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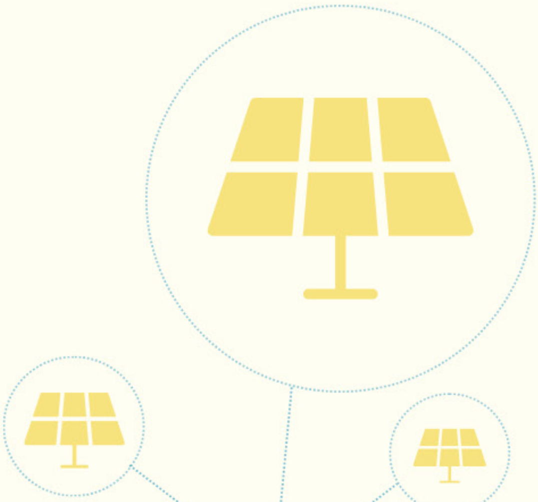

Electrons In, Hydrocarbons Out:

Pakistan's Quest for Economic and Resource Efficiency

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Disclaimer:

All the information and analysis provided in this document are accurate and to the best of our knowledge and understanding, in case you identify any error, please email: info@renewablesfirst.org

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Abbreviations

BCF	Billion Cubic Feet
B	Billion
Capex	Capital Expenditure
DG	Distributed Generation
DISCOs	Distribution Companies
EVs	Electric Vehicles
FY	Fiscal Year
GDP	Gross Domestic Product
GJ	Gigajoule
GW	Gigawatt
IMF	International Monetary Fund
kWh	Kilowatt-hour
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MW	Megawatt
MTOE	Million Tonnes of Oil Equivalent
PEMR 2025	Pakistan Energy Market Review 2025
PES	Primary Energy Supply
PKR	Pakistani Rupee
PRIED	Policy Research Institute for Equitable Development
PV	Photovoltaic
RMI	Rocky Mountain Institute
SHS	Solar Home System
T&D	Transmission and Distribution

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Executive Summary

Pakistan's official energy data suggest a puzzling outcome: despite population growth, urbanisation, and continued economic expansion, measured energy consumption has shown little growth in recent years. This pattern has fuelled claims that Pakistan may be decoupling economic activity from energy use. This paper finds that such interpretations are misplaced and stem primarily from gaps in how energy is currently measured.

A central omission in official statistics is the rapid expansion of distributed solar photovoltaic (PV) capacity. While national data capture grid-based electricity and utility-scale projects, they largely exclude citizen-led deployment of solar systems across households and businesses. Drawing on trade data, installation trends, and independent capacity estimates, this study shows that distributed solar PV has already become a significant source of energy in Pakistan. Once this missing supply is incorporated, aggregate energy use aligns far more closely with the country's economic and demographic trajectory.

The analysis then compares fossil fuels and distributed solar PV through the lenses of economic and physical efficiency. Fossil fuels remain dominant but impose substantial costs through import dependence, foreign exchange exposure, and vulnerability to global price shocks. They also deliver relatively low levels of useful energy due to losses across conversion, transport, and end use. Distributed solar PV, by contrast, transforms upfront investment into power generation asset which can deliver energy services for decades with much higher efficiency, particularly when combined with electrified end uses.

Taken together, these findings suggest that Pakistan's energy system is already undergoing a quiet reorientation driven by consumer economics rather than policy design. As electricity assumes a larger role as an energy carrier, electrification emerges not as a distant policy objective but as a defining feature of how energy demand is being met. This shift challenges existing approaches to energy planning and regulation, which were not designed for a system shaped by decentralised generation, and electrified end uses.

Key findings

- Official energy statistics underestimate Pakistan's energy use by failing to capture distributed solar PV generation, which could have provided **19TWh** of electricity in **fiscal year 2023-24 (FY24).**
- Fossil fuel reliance imposes significant macroeconomic risk and is physically inefficient, with around **60%** of primary energy lost during conversion, transport, and end use.
- Distributed solar PV already contributes materially to national energy supply, displacing inefficient fossil fuel inputs; in FY24 alone, it offset roughly **5MTOE** of primary fossil fuel demand.
- Fully deployed, the **48GW** of imported solar PV capacity could avoid **USD 100-120 billion (B)** in fuel imports over its operational life.
- Electrification offers a high-efficiency pathway forward, reducing primary energy requirements while strengthening energy security and long-term economic resilience.

1. Introduction

Energy has long been a central enabler of economic organisation and social transformation. According to energy historian Vaclav Smil, the development of modern economic systems has been closely linked to successive energy transitions and associated technological innovations[1]. Historically, economies characterised by population growth, urban expansion, and rising incomes have consumed more energy over time, not less a pattern observed in early industrialisers such as Britain and, more recently, in high growth economies including China and India.

Pakistan, home to the world's fifth-largest population and experiencing modest but sustained economic growth, would be expected to follow a similar trajectory. Yet official statistics point to a puzzling divergence. After peaking in the early 2020s, both primary energy supply and final energy consumption appear to have stagnated or declined, returning by fiscal year 2023-24 (FY24) to levels observed several years earlier. This raises a fundamental question: is Pakistan experiencing an unprecedented decoupling of economic activity from energy use, or do prevailing methodologies fail to capture a significant portion of how energy is being produced and consumed across the economy?

This paper examines that question by reappraising Pakistan's recent energy trends. It begins by dissecting official energy supply and consumption data, highlighting inconsistencies between measured energy use and underlying economic dynamics. It then explores whether emerging forms of energy provision particularly those occurring outside conventional reporting structures help explain the apparent divergence. By reassessing the energy system through both economic and physical lenses, the analysis seeks to clarify how different energy sources contribute to useful output and macroeconomic outcomes.

Finally, the paper considers broader implications of these findings for Pakistan's development trajectory. In particular, it explores whether the ongoing shift in energy use point toward a gradual reorientation of the economy around electricity as the dominant energy carrier, and what such a transition would imply for policy, planning, and institutional capacity. Rather than prescribing a single path forward, the analysis aims to provide a clearer empirical foundation for understanding the choices and constraints that will shape Pakistan's energy future.

2. Revisiting the apparent decoupling of economic growth from energy consumption

Although energy intensity varies across economies because of differences in economic structure, geography, and resource availability, total energy demand usually rises as countries become wealthier. In Pakistan, however, reported primary energy supplies stayed broadly flat at about 81 million tonnes of oil equivalent (MTOE) between FY20 and FY24, apart from short-term fluctuations. This stagnation persisted despite average annual growth of 2.6% in real gross domestic product (GDP) over the same period (Fig. 1).

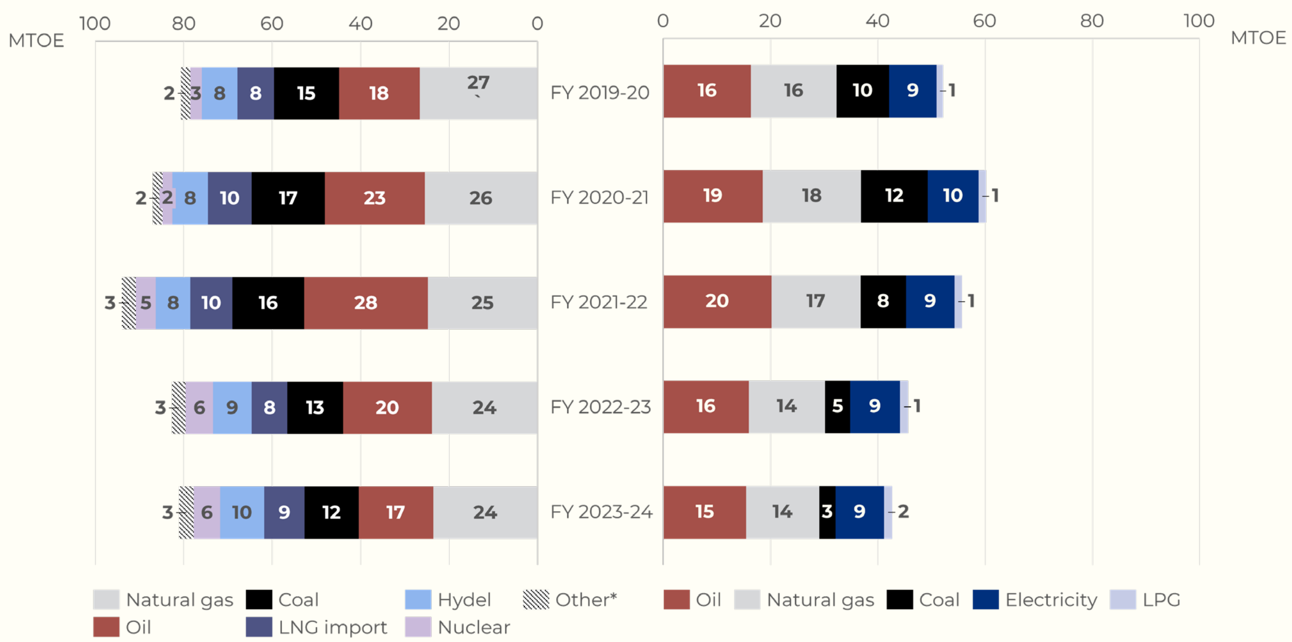


Figure 1: Pakistan's primary energy supply (left) and final energy consumption (right) trend, FY20 – FY24

Data source: Energy yearbook 2024 (HDIP) & RFs' calculations

A more long-term comparison of energy consumption trends with Bangladesh, Egypt, Vietnam, and India, further underscores the perplexity of Pakistan's reported energy trends. Between the years 2014-24, Pakistan's energy consumption grew by only 13%, making it the weakest performer among this group (Fig. 2).

Over the decade, its population increased from approximately 188 million to 242 million[2], contributing to the contraction of primary energy supply per capita, which declined gradually to 11.9GJ in 2024 after peaking at 14.6GJ in 2018 (Fig. 3).

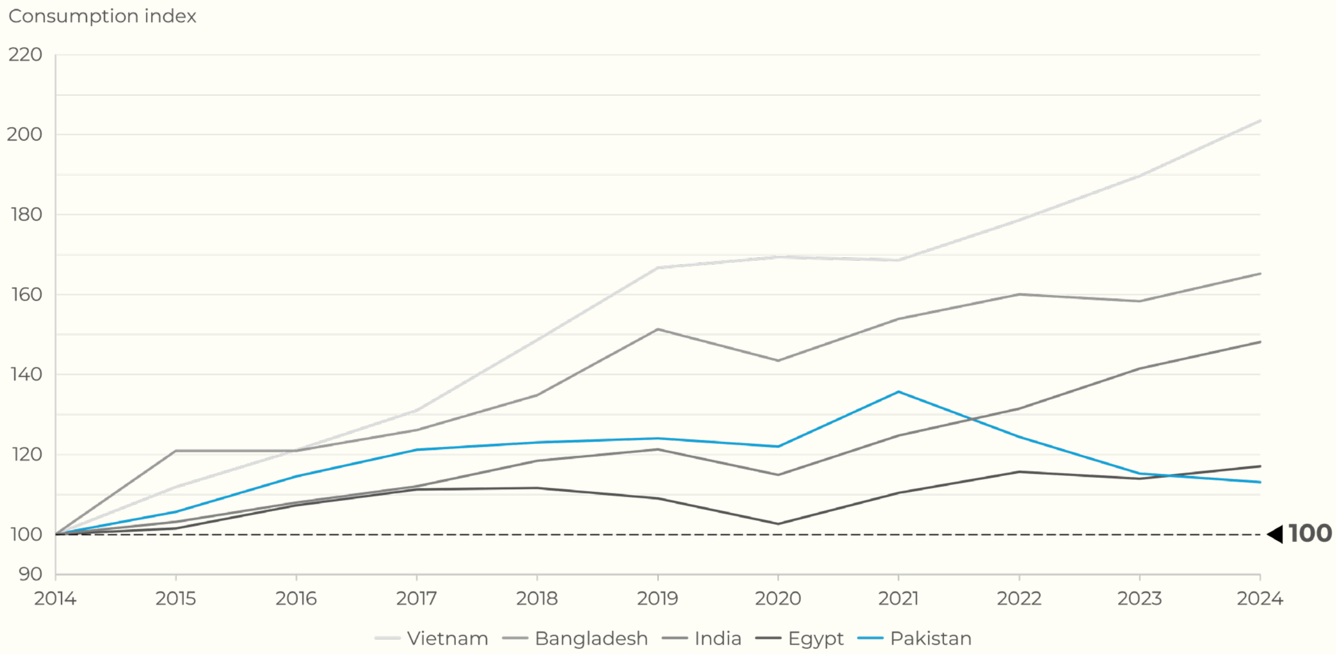


Figure 2: Final energy consumption of select countries, 2014-2024 (2014 = 100)

Data source: Energy Institute (https://www.energyinst.org/)

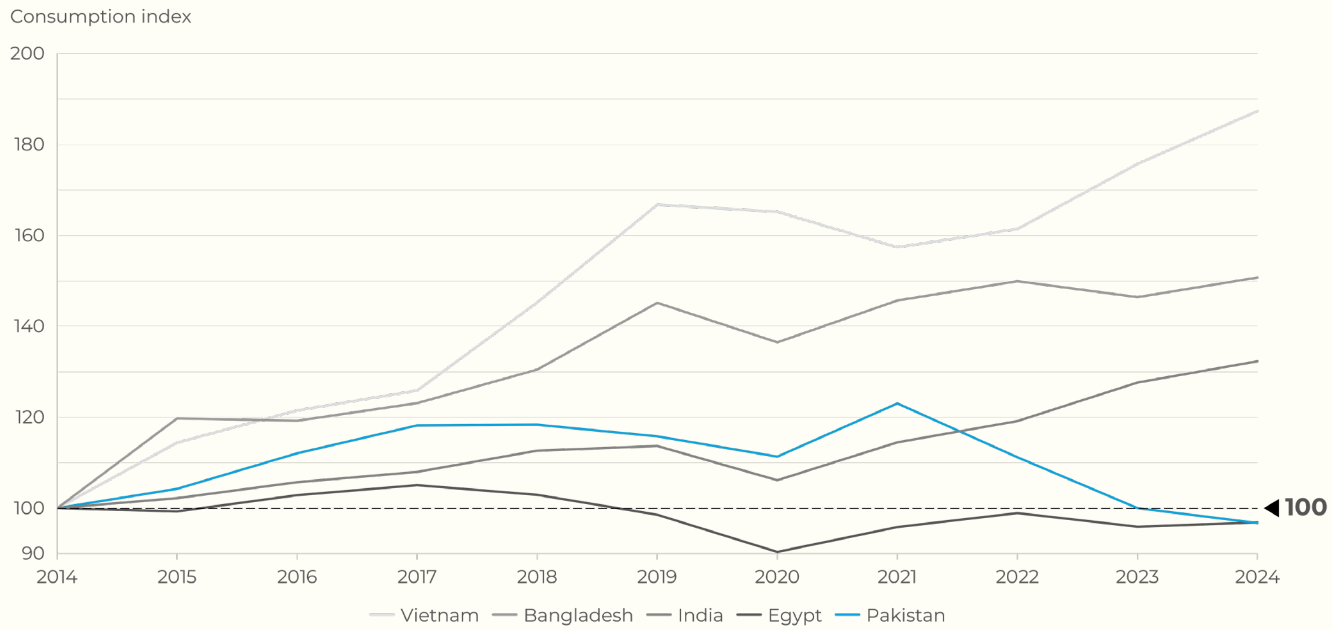


Figure 3: Total energy supply per capita of select countries, 2014-2024 (2014 = 100)

Data source: Energy Institute (https://www.energyinst.org/)

Economic structure and efficiency gains do not explain unusually weak energy demand

While Pakistan's economic performance has been far from the successes of Vietnam, Bangladesh and India, its real GDP nevertheless expanded at an annualised rate of 3.5% [3] over the decade. The sectoral shares of industry and services in the economy remained at around. 18% and 57% [4], respectively, between 2014 and 2024, with no notable structural transformation or measurable gains in energy efficiency. Furthermore, as per the 2023 Census, the urban population grew on average 3.7% [5] per annum between 2017 and 2023.

All these factors are expected to translate into a commensurate increase in measured energy consumption. Yet the reported trends imply a counterintuitive outcome: Pakistan has experienced economic expansion, population growth and urbanisation while consuming progressively less energy over the past decade. This pattern is unusual for a country at Pakistan's stage of development, where declines in energy intensity typically follow sustained industrial growth or a shift toward higher-value services, neither of which has been observed in the country recently. To examine this divergence, we review official energy data and fuel-wise supply dynamics from the Pakistan Energy Yearbook 2024, focusing on a five-year period from FY20 to FY24.

3. Dissecting Pakistan's energy supply and consumption flows

Fossil fuels accounted for 79% of Pakistan's primary energy supply of 81 MTOE in FY24. Insufficient domestic production of oil and gas has shaped an energy system that relies heavily on imports. The country meets over 40% of its fossil fuel demand through imported crude oil, petroleum products, coal, liquified natural gas (LNG) and liquified petroleum gas (LPG). Renewables First's Pakistan Energy Market Review 2025 (PEMR 2025) [6] documented signs of shifting consumption patterns of key fuels between FY20 and FY24.

Natural gas and oil demand fell despite continued economic activity

Natural gas, including domestic production and imported LNG and LPG, represented about 45% of primary energy supply in FY20 (Fig 1). While LNG and LPG imports increased, domestic production slid gradually. Overall gas consumption contracted at a compound annual growth rate (CAGR) of -2% during the review period (Fig. 4). Between FY21 and FY24, the power generation, industrial and fertiliser sectors slashed their combined consumption by 180 billion cubic feet (BCF), or 12% since FY21. The PEMR 2025 [7] attributes part of this decline to IMF-led tariff increases, but gas consumption had already been falling before these reforms took effect, suggesting possible fuel switching in the industrial and power sectors.

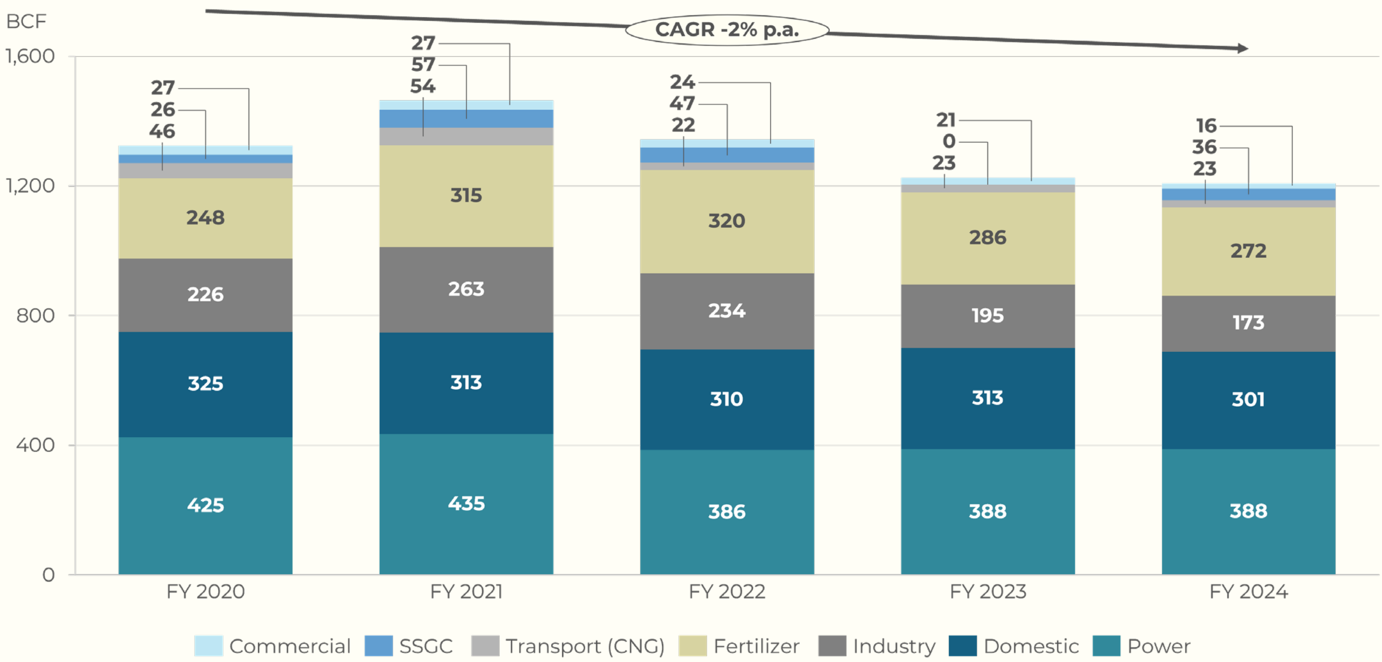


Figure 4: Sector-wise demand of natural gas, FY20- FY24

Data source: Energy yearbook 2024 (HDIP) & RFs' calculations

The share of oil products in primary supplies declined marginally by 1MTOE over the five-year period (Fig. 1). However, this aggregate view conceals a notable cyclical pattern: oil supply surged in the first two years before falling more steeply thereafter. The decline in oil consumption was more pronounced in the latter half of the review period. Initially, oil use moved in line with GDP growth, but it declined in later years even as the economy continued to expand modestly.

The transport sector accounted for the largest absolute reduction, with oil consumption falling by 4.5 MTOE since FY22, while the oil demand for power generation plunged by 83% (Fig. 5). A price shock, exacerbated by rupee depreciation, suppressed demand, alongside the growing availability of alternatives for power and generation and the industrial sector, which have greater fuel-switching flexibility than the country's largely oil-dependent transport sector.

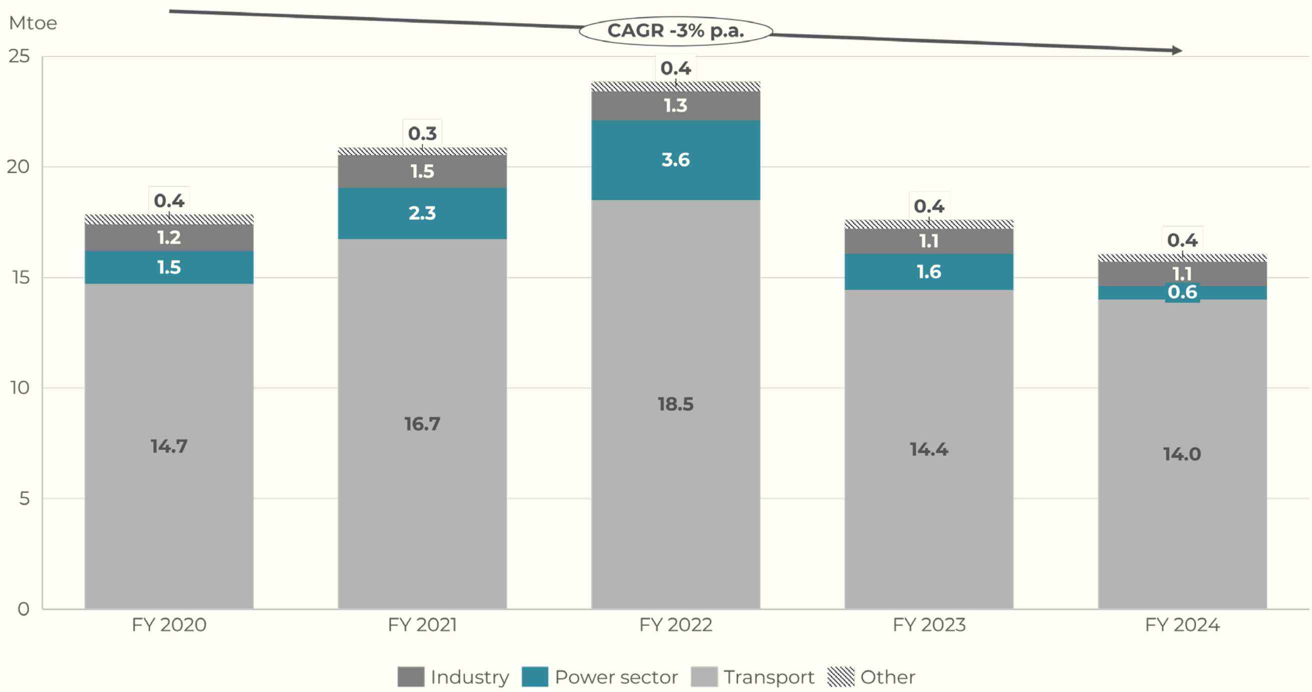


Figure 5: Sector-wise demand of petroleum products, FY20 - FY24

Data source: Energy yearbook 2024 (HDIP) & RFs' calculations

Coal use shifted across sectors without increasing total supply

The role of coal in primary supplies has declined steadily and faster than other fossil fuels with a CAGR of -5% over the review period (Fig.6). Although the power sector increased its reliance on coal from 4.9MTOE to 9.2MTOE, aggregate demand from industry and cement manufacturers fell by 70% (Fig. 6). Meanwhile, the share of domestic lignite in coal supplies has risen sharply, displacing imported coal, which has better physical properties compared with the local alternative, characterised by low energy density and high moisture content.

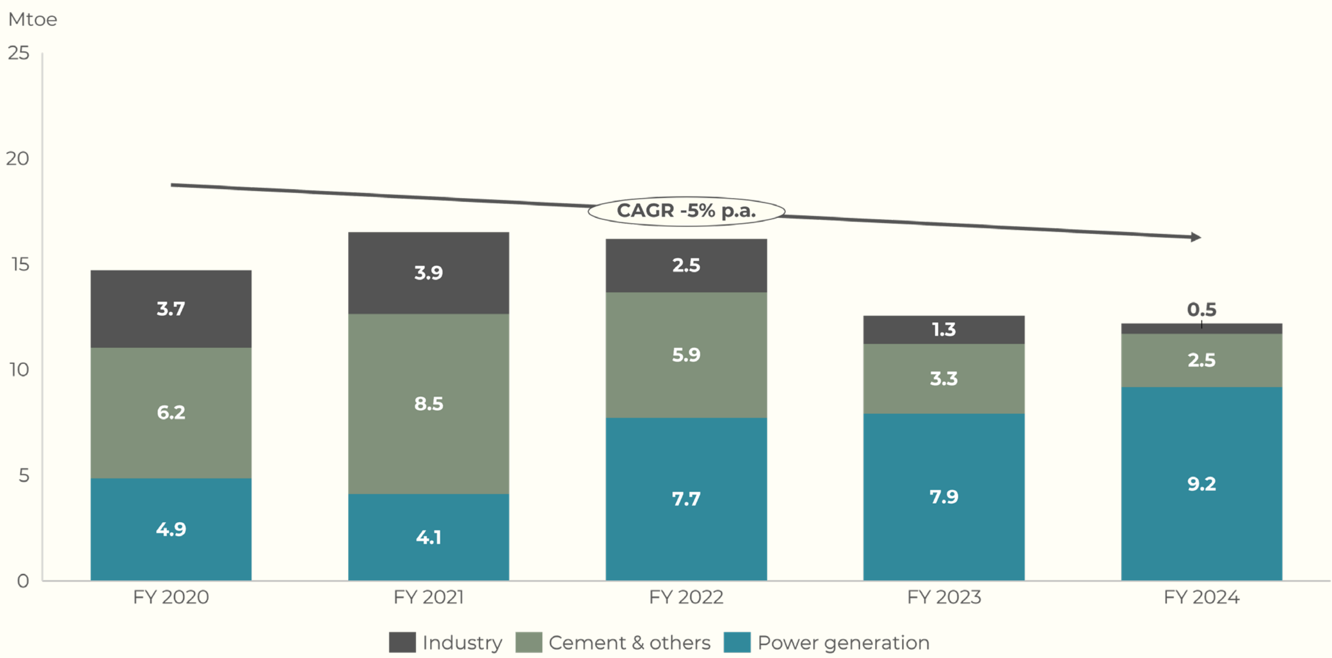


Figure 6: Sector-wise demand of coal, FY20 - FY24

Data source: Energy yearbook 2024 (HDIP) & RFs' calculations

Electricity generation and consumption also point to subdued demand. After increasing from 107 terawatt-hours (TWh) to 125TWh by FY22, grid-supplied sales fell back to around 110TWh [8] in FY24 as electricity tariffs rose by 155% [9] over 2021–24. Industrial consumers reduced their electricity consumption by 6TWh between FY22 and FY24, a relative decline of 18%, compared with a 10% reduction in the residential sector. As with other energy inputs, grid electricity demand contracted disproportionately relative to changes in economic and industrial output.

Price shocks explain part, but not the full stagnation in energy use

In summary, official statistics show that Pakistan's measured energy consumption rose in the early part of the review period before reverting to its FY20 level. While some of this stagnation can be attributed to rising prices and affordability constraints across consumer segments, the absence of continued growth sits uneasily with the economic expansion and accelerating urbanisation. Over the same period [10], the agriculture, industrial, and services sectors grew at average annual rates of 4%, 1.4%, and 3.5%, respectively. As discussed earlier, there is also little evidence of a structural transformation in the composition of the economy that would normally explain either stagnation or a a reduction in energy use.

These inconsistencies point to a second explanation: prevailing energy accounting frameworks may no longer capture the full set of energy flows shaping Pakistan's economy. The next section therefore examines what is missing from official statistics and how incorporating distributed solar generation reshapes the interpretation of recent energy trends.

4. Here comes the sun: Illuminating the blind spot in Pakistan's energy data

Pakistan has won global accolade [11] for the tremendous growth of its solar PV market, even categorised among "the fastest solar revolutions in the world" [12]. Our earlier research, "The great solar rush in Pakistan" [13], highlighted how a monumental shift in solar demand would transform the country's energy landscape. Moreover, it was noted that solar PV systems are being installed throughout the country with system sizes ranging from a single-panel solar home system (SHS) to several MW-strong plants powering major industrial units in the fertilizer, cement and textile sectors.

A growing share of energy use is missing from official reporting

Since conventional accounting methods were intended for fossil fuel-based energy systems, national statistics overlook solar energy. The gap is compounded by the fact that much of the country's solar PV capacity is being installed outside the net-metering scheme and utility-scale projects, which are easier to track. Given the strong uptake of distributed solar and its potential impacts on the country's energy balances, quantifying its scale is essential for understanding the shifting energy and power market dynamics in Pakistan.

As noted earlier, ratepayers were subjected to spiralling power prices between 2021 and 2024 without corresponding improvements in system reliability or service quality. Concurrently, the sustained expansion of Chinese solar manufacturing capacity intensified price competition, driving down PV panel prices from USD 0.25 per watt in 2020 to USD 0.10 per watt in FY24. In addition, Pakistan allowed duty free imports of solar panels, and the central bank initially offered subsidised loans through commercial banks.

Solar PV adoption has accelerated across households, farms, and industry

Solar technology thus became a natural hedge against expensive and unreliable power supply, and PV panel imports grew exponentially. By June 2025, Pakistan had spent USD 7.4B on PV panel imports representing nearly 48GW of capacity, most of which had entered the country by June 2024. Official data accounts for only net-metered capacity of 6.1GW [14] and 780MW of utility-scale buildout, highlighting a major reporting gap. While trade data is a reliable yardstick to quantify the size of domestic PV market, there is no single, fully verifiable source for installed PV capacity across different consumer segments.

Our bottom-up estimates indicate cumulative solar PV capacity of about 32GW as of June 2025 across residential, industrial, and agricultural segments. These installations extend well beyond the net-metering scheme and are financed [15] mainly through household savings and capital expenditure allocations, with partial support from commercial credit. A recent study [16] by TransitionZero (TZ) and the Policy Research Institute for Equitable Development (PRIED) used a combination of satellite images and field surveys techniques to estimate total installed solar capacity at 27–33GW. In addition, a more granular, localised analysis by Herald Analytics shows that actual capacity is often higher than the net-metered capacity reported by distribution companies (DISCOs), owing to off-grid and hybrid installations.

Energy demand has not weakened; it has been misread

Using data on solar PV imports and installation trends, we estimate Pakistan's distributed solar PV capacity to have reached 14.5GW by end-FY24, sufficient to generate over 21 TWh of electricity annually. The highly dispersed nature of these installations, however, makes it very difficult to measure their actual power generation directly. Moreover, capacity estimates do not fully capture differences in PV and inverter technologies, maintenance practices, or utilisation patterns. For instance, agricultural systems tend to be used more intensively during cropping and harvesting seasons, whereas residential and industrial systems generally operate more consistently throughout the year.

To address these uncertainties, we apply industry benchmarks and make a conservative adjustment to the estimates. Assuming a 10% under-utilisation factor, the installed capacity would have generated 19TWh of electricity in FY24, equivalent to about one-fifth of grid-supplied electricity (Fig. 7). In energy terms, distributed solar PV contributed approximately 1.6MTOE to Pakistan's final energy consumption in FY24, while displacing roughly 5MTOE of primary fossil fuel input, reflecting the relatively low efficiency of thermal power generation.

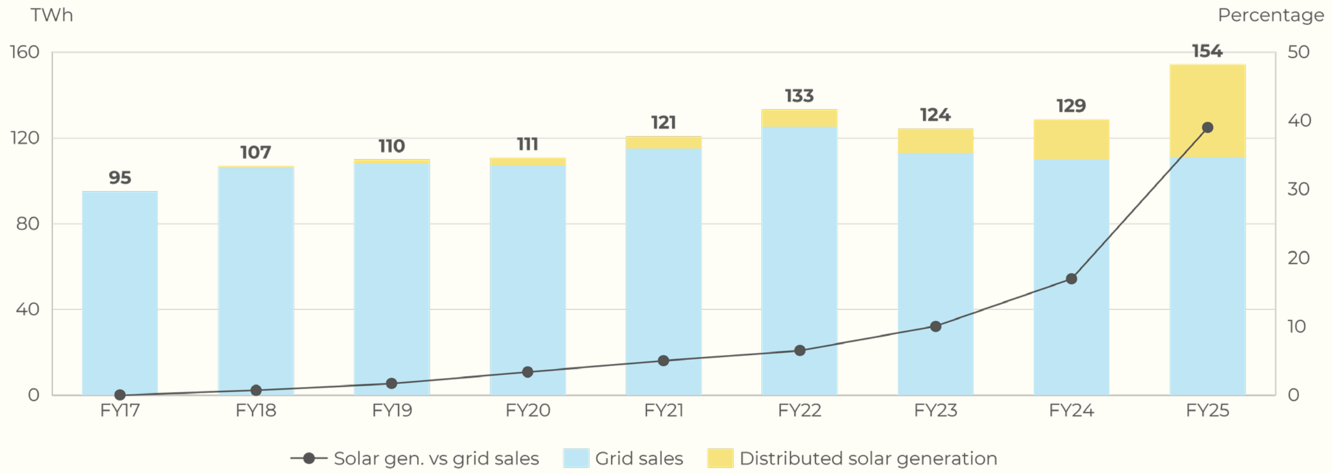


Figure 7: Grid sales vs. distributed solar generation FY17-FY25

Data source: NEPRA and RF's calculations (The Many Dividends of the Solar Rush in Pakistan)

Accurate data on distributed solar energy are key to understanding the evolving energy system

Our estimates place solar PV among Pakistan's major sources of energy, a contribution that is likely to have increased further in FY25 following a sharp expansion in installed capacity. Three broad conclusions emerge from this analysis.

First, Pakistan's energy consumption has continued to grow alongside its economy, countering claims of a decoupling between GDP expansion and energy demand. At the same time, sharp price increases and supply constraints appear to have tested the responsiveness of energy demand during this period, a dynamic that warrants more rigorous econometric examination.

Second, conventional energy accounting frameworks are not only incomplete but potentially misleading, as they fail to adequately capture the scale of distributed solar PV. Updating these legacy methodologies is essential for data-driven policymaking in an energy system increasingly shaped by decentralised electrification.

Third, a growing divergence is evident between consumer and state energy choices. Households and firms are steadily increasing their reliance on distributed renewable alternatives, public investment and planning remain anchored in a centralised, fossil fuel–based model of energy supply. At this juncture, policy choices will have consequences extending well beyond the energy sector, affecting fiscal stability, external balances, and long-term economic competitiveness.

The following section compares these alternative energy systems using two core dimensions of efficiency: economic and physical. Their relative performance is assessed in terms of electricity generated (TWh), the economics of useful energy delivered, and the extent of physical resource losses during conversion. The analysis also considers the macroeconomic implications of fossil fuel and solar PV technology imports, a critical concern for countries like Pakistan that must manage scarce foreign exchange resources carefully.

5. Assessing the outcomes of Pakistan's past energy choices

Pakistan's existing energy system has been shaped by decades of policy and investment decisions. Suboptimal planning and limited domestic oil and gas resources have led to a growing reliance on imported fossil fuels. Today, more than three quarters of the country's primary energy supply comes from natural gas, oil, and coal, with imports accounting for over 40%. Given the central role these fuels play in supporting economic activity, and the substantial financial and fiscal resources they absorb, it is important to assess the economic and physical efficiency of these energy inputs.

Import reliance exposes the economy to global price shocks

In FY24, fossil fuel imports cost PKR 4.4 trillion (T), equivalent to 10.6% of the national GDP and roughly one third of the annual import bill of USD 53.2 B (Fig. 8). This import burden is amplified by persistent currency depreciation, which augments Pakistani consumers' vulnerability to commodity price shocks. Historical episodes such as the 1973 Middle East crisis and the 2022–23 Russia–Ukraine conflict underscore the fragility and unpredictability of global fossil fuel supply chains. The former triggered a fourfold increase [17] in oil prices and reshaped global energy security policies, while the latter pushed LNG and coal prices to record highs [18].

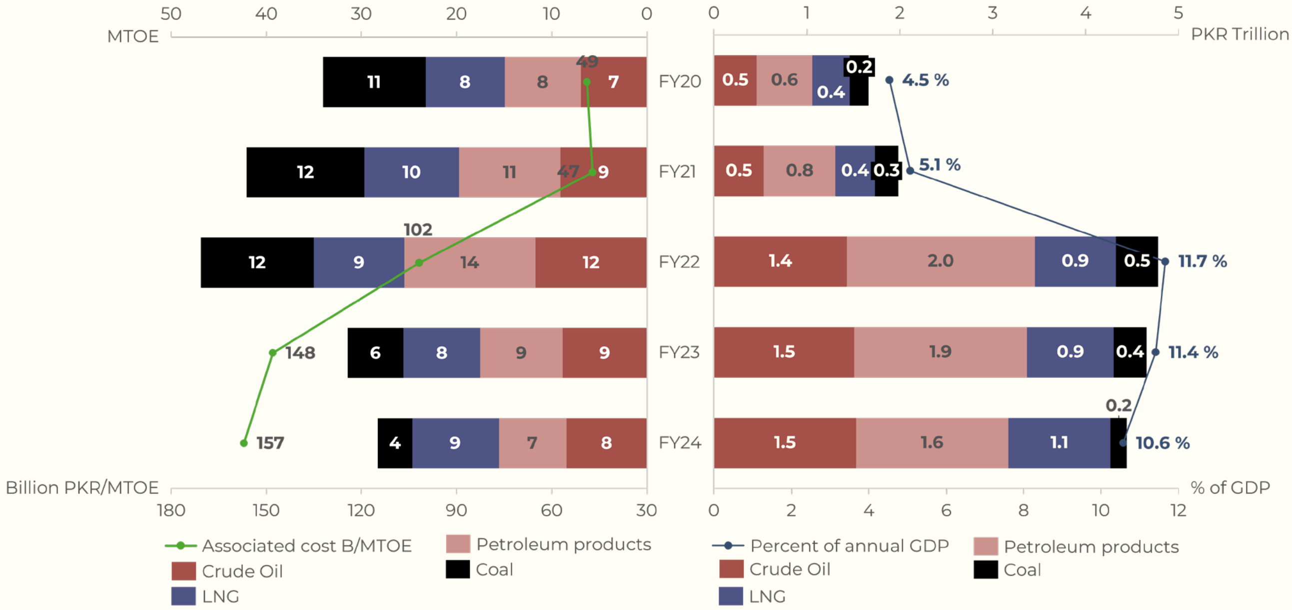


Figure 8: Fossil fuels imported by Pakistan and associated costs, FY20 - FY24

Data source: Energy yearbook 2024 (HDIP), State Bank of Pakistan & RFs' calculations

Commodity price shocks hurt developing economies disproportionately due to their limited purchasing power and fragile macroeconomic stability. This was evident during the 2022–23 energy crisis when energy imports averaged about USD 20B [19], representing over half of Pakistan's annual trade deficit. As the rupee depreciated from 158 per US dollar in 2020 to 248 in 2023, foreign exchange requirements surged to fund the ballooning import bill. The rupee-denominated cost of 1MTOE rose by approximately 215% during the 2021-23 period (Fig 9 and 10), sending inflationary shockwaves across the economy.

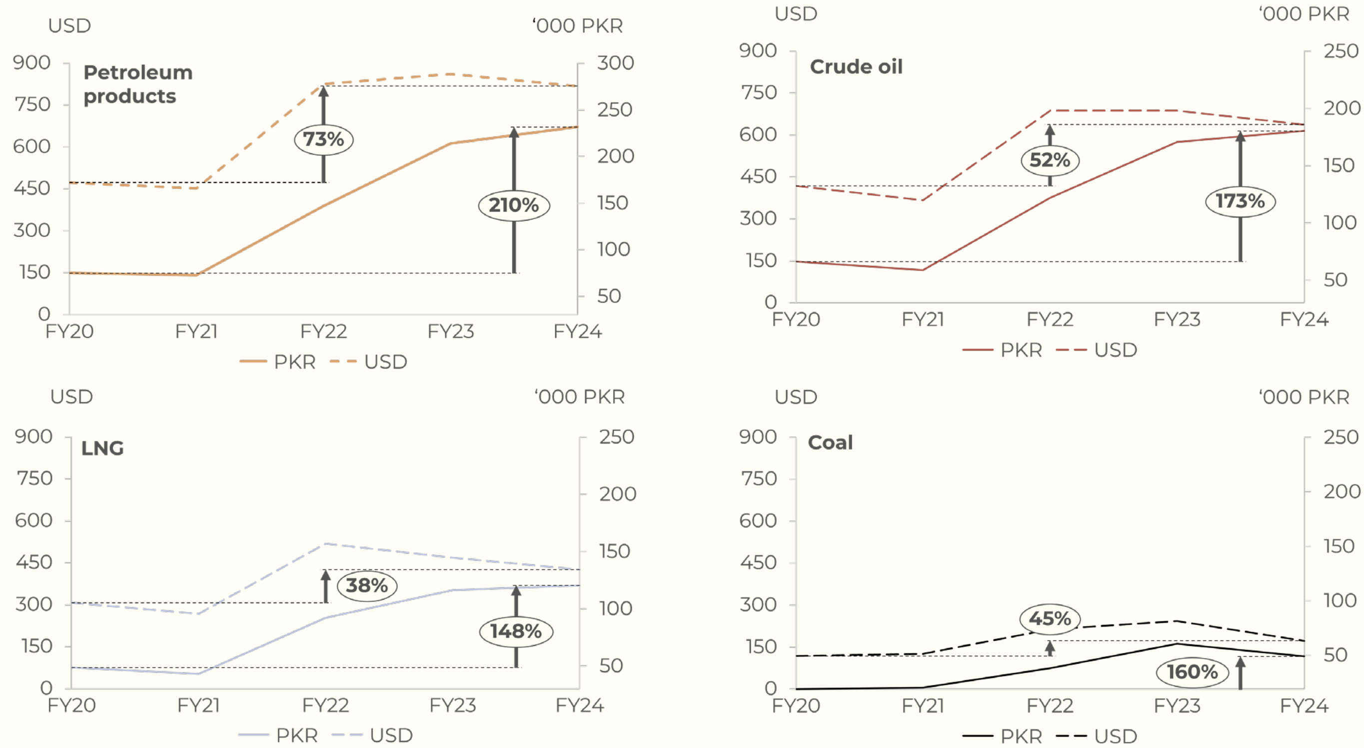


Figure 9: Unit cost of energy imports in PKR and USD per TOE, FY20- FY24

Data source: Energy yearbook 2024 (HDIP), State Bank of Pakistan (SBP) & RF's calculations

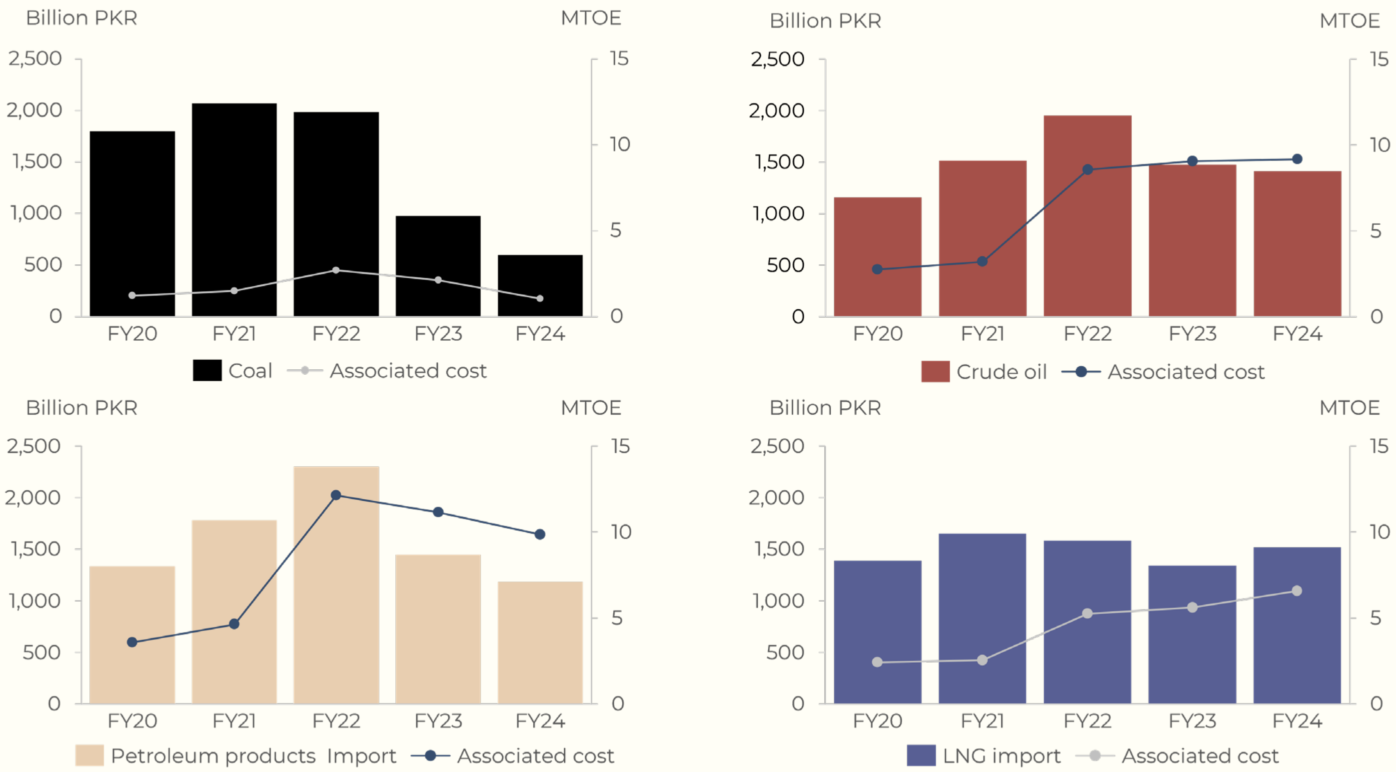


Figure 10: Fossil fuel import volumes by fuel type and total annual cost, FY20- FY24

Data source: Energy yearbook 2024 (HDIP), State Bank of Pakistan & RFs' calculations

Such import dependence reinforces a vicious cycle of currency depreciation, as Pakistan must mobilise ever larger amounts of local currency to secure foreign exchange, a challenge compounded by its narrow, low-value export base. Moreover, the local economy rarely benefits fully from declines in international commodity prices. Instead, it remains exposed to future price shocks, which further erode its already weak macroeconomic fundamentals. Therefore, an energy policy that relies heavily on imported fossil fuels is far from robust, for it lacks the basic ingredients of a risk management framework, including effective and cost-efficient hedges against unfavourable price movements while ensuring that the gains from lower prices are channelled throughout the economy.

Globally, nearly two-thirds of fossil energy is lost before delivering useful output

Physical efficiency is the second core dimension to assess the performance of Pakistan's energy system, measured by the useful energy it ultimately delivers. An assessment [20] of the global fossil energy system by the Rocky Mountain Institute (RMI) finds that nearly two-thirds of total energy input is lost before producing useful output. These losses occur across extraction and processing, transportation, and end use, and together amount to more than USD 4.5 trillion, or almost 5% of global GDP.

This framework is adapted to evaluate the physical efficiency of Pakistan's fossil fuel supplies, accounting for local factors such as sectoral share of different use cases and product mix. Primary energy inputs are converted into useful energy (Annex 1), defined as the energy available after losses during transportation, transformation, and combustion. For instance, conventional energy statistics do not capture the substantial thermal losses inherent in internal combustion engines (ICE) when petrol and diesel are used for transport. Our analysis identifies oil as the least efficient of the three major fossil fuels, with an overall efficiency of about 32% (Annex 2).

Unavoidable physical losses weaken the economic case for fossil fuels

Pakistan derives only 21.4 MTOE of useful energy from 56.5 MTOE of primary energy supply based on oil, gas and coal (Fig. 11). Put differently, every rupee spent on fossil fuels while exposing the economy to macroeconomic risks loses about 59% of its energy value to physical losses. The resulting economic value added is likely even lower, since much of this energy is absorbed by domestic consumption rather than productive activity in commerce and industry. The next section examines how distributed solar PV compares with fossil fuels on these dimensions.

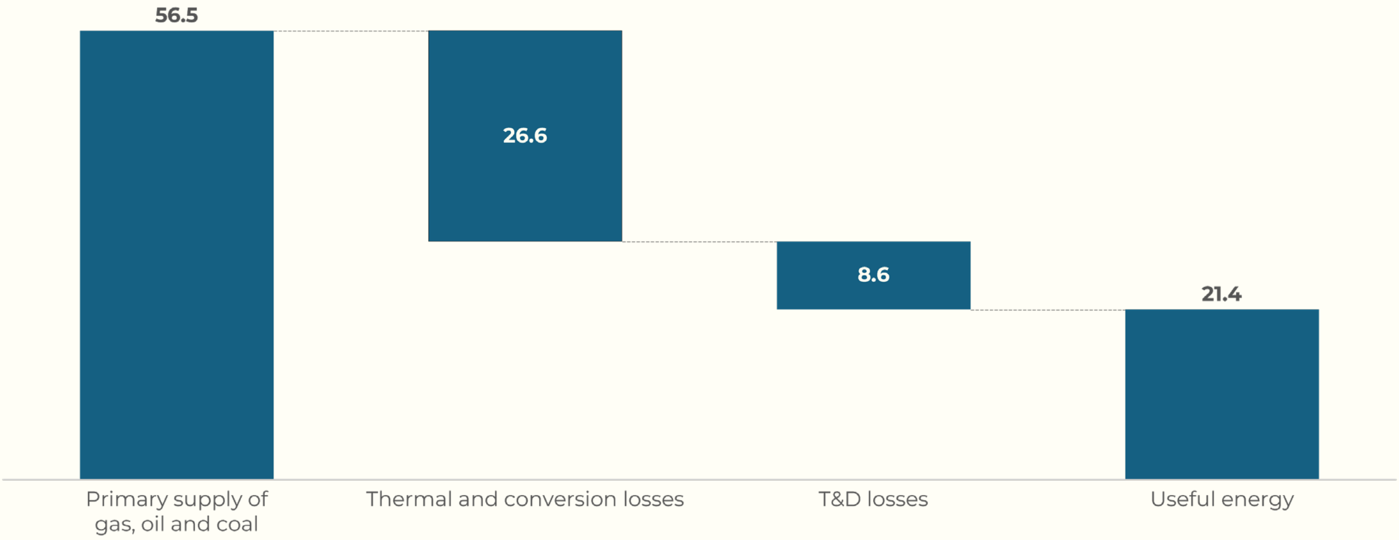


Figure 11: Fossil fuel energy flows and physical resource waste in Pakistan, FY24 (MTOE)

Data source: Energy yearbook 2024 (HDIP)) & RFs' calculations

6. Is distributed solar a more efficient alternative?

Lower costs and the relative simplicity of deployment across a wide range of use case have given solar PV technology a strong competitive advantage over any other alternative of consumer-owned energy source. In FY20, Pakistan imported 2 GW of PV capacity for a sum of PKR 63.2 B, or PKR 31.6 B per GW (Fig. 12). By FY23, the combined effects of rupee depreciation and a temporary increase in Chinese panel prices had pushed the import cost to PKR 54.5 B per GW. Yet that increase did not dampen demand.

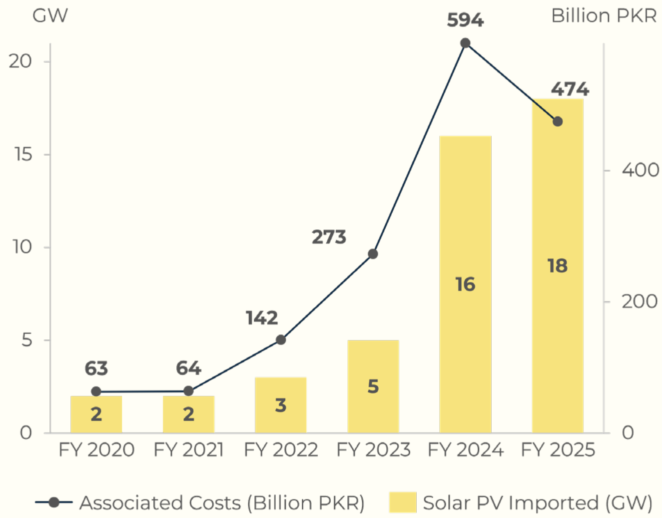
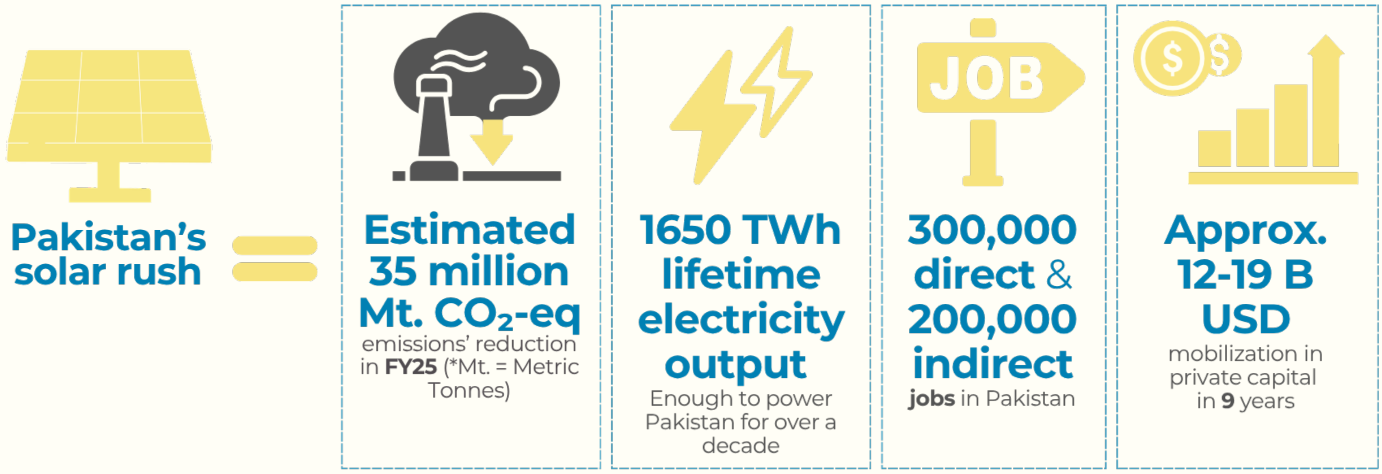


Figure 12: Solar PV imported by Pakistan from China and associated costs, FY20-FY25

Data source: Ember and RF's calculations

Intense price competition among Chinese manufacturers subsequently drove down PV panel prices, even as the rupee depreciated by a further 13% over the same period. Solar PV panels are among the few imported commodities whose prices fell in nominal terms by roughly 17% between FY20 and FY25. Once adjusted for inflation, which averaged above 15% annually during this period, the real reduction in panel prices is substantially larger, strengthening the economic case for solar adoption.



Source: The Many Dividends of Solar Rush in Pakistan, Renewables First

Spending on solar PV builds generation assets with decades-long output

To understand the broader set of macroeconomic implications, it is important to recognise that PV panels represent about 40-45% of a PV system's cost. In addition to importing PV panels worth USD 7.4B between FY17 and FY25, Pakistan is estimated to have spent about USD 2-3 B on inverters and ancillary materials and products. The remaining share of system value of, around USD 10 B, has been mobilised and retained domestically.

Unlike combustible fossil fuels, which are imported and consumed, solar PV systems constitute power generation infrastructure and are therefore capital goods. Scarce foreign exchange invested in their deployment enables consumers to benefit from electricity output over a lifespan of 25–30 years. Once the imported capacity of roughly 48 GW (as of June 2025) is fully operational, it could generate about 1,650 TWh of electricity over its lifetime equivalent to roughly 15 years of Pakistan's current annual grid-supplied electricity consumption of 110 TWh.

Producing an equivalent volume of electricity using Pakistan's coal- and gas-based power fleet would require an estimated 330–400 MTOE of primary fossil fuel input, depending on the generation mix and plant efficiencies. At FY24 import prices and exchange rates, this corresponds to USD 100–120 B in avoided fuel imports. Moreover, while solar power would cost PKR 3.5-5/kWh [1], the blended cost of electricity generated from domestic and imported fossil fuels stood at 29-32 Rs/kWh in FY24 and FY25.

Evaluated on a lifetime basis, solar PV therefore offers a structurally superior pathway for import substitution, converting upfront capital expenditure into decades of energy supply while avoiding large and recurring foreign exchange outflows. Viewed in this light, solar technology functions not merely as an energy alternative but as a potential macroeconomic stabiliser.

Electrified end uses deliver two to three times higher physical efficiency

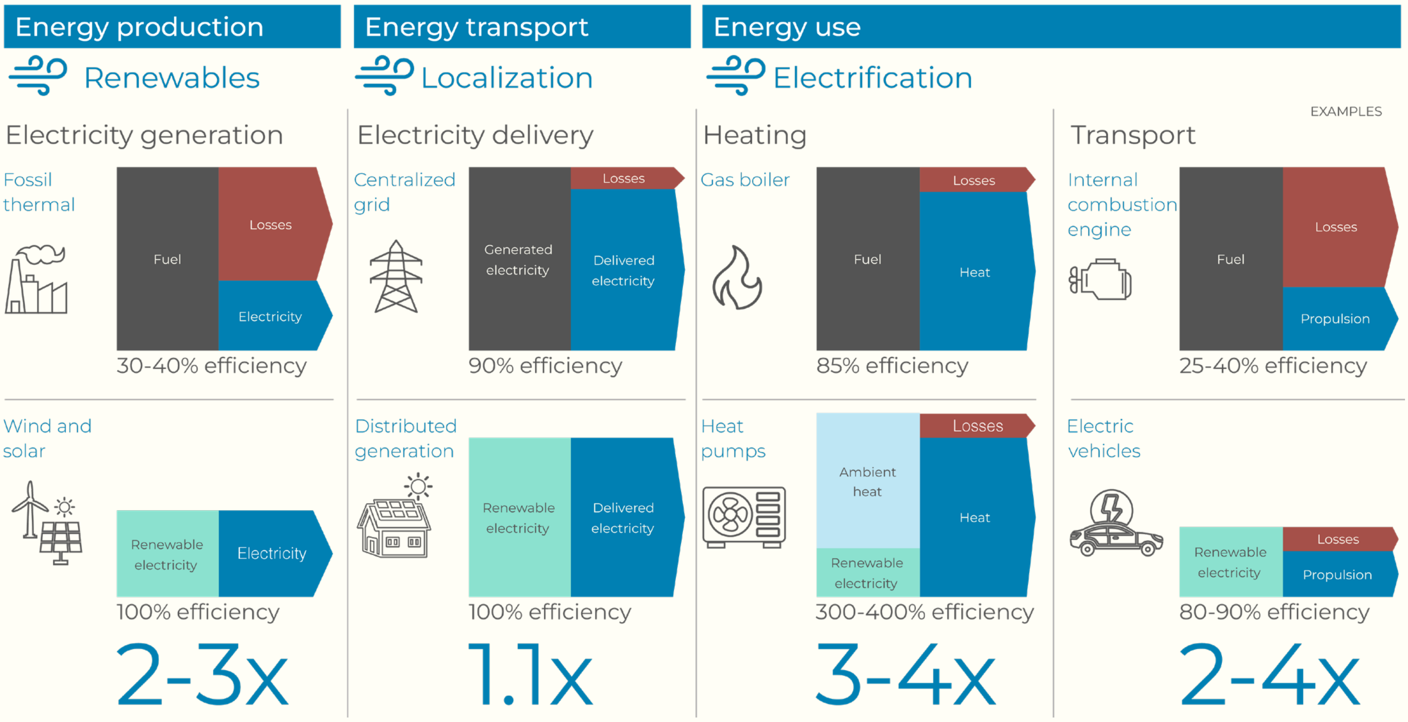
The physical efficiency of distributed solar PV rests on two key advantages: the proximity of generation to consumption and the superior efficiency of electrified end uses relative to combustion-based technologies. The transport sector provides a clear illustration of this contrast. Electric motors typically convert more than 80–90% of delivered electricity into useful work [21], compared with the conversion efficiencies of roughly 20–40% in ICEs.

Assuming that personal mobility accounts for 60% of annual oil consumption of 16.9MTOE, this corresponds to 118 TWh of primary energy input to deliver only 33 TWh of useful traction. By comparison, achieving a similar level of mobility through electric vehicles would require nearly 40 TWh of electricity, reflecting their much higher conversion efficiency and reducing physical resource requirements by nearly two-thirds. Since distributed generation is largely insulated from transmission and distribution losses, electrifying personal mobility through solar PV could displace more than half of Pakistan's oil demand, delivering substantial physical and economic efficiency gains. Over time, residential and industrial consumers are also likely to increase the utilisation of distributed generation by electrifying a wider range of energy services.

Pakistan's continued reliance on oil and gas reflects legacy policy choices rather than comparative economic or physical efficiency of these fuels. Despite playing a role in supporting the economic activity, they remain a persistent source of macroeconomic vulnerability and resource wastage. Distributed solar PV, by contrast, reflects a fundamentally different energy logic, characterised by higher conversion efficiency and lower system losses.

[1] It is assumed that the total cost of adding 48GW of solar PV capacity is USD 20 B, without financing costs.

Viewed through the combined lenses of economic and physical efficiency, the ongoing shift toward electrification appears less as a discretionary policy choice and more as the logical outcome of evolving energy economics and consumer behaviour. The central question for policymakers is therefore not whether Pakistan will electrify, but whether this transition will be guided through coordinated planning and institutional reform or continue to unfold in an ad hoc and uncoordinated manner. The implications of this choice are explored in the following section.



Source: Rocky Mountain Institute

7. Towards an electrified future

Pakistan's historical energy trajectory has imposed high costs on both the economy and consumers, underpinning the inefficiencies and risks associated with sustained fossil fuel dependence. As shown in the preceding sections, future economic growth increasingly depends on our own energy choices. In this context, the expansion of distributed solar generation points toward a broader strategic imperative: to increase the share of renewable electricity across Pakistan's energy and economic activities, thereby moving toward a more electrified energy system. While distributed generation alone does not constitute a national energy system, its rapid uptake highlights the direction in which the system is already evolving.

The term electrostate [22], now widely used in geopolitical and energy policy debates, refers to an economy in which electricity, rather than combustible fuels, becomes the dominant energy carrier. Under such a configuration, electrification is driven not by technology preference but by efficiency outcomes, as renewable electricity sources increasingly outperform fossil fuels on both cost and conversion efficiency. As electrification deepens, the role of fossil fuels would diminish, particularly where renewables can deliver comparable energy services at lower economic and physical cost. Electrostates are further characterised by the expanding deployment and, in some cases, domestic production of clean energy technologies such as solar panels, battery storage systems, and electric vehicles.

China is often described as the world's "first significant electrostate" [23], owing to its rapid electrification and clean tech manufacturing prowess. While China represents a highly advanced case, Pakistan's experience suggests that dividends of an electrostate can emerge even in economies without extensive domestic manufacturing capacity. As demonstrated earlier, Pakistan is already harvesting efficiency and cost benefits from the use of distributed solar PV. Evidence of local value addition in installation, services, and downstream activities further points to the potential for broader economic spillovers as electrification expands. Over time, this creates the possibility of a gradual transition from a primarily consumer-led electrostate toward one that also develops domestic clean tech production capabilities.

Electrification offers a pathway to higher efficiency and resilience

A more rigorous set of industrial and energy policies will be needed to grow the role of renewables and clean tech in displacing the country's fossil fuel consumption while building capabilities to meet this growing demand through local manufacturing. Although some degree of import reliance may persist in the near term, electrification will open pathways for industrial diversification by shifting expenditure from recurrent fuel imports toward investment in equipment, infrastructure, and domestic capabilities. In this sense, electrification should be viewed not only as tool for energy transition but as part of a broader industrial and economic transformation.

At the same time, the proposed transformation presents challenges that must be addressed. First, transmission and distribution companies, originally designed for centralised, one-way energy flows, will need to evolve from passive energy sellers into active system operators and platform managers. Their financial and technical capacity will be critical, as higher shares of consumer-owned and variable generation assets require investments in grid flexibility, digital infrastructure, and system balancing capabilities.

Second, this transition implies a large-scale reallocation of capital toward grid flexibility, battery storage, and electrified end uses. As discussed in Renewables First's study Market Diagnostic Study 2025: Solar Financing Landscape for Retail and SME Segments [24], Pakistan's distributed solar expansion has been driven mainly by self-financed household and business investments, indicating strong underlying demand. Scaling electrification will require deeper financial intermediation, risk mitigation instruments, and targeted credit mechanisms to channel both domestic and institutional capital into the manufacturing and deployment of clean technologies.

An electrostate requires integrated energy and industrial planning

The evidence in this study suggests that Pakistan's shift towards electrification is already being driven by consumer-level economics rather than formal policy direction, with households and businesses adopting electric and distributed energy solutions largely outside coordinated planning frameworks. The central policy challenge, therefore, is not whether electrification will occur, but how institutions, regulation, and utility models will adapt in time to accommodate it. Absent such adjustment, the transition is likely to proceed in an uncoordinated manner, increasing fiscal pressure on utilities and prolonging exposure to volatile fuel imports. A more deliberate response, however, will reduce macroeconomic risk and improve system efficiency by aligning policy and planning with changes already underway.

Finally, the distributional implications of electrification merit careful attention. The benefits of a more electrified energy system may accrue unevenly across sectors and actors, while costs may be concentrated among those tied to legacy fossil fuel value chains. Managing this transition effectively will therefore require policy frameworks that can broaden access to electrification benefits while providing credible adjustment pathways for affected workers, firms, and regions. This reinforces the importance of the coordinated planning apparatus highlighted throughout this section.

The challenge is governance, not technology availability

The evidence in this study suggests that Pakistan's shift towards electrification is already being driven by consumer-level economics rather than formal policy direction, with households and businesses adopting electric and distributed energy solutions largely outside coordinated planning frameworks. The central policy challenge, therefore, is not whether electrification will occur, but how institutions, regulation, and utility models will adapt in time to accommodate it. Absent such adjustment, the transition is likely to proceed in an uncoordinated manner, increasing fiscal pressure on utilities and prolonging exposure to volatile fuel imports. A more deliberate response, however, will reduce macroeconomic risk and improve system efficiency by aligning policy and planning with changes already underway.

8. Conclusion

This paper set out to explain an apparent inconsistency in Pakistan's economic and energy data: how an economy experiencing population growth and modest GDP expansion could appear to consume less energy. By revisiting official statistics and accounting for distributed solar generation outside conventional reporting frameworks, the analysis shows that this pattern reflects incomplete measurement rather than a decoupling between economic activity and energy use. Once distributed solar PV is incorporated, Pakistan's energy consumption aligns broadly with its economic trajectory.

A central contribution of this study is to complete Pakistan's energy picture by quantifying the scale of distributed solar adoption using trade data and independent capacity estimates. The omission of this rapidly growing energy source from conventional reporting frameworks distorts aggregate trends and weakens the basis for energy policy decisions. Accurate and comprehensive energy accounting is therefore a prerequisite for credible analysis and effective planning.

Evaluating Pakistan's energy system through the lenses of economic and physical efficiency further clarifies the implications of this shift. Fossil fuels impose recurring macroeconomic costs through import dependence and price volatility, while delivering relatively low levels of useful energy. Distributed solar PV, on the other hand, converts upfront expenditure into power generation assets and supports far more efficient energy delivery, particularly when paired with electrified end uses.

These findings suggest that Pakistan's energy challenge is not one of declining demand, but of incomplete energy accounting methodology and policy misalignment. Consumer-led adoption of distributed solar indicates that electrification is already reshaping the energy system. The task ahead is to align planning, regulation, and data frameworks with this reality, treating distributed generation as a core system asset rather than an exception.

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Annex 1: Energy accounting framework

This paper adopts a three-layer energy accounting framework to assess Pakistan's energy system: primary energy supply, final energy input, and useful energy. This distinction is critical for understanding both the physical efficiency of different energy sources and their economic implications

1. Primary energy supply (PES) refers to energy in its raw or procured form before any conversion or transformation takes place such as crude oil, coal, natural gas, or non-combustible sources like hydropower and solar radiation. Official energy balances, including those produced by the International Energy Agency (IEA), typically report energy at this level to enable comparability across fuels. However, for thermal electricity generation, PES embeds large conversion losses that do not reflect energy actually delivered to end users.

2. Final energy input (FEI) represents energy supplied to end users after transformation electricity delivered to the grid, petrol at the pump, or gas supplied to households and industry. At this stage, electricity from all sources is treated as a common carrier and measured in physical units (TWh or MTOE), consistent with the IEA's post-2016 "physical energy content" approach for non-thermal renewables.

3. Useful energy goes one step further by accounting for end-use efficiency the portion of final energy that performs actual physical work, such as vehicle propulsion, industrial heat, or mechanical output. This layer exposes substantial inefficiencies embedded in fossil fuel use, particularly in internal combustion transport and thermal power generation, while highlighting the efficiency advantage of direct electrification.

This framework responds to long-standing critiques of conventional primary-energy accounting, notably articulated by Michael Liebreich, who has argued that grossing up renewable electricity to fossil-equivalent primary energy obscures real system efficiency and misrepresents the role of clean technologies. By explicitly separating conversion losses from delivered and useful energy, this paper provides a clearer basis for comparing fossil fuels with solar PV and other non-combustible energy sources in Pakistan's context

Annex 2: Fuel-wise energy flows and waste in Pakistan, FY24 (MTOE)

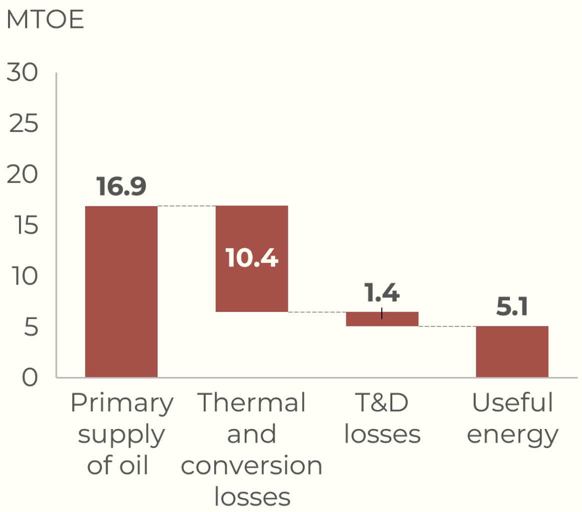
OIL					
End-use category	**Final energy input (TOE)**	**Share of total PES (%)**	**Assumed efficiency (%)**	**Useful energy (TOE)**	**Notes / benchmark**
Transport (road)	14,026,456	90.62%	28%	3,927,408	Internal combustion engines, low-end use efficiency
Aviation (jet fuel)	515,886	3.33%	30%	154,766	
Industry (FO, HSD, LDO)	1,082,414	6.99%	80%	865,931	Direct combustion for boilers, furnaces and captive power
Agriculture	15,118	0.10%	30%	4,535	Diesel-powered tractors, tube-well and machinery
Domestic (kerosene, etc.)	25,437	0.16%	40%	10,175	Traditional stoves and lamps, high loss and declining share due to electrification and/or LPG substitution
Other govt. / miscellaneous	328,640	2.12%	30%	98,592	Excludes oil used for power generation
Total (non-power oil)	**15,478,064**	**100%**		**5,061,407**	
Efficiency %				**33%**	

GAS					
End-use category	**Final energy input (TOE)**	**Share of total PES (%)**	**Assumed efficiency (%)**	**Useful energy (TOE)**	**Notes / benchmark**
Power generation	7,481,690	48%	40%	2,992,676	Fleet-weighted efficiency (RLNG CCGTs + older/open-cycle plants)
Domestic (cooking, water heating)	7,033,633	45%	55%	3,868,498	Household cooking + water heating mix
General industry + PSM	4,039,452	26%	85%	3,433,534	Boilers & industrial process heat
Fertiliser – feedstock	4,427,285	29%	0%	—	Chemical feedstock (excluded from useful energy)
Fertiliser – as fuel	793,054	5%	85%	674,096	Process heat
Commercial	379,827	2%	85%	322,853	Space & water heating
Other sectors	534,765	3%	85%	454,550	Mixed heat uses
Total (energy services)	**24,689,706.00**	**100%**	—	**11,746,207**	Excludes feedstock
Total (subtracting the gas held in pipeline and feedstock)	**20,262,421**		—		Feedstock shown separately
Efficiency %				**58%**	

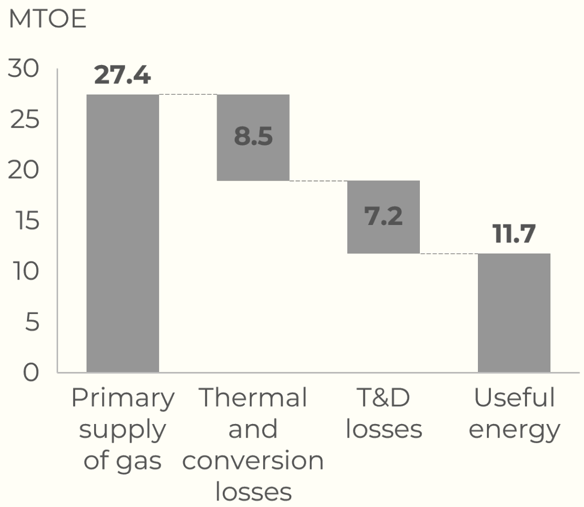
COAL					
End-use category	**Final energy input (TOE)**	**Share of total PES (%)**	**Assumed efficiency (%)**	**Useful energy (TOE)**	**Notes/benchmark**
Power generation	9,177,934	75.18%	35%	3212276.9	Power coal mix: 71% local lignite / 29% imported (cost-driven dispatch); fleet-weighted efficiency benchmark (nepra.org.pk)
Cement & other industry	2,524,427	20.68%	50%	1262213.5	Kiln thermal efficiency range reported ~25–55% depending on kiln type; 50% used as a practical benchmark (unido.org)
Brick-kiln industry	505,236	4.14%	20%	101047.2	Traditional kilns have high losses; 20% benchmark for mixed kiln stock (ccacoalition.org)
Domestic	749	0.01%	20%	149.8	Negligible volume
Total coal FES	**12,208,346**	**100.00%**		**4575687.4**	—
Efficency %				**37%**	

Annex 3: Graphical representation of fuel-wise energy flows and waste in Pakistan, FY24 (MTOE)

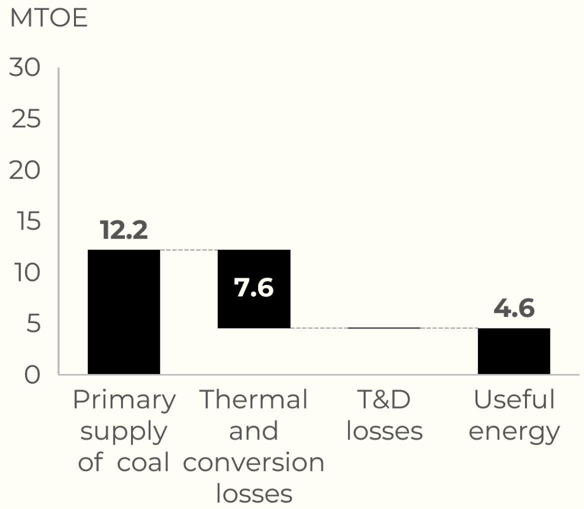
Energy Flows and Waste from **Oil**



Energy Flows and Waste from **Natural Gas**



Energy Flows and Waste from **Coal**



Renewables First (RF) is a think and do tank for energy and environment. Our work addresses critical energy and natural resource issues with the aim to make energy and climate transitions fair and inclusive.

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