

Energizing Karachi: uncovering solutions for long-standing shortfalls

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Abstract. This study investigates Karachi's enduring energy shortfall, which has plagued the city for decades. By analyzing monthly time series data from January 2009 to December 2021 using Pearson correlation, Vector Auto Regression (VAR), and Tobit model, we aim to draw conclusions. Our findings underscore a significant disparity btw energy demand and supply across various sectors of Karachi, including residential and industrial consumption. This imbalance leads to frequent load shedding, exacerbating the city's challenges. Importantly, our research suggests that conventional methods of load shedding fail to empirically alleviate this shortfall. Furthermore, we ascertain that the shortfall significantly influences the unit prices of energy for households and industries alike.

1 Introduction

Pakistan's energy crisis, which emerged in FY2007 and escalated through FY2008-FY2021, has strained the national budget and hindered growth. By FY2019, the energy supply deficit had surged to 15,000 MW during peak summer months, resulting in prolonged power outages and gas shortages. This paper focuses on Karachi's electricity demand, supply, and the resultant gap. We examine whether load shedding offers a viable solution to mitigate the energy shortfall and its impact on unit prices for households, industries, and the government sector (Ivanova, 2023; Luekveerawattana & Sawangdee, 2021).

Karachi is currently grappling with a severe energy crisis exacerbated by inefficient resource utilization. The socioeconomic repercussions of this shortfall are pervasive, affecting all sectors of national life. While global economic recession contributes to some economic challenges, the energy supply shortfall distinctly exacerbates these issues. Industrial closures or reduced production, stemming from energy shortages, lead to unemployment and diminished incomes for workers.

Despite efforts by the Government of Pakistan to address this issue, enhancing energy efficiency emerges as a crucial, cost-impactive short-term solution for sustainable macro-

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economic growth. Improved energy supply has the potential to boost employment, economic productivity, and poverty reduction efforts. Additionally, it can mitigate the negative impacts on social life, education (specifically in the time of tech based education), and overall quality of life.

2 Literature Review

The technical incompetence of Pakistan's power sector has garnered limited attention from various scholars. Energy crises have long plagued Pakistan, profoundly affecting its socioeconomic landscape. Energy stands as a linchpin for any country's economy in the modern era, and power shortages can precipitate severe economic repercussions, diminishing both agricultural and industrial output [1-15].

The severity of Pakistan's energy crisis has escalated in recent years. In 2008, amidst industrial woes caused by the energy crisis, the government hiked commercial tariffs from Rs 8-10 per unit to Rs 14 per unit, with domestic tariffs also increasing from Rs 5-7 per unit to Rs 8-10 per unit and in 2023 commercial tariff increased to Rs 60 per unit and domestic tariff to Rs 35 per unit that made all customers in a un bearable conditions. Despite Karachi Electric grappling with financial turmoil, exacerbated by reluctance to generate electricity via furnace oil to maintain generation of revenue, the shortfall persisted and intensified in subsequent years. By 2010 to onwards, daily electricity demand surged from 14,000-15,000 megawatts to a staggering 20,000 megawatts [16-18].

KE formerly known as KE, serving approximately 20 million domestic consumers and 4,500 industrial consumers, faces escalating demand exacerbated by dwindling gas supplies. With gas supply reduction, furnace oil emerges as the primary, albeit costly, alternative for energy production. The unfulfilled quota of furnace oil during peak summer seasons exacerbates load shedding. Skyrocketing furnace oil prices, soaring by approximately 250% in two years, render oil-based power generation prohibitively expensive. Each 25 MMCFD decrease in gas supply inflates tariffs by 0.83, compounding the burden on consumers (KE Newsletter, 2011).

KE presently generates 65% of total energy demand, with the remaining 35% sourced from WAPDA and Independent Power Producers, facilitated by around 60 grid stations and 125 power transformers (KE Facts & Figures). Researchers Yazdanie and Rutherford (2010) advocate for solar and wind power generation to alleviate Pakistan's energy demands, emphasizing the need for diversified energy sources.

Muhammad and Ahmed (2009) underscore the government's role in implementing cost-impactive electricity generation methods. They advocate for exploring various energy sources, including coal, gas, oil, nuclear, and hydroelectric power. Despite Pakistan's reliance on fossil fuels for 66% of electricity production, Yazdanie and Rutherford (2010) argue that such efforts are insufficient for a country facing burgeoning population and energy challenges.

Comparatively, the United States relies on coal for 50% of electricity generation, followed by natural gas (25%) and petroleum, biodiesel, and solar thermoelectric sources (Younos & Poole, 2009; Mai et al., 2019; Ushakov et al., 2022; Alayli, 2023). Yazdanie and Rutherford (2010) critique Pakistan's centralized power generation structure for impeding decentralized systems' adoption, highlighting the absence of institutions responsible for fostering innovation in power generation.

They lament the lack of trained personnel to address the energy crisis effectively. Notably, household consumption constitutes 45.6% of Pakistan's electricity usage, with 28.4% attributed to industry. In contrast, developed countries allocate 15-20% of energy to households. Dzioubinski and Chipman (1990) advocate for energy-efficient appliances to reduce household energy consumption, citing the success of such initiatives in North

America and Europe compared to Asia, where energy-efficient practices lag behind (Nasir et al., 2009; Dzioubinski & Chipman, 1990).

3 Propositions and Hypotheses

Drawing from the literature reviewed earlier, we have formulated the following hypotheses to investigate the propositions outlined in this paper:

H1: There exists a disparity btw the electricity demand in the Karachi region and the supply provided by Karachi Electric.

H2: There is a correlation btw the electricity demand in the Karachi region and the supply provided by KE.

H3: An association exists btw the electricity demand in the Karachi region and the gap btw demand and supply provided by KE.

H4: There is a correlation btw the electricity demand and the occurrence of electricity load shedding in the Karachi region.

H5: Electricity load shedding mitigates the gap btw the electricity demand and supply in the Karachi region.

H6: The gap btw the electricity demand and supply, at a given order (p), predicts the KE's per unit prices for domestic usage at the current order.

H7: The gap btw the electricity demand and supply, at a given order (p), predicts the KE's per unit prices for industrial usage at the current order.

H8: The gap btw the electricity demand and supply, at a given order (p), predicts the KE's per unit prices for government usage at the current order.

4 Methodology of Research

In order to tackle the deficiencies within the power sector, we gathered monthly time series data from January 2009 to December 2021 from the official website of Karachi Electric (KE). These data encompassed key indicators such as electric power demand in the Karachi region, electric power supply by Karachi Electric, load shedding practices, and per unit pricing for domestic, industrial, and government consumers. The propositions of this study were evaluated and examined using Pearson correlation, Scaled Ordinary Least Squares (Tobit Model /Censored regression), and auto regressive process (VAR).

The Tobit model was utilized to examine the potential fluctuations in load shedding within the current order resulting from changes in the gap between electricity demand and supply at the same order. Simultaneously, AR Process/VAR analysis was performed to investigate potential variations in Karachi Electric's per unit prices for domestic, industrial, and government consumption within the current order, taking into account variances in the demand-supply gap at orders $p=1$ and $p=2$.

5 Findings and Results

Descriptive Findings

Table 1 on the findings via descriptive analysis demonstrates a significant gap btw the demand for electricity in the Karachi region and the supply provided by KE, with a significant difference observed over the last 36 months (i.e., $\text{gap} = 10,00000$, $p < 0.05$). Consequently, we fail to reject H1 (i.e., There is a Gap btw the demands and Supply for electricity).

Table 1: Means (AM) for 1:2009- 12:2011 for the Key Indicators

Demand	2,500,000.00 (MV)
Supply	1,500,000.00 (MV)
Gap	10,00000 (MV) at $p < 0.05$
Figures are rounded off	

Findings via Pearson Correlation

The correlation matrix in Table 2 indicates a strong and significant association btw the supply and demand of electricity in the Karachi region ($r= 0.950$, $p= 0.000$) leading to the acceptance of hypothesis of H2. additionally, a significant association is observed btw the demand for electricity and the gap btw demand and supply in Karachi ($r= 0.550$, $p= 0.000$) leading to the failure to reject hypothesis H3as mentioned in hypotheses assessment summary. Further, a significant correlation is found btw the demand for electricity and the occurrence of load shedding in Karachi ($r= 0.450$, $p= 0.000$) resulting in the failure to rejectof H4 as also mentioned in hypotheses assessment summary.

Findings via Tobit Model

As shown in Table 3, Tobit estimates indicate that load shedding does not diminish the gap btw electricity demand and supply in the Karachi region (Tobit Coef = 1450.000, $p= 0.1200 > 0.05$). Therefore, we cannot support H5 as mentioned and highlighted in hypotheses assessment summary.

Table 2: Associations btw the key indicators for the order ($p=1$)

		Demand for Electric Power for Karachi region
Demand	Pearson Correlation	1
	Sig.(2-tailed)	
Supply	Pearson Correlation	0.950**
	Sig.(2-tailed)	0.000
Gap	Pearson Correlation	0.550*
	Sig.(2-tailed)	0.000
Load-shedding	Pearson Correlation	0.450*
	Sig.(2-tailed)	0.000

Table 3: Tobit estimates for the gap btw the demand and supply for electric power at the current order and load shedding for the same current order

Method: Maximum Likelihood (TOBIT) (Quadratic hill climbing) Dependent Variable: GAP				
Convergence achieved after 5 iterations				
Covariance matrix computed using second derivatives				
	Coefficient	Std. Error	z-Statistic	Prob.
LOADSHED	1450.00	940.5998	1.55600	0.1200
C	-25340.00	129900.0	-0.20000	nce 0.8500
Error Distribution				
SCALE:C(3)	81240.00	11730.00	6.93000	0.0000
Mean dependent var	178132.7	S.D. dependent var	88280.51	
S.E. of regression	89813.45	Akaike info criterion	27.59876	
Sum squared resid	1.67E+13	Schwarz criterion	26.97532	
Log likelihood	-314.2440	Hannan-Quinnriter.	26.78728	
Avg.log likelihood	-14.53421			

Findings via Vector Auto Regression

Table 4 displays VAR estimations for orders $p=1$ and $p=2$, assessing hypotheses H6, H7, and H8. The estimations indicate that the disparity between electricity demand and supply at order $p=2$ significantly influences its per unit price for domestic use ($t=1.7000$), leading to the non-rejection of hypothesis H6. Similarly, the gap between electricity demand and supply at order $p=2$ significantly affects its per unit price for industrial use ($t=1.54891$), resulting in the non-rejection of hypothesis H7. However, the gap/ disparity between electricity demand and supply at any order ($p=1, p=2$) does not impact its per unit price for government use ($t=0.23828$), leading to the non-acceptance of hypothesis H8 as highlighted in hypotheses assessment summary in table 5.

6 Discussions and Conclusion

This study underscores the significant and escalating energy shortfall, represented by the gap btw the demand for electricity in Karachi and the supply provided by Karachi Electric (KE). This gap continues to widen alongside increasing energy consumption, adversely impacting the lives of Karachi residents and the city's commercial activities. Karachi, as Pakistan's premier business hub and a bustling metropolis, faces existential threats due to this persistent energy crisis.

Table 4: VAR estimates for KE per unit prices for domestic, industrial, and government use at the current order and the gap btw the demand and supply for electric power at the p order ($p=1, p=2$)

DV=KE per unit prices for domestic consumption/use IV=gap btw the demand and supply for electric power at the p order ($p=1, p=2$).	DV= KE per unit prices for Industrial consumption/use IV=gap btw the demand and supply for electric power at the p order ($p=1, p=2$).	DV= KE per unit prices for Govt. consumption/use IV=gap btw the demand and supply for electric power at the p order ($p=1, p=2$).			
per unit price for domestic use	per unit price for industrial use	per unit price for govt. use			
PRICEDOM(-1)	0.930123 [0.61800]	PRICEIND(-1)	0.568231 [0.50000]	PRICEGOV(-1)	0.496731 [1.10000]
PRICEDOM(-2)	0.5210731 [0.96789]	PRICEIND(-2)	0.618378 [0.73000]	PRICEGOV(-2)	0.260920 [1.07011]
GAP(-1)	3.88E-09 [0.21101]	GAP(-1)	-1.47E-06 [-0.97368]	GAP(-1)	3.59E-06 [0.78029]
GAP(-2)	1.80E-06 [1.70000]	GAP(-2)	2.98E-06 [1.54891]	GAP(-2)	8.05E-07 [0.23828]
C	1.079011 [1.79100]	C	-0.939872 [-0.98791]	C	2.240911 [1.29801]
R-squared	0.735829	R-squared	0.719811	R-squared	0.662879
Adj. R-squared	0.720311	Adj. R-squared	0.697191	Adj. R-squared	0.588329
F-statistic	65.19801	F-statistic	45.77291	F-statistic	9.801110

Table 5: Hypotheses Assessment

Hypotheses	Empirical Conclusion
H1: There exists a disparity btw the electricity demand in the Karachi region and the supply provided by Karachi Electric	Accepted
H2: There is a correlation btw the electricity demand in the Karachi region and the supply provided by KE	Accepted
H3: An association exists btw the electricity demand in the Karachi region and the gap btw demand and supply provided by KE	Accepted
H4: There is a correlation btw the electricity demand and the occurrence of electricity load shedding in the Karachi region	Accepted
H5: Electricity load shedding mitigates the gap btw the electricity demand and supply in the Karachi region	Rejected
H6: The gap btw the electricity demand and supply, at a given order (p), predicts the KE's per unit prices for domestic usage at the current order.	Accepted
H7: The gap btw the electricity demand and supply, at a given order (p), predicts the KE's per unit prices for industrial usage at the current order.	Accepted
H8: The gap btw the electricity demand and supply, at a given order (p), predicts the KE's per unit prices for government usage at the current order.	Rejected

Moreover, the study establishes that load shedding and prolonged electrical breakdowns are not effective in mitigating the energy deficit. Instead, addressing this challenge requires prudent energy consumption practices and bolstered energy production efforts. Notably, the energy deficit for the preceding month (ΔE_{t-2}) empirically influences the setting of per unit energy prices for both domestic and industrial usage.

7 Policy Implications

Given the urgency of the energy shortfall crisis in Karachi, proactive measures are imperative to avert potential catastrophes. The promotion of energy conservation practices and the swift implementation of strategies to augment energy production are essential. To encourage efficient energy use, the government should facilitate the importation of energy-efficient appliances for households and industries. Simultaneously, investing in infrastructure such as dams to expand energy generation capacity is crucial to meet growing demand and ensure affordable energy access.

Additionally, allocating special funds for coal utilization, recognized as a cost-impactive energy source, can further enhance energy production capabilities and alleviate the energy shortfall in Karachi, often regarded as a microcosm of Pakistan's energy challenges.

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