carbon dioxide emissions over plant lifetimes. Overall, the study concludes that Pakistan is a viable candidate for an Energy Transition Mechanism, provided that initial efforts focus on high-impact, lower-complexity assets and are integrated with broader reforms in grid infrastructure, renewable deployment, and just-transition planning.

1. Introduction

The worldwide energy outlook in 2024–2025 is defined by robust demand growth and an accelerating shift in the generation mix. Global energy consumption expanded by about 2.2 percent in 2024, nearly double the average pace of the previous decade (World Economic Forum, 2024). Electricity use led the surge, rising by about 4 percent in 2024, with over 80 percent of demand growth coming from emerging economies as industrialization and energy access expand, while advanced economies returned to modest growth after earlier declines (World Economic Forum, 2024). Asia, especially China and India, continues to dominate new capacity additions as many Western countries stabilize or retire fossil generation, with coal closures continuing across Europe and the United States even as some new coal plants come online in parts of Asia (World Resources Institute, 2024). Overall, the trend is shifting toward cleaner power, with record renewable additions and nuclear uprates supplying 80 percent of 2024's increase in electricity generation (Global Renewable Energy, 2024).

Electricity is rising faster than any other energy segment as economies electrify industry, transport, and heating. The IEA describes this period as the "Age of Electricity," noting that power demand has grown at about twice the rate of total final energy over the past decade. The World Energy Outlook 2024 projects that global electricity demand will roughly double by 2050, with near-term growth averaging about 900 TWh per year, equivalent to adding Japan's annual electricity consumption each year. Renewables reached record shares, supplying about 30–32 percent of world electricity in 2023–2024, driven by surging wind and solar. In 2023 alone, about 560 GW of renewable capacity was added globally, a one-year record that keeps the world on a path toward 10,000 GW of total renewables by 2030 (International Energy Agency, 2024).

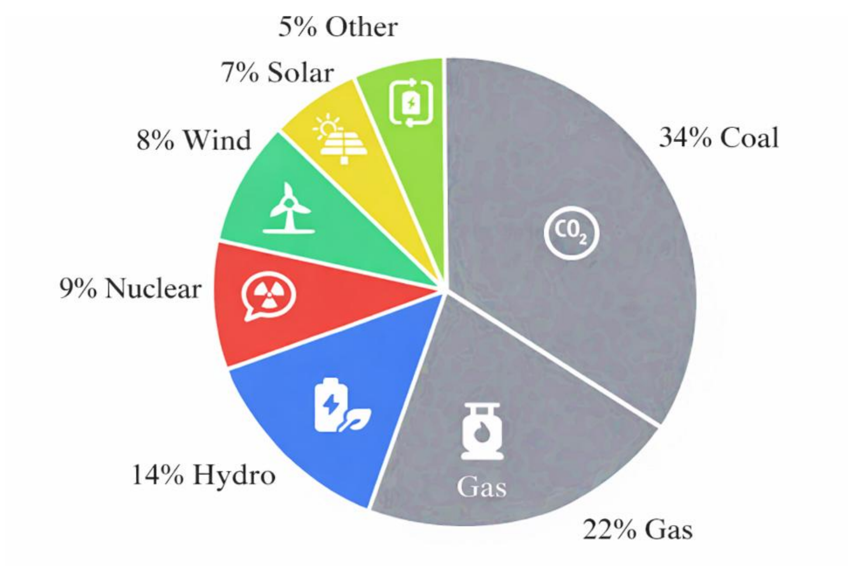

Figure 1 World electricity Generation by Source (Ember-Energy, 2025)

Despite this shift, fossil fuels still dominate in absolute terms. Around 80–81 percent of global primary energy in 2024 came from coal, oil, and natural gas (World Economic Forum, 2024). Coal remains the single largest source of electricity at 34–35 percent in 2024, with natural gas at about 22 percent. As a result, thermal generation still provides about 60 percent of global power. More than 2,400 GW of coal capacity is currently operating, and coal power accounts for about 40 percent of energy-sector CO_2 emissions. Achieving the Paris Agreement goals implies that coal-fired electricity must end by 2040 (International Energy Agency, 2023). In 2024, electricity demand rose about 4.3 percent year on year, and most incremental generation came from clean sources, yet coal remained the largest single source while renewables plus nuclear reached about 40 percent.

Coal demand edged up about 1.2 percent in 2024, largely due to extreme heat, with the power sector using roughly two-thirds of total coal. Developing Asia now accounts for nearly four-fifths of global coal consumption, led by China, which represents around 58 percent of global coal, along with continued growth in India, while the European Union and the United States continue to experience structural declines, and the United Kingdom reached zero coal capacity by September 2024. Without the 2024 surge in wind, solar PV, and nuclear of roughly 770 TWh, coal consumption would have risen nearly twice as much (Global Energy Review, 2025).

At COP 28, governments endorsed a transition away from fossil fuels, called for phasing out inefficient fossil-fuel subsidies, and highlighted just-transition needs and methane abatement, which are signals that are likely to shape 2025 NDCs (United Nations Climate Change). Private finance and the "greening" of initiatives such as the BRI have moved up the agenda, while rapid scaling of renewables still depends on capital availability, grid readiness, and resilient supply chains.

2. Pakistan's Energy Mix

2.1 Pakistan Installed Capacity

As per the estimated power generation capacity in Pakistan in 2024, there is a dominated share of thermal power, which is supplemented by an emerging renewable sector. Thermal sector combination of Natural Gas (23%), RLNG (13%), Coal (16%), and RFO (10%) together constitute more than 60% of the installed base, underlining the country's dependence on fossil fuels to provide grid stability and for the base-load power dispatch. In the low-carbon market, the importance of hydropower cannot be overlooked, which constitutes the second-largest source at 23%, comparable to natural gas. Nuclear power at 8% is the second-largest contributor among the sources of clean power. Wind power at 4%, solar at 2%, with the remaining at 1%, collectively point toward the positive developments taking place in the diversified sources category.

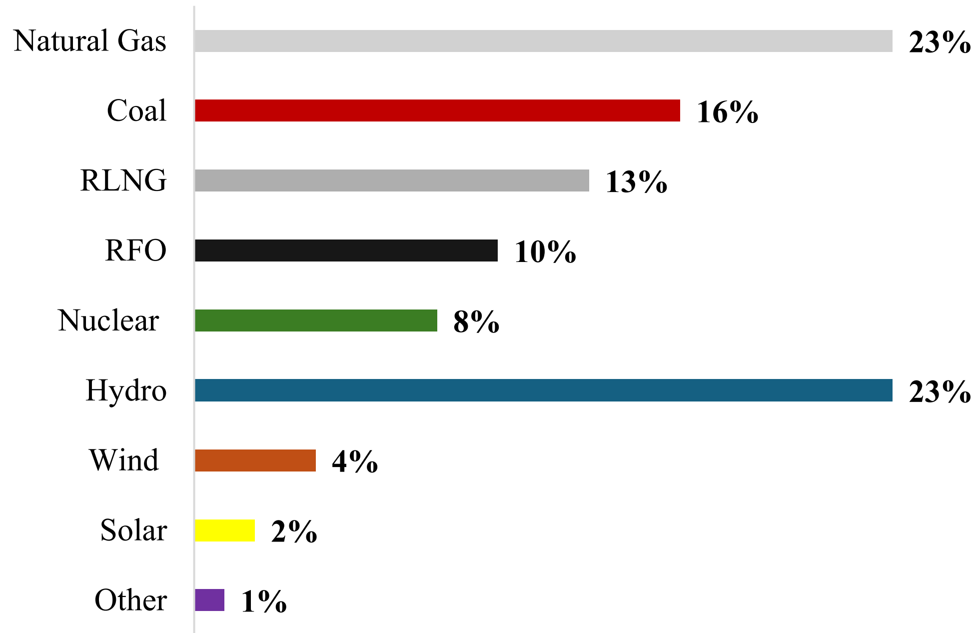

Figure 2 Installed Capacity by Source in 2024 (Renewable First, 2024)

2.2 Electricity Generation by Source

Over the last four years thermal generation has declined modestly in share as nuclear and renewables scaled, with FY2021 at 62.5% thermal and FY2022 at 60.9 percent while hydro fell from 27.8 to 23.7 percent and nuclear rose from 7.2 to 12.3 percent, and by FY2023 the mix was about 58.8 percent thermal, 25.8 percent hydro, 8.6 percent nuclear, and 6.8 percent other renewables, while early FY2024 data indicate just under half of electricity coming from fossil fuels and over 54 percent from hydro, nuclear (Pakistan Economic Survey 2023-24).

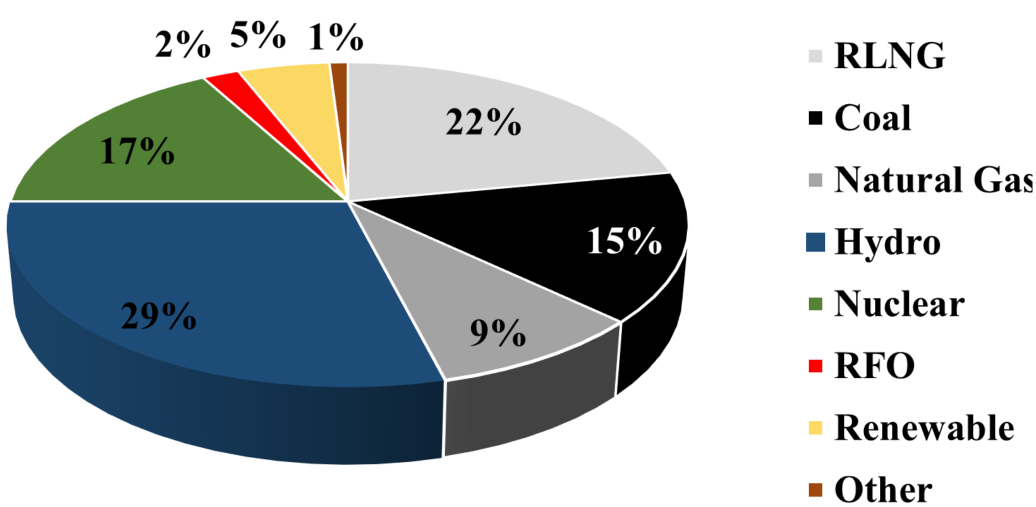

Figure 3 Electricity Generation in 2024 (Reneable First, 2025)

3. Pakistan's Coal Fleet

Large-scale coal deployment began less than a decade ago under CPEC, lifting capacity from 0.15 GW in 2015 (Nedopil et al, 2024) to more than 7.2 GW by March 2023. The fleet is young, but nearly 3 GW is subcritical, the least efficient and most polluting technology. Lifetime CO_2 from subcritical units operating as of January 2023 is projected at a minimum of 117.8 million tons (Song et al. 2023).

To curb import exposure, Pakistan shifted towards domestic Thar lignite in the first half of 2022, domestic coal (Thar) and imported coal fueled about 1,320 MW and 3,960 MW, respectively. Three plants commissioned in late 2022 and early 2023 added 1,980 MW, largely running on Thar coal. Policy signals also contemplate up to another 2 GW of coal capacity before 2030 to substitute imported gas (Hussain,2023).

Operating plants cluster around ports and the Thar coalfield. Port Qasim, China Hub, and Lucky are in southern Sindh near Port Qasim, which facilitates imported coal logistics. In contrast, TEL, Thal Nova, Engro Thar, and SSRL are mine-mouth units situated directly at the Thar coalfield. Sahiwal is the only imported-coal plant outside Sindh, primarily serving Punjab's central-eastern corridor. Gwadar remains under construction on the Balochistan coast and, despite efforts to shift to local coal, is expected to proceed using imported fuel due to the high cost of transporting Thar lignite to the site.

Figure 4 Coal-fired Power Plant at Port Qasim Karachi (Source: cpec.gov.pk/project)

The Jamshoro Thermal Power Station in Sindh is situated alongside these Independent Power Producer (IPP) projects. It combines four older furnace oil and gas units, which are currently being retired after decades of low utilization, high costs, and local environmental damage. It is also a new 660 MW supercritical coal unit built with multilateral support, designed to run on a blend of imported coal and Thar Lignite. Because commissioning of the new unit has been delayed and Pakistan already faces excess capacity, this assessment treats Jamshoro as a public sector coal asset that should be screened together with the existing CPEC coal fleet when considering candidates for early retirement.

Table 1 Technical Profile of Coal Power Plant in Pakistan

Plant (Location)	Capacity (MW)	Technology	COD	Off taker	Fuel Source	Heat Rate (kcal/kWh)	CO_2 Intensity (g/kWh)
Sahiwal (Punjab)	1,320	Supercritical	Oct 2017	CPPA-G	Imported coal	~2200	~880
Port Qasim (Sindh)	1,320	Supercritical	Apr 2018	CPPA-G	Imported coal	~2100	~820
Hub (Balochistan)	1,320	Supercritical	Aug 2019	CPPA-G	Imported coal	~2070	~820
Lucky (Sindh)	660	Ultra-supercritical	Mar 2022	CPPA-G / KE	Thar Lignite (blended)	~2000	~750
Engro Thar (Sindh)	660	Subcritical	Jul 2019	CPPA-G	Thar lignite	~2320	~1050
Thar Energy (Sindh)	330	Subcritical	Oct 2022	CPPA-G	Thar lignite	~2400	~1100
ThalNova (Sindh)	330	Subcritical	Feb 2023	CPPA-G	Thar lignite	~2400	~1100
SSRL (Sindh)	1,320	Subcritical	Feb 2023	CPPA-G	Thar lignite	~2300	~1050
Jamshoro (Sindh)	660	Supercritical	2025 (trial operations)	CPPA-G	Imported coal + Thar lignite blend	~2150	~850

Source: PPIB 2023; Global Energy Monitor 2023s

Table 2 Financial Indicators

Plant	PPA Term	Tariff	Debt Remaining
Sahiwal	30 yrs (22 left)	~7.8¢	~40% unpaid
Port Qasim	30 yrs (23 left)	~7.9¢	~50% unpaid
Hub	30 yrs (24 left)	~7.9¢	~50% unpaid
Lucky	30 yrs (27 left)	~6–7¢	~80% unpaid
Engro Thar	30 yrs (24 left)	~5.4¢	~60% unpaid
TEL	30 yrs (27 left)	~5.4¢	~90% unpaid
ThalNova	30 yrs (28 left)	~5.4¢	~95%
SSRL	30 yrs (28 left)	~5.7¢	~95% unpaid
Jamshoro (GENCO-I)	Public GENCO, design life ~30 years	High cost, indicative tariff above 8¢/kWh (under review)	Very high (most project debt still outstanding)

Source: NEPRA; Reuters 2023

Table 3 Environmental Indicators

Plant	Gross capacity (MW)	Technology	Emissions intensity (tCO_2/MWh)	Annual CO_2 (Mt/yr)	$PM_{2.5}$ (µg/m³ at 10 km)	SO_2 (µg/m³ at 10 km)	Mercury (µg/m³ at 10 km)	Annual water use (m³)
Sahiwal	1,320	Supercritical	0.88	8.1	5	5	0.01	1.77×10^7
Port Qasim	1,320	Supercritical	0.82	7.6	5	5	0.01	1.77×10^7

Hub	1,320	Supercritical	0.82	7.6	5	5	0.01	1.77×10^{7}
Lucky Electric	660	Ultra-Supercritical	0.75	3.5	2	2	0.01	7.35×10^{6}
Engro Thar	660	Subcritical	1.05	4.9	10	10	0.01	9.89×10^{6}
Thar Energy	330	Subcritical	1.10	2.5	10	10	0.01	4.95×10^{6}
ThalNova	330	Subcritical	1.10	2.5	10	10	0.01	4.95×10^{6}
Shanghai Thar	1,320	Subcritical	1.05	9.7	10	10	0.01	1.98×10^{7}
Jamshoro	660	Supercritical	0.85	5.5	5	5	0.01	7.35×10^{6}

Table 4 Socio Indicators

Plant	Direct employment (FTE)	Indirect employment	Host community (location/class)	Local socio-economic conditions
Sahiwal (Punjab)	~300	Coal import/logistics (small)	Sahiwal district (rural-Agri)	Agriculture-based economy and moderate poverty
Port Qasim (Sindh)	~250	Port/logistics (small)	Karachi (urban-industrial)	Industrial/commercial zone and urban livelihoods, mixed income
China Power Hub (Balochistan)	~250	Coal transport/logistics	Hub (coastal Lasbela, rural)	Very high poverty (Lasbela ~94% poor) and fishing/agriculture livelihoods
Lucky Electric (Sindh)	~180	Cement plant (local)	Karachi Port (urban)	Karachi urban economy and better services and port-related employment
Engro Thar (Sindh)	~250	SECMC coal mine (~1000s)	Tharparkar (remote villages, desert)	Extreme poverty and subsistence farming, malnutrition
Thar Energy (Sindh)	~150	SECMC mine (shared)	Tharparkar (villages)	Same as Engro above (Sindh Thar) and very poor
ThalNova (Sindh)	~150	SECMC mine (shared)	Tharparkar (villages)	Same as Engro above and very poor
SSRL (Sindh)	~300	7.8 Mtpa coal mine (~1000s)	Tharparkar (remote desert)	Extreme poverty, undeveloped infrastructure
Jamshoro (Sindh)	~250	Coal logistics, maintenance, and local vendors	Jamshoro town and the surrounding villages along the Indus	Mixed urban and rural areas with previous pollution from the old plant and limited alternative jobs nearby

Sources: Plant reports and analyses sdpi.orgenergyandcleanair.org; news and NGO assessments of Thar and Sindh conditions tribune.com.pktribune.com.pk

Table 4 Electricity Generation from Coal

Fiscal Year	Local Coal	Imported Coal
2022	91%	78%
2024	70%	12%

4. Energy Transition Mechanism (ETM)

The Energy Transition Mechanism (ETM) is the Asian Development Bank's (ADB) blended-finance approach designed to accelerate early retirement or repurposing of fossil plants and channel capital into clean power and grids, while simultaneously supporting affected workers and host communities. For Pakistan, ETM-style transactions are relevant because they directly target the primary drivers of high tariffs and foreign exchange (FX) stress, namely, capacity payments and imported fuels, while enabling clean-energy build-out that reduces long-run costs.

Several key factors underscore the relevance of the ETM:

- **Macroeconomic Strain and Tariff Pressure:** High dollar-linked capacity charges and fuel imports feed circular debt and unaffordability. Easing these requires re-contracting or retiring the costliest fossil resources (Malik and Ayesha n.d.).
- **Young but Misaligned Fleet:** Many units are efficient, yet they are either subcritical or import dependent. Without a managed transition pathway, Pakistan risks locking in high emissions and FX risks through the 2040s (Song et al. 2023).
- **Policy Signals and Finance Windows:** Outcomes of COP 28 and forthcoming Nationally Determined Contributions (NDC) increased ambition (United Nations Climate Change) and Indicative Generation Capacity Expansion Plan (IGCEP) tilts toward Renewable Energy (RE), hydro, and domestic resources (COP28 and Pakistan's Energy Transition,2024). Blended-finance models (such as ETM and Just Energy Transition Partnership (JETP)-style structures) can help reduce retirement costs now, aligning with the current mobilization of global concessional climate capital.
- **System Readiness and Security:** Replacing selected coal with RE plus storage and targeted grid upgrades can preserve system reliability while lowering long-run costs. However, increased domestic lignite use must be weighed against its higher CO_2 intensity and local externalities (Global Energy Review, 2025).

- **Contractual And Legal Realities:** Exit is complicated by long Power Purchase Agreements (PPAs) (25–30 years), significant outstanding debt (per-plant ~$665million – $1.6billion), and high contracted Returns on Equity (ROE) (27–35%). This necessitates negotiated, transparently valued deals.

5. Pakistan's Potential Candidature/ ETM Candidacy Assessment

Coal has expanded rapidly from a near-zero base since 2015 and is now the third-largest source of electricity. More than half of the installed coal capacity still relies on imports even as Pakistan pivots to Thar lignite to reduce foreign-exchange exposure. Capacity rose from 150 MW in 2015 to more than 7,260 MW in 2023, which narrowed short-term adequacy but locked in long-term obligations and currency risk. After 2014, new coal units and Thar production reversed earlier gains in coal-use intensity (Global Energy Review, 2025).

5.1 Economic and Sector Challenges in Pakistan's Power Sector

A decade of capacity additions lifted installed power to the mid-40 GW range, but expensive take-or-pay Power Purchase Agreements (PPAs), dollar-linked fuels, and system inefficiencies pushed tariffs higher and eroded affordability. Circular debt reached about PKR 2.31 trillion by mid-2023, and arrears roughly quadrupled over the decade, reflecting costly contracts, FX shocks, and operational losses. Thermal still dominates capacity, and depleting indigenous gas has increased reliance on imported RLNG and coal. Grid bottlenecks limit renewable integration because most coal plants are clustered in the south, while major load centers lie elsewhere. These factors create a difficult starting point for early coal retirement, even as outages and fiscal pressure persist.

5.2 Alignment with ETM Objectives and International Case Studies

The Energy Transition Mechanism (ETM), launched by the Asian Development Bank (ADB) in 2021, is a financing platform designed to retire or repurpose high-emission power plants ahead of schedule and scale up clean energy investments, all while delivering a "just and affordable" transition for affected communities and economies.

Pakistan's profile fits these objectives because young coal units lock in high emissions and FX-heavy costs. Early retirement paired with renewables and grid upgrades can deliver emissions cuts, import-bill relief, and tariff stabilization (Institute for Energy Economics and Financial Analysis, 2025). Indonesia's pilot uses concessional refinancing to advance retirement at Cirebon-1. The Philippines' SLTEC deal was driven by a private buyout and subsequent reinvestment into renewables (ieefa.org). However, Pakistan faces distinct challenges: It lacks comparable public balance-sheet capacity and dedicated climate finance, its generation is fragmented among Independent Power Producers (IPPs), and macroeconomic stress complicates structuring. A practical path is to sequence feasible coal retirements with firm replacement portfolios, targeted grid investment, and just-transition measures, while using near-term relief from selected oil or gas units to create fiscal space and preparing coal transactions as plants age and financing aligns (ieefa.org).

5.3 Stakeholder Landscape for an ETM in Pakistan

Government of Pakistan: The Power Division and Ministry of Finance require transactions that cut fiscal pressure, lower foreign exchange (FX) exposure, and protect reliability while simultaneously meeting climate goals (ieefa.org). Priority plants for retirement are typically those with high-capacity charges, costly imports, or weak performance. Legal obligations under PPAs and sovereign guarantees require careful structuring and strong safeguards. Given the constraints, Concessional support is needed to limit upfront public costs and political risk.

Plant owners and operators: Most coal IPPs are joint ventures with Chinese and local sponsors, financed primarily by Chinese and local banks. Owners will engage if compensation covers remaining debt and provides a fair return, as these young plants still expect decades of revenue. Assets with fuel risk, high operating costs, or looming retrofit liabilities are likely candidates for early retirement. Public scrutiny of excessive profits and governance concerns can also increase the willingness to negotiate a deal. Chinese sponsors will weigh bilateral signals and require predictable terms (South Asia Program, 2023).

Investors and financiers: The Asian Development Bank (ADB), climate funds, bilateral partners, and private capital will back projects that deliver material emissions cuts at reasonable cost and risk. They need clear policy backing, credible closure mechanisms, and a just transition plan for workers and communities to protect reputation and social stability. Concessional capital is likely needed to anchor the structure to crowd in private co-investment, especially given country risk. Lender consent, particularly from Chinese banks holding project debt, is essential for any refinancing or buyout scenario, and early coordination through an ETM platform can align actors.

6. Coal Fleet Early Retirement Screening

Tables 1 to 4 provide technical, environmental, financial, and socio-economic data for each plant, followed by a screening framework designed to identify candidates for early retirement under the Energy Transition Mechanism (ETM).

To evaluate which coal plants might be best candidates for early retirement under an Energy Transition Mechanism (ETM), a multi-criteria scoring framework is applied. Each plant is scored on four primary dimensions, which reflect the key considerations of stakeholders:

6.1 Parameter selection

- **Technology:** Pakistan's coal fleet commissioned between 2017 and 2023 comprises two main technology types: large 660 MW supercritical and ultra-supercritical units operating on imported coal at sites such as Sahiwal, Port Qasim, Hub, and Lucky, and smaller subcritical mine-mouth lignite units at Thar in 330 MW and 660 MW configurations. The supercritical units typically achieve around 39–41% net efficiency, while the Thar subcritical units operate at approximately 36–38%, implying higher heat rates and greater CO_2 and air-pollutant intensity. All plants were developed as baseload assets undertake-or-pay power purchase agreements, which limits operational flexibility, and power transfers between the south and north depend heavily on the 4 GW Matiari–Lahore HVDC link. For screening purposes, the subcritical Thar units tend to rank higher on environmental grounds and are smaller and therefore easier to backfill, whereas the more efficient supercritical imported-coal units carry greater stranded asset risk and foreign-exchange-indexed contractual exposure, creating a trade-off between environmental benefit, contractual cost, and grid value. Asset age is used as a proxy for both efficiency and remaining operating life. Plants employing older subcritical technology or with many decades of potential service remaining score higher in screening because they are technologically inferior and risk locking in emissions for a longer period if not retired. Fuel sourcing considerations reflect the increasing reliance on Thar Lignite, a vast domestic resource characterized by low calorific value and high moisture content that is best utilized at mine-mouth locations or in limited blends. Shifting generation from imported, dollar-denominated coal to rupee-based domestic supply reduces variable costs and foreign-exchange risk, but introduces logistical challenges, quality penalties in the form of higher heat rates, and significant water and dewatering impacts in an arid region.

- **Financial:** Financial factors such as power purchase agreement (PPA) terms, electricity cost per unit, and remaining outstanding debt are critical screening criteria for assessing the early retirement potential of coal-fired power plants. These factors strongly influence the economic feasibility, compensation requirements, and overall system impacts of plant retirement decisions.
- **Environmental:** This factor is assessed through carbon intensity and local pollution effects. Plants with higher CO_2 emissions per kilowatt-hour, poorer efficiency, and weaker emission control systems are considered environmentally "dirtier" and receive higher scores, as their retirement would deliver greater climate and air-quality benefits. More efficient and cleaner units score lower on this dimension. Economic impact captures both the cost of power and the broader financial burden imposed by the plant, alongside the degree of socio-economic reliance on the facility.
- **Socio-Economic:** This factor recognizes that coal plants and associated mines sustain thousands of direct jobs and extensive local supply chains, with dependence most acute in Tharparkar, where the economy is largely single-industry and communities have been resettled around mining activities, and lower in more diversified urban or coastal locations. Premature closure without a just transition could concentrate income losses and social stress, making mitigation measures essential. These include phased retirement aligned with replacement capacity, funded retraining and redeployment, decommissioning work, support for small and medium enterprises, and broader local development programs.
- **Grid:** Grid role dependency and replaceability assess the technical feasibility of substituting a plant's generation without compromising system stability or reliability. As the energy system

shifts toward renewable sources, dependence on renewables is increasing, while dependence on coal is gradually dropping. Pakistan has also reduced its reliance on imported coal, with a growing shift toward the utilization of local coal resources. At the same time, a rapid expansion of solar PV driven by low technology costs, widespread rooftop adoption, and utility-scale installations has significantly transformed the generation mix. This "solar rush" has reduced daytime demand for coal-fired generation and increased grid flexibility. Consequently, fewer coal plants are now operated on a demand-based basis, and several have become increasingly replaceable. Many coal-fired plants have experienced frequent periods of non-operation due to high generation costs, fuel supply and financing constraints, and a national grid surplus that increasingly prioritizes lower-cost renewable and hydropower sources.

6.2 Scoring Methodology

Based on these criteria definitions and plant-specific data (Tables 1–4), each plant was assigned a qualitative score from 0 (least favorable for early retirement) to 5 (most favorable) on each dimension. This scoring was determined by comparing the plants' attributes relative to one another for each factor.

Plants with a high generation cost and minimal local economic dependence (e.g., an imported coal Independent Power Producer/IPP) receive a high Socio-Economic score (indicating strong retirement benefits in cost terms and manageable social impact). Conversely, a plant providing inexpensive power or supporting a critical local economy (e.g., a Thar mine-mouth plant) scores low on Socio-Economic, signifying that early retirement would impose greater socio-economic costs. Similarly, the Environmental score is highest (approaching 5) for the most carbon-intensive and polluting plants (e.g., subcritical lignite units with high CO_2 per kWh and relatively basic emission controls), while more efficient, cleaner coal units (supercritical plants with lower emissions rates and better pollution controls) receive lower Environmental scores. The Technology/Age dimension follows the same principle: newer, more efficient plants (with supercritical/ultra-supercritical technology and fewer remaining years of operation) score low, whereas plants with older or subcritical technology and decades of remaining life score high (reflecting greater long-term emissions and inefficiency). Lastly, the Grid dependency score is high for plants that have experienced frequent periods of non-operation due to high generation costs, fuel supply, and financing constraints.

6.3 Formula for Ranking Plants

Table 5 shows the resulting scores for all plants across the four dimensions and their overall composite score. Higher scores reflect plants that impose greater fiscal and environmental burdens while being comparatively easier to replace within the power system, whereas lower scores identify plants that are more efficient, system-relevant, or socially embedded. The results highlight that, although all coal plants pose long-term transition challenges, a subset of assets offer particularly strong opportunities for early intervention. The composite score is calculated from following equation:

$$C_i = 0.125 \times S_{Tech} + 0.25 \times S_{Fin} + 0.25 \times S_{S\text{-}E} + 0.25 \times S_{Envi} + 0.125 \times S_{grid}$$

Table 5 Screening Scores

Plant	**Technology (0–5)**	**Financial (0–5)**	**Socio-Economic (0–5)**	**Environmental (0–5)**	**Grid (0–5)**	**Composite Score**
Sahiwal	3.50	3.33	4.00	4.00	4.00	**4.02**
Port Qasim	3.50	3.33	4.00	4.00	4.00	**3.85**
Hub	3.50	3.67	4.00	4.00	4.00	**4.10**
Lucky Electric	3.50	4.00	3.40	4.33	4.00	**3.87**
Engro Thar	5.00	3.33	4.80	3.33	3.00	**4.03**
TEL	5.00	3.67	4.80	4.00	3.00	**4.20**
ThalNova	5.00	4.00	4.80	4.00	3.00	**4.28**
SSRL	5.00	4.00	5.00	3.33	3.00	**4.17**
Jamshoro	4.00	5.00	3.80	4.00	5.00	**4.49**

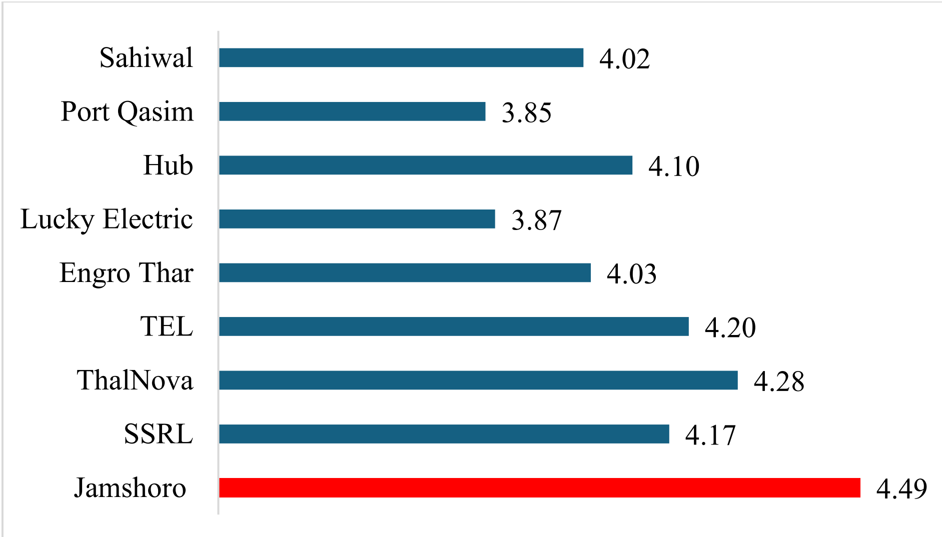

Figure 5 Composite Screening Scores for Coal-Fired Power Plants

Table 5 and figure 5 summarizes the composite screening scores for Pakistan's operational coal-fired power plants based on four weighted criteria: socio-economic impact, environmental performance, technology and age, and grid replaceability. Composite scores range from 3.76 to 4.46, indicating meaningful variation in the suitability of individual plants for early retirement under an Energy Transition Mechanism (ETM).

The results show a clear distinction between imported-coal plants located near coastal or urban centers and mine-mouth lignite plants in the Thar region. Imported-coal plants generally score higher on socio-economic criteria because of their substantial foreign-exchange exposure, high-capacity charges, and relatively limited local employment dependence. Although these plants employ supercritical or ultra-supercritical technology with lower emissions intensity per unit of electricity, their large scale and long remaining lifetimes imply significant cumulative emissions and fiscal lock-in if they continue operating. Given existing surplus capacity and improving transmission connectivity, many of these plants are technically replaceable without compromising grid reliability.

In contrast, Thar-based Lignite plants score particularly high on environmental and technological dimensions due to their subcritical design and high carbon intensity. These plants represent some of the most intensive emissions assets in the system and would deliver substantial climate and local air-quality benefits if retired early. However, their socio-economic scores are moderated by strong linkages to coal mining and their role in supporting livelihoods in one of Pakistan's most economically vulnerable regions. As a result, while technically and environmentally unattractive, their retirement requires careful sequencing and robust just-transition measures to mitigate social impacts.

7. Coal Plant Retirement

Higher composite scores indicate plants that are more attractive for early retirement under ETM when considering all factors. Based on the scoring above, the three highest-scoring plants are: Jamshoro 660, ThalNova (330 MW), and TEL (330 MW), and.

Plant	Score	Rank Retirement
Jamshoro	4.49	1st
ThalNova	4.28	2nd
TEL	4.20	3rd
SSRL	4.17	4th
Hub	4.10	5th
Engro Thar	4.03	6th
Sahiwal	4.02	7th
Lucky Electric	3.87	8th
Port Qasim	3.85	9th

Jamshoro's new 660 MW supercritical unit is not part of the CPEC IPP fleet, but it shares many of the same challenges. If it operates on an imported coal blend, it will add a sizeable new foreign currency burden and lock in several million tons of CO_2 per year at a time when the system already has surplus capacity. Given its public ownership, its location in an area that has already experienced significant pollution from the older Jamshoro units, and the availability of cheaper clean alternatives, this report treats Jamshoro 660 as a strong candidate for early retirement or non-dispatch alongside the imported coal IPPs.

Notably, the small ThalNova and TEL units use the most carbon-intensive subcritical technology and contribute heavily to local pollution per unit of output, yet their capacity is easier to replace. However, their absolute generation is smaller and retiring both would eliminate 660 MW of coal power (and avoid roughly 4–5 million tons of CO_2 annually), whereas retiring a larger plant like this would yield a bigger emissions reduction (on the order of 8–9 Mt CO_2/year). In practice, an ETM portfolio might prioritize a mix of plant sizes to balance impact and feasibility.

From a financial perspective, the three imported-coal plants (Sahiwal, Port Qasim, Hub) impose the greatest costs on Pakistan's power system, and their fuel is expensive (especially after the 2022 coal price spike, when Sahiwal's generation cost soared above Rs 30/kWh), and payments are in foreign currency, straining foreign exchange reserves. These plants also have fewer linkages to local employment (being near urban centers and reliant on imported fuel).

The domestic Thar lignite plants, by contrast, produce cheaper electricity (under Rs 6/kWh in 2022 for Engro Thar) and support local development, which lowers their socio-economic score. Yet, environmentally, they are the worst emitters (due to lower efficiency and high coal moisture), and all use subcritical technology. Engro Thar (660 MW) is the oldest of the Thar units and has been operating at a high-capacity factor (~93%) and retiring it early would free up its sizeable annual CO_2 emissions (and could relieve the government of its high rupee-based capacity payments). On the other hand, shutting Engro or SSRL would also idle their associated coal mines and affect thousands of local workers, which is a major socio-economic drawback. Any retirement plan for these would require just transition measures, like re-employment, economic alternatives for the Thar region to mitigate community impacts.

Overall, these screening results point to Jamshoro 660 as a particularly high-leverage site for targeted retirement efforts. Because the plant is publicly owned, there is no need to renegotiate complex foreign IPP contracts, and the state already plans to retire the older furnace oil and gas units at the same station, which increases the impact of a single Energy Transition Mechanism transaction. The unit has not yet built a long operating track record and has faced commissioning delays, so early retirement or permanent non-dispatch would avoid decades of imported coal exposure and future CO_2 lock-in while the system still has surplus capacity. It would also deliver local environmental gains for Jamshoro town and nearby villages that have lived with pollution from the legacy plant if ETM proceeds are used for remediation, reskilling, and new clean energy projects at or near the site. For these reasons, the analysis treats Jamshoro 660 as a priority candidate within the screened fleet for focused retirement planning alongside the most expensive imported coal IPPs.

Figure 6 Jamshoro Coal-Fired Power Plant

8. Fiscal, Operational, and Environmental Benefits

IEEFA's analysis, "Closing coal plants early makes economic sense in Pakistan," estimates that immediately retiring a selected coal fleet would entail an economic valuation of US$1.1–1.6 billion, reflecting debt-service obligations and contracted ROE consistent with tariff determinations. At the global scale, the IMF estimates that ending coal and substituting renewables would require about $29 trillion of investment, nearly half in Asia (IMF, 2024).

Early retirement of coal-fired plants yields multiple co-benefits. Fiscal benefits include eliminating large, fixed payments and import bills. For example, Sahiwal (1,243 MW) incurred ≈Rs 55.7 billion in capacity charges in FY2021-22.

Shuttering such a plant saves on order of Rs 50+ billion (~$180m) per year in capacity payments alone. It also avoids costly coal imports (Sahiwal burns ~300,000 t/month of coal, and at ~$100/t this is ~$360m/year at full utilization).

Extending this to other CPEC plants (Port Qasim, China Hub, etc.) implies fuel-import savings on the order of ~$1–2 billion annually.

Debt and fiscal relief accrue because CPEC coal projects carry state-guaranteed loans and dollar-indexed tariffs. For instance, seven Chinese coal IPPs have ~Rs 320 billion of unpaid principal + interest.

Early retirement can preempt or reduce these obligations (consumers already pay ~Rs 1.08 trillion per year in debt service via capacity payments).

8.1 Operational benefits

- **Less system inefficiency:** Many coal plants run well below nameplate. For example, Pakistan's coal plants have very low utilization (e.g., Sahiwal ~50–63% CF), forcing the grid to pay for idle capacity. Retiring these units removes costly excess baseload and improves dispatch efficiency.
- **Greater flexibility and reliability:** Removing inflexible "must-run" coal capacity gives dispatchers more headroom to ramp peak and mid-merit plants as needed. In practice, phasing out old coal allows cheaper peaking gas, hydro, and storage to serve the load, which can reduce forced outages and grid stress. It also avoids costly cycling losses of aging units.
- **Easier renewable integration:** With fewer baseload constraints, the grid can absorb more wind and solar. Modeling shows that aggressively expanding VRE (to ~30% of capacity by 2030) could save Pakistan up to ~$5 billion in fuel and other costs by displacing inefficient thermal generators. In other words, retiring coal frees transmission and reserve capacity for clean generation, reducing curtailment and backup needs.

8.2 Environmental benefits

- **CO_2 reductions:** Early coal closures sharply cut greenhouse emissions. For example, one analysis finds that the immediate retirement of Sahiwal avoids about 65 million tons of CO_2 over the remaining life of the plant. (By contrast, deferring retirement by 10 years still avoids ~48 $MtCO_2$.) Similar orders of magnitude apply to Port Qasim and Jamshoro if retired early.
- **Air pollution and health:** Coal power emits large amounts of $PM_{2.5}$, NO_x and SO_2. Avoiding these reduces respiratory diseases and mortality. A case study of Pakistan's Port Qasim plant attributes ~49 premature deaths per year to its $PM_{2.5}$ emissions and shutting coal plants would prevent such exposures and the associated health costs. Regionally, increased coal use in South/Southeast Asia is projected to cause tens of thousands of extra deaths, and one study links CFPP expansion in the region to ~70,000 additional fatalities by 2030. Eliminating coal also cuts acid rain (SO_2/NO_x) and black carbon.
- **Co-benefits:** Fewer emissions also mean cleaner water (less coal ash runoff) and lower climate risk. In addition, avoiding coal generation can free up water for other uses.

9. Challenges for Early Retirement of Coal Power Projects

Shifting to cleaner energy can reduce climate vulnerability, catalyze growth, and advance international commitments. Instruments such as the Asian Development Bank (ADB)-led Energy

Transition Mechanism and Just Energy Transition Partnerships (JETPs), tailored to Pakistan's context, could enable a fair, orderly move away from coal. Nonetheless, early retirement is difficult due to a confluence of factors: Long-term PPAs, Young Fleet, Efficient Plants (high merit), Legal Cover, Complex Governing Landscape, and Entangled Financial Structures.

- **Young Fleet and Long-Term Power Purchase Agreements**

Early retirement is complicated by long-tenor contracts and PPAs for coal plants typically span 25–30 years, leaving around 15 years of remaining fossil generation, which raises the cost and complexity of exit. Most plants still carry significant debt, and per-plant debt obligations in Pakistan are estimated between $665 million and $1.6 billion (Isaad 2024). The assets are highly profitable for owners, and contracted returns on equity (ROE) reportedly range from 27% to 35%. In addition, sovereign guarantees underpinned financing for many coal facilities, ensuring timely payments to sponsors. Because CPEC PPAs were structured as components of government projects, renegotiation is difficult, suggesting these plants were not designed to compete solely on cost.

- **Legal Challenges and Financial Structures**

Pakistan's coal PPAs embed substantial legal and fiscal commitments, long-term contracts, sovereign guarantees, implementation agreements, and other state support that shape asset economics. Significant project debt, sponsor equity, and government-approved contributions enlarge the book value at risk in any retirement scenario. The governance landscape involves multiple counterparties, state-owned entities, and financial institutions, with incentives aligned to fossil-linked cash flows. Practical proposals to relocate or convert coal plants frequently run into the dense web of these financial structures. Navigating a transition, therefore, requires balancing environmental objectives with financial sustainability and stakeholder risk allocation.

- **Transmission Network Constraints**

Pakistan's transmission grid is a major bottleneck for accelerated coal retirement. The network is aging, and geography compounds the challenge: most coal plants are in the south, hydro and other large assets lie in the north, while load centers cluster in central corridors. Replacing coal with variable renewables will require substantial grid reinforcement and expansion, an essential precondition for unlocking RE investment at scale.

10. Recommendations

Based on the analysis of Pakistan's power sector dynamics, coal generation portfolio, fiscal exposure, and environmental impacts, a gradual and sequenced approach to coal transition is recommended. The coal fleet exhibits substantial heterogeneity in terms of technology, commissioning timelines, ownership structures, environmental performance, and system role. As such, early implementation of an Energy Transition Mechanism (ETM) should focus on assets where emissions reduction, fiscal relief, and system efficiency gains can be achieved with relatively lower transaction and implementation risk. Prioritization should be guided by plant-level indicators, including capacity payment obligations, foreign exchange exposure, utilization trends, and emissions intensity, rather than adopting a uniform retirement strategy.

The Asian Development Bank (ADB) can play a pivotal role in supporting Pakistan's coal transition, particularly in facilitating the early retirement of high-cost and environmentally intensive plants such as Jamshoro 660 MW. ADB can provide blended finance, concessional loans, or guarantees to enable the buyout or refinancing of coal assets, reducing fiscal pressures and mitigating stranded debt risks. It can also support technical and planning studies to ensure grid stability during retirement, including modeling renewable energy and storage integration, demand-side management, and sequencing of plant closures. On the policy side, ADB can assist in designing regulatory frameworks and just-transition measures, including workforce reskilling and local economic support for communities dependent on coal operations. Furthermore, ADB can help mobilize international climate finance and carbon credit mechanisms to offset transition costs while piloting early retirement transactions as a demonstration for other high-cost coal plants. By combining financial, technical, and policy support, ADB can help Pakistan retire coal plants like Jamshoro in a structured, economically viable, and environmentally responsible manner, while simultaneously accelerating renewable energy deployment.

Given the significant participation of Chinese sponsors and lenders in Pakistan's coal power sector, early and structured engagement with these stakeholders will be central to ETM feasibility. Coordinated dialogue involving government authorities, plant sponsors, lenders, and multilateral development banks can help align ETM transactions with evolving international green finance principles and lender risk considerations. Clarity regarding debt treatment, credit risk mitigation, and reinvestment opportunities in lower-carbon infrastructure will be important in securing timely lender consent.

Finally, coal transition efforts should be positioned within Pakistan's broader climate and development policy framework. Explicit integration of ETM-based coal retirement pathways into national climate commitments and long-term decarbonization strategies would improve policy coherence and strengthen the case for concessional and blended finance. Framing ETM as a component of power sector modernization and macro-fiscal risk management, rather than solely as a climate intervention, is likely to increase stakeholder alignment and support sustained implementation.